BRICS STI FRAMEWORK PROGRAMME

Russian Centre for Science Information

BRICS STI Framework Programme Bulletin

2024

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BRICS 2024
RUSSIA

I. EDITOR'S NOTE

Vladislav Panchenko
Russian Centre for Science Information Board Chairman 2008-2023
Vice President of the Russian Academy of Sciences

Dear reader!

Welcome to the first edition of the BRICS STI Framework Programme information bulletin. It was designed to share information on the programme results, including best performed projects supported within this BRICS initiative for multilateral research funding, coordinated by the Russian Centre for Science Information from the program launch in 2016.

While advancements in BRICS general activities draw great attention, very little is known about how its member states act to accelerate cooperation in the field of science, technology and innovation, as also about the results of those efforts. By issuing this publication RCSI addresses this knowledge gap.

Participants of the BRICS research projects are at the forefront of integrating the results of their collective work into their national science environments, shaping the future of innovation and discovery in their home countries. The success stories presented herein offer insights into their aspirations, accomplishments, and future challenges. These articles do not only serve as a valuable firsthand resource but also intend to stimulate discussions and partnerships among researchers across all BRICS countries, especially in the time of BRICS enlargement with new member states.

With this collection of articles our aspiration is not only to document BRICS STI Framework Program current activities, but also to facilitate collective efforts towards development of the research potential of the BRICS countries, which can be best achieved through international cooperation based on a mutual benefit.

This edition shows how RCSI is able to disseminate scientific data within the research community as also to the general public. Researchers do not necessary receive recognition or rewards for making data generated by them available for sharing. Therefore, we are very thankful to the authors of the presented articles for their input in making release of the first BRICS STI Framework Programme bulletin a success.

II. DEVELOPMENT OF THE BRICS STI FRAMEWORK PROGRAMME

Yaroslav Sorokotyaga
Russian Centre for Science Information
Head of BRICS STI FP Secretariat

Development of the BRICS STI Framework Programme

The BRICS founding countries of Brazil, Russia, India, and China held the first summit in Yekaterinburg in 2009, with South Africa joining the bloc a year later. Over time, BRICS has developed into a multipronged strategic partnership based on three key pillars: politics and security, economics and finance, culture and humanitarian ties. Relations between BRICS partners are built on the basis of equality and mutual respect, as well as the principles of openness, pragmatism, solidarity, and without orientation against third parties.

In line with the mandate of the eThekwini Declaration and Action Plan of March 2013 adopted at the Fifth BRICS Summit in South Africa, the BRICS STI Ministers and their representatives officially met for the first time in February 2014, at Cape Town (South Africa). The meeting was the result of close and efficient collaboration of the parties during the previous five years and became a boost for strengthening science, technology and innovation (STI) cooperation within the BRICS. In March 2015 the BRICS Memorandum of Understanding on Cooperation in Science, Technology and Innovation between the Governments of the Federative Republic of Brazil, the Russian Federation, the Republic of India, the People's Republic of China and the Republic of South Africa was adopted in Brasilia (Brazil), establishing a strategic framework for BRICS cooperation in STI to address common social and economic challenges trough co-generating knowledge and innovation and promoting international partnerships.

Benefiting from the created environment for cooperation, in July 2015 representatives of the BRICS research funding agencies and BRICS STI decision makers for the first time met together in Moscow (Russia) to discuss an idea to launch a multilateral programme that should focus on support of BRICS multilateral STI projects. After fruitful discussion participants of the meeting agreed on the vision concept for the BRICS multilateral research funding initiative and tasked Russia to coordinate elaboration of the statutory documents for the initiative, as well as to start building community of partner organizations. It was expected that the initiative would be approved by the BRICS STI Ministers meeting later the same year.

Working meeting of BRICS STI funding agencies and policy makers. July 7, 2015. Moscow, Russia

BRICS STI Framework Programme (BRICS STI FP) was endorsed by Moscow Declaration adopted during 3rd BRICS Science, Technology and Innovation Ministerial Meeting conducted on 28th of October 2015 in Moscow. Same document established BRICS Working Group (WG) on STI Funding with a mandate to govern BRICS STI FP implementation and developments.

On 18–19 January 2016 an inception meeting of the BRICS WG on STI Funding took place in Beijing (China). The participants of the meeting agreed on the basic principles of how the future mechanism for supporting joint research would be structured and operated. Despite the differences in national research funding mechanisms, policies and legal frameworks, the funding agencies managed to find a common ground and to reach an agreement on all modalities for launching the initiative on joint research funding. One of the BRICS STI Framework Program features was a multilateral approach: research involving representatives of at least three BRICS countries was a subject of support. It was agreed that the programme would have a 5-year pilot phase starting in 2016, with annual calls for competitive grants to be launched on case-by-case basis. At that time an idea was to review the initiative and decide its future as 5-year pilot phase is completed. Russia was appointed to coordinate the overall development process and pilot call preparations.

Participants of the first meeting of the BRICS WG on STI Funding. 18–19 January 2016, Beijing, China

The group made an outstanding work. Just within the next four months after the BRICS WG on STI Funding met for the first time, 8 research funding agencies from 5 BRICS states have signed the Arrangements for the BRICS STI Framework Programme, signifying the launch of the initiative. Meanwhile the preparation of the pilot call for projects was also completed, so together with signing the Arrangements founders of the BRICS STI FP adopted Implementation Plan for the Pilot BRICS STI FP Call 2016.

It's hardly possible to recall any international multilateral research funding initiative arising at such a fast pace. Bearing in mind that BRICS countries live in different time zones (when Brazil just starts business hours, it is evening dinner time in China), just in four months the parties agreed on general terms for running the programme, established coordination mechanism and fully elaborated an instrument for multilateral research funding. That included legal framework, definition of the thematic call areas, public announcements and various call documents, as well as the website with online application submission tool.

The 10 thematic areas selected for the pilot call were based on BRICS STI thematic leadership areas stated in Brasilia Declaration and Moscow Declaration, namely:

Overall, the pilot coordinated call for BRICS multilateral research projects was successfully announced on the 18th of May 2016, bringing together 8 funding organizations for the joint support of research projects in 10 priority thematic areas. The Call gained very high interest within scientific community of the BRICS countries, overcoming any expectations of BRICS WG on STI Funding members. With the deadline for proposal submission set on 25th of August 2016, a total number of 320 projects with at least three partners from BRICS countries have been submitted in response to the call. 22 projects were prepared by project consortia representing all 5 BRICS countries.

Apart from dry numbers of the first call statistics, there was also a visible demand from BRICS scientific community for the next call. Upon submission deadline for the first call the Secretariat and BRICS funding agencies faced numerous requests from researchers for a new BRICS STI projects call. Thus, the talks on the preparation of the second BRICS STI FP call has began before the results for the pilot one were delivered.

- Prevention and monitoring of natural disasters;
- Water resources and pollution treatment;
- Geospatial technology and its applications;
- New and renewable energy, and energy efficiency;
- Astronomy;
- Biotechnology and biomedicine including human health and neuroscience;
- Information technologies and high performance computing;
- Ocean and polar science and technology;
- Material science including nanotechnology;
- Photonics.

In May 2017 the BRICS WG on STI Funding met in Pretoria (South Africa) to agree on the results of the pilot call and confirm launch for the second BRICS STI FP call. Within one month after selected 26 BRICS research projects were announced for funding as an outcome of the Pilot BRICS STI FP Call 2016, announcement of the second BRCIS STI FP call was published. As the interest from BRICS research community was beyond expectations, the success rate of the first call was relatively small – just 8%. It was not possible to drastically increase budget allocations for the second call in such a short time, so one of the additional measures to moderately increased call budget was a decrease in the number of the call thematic areas, in order to lower down a number of project applications. Thus, only 6 thematic areas were introduced for the 2nd BRICS STI FP Call 2017.

However, the funders underestimated the popularity of BRICS STI FP gained within one year from the start of the initiative. Despite decreased number of call thematic areas the amount of submitted project applications rose by ~45% in comparison with the pilot call, resulting in 462 applications received. So, despite increased call cumulative budget and number of supported projects as an outcome of the second call rose to 33, the overall approval rate dropped down to even more critical 7%.

3rd meeting of the BRICS WG on STI Funding. 29–31 May 2017. Pretoria, South Africa

On 30th of June 2018 a 4th WG for BRICS STI Funding meeting took place in Durban, South Africa

As it was earlier mentioned, the first phase of BRICS STI FP implementation foresee 5-year pilot phase, targeting conduction of three separate joint calls. In this regard on the fourth meeting of the BRICS WG on STI Funding in Durban (South Africa) the parties decided that the third call should provide the widest thematic coverage in order to practically see the bottom-up interest from the BRICS research community, so 13 thematic areas were presented in the 3rd BRICS STI FP Call 2019.

However, the implementation of the third BRICS STI FP call faced certain difficulties caused by the reorganization or internal policy changes for some of the BRICS STI FP member-organizations, while the number of call organizers was enlarged to 9 BRICS research funding organizations. All that combined did not allow to smoothly coordinate simultaneous launch of national call procedures, what resulted in decrease in the number of projects submitted in response to the call. Nevertheless, according to the results of the third call, a record number of projects was supported — 35. In total, as an outcome of three BRICS STI FP calls, 93 projects in 11 scientific areas were supported.

projects *Thematic areas*	Pilot Call 2016		2nd Call 2017		3rd Call 2019		**Total**	
	submitted	supported	submitted	supported	submitted	supported	submitted	supported
Astronomy*	11	3	-	-	13	2	**24**	**5**
Biotechnology and biomedicine including human health and neuroscience	62	5	108	6	33	2	**233**	**13**
Geospatial technology and its applications	20	2	-	-	4	2	**24**	**4**
Information technologies and high performance computing	19	2	33	3	17	3	**69**	**8**
Material science including nanotechnology*	63	6	134	11	122	12	**319**	**29**
New and renewable energy, and energy efficiency	52	2	73	6	45	3	**170**	**11**
Ocean and polar science and technology	19	1	-	-	7	2	**26**	**3**
Photonics*	12	3	-	-	17	3	**29**	**6**
Prevention and monitoring of natural disasters	24	1	46	2	32	2	**102**	**5**
Water resources and pollution treatment	38	1	68	4	37	3	**143**	**8**
Aeronautics	-	-	-	-	3	1	**3**	**1**

* - not supported by Brazil in Pilot Call

By 2020 despite a relatively short period of BRICS STI FP existence, the initiative has become a noticeable phenomenon in the scientific life of BRICS: several thousand scientists took part in its activities preparing over 1,100 projects proposals. Some of the projects funded as result of earlier calls have been already completed showing excellent results. More than half of the supported projects lead to an establishment of collaboration at a higher level. Of course, as a young mechanism acting across states and actors with different national research organization models, legislations, scientific traditions and managements a number of challenges were encountered in the 1st phase of BRICS STI FP implementation. Some of them could easily be dealt with ad hoc; some could not be solved up to date.

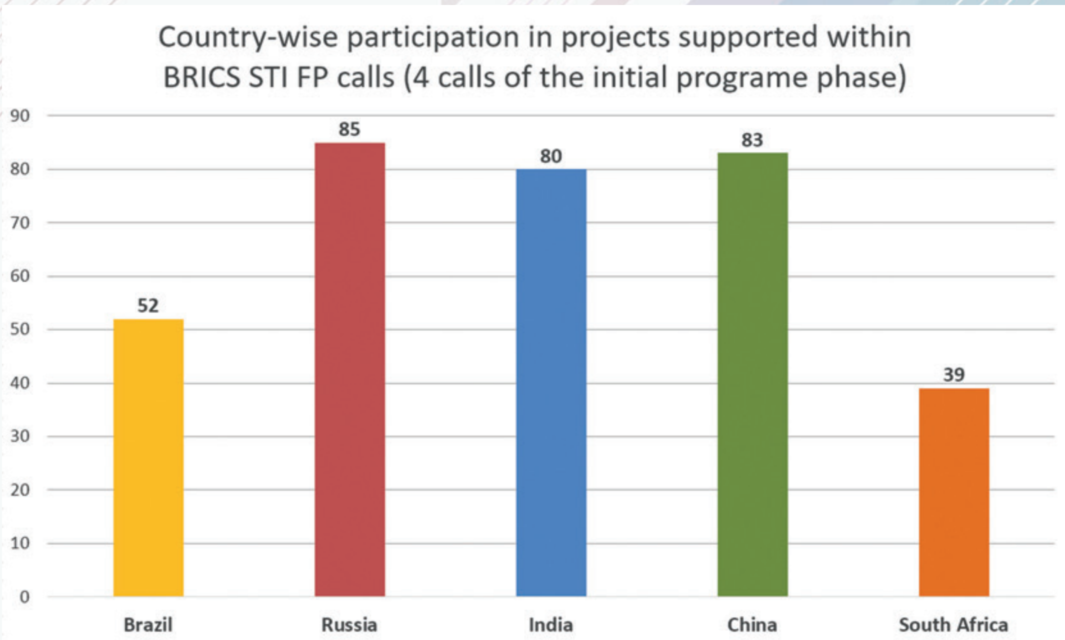
Nevertheless, in order to address the faced challenges and improve the procedures for the next 5-year implementation cycle of the BRICS STI FP, aiming at further strengthening BRICS research cooperation and raising the efficiency of operational activities, the BRICS STI Funding Working Group on the 5th meeting in Campinas (Brazil) held in September 2019 initiated the process of improving the call implementation mechanism. In this regard, it was decided to develop pathways for advancing the architecture of call activities during the implementation of the second stage of the BRICS STI FP for the period of 2020–2025. The approval of the implementation plan for the second phase of the BRICS STI FP was scheduled for the second quarter of 2020. However, the global pandemic of the new coronavirus infection has adjusted plans and activities of the BRICS STI FP.

The agenda was shifted from discussion on the mechanisms for implementing the second stage of the BRICS STI FP to overcoming the consequences of the global COVID-19 pandemic. In this regard members of the BRICS STI FP have approved a launch of an extraordinary call for interdisciplinary projects aimed to tackle COVID-19 challenges. Thus, second quarter of 2020 was a busy time for rapid call preparations. As the result, on the 1st of July 2020 the fifth BRICS STI FP call was announced in five topics related to the novel coronavirus infection. With only two months submission period duration and relatively narrow call thematic scoping a promising number of 111 project applications were received in response to the call.

The 2020 world crisis not only did not slow down the pace of work within BRICS STI FP track, but, perhaps, even gave it an additional impetus. Instead of one traditional annual meeting of the BRICS WG on STI Funding, its participants held several videoconferences during the year, which facilitated and accelerated the preparation of solutions and its implementation. As soon as the projects submitted to the 2020 call were sent for evaluation, work on elaboration of the improvements for the second phase mechanism of the BRICS STI FP resumed.

All together, the results of the extraordinary call of the BRICS STI FP on COVID-19 were delivered by the end of 2020. 12 projects received support as a result of the call, one of them being carried out by researchers from all five BRICS countries.

During 2020 representatives of the BRICS STI FP programme and supported projects made presentations at several special sessions conducted within the BRICS meetings held within cooperation tracks on STI and Energy. By the end of the 2020, the architecture for the implementation of the second stage of the BRICS STI Framework Program was approved by BRICS WG on STI Funding. During the second stage of the BRICS STI FP implementation, it was planned not only to continue conduction of calls for projects, which had already become regular, but also introduce a new format of support — BRICS Flagship Projects as well as other activities. It was assumed that such projects would be carried out by researchers from five BRICS countries and have increased funding.



Thus, having passed the five-year milestone of its existence, the BRICS STI FP has not only proved its relevance, but also its effectiveness. According to the survey conducted in the 1st quarter of 2020 by BRICS STI FP Secretariat among coordinators of selected projects, without the BRICS STI FP funding mechanism cooperation within more than 1/3 of the supported projects would have even never happened, other 40% potentially could get some work done but at lower pace or with less ambitious goals. More than half of the respondents stated that BRICS STI FP selected projects had already lead not only to the establishment of collaboration between research groups but also to the establishment of cooperation on a higher level, e.g. between research organizations, universities etc. There are cases when even the preparation of an application for a BRICS STI FP call led to increased cooperation among researchers, or cases when after the first unsuccessful attempt projects were not put aside, but were improved and later supported as an outcome of a following call. Evidence of the success of the work that has already been completed by BRICS projects can be found in articles published in leading scientific journals, obtained patents for inventions and implemented project results. A global multilateral approach in priority scientific areas of cooperation and a high-quality selection of projects (unfortunately for the participants, with ultra-high competition) made it possible to achieve high efficiency of the programme. Of course, the BRICS STI Framework Programme will continue to develop, offering new opportunities for joint scientific and technological cooperation.

Some of them have been already implemented within the second phase of the BRICS STI FP implementation. The 5th BRICS STI FP Call was launched in 2021 in several thematic areas resulting in 33 selected projects for funding. The next thematic call targeting climate change challenges was launched in 2023 with results delivered in 2024. The first BRICS STI FP thematic scientific conference on Biomedical Sciences and Technologies was held in 2023, with special sessions on reporting from projects selected as result of 2020 “covid-19” call and projects in thematic area of “Antimicrobial resistance: technologies for diagnosis and treatment” selected as result of the 5th BRICS STI FP call 2021.

The 2024 is a year of big transformations in BRICS. Besides enlargement of the block with new member states, what obviously will reflect the composition and procedures of the BRICS STI FP activities itself, in 2024 the BRICS STI thematic leadership areas are expected to be revised. This is a natural process which can also be visible from the thematic areas of the BRICS STI FP calls, when starting from 10 initial leadership areas in 2016 pilot call, throughout the later calls some of the new thematic areas were introduced while some of the initial ones were no longer included in its original definitions. By 2024 all the projects supported as results of the BRICS STI FP calls launched during the pilot phase of the programme implementation have been completed.

So we thought this would be a good moment, at the year of significant changes, to once again overview the activities and results of the BRICS STI FP pilot phase. Of course the main achievement of the BRICS STI FP is creation for the BRICS scientists an environment that made it possible for them to work together, conduct joint research and achieve outstanding results. All the rest arose is purely achievement of those brilliant minds that could jointly drive our societies to the better future.

With this said, this bulletin is aimed to provide opportunity for some of the BRICS project consortia from each of the BRICS leadership thematic area that were of the priority focus of the programme to introduce their success stories.. We hope this not only will serve as a tribute to their work, but also inspire many other scientists from enlarged BRICS community to work together for the better future.

III. BRICS STI FP SUCCESS STORIES

1. PREVENTION AND MONITORING OF NATURAL DISASTERS

Comprehensive experimental and simulation study on wildfire of BRICS countries: Fire occurrence, spread and suppression

Project details:

BRICS STI FP call	3rd BRICS STI FP Call 2019
Project number and Acronym	BRICS2019-142 “CESSW”

National Principal Investigator	National Principal Research Organization	Country
Guenther C. Krieger Filho	University of São Paulo	BRAZIL
Oleg Korobeinichev	Voevodsky Institute of Chemical Kinetics and Combustion SB RAS	RUSSIA
Amit Kumar	Indian Institute of Technology Madras	INDIA
Naian Liu	University of Science and Technology of China	CHINA
Funding agencies: National Council for Scientific and Technological Development (CNPq, Brazil), Russian Centre for Science information (RCSI, Russia), Department of Science and Technology (DST, India), National Natural Science Foundation of China (NSFC, China).		

Wildfire is one of the major natural disasters in the world, which seriously threatens the stability of economic systems and the safety of life and property. Averagely, there are around 220,000 wildfires per year in the world, leading to serious disastrous consequences. Wildfires per year destroy over 10 million hectares of wildland areas and burn up about 9 billion tons of biomass in average. Wildfires also pose a serious threat to the stability and balance of global ecosystems. For example, the carbon emissions from a forest fire in Indonesia in 1997 accounted for more than 13% of the total carbon emissions from fossil fuel combustion in the world that year. In recent years, the global climate change and also the increased anthropogenic impact have caused more and more wildfires in the world, causing severe environmental and economic damages. In the strategy framework document "Agenda 2030 for a Fire Safe World" formulated by the International Association for Fire Safety Science (IAFSS), wildfire has been listed as the top challenge of the fire community.

The BRICS is one of the hardest hit areas by wildfires in the world. In recent years, the risk of wildfires has continued to rise, seriously hindering the sustainable development and endangering social security and stability of BRICS. Russia's vast forests and grasslands have been ravaged by fires for years. Official data show that wildfires burned more than 15 million hectares of land across the country, which is almost twice the territorial area of Ireland. India's State of Forest Report (ISFR) indicates that about 60% of the country's forests are fire-prone areas, leading to annual economic losses of 55 billion rupees. According to the Centre for Science and Environment (CSE), there were about 16 thousands wildfires in India every year. Such uncontrolled wildfires not only burned down the vegetation but also the surface organic matter, increasing the frequency of flooding and soil erosion in India. In order to handle this the Indian government officially upgraded "Intensification of Forest Management Scheme" to "Forest Fire Prevention & Management Scheme". Brazil's vast territory is located in the Amazon rainforest. According to the statistics by the National Institute for Space Research (INPE), the annual carbon emissions of the rainforest are as high as 255 million tons, which seriously threatens the global ecological climate. Frequent wildfires are deemed to be the primary source of carbon emissions. China's wildfires are even more serious. Since 1950, there have been more than 13,000 wildfires annually in China, and the affected area is as large as 650,000 hectares. The 1987 Daxing'anling Wildfire was the world's most serious fire in the past 100 years. In March 2019, the Liangshan forest fire in China took away the precious lives of 30 firefighters.

Investigating the ignition and spread process of wildfires is essential to reduce their fire risks. The risks and complexities of wildfires are essentially attributed to the coupling mechanism of fluid, heat transfer and kinetics involved in its leader process of ignition (pyrolysis), ignition (e.g., lightning fire), and spread processes (e.g., surface fire, crown fire). This is also the main bottleneck for the development of advance wildfire predictive model and technology. The solution of the above cited problems is of great scientific and technological significance in understanding, predicting and suppressing wildfires. In Russia, China, India and Brazil, studies of natural fires are carried out almost constantly over a long period of time by highly qualified scientific teams. The international research program within the framework of projects of the BRICS countries made it possible to combine the efforts of such 4 national research groups. The main composition of these groups is presented below.

RUSSIAN TEAM: Prof. Oleg Korobeinichev

Lead PI (project coordinator): Professor Oleg Korobeinichev (Voevodsky Institute of Chemical Kinetics and Combustion, Siberian Brunch Russian Academy of Sciences, Novosibirsk); Professor Alexander Karpov (Udmurt Federal Research Center, Ural Branch of the Russian Academy of Sciences, Izhevsk); Dr Galina Ivanova (Sukachev Forest Institute, Siberian Brunch Russian Academy of Sciences, Krasnoyarsk); Dr Egor Loboda (Tomsk State University, Tomsk); Dr Alexander Paletsky (Voevodsky Institute of Chemical Kinetics and Combustion Siberian Brunch Russian Academy of Sciences, Novosibirsk)

CHINESE TEAM: Prof. Naian Liu

Leader: Professor Naian Liu, Ph.D (University of Science and Technology of China, State Key Laboratory of Fire Science); Professor Wei Gao, Ph.D (University of Science and Technology of China, State Key Laboratory of Fire Science, Hefei); Professor Haixiang Chen, Ph.D (University of Science and Technology of China, State Key Laboratory of Fire Science, Hefei); Professor Jiao Lei, Ph.D (University of Science and Technology of China, State Key Laboratory of Fire Science, Hefei)

BRAZIL TEAM: Prof. Guenther C. Krieger Filho

Leader: Professor Guenther C. Krieger Filho, Dr.-Ing. (University of São Paulo, Sao Paulo); Professor Joao A. Carvalho Junior (The Universidade Estadual Paulista, Sao Paulo); Professor Marcos Buckeridge, Ph.D (University of Sao Paulo, Sao Paulo)

INDIAN TEAM: Prof. Amit Kumar

Leader: Professor Amit Kumar, Ph.D (Indian Institute of Technology Madras, Aerospace Engineering, Chennai); Professor Vasudevan Raghavan, Ph.D (Indian Institute of Technology Madras, Mechanical Engineering, Chennai)

Cooperation of Russian participants with specialists from the State Key Laboratory of Fire Science, University of Science and Technology of China in Hefei (The head of this group is Prof. N. Liu) in the field of research of the kinetics and mechanism of thermal decomposition of forest combustible materials and the processes of flame propagation along them layer began in 2012. In 2012 prof. Oleg Korobeinichev was invited by the Chinese Academy of Sciences to the University of Science and Technology of China, where in 2013–2014 joint research was carried out with Chinese colleagues within the framework of the Russian Foundation for Basic Research project “Experimental study of the kinetics and mechanism of thermal decomposition of forest combustible materials and the processes of flame propagation along their layer.”

The collaboration of Russian researchers with Indian partners was established in 2016–2019 within the framework of the Russian Science Foundation project “Experimental study and numerical modeling of polymers' pyrolysis and burning for the prediction of flame spread behavior under fire growth” as a result of which new findings on the study of combustion of polymer materials, including those with fire retardant additives, were obtained and published in leading scientific journals on combustion.

As a result of joint research in frame of the BRICS project, the characteristics of forest materials from the forests of Central Siberia (pine needles Pinus Sylvestris, grass from the Tomsk region, litter of the Siberian boreal forest from the Krasnoyarsk Forest site) and Brazil (peat, sphagnum, Amazonian leaves) were collected and generalized. During the project, for the first time, a complex of comprehensive experimental studies and numerical modeling was carried out using the FDS program to describe the parameters of natural forest ground fires, using the example of flame propagation through a layer of pine needles in the Siberian boreal forests (occupying vast areas of the northern hemisphere of the Earth). Measurements were made of the speed of flame propagation, the temperature field in the flame, total and radiative heat flows from the flame into the layer of pine needles, using microthermocouples, as well as miniature heat flow sensors developed by the project executors. The influence of wind speed (0.1–0.4 m/s), needle humidity (1%–8%), pine needle layer width (8–100 cm), depth (2–4 cm), loading density (343–1370 g/m2) was studied, as well as the angle of inclination of the layer 0–30 degrees to the horizon (which models the spread of fire in hilly areas) to the above parameters. It was established for the first time that at wind speeds in the range of 0.2–0.3 m/s, a small increase in wind speed causes a significantly greater increase in flame speed, while at the same time there is a sharp increase in the angle of inclination of the flame towards the surface of the layer.

Photo of a flame when a layer of pine needles burns on an inclined (15° — left picture) and horizontal surface (right picture), side view.

The authors of the project, based on the data of thermal analysis (TG, DTG and DSC) in an inert and oxidizing environment, using a genetic algorithm, found the kinetic parameters of the thermal decomposition of Siberian pine needles, peat, sphagnum and Amazonian leaves with the formation of a carbon residue and its subsequent oxidation. It was revealed that peat and pine needles have a complex chemical structure, which is difficult to describe within the framework of a 4-stage reaction mechanism in the condensed phase, and their decomposition involves a greater number of elementary reactions than Amazonian leaves and sphagnum.

For the first time, the influence of the type and amount of an aqueous solution of fire retardant applied to the surface of pine needles on the speed and propagation limits of flame along an individual pine needle and layer of pine needles was studied. It was shown that applying 10–12 wt.% aqueous solutions of yellow blood salt to a layer of pine needles reduce the extinguishing concentration of water by 1.5 times at a wind speed of 0.4 m/s.

Partners from India, based on the experimental data received from the Russian side for burning a layer of pine needles, carried out numerical modeling of flame propagation using the FDS 6.7.4 program. A comparison of the modeling data for flame speed, temperature profiles, and heat flow profiles with the data of all experiments showed, in general, their satisfactory agreement. Analysis of the parameters of the numerical model showed that the flame speed is limited (determined) by the rate of pyrolysis of pine needles and depends little on the rate of oxidation of charred (coke) residues. Numerical results reveal the underlying physics of flame propagation through a layer of pine needles. Using the model, the fields of concentrations of the main substances in the flame, temperature, flow velocity and mass fraction of particles as the fire spreads through the layer of pine needles are numerically calculated. The entrainment of air into the flame on both sides of the flame, both in the gas and porous phases, was revealed.

Taking into account the complexity of the problem, which includes complex pyrolysis of a porous layer of fuel, approximations in the shape and location of pine needles, it was concluded that the developed fully three-dimensional model satisfactorily describes the spread of a ground forest fire over layer of forest fuels depending on external conditions (wind speed and direction, angle of inclination to the horizon) and the properties of the fuel (humidity, filling density, layer dimensions). The experimental results obtained and the developed model have important practical applications, since they can be used to predict the occurrence and spread of ground forest fires, develop methods to combat them, as well as to assess fire risks.

2. WATER RESOURCES AND POLLUTION TREATMENT

Development of membrane-based methods to improve the recovery of pure water and valuable products from the waste

Project details:

BRICS STI FP call	2nd BRICS STI FP Call 2017
Project number and Acronym	BRICS2017-517 "From waste to resources"

National Principal Investigator	National Principal Research Organization	Country
Andrea Moura Bernardes	Federal University of Rio Grande do Sul	BRAZIL
Alexey Volkov	A.V. Topchiev Institute of Petrochemical Synthesis RAS	RUSSIA
Sourja Ghosh	CSIR-Central Glass and Ceramic Research Institute	INDIA
Tao He	Shanghai Advanced Research Institute CAS	CHINA
Lueta-Ann de Kock	University of South Africa	SOUTH AFRICA
Funding agencies: National Council for Scientific and Technological Development (CNPq, Brazil), Russian Centre for Science information (RCSI, Russia), Department of Science and Technology (DST, India), National Natural Science Foundation of China (NSFC, цChina), National Research Foundation (NRF, South Africa).		

DESCRIPTION OF THE PROJECT

The continuous growth of the human population and world economy poses a significant challenge to the availability of fresh water for drinking and agricultural purposes. This is due to the increasing demand for water, which leads to depletion of freshwater resources. As a result, municipal waste and groundwater have been contaminated with pesticides, fertilizers, and other chemicals. Another major source of water pollution is the increased consumption of various goods, including electronic devices, which require the extraction of natural resources such as carbon and minerals from underground deposits. This process disrupts the balance of chemical elements in the environment, as these compounds end up in polluted streams at each stage of a product's life cycle.The reuse of contaminated streams and the recovery of valuable chemicals are essential for the sustainability of humanity and the world economy. This project aims to develop membrane-based processes that can significantly reduce energy consumption and costs, or operate independently to:

(i) Effectively produce clean water in remote areas.

(ii) Recover organic and inorganic components from polluted water, along with clean water.

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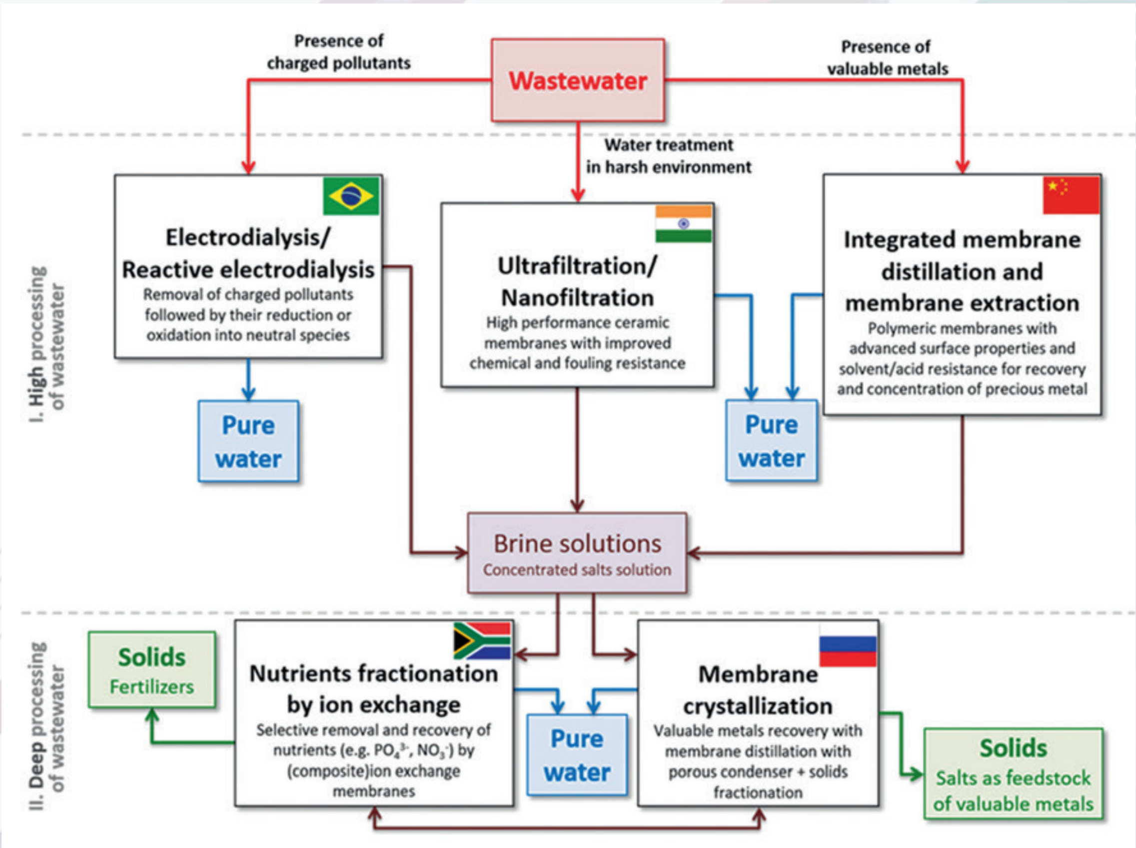
Extraction of resources from waste streams is revolutionizing the paradigm we manage waste. Recovering as much resources as possible remains a major challenge for scientists and engineers. The work of research teams from Brazil, Russia, India, China, and South Africa (the BRICS countries) within the BRICS2017-517 project aims to simultaneously address three scientific challenges. The first challenge is the development of efficient and energy-saving membrane separation technologies to reduce the environmental impact of pollution from waste and sewage on the aquatic ecosystem. The second challenge is extracting valuable products from wastewater for reuse. The third challenge is recovering treated water for domestic and industrial use. Below is a general overview of the work being done by partners from BRICS countries.



