РОСАТОМ

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ

Scientific programme of the National Centre for Physics and Mathematics

Bisikalo Dmitry

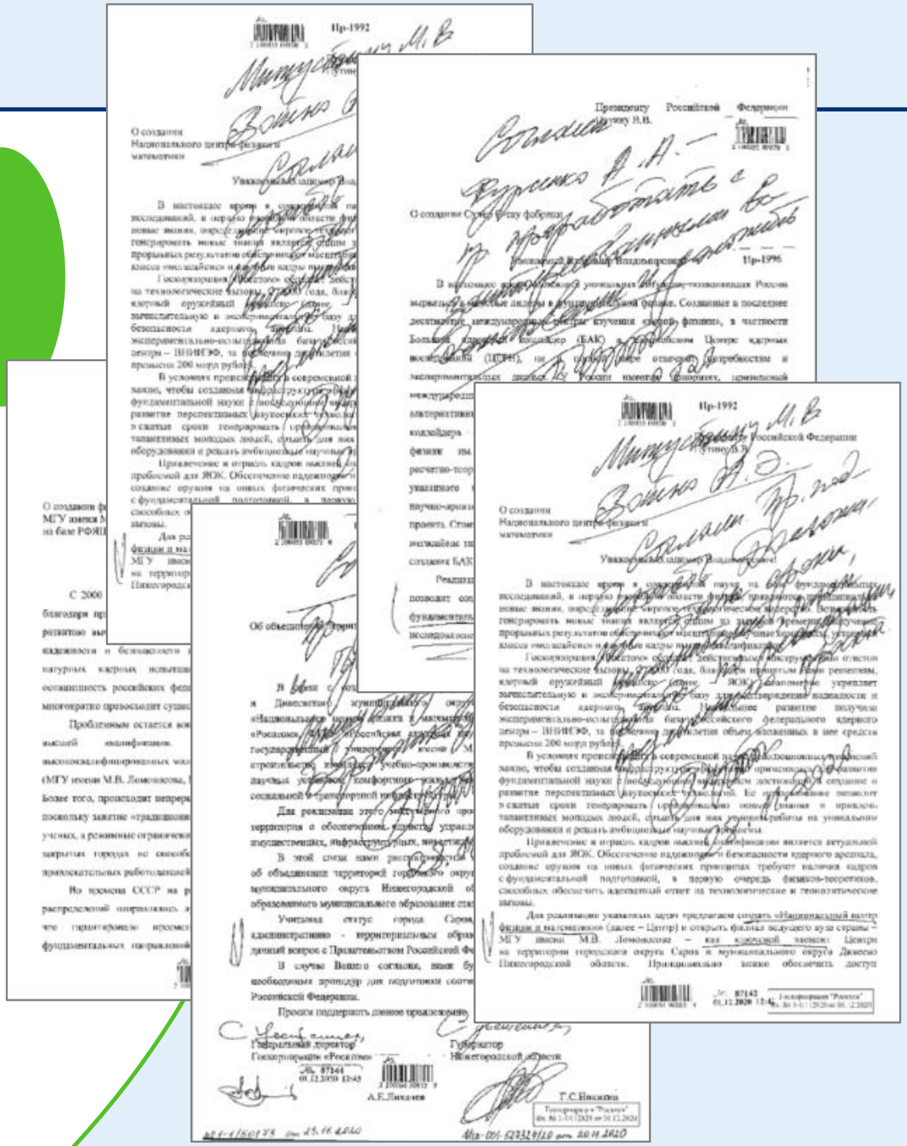
Deputy scientific director of NCPhM

NATIONAL CENTRE FOR PHYSICS AND MATHEMATICS (NCPhM)

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ

Established pursuant to the directives of the President of the Russian Federation of November 28, 2020, Nos. Пр-1992 – Пр-1996.

- Establish the NATIONAL CENTRE FOR PHYSICS AND MATHEMATICS
- Determine the utilization protocol for nuclear research facilities to promote scientific advancement
- Develop and ratify a scientific program and a development program for the Center for Physics and Mathematics
- Establish a branch of Moscow State University named after M.V. Lomonosov in Sarov
- Coordinate with relevant government departments to address the feasibility of establishing 'mega-science' class experimental facilities



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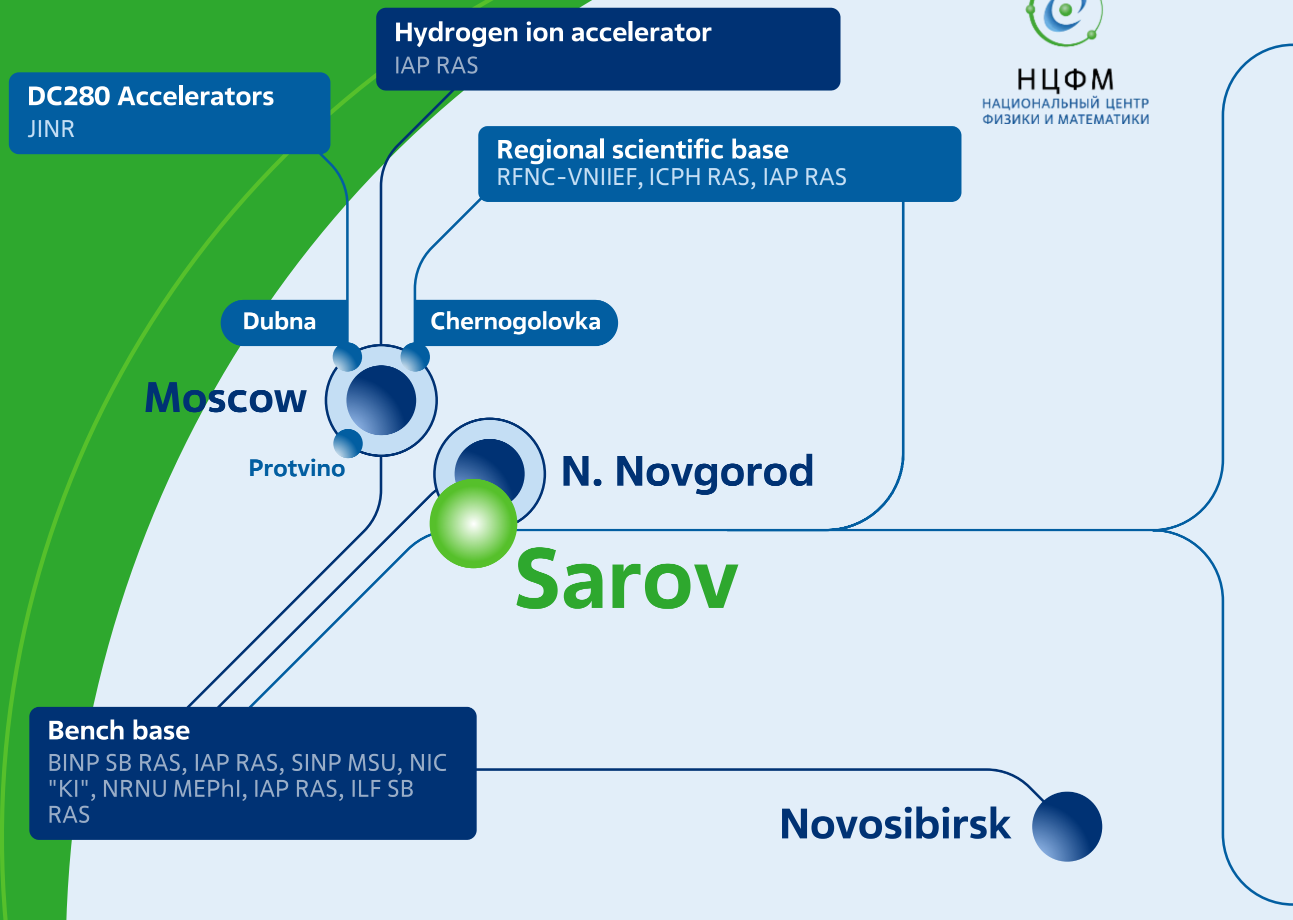

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР
ФИЗИКИ И МАТЕМАТИКИ

NATIONAL CENTRE FOR PHYSICS AND MATHEMATICS – A HUB FOR

specialists in physics, mathematics, and information technologies

THE NATIONAL CENTRE FOR PHYSICS AND MATHEMATICS is one of the flagship initiatives of the Decade of Science and Technology.

OBJECTIVES:

1. Strengthening the country's technological sovereignty and defense capabilities
2. Pioneering novel insights and advancing cutting-edge experiments to verify the theoretical frameworks of modern science
3. Fostering the development of new scientific and technological leaders
4. Strengthening the country's scientific potential

MSU Sarov – a branch of Lomonosov Moscow State University – is the educational core of the National Centre for Physics and Mathematics.

OBJECTIVES until 2030:

- Become one of the world's leading scientific centers
- Build unique "midi-science" and "megascience" class facilities

11 SCIENTIFIC DIRECTIONS of NCPhM

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР
ФИЗИКИ И МАТЕМАТИКИ

01 National Centre for Supercomputer Architecture Research

Kaliaev I.A.
Academician, RAS

Shagaliev R.M.
Corresponding Member, RAS

02 Mathematical Modeling on Exa- and Zettaflop Supercomputers

Shagaliev R.M.
Corresponding Member, RAS

Voevodin V.V.
Corresponding Member, RAS

03 Gas Dynamics and Explosion Physics

Lomonosov I.V.
Corresponding Member, RAS

Erunov S.V.
Dr. Sc. Tech.

04 High Energy Density Physics

Sergeev A.M.
Academician, RAS

Garanin S.G.
Academician, RAS

05 Particle Physics and Cosmology

Neznamov V.P.
Academician, RAS

Boos E.E.
Corresponding Member, RAS

06 Nuclear and Radiation Physics

Logachev P.V.
Academician, RAS

Zavyalov N.V.
Academician, RAS

07 Research in Strong and Superstrong Magnetic Fields

Selemir V.D.
Corresponding Member, RAS

08 Hydrogen Isotope Physics

Tkachev I.I.
Academician, RAS

Grigorenko L.V..
Corresponding Member, RAS

Yukhimchuk A.A.
Dr. Sc. Tech.

