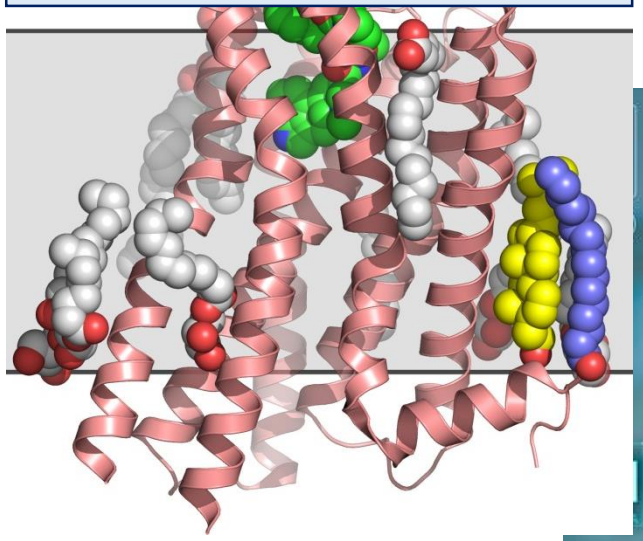
First phase SKIF beamlines design

I. Rakshun

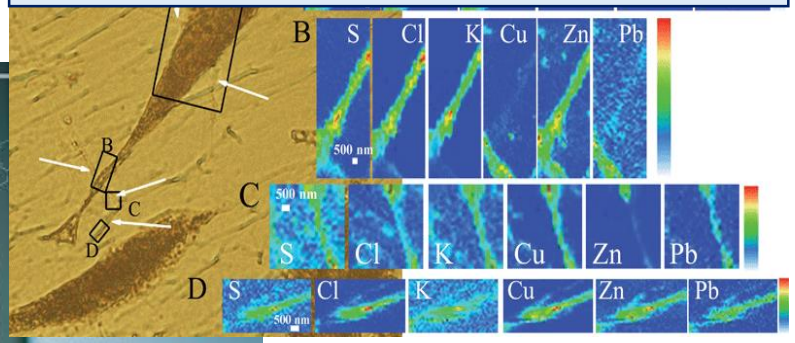
Y. Zubavichus, S. Rashchenko, B. Zakharov, I. Rubtsov, A. Saraev, K. Kuper, A. Bukhtiyarov, Z. Vinokurov, I. Venediktova, A. Trebushinin, M. Chernetskaya, F. Darin, A. Nikolenko, B. Goldenberg, O. Tereshchenko, S. Arkhipov, E. Boldyreva, etc…