General structure of the work carried out by project participants from the BRICS countries.

HISTORY OF COOPERATION

The international scientific consortium created under the project is represented by organizations from all the countries participating in the BRICS STI Framework Program. These include: the Federal University of Rio Grande do Sul (UFRGS), Brazil; the Institute of Petrochemical Synthesis of the Russian Academy of Sciences (TIPS RAS), Russia; the CSIR-Central Glass and Ceramic Research Institute (CSIR CGCRI), India; the Shanghai Advanced Research Institute (SARI), China; and the University of South Africa (UNISA). There were preliminary contacts between TIPS RAS and SARI at international conferences and workshops in 2017, which led to the formation of a consortium of five teams working together on the BRICS project. This consortium was then further developed into the BRICS "From Waste to Resource" project, also involving the five original teams. The partners were identified through mutual contacts within the scientific community. The strong expertise of each organization in their respective fields was taken into consideration in order to incorporate the most advanced and promising approaches to wastewater treatment, which complement each other.

The partners from other countries were identified through searching for relevant articles on membrane technology in Scopus and Web of Science. Their expertise in their respective areas was also considered in order to include the most cutting-edge and innovative techniques for wastewater treatment. These approaches are complementary to each other and contribute to a more holistic and effective approach to this complex issue. After the international project was supported by funding organizations from all five countries, a website (https://brics4water.org) was created to coordinate the initiative. The website provides information about the participating organizations, the research conducted, the main findings, and published papers.

Also, interactions between the consortium members took place on the sidelines of various international conferences and face-to-face and online meetings.

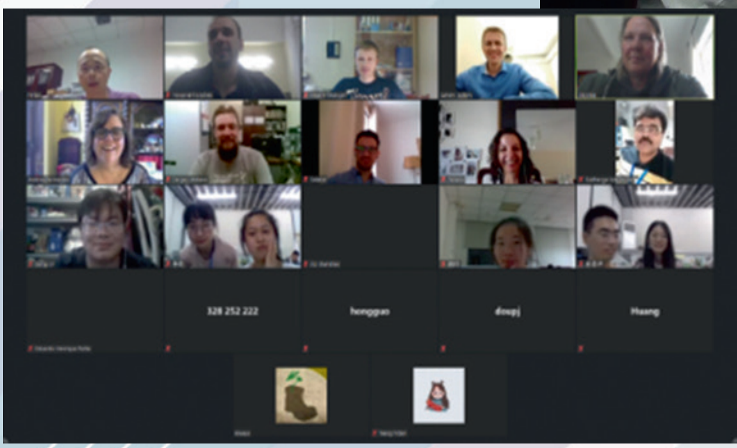
In the first year of the project, a kick-off meeting was held at the SARI site (Shanghai, China) where the partners gathered in one room to plan the further work plan and merge all different experiences and backgrounds on solving the common problem of wastewater treatment. At the end of 2019, another meeting was held in Calcutta, India at CSIR CGCRI, where the results of work of all project countries were presented and future prospects for project development were discussed. This meeting allowed for better interaction between countries in search for new, integrated, and synergistic solutions for effective wastewater processing to recover valuable metals and purify water.

The COVID-19 pandemic impacted collaboration. Two project meetings in Brazil and Russia were cancelled. All partners had to adjust their research schedules due to the long-term closure of laboratories and replace face-to-face meetings with Zoom meetings. Despite the COVID-19 restrictions, all team members continued to work, either in the lab or from home. For example, the Russian team presented a membrane module prepared by one researcher at home using a 3D printer.

SARI, Shanghai, China (2019)

International Workshop, Kolkata, India (2019)

CSIR CGCRI, Kolkata, India (2019)

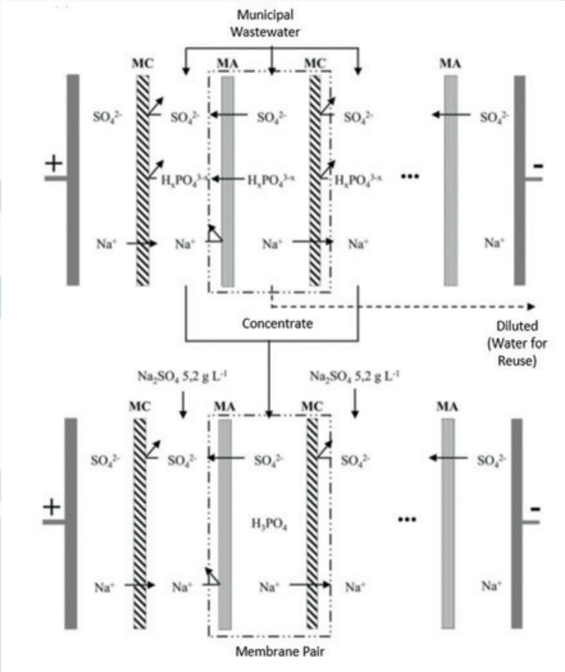


Project meeting on ZOOM (2020)

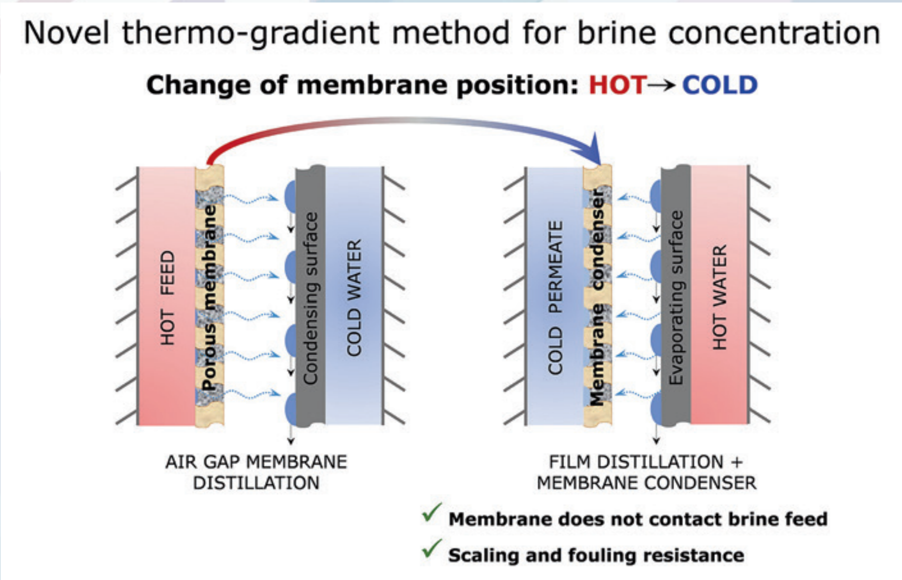
SCIENTIFIC RESULTS

The team from UFRGS (Brazil) have developed a two-stage electromembrane setup to phosphorus recover from a low phosphate-containing municipal wastewater, where the first stage consists in the use of underlimiting current density conditions to obtain a phosphate concentrated solution. The second step is based on the use of overlimiting current density conditions, allowing the separation of phosphate from the coexisting anions, such as sulfate, in a municipal wastewater. [1].

The team from TIPS RAS (Russia) has developed a new compact membrane method for concentrating metal salts from technogenic waters for their subsequent crystallization while simultaneously producing clean water [2]. At TIPS RAS, the first pilot prototype of the installation was assembled and tested, the operating principle of which is based on the evaporation of water from the surface of a thin film of salt concentrate (brine) with almost instantaneous capture of water vapor by a porous membrane. This approach made it possible to concentrate and recovery target products from their aqueous solutions when solving current industrial and environmental problems.



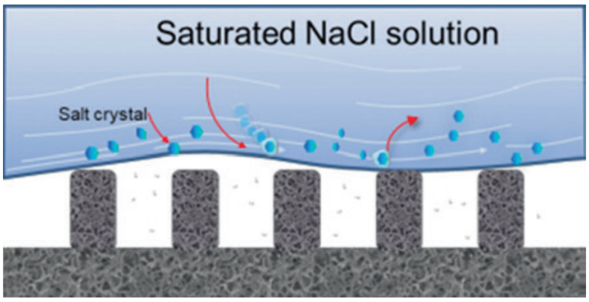
Schematic representation of the experimental two-stage electrodialysis system to recover phosphorus from low-phosphate municipal wastewater [1].



Proposed new effective method for concentrating metal salts [2].

The team from CSIR CGCRI (India) has developed a number of methods and technical solutions, including the production of low-cost, high-performance ceramic membranes based on clays and aluminum oxides in single-channel and multi-channel configurations, as well as single-layer ceramic ultrafiltration membranes. The resulting membranes also showed resistance to fouling, and the pure water flux was about 180 $l \cdot m^{-2} \cdot h^{-1}$ at a transmembrane pressure of 1 bar [3].

The team from SARI (China) has proposed a new slippery model for understanding the scaling/fouling resistance and produced polymer membranes with advanced surface properties in membrane distillation [4, 5]. The obtained polyvinylidene fluoride (PVDF) membranes had a superhydrophobic slippery surface, which allowed them to demonstrate significant resistance to scale formation when treating complex brine using membrane distillation. Figure below demonstrated an example for a feed with saturated NaCl solutions.



Schematic of the slippery interface in relation to anti-scaling [4].

The team from UNISA (South Africa) has obtained ultrafiltration heterogeneous ion exchange membranes for the purification of low-mineralized groundwater. The removal efficiency of Mg^{2+} and Ca^{2+} was 93.5 and 85.4%. In addition, the removal efficiency of anions, NO^{3-} was 84.2% [6]. Further, functionalization of this membrane with nanoparticle sized Ag or Cu, result in reduced fouling as well as antimicrobial properties.

During the implementation of the project, the participants of the international consortium published more than 40 articles in high-ranking journals, of which 15 were published in Q1 journals, for example, Journal of Materials Chemistry A (IF=11.9), Journal of Membrane Science (IF=9.5), Desalination (IF=9.9), Separation and Purification Technology (IF=8.6), etc. Project implementers took part in more than 10 international scientific conferences, where they demonstrated the results obtained to the world community.

FUTURE OF THE PROJECT AND FURTHER COOPERATION

In the project, BRICS partners will focus on different complimentary approaches that can be combined together to address the issues related to the treatment of water streams typical for each BRICS country, including the polluted ground and sea water, municipal water, wastewaters of mining, oil/gas, automotive, refineries and electronics industrial sectors.

This BRICS project has initiated broader and deeper cooperation between partners. Particularly, teams from TIPS RAS and SARI submitted the proposal within the bilateral call, and were granted by project on the development of scaling resistance hybrid approach for the recovery of lithium from geothermal waters. Two teams from SARI and UNISA submitted bilateral projects to the Ministry of Science and Technology on the topic of resource recovery from acid mine drainage. In 2021, five teams from Brazil, Russia, India, China and South Africa, who previously interacted within the framework of the BRICS2017-517 project, submitted their applications for the new BRICS project (5th BRICS Call 2021) and received support. A new project (BRICS2021-358, Drug-Free Wastewater) aims to removal antibiotics from wastewater by membrane separation. Thus, the accumulation of antibiotics in environment leads to the emergence of new resistant strains, while the use of new generation of drugs just triggers the appearance of multi-drugs resistant strains. Therefore, the goal of the new project is to identify, concentrate and remove antibiotics using membrane-based hybrid processes. The project includes: (i) the identification of high-risk water sources by monitoring antibiotics and pathological microorganisms in municipal and surface waters, through advanced analytical services available at the Institute of Nanotechnology and Water Sustainability laboratories (South Africa); (ii) treatment of identified water sources by membrane separation for isolation of antibiotics and pathological microorganisms to concentrated solution by using nanofiltration membranes with different functionalities (China, India and Russia); (iii) electrochemical oxidation to eliminate these chemicals (Brazil).

CONCLUSIONS

In the process of implementing this project, collaboration with participants from the international consortium within the BRICS framework was strengthened. The laboratories of countries participating in the project are among the leading in the world in developing membrane technologies for producing clean water and extracting valuable resources from contaminated water. To achieve all the goals as efficiently as possible, scientific knowledge and samples of membranes were exchanged between project participants. Access to the equipment base of each project participant was provided. As a result of collaboration between project partners, valuable experience was shared for the further development of membrane technologies to produce clean water and extract valuable products from polluted water in order to solve technological and environmental challenges more effectively in each country.The BRICS project has revealed new opportunities, challenges, and perspectives that are worthy of further joint research and collaboration. The joint development of new applications and projects is a good example of the excellent outcomes of the BRICS platform.

ACKNOWLEDGMENT

This project was founded by CNPq (CNPq/BRICS-STI-2-442229/2017-8), RFBR (№ 18-58-80031), DST (DST/IMRCD/BRICS/PC2/From waste to resources/2018 (G)), NSFC (51861145313), NRF (No: 116020).

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3. GEOSPATIAL TECHNOLOGY AND ITS APPLICATIONS

Research and development of algorithms and software for the processing, storage and visualization of laser scanning and photography data

Project details:

BRICS STI FP call	Pilot BRICS STI FP Call 2016
Project number and Acronym	BRICS2016-464 “POINTCLOUD”

National Principal Investigator	National Principal Research Organization	Country
Vladimir Badenko	Peter the Great St. Petersburg Polytechnic University	RUSSIA
R.D. Garg	Indian Institute of Technology Roorkee	INDIA
Lei Zhang	East China Normal University	CHINA
Funding agencies: Ministry of Science and Higher Education (MSHE, Russia), Department of Science and Technology (DST, India), Ministry of Science and Technology (MOST, China).		

Prof. Rahul Dev Garg

Prof. Vladimir Badenko

Prof. Liu Min

Project coordinator: Peter the Great St. Petersburg Polytechnic University. Scientific supervisor: Doctor of Technical Sciences Badenko Vladimir Lvovich. Project partners from the BRICS countries were the Indian Institute of Technology Roorkee PI prof Rahul Dev Gargand the East China Normal University, PI prof Liu Min.

During 3 years of the research (2017–2019), experimental samples of software for hybrid processing, storage and visualization of laser scanning and photography data based on decoding and vectorization algorithms in real time were developed. At the same time, corresponding original algorithms have been developed: visualization of laser scanning and photographic data, creation of raster projections, decoding and vectorization of laser scanning data with increased performance, as well as hybrid data processing. Comprehensive testing of the developed software was carried out, based on field and office work to obtain hybrid laser scanning data of cultural and historical heritage sites and road infrastructure and the construction of corresponding 3D models. As a result of generalization and evaluation of the research results obtained, proposals and recommendations for the implementation (commercialization) of research results were formed.

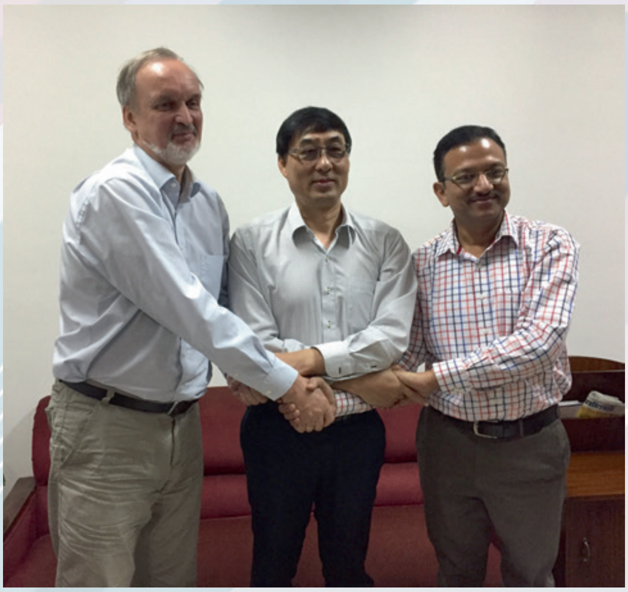
The functions of the Indian Institute of Technology Roorkee (IITR) included research and testing of the created algorithms, as well as the creation of 3D models of civil engineering objects, developed based on the results of laser scanning and photography. Scientists from East China Normal University (ECNU) were engaged in calibrating a photogrammetric camera to combine photographic data with laser scanning results, were engaged in laser scanning and photography of civil engineering objects, testing algorithms, and creating 3D models developed from the results of laser scanning and photography of civil engineering objects using new software developed during the project, in addition, they developed a method for photogrammetric calibration of a digital camera.

Laser scanning (LS) is the most modern and actively developing type of remote sensing (RS), using the active remote sensing method. The operating principle of laser scanners, regardless of their type and purpose, is based on measuring the distance from the laser pulse source to the object. The laser beam emerging from the emitter is reflected from the surface of the object being examined. The reflected signal enters the scanner receiver, where the required distance is determined by the time delay (pulse method) or phase shift (phase method) between the emitted and reflected signals.

Knowing the coordinates of the scanner and the direction of the pulse, it is possible to determine the three-dimensional coordinates of the point from which the pulse was reflected. In addition, a numerical indicator of the intensity of the reflected signal is recorded. It is determined by the properties of the surface on which the laser beam falls. The result of the measurements ("scanning") is a cloud of three-dimensional points that accurately describe the object being examined. The cloud of points can be colored depending on the degree of intensity and the scanned result on the computer screen looks like a three-dimensional digital photo. Moreover, most modern models of laser scanners have a built-in video or photo camera, thanks to which the point cloud can also be painted in real colors. The result of laser scanning is usually a cloud of points, which is combined with a photograph of the object being examined. Laser scanning technology is used in a wide range of applications: road management, urban modeling, industrial research, historic preservation, etc. Laser scanning (or lidar) is classified into aerial, ground and mobile.

A significant disadvantage of laser scanning, which significantly limits its use, is the continuing gap between the rapid development of laser scanning technology and the capabilities of processing the results (processing point clouds). The standard methods of geoprocessing data and image analysis used, as well as high requirements for computing resources, do not allow full use of the capabilities of laser scanning. Currently, laser scanning and results processing are often associated with the developer/manufacturer of laser scanning equipment and software for processing the results, and there are practically no universal tools for communicating and processing laser scanning results from different sources.

One of the main advantages of the developed software is the formation of a new type of presentation of laser scanning and photography data for users. We are talking about creating raster projections (scans) of a cloud of points onto an imaginary pseudo-cylindrical surface, the axis of which coincides with the trajectory of the filming complex in



the case of mobile laser scanning. This projection is subsequently textured with photographic data, which significantly increases its spatial resolution (image detail). The use of such projections (sweeps) for modeling, in comparison with traditional point cloud modeling, allows you to view scanning and photographic data directly from the shooting trajectory, which allows you to do without "holes" (shadows) and more flexibly adjust the desired display scale. In addition, it becomes possible to visually display all three-dimensional data on a plane (monitor), which facilitates their perception and vectorization. At the same time, texturing scans with images allows you to increase the spatial resolution of the data. Such data is convenient to store and exchange, reproduce remotely, and semi-automatic vectorization tools, through the use of numerous libraries for working with rasters, increase work efficiency. All these technical advantages ultimately result in an economic effect, which consists in increasing the speed of the operator or algorithm with scanning data, and, consequently, reducing labor costs for modeling. And as you know, it is the modeling stage that requires significantly more labor time than filming or its pre-processing.

Based on the results of joint research, several articles have been published in high-ranking journals.

Regular meetings and seminars were held in Russia, the People's Republic of China and the Republic of India.

The consumers of the developed technologies are companies associated with various types of surveys that use laser scanning and photography data, including hybrid ones. The main advantages of the developed experimental samples of software components are associated with the ability to use large clouds of laser scanning points up to 50 GB in size or more.

It is advisable to use the developments to create digital models of objects for which there is no design and as-built documentation in digital form. This primarily applies to cultural heritage sites and industrial enterprises with old buildings/assets where it is planned to introduce new production technologies. The practical application of the developed technologies has also shown effectiveness in monitoring deformations of both road infrastructure objects and capital construction objects. The main prospects for implementation are related to the formation of digital twins/digital assets for existing objects — the so-called scan-to-BIM technologies. Such technologies are especially important for historical architectural monuments.

4. NEW AND RENEWABLE ENERGY, AND ENERGY EFFICIENCY

BRICS technology platform for integrated bioprocessing of agricultural residues for eco-sustainable production of biofuels and by-products

Project details:

BRICS STI FP call	2nd BRICS STI FP Call 2017
Project number and Acronym	BRICS2017-418 “BRICS-BEST”

National Principal Investigator	National Principal Research Organization	Country
Carlos Ricardo Soccol	Federal University of Parana	BRAZIL
Arkady P. Sinitsyn	Federal Research Centre “Fundamentals of Biotechnology” RAS	RUSSIA
Sudesh K Yadav	Center of innovative and Applied Bioprocessing	INDIA
Zhengxiang Wang	Tianjin University of Science & Technology	CHINA
Kugenthiren Permaul	Durban University of Technology Biotechnology and Food Technology	SOUTH AFRICA
Funding agencies: National Council for Scientific and Technological Development (CNPq, Brazil), Russian Centre for Science information (RCSI, Russia), Department of Science and Technology (DST, India), Ministry of Science and Technology (MOST, China), National Research Foundation (NRF, South Africa).		

Prof. Kugen Permaul jointly leads the Enzyme Technology Research Group in the Department of Biotechnology and Food Technology at DUT. His research focuses on the cloning, expression and characterisation of industrially-important enzymes and the production of chitosan from fungi.

Prof. Zhengxiang Wang is a distinguished professor of the Tianjin Municipality and Full Professor in Biotechnology and Industrial Microbiology at the Tianjin University of Science and Technology, China. His research focuses on molecular modification, high efficiency expression and production of industrial enzymes, industrial strain development, microorganism collections, and bio-based biofinery of biomass.

Prof. Carlos Ricardo Soccol is the research group leader of the Department of Bioprocesses Engineering and Biotechnology (DEBB) at The Federal University of Parana, Brazil. He has experience and a prolific publication record in Industrial Biotechnology, especially in the area of biofuels, enzymes, industrial bioprocesses, nutraceuticals and functional foods, applied microbiology, fermentation and environmental technology.

Prof. Arkady P Sinitsyn is the head of Enzyme Biotechnology Laboratory at Federal Research Center of Biotechnology, A.N. Bach Institute of Biochemistry, Moscow, Russia. His research focuses on: Enzymology, biochemistry, and biotechnology of carbohydrases, bioconversion of lignocellulosic materials, application of carbohydrases and other enzymes in textile and pulp and paper industries and in feed and food processing, as well as strain development and development of fungal host-vector systems, and cloning and expression of carbohydrases.

Dr. Sudesh Kumar holds the position of Scientist-F at the Center of Innovative and Applied Bioprocessing (CIAB), Mohali, India. His areas of specialisation are: Metabolic engineering of plants and microbes for value added products; Enzyme/microbes-based bioprocesses for value added products from biomass; Synthetic biology and omics approaches for improving metabolic pathways or enzymatic proteins and the use of nanobiology approach in improving enzyme-based bioprocesses for biomass conversion.

Global lignocellulosic biomass production exceeds 220 billion tons annually, while BRICS countries being highest producers of sugarcane, rice and maize, generate significant amount of lignocellulosic biomass. Unfortunately, most of the biomass remains unutilized or is burnt which results in wastage of potential high-energy sources and drastic deterioration of air quality and generation of carcinogenic chemicals. It is, therefore, of major global interest to use biomass as a renewable energy source and produce commercially-important co-products. Intensification of biomass to bioenergy conversion is preferred over non-renewable and polluting fossil fuels to meet the increasing global energy demand. Bioenergy represents around 10% of the total world energy consumption today, and the growth rate of biofuel production has been around 15% per year in the last decade. Energy-dense liquid biofuels are expected to reach a world production of around 105 million barrels of oil equivalent per year.

The use of lignocellulosic residues is being actively researched, but the economic conversion of these materials into viable products is a major challenge that demands an interdisciplinary and integrated approach.

The BRICS technology platform comprised researchers from Brazil, Russia, India, China, and South Africa. This collaborative effort focused on integral conversion of biomass into biofuels in a synergistic approach, exchanging experiences and knowledge, and developing local capacity for enhancement of bioenergy production chains through biorefinery approaches. Major lignocellulosic biomass such as oil palm solid residues from Brazil, rice straw from India, sugarcane bagasse from China and South Africa and wood residues from Russia were investigated for eco-sustainable production of bioethanol and co-products in a zero-waste approach. The Russian team has competence in pretreatment of wood residues and sugarcane bagasse as well as in development of enzyme cocktails and fermentation that will be useful in application by the consortium partners. The expertise of the Chinese team in engineering improved strains and access to pilot scale production facilities were used to improve the saccharification and fermentation efficiency, while the South African team with proficiency in enzymatic bioprocessing and molecular biology developed carbohydrate fermenting strains and enzyme cocktails for enhanced saccharification and fermentation. The collaborative expertise of partners was intended to contribute to the eco-sustainability of the proposed integrated processing *(Figure 1)*.

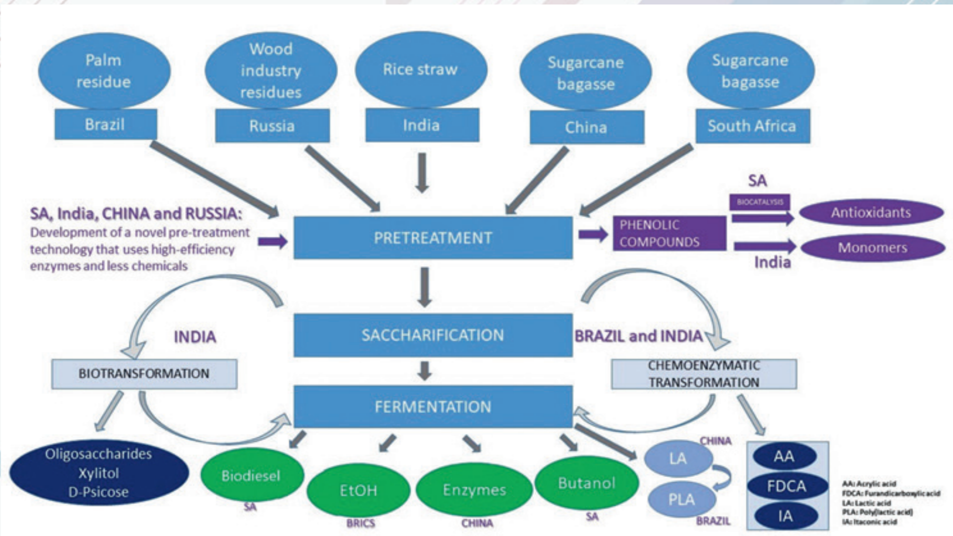


Figure 1. *Fuels and chemical bioproducts derived from agricultural by-products by the BRICS-BEST consortium*

RESEARCH OUTCOMES

BRAZIL:

- Advanced and alternative pretreatment, using green solvents (imidazole) or citric acid, of palm oil empty fruit bunches (EFB), soybean husks (SH), and sugarcane bagasse (SB) and other lignocellulosic. Enzymatic hydrolysis employed in the production of bioethanol and different medium-to-high value biomolecules (enzymes, succinic acid, lactic acid, xylooligosaccharides (XOS), pectin, and bioactive peptides).
- Alkaline pretreatment of SH and subsequent enzymatic hydrolysis for PHB production by a strain of Cupriavidus necator, with an accumulation of 39% of the biopolymer.
- Production of microbial lipids from soybean hull hydrolysates to produce biodiesel. The microbial strain used consumed the pentoses present in the hydrolysate to produce microbial lipids.
- Second-generation itaconic acid production from xylose and glucose.

RUSSIA:

- Production (cultivated, purified, isolated and analyzed) of hydrolytic enzymes to 85–95% homogeneity. Enzymes were subsequently distributed and used by all BRICS members.
- The reactivity of plant raw materials obtained from project partners and pre-treated in various ways was determined. The reactivity of wood during alkaline treatment increased by 5 times, and bagasse of sugar cane from 3.8 to 5.5 times, depending on the type of bagasse (bagasse from China was more reactive than bagasse from South Africa). Alkali concentration of should be not more than 1.5%.
- The mechanism of synergistic interaction of cellobiohydrolase I (CBHI) and cellobiohydrolase II (CBHII) was determined.
- Highest yield of glucose during hydrolysis of birch wood includes up to 80% cellobiohydrolases (CBHI and CBHII), about 20% EGII, and beta-glucosidase, BG, (about 10% of the total cellulase complex). The presence of polysaccharide monooxygenase, PMO, (10–15%) increased the hydrolytic ability of the complex by 10–12%.
- Ternary mixtures of EGII, CBHII, and CBHI in the presence of BG led to a cellulose conversion of about 20% in 72 h of hydrolysis of chopped birch wood. For deep destruction of birch wood, the presence of hemicellulases (xylanases) is also necessary. Such an integrated approach increases the yield of cellulose by 25%.

INDIA:

- Process for ethanol production from rice straw biomass: The mild acid (0.8%) optimized pretreatment resulted in approx. 83% of the cellulose in pretreated rice straw hydrolyzed into sugars. Meyerozyma caribbica produced 24.36 g/L ethanol with a fermentation efficiency of 95%.
- Process for ethanol production from Giant reed biomass: Meyerozyma guilliermondii produced bioethanol from pretreated biomass of giant reed (Arundo donax). Pretreated biomass could make 90.56% cellulose accessible for enzymatic attack. Subsequently, saccharification of pretreated biomass with two enzyme variants resulted in conversion efficiency of 85–87%.
- Process for transformation of acetylated xylan into xylooligosaccharides: A chimeric bifunctional enzyme was developed for two activities xylanase and deacetylase. Stable at higher temperature of 71°C. The designed bifunctional enzyme was found to be highly efficient.
- New LPMO for oxidation of lignin of rice straw: A unique LPMO has been identified and expressed in E. coli. Apart from oxidising lignin monomers, this thermally stable enzyme could also produce guaiacol. Novel activity of LPMO could be very useful to design an efficient, yet greener and sustainable process for producing aromatic compounds through lignin depolymerisation.
- Production of 2,5-furandicarboxylic acid from 5-hydroxymethylfurfural: This study focused on designing a suitable mono- or bimetal oxide catalytic system for the efficient transformation of HMF to FDCA — an alternative to production from fossil fuels.

CHINA:

- Construction of comprehensive enzymes library for efficient utilization of biomass and their related pilot-production technology. Completed the construction of an enzyme library containing 529 enzyme molecules; completed 6 enzymes pilot scale production (including endoglucanase, exoglucanase, β-glucosidase, xylanase, sucrase and fructosyltransferase), and production cost is not higher than 10 000 RMB per ton.
- Determination of efficient enzymatic hydrolysis methods and related hydrolysis technology systems. Established four protocols for sugarcane bagasse hydrolysis technologies. The hydrolysis rate of cellulose reached 90%, the hydrolysis rate of hemicellulose reached 100%, the hydrolysis rate of lipid reached 99%, and the hydrolysis rate of protein was higher than 95%. Established three corresponding enzymatic hydrolysis technology systems.
- Construction of recombinant strains for biofuels and material monomers, and scale-up for pilot production. Two new strains for ethanol production from hydrolysate of sugarcane baggage, and four new strains of lactic acid monomer production from hydrolysate of sugarcane bagasse were developed. Four sets of pilot-scale production technologies for D-lactic acid monomer and L-lactic acid monomer were created. Lactic acid production technologies have been successfully implemented in industrial applications. The conversion rate of lactic acid monomer was up to 102%, and the productivity was not less than 5.1 g/l/h.

Figure 2. *Lauch of the BRICS-BEST Consortium at DUT in March 2019.*
From left to right: Dr Ivan Zorov, Moscow State University; Dr Alexandra Rozhkova, Russian Academy of Science; Prof. Suren Singh, DUT; Prof. Kugen Permaul, Project Leader, DUT; Prof. Júlio de Carvalho, University of Paraná; Prof. Carlos Soccol, Research Leader, University of Paraná; Mr Fei Mingxing, Chinese Consul General; Prof. Zhengxiang Wang, Research Leader, Tianjin University of Technology; Prof. Theo Andrew, DUT.

SOUTH AFRICA:

- An optimised pre-treatment procedure for thermochemical degradation of sugarcane bagasse was developed that minimised the use of corrosive acids/bases and production of phenolic derivatives.
- Lignin was isolated and characterised from both sugarcane bagasse (SA) and aspen wood (Russia).
- A xylose reductase gene was cloned and characterised with a potential application for xylitol production explored.
- A xylose-utilising Mucor circinelloides strain was used in co-cultures with Saccharomyces cerevisiae for bioethanol production, but also chitosan, microbial lipids, protein and lignin recovery.
- Saccharomyces and Sheffersomyces strains were also used in co-cultures to produce bioethanol from another plant residue, cowpea haulm.
- Biobutanol was produced from sugarcane bagasse and aspen wood after a 2-step pre-treatment process using Clostridium acetobutylicum, yielding 7.08 and 8.65 g/L for sugarcane bagasse and aspen wood, respectively, after 72 h.
- In a partnership with local collaborators, a cellulosic effluent from a pulp mill was pre-treated and used for PHA production by Bacillus thuringiensis.

RESEARCH OUTPUTS

A total of 59 journal articles and 18 book chapters were published by the consortium.

A highlight was the publication of a book, edited by the Brazilian project leader, Prof. CR Soccol, which included chapter contributions from the Russian, Indian and South African teams.