09 Artificial Intelligence and Big Data in Technical, Industrial, Natural, and Social Systems

Kaliaev I.A.
Academician, RAS

Soloviev V.P.
Corresponding Member, RAS.

10 Experimental Laboratory Astrophysics and Geophysics

Zelenyi L.M.
Academician, RAS

Mareev E.A.
Academician, RAS

Soldatov A.V.
Dr. Sc. Phys.-Math.

11 Digital Materials Science

Dub A.V.
Dr. Sc. Tech.

Dremov V.V.
Dr. Sc. Phys.-Math.

Yanilkin A.V.
Cand. Sc. Phys.-Math.

11 SCIENTIFIC DIRECTIONS of NCPhM

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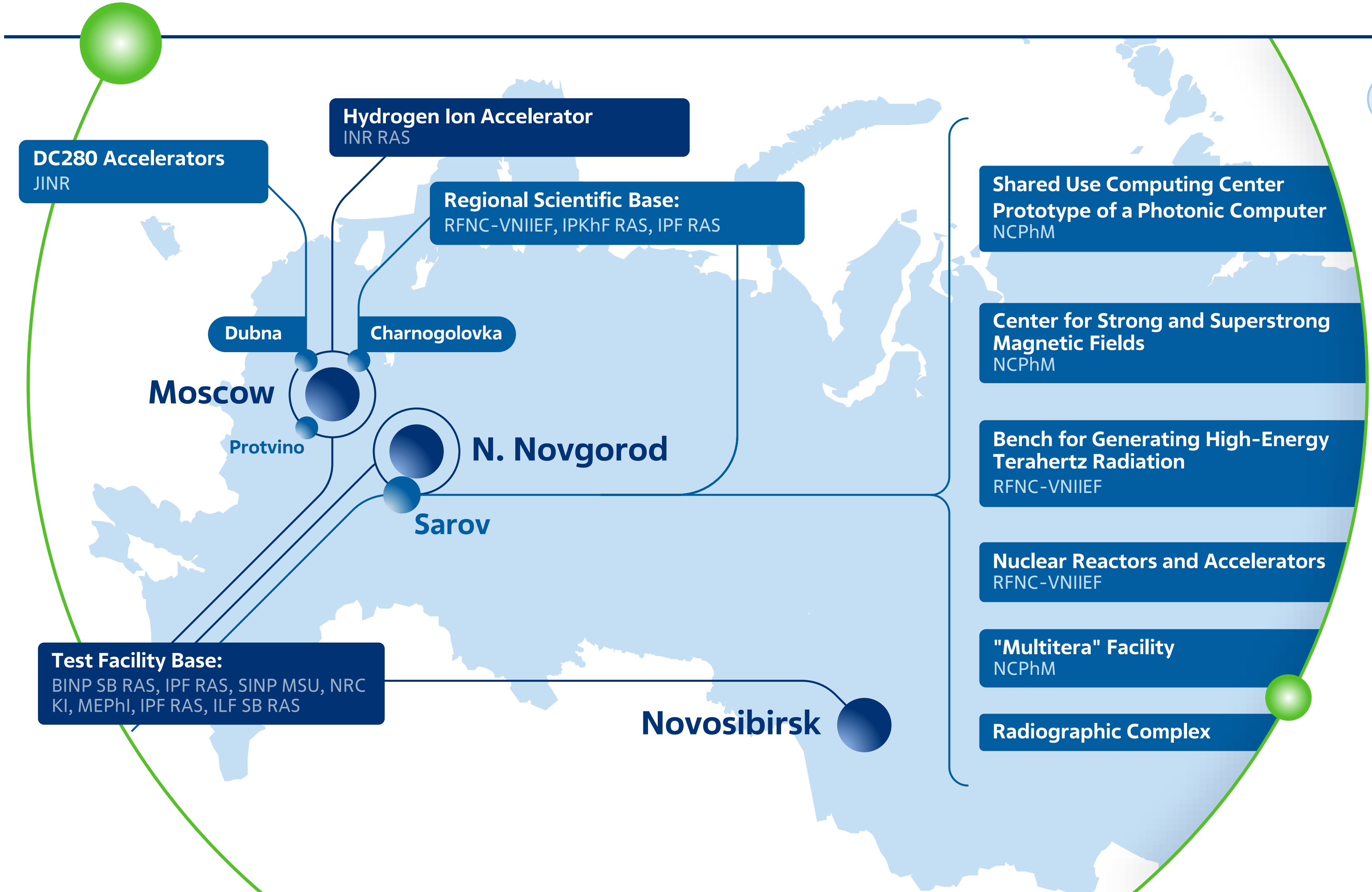
DISTRIBUTED RESEARCH INFRASTRUCTURE OF NCPhM



#scientificcooperationNCPhM

>2 000 scientists

57

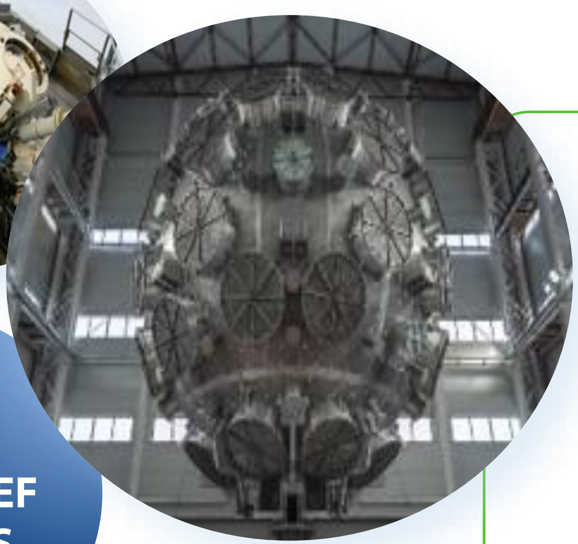
scientific organizations, institutes, and high-tech companies from across Russia

MAIN PARTICIPANTS

- State Corporation "Rosatom"
- Russian Academy of Sciences
- Lomonosov Moscow State University
- Ministry of Science and Higher Education of the Russian Federation
- NRC "Kurchatov Institute"
- Joint Institute for Nuclear Research
- RFNC-VNIIEF

SCIENTIFIC FACILITIES FOR IMPLEMENTING THE NCPhM SCIENTIFIC PROGRAMME

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ



20 RFNC-VNIIEF FACILITIES

27 RFNC-VNIITF FACILITIES

Decree of the Government of the Russian Federation dated November 17, 2021, No. 3231-r

УТВЕРЖДЕН
распоряжением Правительства
Российской Федерации
от 17 ноября 2021 г. № 3231-р

П Е Р Е Ч Е Н Ь

экспериментальных установок и вычислительных комплексов федеральных государственных унитарных предприятий, которым присвоен статус федеральной ядерной организации, в целях проведения экспериментальных исследований Национальным центром физики и математики

I. Федеральное государственное унитарное предприятие "Российский федеральный ядерный центр - Всероссийский научно-исследовательский институт экспериментальной физики"

1. Вычислительный центр коллективного пользования с суперЭВМ производительностью 200 Тфлоп/с.
2. Вычислительный центр коллективного пользования на открытой площадке "Технопарк" с суперЭВМ производительностью 40 Тфлоп/с.
3. Вычислительный центр коллективного пользования на открытой площадке "Технопарк" с суперЭВМ производительностью 1000 Тфлоп/с.
4. Ракетная катапультирующая установка.
5. Открытая аэробаллистическая трасса.
6. Аэробаллистический тир.
7. Комплекс стендов динамических испытаний.
8. Стенд высокоскоростных ударно-осколочных испытаний (широкая номенклатура калибров ствольных пороховых и легкогазовых баллистических установок).
9. Кислородно-водородный тепломеханический стенд.
10. Камера многоцелевого исследовательского комплекса МИК лазерной установки нового поколения для моделирования процессов при высоких плотностях энергии.
11. Лабораторный испытательный стенд "Каскад" для отработки взрывомагнитных генераторов.
12. Линейный индукционный ускоритель электронов ЛИУ-30.
13. Линейный резонансный ускоритель электронов ЛУ-10-20.
14. Малогабаритные импульсные ускорители электронов АРГУМЕНТ-1000, АРГУМЕНТ-М.
15. Субнаносекундный ускоритель электронов АРСА-М.
16. Генератор нейтронов НГ-11И.
17. Электростатический тандемный ускоритель ЭГП-10.
18. Электромагнитный масс-сепаратор С-2.
19. Комплекс магнитокумулятивных генераторов МК-1 для получения данных при изоэнтропическом сжатии материалов.
20. Экспериментальный электрофизический стенд НПМ-01 для моделирования генерации и распространения электромагнитных волн в плазме.

II. Федеральное государственное унитарное предприятие "Российский Федеральный Ядерный Центр - Всероссийский научно-исследовательский институт технической физики имени академика Е.И. Забабахина"

1. Микроцентр обработки данных с вычислительным комплексом производительностью до 124 Тфлопс.
2. Ускоритель электронов прямого действия ИГУР-3.5.
3. Линейный индукционный ускоритель электронов ЛИУ-2.
4. Бетатронный комплекс на базе безжелезных бетатронов БИМ234.3000М.
5. Линейный индукционный ускоритель электронов ЛИУ-20.
6. Генератор ударных волн ГНУВ.
7. Участок исследований теплофизических, физико-химических характеристик радиоактивных и делящихся материалов.
8. Участок исследований эксплуатационных характеристик изделий новой техники.
9. Участок разработки, изготовления материалов и изделий на основе радиоактивных и делящихся материалов.
10. Участок разработки методов определения состава радиоактивных и делящихся материалов.
11. Дифрактометр рентгеновский.
12. Сканирующий (атомно-силовой) базовый микроскоп.
13. Установка неразрушающего контроля паяных соединений Филин-273MF.
14. Установка БМ-П для поведения экспериментов по изучению процессов распространения и горения водородно-парогазовых смесей в модельных помещениях атомных электростанций.
15. Установка БМ-Т для определения пределов ускорения пламен в однородиых смесях.
16. Установка БМ-К для исследования ускорения пламен в стратифицированных водородных смесях.
17. Установка БМ-У, имитирующая замкнутое помещение с ключевыми объектами водородной энергетики.
18. Стенд СТРУЯ для проведения исследований струйного истечения однокомпонентных газов с высокой чистотой из сосудов высокого давления.
19. Стенд СТРУЯ-700 для определения излучательных и газодинамических характеристик струй и диффузионных пламен при аварийном истечении смесей водород-монооксид углерода-воздух.
20. Стенды БМ-Л, БМ-ЛМ1, БМ-ЛМ2 для проведения испытаний пассивных рекомбинаторов водорода и их имитаторов при атмосферных давлениях.
21. Стенд Бассейн для исследований проливов крио-водородов на твердую и водную поверхности.
22. Циклотрон СС-18/9.
23. Ускоритель электронов ЭМИР-2 модернизированный.
24. Ускоритель электронов ИПУЭ.
25. Ускоритель электронов СПРУТ (УЭЛР-7-1А).
26. Ускоритель электронов РАПИД-2.
27. Ускоритель электронов ИГУР-3.