NOVEL MEDICINE TECHNOLOGIES

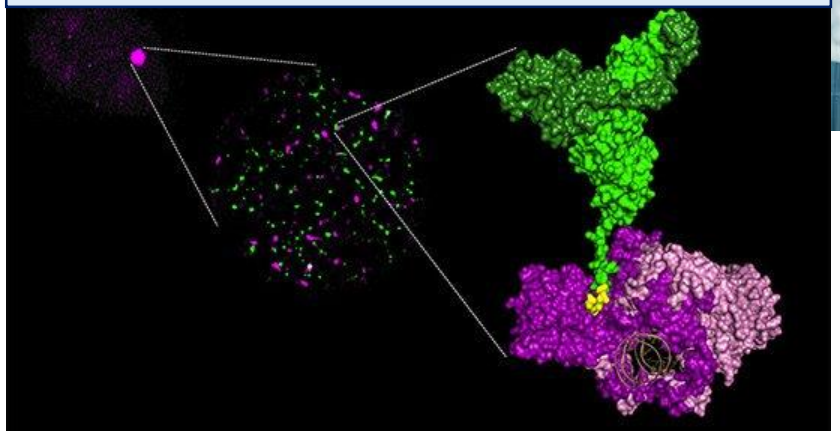
NOVEL TARGETED DRUGS



ULTRASENSITIVE TOXICOLOGY



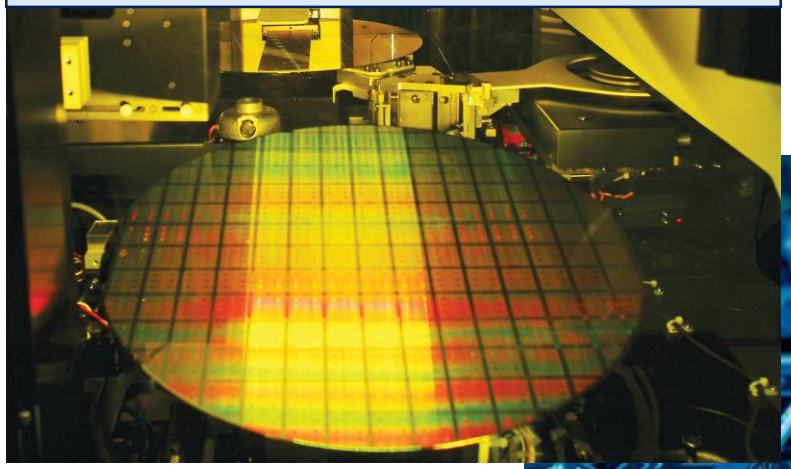
TEST SYSTEMS (ANTIBODY-ANTIGEN)