MEETINGS AND COLLABORATIVE VISITS

- The launch meeting was held on 19 March at DUT in Durban, South Africa *(Figure 2)*.
- The 1st Joint Workshop and planning meeting of BRICS-BEST was held from 20–21 March 2019 at the Oribi Gorge Hotel, KZN, South Africa.
- A Russian staff member visited DUT from June–July 2019.
- A Russian staff member visited China in August 2019.
- Two Chinese staff visited DUT in August 2019.
- The Second Joint Workshop of the BRICS-BEST Technology Platform was held from 20–24 November 2019, at The Residency Tower Hotel, Trivandrum, India.
- A DUT staff member and a PhD student visited China from November–December 2019.
- A Brazilian staff member visited Russia from December 2019–January 2020.
- An online conference — Utilization of Agricultural Biomass Waste Digital Conference was hosted by the Chinese team from 15th–16th November 2021 and included presentation by lead researchers and students from each country.

Unfortunately, due to Covid-19 all proposed research visits in 2020 and 2021 were cancelled. This included the Final Joint Workshop of the BRICS-BEST Technology Platform which was scheduled for 08–10 December 2021, at the Crowne Plaza Dubai Marina, Dubai, UAE, and had to be cancelled due to flight restrictions imposed on South Africans in November 2021.

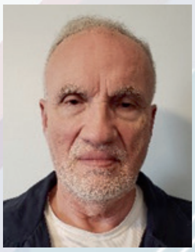
5. ASTRONOMY

Superconducting Terahertz Receivers for Space and Ground-based Radio Astronomy

Project details:

BRICS STI FP call	3rd BRICS STI FP Call 2019
Project number and Acronym	BRICS2019-053 "STARS"

National Principal Investigator	National Principal Research Organization	Country
Jacques Lepine	University of São Paulo	BRAZIL
Valery Koshelets	Kotel'nikov Institute of Radio Engineering and Electronics	RUSSIA
Huabing Wang	Nanjing University	CHINA
Coenrad Fourie	Stellenbosch University	SOUTH AFRICA
Funding agencies: National Council for Scientific and Technological Development (CNPq, Brazil), Russian Centre for Science information (RCSI, Russia), National Natural Science Foundation of China (NSFC, China), National Research Foundation (NRF, South Africa).		



BRAZIL: Jacques Lepine

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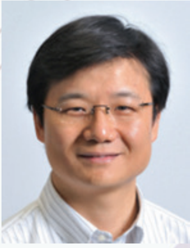
RUSSIA: Valery Koshelets

Kotel'nikov Institute of Radio Engineering and Electronics; Prof, Dr. Sci.; Radio Physics



CHINA: Huabing Wang

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SOUTH AFRICA: Coenrad Fourie

Stellenbosch University, Department E&E Engineering; Prof, PhD; Electronic Engineering, Josephson junction circuit design software

A major goal of the project was to advance sub-THz technology and develop quantum-limited SIS receivers and THz sources for applications in ground-based and space radio astronomy, including super-VLBI. The BRICS project member countries have strong traditions of excellence in radio-astronomy, which has the potential to answer fundamental questions on the origins of the universe. In particular, the Russian ground-space interferometer "Radioastron" is already conducting surveillance of supermassive black holes. Black holes are the one of the most interesting predictions of General Relativity, and the attempts to prove or disprove their existence are the one of the main goals of astronomy. The quantum limited receivers are required to obtain top scientific results in radio astronomy. The importance of this direction was recently confirmed by the publication of the first ever "image" of a supermassive black hole in the center of the M 87 galaxy.

The Russian space observatory "Millimetron" [1] with a 10-m coolable telescope, which is a successor of "Radioastron", is designed to study different objects in the Universe, including black holes, at sub-THz and THz frequencies. As an event horizon of a black hole is very compact, required extremely high angular resolution, up to tens of billionths of a second of arc, will be provided by the "Millimetron" orbit configuration in combination with ground-based telescopes [2]; the observatory will be located in the vicinity of the Lagrange point L2, at 1.5 million km from Earth. The observatory has two operational modes — the single-dish and Space-Earth interferometer modes. In the first mode observations are carried out with maximum sensitivity, which can be achieved using the on-board detectors of radiation from space objects.

The BRICS program has bridged together Brazil, Russian, Chinese and South African groups who all have an international reputation and recognized track record in their field. Their complementary scientific and technical strengths, expertise in instrumentation development and experience in international collaborations resulted in highly successful prior collaborations. The BRICS grant helped the participating groups to collaborate in a more structural way than it was before the project realization. To this end the participating groups embarked on a joint and coordinated research program with number of world class results:

1) Development and characterization of the 211–275 GHz low noise Superconductor-Insulator-Superconductor (SIS) receivers for Russian space project "Millimetron", ground-based Event Horizon Telescope (EHT) project and the Large Latin American Millimeter Array (LLAMA).

2) Development of the SIS mixers based on Nb/AlN/NbN twin tunnel junctions incorporated in a NbTiN/Al microstrip line for waveguide receiver operating in frequency range of 700–950 GHz for Chinese radio observatory at Dome A, Antarctic, for Champ II+ (APEX observatory at Atacama site in Chile) and for Brazilian LLAMA located in the Argentinean Andes.

The extremely high operating frequency and exceptionally strong nonlinearity of superconducting nanostructures make it possible to create systems for receiving and generating radiation in the terahertz range with characteristics that significantly exceed the parameters of the devices based on other principles. The use of nanoelectronics techniques makes it possible to fabricate superconducting integrated structures for operation in the terahertz spectral region with ultimate (quantum) sensitivity. The research program of our BRICS project naturally combined work in two priority areas of science and technology: the creation of practical foundations for superconducting microwave electronics and the development of unique devices for ultrasensitive signal reception and their further processing. The use of modern microelectronics techniques, implemented at successfully operating large-scale research facility (UNU "Cryointegral") in Moscow, allowed the project team to create Nb based SIS junctions and integrated superconducting for operation in the THz range with quantum sensitivity. In the course of the proposed research, a number of both fundamental results and applications were obtained. The result of the project is also advancing THz technology and development of the THz detectors/sources suitable for scientific and industrial applications and technological spin-offs.

We report here on research carried out by the project participants, aimed at developing receivers with quantum sensitivity for implementation in space and ground-based radio telescopes. SIS mixers based on high-quality tunnel junctions are the key elements of the most sensitive sub-THz heterodyne receivers. We present results of the SIS receiver developments for the 211–275 GHz and 700–950 GHz frequency ranges with a noise temperature in the double sideband (DSB) mode of approximately 20 K and 120 K, respectively. These designs and achievements are implemented in the development of the receiving systems for the Russian Space Agency mission "Millimetron", and for the ground-based APEX (Atacama Pathfinder EXperiment) telescope.

For the Space-Earth interferometer, single sideband 211–275 GHz receivers sensitive for both side-bands (2SB) with a noise temperature below 50 K are required. In this report, the results of the development of a prototype of the DSB SIS waveguide receiver with suitable parameters are presented [3]. Usually, the well-pronounced knee-like feature arises on the IVC of a Nb/Al-AlOx/Nb tunnel junction at voltages slightly higher than Vg. The presence of the knee structure results in the negative differential resistance on the quasiparticle steps that in turn leads to the mixer instability and nonlinear operation at some frequencies. It was demonstrated that the knee structure can be completely suppressed by introducing an additional Al layer in the base electrode. The current-voltage characteristic (IVC) of an Nb-Al-Nb/Al-AlOx/Nb SIS mixing element (area of approximately 1 μm^2) with an additional Al layer in the bottom electrode, measured in the voltage-bias mode, is shown in *Figure 1;* the SIS junction critical current is suppressed by a magnetic field. The normal resistance of the SIS junction is Rn = 22 Ω; the quality parameter characterized by the ratio of the resistances under and above the gap Rsg/Rn = 39; the gap voltage Vg = 2.8 mV, and the energy gap spreading δV is approximately 0.1 mV.

In the design of the mixer block for the frequency range 211–275 GHz, we follow a successful modular construction approach developed for the ALMA Band 9 receiver [4]. The mixer block (see *Figure 2*) consists of a few separate elements: (1) an input horn; (2) a central part with the waveguide; (3) a back piece (BP) unit where the mixer chip is installed; and (4) a magnet block unit with two magnet pins to suppress the Josephson critical current of the SIS mixer. The receiving chip (width 150 μm,) is located in a rectangular 1000 × 500 μm waveguide at a distance of 230 μm from the back short in the waveguide, orthogonal to the propagation direction. The Nb/AlO_x/Nb SIS junction is placed into a planar Nb/SiO_2/Nb tuning structure made on a 125 µm thick quartz substrate (see *Figure 3*). To prevent leakage of the high frequency input signal through this dielectrically filled waveguide, blocking low-pass filters were used. To match the waveguide impedance of approximately 400 Ohm and the high frequency SIS impedance, a waveguide probe and a tuning structure were used.

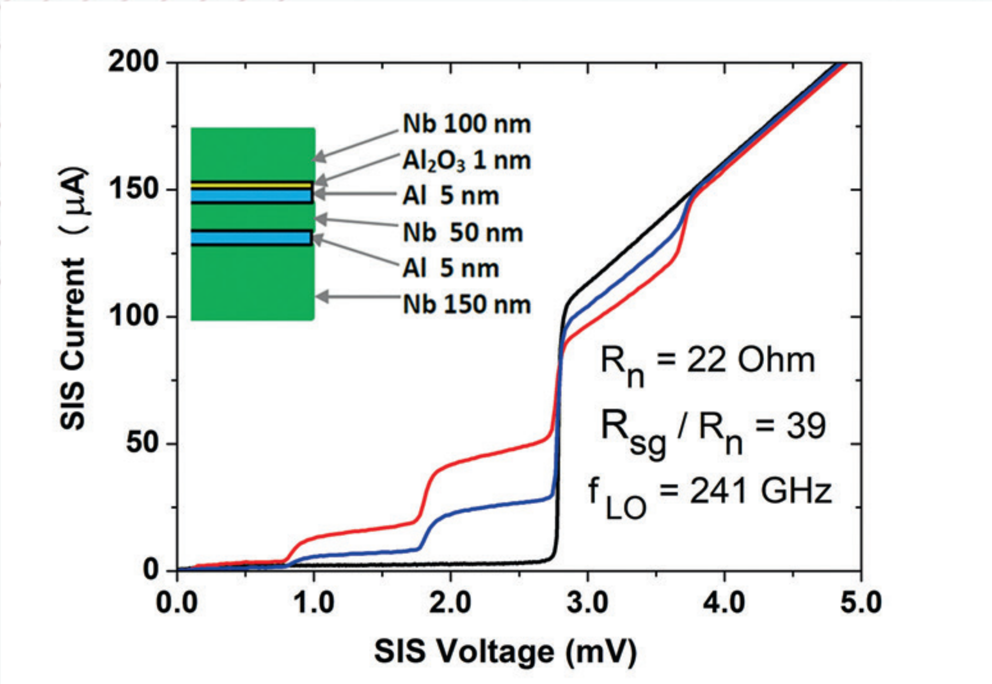

Figure 1. *IVC of the Nb-Al-Nb/Al-AlOx/Nb mixer element fabricated on quartz substrate (area of tunnel junction A = 1 µm², Vg = 2.8 mV, RnA = 22 Ω µm²); the Josephson supercurrent is suppressed by the magnetic field (black line). The IVCs of the SIS mixer pumped by LO at 241 GHz at two different LO powers are shown by the blue and red lines. A cross-section of the three-layer structure is presented in the inset.*

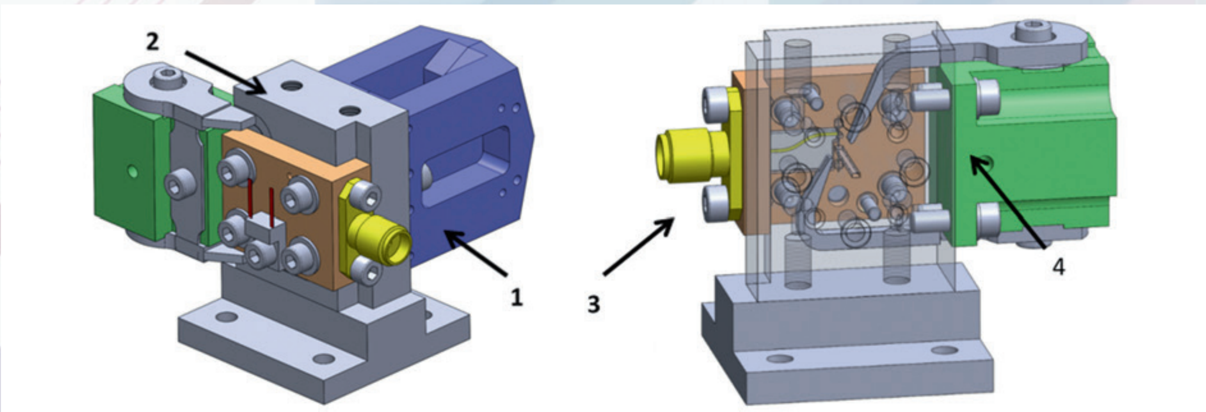

Figure 2. *A 3D model of the mixer block for the frequency range 211–275 GHz; all main parts are shown: (1) input horn, (2) central part with the waveguide, (3) back piece with mixer chip, (4) magnet block unit.*

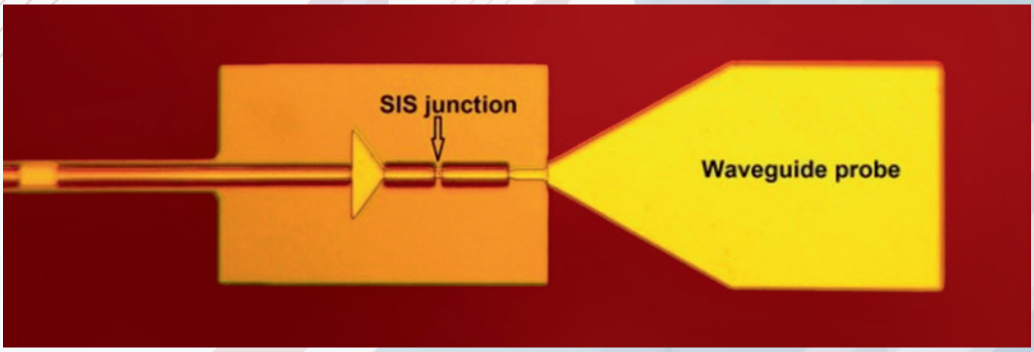

Figure 3. Photo of the SIS mixer structure for the frequency range 211–275 GHz. The SIS element is inserted in the planar structure formed by segments of coplanar and microstrip Nb-SiO2-Nb lines. The waveguide probe is shown on the right.

The DSB mixer noise temperature was determined by the standard Y-factor measurement method; an absorber at room temperature (295 K) was used as a “hot” load, and an absorber cooled by liquid nitrogen (78 K) was used as a “cold” load [5, 6]. *Figure 4* shows the SIS receiver output versus the bias voltage measured for 241 GHz LO at 6.5 GHz IF (60 MHz IF filter bandwidth). The Y-factor was determined by subtracting the responses measured for hot and cold loads. The value of the Y-factor at the best point exceeds 5.0 dB, which corresponds to a receiver noise temperature of approximately 22 K. The values of the noise temperature T_n were obtained without any corrections for losses in the beam splitter and the cryostat window [6]; they were only twice the value of hf/k_B in the frequency range from 240 to 275 GHz (see *Figure 5*). The obtained values meet the technical requirements for the 211–275 GHz receiver of the Millimetron space radio telescope; this receiver can be used as a prototype for future space missions and for novel ground-based radio telescopes (Suffa [7], LLAMA [8]).

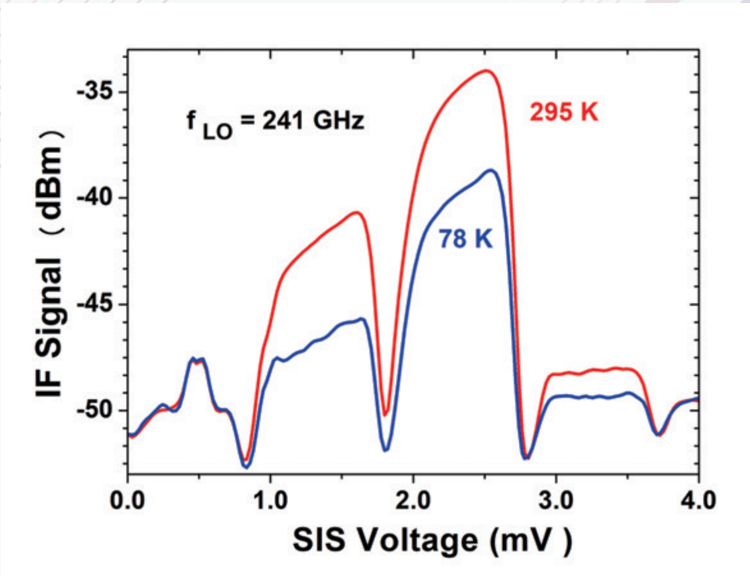

Figure 4. The output signal of the SIS receiver at intermediate frequency (IF) 6.5 GHz on the SIS bias voltage, measured for the cold and hot input loads (78 K—blue curve and 295 K—red curve, correspondingly) at the local-oscillator frequency 241 GHz.

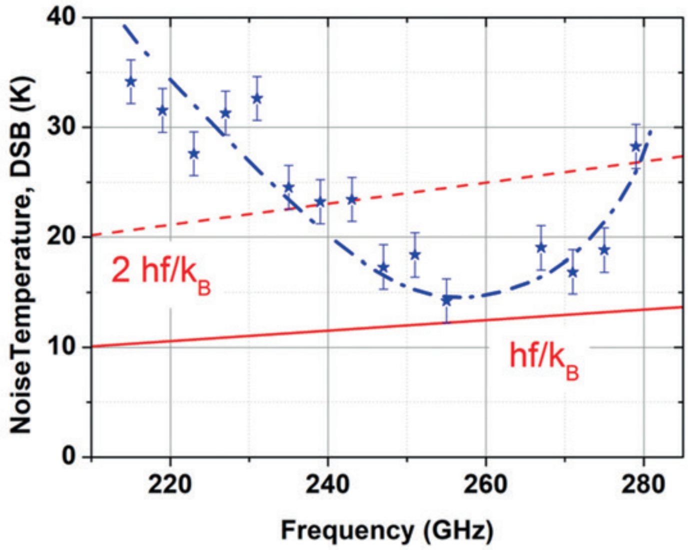

__Figure 5.__ DSB receiver noise temperature of the SIS receiver on the local oscillator (LO) frequency; the experimental data are presented without any corrections for losses in the input optic elements. Measurement uncertainty is approximately 2K, shown by error bars. The dash-dotted line is given as a guide for the eyes.

The operating frequency of the Nb SIS receivers is constrained by the gap frequency of Nb (approximately 700 GHz). The possible solution for this problem may be found in the fabrication and utilization of the devices with microstrip lines based on compounds of Nb with the higher gap frequencies, particularly NbTiN; the top electrode of the line is usually made from normal metal to avoid SIS junction overheating [9–11]. We developed an SIS mixer based on high current density Nb/AlN/NbN tunnel junctions embedded in a microstrip line consisting of a 320 nm NbTiN lower electrode (ground plane) and a 500 nm Al upper electrode [12]. The microstrip electrodes are separated by a 250 nm thick SiO_2 insulating layer. The SIS junction is placed on the NbTiN film and the top NbN layer is in contact with the upper Al electrode (see inset in *Figure 6*).

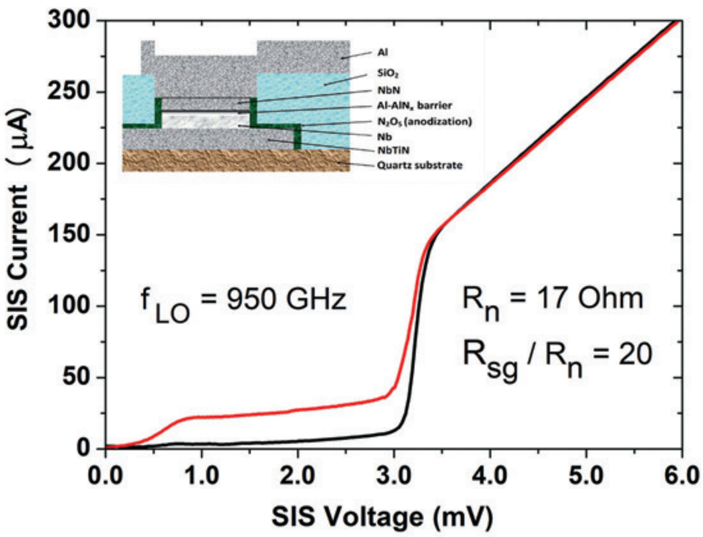

__Figure 6.__ IVC of the Nb/AlN/NbN mixer element inserted in the NbTiN/Al stripline, fabricated on quartz substrate for APEX telescope (area of tunnel junction A = 0.5 μm^2, Vg = 3.22 mV, RnS = 8.5 Ω μm^2, Jg of approximately 30 kA/cm^2); the Josephson supercurrent is suppressed by the magnetic field (black line). IVC of the SIS mixer pumped by a CW LO source delivering approximately 0.5 µW of power to the SIS junction at 950 GHz is shown by the red line. A cross-section of the mixer element incorporated in a NbTiN/Al microstrip line is presented in the inset.

To make a wideband receiver for the 700–950 GHz frequency range we used twin SIS junctions (each with an area of 0.5 μm^2, see Figure 7), coupled by a waveguide probe to the E-field of a rectangular waveguide of 300 × 75 μm. The SIS mixer [5, 6] was based on high critical current density Nb/AlN/NbN tunnel junctions included in the NbTiN-Al microstrip line [12]. The detailed procedure for making the circuit is described in the previous subsection.

Due to the high current density of the AlN barrier, a lower Rn value is realized, which gives a higher $1/R_nC$ ratio for junctions (with C-junction capacitance), providing a wider reception bandwidth. A twin mixer circuit was formed by two SIS junctions with 6.5 μm junction spacing, embedded in a 4.5 μm wide microstrip line, which is connected to the antenna by a 7 × 27 μm impedance transformer [6] designed to match the high current density junctions to the waveguide probe (see *Figure 7*).

The SIS mixers for the waveguide receiver with an operation frequency up to 950 GHz were developed and tested [6, 12]; these mixers are based on Nb/AlN/NbN twin tunnel junctions incorporated in a NbTiN/Al microstrip line. The above technology makes it possible to achieve a junction current density of up to 30 kA/cm^2; providing a figure of merit (the ratio of the resistance of the sub-gap to normal) above 20. Using the twin SIS junction design, we have achieved a wide receiver operating range (675 to 950 GHz) and quite good noise temperature in this frequency range, as shown in *Figure 8*. These mixers are intended for the Chinese radio observatory at Dome A, Antarctic, for Champ II+ (APEX observatory at Atacama site in Chile) and Brazilian LLAMA located in the Andes.

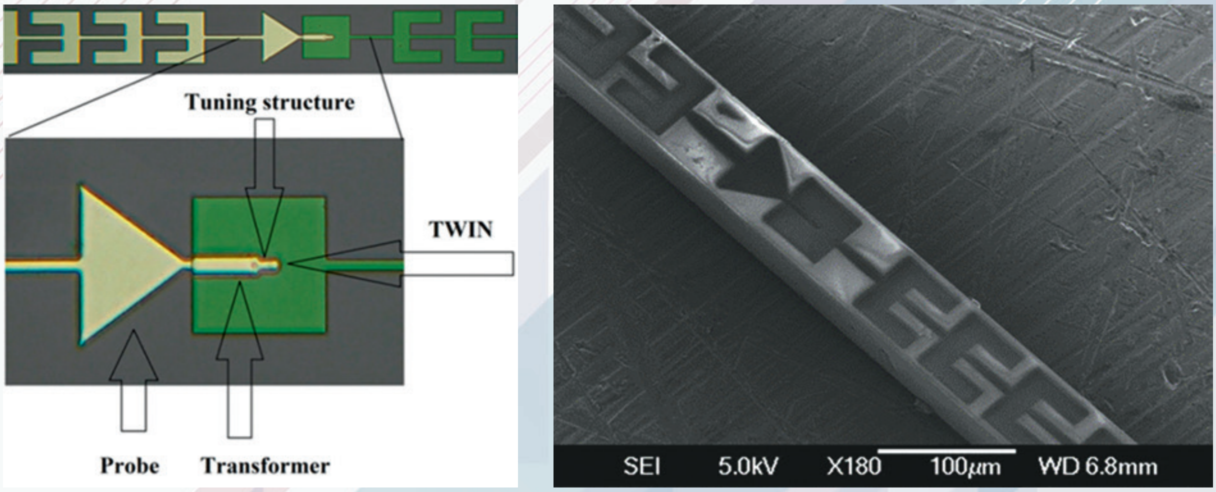

Figure 7. *Layout (left) and SEM photo (right) of the CHAMP+ high band SIS mixer. The central part of the chip (including SIS twin junction, transformer, and probe) is magnified.*

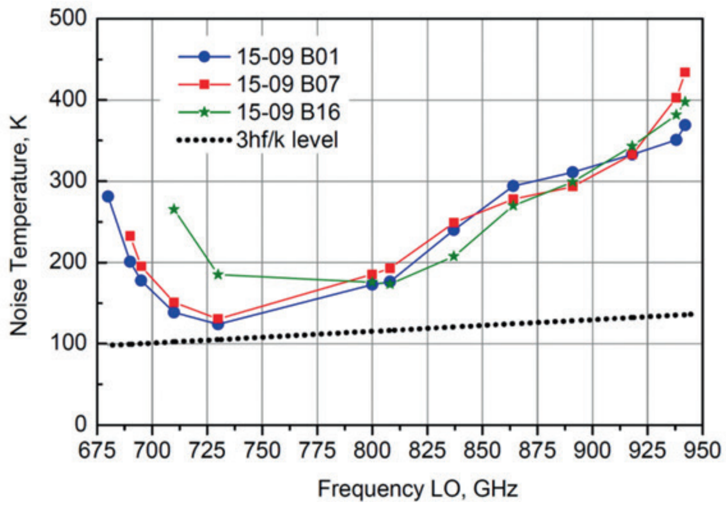

Figure 8. *DSB noise temperature for three SIS mixers as a function of frequency; noise temperature was corrected for losses in the input window and beam splitter. The dotted line shows the noise temperature, which corresponds to 3hf/kB.*

The CHAMP+ heterodyne array [13] is installed on the APEX telescope; the instrument consists of two separate sub-arrays of 7-pixels each; the pixels are placed in a hexagonal configuration. The input frequency ranges of two sub-arrays were chosen in accordance with the atmospheric transparency windows: 600–720 GHz and 790–950 GHz for low and high band, correspondingly *(Figure 9)*. The characteristics of the optimized high-frequency CHAMP+ mixers are described below and compared with previous results.

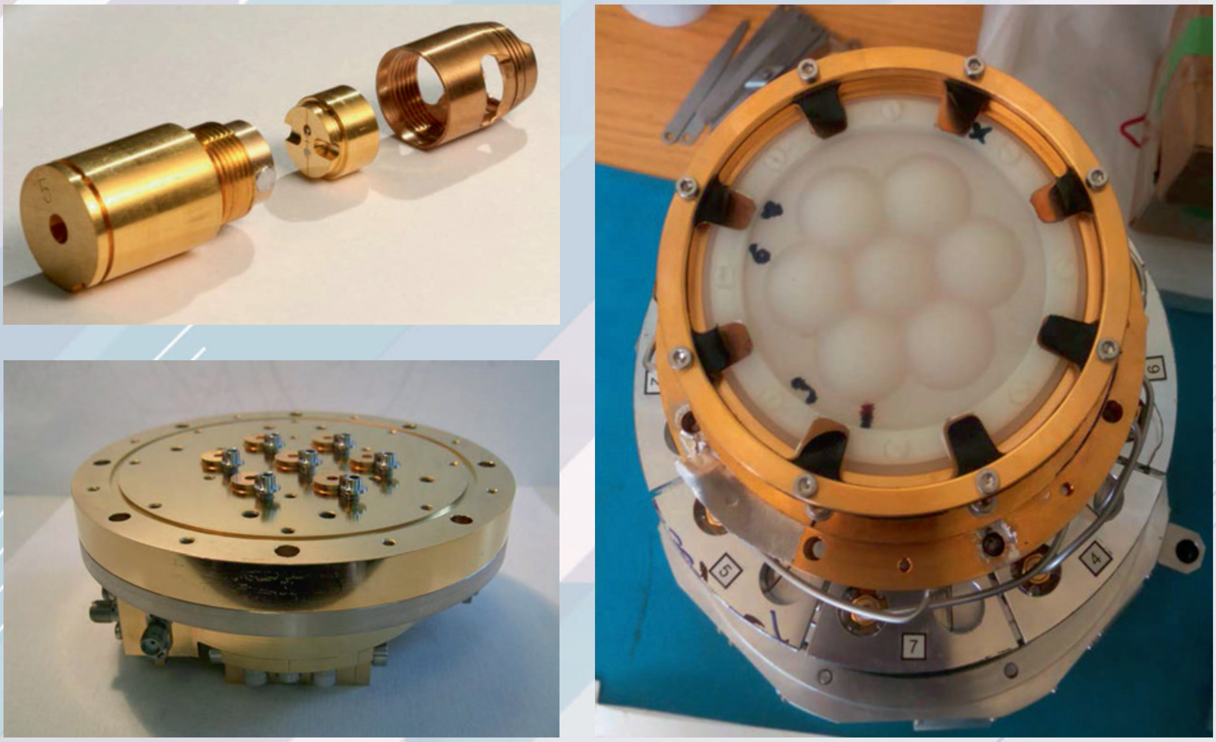

Figure 9. *7-pixel array for high band (790–950 GHz) receiver CHAMP+ at radio telescope APEX (Atacama Pathfinder EXperiment): (a) Photo of the pixel mixer block elements, (b) 7-pixel mixer array with open horns, (c) Lens array at the top of the cartridge body.*

To upgrade the high-frequency receivers, we have employed Nb/AlN/NbN mixers incorporated in an NbTiN/Al microstrip line. The presented mixer technology in comparison with Nb/AlOx/Nb mixers looks quite promising: (1) a higher Vg value provides a 0.7 mV wider quasiparticle step for high frequencies; (2) high current density allows for a very broadband mixer; (3) heating of the SIS junctions is not critical for the operation of the mixer. SIS mixers designed to upgrade the CHAMP + high frequency array (790–950 GHz) on the APEX telescope (Figure 10) exhibit DSB noise temperatures of 210 to 400 K [14]. This improves sensitivity by up to 40% compare to the previous receivers (i.e., almost a factor of 2 in observation time).

The development of superconducting THz receivers for space and ground-based radio astronomy, begun as part of the BRICS project, continues after the formal completion of the project; see below for a list of recent publications.

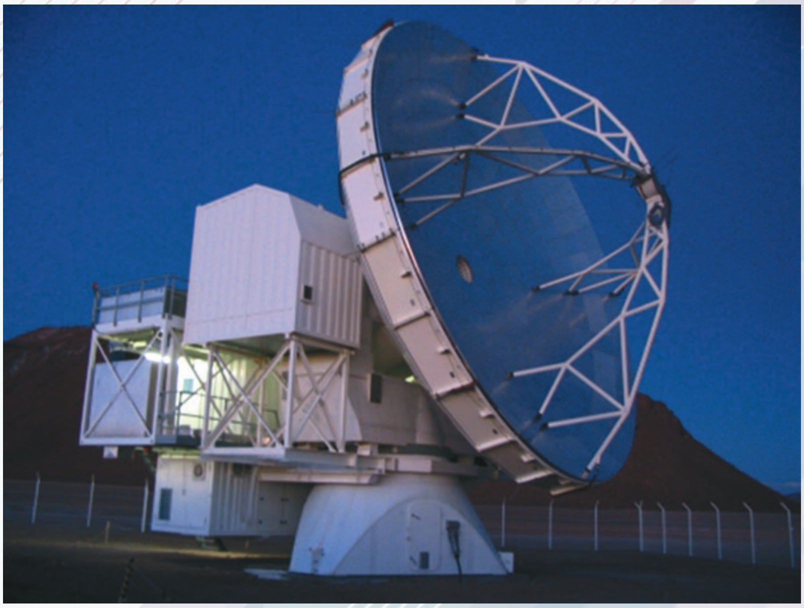

Figure 10. Array receiver CHAMP+ is installed at APEX 12 m telescope; LAMA site, Chile, altitude 5105 m.

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6. BIOTECHNOLOGY AND BIOMEDICINE INCLUDING HUMAN HEALTH AND NEUROSCIENCE

SARS-CoV-2 Network for Genomic Surveillance in Brazil, Russia, India, China and South Africa

Project details:

BRICS STI FP call	BRICS STI FP response to COVID 19 pandemic call 2020
Project number and Acronym	BRICS2020-049 “NGS-BRICS”

National Principal Investigator	National Principal Research Organization	Country
Ana Tereza Ribeiro de Vasconcelos	National Laboratory for Scientific Computation — LNCC/MCTI	BRAZIL
Georgii Bazykin	Skolkovo Institute of Science and Technology	RUSSIA
Arindam Maitra	National Institute of Biomedical Genomics	INDIA
Mingkun Li	Beijing Institute of Genomics, CAS	CHINA
Tulio de Oliveira	University of KwaZulu-Natal	SOUTH AFRICA
Funding agencies: National Council for Scientific and Technological Development (CNPq, Brazil), Russian Centre for Science information (RCSI, Russia), Department of Biotechnology (DBT, India) / Department of Science and Technology (DST, India), National Natural Science Foundation of China (NSFC, China), South African Medical Research Council (SAMRC, South Africa).		