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ

Education

EDUCATIONAL CORE OF NCPhM - MSU SAROV

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ

GOAL: TRAINING HIGHLY QUALIFIED PERSONNEL TO SOLVE NATIONAL CHALLENGES

TRAINING AREAS

2021 → 2030

- Theoretical Physics
- Extreme Electromagnetic Fields, Relativistic Plasma, and Attosecond Physics
- Nuclear Physics and Nuclear Photonics
- Computational Methods and Modeling Techniques
- Supercomputer Technologies and Fundamental Informatics

ENROLLMENT

2021 — FIRST ENROLLMENT
- **50** students

2022 — FIRST GRADUATION
- **42** master's graduates
- **50** first-year graduates
- **10** graduate students

2023
- **79** first-year graduates
- **21** graduate students

2030
- **>1 000** students
- **>100** graduate students

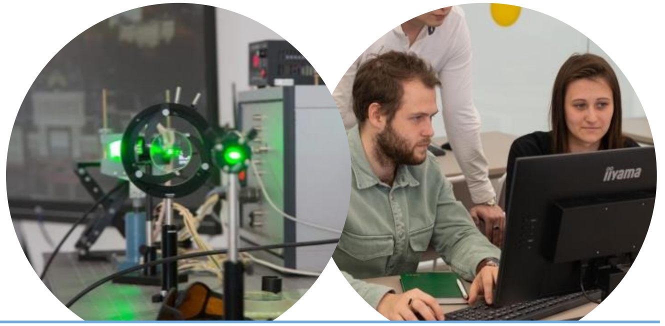
XXI CENTURY UNIVERSITY

- Unique Educational Programs
- Solving world-class scientific problems
- Participation in federal-level projects
- Conducting research on "megascience" class facilities
- Connection with the real sector of the economy

TRAINING IS CONDUCTED USING THE UNIQUE EXPERIMENTAL BASE OF NCPhM

FORMING THE NCPhM ECOSYSTEM

- Annual scientific conferences and schools for young scientists and specialists in NCPhM scientific program areas (since 2022)
- All-Russian Gathering of Student Physics and Mathematics Scientific Societies
- Deployment of student construction brigades to build NCPhM facilities (since 2023)
- Start of operation of NCPhM scientific facilities (2024-2025)
- Establishment of a world-leading science city



Professorial and Teaching Staff of the MSU Branch

A collaborative platform for leading scientists, young professionals, and students

SERGEEV A.M.

Научный руководитель
NCPhM
Academician, RAS
President of RAS
(2017-2022)

TYRTYSHNIKOV E.E.

Academician, RAS
Director IVM RAS

- **6** Academicians, RAS
- **8** Corresponding members, RAS
- **3** Professors, RAS
- **42** Doctors of science
- **68** Candidates of science

BOOS E.E.

Corresponding Member, RAS
Dr. Phys.-Math. Sci.,
Director of the Skobeltsyn Institute of Nuclear Physics, Moscow State University

SHESTAKHOV O.V.

Prof., Dr. Sc. Phys.-Math.

ABAKUMOV M.V.

Candidate of Physics and Mathematics,
Associate Professor, Faculty of Computational Mathematics and Cybernetics, MSU

KHIMCHENKO L.N.

Deputy Director of the Russian ITER Agency

KUZELEV M.V.

MSU Prof., Dr. Sc. Phys.-Math.

TCHETVERUSHKIN B.N.

Academician, RAS
Scientific Supervisor IMP RAS

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР
ФИЗИКИ И МАТЕМАТИКИ

Science

NCPhM
SCIENTIFIC PROGRAMME

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ

A pipeline of scientific and technological advancements for decades to come, including for the NWC

World-class research center

2030

2 000 Researchers and engineers

2029

2028

2027

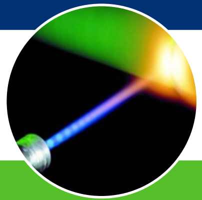
500 Researchers and engineers

2026

2025

3 megascience-class facilities

Photonic computing machine with performance up to 10^{22} operations per second



Center for Research of Extreme Light Fields based on an exawatt-power laser complex

Multifunctional accelerator complex with a Compton source of gamma radiation with record luminosity of 10^{11} photons/s

New technologies

- Photonic computing and communication systems
- X-ray lithographs and navigators, industrial lasers
- Unique diagnostic systems

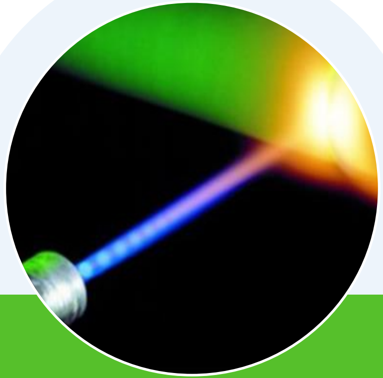
7 new midi-laboratories

1. Laboratory of Photonic Computing Devices
2. Laboratory of Supercomputer Digital Twins of Industrial Objects
3. Laboratory of Superstrong Optical Fields
4. Laboratory of Nuclear Photonics
5. Laboratory of Strong Magnetic Fields
6. Laboratory of Neuromorphic Artificial Intelligence
7. Laboratory of Modeling of Astrophysical and Geophysical Phenomena

FUNDAMENTAL SCIENCE

Flagship megascience-class projects

Photonic computing machine
with performance of 10^{21}
operations per second



Center for Research of Extreme Light Fields
based on an exawatt-power
laser complex

Multifunctional accelerator complex
with a Compton scattering
source of γ-quanta with record
luminosity of 10^{11} ph/s

PHOTONIC COMPUTING MACHINE

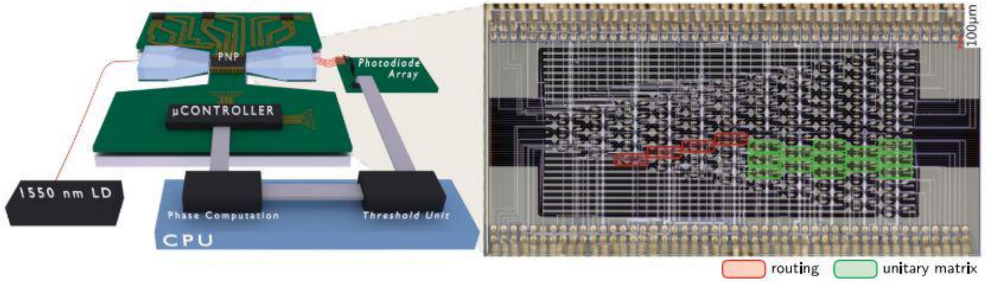
We are approaching the physical performance limits of traditional electronic microchips. **A new paradigm is needed, using a different information carrier**: **PHOTONS INSTEAD OF ELECTRONS** for data recording, transmission, and processing.

PHOTONIC COMPUTERS

Optical component base: classical (non-quantum) states of light.

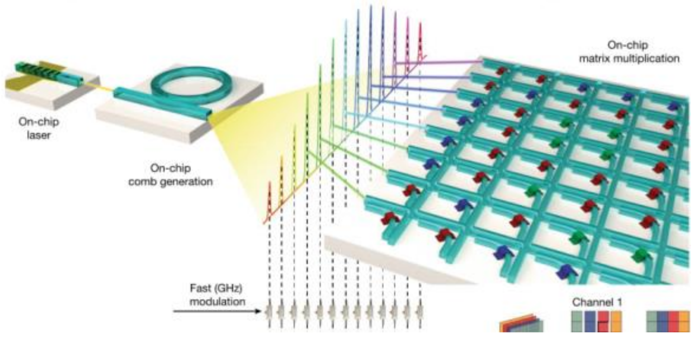
Objectives:

- Development of optical chips.
- Parallel computations for different wavelengths, polarizations, or optical pulses.
- Optoelectronic interfaces.



SPECIALIZED COMPUTING DEVICES WITH HYBRID ARCHITECTURE

Solving specific problems in the field of numerical modeling of complex systems, artificial intelligence, and big data processing (e.g., matrix multiplication and matrix-vector multiplication on an optical processor).



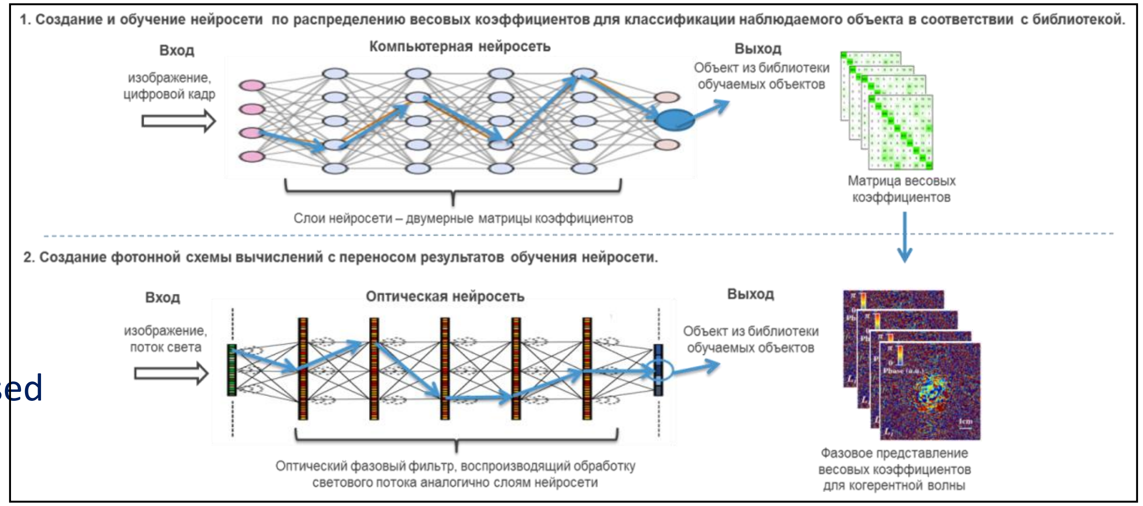
A hybrid optoelectronic computer based on optical coprocessors with a performance of up to 10^{21} OPS (operations per second) will be created.