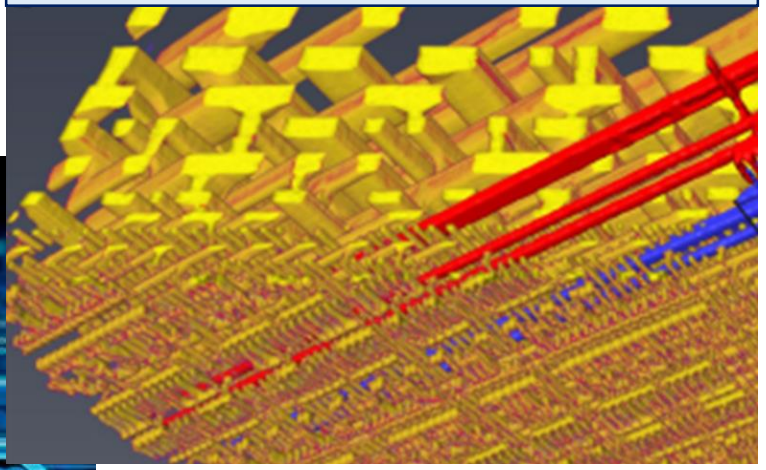
BIOCOMPATIBLE IMPLANTS

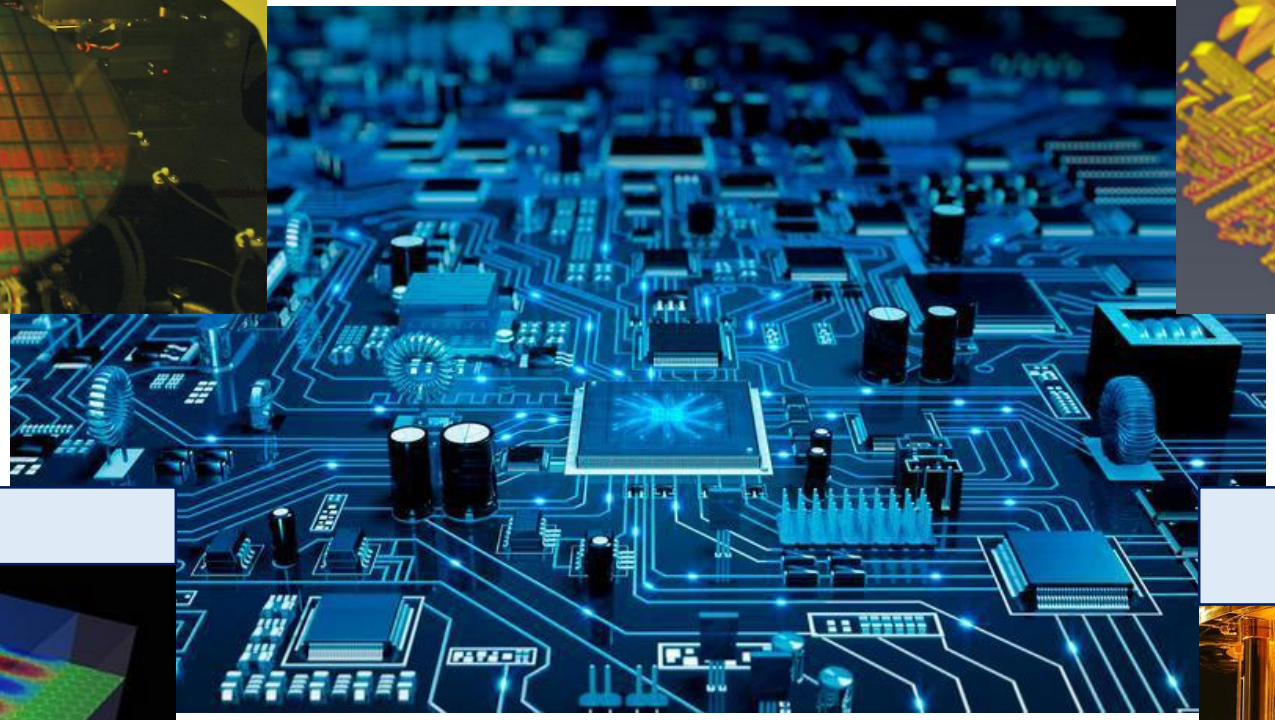
NOVEL NANOELECTRONICS

ENERGY EFFECTIVE TECHNOLOGIES

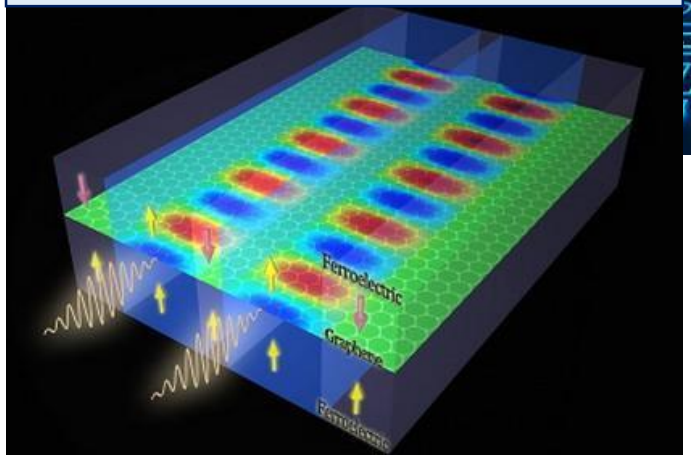


UNDOCUMENTED FEATURES





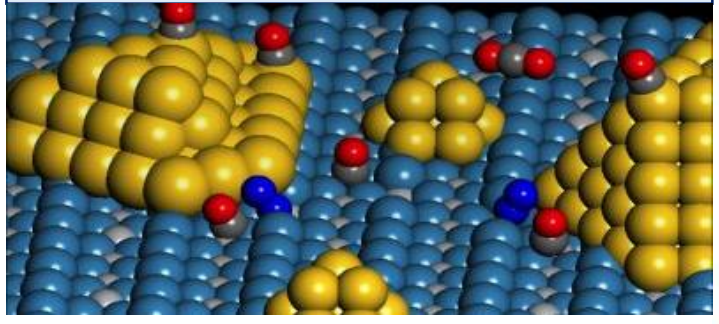
SPINTRONICS



QUANTUM COMPUTERS

"GREEN" CHEMISTRY

STABLE HIGHLY SELECTIVE CATALYSTS



ZERO-WASTE TECHNOLOGIES

СОЗДАНИЕ В ОМСКЕ ПЕРВОГО ПРОИЗВОДСТВА ВЫСОКОТЕХНОЛОГИЧНЫХ КАТАЛИЗАТОРОВ ДЛЯ НПЗ

ГАЗПРОМ НЕФТЬ | СТРЕМИМСЯ К БОЛЬШЕМУ!