Leading the NGS-BRICS project from South Africa were **Dr Eduan Wilkinson** (left) and Prof. **Tulio de Oliveira** (right)

SUMMARY

Since the outbreak of the COVID-19 pandemic, the SARS-CoV-2 virus has spread across the entire world, causing millions of deaths and severe economic losses. Four of the BRICS countries (Brazil, India, Russia and South Africa) are amongst the most severely affected countries in the world.

The NGS-BRICS program was initiated in 2021 with the goal of creating a collaborative research programme for genomic sequencing of SARS-CoV-2 in the five BRICS countries. This project allowed the Network for Genomic Surveillance in South Africa (NGS-SA) (funded by South African Medical Research Council) to collaborate with the NGS-BRICS, fostering an integrated, cross-disciplinary, collaborative research programme. The NGS-BRICS project used genomic sequencing to help track the evolution, spread and outbreaks of SARS-CoV-2 in South Africa and other BRICS countries.

The project objectives were to:

1. Increase access to genomic methods to sequence SARS-CoV-2 in BRICS countries in near real-time and to trace the evolution of the virus in each country.
2. Trace SARS-CoV-2 introductions, identify community transmissions and to use this information to characterize and control local outbreaks.
3. Use knowledge generated from SARS-CoV-2 sequences to improve diagnostics and therapeutics.

The South African part of the project was launched in July 2021 and was completed in December of 2023. Here we describe the describe the collaboration with the BRICS countries and highlight some of the important results and their impact from the South African part of the project.

COLLABORATION WITH BRICS COUNTRIES

The NGS-BRICS partnership started in April 2021 to address key questions and challenges faced by South Africa due to the COVID-19 pandemic. The partnership included investigators from Laboratório de Bioinformática, Institute of Agricultural Sciences and Instituto René Rachou in **Brazil**; the A.A. Kharkevich Institute for Information Transmission Problems of the Russian Academy of Sciences in **Russia**; the National Institute of Biomedical Genomics and Indian Institute of Science in **India**; the CAS Key Laboratory of Genomic and Precision Medicine, Beijing Institute of Genomics and University of Chinese Academy of Sciences in **China**; and the Centre for Epidemic Response and Innovation (CERI) and KwaZulu-Natal Research Innovation and Sequencing Platform in **South Africa**. The consortium met regularly throughout the project to discuss the developments in each BRICS partner country over the lifespan of the project.

RESULTS AND IMPACT

At the start of the NGS-BRICS consortium in April 2021 South Africa was emerging from the second wave of infections in the country that was caused by the Beta variant. CERI focused on several outbreak investigations in 2021. One such investigation was focused on an outbreak onboard a cargo vessel that was docked in the Durban harbour. Sequencing of these infections quickly identified the first Delta SARS-CoV-2 variants of concern (VOCs) in South Africa. Another outbreak investigation at the time was focused on the emergence of the C.1.2 lineage, which evolved from the C.1.1 lineage that our team had described the year before. Other outbreak investigations assessed the spread of SARS-CoV-2 within a busy renal unit in Durban to determine if patients had been infected via multiple sources or if the outbreak originated from a single source. In the winter months of 2021, the pandemic in South Africa was driven by the Delta VOC, similar to other areas of the world at the time. The Delta wave was followed by a short period of low transmission in the spring of 2021, with <10 cases being recorded nationally. However, in November of 2021 a new wave of infections hit the country following the discovery of the Omicron VOC by the Network for Genomic Surveillance in South Africa (NGS-SA).

In the 2022–2023 period, the pandemic in South Africa was dominated by Omicron and Omicron sub-lineages. December 2021 and January 2022 saw the biggest wave of infections since the pandemic started with roughly 20,000 cases being reported daily. This infectious wave was caused by the BA.1 and the BA.2 sub-lineages of Omicron. A smaller wave of infections followed in April/May of 2022, being caused by the BA.4 and BA.5 sub-lineages of the virus. Since then, the pandemic curve has remained flat, either due to increase population immunity due to vaccination or prior exposure, or due to reduced testing numbers. Towards the end of 2022 we observed the rise of BQ.1and XBB.15 sub-lineages of Omicron dominating the viral landscape within the country. By the middle of 2023 these lineages were starting to be replaced by the XBB.1.16 and BA.2.86 sub-lineages (*Figure 1*).

Over the course of the partnership, CERI and NGS-BRICS colleagues, also worked towards the writing of a review article assessing the different epidemic responses across the five nations and how each approached their own unique challenges faced during the pandemic.

Increase access to genomic methods in order to sequence SARS-CoV-2 in BRICS countries in near real-time and to trace the evolution of the virus in each country

Over the course of the NGS-BRICS partnership, genomic sequencing of SARS-CoV-2 cases expanded greatly in all five countries. From April 2021 until December 2023, >750,000 high quality genomes were shared on GISAID from the five BRICS nations. Of this, 241,340 genomes were from Brazil; 80,847 from Russia; 335,529 from India; 67,748 from China and 50,892 from South Africa. SARS-CoV-2 genotyping in South Africa was led by the Network for Genomics Surveillance in South Africa (NGS-SA), which included 11 laboratories from academic and public health institutes. In South Africa, the project supported the acquisition of important

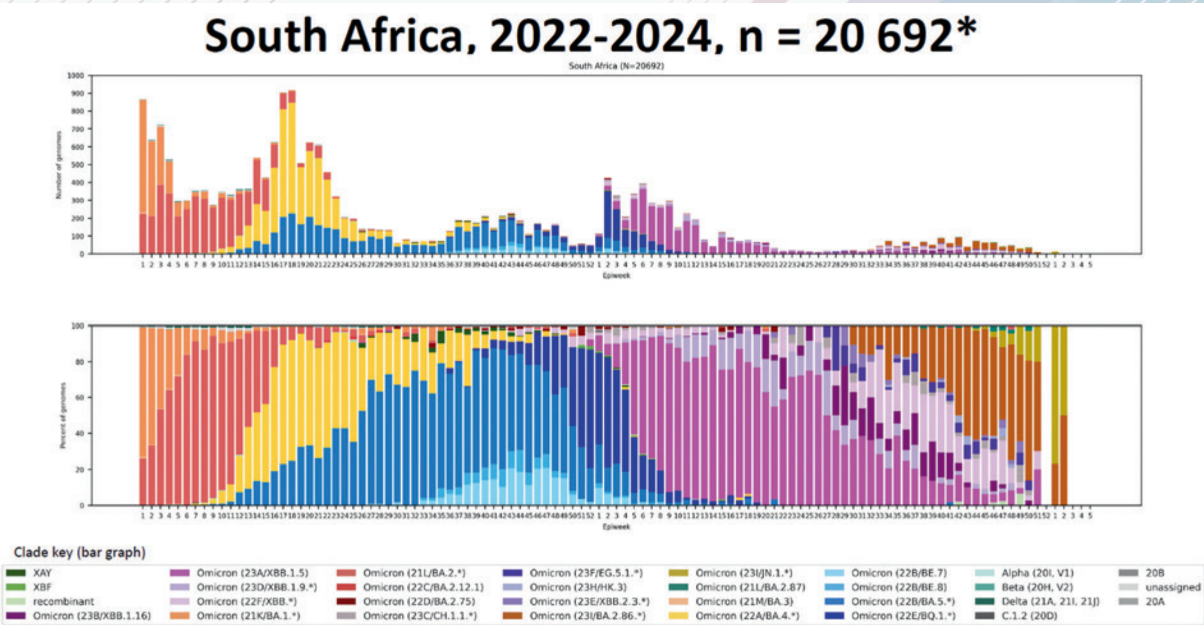

Figure 1. *The total number of SARS-CoV-2 whole genome sequences from South Africa that have been shared between January 2022 and January 2024 and their lineage classification. The top plot represents the total number of sequences/lineages per epidemiological week in 2022 and 2023. The bottom plot represents the total frequency of each lineage through time.*

laboratory infrastructure, including NextSeq, MiSeq, and NovaSeq platforms from Illumina to compliment the GridIon platform that was already in place at the time. This equipment supported the sequencing endeavours during the project. The resulting sequences were used for outbreak investigations and to answer other key scientific question, which resulted in several high impact publications (Panel insert). CERI, along with her NGS-BRICS partners, have also worked towards a joint review exploring the unique experiences to epidemic response and genomic surveillance in each of the five BRICS nations during the pandemic.

Increases in sequencing in all five countries followed pandemic growth trajectories. At the start of the partnership, South Africa and Brazil had already identified two VOCs namely Beta and Gamma. By April 2021, a new VOC namely Delta, which originated in India was spreading globally causing the third big wave of infections. South Africa through the NGS-SA consortium identified the fifth VOC in November 2021, namely Omicron which can be classified into sub-variants (BA.1–BA.5). The pandemic progression and genetic profile of infection in BRICS countries followed general global patterns, with the exception of China which pursued a strict zero-COVID strategy until the end of 2022. Since the emergence and global spread of Omicron sub-variants in late 2021, the virus has continued to evolve, mainly driven by high levels of population immunity, either from vaccination or prior exposure *(Figure 2)*.

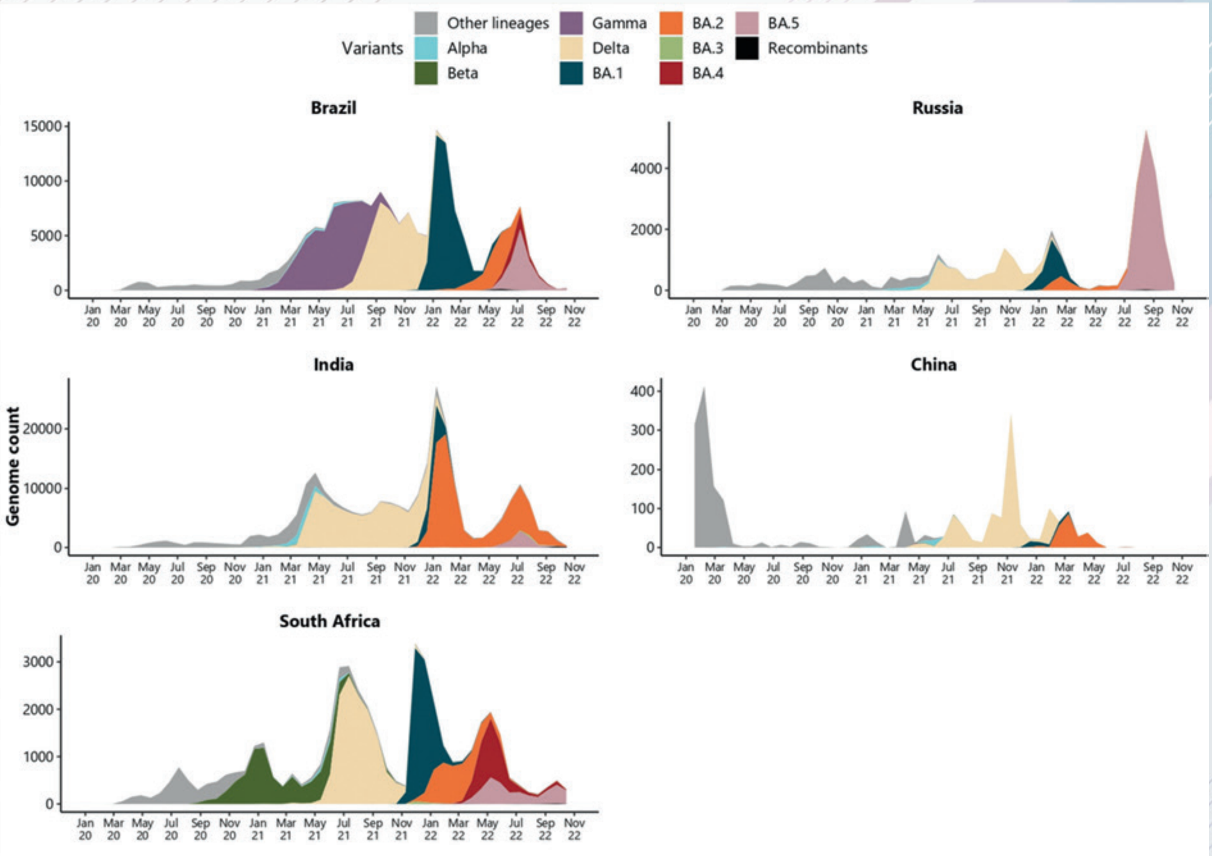

Figure 2. *Schematic representation of the changes in the genetic compositions of SARS-CoV-2 lineages recorded for BRICS countries for 1 January 2020 to 31 October 2022.*

GENOMICS AND BIOINFORMATICS TRAINING OF BRICS SCIENTISTS

The partnership also made important contributions to building human capacity in wet and dry laboratory skills to advance genomic surveillance of SARS-CoV-2 in BRICS and other global south countries. CERI staff has played a key role in this regard.

1. CERI assisted with the organization and teaching of the online webinar (COVEME) — Monday, August 30 — Friday, 3rd of September 2021, Belo Horizonte, Brazil with ~400 participants, of which a third were from BRICS countries.
2. In November 2021, CERI, in partnership with the Africa CDC, facilitated a hands-on sequencing workshop focused on the generation of SARS-CoV-2 genomes and the analysis of data. This workshop was attended by 22 delegates from African countries.
3. In August 2022, CERI participated in the planning, execution and teaching of the 26th Viral Evolution and Molecular Epidemiology Workshop (VEME) from 21–27th in Panama City, Panama. Several investigators from CERI served as instructors in this workshop.
4. Building on the success of the COVEME in 2021, CERI and the NGS-BRICS partners hosted the first NGS-BRICS virtual workshop on Viral Molecular Epidemiology and Bioinformatics between 26–30 September 2022. This workshop was attended by >200 scientist working in BRICS countries and included topics such as sequence assembly, data reporting, uploading of data to public databases and basic phylogenetic techniques.
5. In October of 2022, colleagues from South Africa and Brazil presented and served as facilitators at a UWARN workshop that focused on Oxford Nanopore sequencing of SARS-CoV-2. This workshop combined both wet and dry laboratory methods and was attended by >30 young African scientist working in academia or at public health laboratories on the continent.
6. In April 2023, CERI hosted another 36 African young fellows working on genomic surveillance of pathogens in academia or public health institutions on the continent. This workshop provided hands on training of SARS-CoV-2 on the Oxford Nanopore platform and sequencing of *M. tuberculosis* on the illumina platform.
7. In June 2023, the South African investigators taught at a one-day workshop in Washington DC. This workshop focused on both metagenomics (e.g. wastewater surveillance) and targeted sequencing surveillance.
8. In August 2023, CERI participated in the planning, execution and teaching of the 27th Viral Evolution and Molecular Epidemiology Workshop (VEME) in Stellenbosch, South Africa. This week-long workshop brought together some of the world's top experts in viral evolutionary analyses and included 107 participants from 35 different countries.
9. In November 2023, CERI hosted a large African-centred training program at CERI's Tygerberg facilities for 33 African fellows that combined both wet and dry laboratory methods.

In addition to these listed training and capacity building activities, CERI also hosted several weekly calls with African partners on the conceptualization and writing of two Africa centred papers on SARS-CoV-2 evolution and spread on the continent. In many of these weekly calls, CERI staff taught in online webinars to teach attendees how to perform their own data analyses.

In summary, the NGS-BRICS project fostered an integrated, cross-disciplinary, collaborative research programme that used genomic sequencing to help track the evolution, spread and outbreaks of SARS-CoV-2 in South Africa and other BRICS. Overall, the project made some important contributions to describing new SARS-CoV-2 variants of concern and variants of interest, provided unique insights into several outbreak investigations in South Africa, evaluated several diagnostic tests to determine their performance given the high viral diversity, and most importantly, contributed to building capacity in the BRICS countries through training courses and workshops that reached over 500 individuals working in genomic surveillance.

Georgii Bazykin, Skolkovo Institute of Science and Technology:

This project has established an integrated, cross disciplinary, collaborative genomics research programme between leading BRICS scientific organizations to advance COVID-19 health-relevant knowledge and contribute to improvements in health outcomes. The SARS-CoV-2 NGS-BRICS consortium will include some of the leading scientific organizations in Brazil, Russia, India, China and South Africa.

The consortium has four main objectives:

1. To increase access to genomic methods in order to sequence SARS-CoV-2 in BRICS countries in near real-time and to trace the evolution of the virus in each country.
2. To trace SARS-COV-2 introductions, identify community transmissions and to use this information to characterize and control local outbreaks.
3. To use knowledge generated from SARS-CoV-2 sequences to improve diagnostics and therapeutics.
4. To capacitate BRICS's scientists on the production and analysis of SARS-CoV-2 genomic data.

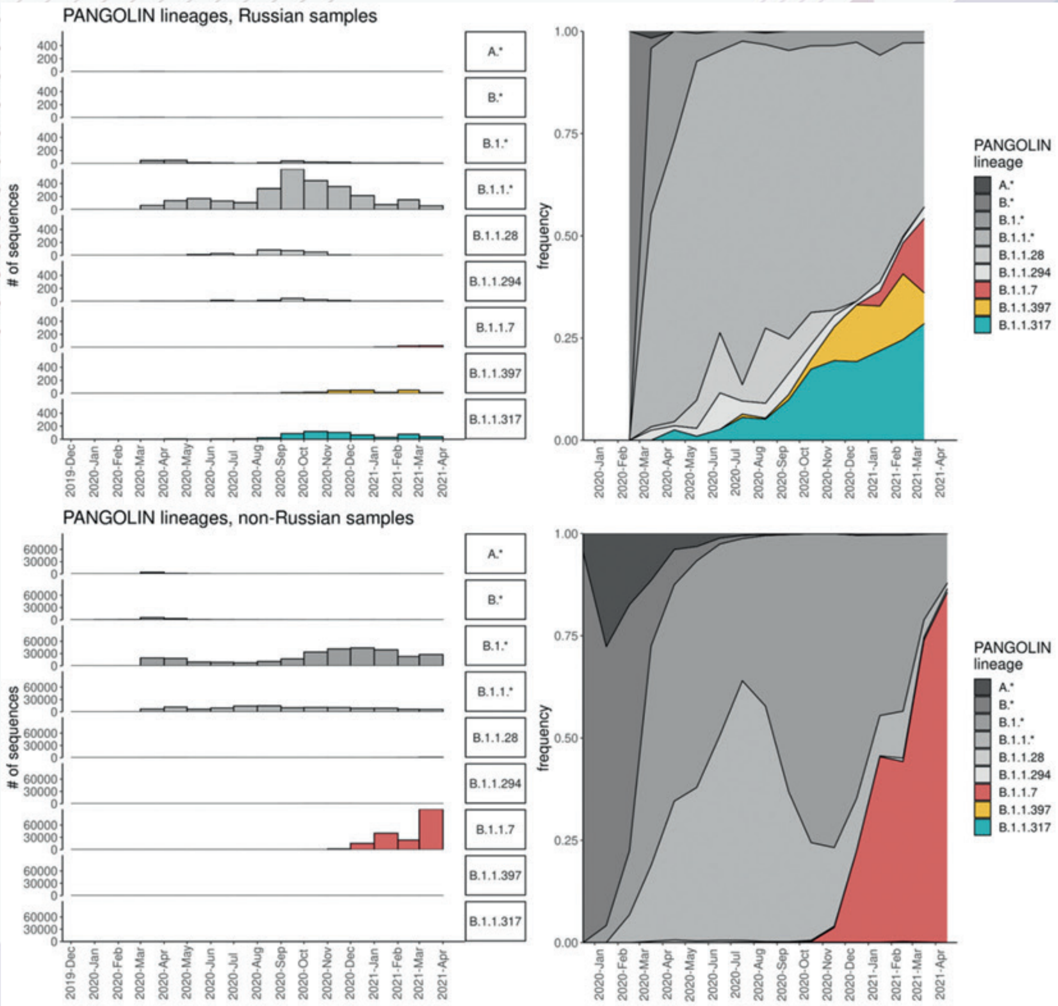

Figure. Dynamics of line frequencies in Russia (top row) and among the non-Russian GISAID sample (bottom row).

Throughout the project, members of the consortium collaborated to analyze the emergence and global spread of SARS-CoV-2 variants. In addition, the Russian project participants described the diversity and dynamics of SARS-CoV-2 variants in the Russian Federation. We plan to continue the work of the Consortium even after the end of the term of the grant.

Among other results, during the project we investigated the dynamics of the diversity of SARS-CoV-2 in Russia. Russia has been severely affected by COVID-19, but the diversity of SARS-CoV-2 is relatively poorly understood. The genetic composition of SARS-CoV-2 in Russia differed somewhat from the rest of the world throughout the pandemic; in particular, the variants of concern spread here either later (Alpha, Omicron) or earlier (Delta) than in most neighboring countries. Such isolation could lead to the emergence and local spread of new adaptive variants. We traced the temporary changes in the genetic composition of SARS-CoV-2 in Russia and showed that by the end of 2020 it was dominated by two lines that remained rare in non-Russian samples. Both lines carried a number of previously described mutations of interest. From the beginning of 2021 until the global spread of the Delta, four new lines were distributed in Russia, including Alpha (B.1.1.7) and three newly described lines carrying interesting combinations of mutations. The mutational composition of these lines, together with a constant increase in their frequency, indicated their potentially increased transmissibility.

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Arindam Maitra, Biotechnology Research Innovation Council-National Institute of Biomedical Genomics; Anup Mazumder, Biotechnology Research Innovation Council-National Institute of Biomedical Genomics:

The project BRICS2020-049-NGS-BRICS for SARS-CoV-2 Genomic Surveillance was a great initiative among the five participating countries. Representative from all the five countries met online once in every month during the pandemic and substantial relevant information on genomic surveillance were exchanged among the countries. In addition to contributing significantly to the surveillance program in India, some of the findings were published in an international peer reviewed journal on emergence of a unique SARS-CoV-2 Delta sub-cluster harboring a constellation of co-appearing non-Spike mutations by the investigators (https://doi.org/10.1002/jmv.28413).

In this studyconducted by the investigators of BRIC-NIBMG in collaboration with scientists of ICMR-NICED, a unique signature set of eight non-Spike co-appearing mutations was identified that could have led to the evolution of a distinct Delta subcluster across Eastern India during the mercurial second pandemic wave in India during 2021. This was the first report from eastern India based on the whole genome sequencing of 239 viral SARS-CoV-2 RNA samples (collected from both the adult and paediatric patients in West Bengal). 41.4% of the Delta strains harboured this signature array of eight co-appearing non-Spike mutations, which could have caused the evolution of such distinct Delta sub cluster. Continuous monitoring of such unique non-Spike mutations in the emerging variants will assist in the formulation of any future vaccines against those SARS-CoV-2 variants that might evade the current vaccine-induced immunity, among both the paediatric and adult population in India (*Figure 1*) (doi: 10.1002/jmv.28413). Another review manuscript entitled "The COVID-19 Pandemic in BRICS: milestones, mitigation, and molecular epidemiology" was developed by the researchers from all the five BRICS countries and this emerged from the regular monthly meetings which were conducted as a significant collaborative spirit *(manuscript under review in PLOS Global Public Health)*.

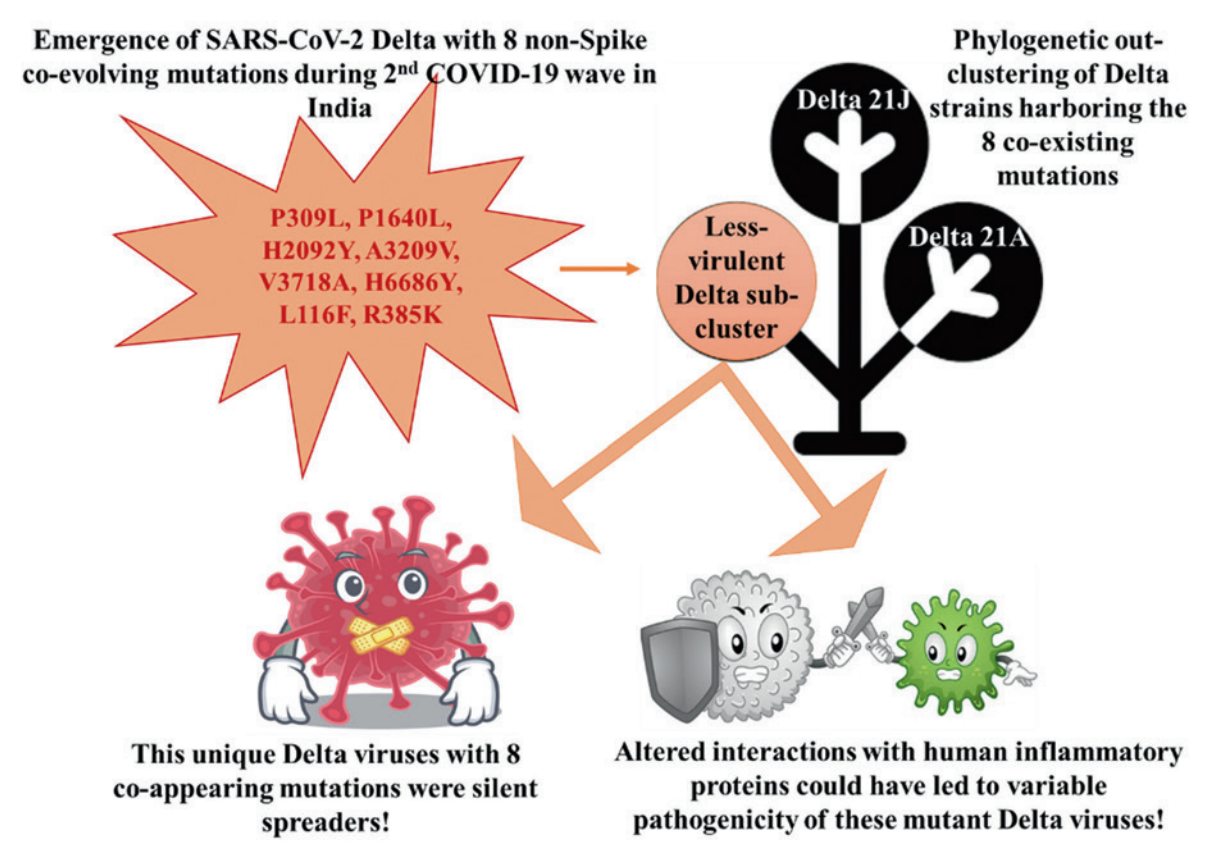

Figure 1. *Schematic representation of study which revealed a unique signature set of eight non-Spike co-appearing mutations that could have led to the evolution of a distinct Delta sub-cluster across Eastern India during the mercurial second pandemic wave in India during 2021.*

The project led to capacitating clinicians and scientists in BRICS countries on the generation and analysis of SARS-CoV-2 genomic data, a 4-day hands-on training workshop was organized by NIBMG to train the clinicians from Sir Thutob Namgyal Memorial Hospital, Govt. of Sikkim, India. The workshop encompassed techniques like sample preparation for NGS, followed by bioinformatics analysis for viral variant calling. Further, Dr Nidhan K Biswas delivered a lecture in an International virtual workshop on SARS-CoV-2 genome sequencing, assembly, and phylogenetic analyses was organized by the BRICS-NGS consortium from 26th–30th September 2022, which aimed at scientists working in a BRICS country in the field of academia or in a public health laboratory. Dr Anup Mazumder also delivered a lecture on the topic entitled "SARS-CoV-2 Network for Genomic Surveillance in Brazil, Russia, India, China and South Africa NGS-BRICS" in the BRICS STI FP Conference on Biomedical Sciences and Technologies, held virtually during 25–26 May, 2023 in Moscow, Russia. Prof. Arindam Maitra delivered a lecture entitled "Covid 19 and the next Pandemic" ina CME for Clinicians on Genome surveillance of SARS-CoV-2: Lessons for future at STNM Hospital, Gangtok, Sikkim, India, on 11 March 2022. Prof. Arindam Maitra also delivered an invited lecture on "Genomics Surveillance of the Pandemic… The Past, The Future and What We Achieved" at the 91st Annual Meeting of the Society of Biological Chemists (India), 08 December 2022.

To improve and expedite diagnostics for SARS-CoV-2, the researchers at NIBMG have also standardized the technology called Droplet Digital PCR which aims at quantifying the absolute SARS-CoV-2 viral copies (mainly Omicron and Delta variants) present in the samples. dd-PCR is based on water oil emulsion droplet technology which is more sensitive than the conventional quantitative real-time PCR. The method is applicable for faster detection of known SARS-CoV-2 variants, significantly in cases of outbreaks and samples from international travellers.

Hands on training workshop for training on NGS for SARS-CoV-2 organized by NIBMG, Kalyani-India team for Clinicians

7. INFORMATION TECHNOLOGIES AND HIGH PERFORMANCE COMPUTING

Electronic synapses based on two dimensional materials for neuromorphic computing

Project details:

BRICS STI FP call	2nd BRICS STI FP Call 2017
Project number and Acronym	BRICS2017-211 "2DNEURO"

National Principal Investigator	National Principal Research Organization	Country
Gilson Inacio Wirth	Universidade Federal do Rio Grande do Sul	BRAZIL
Vladimir Gritsenko	Rzhanov Institute of Semiconductor Physics SB RAS	RUSSIA
Santanu Mahapatra	Indian Institute of Science Bangalore	INDIA
Mario Lanza	Soochow University	CHINA
Funding agencies: National Council for Scientific and Technological Development (CNPq, Brazil), Russian Centre for Science information (RCSI, Russia), Department of Science and Technology (DST, India), Ministry of Science and Technology (MOST, China).		

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RESEARCH BACKGROUND

Achieving brain-inspired computing represents a significant technological objective for the coming decades. This advancement would enable the execution of complex, error-tolerant operations, such as pattern recognition and associative sequence learning, which remain unfeasible with current von Neumann architecture. The human brain consists of approximately 1012 neurons interconnected by roughly 1015 synapses. These synapses can alter their conductivity through the uptake of Ca2+ and Na+ ions, which are released when neurons transmit electrical impulses. Artificial neural networks, modeled on this resistive switching (RS) principle, have been developed using various electronic devices. Among these, memristors have shown superior performance. Modern memristors, composed of metal/insulator/metal (MIM) cells, can toggle their conductivity between a high resistive state (HRS) and a low resistive state (LRS) in response to electrical impulses, thus mimicking the functionality of biological synapses. The intermediary dielectric material possesses the remarkable capability to support reversible changes in electric resistance. These changes facilitate the emulation of biological synaptic behaviors, specifically the potentiation and depression phases, through cyclic transitions between the HRS and LRS.

Over the past decade, numerous memristive cells fabricated with various materials and exhibiting diverse characteristics have been reported. State-of-the-art memristors typically employ transition metal oxides (TMO) such as HfO2, Al2O3, TiO2, and TaOX as insulators. Despite significant advancements, no single memristive device currently meets all non-volatile memory (NVM) technology requirements simultaneously, indicating that the search for optimal materials that encompass all necessary capabilities continues. The main challenges in memristive technology include balancing speed with retention, power efficiency with speed, and endurance with retention. Additionally, reliability and variability issues still pose significant barriers to large-scale manufacturing, with considerable variation observed in switching voltages and resistances in both HRS and LRS states. The uniformity of the RS phenomenon thus remains a critical area of research, as the inconsistency in device characteristics poses a major challenge for the widespread adoption of memristive technologies.

To address these challenges, recent methodologies suggest replacing traditional metal and/or insulating films in MIM structures with novel materials that offer enhanced properties. The emergence of two-dimensional (2D) materials has garnered considerable interest in microelectronics due to their unique electronic, physical, chemical, mechanical, optical, magnetic, and thermal properties. Early prototypes using 2D materials, such as graphene, have shown potential benefits in stabilizing RS characteristics, reducing power consumption, and enhancing device properties through surface functionalization and improved three-dimensional stackability. This approach not only addresses the challenges of conventional memristive devices but also opens new avenues for the development of flexible and transparent electronic components.

The most reasonable option for fabricating memristive devices based on 2D materials is to use a layered insulator as RS material. In this direction, hexagonal boron nitride (h-BN) is a layered dielectric with a permittivity between 2 and 4 and a band gap of 5.2–5.9 eV. However, more efforts in this direction need to be devoted. Fabricating memristors using truly layered h-BN stacks would be interesting not only due to all the above mentioned advantages, but also due to its good thermal stability, which should facilitate heat dissipation. Furthermore, its good compatibility with graphene can open the door to the design of fully two-dimensional G/h-BN/G memory devices.

NECESSITY OF INTERNATIONAL COLLABORATION

Brain-inspired computing research is poised to become one of the most significant business sectors globally in the upcoming decades. This field promises a revolutionary shift in system architecture, enabling the execution of complex tasks that current computational models cannot efficiently manage. The significance of this research trajectory was underscored in 2014 when it was named a runner-up topic of the year by Science magazine, highlighting its potential impact on technological advancement. Countries and institutions that have been at the forefront of this research are likely to secure a competitive edge and could play pivotal roles in this technological revolution.