HYBRID ELECTRONIC-PHOTONIC COMPUTING SYSTEM – Current Status

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ

Goals and Expected Results

- Development of a computing system with a performance of up to 1 ZettaOPS using the component base available within the Russian Federation.
- Solving applied problems for the defense industry and civilian sectors.
- Achieving technological sovereignty of the Russian Federation in the field of supercomputers of ultra-high performance.



Status, groundwork

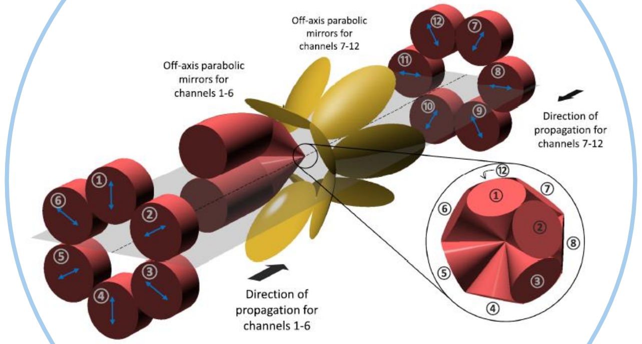
- A demonstration model of an optical arithmetic-logic unit has been created based on standard laboratory components.
- An information processing speed of $5.3 \cdot 10^{15}$ bits/s has been achieved.
- A collaboration (**Institute of Semiconductor Physics SB RAS, NIIIS**) has been established, and work has begun on developing domestic spatial light modulators based on liquid crystals.
- Research is being conducted for the development of a photonic coprocessor based on the principles of integrated photonics (**NIFTIS NNGU, MIPT, Sedakov NIIIS, JSC Mikron, IFM RAS**).
- The first photonic integrated circuits (PICs) have been developed and manufactured based on 90 nm (Mikron) and 350 nm (NIIIS) topological design.
- The project was reported at 2 meetings of the Bureau of the Division of Physical Sciences of the Russian Academy of Sciences (RAS).
- An extended meeting of the Bureau of the RAS Division of Physical Sciences (Minutes No. 85 dated November 14, 2024) decided to support the project and recommend it for submission to the President of the Russian Federation (in execution of clause 4 of the list of instructions dated October 19, 2023, No. Pr-2113).

June 2, 2025: Russian Prime Minister M.V. Mishustin visited Sarov, where he met with students of MSU Sarov and held a meeting on the development of high-performance computing for the advancement of artificial intelligence and big data processing.

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ

EXAWATT LASER XCELS
(eXawatt Center for Extreme Light Studies)

- Vacuum ionization and generation of particles and antiparticles
- Generation of superdense ultrarelativistic electron-positron plasma and gamma radiation of ultra-high brightness
- Directed sources of gamma radiation with photon energies in the GeV range
- Generation of attosecond pulses with fields approaching the Schwinger limit
- Study of the spatio-temporal structure of vacuum



Intra-atomic field holding an electron in a hydrogen atom

Existing facilities

XCELS

Field holding electron-positron pairs in the quantum vacuum (Schwinger limit)

10^{14} | 10^{16} | 10^{18} | 10^{20} | 10^{22} | 10^{24} | 10^{26} | 10^{28} | 10^{30} W/cm²

Peak intensity

EXAWATT LASER XCELS – Current status

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ

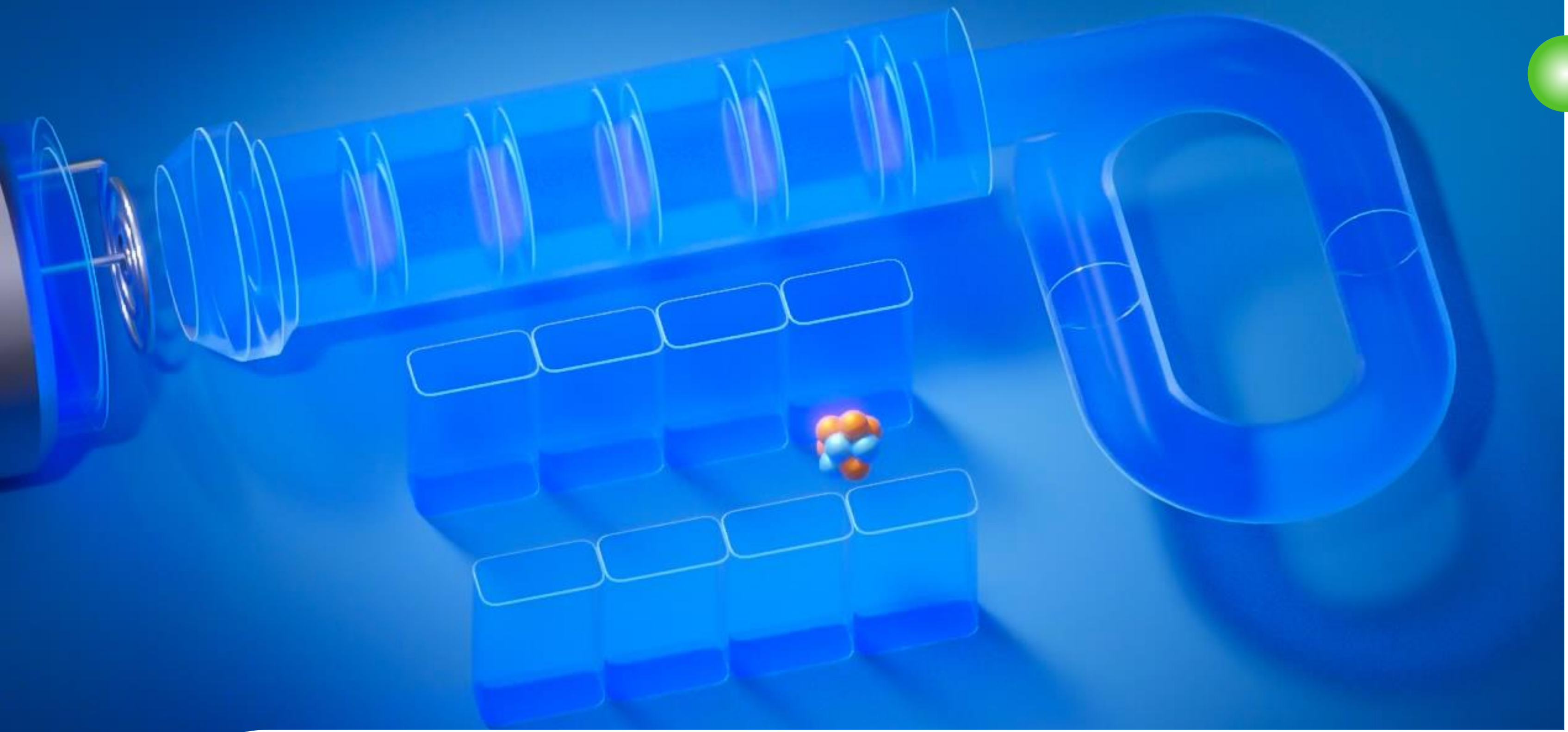
Status, groundwork

- A scientific program and a roadmap for the creation of the facility have been developed.
- It is the successor to the EXAWATT LASER XCELS (eXawatt Center for Extreme Light Studies) project, which in 2011 was approved by the Government Commission on High Technology and Innovation following an international review, being one of six mega-science class projects.
- An extended meeting of the Bureau of the RAS Division of Physical Sciences (Minutes No. 85 dated November 14, 2024) decided to support the project "Center for the Study of Extreme Light Fields based on an Exawatt-Class Laser Complex" and recommend it for submission to the President of the Russian Federation (in execution of clause 4 of the list of instructions dated October 19, 2023, No. Pr-2113).
- On January 16, 2024, the details of the scientific program and the project's design were discussed at an Extended Meeting of the Bureau of the RAS Division of Physical Sciences, initiated by 2 of its Scientific Councils.
- Preliminary theoretical and experimental studies have confirmed the feasibility of meeting the XCELS-100 project requirements using the UFL-2M megajoule-class facility as a base.
- A unique feature of IKI and XCELS is the synergy of their combined use. The establishment and commissioning of a direct channel for the interaction of 2 GeV electrons and femtosecond laser radiation from the XCELS intermediate amplifier (1 PW, 20 fs) will, for the first time, enable the study of the spatiotemporal structure of the vacuum and unknown phenomena at the intersection of high-energy physics and physics of superstrong fields.

At the initial stage (until 2030), a testbed for a dual-channel facility with a peak power of 100 PW will be created based on the available infrastructure.