2014 Старт совместных исследовательских работ с российскими научными институтами

2015 Получение статуса национального проекта

2016 Выпуск высокотехнологичных катализаторов каткрекинга и первого отечественного катализатора гидроочистки

2018 Разработка высокоактивных катализаторов для выпуска бензина

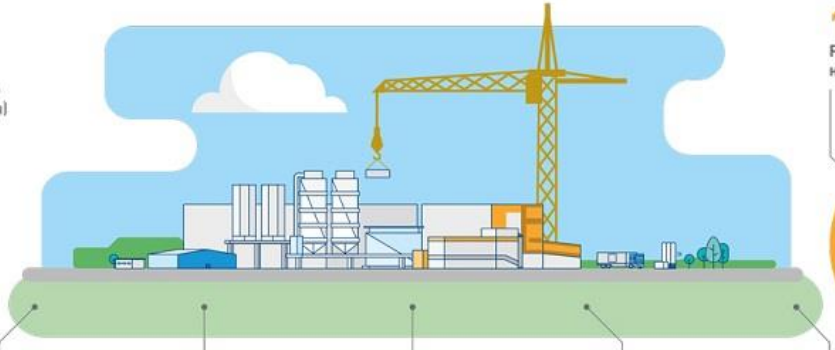
2019 Старт строительства завода

2021 Ввод в эксплуатацию

Зависимость российской нефтепереработки от импорта катализаторов

28% Российские производители (катализаторы предыдущего технологического поколения)

72% Импорт



Обеспечение независимости российской переработки от импорта катализаторов

100% Российские катализаторы нового поколения

Российские технологии производства катализаторов

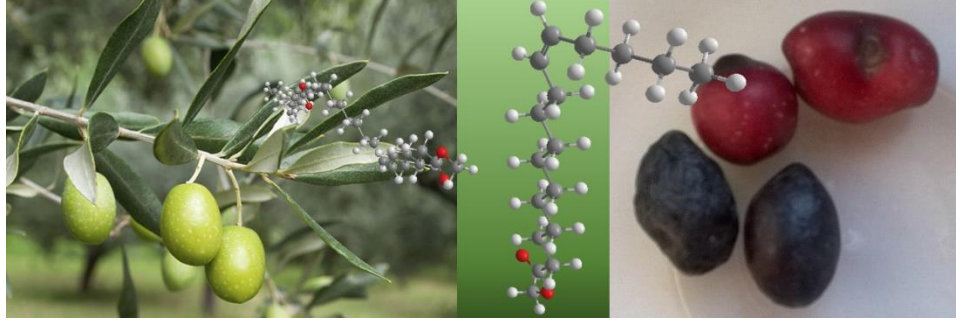
Конкурентное качество по сравнению с лучшими зарубежными брендами катализаторов

Правительством РФ проекту присвоен статус национального

Плановый объем производства:

300 высокотехнологичных рабочих мест

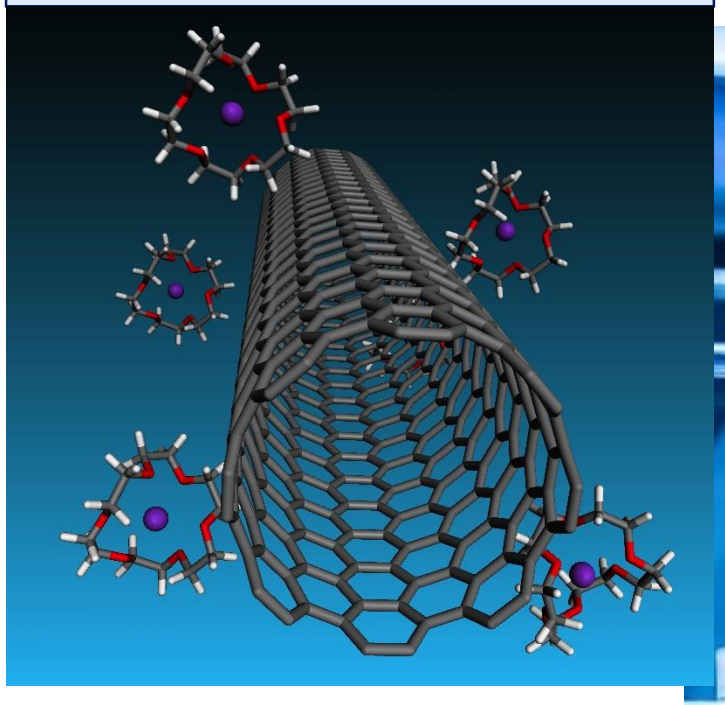
TARGETED BIOSYNTHESYS



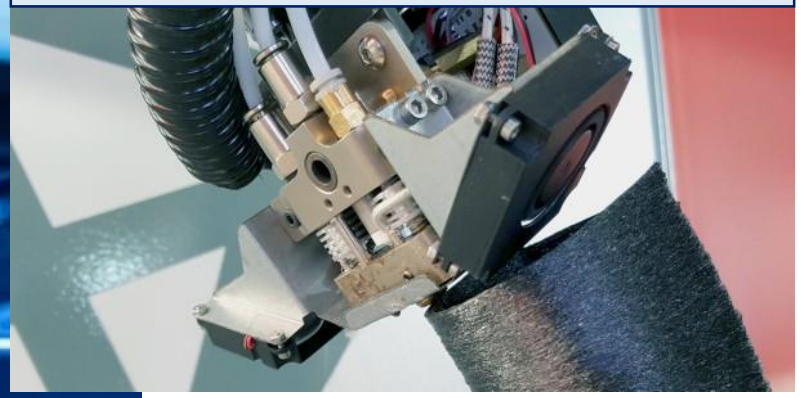
DEEP OIL PROCESSING

ADDITIVE MANUFACTURING

LIGHT COMPOSITES

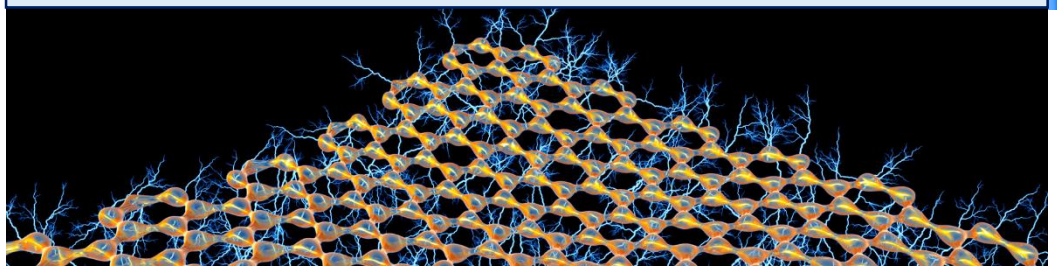


THERMAL 3D PRINTING



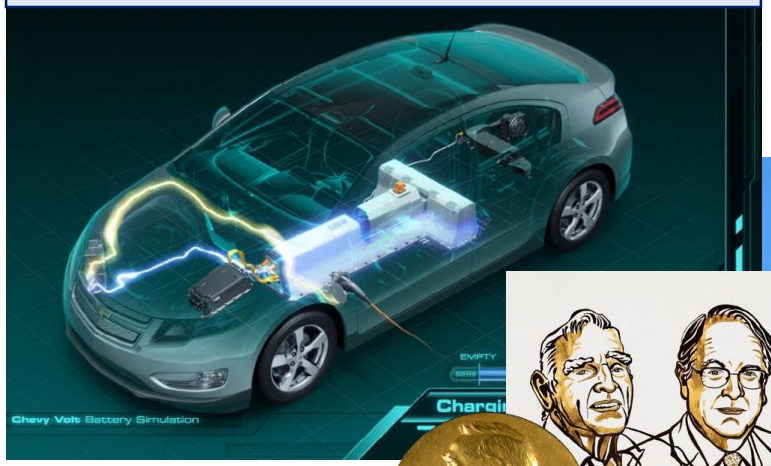
LAM

NOVEL PHOTOPOLYMERS



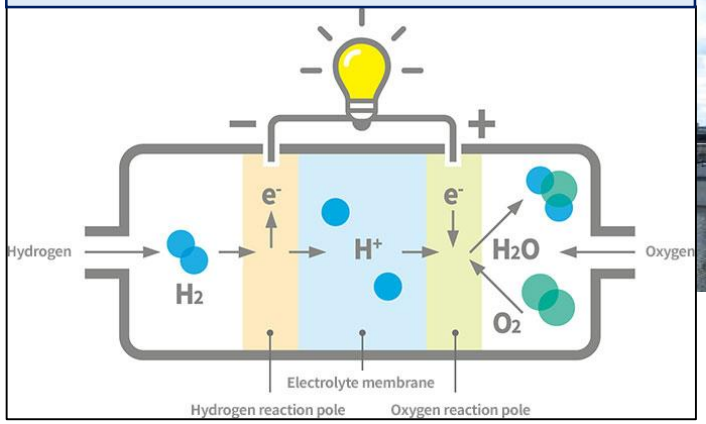
ENERGETICS OF FUTURE

NOVEL ACCUMULATORS



HYDROGEN ENERGETICS