For the BRICS nations — Brazil, Russia, India, China, and South Africa — taking the lead in brain-inspired computing could prove particularly advantageous. These countries, with their substantial populations and rapidly expanding digital infrastructures, are uniquely positioned to benefit from advancements in this field. The vast amounts of data generated daily within these nations not only drive economic activity but are also critical to national security. By harnessing and analyzing this data more effectively, brain-inspired computing can offer enhanced decision-making capabilities, more robust security protocols, and increased economic efficiency. In developing countries, where urbanization and digital transformation are occurring at an unprecedented pace, the demand for more sophisticated data processing and storage solutions is acute. These nations are already making significant strides in developing their digital economies and integrating advanced technologies into various sectors. Therefore, investing in brain-inspired computing could further accelerate their technological sovereignty and economic growth. Moreover, the strategic implementation of brain-inspired computing technologies could facilitate the development of more resilient and efficient systems for managing urban infrastructure, healthcare, and public services. These systems could be designed to optimize resource allocation, improve service delivery, and enhance the quality of life for millions. Additionally, by fostering innovation in this area, the BRICS nations could also develop new intellectual property, catalyzing further industrial and academic advancements. Finally, the collaborative efforts among these nations in brain-inspired computing research could foster stronger political and economic alliances. Shared technological goals might lead to cooperative frameworks that support not only shared research and development initiatives but also joint ventures and commercial enterprises. This cooperative model could serve as a template for other regions and help bridge gaps in global technology and innovation landscapes.

In conclusion, as brain-inspired computing continues to evolve, the strategic involvement and leadership of BRICS countries in this field are not merely beneficial but essential. These nations have the opportunity to steer the future of this promising technology, leveraging their unique strengths to foster economic growth, enhance national security, and play a leading role in a global technological revolution.

ROLES AND RESPONSIBILITIES IN THE JOINT PROJECT

The collaborative effort among the BRICS nations in advancing brain-inspired computing technologies demonstrates a strategic alignment of each country's strengths and capabilities.

Chinese Team: The Chinese team, leveraging the sophisticated infrastructure of their institute's clean room, will spearhead the fabrication of electronic synapses. This facility is well-equipped with the necessary equipment to ensure precise and controlled manufacturing processes. Additionally, the Chinese team will lead the nanoscale electronic characterization using Conductive Atomic Force Microscopy (CAFM) and Transmission Electron Microscopy paired with Electron Energy Loss Spectroscopy (TEM+EELS). As project coordinators, they will also oversee the integration of research outputs across different teams, ensuring that the project milestones are met efficiently.

Russian Team: The Russian team will focus on device-level characterization, primarily utilizing probe station techniques. This involves detailed assessments of device performance under various electrical test conditions to understand the properties and behaviors of the fabricated synapses. Additionally, they will provide crucial support to the Indian team by contributing expertise in device simulation, which is vital for predicting device behavior under theoretical and practical scenarios.

Indian Team: Tasked with leading the device modeling efforts, the Indian team will develop a multi-scale simulation platform. This platform is designed to provide a comprehensive understanding of the synaptic devices from atomic to macroscopic levels. Collaborating closely with the Russian team, the Indian researchers will ensure that simulations are both accurate and reflective of actual device performance, which is critical for the iterative design and enhancement of the synapses.

Brazilian Team: Concentrating on the study of random telegraph noise (RTN) signals in the synapses, the Brazilian team will analyze these signals to extract practical information about charge trapping and de-trapping dynamics during the switching mechanisms. Such phenomena are crucial for understanding the fundamental issues related to performance and reliability in memory devices. This team's work will not only aid in the characterization of defects such as charge trapping centers and oxygen vacancies but also enhance the understanding of their impact on resistive switching, device aging, and breakdown. The insights gained will be instrumental for circuit designers and will contribute to the development of models that link atomic-level phenomena with observed electrical behavior, thereby optimizing the resistive switching processes.

Through this international collaboration, the project aims to harness each team's specialized knowledge and resources, fostering a multidisciplinary approach to tackle the complex challenges of developing next-generation computing technologies. The synergy among the teams will not only accelerate the pace of innovation but also ensure that these advancements are robust, scalable, and applicable across a variety of technological applications.

REPRESENT ACHIEVEMENTS

This project focused on resistive switching devices, often called memristors, for different applications, including information storage, stochastic computing and computing inspired by brain activity. We investigated the fabrication of electronic synapses capable of providing resistive switching, both volatile and non-volatile, to simulate both long-term plasticity, short-term plasticity and learning rules including time-dependent plasticity. In collaborative work between BRICS teams, we manufactured, tested and modeled advanced memristor devices made from different materials (including two-dimensional — 2D materials), which have advanced physical, chemical, electronic, mechanical and thermal properties. By executing the research project, we improved the understanding of atomic rearrangements derived from resistive switching, developed circuit simulation capabilities for simulating neuromorphic systems, as well as carried out the design and implementation of case study circuits. Our investigations can represent a significant advance by reducing the complexity of the hardware needed to develop neuromorphic computers and circuits that require devices capable of stochastic behavior, such as those used in true random number generators, fundamental to encryption and internet security.

The development of the internet-of-things requires cost-efficient, light, small and reliable true random number generator (TRNG) circuits to encrypt the data before transmitting them. However, usual solutions consume too much power and require a relatively large battery, hindering the integration of TRNG circuits on most objects. We fabricated a TRNG circuit by exploiting stable RTN current signals produced by memristors made of two-dimensional (2D) multi-layered hexagonal boron nitride (h-BN). Our study was the first full hardware implementation of 2D-material-based TRNGs, enabled by the unique stability and figures of merit of the RTN signals in h-BN based memristors.

We also advanced the analysis of noise, dielectric breakdown growth, and ambipolar resistive switching in memristors based on multilayer hexagonal boron nitride (h-BN), one of the most promising novel nanomaterials for memristive applications. We studied the random telegraph noise in pristine memristors and its evolution as the devices degrade, covering ~7 orders of magnitude in current with consistent observation. We observed trapping activity that imposes giant random conductance fluctuations. These events appeared reproducible over different RS device types in sequential measurements and under different bias. This behavior is very beneficial to ensure recognition of the device's two-state in applications such as stochastic computing and brain inspired architectures.

INTERNATIONAL EXCHANGES

The project effectively started in 2019, just before the COVID-19 pandemic. The pandemic restricted international travel and access to laboratories and to other workplaces. In addition to the necessary daily adaptations and more complex personal management of all team members, remote/virtual work was incorporated. Exchange activities are summarized below:

- On April 19th, 2019, Prof. Gilson Wirth traveled to China, returning on May 1st, 2019. During his stay at Institute of Functional Nano & Soft Materials (FUNSOM), Soochow University, in Suzhou, China, he participated in the manufacturing process of RS devices, as well as carried out electrical characterization, in addition to meetings and discussions with the Chinese team. Upon returning, he brought samples manufactured there to continue electrical characterization and modeling work in Brazil.

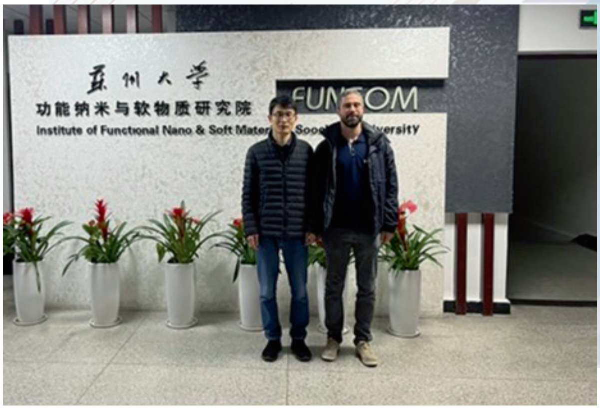
- On August 25th, 2022, Prof. Xu Gao was invited to attend SBMicro 2022 held in Brazil (online) and the 6th Meeting of the BRICS Working Group on ICT and HPC held in India (Online).

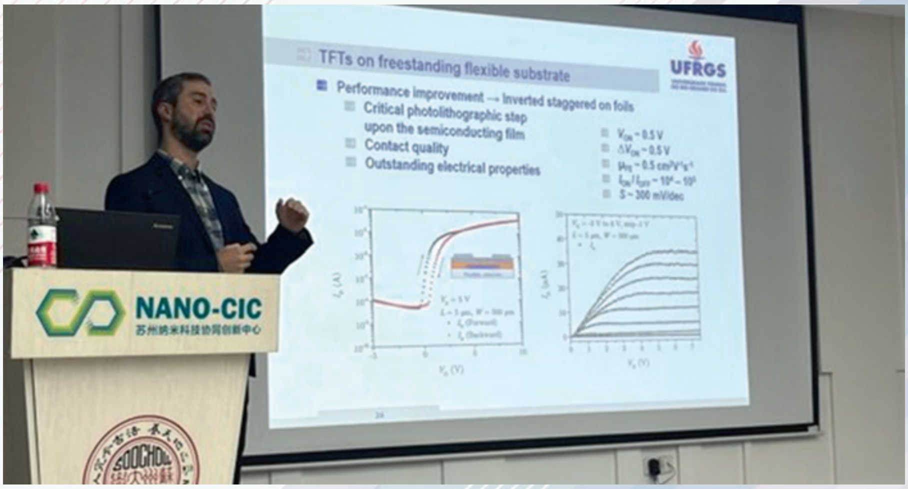
- From February 16th to 23rd, 2023, Prof. Gilson Wirth was in Bangalore, India, visiting the Indian Institute of Science. The technical discussions with the group of Prof. Santanu Mahapatra focused mainly on applying Density Functional Theory (DFT) on the electrical modeling of resistive switching devices.

- From October 30th to November 08th, 2023, Prof. Gilson Wirth was in Suzhou, China. Besides the interaction with the Chinese Research Team at FUNSOM, he also took part on the 5th BRICS WG Meeting on Material Science and Nanotechnology, held in Suzhou, China, where he could interact with members of different BRICS countries, aiming the consolidation and expansion of the collaborative network. Among the topics for joint research, are being studied. Prof. Gilson Wirth brought some samples from FUNSOM to the Lab in Brazil; They now are working to engage graduate and undergraduate students on this research.

- On November 3th, 2023, Prof. Xu Gao hosted the working group members attending the BRICS working group meeting at Suzhou University, marking a significant opportunity for academic exchange and international cooperation. The members include Prof. Vladimir Shur from Ural Federal University (Russia), Prof. Aleksandr Nosov from Institute of Metal Physics RAS (Russia), Alexey Nashchekin from Ioffe Institute (Russia), Dmitry Podgorny from University of Science and Technology (MISIS, Russia), Dr Irina Kuklina from International Centre for Innovations in Science, Technology and Education (Russia), Prof. Ruy Carlos Ruver Beck from Federal University of Rio Grande do Sul (UFRGS Brazil), Dr Felipe Silva Bellucci from Ministry of Science, Technology and Innovation of Brazil (MCTI-Brazil), Prof. Solange Binotto Fagan from Franciscan University (UFN, Brazil), Prof. Eliana Martins Lima from Federal University of Goias (UFG, Brazil), Prof. Lizandro Manzato from Federal Institute of Amazonas (IFAM, Brazil), Prof. Maximiliano Delany Martins from Nuclear Technology Development Center (CDTN-MCTI, Brazil), Prof. Antonio Claudio Tedesco from University of Sao Paulo (USP, Brazil), Prof. Gilson I Wirth from Federal University of Rio Grande do Sul (UFRGS, Brazil), Dr S. K. Varshney from Ministry of Science and Technology Govt. of India, and Dr Tebogo Mokoma from BRICS Desk Official Department of Science and Innovation (South Africa). We have arranged visits to the laboratories and research centers at Suzhou University, showcasing the university's research facilities and achievements to the working group members. This not only helps enhance the international reputation of Suzhou University but also provides substantive support for scientific research collaboration among BRICS countries.

- From January 11th to 21st, 2024, Prof. Fábio Vidor was in Suzhou, China, meeting with the researchers of FUNSOM at the Soochow Univ. Fábio Vidor was welcomed by Prof. Sui-Dong Wang and Prof. Xu Gao during a presentation he hold to the group. Additionally, he has contributed to topic-related discussions and meetings. During this technical visit, it was possible to expand the cooperation between both groups and to promote further cooperative initiatives.





BENEFITS FROM BRICS PROJECT

The BRICS Project represents a landmark collaboration among international research teams from Brazil, Russia, India, and China. This initiative focuses on the cutting-edge development of electronic synapses for Artificial Neural Networks, which are pivotal for the hardware implementation of advanced neuromorphic computing and AI systems.

Technical Synergy and Scholarly Output: The project leverages the unique expertise of each partner country to tackle complex technical challenges and ensure research excellence. Through this collaborative effort, the project has yielded significant scholarly contributions, with a total of 36 journal articles and 2 conference papers published in highly prestigious venues. Notable publications include 3 papers in Nature Electronics, 1 in Nature Communications, several others in Advanced Materials, Advanced Functional Materials, ACS Applied Materials & Interfaces, and so on. This prolific output not only advances the field of neuromorphic computing but also significantly boosts the international stature of the participating teams.

Impact on Neuromorphic Computing: The construction of electronic synapses is a critical area of research that has the potential to revolutionize neuromorphic computing. These components are essential for creating more efficient neural network implementations compared to traditional hardware approaches. The success in developing these advanced systems fulfills crucial technological needs that contribute to economic, health, and safety improvements globally.

Enhancement of International Influence and Education: The international collaboration fostered by the project has greatly enhanced the global influence of the research teams and has contributed to advancing the state of research in the respective domestic fields of the participating countries. Furthermore, the project has been instrumental in nurturing a new generation of researchers, equipping students with broad perspectives and deep professional knowledge through exposure to high-level international research environments.

Multilateral Cooperation and Policy Advancement: Implemented by BRICS international teams, including Universidade Federal do Rio Grande do Sul, Rzhanov Institute of Semiconductor Physics, Ioffe Physical-Technical Institute St-Petersburg, Indian Institute of Science Bangalore, and Soochow University, this project exemplifies effective multilateral cooperation. It has not only promoted academic and research exchange between local universities and globally renowned institutions but has also facilitated advancements in research, education, and international diplomacy. Moreover, the project benefits from and contributes to the enhancement of cultural and scientific collaboration policies among the BRICS nations, supporting the implementation and refinement of these policies.

Setting a Precedent for Future Collaborations: Overall, the BRICS Project enriches the models of international scientific and technological cooperation and sets a high standard for the execution of global research initiatives. The successful implementation of this project serves as a robust model for future international scientific endeavors, demonstrating the substantial benefits of collaborative innovation in addressing complex global challenges in science and technology.

8. OCEAN AND POLAR SCIENCE AND TECHNOLOGY

A BRICS Predicted Ocean: Roadmap and Demonstration of model validations, intercomparisons and applications for sustainable management of the coastal oceans

Project details:

BRICS STI FP call	5th BRICS STI FP Call 2021
Thematic area	Ocean and polar science and technology
Project number and Acronym	BRICS2021-130 “PARADIGM”

National Principal Investigator	National Principal Research Organization	Country
Mauro Cirano	Federal University of Rio de Janeiro	BRAZIL
Roman Sedakov	Shirshov Institute of Oceanology	RUSSIA
P. N. Vinayachandran	Indian Institute of Science	INDIA
Fangli Qiao	First Institute of Oceanography	CHINA
Jennifer Veitch	South African Environmental Observation Network — Egagasini Node	SOUTH AFRICA
Funding agencies: National Council for Scientific and Technological Development (CNPq, Brazil), Ministry of Science and Higher Education (MSHE, Russia), Department of Science and Technology (DST, India), Ministry of Science and Technology (MOST, China), National Research Foundation (NRF, South Africa).		

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INTRODUCTION

PARADIGM unites scientists from all BRICS representatives countries (Brazil, Russia, India, China and South Africa) with the purpose of providing high quality ocean forecasting products and strengthening three already endorsed programs of the United Nations Decade of Ocean Science for Sustainable Development (hereafter, UN Ocean Decade). They are: i) CoastPredict[1] — Observing and Predicting the Global Coastal Ocean; ii) ForeSea[2] — an OceanPredict[3] contribution to the UN Ocean Decade and iii) OSF[4] — Ocean to climate Seamless Forecasting System. Scientists involved in PARADIGM participate in these programs and integrate the BRICS Working Group on Ocean and Polar Science and Technology.

The project aims to: i) Use the observations collected within the BRICS countries to validate and intercompare Ocean Forecasting and Analysis Systems (OFAS) at each region *(Figure 1)*; ii) Implement high-resolution OFAS in specific sites (e.g., pilot studies) and iii) Provide capacity building by organizing training/workshops focusing on Operational Oceanography in BRICS countries.

In 2021, PARADIGM was submitted to the 5th BRICS Science, Technology, and Innovation (STI) Framework Programme Call, competing with more than 383 pre-proposals, from which 322 projects were invited to submit full proposals. With an overall approval rate of 9%, only 33 projects were approved. PARADIGM represents one of the two approved projects in the thematic area of Ocean and Polar Science and Technology (OPST).

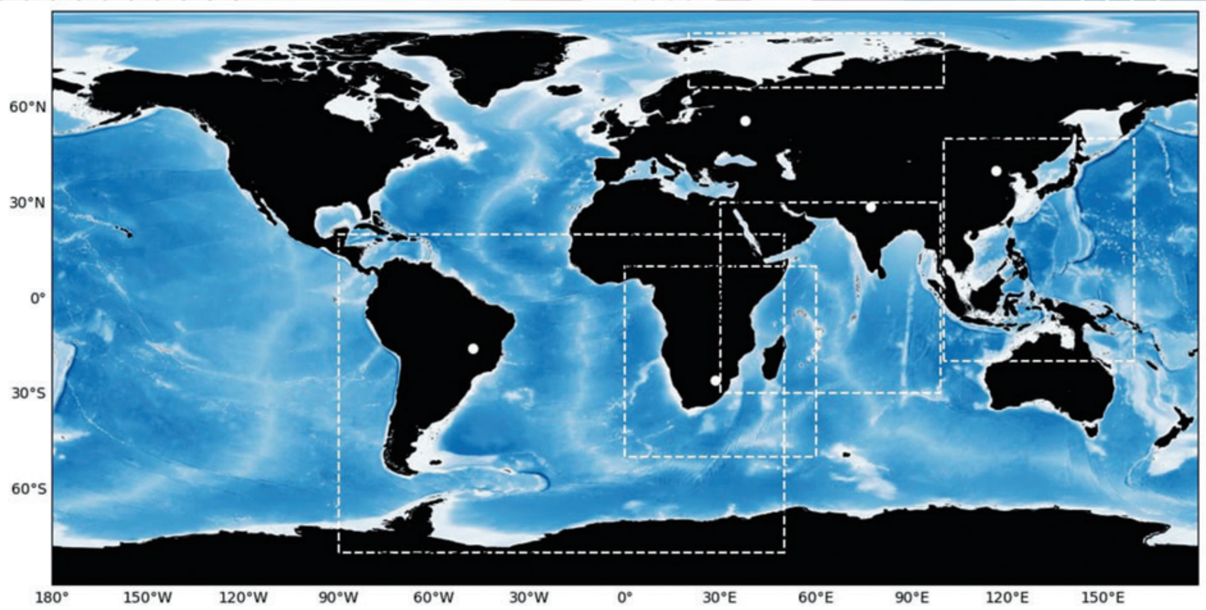

***Figure 1:** General Bathymetric Chart of the Oceans (GEBCO)[5] highlighting the schematic BRICS study regions. The white dots represent the administrative capitals of each country.*

1 - coastpredict.org
2 - oceanpredict.org/un-decade-of-ocean-science/foresea
3 - oceanpredict.org
4 - osf-un-ocean-decade.com
5 - www.gebco.net

BRICS WORKING GROUP ON OCEAN AND POLAR SCIENCE AND TECHNOLOGY

Science and technology serve as pivotal tool to foster cooperation between BRICS countries, from technology development to the gathering of scientists in joint research projects (Mayer et al., 2014). The BRICS countries boast a rich history of oceanographic research, despite the geographical, oceanographic, and environmental diversity among them. Altogether, the BRICS cover all ocean basins of the planet, where OPST becomes a natural convergence. Naturally, the BRICS ocean and polar sciences community benefit from the exchange of expertise and capacities tailored to their respective national contexts, thereby supporting one another in this arduous endeavor. By leveraging the diverse expertise of each nation, comparative analyses can identify optimal solutions tailored to local contexts.

The 2nd BRICS Ministerial Meeting on STI held in 2015 became a significant milestone with the signing of the Brasilia Declaration, alongside which a Memorandum of Understanding (MoU) on Cooperation in STI was endorsed (Kahn, 2015). In this MoU, countries agreed to launch a BRICS Research and Innovation Initiative, highlighting areas of interest, among which Ocean and Polar Sciences. This signified a collective recognition of the significance and relevance of these issues on the international cooperation agenda within the BRICS nations (Gokhberg et al., 2012).

Later in 2015, the BRICS STI Funding Partners approved the Work Plan for the BRICS STI 2015–2018 and, together with it, the establishment of a specific Working Group on Marine and Polar Science and Technology, initially co-chaired by Brazil and Russia. This working group resulted from a bottom-up movement from marine and polar BRICS scientists who met one year earlier in China to discuss possibilities and define areas of mutual interest. Since then, the cooperation under the Working Group produced joint scientific cruises and exchange of researchers to tackle global ocean and polar concerns through science and technology. PARADIGM represents a result of these science diplomacy efforts (Polejack, 2021).

UN OCEAN DECADE ASSOCIATED PROGRAMS

PARADIGM is closely linked to 3 already endorsed programs of the UN Ocean Decade CoastPredict, ForeSea and OSF. The first two are programs intimately linked to OceanPredict, which is a science program for the coordination and improvement of global and regional OFAS. OceanPredict provides a platform for communication and knowledge exchange run by scientists and experts in Operational Oceanography from around the world to accelerate, strengthen and increase the impact of ocean prediction. OSF is a programme that focuses on improving the prediction ability of ocean, tropical cyclones and climate, providing solid science and technological support for PARADIGM.

Firstly, the high-level objectives of CoastPredict include: i) A predicted global coastal ocean; ii) The upgrade to a fit-for-purpose oceanographic information infrastructure; iii) To co-design and implement an integrated coastal ocean observing and forecasting system adhering to best practices and standards, designed as a global framework, and implemented locally.

Secondly, the ForeSea's vision is to extend and modify the current ocean prediction capacity with the following high-level objectives: i) Coordinate ocean prediction world-wide in a sustainable manner towards maximum societal benefits; ii) Maximize the benefits of ocean observations for ocean predictions and societal impact; iii) Support development and maturation of the full-length Operational Oceanography value chain, from observations to end users, by using best practices and coordinating the integration of existing and new partners (international science initiatives and intergovernmental organizations); iv) Advance the science behind ocean prediction and its connection to the other components of the earth system (e.g., the atmosphere, land, cryosphere, continental hydrology) and v) Make ocean prediction science more impactful and relevant by collaborating with socioeconomic experts and stakeholders to quantify impacts and benefits of ocean prediction for science and society, particularly in coastal areas.

Finally, OSF's vision is also to improve scientific understanding of the ocean-climate nexus, to provide seamless forecasting, and to serve effective ocean management. The fundamental goals of OSF are to: i) Understand the ocean-climate nexus; ii) Enhance observation capabilities using novel technologies; iii) Integrate observations with cutting-edge ocean-to-climate; iv) Provide public services and v) Exchange advanced knowledge and theories on ocean science and management among the young generation who dwell in Small Islands developing States (SIDS), Least Developing Countries (LDC) and Landlocked Developing Countries (LLDC).

HOW WILL WE ACHIEVE OUR TARGETS?

PARADIGM is in the thematic area of OPST and by addressing both the availability and quality of observational data as well as the capacities of OFAS to assimilate them we intend to cover the following topics: i) Operational Oceanography including observations, model forecasts, and data assimilation in numerical models and ii) Coastal and shelf processes and ocean-land interactions. We believe that reliable OFAS are crucial for enhancing areas such as: i) Marine pollution, disaster prevention, mitigation, restoration and blue carbon and ii) Impacts of climate variability and climate change on polar environment and the teleconnections with tropical areas.

Moreover, PARADIGM is very aligned with the joint statement of the 4th meeting of the BRICS Working Group on OPST, that targeted six different actions, which are: i) To formulate the roadmap for the Working Group within the BRICS STI frameworks; ii) To update and identify priority cooperation themes for establishing guidelines for future collaborative research and development activities; iii) To specify capacity development including, but not limited to, training and MSc/PhD education; best practices in infrastructure utilization; development of standardized and harmonized methodological approaches; iv) To reiterate the commitment to the joint research cruises and expeditions in areas of common interests; v) To update the mutual cooperation in planning among BRICS countries and vi) To pave the joint activities of BRICS countries in the UN Ocean Decade.

Finally, PARADIGM is in tune with the UN Ocean Decade vision, and shall benefit the following areas: i) Advance in Knowledge, by Integrating knowledge of the global coastal ocean from events to climate; ii) Integration between observation and prediction, based on the design and implementation of an integrated river/estuarine/coastal/open ocean observing and modeling multidisciplinary system in pilot regions; iii) Accurate predictions, by improved coastal marine forecasting and extended range predictive capabilities for the coastal zone; iv) Open and free access to coastal information, based on the development of methods for trusted data/information exchange and interoperability across the value chain and adopt these as best practices; v) Solutions, by providing innovative and sustainable applications for coastal solutions/services that directly benefit local populations, including well-being and human health; vi) Capacity building, by Increased equitable education and capacity for observing and forecasting in the global coastal ocean as well as vii) Education, based on a strong engagement of Early Career Professionals and promotion of education, training and research under principles of diversity, equity and inclusion.

EXPERTISE OF THE CONSORTIUM

An African proverb says that "If you want to go fast, go alone, if you want to go far, go together". With that in mind and considering that BRICS countries are at different maturity levels in terms of national OFAS, we strongly believe that this collaboration will act to reduce the differences among these countries in terms of ocean prediction. As it will be shown in the qualifications of the research teams, PARADIGM was able to gather scientists that have significant roles in key groups related to this project, including: i) The BRICS Working Group on OPST; ii) The OceanPredict Science Team and their task teams, such as the Coastal Ocean and Shelf Seas Task Team; iii) The CoastPredict, ForeSea and OSF UN Ocean Decade endorsed programs. Especially, one of our team member is leading the OSF programme with more than 50 countries joined; iv) Regional representations of the Global Ocean Observing System (GOOS); v) Executive Planning Group of the UN Ocean Decade; vi) Climate and Ocean — Variability, Predictability, and Change (CLIVAR) panels and vii) The International Eurasian Academy of Sciences.

Taking into consideration that there is some heterogeneity in the way that oceanographic data and forecasting systems are organized in BRICS countries, this partnership could leverage future implementation of National Institutes of Operational Oceanography in other BRICS countries, facilitating the dissemination of ocean information. Brazil, for instance, has already launched a prototype of such an organization.

In terms of capacity building, and in addition to the two workshops on Operational Oceanography mentioned above, we are also planning to use the host institutions to articulate a MoU between the Postgraduate Programs among the leading research centers on OPST functioning in the BRICS countries to include: i) Training courses and summer school courses on a rotating basis; ii) Student exchange and (iii) Joint cruises.

The fact that the First Institute of Oceanography (FIO) hosts a Regional Training and Research Center on Ocean Dynamics and Climate (RTRC-ODC) affiliated to the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (UNESCO/IOC) will provide an excellent platform for the organization of the training courses and workshops focusing on Operational Oceanography.

NATIONAL TEAMS AND TARGETED REGIONS

BRAZIL

The leading Principal Investigator (PI) of PARADIGM is **Professor Mauro Cirano** from the Federal University of Rio de Janeiro (UFRJ). Professor Cirano coordinates two Operational Oceanography programs that are part of the regional office of GOOS in Brazil named: the i) NOAA-AX97 High Density XBT line and ii) The Brazilian Coastal Monitoring System — SiMCosta. The research team is mostly based at UFRJ and also includes Assoc. Prof. Afonso M. Paiva, a senior expert in Global, Regional, and Coastal Ocean modeling as well as 3 PhD students, 4 MSc students and undergraduate students. Dr Pedro P. Freitas, based at the Federal University of Para and specialized in continental shelf processes and the interaction between coastal and oceanic circulation, is also an early career scientist that is a partner of the Brazilian team.

Brazil will perform an intercomparison of the available OFAS for the South Atlantic Ocean *(Figure 1)*. This activity will rely on common metrics agreed between all BRICS partners and data available not only in the GOOS framework but also including specific national observing systems that are not available worldwide. The intercomparison rely on strategic long term hydrographic sections as well as horizontal maps where important dynamic aspects are evaluated, such as: i) The main water masses at the region; ii) The vertical structure of both the Western and Eastern Boundary Current Systems as well as the thermohaline circulation; iii) The bifurcation/retroflection/confluence of these currents; iv) Transient processes (e.g. eddies and CTWs) and v) The air-sea interaction related properties (e.g. Mixed Layer Depth — MLD and fluxes).

Some of these OFAS will be used as initial and boundary conditions to implement a high resolution OFAS aiming to seamlessly connect the ocean region with the coastal and estuarine region of Rio de Janeiro, including the internationally famous Guanabara Bay, which hosts the second largest metropolitan population in Brazil.

As part of the capacity building of this project, we aim to train all students involved and engage them in the various training courses promoted not only by PARADIGM, but also by national and international collaboration.

RUSSIA

The Russian national team is represented by researchers from the Shirshov Institute of Oceanology of the Russian Academy of Sciences (IORAS) and led by **Prof. Sergey Gulev**, a chair of the Sea Atmosphere Interaction and Climate Laboratory at IORAS. The team is based in Moscow and includes 5 senior scientists (with 4 being young scientists under the age of 39), 2 PhD students, and 3 MSc students.

The Russian study area is the Arctic coastal region *(Figure 1)* in the Barents and Kara Seas. We report insufficient accuracy of existing global OFAS at regional scale, which results in high uncertainties and prevents economic development in the region. Improving forecasting quality will substantially advance planning of human activities in the Arctic, such as safe year-round navigation along the Northern Sea Route, fishing, oil and gas exploration, and infrastructure projects.

Specific goals to be met by the Russian team include verification of global OFAS in the study region — Barents and Kara Seas, assessment of the accuracy and quantification of uncertainties of forecasting systems and assessment of its capabilities.

Within the project framework, regional circulation processes in the Russian Arctic Seas are assessed using well-known OFAS. Being crucial for regional forecasts, this activity also contributes to improving fundamental understanding of regional physical, biological, and geochemical processes, thus providing a framework for monitoring anthropogenic impacts on the Arctic climate and ecosystems. Intercomparison and validation of OFAS will contribute to creating the first national operational forecasting system for the Russian Arctic Seas.

These scientific goals go hand in hand with capacity building activities. These included (while not limited to) the development of training courses in numerical modeling and ocean forecasting. Some of these activities are organized onboard research vessels making it possible for undergraduate and postgraduate students to be engaged in observational data collection and preprocessing.

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INDIA

The Indian partner investigators of this project are **Prof. P. N. Vinayachandran** and Dr Deepak Subramani of the Indian Institute of Science, Bengaluru. The major goals of the Indian component of the project are aligned with the common goals of PARADIGM described in section 1.

It is expected that meeting each of these objectives would result in an assessment of the global OFAS for scientific and commercial applications relevant to BRICS countries by means of reports and journal publications on validation and intercomparison of OFAS from BRICS. The implementation of the project would also result in substantial advancement in capacity building in the area of Operational Oceanography.

Towards the first objective, the Indian team has carried out a detailed model intercomparison of the High Salinity Core (HSC) in the Bay of Bengal (BB). This water mass lays a crucial role in the salt and freshwater balance of the Indian Ocean. The BoBBLE program conducted in the BB during the summer of 2016 provided an excellent in situ data which has unraveled the structure of the HSC and this data set has been used as the reference data set for the assessments. In addition, Argo profiles have been used for a wider spatial coverage. The models have been subjected to a rather stringent test of reproducing the feature captured by a one-time observational data set. Nine reanalysis products and two model simulations have been used in this intercomparison exercise. An algorithm has been developed to detect the HSC, its strength, and thickness in the observations and models. The results are encouraging as some of the reanalysis products are able to capture the HSC but it is completely missing in some products. This suggests that, for regional application the reanalysis products have to be selected with caution.

Towards the second objective, a high resolution model of the BB has been developed at a horizontal resolution of 1 km. An experimental simulation of this model has been carried out to test the sensitivity of the model to varying resolutions to evaluate the submesoscale features of the model.

Towards capacity development part of the project one MSc student, two PhD students and one postdoctoral fellow is being trained in ocean modeling.

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CHINA

The PARADIGM team in China is based at the FIO, Ministry of Natural Resources, with **Professor Fangli Qiao** being the PI of the Chinese team. Professor Qiao is a Member of Academia Europaea, Deputy Director General of FIO and also the PI of OSF. Key research team members also include Professor Changshui Xia and Associate Professor Chang Zhao.

Under the PARADIGM project cooperation, the Chinese team has achieved the following scientific breakthroughs:

1. Development of the non-breaking surface wave-induced mixing (Bv) theory:
   Overestimated Sea Surface Temperature (SST) and underestimated Mixed Layer Depth (MLD) in summer are common problems of ocean circulation models. Professor Qiao led his team established the Bv theory, and discovered the Bv generation mechanism of wave-turbulence interaction based on in-situ observation (Qiao et al., 2004, 2016; Babanin, 2023). The Bv theory has been widely used and validated by tens of leading research centers on model developments from different countries, and all ocean and climate models with Bv have been dramatically improved, including GFDL model (USA), NEMO model (Europe), FESOM model (Germany), CROCO model (France) and so forth.
2. Development of the first in the world surface wave-tide-circulation fully coupled ocean model:
   Professor Qiao led his team developed the first in the world new generation surface wave-tide-circulation fully coupled ocean model (FIO-COM) which dramatically surmounts the ground challenge for half century of too shallow simulated MLD in the upper ocean, overestimated SST and too cold subsurface temperature especially in summertime (Xiao et al., 2023).
3. Development of the Atmosphere-Ocean-Wave fully coupled Tropical Cyclone model (FIO-AOW):
   Improving intensity simulation and forecast of tropical cyclones has been a great challenge for several decades. Professor Qiao led his team

developed the FIO-AOW, which greatly enhances the Typhoon intensity forecasting ability, with the intensity common bias reduced by 40% (Zhao et al., 2022). They also developed the earth system model including surface waves (FIO-ESM v1.0 and 2.0), which eliminates more than half of the ever-standing SST biases (Bao et al., 2020).