MULTIFUNCTIONAL ACCELERATOR COMPLEX WITH A COMPTON SCATTERING RADIATION SOURCE

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ



Nuclear Photonics

**(by analogy with atomic optics)
aims to study nuclear matter using a quasi-monochromatic source of gamma quanta with an energy of 5-300 MeV. This includes research in::**

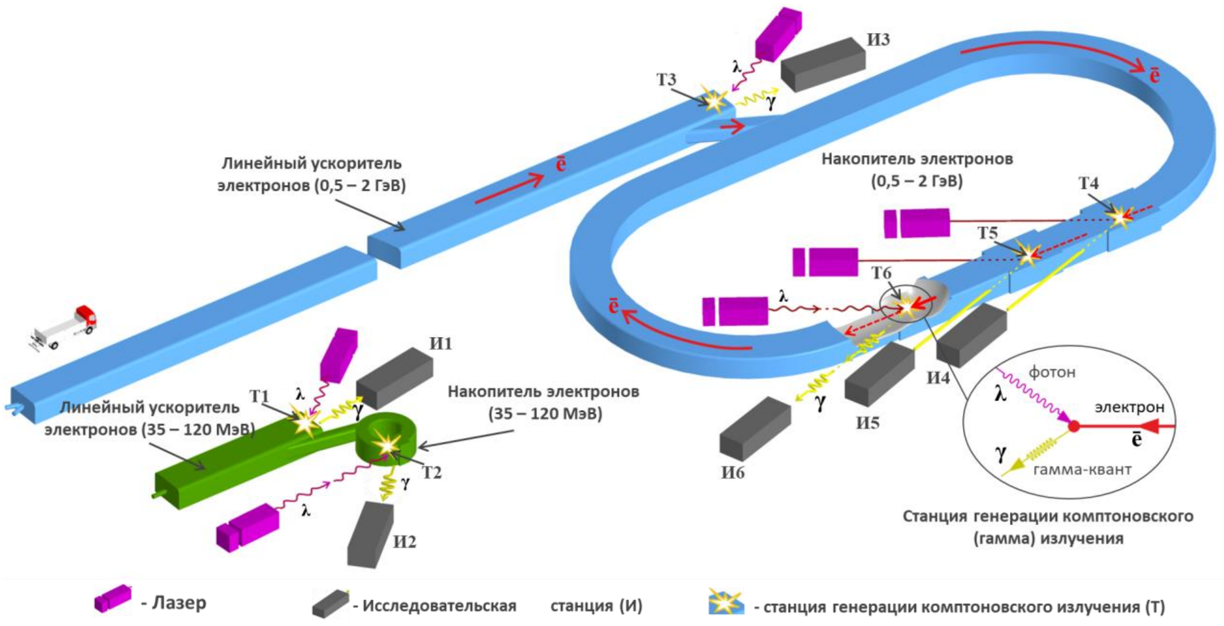
- Physics of nuclear isomers
- Nuclear fission upon photoexcitation
- Structure of the giant dipole nuclear resonance
- Exotic modes of nuclear excitation and the structure of the "pygmy" resonance
- Photodisintegration of nuclei and nucleosynthesis in nuclear astrophysics

The creation of a source of quasi-monochromatic gamma radiation with record brightness in the 0.02-200 MeV energy range, a flux of up to 10^{11} photons per second, and an angular divergence on the order of 1 mrad will enable a qualitative leap in photonuclear physics.

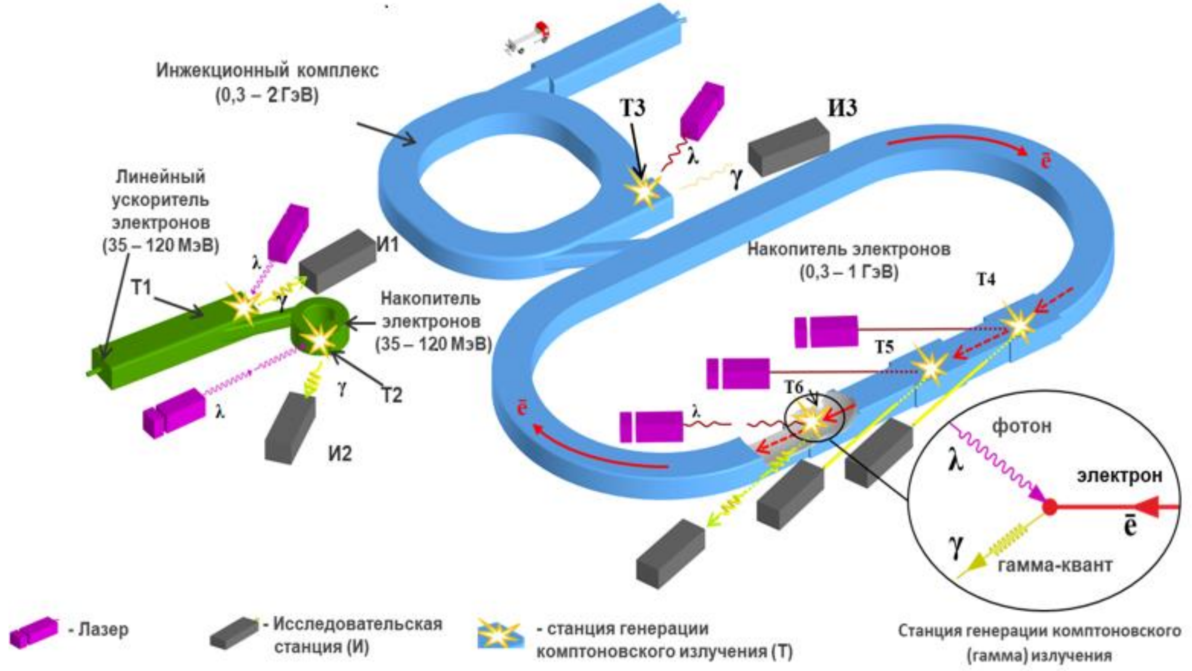
A small-scale storage ring will enable the creation of a Compton scattering source with a quantum energy of 10-100 keV for various diagnostic applications.

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ

Characteristics of the IKI complex	Value
Compton radiation energy range, MeV	0,02 - 200
Maximum flux, photon/s	10^{11}
Maximum monochromaticity, % FWHM	0,2 - 1,5
Quantum energy step, %	0,25



IKI Complex Design (2023)



Optimized IKI Complex Design (2025)

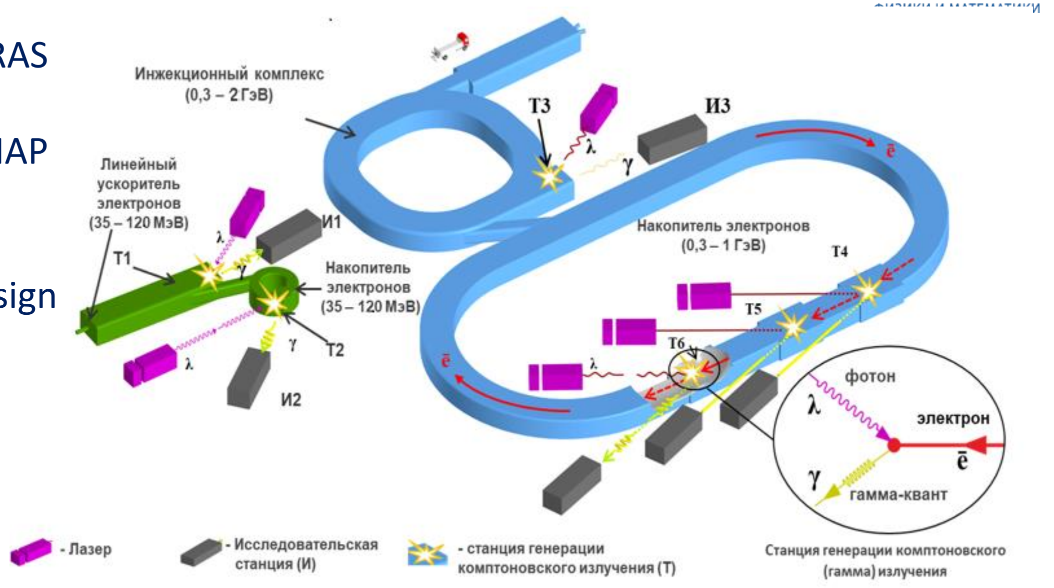
To optimize costs and significantly reduce the manufacturing timeline of the complex, a new design has been developed. Instead of a linear electron accelerator with a maximum energy of 2 GeV, an injection complex has been proposed. This complex consists of a linear electron accelerator with a maximum energy of 200 MeV and an intermediate cyclic electron accelerator with an energy range of 0.2-2 GeV.

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР

Status, groundwork

- A scientific program has been developed and published (71 authors) in the journal PHYSMAT (2023, Volume 1, No. 3–4, pp. 121–259).
- A collaboration has been established (Budker Institute of Nuclear Physics SB RAS (BINP SB RAS), RFNC-VNIIEF (Russian Federal Nuclear Center - All-Russian Research Institute of Experimental Physics), Institute of Applied Physics RAS (IAP RAS), Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University (SINP MSU), and others).
- To optimize costs and significantly reduce manufacturing timelines, a new design for the complex has been created (utilizing an injection complex instead of a linear accelerator).
- Design documentation has been prepared, including:

- A technical specification for the design,
- A preliminary description of the future facility, encompassing:
- Proposals for its location (Sarov),
- Key technical specifications and components (functional block diagram),
- A work plan (roadmap) for the creation of the IKI complex for the period 2025-2031.



OPTIMIZED IKI Complex Design (2025)

Characteristics of the IKI complex	Value
Compton radiation energy range, MeV	0,02 – 200
Maximum flux, photon/s	10^{11}
Maximum monochromaticity, % FWHM	0,2 - 1,5
Quantum energy step, %	0,25

IF
funding is allocated from the federal budget starting in 2026,

THEN

by 2028-2029, the 1st stage of the facility will be completed, comprising a 200 MeV accelerator, a 2 GeV booster synchrotron, and the main elements of a 0.5-2 GeV storage ring. This will enable the start of the facility's trial operation beginning in 2029;

by 2031, the construction of the entire complex will be finalized.

A small ring (comprising a 35-120 MeV accelerator and a 35-120 MeV storage ring) will be built by 2028, allowing experiments to commence starting in 2029.

What tasks are upcoming?

7 MIDI-SCIENCE CLASS LABORATORIES

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ

01 Laboratory of Photonic Computing Devices

Kaliaev I.A.
Academician, RAS
Shagaliev R.M.
Corresponding Member, RAS

02 Laboratory of Supercomputer Digital Twins of Industrial Objects

Shagaliev R.M.
Corresponding Member, RAS
Voevodin V.V.
Corresponding Member, RAS

03 Laboratory of Superstrong Optical Fields

Sergeev A.M.
Academician, RAS
Garanin S.G.
Academician, RAS

04 Laboratory of Nuclear Photonics

Logachev P.V.
Academician, RAS
Zavyalov N.V.
Academician, RAS

"Roadmaps" for the 7 midi-laboratories
have been submitted to the Government of the Russian Federation to identify budgetary funding sources.