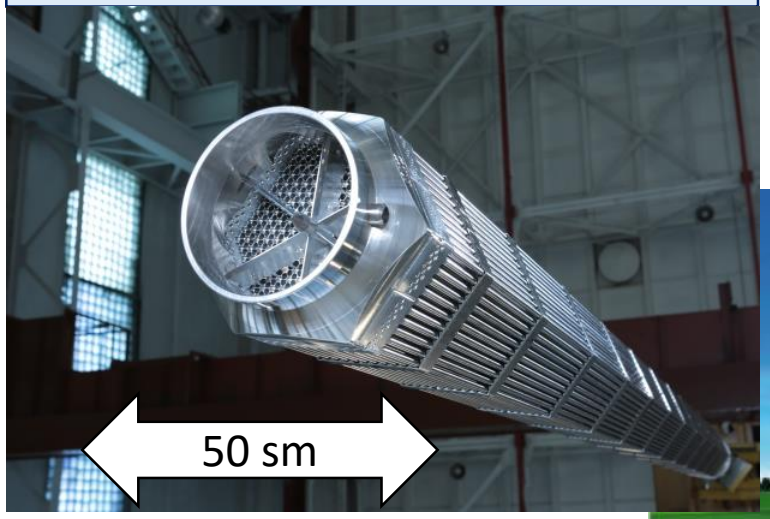
FUEL CELLS



SUPERCONDUCTIVITY

NUCLEAR TECHNOLOGY

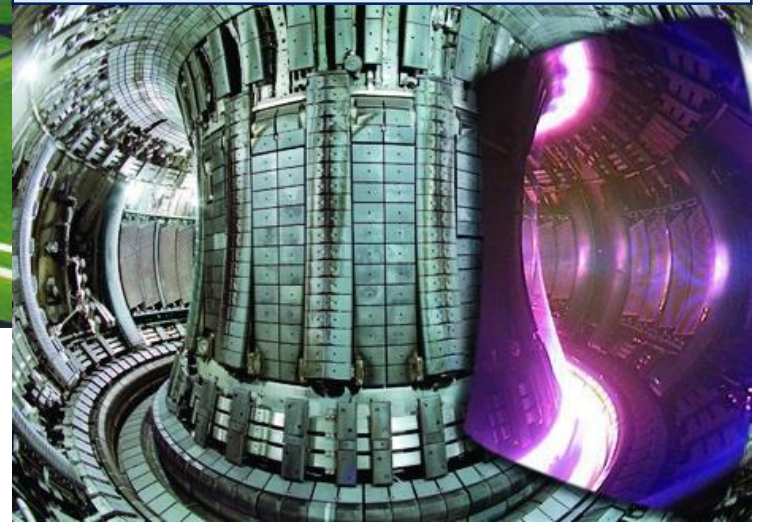
TOLERANT FUEL



REACTOR MATERIALS

WASTE IMMOBILIZATION

NUCLEAR SYNTHESIS

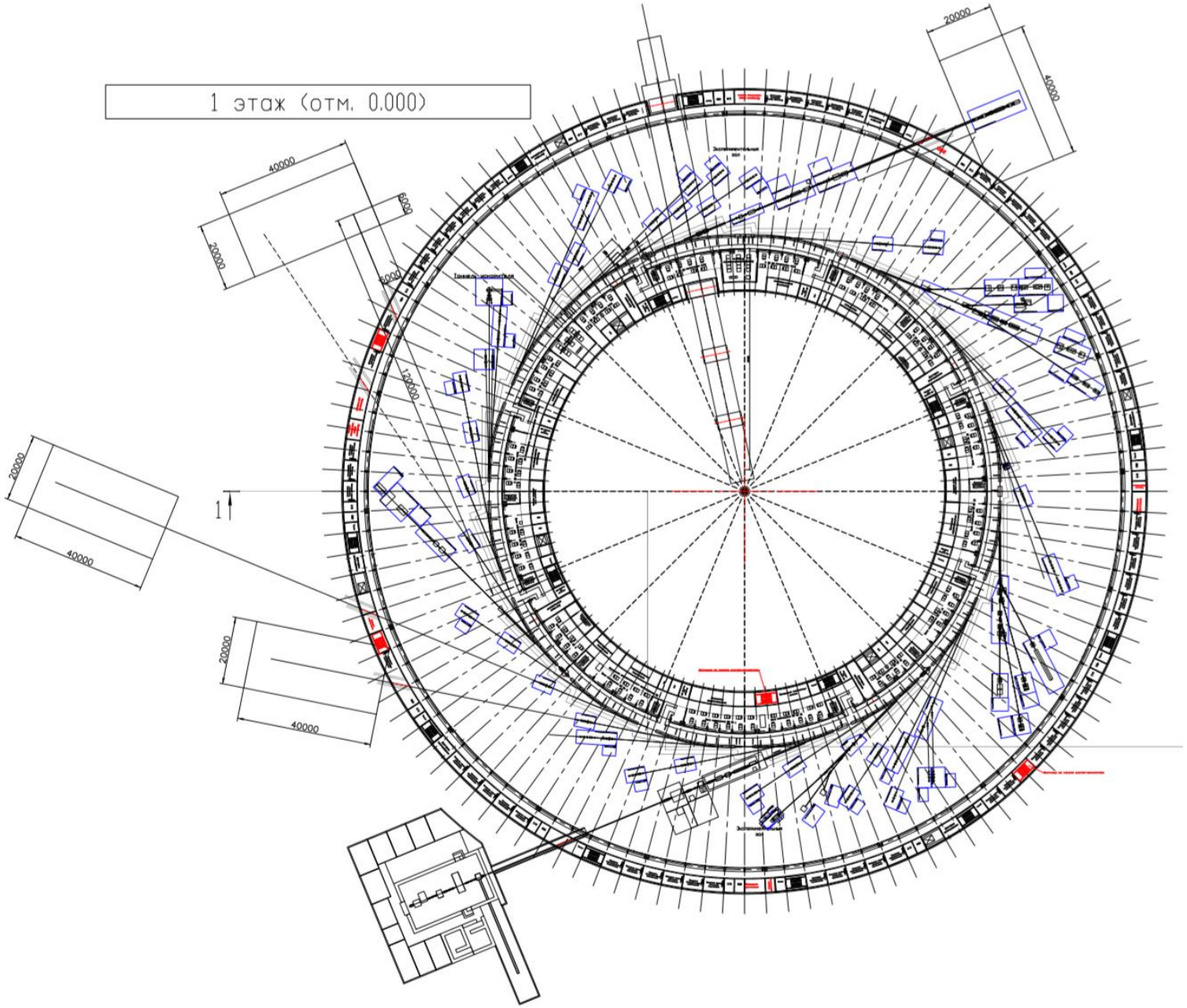


Scientific case

First-phase beamlines address the most important tasks

- **1-1 "Microfocus"**
  - nm-resolution tomography of nanoelectronics
  - structural biology
- **1-2 "Structural analysis"**
  - biocompatible composites
  - *in situ* materials science
- **1-3 "Fast processes"**
  - thermonuclear reactor materials
  - extreme conditions physics
- **1-4 "XAFS spectroscopy"**
  - *operando* study of novel catalysts
  - local order studies
- **1-5 "Hard x-ray diagnostics"**
  - laser additive manufacturing
  - X-ray tomography and large field bioimaging
- **1-6 "Electronic structure"**
  - novel catalysts
  - quantum electronics