Further activities of the Chinese team related to the PARADIGM include the following aspects:

Firstly, implement reanalysis simulations based on FIO-COM from 2013 to 2022, and provide the product for verification and comparison with the cooperation partners. Secondly, organize a training course on ocean numerical models for the BRICS countries based on the RTRC-ODC of the UNESCO/IOC in 2024. Thirdly, develop the pilot OFAS aligned with OSF.

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SOUTH AFRICA

The South African partner PI, **Dr Jennifer Veitch**, is based at the South African Environmental Observation Network (SAEON) and leads its Sustainable Ocean Modelling Initiative (SOMISANA[6]). South African partners include Dr Moagabo Ragoasha (University of Cape Town), Dr Ramontsheng Rapolaki (the South African Weather Service) and Mr Thomas Mtonsi (SAEON) who are involved with the capacity development, operational systems and education outreach aspects of the project respectively.

PARADIGM objectives are well within both the mandate of SAEON and SOMISANA and align with South Africa's national priorities to support the sustainable development of the marine environment. The SOMISANA team have developed high resolution downscaled ocean forecast models of high-use regions of South Africa's coastline that form part of the National Oceans and Coastal Information Management System (OCIMS), a Department of Forestry, Fisheries and Environment (DFFE) initiative that provides customized decision support tools for stakeholders to support good governance of South Africa's oceans and coasts.

The capacity development objective of PARADIGM is of particular importance for the South African partners, given its lack of human capacity. This project supported the attendance of two South African early career researchers to attend the 12th UNESCO/IOC RTRC-ODC Training Course on Ocean Model and Data Assimilation that was hosted by the FIO in Qingdao in July 2023. In addition, it contributed to the running of a two-week long Coastal and Regional Ocean Community Model (CROCO) ocean modeling workshop, hosted at the Center for High Performance Computing (CHPC) in Cape Town. The South African team are also engaging with high school learners by providing them python coding skills for marine science. These engagements are facilitated by Mr Thomas Mtonsi, and are run within a weekend 'camp' during which various aspects of marine science are taught.

6 - somisana.ac.za

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9. MATERIAL SCIENCE INCLUDING NANOTECHNOLOGY

Fundamentals for development of individual nano-objects and nano-devices bottom-up mechanical integration for quantum and non-local phenomena study, nano-electronics and nano-bio-medical diagnostics

Project details:

BRICS STI FP call	Pilot BRICS STI FP Call 2016
Project number and Acronym	BRICS2016-437 “nanoBRICSrough”

National Principal Investigator	National Principal Research Organization	Country
Monica Cotta	Instituto de Fisica Gleb Wataghin, Universidade Estadual de Campinas	BRAZIL
Victor Koledov	Kotel’nikov Institute of Radioengineering and Electronics Russian Academy of Sciences	RUSSIA
Digbijoy N. Nath	Indian Institute of Science, Bangalore	INDIA
Zhongming Zeng	Suzhou Institute of Nano-Tech and Nano-Bionics, Chinese Academy of Sciences	CHINA
Somnath Bhatachryya	School of Physics, University of the Witwatersrand	SOUTH AFRICA
Funding agencies: National Council for Scientific and Technological Development (CNPq, Brazil), Russian Centre for Science information (RCSI, Russia), Department of Science and Technology (DST, India), National Natural Science Foundation of China (NSFC, China), National Research Foundation (NRF, South Africa).		

The idea of the project arose due to the fact that currently, for fundamental and applied research in nanoscience and for industrial production in nanotechnologies are mainly used "top-down" technologies. Equipment for "top-down" technologies, including nano-lithography, are very expensive, bulky, have high running cost. All these equipment, worth millions and tens of millions of euros, are produced mainly in Western countries, and the BRICS countries are forced to pay very dearly for this. At the same time, all BRICS countries already had their own developments in the field of nanotechnology, which were significantly ahead of Western ones.

One of the problems in the search for alternative nanotechnologies is that separate developments of various nanodevices or their components are being carried out. These research, while interesting in their own right, do not represent technologies that can compete with industrial nanolithography facilities and other expensive top-down technologies. In this regard, the Russian partner worked to identify and bring together the scattered outstanding developments and technologies of all BRICS countries in order to jointly create a new breakthrough nanotechnology. According to the plan, this nanotechnology would have to compete with Western, very expensive, with high running cost nano-lithography and other "top-down" technologies. The project proposed to concentrate the synergy of the best Nano-Bio-Centers of all 5 BRICS countries with the aim of changing this situation by developing a low-cost breakthrough technology of three-dimensional mechanical nano-assembly (3DMNA) within the framework of the "bottom-up" nanotechnology paradigm.

This new nanotechnology, after commercialization will be mastered, primarily in the BRICS countries, it will be cheap and accessible to small businesses, departments of modest universities and even schools. The proposed technology should enable the creation of nano-devices for various industries, including those that would be impossible to create using nano-lithography. Also, the new nanotechnology should have made it possible to produce small batches of individual nanodevices more economically and of higher quality than nanolithography.

Recently, numerous types of nanomaterials have been created all over the World. These are, first of all, one-dimensional nano-objects such as nanotubes, nanowires, nanorods, made of various materials. Also of great interest are two-dimensional nano-objects, such as the well-known graphene, Mxene — two-dimensional carbides, carbonitrides and nitrides of transition metals and many others. All of these unique nanomaterials do not exist as solid, continuous nanostructured macroscopic materials, but as huge arrays consisting of individual nanoobjects, such as nanowires. For example, in the *figure 1* shows such an array of InP semiconductor nanowires created by a project partner in Brazil.

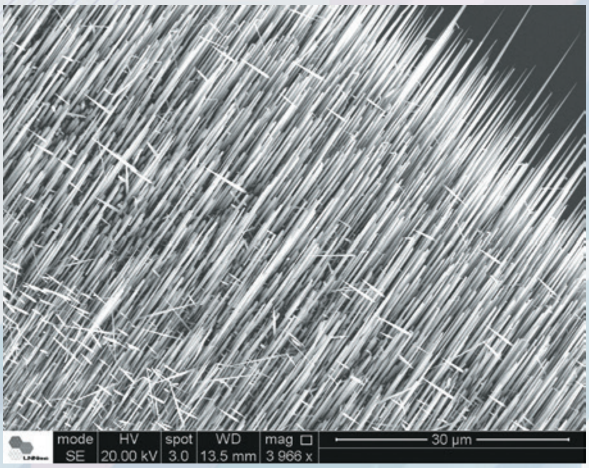


***Figure 1**. Micrograph of an array of InP nanowires synthesized by a Brazilian partner of the BRICS project.*

Photo in the figure 1 made in an electron scanning microscope (SEM) makes it possible to imagine that if you have the technology, then from such a material you can select and pick-up individual nano-objects, in this case single InP semiconductor nanowires. Individual nano-objects have amazingly unique physical, functional, chemical and other properties that are inaccessible to the same chemical elements and their compounds in macroscopic form. If you somehow obtain and take such single nano-objects, then nano-devices can be assembled from them for various applications.

In recent years, many works in the world literature have shown that the unique properties of single nano-objects make it possible to create individual nano-devices from these single nano-objects. The creation of such nanodevices is reminiscent of the assembly of products from component parts in the macrocosm. However, such a nano-assembly should provide not only mechanical contacts, but also electrical ones, that is, include a nano-analog of soldering, if optical contacts is needed, then optical contacts, and other necessary properties. If the macroworld is clear to us, in it, for ordinary mechanical assembly, objects are taken with hands or robotic manipulators, at smaller sizes, with the help of fingers or tweezers, and electrical contacts can be made using a soldering iron, then in the nanoworld everything, including the balance of forces, is arranged completely different. Therefore, each operation requires the study of new physical principles and the creation of new technologies, almost like when flying into Kosmos. And such a "flight into the nanoworld" is excitingly interesting and promising.

The implementers of the BRICS project imagined the world of the future, with nano-matters with nano-tweezers and nano-forceps, nano-soldering irons, nano-knives and scissors. With the help of all these nano-workshop items, it will be possible to make the smallest nano-lasers, nano- diode and nano-transistors, nano-sensors, nano-radios and many other nano-objects from individual nano-objects. And from these nano-devices it will be possible either to create larger micro or macro-devices, or to insert these single nano-devices, for example, into smartphones, which in this case can also play the role of a device with sensors for the freshness of meat, the presence of single viruses, etc.

Within the framework of the BRICS project, it was proposed to develop an original 3 dimensional mechanical nano-assembly (3DMNA) of individual nano-objects into single nano-, then meso-, micro and macro devices and their integration with the standard element base of modern electronics, spintronics, photonics, MEMS, NEMS, devices alternative energy, micro-biosensors and telecommunications, devices for fundamental and applied scientific research, etc. 3DMNA installations will be compact, cheap, will not require large production costs, that is, they will be available to medium and small educational and scientific teams with a modest budget, and small business enterprises. Therefore, devices that can be created using 3DMNA will not only have much better parameters, but will also be cheap, both in small and large-scale mass production. This will also create new opportunities for many scientific and educational teams to conduct breakthrough fundamental and applied research.

***Figure 2**. Photo of the head of the Brazilian partner, Full professor at the Institute of Physics. Gleb Vatagin at the University of Campinas (UNICAMP) · Monica Alonso Cotta.*

By the time the project was conceived, scientists from different countries, including the BRICS countries, had already learned how to make laboratory prototypes of various nanodevices. For example, individual bio-nano sensors under the leadership of the head of the Brazilian partner, Professor Institute of Physics.

Gleb Vatagin at the University of Campinas (UNICAMP) · Monica Alonso Cotta, (photo in *Figure 2*).

Under the leadership of Professor Monica Cotta, a unique nano-biosensor was created based on the nanowire shown in Figure 1. The nanobiosensor had a record femtomolar sensitivity and could detect minute amounts of dangerous viruses. However, it took Professor Monika Cotte and her team two years to assemble one such sensor. Therefore, she happily agreed, at the suggestion of her Russian partner, to participate in a joint BRICS project, which aimed to create a new breakthrough technology for 3 dimensional mechanical bottom up nanoassembling of such nanobiosensors. This technology would greatly reduce the time needed for design of such individual bio-nanosensors, as well as many other individual nanodevices.

To implement this idea, the BRICS countries had the following developments. The world's smallest and fastest nano-gripper with shape memory effect has been developed in Russia. This nanogripper was to play a central role in the project, providing, in effect, nano-fingers that were to select, tear off, pick-up and place, transfer individual nano-objects to the substrate where the nanodevice was to be integrated. That is, to provide a 3-dimensional mechanical bottom-up nano-assembly process. Such a nanogripper in the nanoworld can act like tweezers or the fingers of an operator assembling nanodevices. *Figure 3* shows a Russian nano-tweezers with a shape memory effect in the process of capturing a hair, or more precisely a nano-sensor-sensilla on a mosquito leg. If usually in nanotechnology sizes are compared to the scale of a human hair, then the World's smallest nano-gripper in *Figure 3* is shown in comparison with a sensilla hair on a mosquito leg.

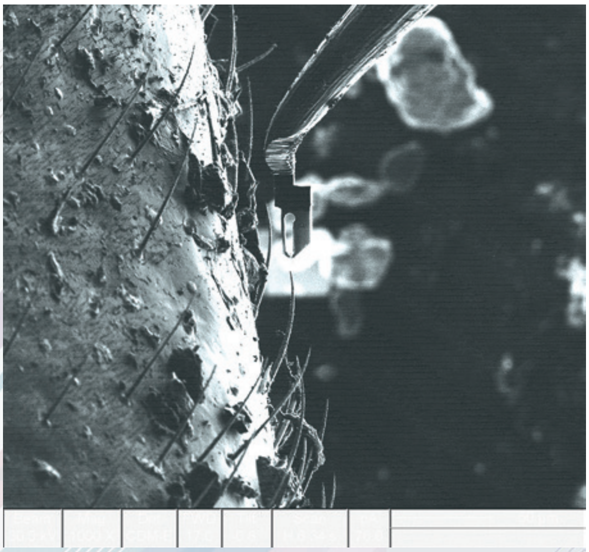


***Figure 3**. Focused ion microscope micrograph. The nanogripper moves towards the sensilla-nanosensor — on the mosquito leg*

This nanogripper was created by a team of a Russian partner under the leadership of Dr of Physics and Mathematics Victor Victorovich Koledov from the Institute of Radio Engineering and Electronics named after V.A. Kotelnikov Russian Academy of Sciences. A photo by V.V. Koledov is shown in Figure 4. V.V. Koledov was also the project organizer and international coordinator of the nanoBRICSrough project.

***Figure 4**. Doctor of Physics and Mathematics. V.V. Koledov from the Institute of Radio Engineering and Electronics named after V.A. Kotelnikov Russian Academy of Sciences.*

The Indian partner has long been engaged in the research of new functional materials that could be turned into the basis of nano-soldering technology to create electrical contacts for nano-devices. *Figure 5* are shown a photo professors from India team. Left to the right are shown the head of the Center for Nanoscience and Engineering (CeNSE) of the Indian Institute of Science (ISS) in Bangalore, Professor Rudra Pratap (left). In the middle is Professor of the same center Praveen Kumar, who studied droplets of liquid metals, on the left is the project coordinator of the Indian side, Professor Diploy Nath (right). The Center for Nanoscience and Engineering (CeNSE) of the Indian Institute of Science (ISS) in Bangalore is one of the leading science centers in India with state-of-the-art nanotechnology facilities.

Figure 5. *Professors Center for Nanoscience and Engineering (CeNSE) of the Indian Institute of Science (ISS) in Bangalore from left to right — Professor Rudra Pratap, Professor Praveen Kumar, Professor Diploy Nath.*

The role of the South African and Chinese teams was related to the creation of specific nano-devices using the emerging mechanical nanoassembly technology using a Russian nanotweezers. The South African team was led by Professor Somnath Bhattacharyya, from the University of the Witwatersrand in Johannesburg, the world's leading expert on nano-scale devices based on carbon nanomaterials. His photo is shown in *Figure 6*. The South African team created nano-devices based on single carbon nanomaterials — carbon nanotubes and nanodiamonds.

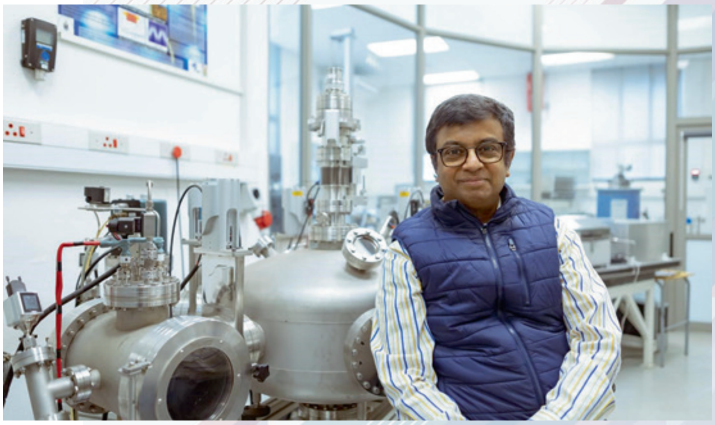


Figure 6*. Professor Somnath Bhattacharyya in the laboratory of the Quantum Center, which he had founded at the University of the Witwatersrand in Johannesburg, South Africa.*

Figure 7*. Professor and Dr Zhongming Zeng from the Suzhou Institute of Nanotechnology and Nanobionics of the Chinese Academy of Sciences (SINANO).*

The Chinese team was led by Professor and Dr Zhongming Zeng from the Suzhou Institute of Nanotechnology and Nanobionics of the Chinese Academy of Sciences (SINANO), the world's leading expert in nanodevices based on Spin-Transfer Torque Oscillators and spintronics. His photo is shown in *Figure 7*.

The Chinese team has been busy in creating nano-oscillators and nano-receivers using Spin-Transfer Torque Oscillators.

To develop alternative nanotechnologies to creating various devices within the "bottom-up" nanotechnology paradigm, it is necessary to resolve a number of issues.

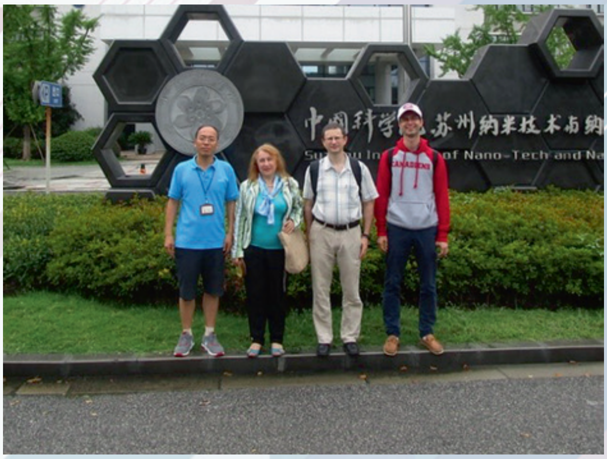
1. Create individual nano-objects (nanowires, nanotubes, etc.).
2. By mechanical nanoassembly "bottom-up" to create nano-devices from them. It is also important to establish reliable mechanical, and in many cases also electrical, optical, acoustic or other necessary contacts between nano-components.
3. If necessary, carry out further assembly of these nano-devices into meso, micro, and then macro-devices.

Work on the project took place in an atmosphere of friendship and mutual assistance. If necessary, all teams provided each other with the necessary infrastructure and helped in the creation of samples. Remote meetings via the

Internet and in-person consortium summits were held regularly in Bangalore, Suzhou, Campinas and Moscow. Joint trips to conferences were carried out, and training was provided for undergraduate and graduate students. All this helped to fulfill the very difficult task set in the project, to publish dozens of joint works. The consortium became very united during the joint work, and joint work with all BRICS countries continues to this day. The BRICS summits in Bangalore *(8a)*, Suzhou *(8b)*, Campinas *(8c)* and Moscow *(8d)* are presented in *Figures 8*.

8a

8b



8c

8d

Special sessions on 3D mechanical bottom up nanoassembly and creation of nanodevice were also organized at international conferences. Thus, at the 3 M Nano (annual International Conference on Manipulation, Manufacturing and Measurement on the Nanoscale) conferences in China, a whole series of such special sessions were organized, in which the entire consortium took part. Also, special sessions were organized at the conferences METANANO (IV International Conference on Metamaterials and Nanophotonics) 2019 in St. Petersburg and MARSS (International Conference on Manipulation Automation and Robotics at Small Scales) in Helsinki.

Figure 9 shows a joint photograph of the consortium after one of such the special sessions of the 3M Nano conferences. Special T-shirts with the symbols of the project were issued for consortium members, and consortium members wore these T-shirts at presentations at international conferences. The photo shows members of the consortium after the end of the session wearing personalized T-shirts dedicated to the project on 3D mechanical bottom up nanomanipulation and nanoassembly with the acronym NanoBRICSthough.

In conclusion, we can say that the work on this project and its results can provide an opportunity to overcome very large scientific and technological difficulties and unite the BRICS countries. All this, through the combined efforts of all BRICS countries, makes it possible to bring the BRICS countries to leading positions in the world in nanotechnology and nano-nanoscience.

Figure 9. *BRICS consortium teams at the 3 M Nano conference after joint special sessions.*

10. PHOTONICS

Multi-photon and high-dimensional platforms for photonic quantum information processing

Project details:

BRICS STI FP call	3rd BRICS STI FP Call 2019
Project number and Acronym	BRICS2019-173 "MHPPQIP"

National Principal Investigator	National Principal Research Organization	Country
Paulo Henrique Souto Ribeiro	Universidade Federal do Rio de Janeiro	BRAZIL
Seigei Kulik	Moscow State University	RUSSIA
Xiaosong Ma	Nanjing University	CHINA
Funding agencies: National Council for Scientific and Technological Development (CNPq, Brazil), Russian Centre for Science information (RCSI, Russia), National Natural Science Foundation of China (NSFC, China).		

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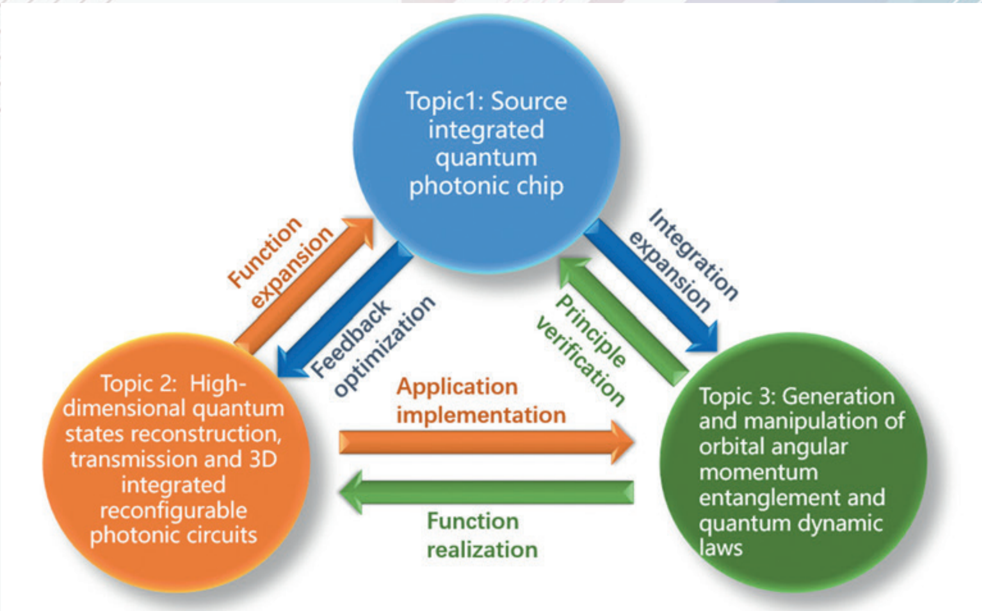
DESCRIPTION OF THE PROJECT

The second half of the 20th century witnessed a technological revolution of unprecedented scale and speed. Humanity began to construct machines whose sole purpose was to process information. However, the driving force behind the information revolution was not theoretical advancements, but rather practical applications. It spurred numerous urgent research topics, one of which is the creation of devices with high efficiency and high computing speed. In the post-Moore era, the physical size limitations of components, the further development of integrated chips, and the improvement of information processing capabilities have become a major scientific issue and challenge. Quantum information processing, which is based on the principles of quantum mechanics and the unique characteristics of entanglement, offers unprecedented advantages and vast potential in terms of speed, capacity, and precision, surpassing traditional information technology. It will emerge as the supporting technology of the post-Moore era. The goal of this project is to develop high-dimensional quantum systems that will revolutionize quantum photonic information processing. Specifically, this involves:

(i) the effective production of high-dimensional quantum entanglement; and

(ii) the investigation of the application of high-dimensional quantum systems in quantum computing, quantum simulation, and quantum communication.

The utilization of quantum information processing based on the principles of quantum mechanics and the characteristics of entanglement offers unparalleled advantages and broad prospects in comparison to traditional information technology about speed, capacity, and precision. This technology is poised to become a foundational technology of the post-Moore era. The work of research teams from China Brazil and Russia (the BRICS countries) within the BRICS2019-173 project is aimed at identifying the potential applications of high-dimensional quantum systems in quantum computing, quantum simulation, and quantum communication.



General structure of the work carried out by project participants from the BRICS countries.

The research is primarily concerned with three key areas:

The first objective is to prepare multi-functional silicon-based quantum photonic chips, integrating photon sources and reconfigurable circuits onto a single device. The utilization of path degree of freedom on photonic chips will facilitate the realization of quantum computation, quantum simulation and quantum communication by high-dimensional states, thereby providing a novel concept for chip-based quantum photonic information processing.

The second objective is to utilize bulk optical components to generate and manipulate orbital angular momentum entanglement. The generated high-dimensional entangled states will be employed to investigate the dynamics of entanglement, quantum simulation and quantum thermodynamics.

The third area of focus is the reconstruction of quantum states and the precise preparation of biphoton high-dimensional entangled states.

HISTORY OF COOPERATION

The Russian group's contributions to the BRICS project, in collaboration with their Brazilian and Chinese counterparts, have facilitated the experimental implementation of a quantum algorithm (variational) for the search of the ground state energy of the Schwinger Hamiltonian in a system of polarization qubits prepared through spontaneous parametric scattering.

Moreover, the project yielded valuable insights into the coordination of scientific endeavors pertaining to the field of "quantum engineering" between research institutions in the Russian Federation, Brazil, and China.

The outcomes of the project were presented at the 6th International School of Quantum Technologies in two plenary lectures, delivered by the leaders of the Brazilian and Chinese groups, namely Professor Paulo H. Souto Ribeiro of the Federal University of Santa Catarina in Florianópolis, Brazil, on the topic of *"Quantum Technologies with Partially Coherent Light"*. The second plenary lecture was delivered by Professor Xiaosong Ma of the School of Physics at Nanjing University, China, on the topic of *"Harnessing Single Photons in Quantum Technology"* (see figure below).

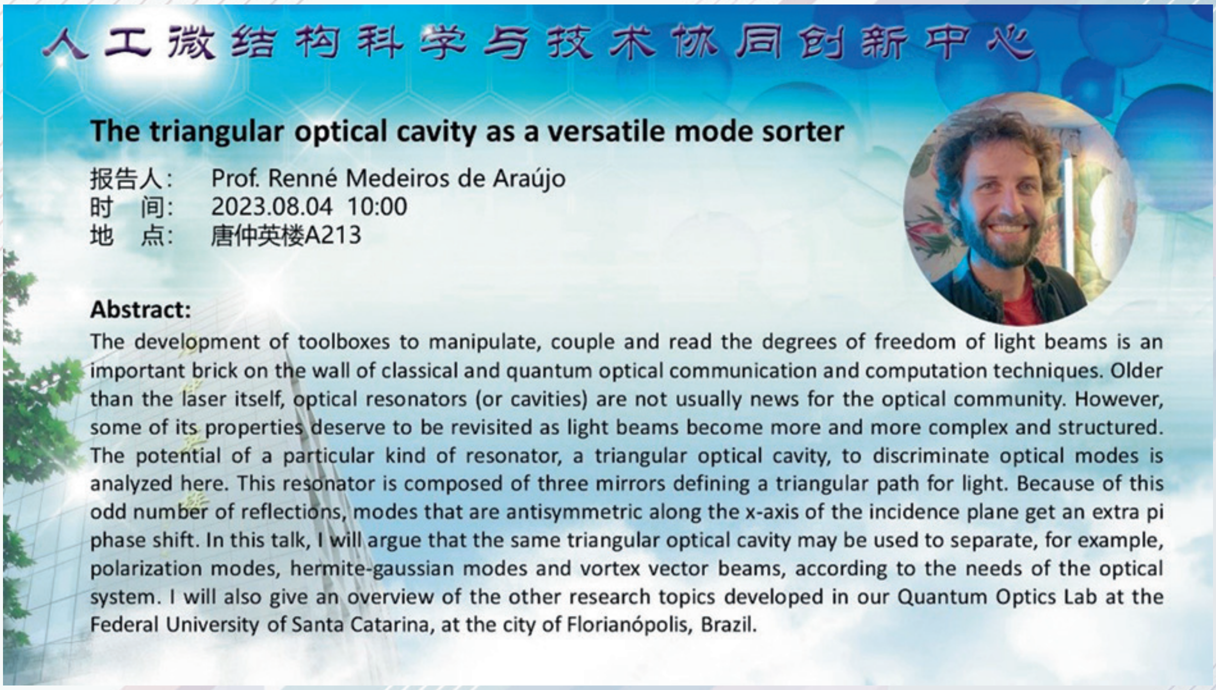
International School (6th QTS, 2023, Miass, Russia)

In August 2023, an international cooperation seminar was held between the Chinese and Brazilian teams at Nanjing University. At this seminar, Professor Renne presented a report titled “The triangular optical cavity as a versatile mode sorter.” The atmosphere of the meeting was amicable, with everyone engaging in friendly discussions.

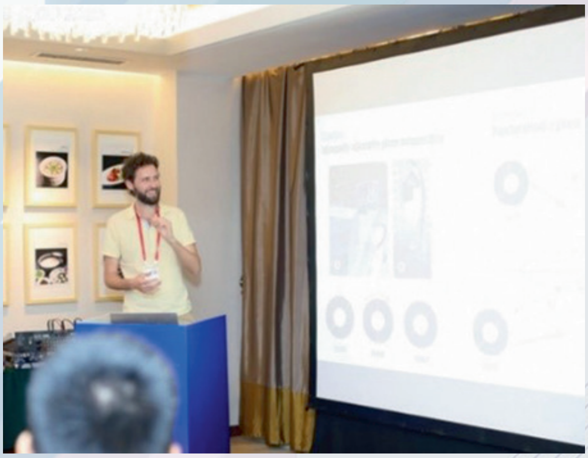
The symposium provided a platform for both teams to share their research insights, exchange ideas, and explore potential areas of collaboration. Professor Renne's report, in particular, provoked lively debates and in-depth discussions among the participants. His insights and perspectives not only enriched the discussion but also broadened the horizons of everyone in attendance.

Subsequently, they joined Prof. Ma’s group in the conference CIOP 2023. Professor Renne delivered a keynote speech at the ICOP conference on “The Triangular Optical Cavity as a Versatile Mode Sorter.” The speech provided valuable insights into the technology’s potential applications. Additionally, two doctoral students, Lucas and Raphael, presented their research. Lucas discussed “Photonic Entanglement with Accelerated Light,” exploring entanglement phenomena in accelerated light systems. Raphael, on the other hand, presented his work on “Sorting Vector Vortex Beams with a Triangular Optical Cavity,” highlighting the complexities of sorting vector vortex beams using this technology.

The presentations by Professor Renne, Lucas, and Raphael were all informative and engaging, showcasing the exciting advancements in the field of optics and photonics.



International seminar, Nanjing University, Nanjing, China (2023)



CIOP 2023, Xi'an, China (2023)

SCIENTIFIC RESULTS

Source integrated quantum photonic chip

Quantum entanglement is a distinctive attribute of quantum systems, first introduced in 1935 by Einstein, Podolsky, and Rosen in the EPR paradox and subsequently defined by Schrödinger in the same year. The types of entanglement in quantum systems can be broadly classified into two categories: multipartite entanglement and multi-dimensional entanglement. Among these, high-dimensional entangled states (dimension > 2) have attracted considerable interest due to their distinctive properties. As the dimension of quantum systems increases, high-dimensional quantum systems exhibit advantages, including strong parallel computing capability, high information capacity, and strong noise resistance, in comparison to two-dimensional quantum systems, which are more commonly used. Photons, as carriers of quantum information, possess several advantageous properties, including good coherence, multiple degrees of freedom, and ease of control. These attributes make them an optimal platform for achieving high-dimensional entanglement. Currently, high-dimensional entangled photons have been realized in degrees of freedom such as orbital angular momentum, frequency, time, and path. Nevertheless, the efficient preparation of high-dimensional entangled photons and the achievement of high-precision, arbitrary programmable coherent control present significant challenges for the scalability of quantum information technology.

Integrated photonic circuits based on silicon offer a high degree of component integration, high optical non-linearity, and good phase stability, which are highly desirable properties for photonic quantum technology. Moreover, silicon photonic devices are frequently manufactured in complementary metal oxide semiconductor (CMOS) processes, which has led to the emergence of a novel field, namely silicon quantum photonics. This field has emerged as a promising platform for large-scale quantum information processing. Recent advances in on-chip high-dimensional entanglement have employed frequency-encoding generated from a micro-resonator photon-pair source and path-encoding generated from meander waveguides photon-pair source. Silicon waveguides with a length of centimeters are often employed as a source to create photon pairs. However, the natural bandwidth of the photons generated from meander waveguides is approximately 30 nm. To obtain high-quality photons, it is necessary to employ band-pass filters, which unavoidably results in a significant reduction in the photon count rate.

To address this challenge, the team from NJU (China) has recently combined traditional integrated optical chips with quantum information to achieve on-chip quantum information processing utilizing the nonlinear properties of materials, forming integrated photonic quantum chips. In comparison to traditional spatial modes, the nearly perfect mode overlap, high robustness, low loss, and low power consumption in quantum integrated circuits can enhance the capability for quantum information processing and make it more scalable. In this study, researchers employed an optimized design of interference-type micro-ring resonators, integrating Mach-Zehnder interferometers with micro-ring resonators to encode the path modes of photons on the chip, thereby achieving on-chip path entanglement in high dimensions. The team achieved a dual-photon source with an extraction efficiency of over 97% through the spontaneous four-wave mixing effect in silicon waveguides and high-stability, reconfigurable coherent control of linear light paths. This source does not require post-filtering processing and exhibits high suppression of pump photons. The team achieved an on-chip quantum interference visibility exceeding 96.5% and a fidelity of the three-dimensional maximum entangled state reaching 95.5%. Furthermore, the researchers experimentally validated high-dimensional Bell inequalities (with an inequality violation of 51.46 standard deviations) and demonstrated, for the first time, on-chip quantum mutual information verification without compatibility loopholes. By controlling the entangled system, researchers further validated the feasibility of graph quantum simulation experiments, thereby paving the way for the utilization of quantum optical devices to resolve #P-complete problems. The study also demonstrated high-precision quantum phase measurement, achieving a phase sensitivity of 1.476 rad-1, which surpassed the theoretical limits of traditional three-path interferometers and second-order nonlinear interferometers. This research provides a crucial foundation for the on-chip preparation of multi-dimensional quantum entangled systems and the application of quantum control technology.