05 Laboratory of Strong Magnetic Fields

Selemir V.D.
Corresponding Member, RAS

06 Laboratory of Neuromorphic Artificial Intelligence

Kaliaev I.A.
Academician, RAS
Solovyev V.P.
Corresponding Member, RAS

07 Laboratory of Modeling of Astrophysical and Geophysical Phenomena

Zelenyi L.M.
Academician, RAS
Mareev E.A.
Academician, RAS
Soldatov A.V.
Dr. Sci. (Phys.-Math.)

1. Laboratory of Photonic Computing Devices

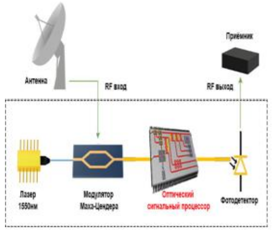
НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР
ФИЗИКИ И МАТЕМАТИКИ

Goal: Development of domestic high-performance tools based on new physical principles of photonics, offering an alternative to those used in modern microelectronics.

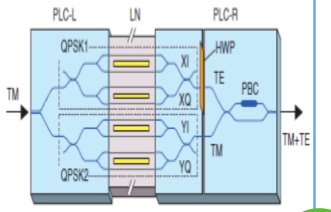
The project for creating demonstration prototypes of a new type of computing units includes:

- **The development and fabrication of analog photonic processor prototypes based on Photonic Integrated Circuits (PICs).**
- **Analysis and research into the potential application of optical components in Digital Optical Computers (DOCs). Fabrication of optical computing component prototypes based on planar waveguides and photonic crystals.**
- **Development of architectural, structural, and functional schematics, along with design and manufacturing technologies for DOC components. Fabrication of prototype individual optical computing units.**
- **Simulation of DOC operation. Experimental testing and debugging of DOC prototypes.**

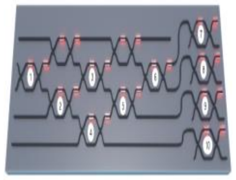
Photonic Component Base (PCB) for:
Phased Array Antennas: Anti-jamming protection, fast beam steering.



PCB for Fiber-Optic Communication:
Speeds >100 Gb/s.



PCB for Optical Processors:
Performance $>10^{21}$ operations/second



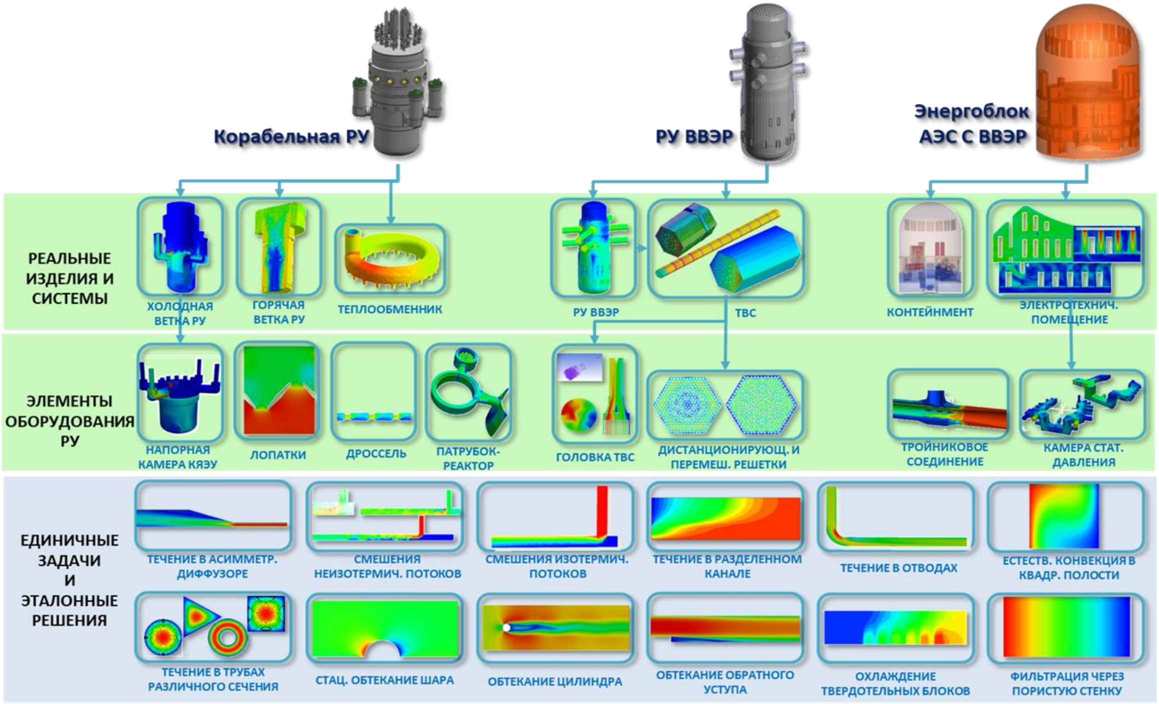
Solving specialized tasks in the field of numerical modeling of complex systems, artificial intelligence, and big data processing (e.g., matrix multiplication using an optical processor).

Key technological outcome: A photonic component base for computing, high-speed telecommunications, and radio-photonics.

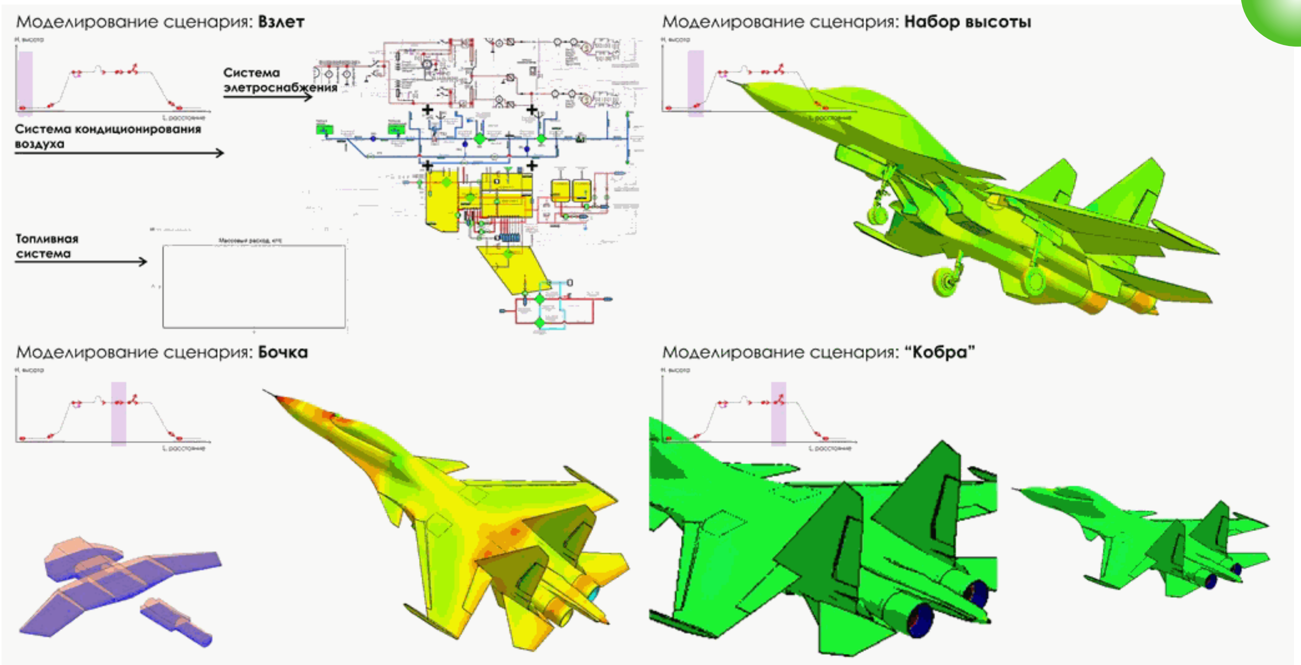
2. Laboratory of Supercomputer Digital Twins of Industrial Objects

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР
ФИЗИКИ И МАТЕМАТИКИ

Goal: development and implementation of a complex of domestic mathematical numerical methods, models, and algorithms for full-scale modeling of physical processes in industrial objects



Twin of a low-power reactor



Creation of a unified model of a combat maneuverable aircraft's operation

Key technological result: digital twins for the interests of aircraft manufacturing, nuclear, and rocket-space industries to substantiate the characteristics of industrial objects under normal and critical operating conditions

3. Laboratory of Superstrong Optical Fields "Multitera"

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР
ФИЗИКИ И МАТЕМАТИКИ

Goal: Creation of a research complex based on pulsed-periodic laser facilities with femtosecond and nanosecond pulse duration and energy of ~1 J and ~1 kJ