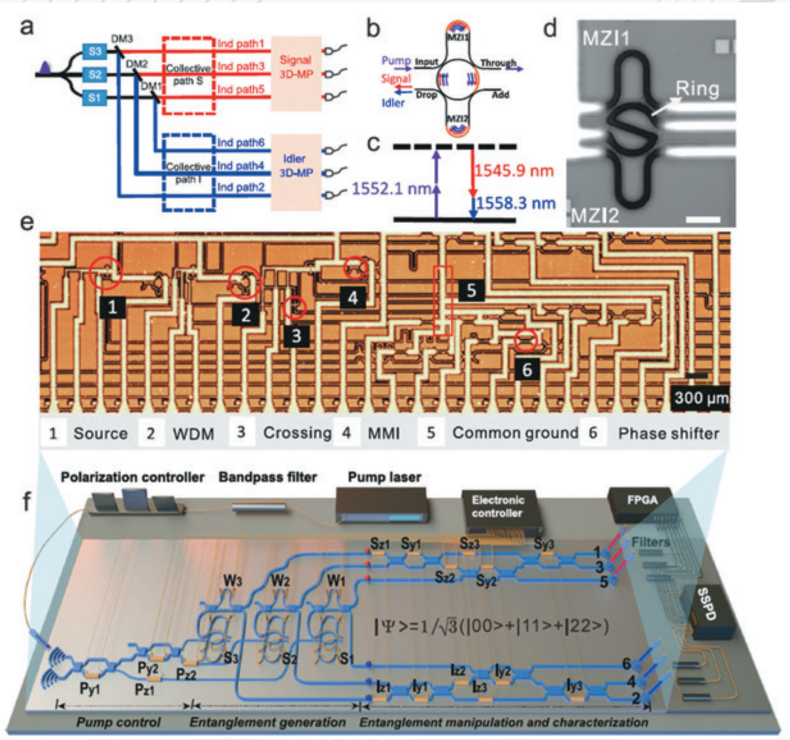


Figure 1. Silicon quantum photonic chip and schematic of the experimental setup. a, Conceptual scheme of the approach for generating and manipulating two entangled qutrits. b, Diagram of a dual Mach-Zehnder interferometer micro-ring (DMZI-R) photon-pair source. c, Two identical pump photons (1552.1 nm) generate one signal (1545.9 nm) and one idler (1558.3 nm) photons in non-degenerate spontaneous four wave mixing. d, Optical microscopy image of the DMZI-R photon-pair source, with scale bar representing 20 μm. e, Optical microscopy image of the whole entangled qutrit chip. f, Schematic of the complete experimental setup.

High-dimensional quantum systems

The Russian part of the Joint BRICS Project, "Multiphoton high-dimensional states of light for quantum information tasks," addresses the challenge of studying high-dimensional quantum systems using one of the most prevalent physical platforms for quantum computers today: the linear optical platform.

The instrument employs both conventional bulk optical components and integrated optical structures. In order to construct integrated optical devices with the greatest efficacy for the utilization of quantum algorithms, it is necessary to employ photonic chips, the input of which is simultaneously supplied with several indistinguishable photons *(Figure 2)*. Consequently, it is possible to obtain quantum states of light that exist in high-dimensional space. The subsequent objective is to develop and implement optical circuits in which the input photons are converted in accordance with the dictates of the corresponding algorithm. At the output of the integrated optical circuit, single-photon detectors are placed, the activation of which signals the registration of a certain event — either one or several of all possible ones. Statistical processing of the number of detector operations enables two key insights: firstly, it allows conclusions to be drawn about the result of the algorithm at a certain step; secondly, it enables a "feedback" strategy to be employed, whereby the input signal is adjusted in accordance with the outcome of the algorithm at the previous step.

At the initial stage of the project, the efficacy of neural network algorithms in accurately reconstructing (measuring) high-dimensional quantum states was demonstrated. Convolutional neural networks have been demonstrated to be capable of identifying whether a selected set of tomographic measurements is informationally complete. Furthermore, we tested several algorithms for the reconstruction of quantum states, which significantly simplify the work with high-dimensional states, which usually require a large number of real measurements and sufficiently large computing resources to perform the reconstruction algorithm.

In the second and third stages of the project, the primary objective shifted towards the development of algorithms for the design of linear optical interferometers with the capacity to perform a specific operation. The nature of the carrier of quantum information in an optical computer — a single photon — precludes the implementation of multi-qubit operations with 100% probability. Consequently, the project addressed the issue of identifying optical interferometer designs capable of generating entangled quantum states of light with the highest probability. Moreover, experimental studies were conducted with the objective of resolving the issue of establishing a complex

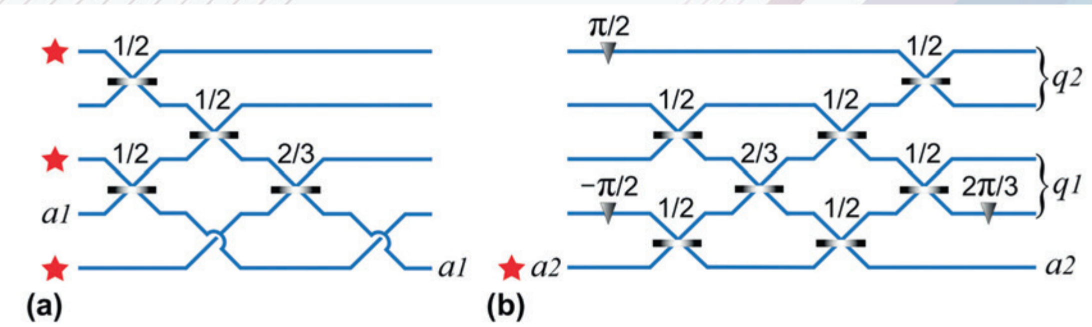


Figure 2. *The optimized scheme, based on two five-mode interferometers for generation of dual-rail-encoded Bell states using four separable photons (Suren A. Fldzhyan, Mikhail Yu. Saygin, and Sergei P. Kulik, Compact linear optical scheme for Bell state generation. Phys. Rev. Res. 3, 043031 (2021)).*

multiport interferometer in a manner that would facilitate the generation of the requisite output states.

Development of optical approaches for processing and transmitting quantum information

The project commenced during the global health crisis caused by the novel coronavirus (COVID-19). From the outset, we have advocated for the use of video conferencing for periodic meetings. Following several meetings, we gained considerable insight into the scientific activities of each group and were able to establish contact with the researchers engaged in the research topics pertinent to our project in each site. The exchange of knowledge was considerable, given the restrictions imposed by the pandemic. Our project has benefited greatly from the suggestions and discussions with our BRICS collaborators. Furthermore, we were able to conduct a site visit to the Chinese group. The experience has had a profound impact on the visitors' perceptions of Chinese science and the potential benefits of high-quality collaborations.

The Brazilian component of the Joint BRICS Project, entitled "Multiphoton High-Dimensional States of Light for Quantum Information Tasks," addresses the development of optical approaches for the efficient processing and transmission of quantum information. We underscore the advancements in the manipulation of transverse spatial degrees of freedom of light. The following section will provide further details.

a. Optical processor for Multiply-Accumulate (MAC) operations.

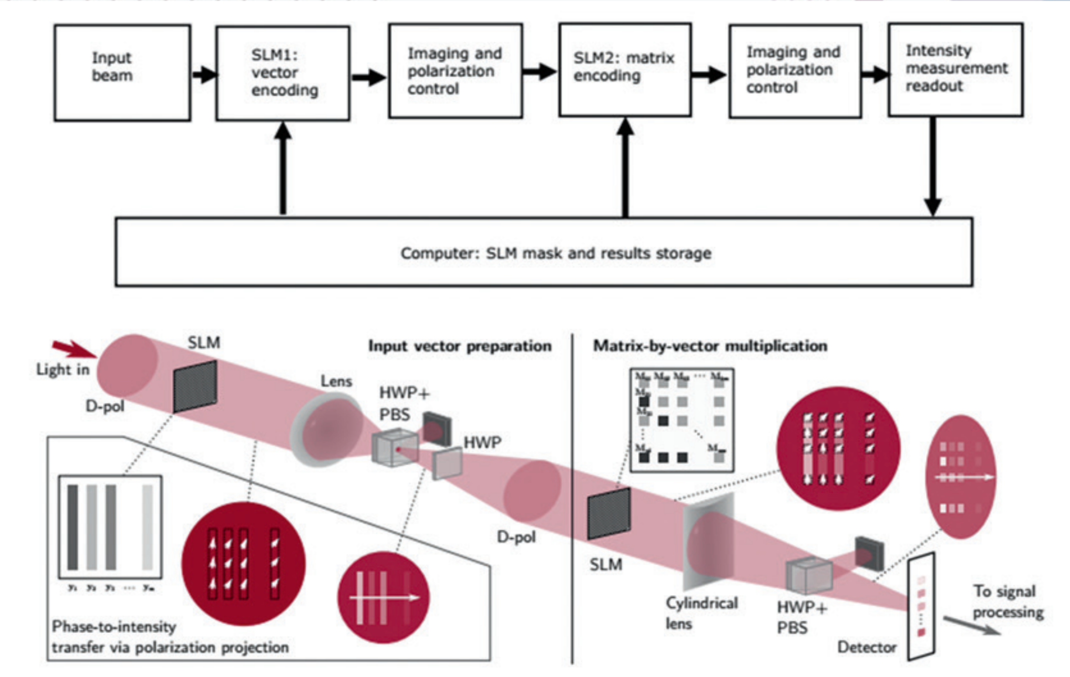


Figure 3. S B Hengeveld et al 2022 J. Opt. 24 015701

We have designed an optical processor based on spatial light modulators (SLM) having the potential to perform 1.2 Giga multiply and accumulate (MAC) operations per second using commercially available devices to build it. This system is being currently tested in the laboratory and improved to make use of quantum advantage through a Hong-Ou-Mandel scheme.

b. Quantum communication with Twisted-Gaussian-Schell-Model beams

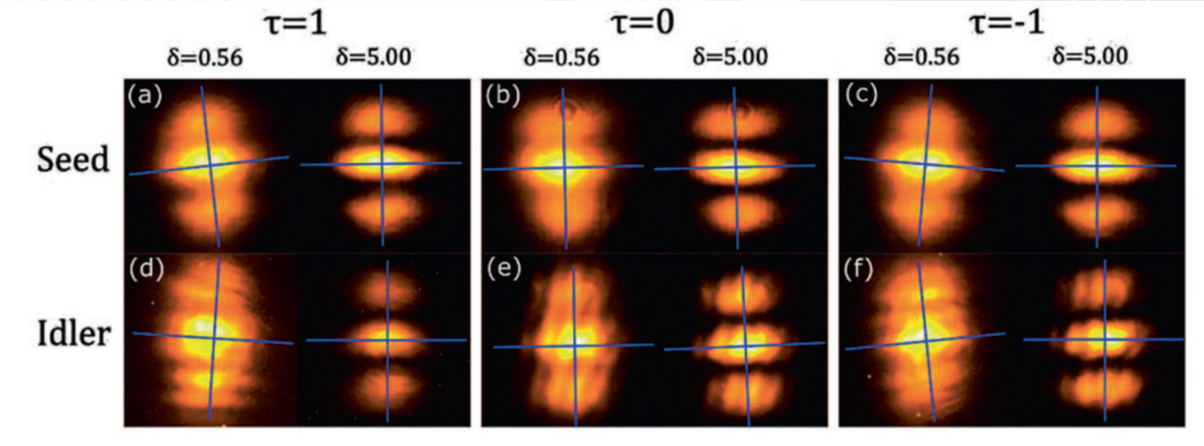


Figure 4. *https://doi.org/10.1515/nanoph-2021-0502 (2021)*

We have demonstrated phase-conjugation capabilities of TGSM partially coherent beams that are robust against perturbations during free-space propagation. The quantum version is being developed using entangled TGSM photon-pairs.

c. Quantum communication with High-Order Spatial Modes of light

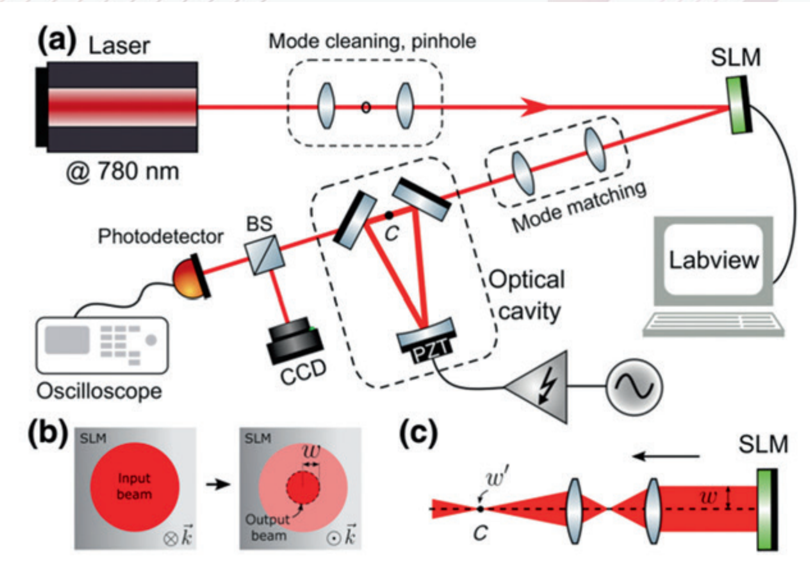


Figure 5*. G. H. dos Santos et al. Phys. Rev. Applied 16, 034008 (2021)*

We have demonstrated the use of a triangular optical cavity to discriminate high-order spatial modes of light like Hermite-Gaussian modes. This approach can be useful for discrimination of single-photons populating high-order spatial modes in a quantum communication scheme.

CONCLUSIONS

In conclusion, the implementation of this project facilitated the strengthening of collaboration with participants from the international consortium within the BRICS framework. It can be argued that the work on this project and its results present an opportunity to overcome significant scientific and technological difficulties and unite the BRICS countries. Through collaborative efforts, the members have successfully addressed several theoretical and experimental challenges in high-dimensional quantum information processing. The joint development of new applications and projects provides a clear illustration of the excellent outcomes that can be achieved through the BRICS platform.

IV. FULL LIST OF BRICS STI PROJECTS SUPPORTED WITHIN THE PILOT PHASE OF THE BRICS STI FP (2016-2020)

National funding organizations:

CNPq – National Council for Scientific and Technological Development, Brazil
DBT – Department of Biotechnology, India
DST – Department of Science and Technology, India
MON – Ministry of Science and Higher Education (former Ministry of Education and Science), Russia
MOST – Ministry of Science and Technology, China
NRF – National Research Foundation, South Africa
NSFC – National Natural Science Foundation of China, China
RFBR – Russian Centre for Science Information (former Russian Foundation for Basic Research, Russia)
SAMRC – South African Medical Research Council, South Africa

BRICS STI FRAMEWORK PROGRAMME PILOT CALL 2016

№	Registration number and Acronym	Full Title	Country	PI	Organization	National funding organization
1	84 - LDSPIWDS	Leakage Detection and Soil-Pipe Interactions in Water Distribution Systems	BRAZIL	Iran Eduardo Lima Neto	Federal University of Ceará	CNPq
			CHINA	Tuqiao Zhang	1st Zhejiang University, 2nd China Jiliang University	NSFC
			SOUTH AFRICA	Jakobus van Zyl	University of Cape Town	NRF
2	112 - NEUROTHE-RAPY	Development of a new screening platform for the discovery of novel therapeutics to cure neurodegenerative diseases	RUSSIA	Kaznache-yeva Elena	Institute of Cytology RAS	RFBR
			INDIA	Nihar Ranjan Jana	National Brain Research Centre	DST
			CHINA	Guanghui Wang	College of Pharmaceutical Sciences, Soochow University	NSFC

№	Registration number and Acronym	Full Title	Country	PI	Organization	National funding organization
3	115 - Loop	Nano-Engineered Concrete for Sustainable Infrastructure	RUSSIA	Valeria Strokova	Belgorod State Technological University named after V.G. Shoukhov	MON
			INDIA	L P Singh	CSIR-Central Building Research Institute, Roorkee	DST
			CHINA	Shifeng Huang	University of Jinan	NSFC
4	164 - EpiMacroTB	Epigenetics of macrophages during Mycobacterium tuberculosis infection	RUSSIA	Yulia Medvedeva	Vavilov Instutute of General Genetics; Research Center of Biotechnology RAS, Institute of Bioingeneering	RFBR
			INDIA	Sanjeev Khosla	Laboratory of Mammalian Genetics, CDFD, Hyderabad	DST
			SOUTH AFRICA	Reto Guler	Division of Immunology, IDM, University of Cape Town	NRF
5	183 - Helimagnets	Ground state magnetic structure, spin dynamics, and hyperfine interactions in frustrated 3d-metal based helimagnets: nuclear resonance spectroscopy study	RUSSIA	A.A. Gippius	M.V. Lomonosov Moscow State University; Faculty of Physics	RFBR
			INDIA	A.V. Mahajan	Indian Institute of Technology Bombay, Department of Physics	DST
			SOUTH AFRICA	A.M. Strydom	University of Johannesburg, Department of Physics	NRF
6	225 - BGNCDT	Boron and gadolinium nanoparticles for cancer diagnosis and therapy	RUSSIA	V.Bregadze	Institute of Organoelement Compounds, Russian Academy of Sciences (INEOS RAS)	RFBR
			INDIA	S. Mandal	Department of Chemical Sciences Indian Institute of Science Education and Research-Kolkata	DST
			CHINA	Zheyu Shen	Ningbo Institute of Materials Technology & Engineering (NIMTE), Chinese Academy of Sciences (CAS)	NSFC
7	233 - ADHNMS	All-dielectric and hybrid nanoantennas for multifunctional sensors	RUSSIA	Pavel Belov	Saint Petersburg National Research University of Information Technologies, Mechanics and Optics (ITMO University), Department of Nanophotonics and Metamaterials	MON
			INDIA	Ravindra K Sinha	CSIR-Central Scientific Instruments Organisation	DST
			CHINA	Qiang Li	College of Optical Science and Engineering, Zhejiang University	MOST

№	Registration number and Acronym	Full Title	Country	PI	Organization	National funding organization
8	241 - OPTIMODE	Optical communication with spatial modes of light	RUSSIA	Alexis Kudryashov	Institute of Geosphere Dynamics Russian Academy of Science	
			INDIA	Shanti Bhattacharya	Indian Institute of Technology (Madras)	DST
			SOUTH AFRICA	Andrew Forbes	University of the Witwatersrand	NRF
9	258 - Nanomag-SmCoFe	Nanocrystalline hard magnetic Sm-Co-Fe-T alloys (T = Cu, Ti, Zn, and Zr) with the normal and abnormal temperature dependence of coercivity	RUSSIA	Popov A.G.	M.N. Miheev Institute of Metal Physics of Ural Branch of Russian Academy of Sciences, Laboratory of Ferromagnetic Alloys	RFBR
			INDIA	Raghavan Gopalan	International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI) (Dept.of Science and Technology, Govt. of India)	DST
			CHINA	Tianli Zhang	School of Materials Science and Engineering, Beihang University	NSFC
10	266 - HMAero	Hybrid Manufacturing of Aerospace Parts: Software Modeling, Simulation, Verification and Development	RUSSIA	Vladimir Belenky	Perm National Research Polytechnic University, Mechanical Engineering Faculty	MON
			INDIA	K.P. Karunakaran	Indian Institute of Technology Bombay, Rapid Manufacturing Laboratory, Department of Mechanical Engineering	DST
			CHINA	Shengyong Pang	Huazhong University of Science and Technology, Computational Welding Process Design Laboratory, State Key Laboratory of Material Processing and Die & Mould Technology	MOST
11	279 - HPCSLED	Development of novel cooling systems for high power LEDs for enhanced reliability and lifetime	RUSSIA	Oleg Kabov	Kutateladze Institute of Thermophysics SB RAS	MON
			INDIA	Sameer Khandekar	Indian Institute of Technology Kanpur	DST
			CHINA	Liang Zhao	Xi'an Jiaotong University	MOST

Nº	Registration number and Acronym	Full Title	Country	PI	Organization	National funding organization
12	315 - IKMMT	Identification of Key genetic/ epigenetic Marker(s) in cervical carcinogenesis and development of corresponding Molecular Therapeutics for precision medicine of cervical cancer	RUSSIA	Konstantin V. Severinov	Skolkovo Institute of Science and Technology	RFBR
			INDIA	Bhudev C.Das	Amity University, Noida Amity Institute of Molecular Medicine & Stem Cell Research	DST
			CHINA	Zheng Hu	The First Affiliated Hospital of Sun Yat-sen University	NSFC
			SOUTH AFRICA	Inga I. Hitzeroth	University of Cape Town, Biopharming Research Unit, Department of Molecular and Cell Biology	NRF
13	352 - RMGeT	Development of methods for remote monitoring of the dynamics of vegetation, soil and land use taking into account natural and anthropogenic factors on the basis of geospatial technologies for rational use of natural resources	BRAZIL	Paulo Márcio Leal de Menezes	Federal University of Rio de Janeiro (UFRJ)	CNPq
			RUSSIA	Bondur V.G.	State scientific institution "Institute for Scientific Research of Aerospace Monitoring "AEROCOSMOS" (ISR "AEROCOSMOS")	MON
			CHINA	Fang Chen	The Institute of Remote Sensing and Digital Earth (RADI)	MOST
14	369 - DomEng	Physical basis of domain engineering in piezoelectric single crystals of PMN-PT family and lead-free piezoceramics	RUSSIA	Vladimir Shur	Ural Federal University, School of Natural Sciences and Mathematics	RFBR
			INDIA	S S Islam	Centre For Nanoscience and Nanotechnology (CNN), Jamia Millia Islamia	DST
			CHINA	Xiaoyong Wei	Xian Jiaotong University, Electronic Materials Research Laboratory	NSFC
15	373 - CloudHPC	Harnessing Cloud Computing to Power Up HPC Applications	BRAZIL	Luciano Paschoal Gaspary	Institute of Informatics, Federal University of Rio Grande do Sul (UFRGS)	CNPq
			RUSSIA	Vladimir Korkhov	Department of Computer Modeling and Multiprocessor Systems, St. Petersburg State University (SPbSU)	
			CHINA	Wang Xingce	Computer Science Department, College of Information Science and Technology, Beijing Normal University (BNU)	MOST

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16	383 - UV-BRIDGE	New principles and fabrication technologies of extreme 2D and 0D AlGaInN nanohetero-structures for high efficiency mid- and deep-ultraviolet spontaneous and laser emitters	RUSSIA	Sergey Ivanov	Ioffe Institute, Center of Nanoheterostructure Physics	RFBR
			INDIA	Anirban Bhatta-charyya	University of Calcutta, Institute of Radio Physics and Electronics	DST
			CHINA	Zhixin Qin	Peking University, School of Physics	MOST
17	388 - ProFChEAP	Probing fundamental characteristics of extreme astrophysical phenomena	RUSSIA	Lutovinov Alexander A.	Space Research Institute (IKI), High Energy Astrophysics Dept.	RFBR
			INDIA	Shashi Bhushan Pandey	ARIES Nainital/Astronomy & Astrophysics	DST
			SOUTH AFRICA	David Buckley	University of Cape Town, Astronomy Department	NRF
18	405 - BICBRAIN	Brazil-India-China collaborative study on brain connectivity and neuromodulation techniques	BRAZIL	Marco A. Romano-Silva	Universidade Federal de Minas Gerais (UFMG), Medicina Molecular, Dept Mental Health	CNPq
			INDIA	Bangalore N Gangadhar	National Institute of Mental Health and Neurosciences	DST
			CHINA	Haijing Niu	State Key Lab of Cognitive Neuroscience and Learning, & IDG/McGovern Institute for Brain Research	NSFC
19	437 - nanoBRICS-rough	Fundamentals for development of individual nano-objects and nano-devices bottom-up mechanical integration for quantum and non-local phenomena study, nano-electronics and nano-bio-medical diagnostics	BRAZIL	Monica Cotta	Instituto de Fisica Gleb Wataghin, Universidade Estadual de Campinas (UNICAMP)	CNPq
			RUSSIA	Victor Koledov	Kotel'nikov Institute of Radioengineering and Electronics Russian Academy of Sciences, Laboratory of Magnetic Phenomena in microelectronics	RFBR
			INDIA	Digbijoy N. Nath	Indian Institute of Science Centre for Nano Science and Engineering (CeNSE) Bangalore	DST
			CHINA	Zhongming Zeng	Suzhou Institute of Nano-Tech and Nano-Bionics, Chinese Academy of Sciences) (SINANO)	NSFC
			SOUTH AFRICA	Somnath Bhatachryya	School of Physics, University of the Witwatersrand, Johannesburg	NRF

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20	444 - Coast-CARE	Coastal Communities Adaptive and Resilient at the Edge	BRAZIL	Carlos Eduardo de Rezende	Universidade Estadual do Norte Fluminense, Environmental Sciences Laboratory	
			INDIA	Sameer M. Deshkar	Department of Architecture and Planning, Visvesvaraya National Institute of Technology, Nagpur	DST
			CHINA	Carlo Jaeger	Beijing Normal University, ESPRE	MOST
			SOUTH AFRICA	Merle Sowman	University of Cape Town	NRF
21	451 - Superflares	Superflares on stars and the Sun	RUSSIA	Alexey Kuznetsov	Institute of Solar-Terrestrial Physics	RFBR
			INDIA	Dipankar Banerjee	Indian Institute of Astrophysics	DST
			CHINA	Bo Li	Shandong University, Institute of Space Sciences	NSFC
22	462 - Col-GaSS	Collaboration on Glaciers and Snow/Firn Characteristics Variability Studies in Polar and Subpolar Regions	BRAZIL	Jorge Arigony-Neto	Universidade Federal do Rio Grande - FURG Instituto de Oceanografia - IO Laboratório de Monitoramento da Criosfera - LaCrio	CNPq
			RUSSIA	Andrei Glazovsky	Dept. of Glaciology, Institute of Geography Russian Academy of Sciences	RFBR
			INDIA	Gulab Singh	Centre of Studies in Resources Engineering Indian Institute of Technology Bombay	DST
23	464 - POINTCLOUD	Research and development of algorithms and software for the processing, storage and visualization of laser scanning and photography data	RUSSIA	Vladimir Badenko	Peter the Great St.Petersburg Polytechnic University, Water management and hydraulic engineering	MON
			INDIA	R.D. Garg	Indian Institute of Technology Roorkee, Geomatics Engineering, Civil Engineering Department	DST
			CHINA	Lei Zhang	East China Normal University, School of Information Science Technology, Shanghai Key Laboratory of Mutimensianal Information Processing, Engineering Center of SHMEC for Space Information and GNSS	MOST

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24	482-	The role of region-specific SNPs in virulence genes in Mycobacterium tuberculosis drug resistance	RUSSIA	Valery N. Danilenko	Vavilov Institute of General Genetics, RAS	MON
			CHINA	Lingyun Shao	Department of Infectious Diseases, Huashan Hospital, affiliated to Fudan University, China	NSFC
			SOUTH AFRICA	Martie van der Walt	TB Platform unit, South African Medical Research Council	NRF
25	485 - Platinum nano	Platinum as an essential element in an integrated process for efficient energy conversion	BRAZIL	Antônio José Roque da Silva	Brazilian Synchrotorn Light Laboratory	CNPq
			INDIA	Ankur Bordoloi	CSIR-Indian Institute of Petroleum	DST
			SOUTH AFRICA	Eric van Steen	University of Cape Town, Department of Chemical Engineering	NRF
26	500 - MuMeSTU	Multi-Wavelength and Multi-Messenger Studies of the Transient Universe	RUSSIA	Vladimir Mikhaylovich Lipunov	Physics department of Lomonosov Moscow State University, Sternberg Astronomical Institute	RFBR
			INDIA	Devendra Kumar Sahu	Indian Institute of Astrophysics	DST
			CHINA	Hongbo Hu	Astroparticle Physics Division, Institute of High Energy Physics, CAS	NSFC

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№	Registration number (BRICS2017-) and Acronym	Full Title	Country	PI	Organization	National funding organization
1	022 - RDRNCD	Radical decrease in risk of natural catastrophic disasters	RUSSIA	Vladimir V. Makarov	Far Eastern Federal University	MON
			INDIA	Pijush Samui	National Institute of Technology Patna	DST
			CHINA	Meifeng Cai	University of Science and Technology Beijing	MOST

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2	026 - NanoHybrid	New core-shell hybrid nanostructures: Evaluation of surface coating impact to biosafety and potential therapeutic applications	RUSSIA	Sergey O. Bachurin	Institute of Physiologically Active Compounds RAS	MON
			CHINA	Ying Zhao	National Center for Nanoscience & Technology of China	NSFC
			SOUTH AFRICA	Mary Gulumian	National Institute for Occupational Health	NRF
3	053 - TherNC	Biofunctional theranostics nanocomplexes for combined therapy of solid cance	RUSSIA	Andrei V. Zvyagin	Lobachevsky State University of Nizhni Novgorod	MON
			INDIA	Indrajit Roy	University of Delhi	DST
			CHINA	Quan Lin	Jilin University	NSFC
4	059 - SEAMLESSIPS	Development and realization of high accuracy Indoor and Outdoor Seamless positioning system: Hardware and software	RUSSIA	Vladimir Badenko	Peter the Great St. Petersburg Polytechnic University	MON
			INDIA	R.D. Garg	Indian Institute of Technology	DST
			CHINA	Lei Zhang	East China Normal University Shanghai	MOST
5	064 - RICS-MH	Metal hydride materials and systems for the increase of efficiency in renewable and hydrogen energy	RUSSIA	Boris Tarasov	Institute of Problems of Chemical Physics RAS	MON
			INDIA	Muthukumar Palanisamy	Indian Institute of Technology Guwahati	DST
			CHINA	Xiao Fangming	Guangdong Research Institute of Rare Metals	MOST
			SOUTH AFRICA	Mykhaylo Lototskyy	University of the Western Cape	
6	069 - 3DeepCV	Machine Learning Technologies for 3D Data Processing in Computer Vision and Remote Sensing Applications	BRAZIL	Luiz Velho	Instituto Nacional de Matematica Pura e Aplicada	CNPq
			RUSSIA	Evgeny Burnaev	Skolkovo Institute of Science and Technology	MON
			CHINA	Youyi Zheng	Zhejiang University	MOST
7	116 - ICP-BIO	Development of fundamentals for Integrated Catalytic Processing of BIOmass to fuels and value-added chemicals	BRAZIL	Simoni Margareti Plentz Meneghetti	Federal University of Alagoas	CNPq
			RUSSIA	Esther M. Sulman	Tver State University	RFBR
			INDIA	Bhalchandra M. Bhanage	Institute of Chemical Technology	DST

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8	144 - IWMM-BIS	Integrated Water Management Model for BIS Countries Under Climate Change Scenarios	BRAZIL	Suzana Maria Gico Lima Montenegro	Universidade Federal de Pernambuco	CNPq
			INDIA	Venkata Reddy Keesara	National Institute of Technology Warangal	DST
			SOUTH AFRICA	Bloodless Dzwairo	Durban University of Technology	NRF
9	146 - IEEE-OSC	Interface-engineered and energy-efficient organic solar cells based on porphyrin small molecules	BRAZIL	Paulo Barbeitas Miranda	University of Sao Paulo	CNPq
			INDIA	Sai Santosh Kumar Raavi	Indian Institute of Technology Hyderabad	DST
			CHINA	Xiaobin Peng	South China University of Technology	NSFC
10	150 - EPNAPT	Engineering peptide-based nano-biomaterials for antitumor photodynamic therapy	RUSSIA	Rawil Fakhrullin	Kazan Federal University	RFBR
			INDIA	Thimmaiah Govindaraju	Jawaharlal Nehru Centre for Advanced Scientific Research	DST
			CHINA	Xuehai Yan	Institute of Process Engineering CAS	NSFC
11	191 - BNEAT	Energy Band and Nanostructure Engineering of AIV-BVI — based Thermoelectrics for Efficient Heat Energy Conversion	RUSSIA	Alexander Burkov	Ioffe Institute	RFBR
			INDIA	Kanishka Biswas	Jawaharlal Nehru Centre for Advanced Scientific Research	DST
			CHINA	Yanzhong Pei	Tongji University	NSFC
12	209 - GPCRArrSig	Understanding the structural basis of biased GPCR signaling to develop novel therapeutics with minimized side-effects	RUSSIA	Vadim Cherezov	Moscow Institute of Physics and Technology	RFBR
			INDIA	Arun Shukla	Indian Institute of Technology	DST
			CHINA	Haitao Zhang	Zhejiang University	NSFC
13	211 - 2DNEURO	Electronic synapses based on two dimensional materials for neuromorphic computing	BRAZIL	Gilson Inacio Wirth	Universidade Federal do Rio Grande do Sul	CNPq
			RUSSIA	Vladimir Gritsenko	Rzhanov Institute of Semiconductor Physics SB RAS	RFBR
			INDIA	Santanu Mahapatra	Indian Institute of Science Bangalore	DST
			CHINA	Mario Lanza	Soochow University	MOST

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14	236 - CCT	Development of the dual inhibitors targeting Wnt signaling as colorectal cancer therapeutics	RUSSIA	Vladimir A. Palyulin	Lomonosov Moscow State University	RFBR
			INDIA	Ahmed Kamal	Hamdard University	DST
			SOUTH AFRICA	Vinees Pillay	University of the Witwatersrand	NRF
15	256 - GLOWSENS	Global and local water quality monitoring by multimodal sensor systems	BRAZIL	Osvaldo Novais de Oliveira Jr.	University of São Paulo	CNPq
			RUSSIA	Andrey Legin	ITMO University	RFBR
			INDIA	Nabarun Bhatta-charyya	Centre For Development of Advanced Computing	DST
			CHINA	Chunsheng Wu	Xi'an Jiaotong University	NSFC
			SOUTH AFRICA	Gordon O'Brien	University of KwaZulu-Natal	NRF
16	258 - EMPMM	Electronic and magnetic properties of multiferroic materials	RUSSIA	Alexander Pyatakov	M. V. Lomonosov Moscow State University	RFBR
			INDIA	A.Sundaresan	Jawaharlal Nehru Centre for Advanced Scientific Research	DST
			CHINA	Wei Ren	Shanghai University	NSFC
17	390 - SCBCPCVD	Silicon Carbide Biomedical Coatings Prepared By Chemical Vapor Deposition	RUSSIA	Marina Kosinova	Nikolaev Institute of Inorganic Chemistry SB RAS	RFBR
			INDIA	Bikramjit Basu	Indian Institute of Science Bangalore	DST
			CHINA	Rong Tu	Wuhan University of Technology	NSFC
18	418 - BRICS-BEST	BRICS technology platform for integrated bioprocessing of agricultural residues for eco-sustainable production of biofuels and by-products	BRAZIL	Carlos Ricardo Soccol	Federalm University of Parana	CNPq
			RUSSIA	Arkady P. Sinitsyn	Federal Research Centre "Fundamentals of Biotechnology" RAS	RFBR
			INDIA	Sudesh K Yadav	Center of innovative and Applied Bioprocessing	DST
			CHINA	Zhengxiang Wang	Tianjin University of Science & Technology	MOST
			SOUTH AFRICA	Kugenthiren Permaul	Durban University of Technology Biotechnology and Food Technology	NRF

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19	422 - REMULFUN	Renewable Energy Based Multifunctional Solid Sorption Thermal Battery for Year-round Building Thermal Management or Diverse Climatic Conditions of Russia, India and China	RUSSIA	Yuriy Aristov	Boreskov Institute of Catalysis	RFBR
			INDIA	Pradip Dutta	Indian Institute of Science	DST
			CHINA	Li Tingxian	Shanghai Jiao Tong University	MOST
20	431 - LiESTER	Investigating the links between different environmental conditions and severe thunderstorms characteristics and structure for Different Earth Region	RUSSIA	Andrei Sinkevich	Voeikov Main Geophysical Observatory	RFBR
			INDIA	Sunil Dnyandeo Pawar	Indian Institute of Tropical Meteorology	DST
			CHINA	Jing Yang	Institute of Atmospheric Physics CAS	MOST
21	433 - NFSMAFPSC	Development of efficient polymer solar cells based on non fullerene small molecules acceptors with low energy loss	RUSSIA	Alexei Khokhlov	A.N.Nesmeyanov Institute of Organoelement Compounds RAS	RFBR
			INDIA	Ganesh D. Sharma	The LNM Institute of Technology	DST
			CHINA	Chuandong Dou	Changchun Institute of Applied Chemistry	MOST
22	435 - MRP-TB	Multidisciplinary research platform to identify new TB drug targets	INDIA	Shekhar C Mande	Pune University	DST
			CHINA	Shiyun Chen	Wuhan Institute of Virology CAS	NSFC
			SOUTH AFRICA	Adrie JC Steyn	Africa Health Research Institute	NRF
23	486 - SIAOESUF	Studies into aspects of energy storage using flywheels	BRAZIL	Aly Ferreira Flores Filho	Federal University of Rio Grande do Sul	CNPq
			CHINA	Wei Xu	Huazhong University of Science and Technology	MOST
			SOUTH AFRICA	David G. Dorrell	University of KwaZulu-Natal	NRF
24	487 - POLYCAT	Finely tuning late-transition metal precatalysts towards ethylene polymerization for the amorphous highly-branched and elastomeric polyethylenes	BRAZIL	Osvaldo de Lazaro Casagrande Junior	Federal University of Rio Grande do Sul	CNPq
			RUSSIA	Evgenii P. Talsi	Boreskov Institute of Catalysis	RFBR
			CHINA	Wen-Hua Sun	Institute of Chemistry CAS	NSFC

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25	493 - Envirorganic	Environmental geochemistry and treatment of organic pollutants in aquatic systems in the selected areas of China, India, and Russia	RUSSIA	Oleg Savichev	National Research Tomsk Polytechnic University	RFBR
			INDIA	Supriya Pal	National Institute of Technology Durgapur	DST
			CHINA	Sun Zhanxue	East China University of Technology	NSFC
26	517 - From waste to resources	Development of membrane-based methods to improve the recovery of pure water and valuable products from the waste	BRAZIL	Andrea Moura Bernardes	Federal University of Rio Grande do Sul	CNPq
			RUSSIA	Alexey Volkov	A.V.Topchiev Institute of Petrochemical Synthesis RAS	RFBR
			INDIA	Sourja Ghosh	CSIR-Central Glass and Ceramic Research Institute	DST
			CHINA	Tao He	Shanghai Advanced Research Institute CAS	NSFC
			SOUTH AFRICA	Lueta-Ann de Kock	University of South Africa	NRF
27	526 - MBLI	Development of new approaches to overcome MBL-related resistance in bacteria	BRAZIL	Cristiano Marcelo Espinola Carvalho	Dom Bosco Catholic University	CNPq
			RUSSIA	Tatiana V. Ovchinnikova	M.M.Shemyakin & Yu.A.Ovchinnikov Institute of Bioorganic Chemistry RAS	RFBR
			INDIA	Jayanta Haldar	Jawaharlal Nehru Centre for Advanced Scientific Research	DST
			CHINA	Hixen Xie	East China University of Science and Technology	NSFC
28	563 - APARDS	Antiparasitic drug delivery system	BRAZIL	Vanessa Mosqueira	Universidade Federal de Ouro Preto	CNPq
			CHINA	Fenghua Meng	Soochow University	NSFC
			SOUTH AFRICA	Bert Klumperman	Stellenbosch University	NRF
29	591 - LargEWiN	Design and Development of Large-Scale Ambient Energy Harvesting Wireless Networks	BRAZIL	Daniel Benevides da Costa	Federal University of Ceará	CNPq
			INDIA	Prabhat Kumar Upadhyay	Indian Institute of Technology Indore	DST
			CHINA	Haiyang Ding	National University of Defense Technology	MOST
			SOUTH AFRICA	Jules Moualeu	University of the Witwatersrand	NRF

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30	617 - FDDLC	Fracture and delamination under dynamic loading	RUSSIA	Yuri Petrov	Saint Petersburg State University	RFBR
			INDIA	P. Venkitana-rayanan	Indian Institute of Technology Kanpur	DST
			CHINA	Ya-Pu Zhao	Institute of Mechanics CAS	NSFC
31	624 - FAIE	Fluxes-Assisted Inclusion Engineering: Applications in Low-carbon Low-alloy Shipbuilding Plates	INDIA	Somnath Basu	Indian Institute of Technology Bombay	DST
			CHINA	Cong Wang	Northeastern University	NSFC
			SOUTH AFRICA	Theresa Coetsee	University of Pretoria	NRF
32	663 - Optonanospin	Nanostructures with large magneto-optical activity and spin-orbit interaction	RUSSIA	Vladimir I. Belotelov	International Center for Quantum Optics & Quantum Technologies	RFBR
			INDIA	Venu Gopal Achanta	Tata Institute of Fundamental Research	DST
			CHINA	Yujun Song	University of Science and Technology Beijing	NSFC

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Nº	Registration number (BRICS2019-) and Acronym	Full Title	Country	PI	Organization	National funding organization
1	028 - GEMOECO	Environmental MOnitoring and assessment of land use / land cover change impact on ECOlogical security using GEospatial technologies	RUSSIA	Eldar Kurbanov	Volga State University of Technology	RFBR
			CHINA	Jinliang Wang	Yunnan Normal University	MOST
			SOUTH AFRICA	Abraham Thomas	Council for Geoscience	NRF
2	032 - MHSSSHP	Modelling of the hydrogen storage and supply systems with output hydrogen pressure in wide range of pressures (up to 80MPa) using low-potential heat-transfer agent	RUSSIA	Mitrokhin Sergey	Moscow State University	RFBR
			INDIA	Bhogilla Satya Sekhar	Indian Institute of Technology Jammu	
			CHINA	Yan Huizhong	BRIRE Rare Earth Functional Materials Engineering Technology Research Center	MOST

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3	036 - SONG	Supercomputer Simulation and Big Data Analysis Of Environmental Noise from Aircraft and Mechanisms of its Generation	BRAZIL	Juan Salazar	Universidade Federal de Santa Catarina	CNPq
			RUSSIA	Tatiana Kozubskaya	Keldysh Institute of Applied Mathematics RAS	RFBR
			CHINA	Xin Zhang	HKUST Shenzhen Research Institute	MOST
4	040 - TCLB/ WBBUICE	Thermochemical conversions of lignocellulosic biomass/wastes into bioenergy and biofuels and its utilization in internal combustion engine	BRAZIL	Electo Eduardo Silva Lora	Federal University of Itajubá	CNPq
			RUSSIA	Alexander N. Kozlov	Melentiev Energy Systems Institute	RFBR
			INDIA	K.A. Subra-manian	Indian Institute of Technology Delhi	DST
			CHINA	Shu Zhang	Nanjing Forestry University	MOST
			SOUTH AFRICA	Yusuf Isa	Durban University of Technology	NRF
5	053 - STARS	Superconducting Terahertz Receivers for Space and Ground-based Radio Astronomy	BRAZIL	Jacques Lepine	University of São Paulo	CNPq
			RUSSIA	Valery Koshelets	Kotel'nikov Institute of Radio Engineering and Electronics	RFBR
			CHINA	Huabing Wang	Nanjing University	NSFC
			SOUTH AFRICA	Coenrad Fourie	Stellenbosch University	NRF
6	058 - IENA	Installed Engine Noise Attenuation	BRAZIL	Julio Apolinário Cordioli	Federal University of Santa Catarina	CNPq
			RUSSIA	Victor Kopiev	Central Aerohydrodynamic Institute named after Professor N.E. Zhukovsky	RFBR
			CHINA	Chen Bao	AVIC Harbin Aerodynamics Research Institute	MOST
7	070 - Vibrios as biosensors	Vibrios as biosensors of global/local changes	BRAZIL	Fabiano Lopes Thompson	Universidade Federal do Rio de Janeiro	CNPq
			INDIA	Neelam Taneja	Vellore Institute of Technology	DST
			CHINA	Shenghua Liu	Xi'an Jiaotong University	MOST

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8	075 - PLUMPLAS	River plumes as major mediators of marine plastic pollution	BRAZIL	Osmar Olinto Möller Jr.	Instituto de Oceanografia	CNPq
			RUSSIA	Peter Zavialov	Shirshov Institute of Oceanology RAS	RFBR
			CHINA	Xinhong Wang	Xiamen University	NSFC
9	083 - LDMHW-BEATAILED	Low-dimensional metal halides with broadband emission and their application in light-emitting diodes	RUSSIA	Maxim Molokeev	Kirensky Institute of Physics SB RAS	RFBR
			INDIA	Angshuman Nag	Indian Institute of Science Education and Research	DST
			CHINA	Zhiguo Xia	South China University of Technology	NSFC
10	104 - IRMMA	Improving risk management of landslide and debris flow hazards in mountainous area	BRAZIL	Francisco Dourado	University of Rio de Janeiro State	CNPq
			RUSSIA	Sergey A. Sokratov	Lomonosov Moscow State University	MSHE
			CHINA	Mingtao Ding	Southwest Jiaotong University	
11	122 - BIO-OCD	Biosignatures as predictors of response to SSRIs in OCD: Developing a successful paradigm of personalized medicine	BRAZIL	Roseli G. Shavitt	University of São Paulo	CNPq
			INDIA	Y.C. Janardhan Reddy	National Institute of Mental Health and Neurosciences	DST
			SOUTH AFRICA	Christine Lochner	Stellenbosch University	NRF
12	123 - GPTNOM	Green Printing Technology for Novel Optical Metadeviecs	RUSSIA	Pavel Alexandrovich Belov	ITMO University	RFBR
			INDIA	A.K. Ganguli	Indian Institute of Technology, Delhi	DST
			CHINA	Yanlin Song	Institute of Chemistry, CAS	NSFC
13	124 - CRIAP	Characterizing Risk Indicators to cause Anaemia Prevalence among young Children and Adolescents in BRICS countries using Artificial Intelligence	RUSSIA	Aleksandra Mashkova	Central Economics and Mathematics Institute RAS	RFBR
			INDIA	Rishemjit Kaur	Central Scientific Instruments Organisation, Chandigarh	DST
			SOUTH AFRICA	Natisha Dukhi	Human Sciences Research Council	NRF
14	134 - Ga2O3: Galium Oxide	Ga2O3-based nanomaterials with controlled defect and impurity composition for advanced electronic devices	BRAZIL	Pedro Luis Grande	Federal University of Rio Grande do Sul	CNPq
			RUSSIA	David Tetelbaum	Lobachevsky University	RFBR
			INDIA	Mahesh Kumar	Indian Institute of Technology Jodhpur	DST

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15	142 - CESSW	Comprehensive experimental and simulation study on wildfire of BRICS countries: Fire occurrence, spread and suppression	BRAZIL	Guenther C. Krieger Filho	University of São Paulo	CNPq
			RUSSIA	Oleg Korobeinichev	Voevodsky Institute of Chemical Kinetics and Combustion SB RAS	RFBR
			INDIA	Amit Kumar	Indian Institute of Technology Madras	DST
			CHINA	Naian Liu	University of Science and Technology of China	NSFC
16	154 - CO2 - Carbon dioxide	Life cycle assessment of CO2 reduction by energy efficient hybrid biomass pyrolysis and gasification	BRAZIL	Amaro Pereira	Universidade Federal Rio de Janeiro	CNPq
			RUSSIA	Pavel A. Strizhak	National Research Tomsk Polytechnic University	RFBR
			INDIA	Anand Ramanathan	National Institute of Technology Tiruchirappallli	DST
17	156 - SPMMWSMC	Single phase multiferroic materials with strong magnetoelectric coupling	BRAZIL	Jose Antonio Eiras	Federal University of São Carlos	CNPq
			RUSSIA	Anatoly K. Zvezdin	A.M. Prokhorov General Physics Institute RAS	RFBR
			CHINA	Xiang Ming Chen	Zhejiang University	NSFC
18	173 - MHPPQIP	Multi-photon and high-dimensional platforms for photonic quantum information processing	BRAZIL	Paulo H. Souto Ribeiro	Universidade Federal de Santa Catarina	CNPq
			RUSSIA	Sergei Kulik	Moscow State University	RFBR
			CHINA	Xiaosong Ma	Nanjing University	NSFC
19	174 - JVRIS	Joint validation of multi-source remote sensing information and sharing in BRICS countries	RUSSIA	V.G. Bondur	State scientific Institution “Institute for Scientific Research of Aerospace Monitoring “AEROCOSMOS”	RFBR
			INDIA	R B Singh	University of Delhi	DST
			CHINA	Xiang Zhou	Institute of Remote Sensing and Digital Earth Research CAS	MOST
20	191 - PRISE	Precision Radio Imaging In The SKA Era	INDIA	Dharam Vir Lal	Tata Institute of Fundamental Research	DST
			CHINA	Feng Wang	Center For Astrophysics Guangzhou University	NSFC
			SOUTH AFRICA	Oleg Smirnov	Rhodes University & South African Radio Astronomy Observatory	NRF

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21	198 - F3DNCFM-TERM	Fabrication of three-dimensional nanocellulose-based multifunctional materials for tissue engineering and regenerative medicine applications	RUSSIA	Victor Vasilievich Revin	National Research Ogarev Mordovia State University	RFBR
			INDIA	Sabu Thomas	Mahatma Gandhi University	DST
			CHINA	Guang Yang	Huazhong University of Science and Technology	MOST
22	210 - SIMRO	Sustainable and Integrated Solutions for Monitoring and Remediation of Emerging Contaminants (Organo-chlorine) from Non-point Source	RUSSIA	Inna P. Solyanikova	Institute of biochemistry and physiology of microorganisms RAS	RFBR
			INDIA	S. Venkata Mohan	CSIR-Indian Institute of Chemical Technology, Hyderabad	DST
			CHINA	Yonghong Wu	Institute of Soil Science CAS	NSFC
23	224 -	The fundamental research and key materials development in the novel high performance alkaline membrane fuel cells	RUSSIA	A. Bulanova	Samara University	RFBR
			INDIA	K. Ramya	International Advanced Research Centre for Powder Metallurgy and New Materials	DST
			CHINA	Zhongming Wang	Beijing University of Chemical Technology	NSFC
24	228 - GaO-Nitrides	Wide Bandgap Semiconductor (Al)GaO/Nitrides Heterostructures for High Power Electronic and Optoelectronic Devices	RUSSIA	Wsevolod Lundin	Ioffe Institute	RFBR
			INDIA	Rajendra Singh	Indian Institute of Technology Delhi	DST
			CHINA	Shibing Long	University of Science and Technology of China	NSFC
25	240 - NanoDrug	Polymeric Nanostructures for Treatment of Microbial Infections	BRAZIL	Pedro Henrique Hermes de Araujo	Federal University of Santa Catarina	CNPq
			INDIA	Amit K. Goyal	National Institute of Animal Biotechnology, Hyderabad	DST
			CHINA	Xiaoyu Huang	National Engineering Research Center for Nanotechnology	NSFC
26	243 - IRUEMSCAR-GLRB	Impact of rapid urbanization on the evolution and multi-scale control of antibiotic resistance genes in the large river basin	BRAZIL	José Tavares Araruna Júnior	Pontifical Catholic University of Rio de Janeiro	CNPq
			RUSSIA	Aleksei Nikolavich Makhinov	Institute of Water and Ecology Problems FEB RAS	RFBR
			CHINA	Shuguang Liu	Tongji University	NSFC

№	Registration number (BRICS2019-) and Acronym	Full Title	Country	PI	Organization	National funding organization
27	252 - ERSPIC	Energy-efficient reconfigurable silicon photonic integrated devices and circuits for optical interconnects	BRAZIL	Roberto Ricardo Panepucci	Centro de Tecnologia da Inovação Renato Archer	CNPq
			INDIA	Rajesh Kumar	Indian Institute of Technology Roorkee	DST
			CHINA	Daoxin Dai	Zhejiang University	NSFC
28	286 - PORMAT	Natural and artificial porous materials filled with liquid and solid dielectrics	RUSSIA	Sergey Vakhrushev	Peter the Great St. Petersburg Polytechnic University	RFBR
			INDIA	Ravi Kumar N V	Indian Institute of Technology-Madras	DST
			SOUTH AFRICA	Georges-Ivo Ekosse	University of Venda	NRF
29	314 - QuSaF	Quantum Satellite and Fibre Communication	RUSSIA	Anton Bourdine	Povolzhskiy State University of Telecommunications and Informatics	RFBR
			INDIA	Manish Tiwari	Manipal University Jaipur	DST
			CHINA	Juan Yin	University of Science and Technology of China	NSFC
			SOUTH AFRICA	Francesco Petruccione	University of KwaZulu-Natal	NRF
30	374 - FunTiSurf	FUNCTIONALI-ZATION OF NEW TITANIUM ALLOYS AFTER ECAP PROCESSING AND SURFACE TREATMENT	BRAZIL	Paulo Noronha Lisboa-Filho	São Paulo State University	CNPq
			RUSSIA	Dmitry Gunderov	Ufa State Aviation Technical University	RFBR
			INDIA	Murugan Ramalingam	Vellore Institute of Technology	DST
31	394 - HyMMIA	Hybrid Methods for Radiological Medical Image Analysis and Pathological Grading Prediction	BRAZIL	Mylene Christine Queiroz de Farias	University of Brasilia	CNPq
			RUSSIA	Andrey S. Krylov	Lomonosov Moscow State University	RFBR
			CHINA	Yong Ding	Zhejiang University	MOST
32	439 - Climate change and flow regimes in the plateaus of Asia	Detect and predict the impacts of climate change on the flow regimes of rivers originated from plateaus in Asia	RUSSIA	Olga Makarieva	Melnikov Permafrost Institute	RFBR
			INDIA	J. Indu	Indian Institute of Technology Bombay	DST
			CHINA	Lei Cheng	Wuhan University	NSFC

№	Registration number (BRICS2019-) and Acronym	Full Title	Country	PI	Organization	National funding organization
33	444 -	Stimuli responsive photothermal nanoparticles in cancer therapy	INDIA	Kaushik Pal	Indian Institute of Technology Roorkee	DST
			CHINA	Yucai Wang	University of Science and Technology of China	NSFC
			SOUTH AFRICA	Moganavelli Singh	University of KwaZulu-Natal	NRF
34	447 - BioThera-Bubble	Bioactive ultrasound-driven microbubbles for theranostics	RUSSIA	Dmitry Gorin	Skolkovo Institute of Science and Technology	RFBR
			INDIA	Krishna Kanti Dey	Indian Institute of Technology Gandhinagar	DST
			CHINA	Yongfeng Mei	Fudan University	NSFC
35	470 - Designing novel inhibitors for HIV protease	An integrative approach for understanding the structure, function and dynamics of HIV protease: applications to design novel inhibitors	BRAZIL	Vasco Azevedo	Federal University of Minas Gerais	CNPq
			INDIA	M. Michael Gromiha	Indian Institute of Technology Madras	DST
			SOUTH AFRICA	Yasien Sayed	University of the Witwatersrand	NRF

BRICS STI FRAMEWORK PROGRAMME
Call 2020: Response to COVID-19 global pandemic

№	Registration number (BRICS2020-) and Acronym	Full Title	Country	PI	Organization	National funding organization
1	010 - COVID-AI	Multidisciplinary platform based on artificial intelligence for accelerating drug discovery and repurposing for COVID-19	BRAZIL	Carolina Horta Andrade	Federal University of Goias	CNPq
			RUSSIA	Vadim Makarov	Federal Research Center “Fundamentals of Biotechnology” RAS	RFBR
			SOUTH AFRICA	Kelly Chibale	University of Cape Town	SAMRC
2	027 - GSSEMMCP	Genomic sequencing of SARS-CoV-2 and studies on the epidemiology and mathematical modelling of the COVID-19 pandemic	BRAZIL	Marilda Mendonça Siqueira	Oswaldo Cruz Foundation, Brazilian MoH	CNPq
			RUSSIA	Ivan Sobolev	Federal Research Center of Fundamental and Translational Medicine	RFBR
			INDIA	Ch. Sasikala	JNT University Hyderabad	DST
			CHINA	Yuhua Xin	Institute of Microbiology, CAS	NSFC

№	Registration number (BRICS2020-) and Acronym	Full Title	Country	PI	Organization	National funding organization
3	033 - BRICSmart	BRICS-ICT Alliance for Smart Resource Utilization to Combat Global Pandemic Outbreaks	BRAZIL	Esther Luna Colombini	University of Campinas	CNPq
			RUSSIA	Vladimir Sudakov	Keldysh Institute of Applied Mathematics, RAS	RFBR
			SOUTH AFRICA	Hanlie Smuts	University of Pretoria	SAMRC
4	048 - MFQuantiC	Multi-level framework for quantitative analysis of COVID-19 Pandemic: mathematical modeling approaches	BRAZIL	Daniel Villela	Oswaldo Cruz Foundation	CNPq
			RUSSIA	Eduard Vladimirovich Karamov	National Medical Research Center of Phthisiopulmonology and Infectious Diseases	RFBR
			CHINA	Jingyuan Wang	Beihang University, School of Computer Science	NSFC
5	049 - NGS-BRICS	SARS-CoV-2 Network for Genomic Surveillance in Brazil, Russia, India, China and South Africa	BRAZIL	Ana Tereza Ribeiro de Vasconcelos	National Laboratory for Scientific Computation - LNCC/MCTI	CNPq
			RUSSIA	Georgii Bazykin	Skolkovo Institute of Science and Technology	RFBR
			INDIA	Arindam Maitra	National Institute of Biomedical Genomics	DBT
			CHINA	Mingkun Li	Beijing Institute of Genomics, CAS	NSFC
			SOUTH AFRICA	Tulio de Oliveira	University of KwaZulu-Natal	SAMRC
6	051 - ABRICOT	Impact of COVID-19 on clinical manifestations, diagnosis, treatment outcome and immune response for pulmonary tuberculosis	BRAZIL	Valeria Cavalcanti Rolla	National Institute of Infectious Diseases Evandro Chagas, FIOCRUZ	CNPq
			INDIA	Subash Babu	National Institute for Research in Tuberculosis, ICMR	DBT
			SOUTH AFRICA	Bavesh Kana	University of the Witwatersrand	SAMRC
7	071 - RDCEEA-S-C-2NND	Research and development and clinical effect evaluation of anti-SARS-CoV-2 new nucleoside drugs	BRAZIL	Renato Martins da Silva	Galzu Institute for Research	CNPq
			RUSSIA	Mariia Sergeeva	Smorodintsev Research Institute of Influenza	RFBR
			CHINA	Jijie Chai	Tsinghua University	NSFC

№	Registration number (BRICS2020-) and Acronym	Full Title	Country	PI	Organization	National funding organization
8	085 - ChitoTarCoV	Chitosan-based carriers and targeted delivery systems for clinically approved/ repurposed anti-SARS-CoV-2 drugs and disinfectants	BRAZIL	Thiago Moreno L. Souza	Center for Technological Development in Health, FIOCRUZ	CNPq
			RUSSIA	Andrey Vladimirovich Shibaev	Moscow State University	RFBR
			CHINA	Jun Liu	National Institution for Viral Disease Control and Prevention	NSFC
9	086 - MULTICON-19	COVID-19: Integrated multi-scale spread model and control strategies	BRAZIL	Elbert E. N. Macau	Federal University of Sao Paulo	CNPq
			RUSSIA	Mikhail Kirillin	Institute of Applied Physics RAS	RFBR
			CHINA	Ming Tang	East China Normal University	NSFC
10	101 - IMPAC19TB	Epidemiological impact and intersection of the COVID-19 and tuberculosis pandemics in Brazil, Russia, India and South Africa	BRAZIL	Anete Trajman	State University of Rio de Janeiro	CNPq
			RUSSIA	Yakov Sh. Schwartz	Novosibirsk Tuberculosis Research Institute	RFBR
			INDIA	Kuldeep S. Sachdeva	National TB Elimination Program	DBT
			SOUTH AFRICA	Anneke Hesseling	Desmond Tutu TB Centre	SAMRC
11	115 - BRICS/COVID-UFPB	Epidemiological features and geospatial evaluation of COVID-19: Correlation with comorbidities and prognostic biomarkers between SARS-CoV-2 and Mycobacterium tuberculosis	BRAZIL	Tatjana Keesen de Souza Lima	Federal University of Paraíba	CNPq
			INDIA	Sanghamitra Pati	ICMR-RMRC Bhubaneswar	DST
			SOUTH AFRICA	Uchechukwu Nwodo	University of Fort Hare	SAMRC
12	127 -	Repurposing of drugs and validation of lead compounds against main protease and RNA dependent RNA polymerase of SARS-CoV-2	BRAZIL	Lindomar Jose Pena	Centro de Pesquisas Aggeu Magalhães, FIOCRUZ	CNPq
			RUSSIA	Vladimir Potemkin	South Ural State University	RFBR
			INDIA	Dhruv Kumar	Amity University Uttar Pradesh	DST
			SOUTH AFRICA	Anil Chuturgoon	University of KwaZulu-Natal	SAMRC

V. PHOTO GALLERY

BRICS 2016-225 — BGNCDT

Boron and gadolinium nanoparticles for cancer diagnosis and therapy

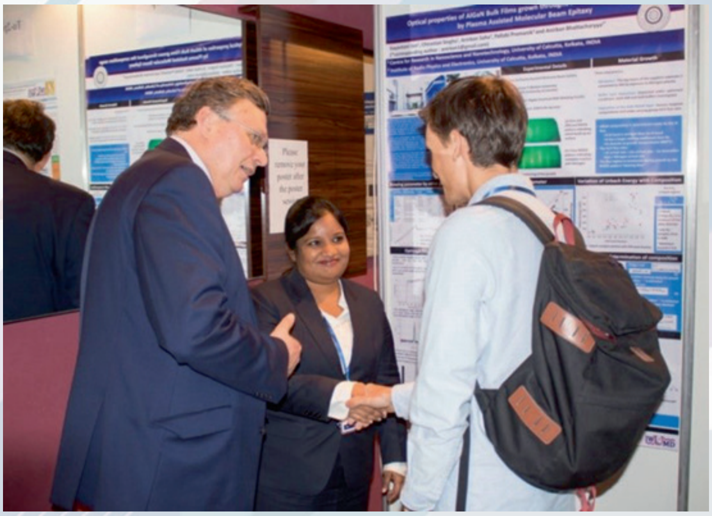
Prof. Arindam Sarkar, Invictus Oncology (India), Prof. Swadhin Mandal, Indian Institute of Science Education and Research, Prof. Zheyu Shen, Southern Medical University (China), Prof. Vladimir Bregadze, Institute of Organoelement Compounds, Russian Academy of Sciences, Kolkata, India

Work visit in Kolkata, India

BRICS 2016-383 — UV-BRIDGE

New principles and fabrication technologies of extreme 2D and 0D AlGaInN anoheterostructures for high efficiency mid-and deep-ultraviolet spontaneous and laser emitters

Discussions and friendly conversations between the participants of the Project Prof. X. Wang (Peking University) and Prof. S. Ivanov (1 photo) and Prof. T. Shubina (2 photo) (both from the Ioffe Institute) during the 4th International Workshop on UV Materials and Devices symposium (St. Petersburg, autumn 2019)

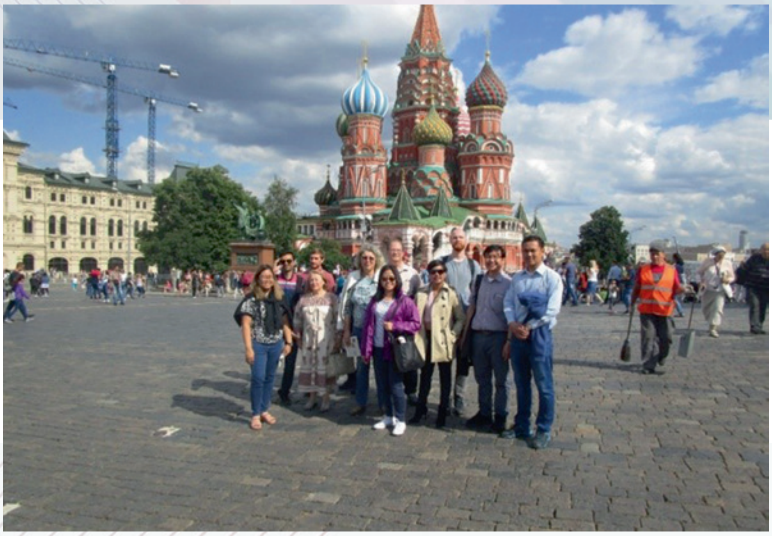


Presentation of the report by the representative of the Indian Project team Dr Syanti Sen from University of Calcutta «Optical Properties of AlGaN Bulk Films Grown throughout the Composition Range by Plasma Assisted Molecular Beam Epitaxy» prepared within framework of the Project. (St. Petersburg, autumn 2019)

BRICS2016-437 — NANOBRICSROUGH

Fundamentals for development of individual nano-objects and nano-devices bottom-up mechanical integration for quantum and non-local phenomena study, nano-electronics and nano-bio-medical diagnostics

Meetings of the BRICS consortium summit at the Center for Nanoscience and Engineering (CeNSE) of the Indian Institute of Science (ISS) in Bangalore



Members of the nanoBRICSrough consortium in Moscow

consortium teams after a session at the METANANO 2019 conference in St. Petersburg

BRICS 2016-451 — SUPERFLARES

Superflares on stars and the Sun

Participants of the 1st conference «Eruptive energy release processes on the Sun and stars» Irkutsk, Russia, October 10, 2018

Participants of the 2nd conference «Eruptive energy release processes on the Sun and stars» Weihai, China, August 8, 2019

BRICS 2017-390 — SCBCPCVD

Silicon Carbide Biomedical Coatings Prepared By Chemical Vapor Deposition

Research team

Work visit in Materials Research Centre, India

BRICS2017-418 — BRICS-BEST

BRICS technology platform for integrated bioprocessing of agricultural residues for eco-sustainable production of biofuels and by-products

2nd joint meeting of the BRICS-BEST Consortium held at the Residency Tower Hotel, Tivandrum, India on 22 November 2019

BRICS 2017-431 — LIESTER

Investigating the links between different environmental conditions and severe thunderstorms characteristics and structure for Different Earth Region

V. Gopalakrishnan, Indian Institute of Tropical Meteorology (IITM) and N.E. Veremey, Voeikov Main Geophysical Observatory (MGO) near laboratory airplane. Mumbai Airport

BRICS 2017-493 — ENVIRORGANIC

Development of efficient polymer solar cells based on non fullerene small molecules acceptors with low energy loss

Participants of sampling in the eastern part of the Vasyugansky bog, Ryam, 09.11.2018 (Rudmin M.A., Savichev O.G.)

Release of NaCl solution on the surface of the Ob bog (the hole is made in the fringe) March 19, 2021; Associate Professor of TPU Ivanov A.Yu, graduate students of TPU Zhou Dan and Yang Heng

BRICS STI Framework Programme Bulletin

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