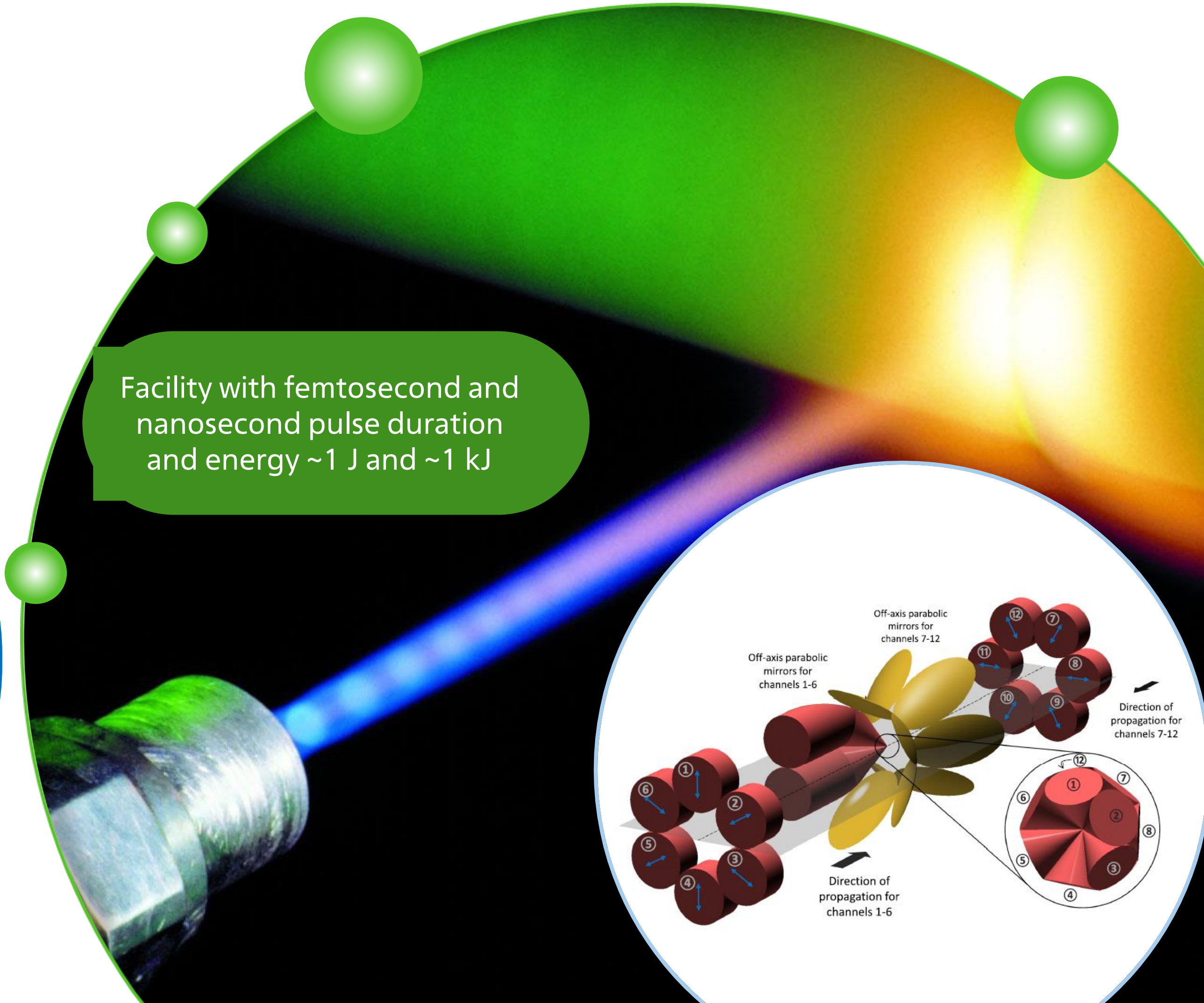
The "Multitera" complex will implement 4 sectors for conducting research in the areas of:

- terahertz photonics,
- attosecond physics,
- research on laser-plasma methods of charged particle acceleration and instabilities in laser plasma,
- modeling of astrophysical phenomena.

Results in the field of applied research:

Application of terahertz radiation for:

- remote sensing of objects;
- non-destructive testing of components;
- vision and communication systems;
- electron acceleration.
- Potential use cases for laser-electron FLASH radiotherapy, etc.



4. Laboratory of Nuclear Photonics

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ

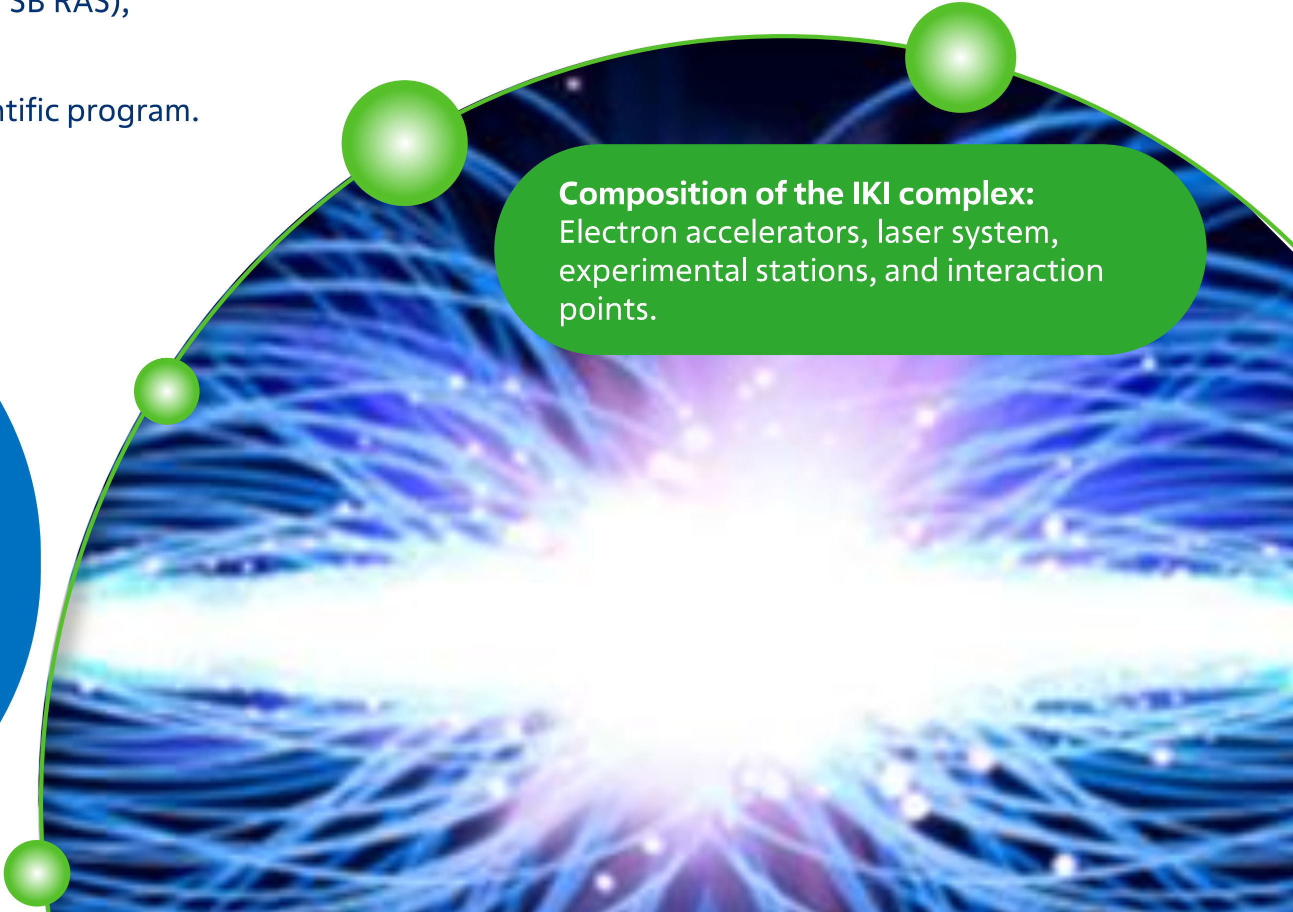
Goal: calculation-experimental substantiation of the complex based on an inverse Compton scattering source and development of experimental methodologies for executing the IKI scientific program

Research directions:

- Computational studies to optimize the parameters of electron accelerators, laser systems, and electron-laser interaction points;
- Development and testing of experimental methods, bench testing and validation of technical solutions at existing RFNC-VNIIEF facilities and accelerator complexes of the Budker Institute of Nuclear Physics SB RAS (BINP SB RAS);
- Development of beamlines, including those with dynamic loading devices;
- Development of measurement systems for conducting research under the IKI scientific program.

Results in the field of applied research:

- Experimental data for building and verifying models of combustion and detonation of explosives, enabling the development of novel explosives with enhanced safety;
- Experimental data on the mechanisms and kinetics of phase transitions in materials under extreme conditions, facilitating the creation of new advanced materials;
- New detection systems for studies of atomic nucleus structure, nuclear isomerism, and highly sensitive methods for analyzing the elemental and isotopic composition of samples with large mass thickness at a new level;
- New and precision data on photonuclear reaction cross-sections for nuclear waste "incineration" methods.



Composition of the IKI complex: Electron accelerators, laser system, experimental stations, and interaction points.

5. Laboratory of Strong Magnetic Fields

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ

Goal: Creation of a world-class experimental facility for researching the properties of matter in strong magnetic fields.

The establishment of the **Laboratory of Strong Magnetic Fields** will enable systematic studies of material properties in strong (**up to 75 T**) and superstrong (**up to 600 T**) magnetic fields, as well as under ultra-high (**up to 5 Mbar**) pressures. This research will support the development of new semiconductor, magnetic, and superconducting materials, address other fundamental challenges, and facilitate applied research and development.

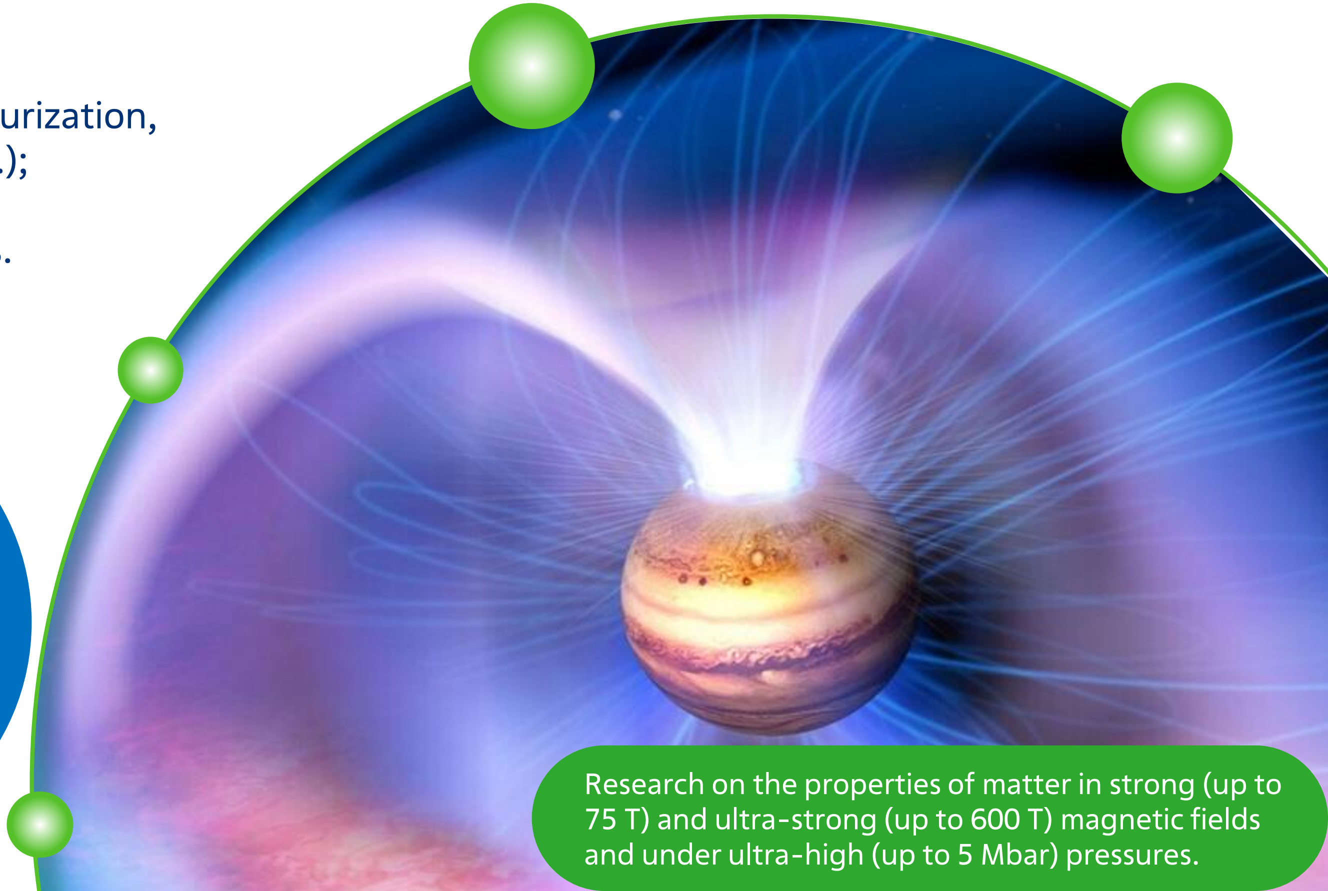
The outcomes of the Laboratory's work will include:

Materials for micro- and nanoelectronics with novel properties (miniaturization, high efficiency, reduced power consumption, radiation resistance, etc.);

Planetary models to explain the origin of their intrinsic magnetic fields.

Results in the field of applied research:

- Establishment of a technological pipeline for studying material properties in strong and ultra-strong magnetic fields (facilities, measurement techniques, cryogenic equipment);
- Investigation of new semiconductor, magnetic, and superconducting materials, as well as nanostructures based on them.



Research on the properties of matter in strong (up to 75 T) and ultra-strong (up to 600 T) magnetic fields and under ultra-high (up to 5 Mbar) pressures.

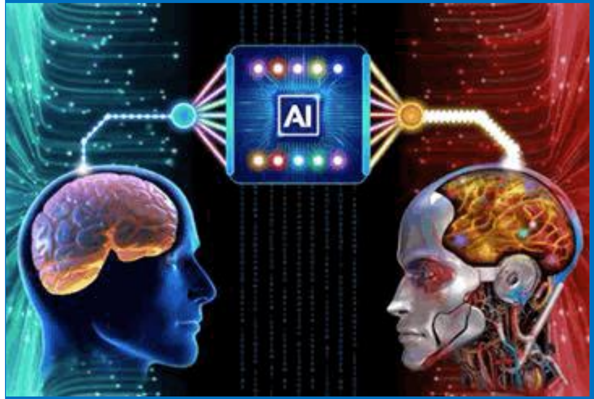
6. Neuromorphic Artificial Intelligence Laboratory

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР ФИЗИКИ И МАТЕМАТИКИ

Goal: Creation of a component base and prototypes of next-generation information-computing systems; development of new artificial intelligence technologies.

3 sectors:

1. "Neuromorphic computing systems"
2. "Multi-agent and predictive modeling with decision support"
3. Artificial intelligence technologies for preventive medicine and healthcare"



Application areas:

- Solving computer vision tasks
- Controlling robotic systems
- Analog signal processing in sensors

Competitive advantages:

- Pioneering development of new AI hardware
- Focus on neurohybrid systems (neurointerfaces)

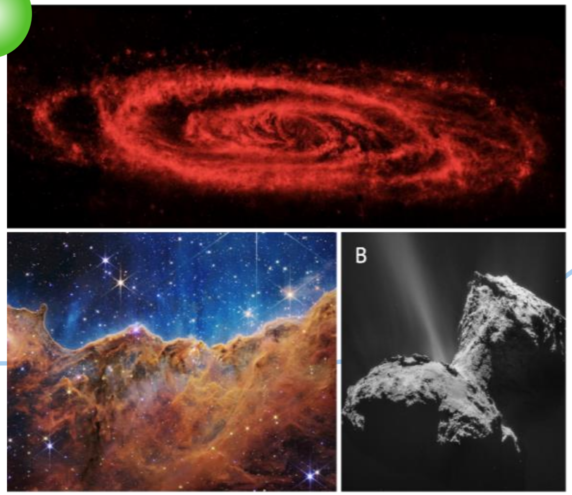
7. Laboratory of Modeling of Astrophysical and Geophysical Phenomena

НЦФМ
НАЦИОНАЛЬНЫЙ ЦЕНТР
ФИЗИКИ И МАТЕМАТИКИ

Goal: studying the influence of various space factors on living organisms and technological systems of spacecraft

Laboratory structure:

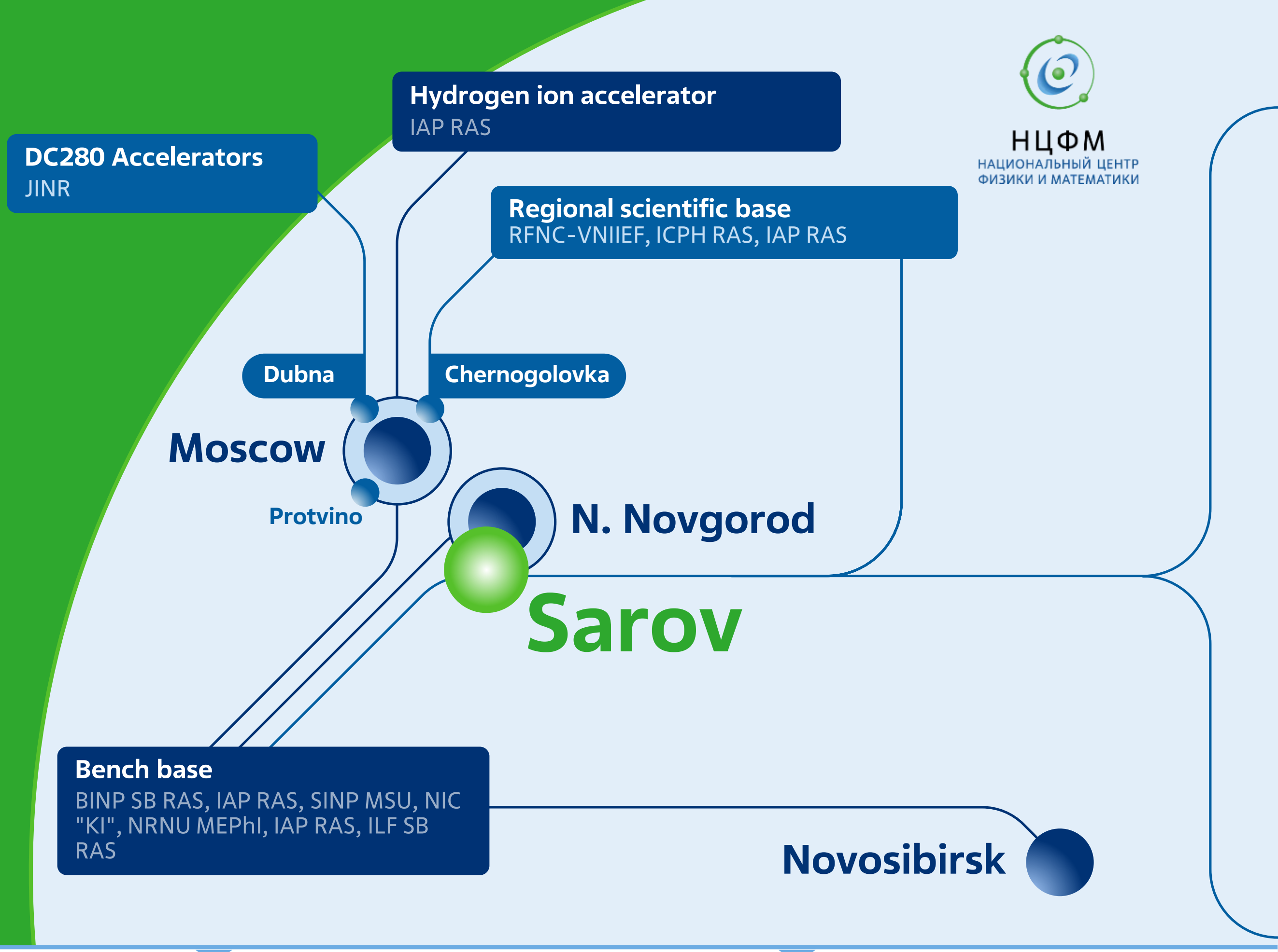
- Sector of Dusty Plasma Physics
- Sector of Biophysics
- Sector of Experimental Plasma Physics



Areas of application for the results:

- The Roscosmos Lunar Program (in the development and implementation of projects for landing vehicles on the Moon and small bodies of the Solar System);
- Manned spaceflight (creation of closed-loop ecosystems);
- Searching for effective strategies to mitigate the adverse effects of astro- and geophysical factors, including space weather, for the inhabitants of Earth.

Thank you for your attention!



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