Beamlines



Straight section (6 m) :	13
Straight section (3 m):	1
Bending magnet (0,5 T):	8
Bending magnet (2 T) :	8
	=30
End-stations	=50

Number of beamlines

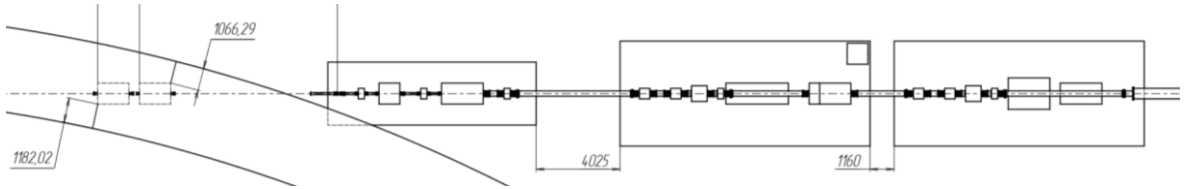
at the end of 2023:	1
at the end of 2024:	5
	=6

Total cost:

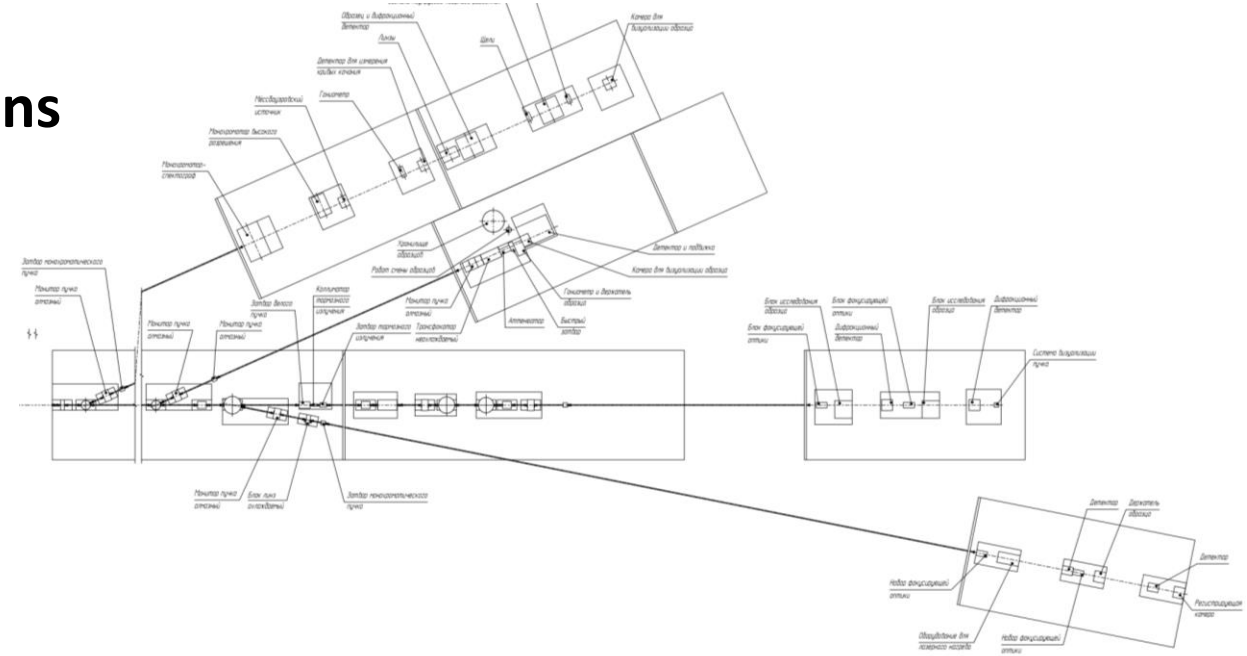
75 millions euro

Optimization ID-based beamlines

- a drawback of SRF “SKIF” compactness is limited number of ID straight sections (14)
- around 100 research techniques are currently available for SR users with many of them requiring highly-specialized end-stations and beamlines
- to maximize user access to research techniques the following measures can be taken given a single ID straight section:
  - **“train-like” configuration of end-stations**
  - **beam multiplexing**
  - canted undulators



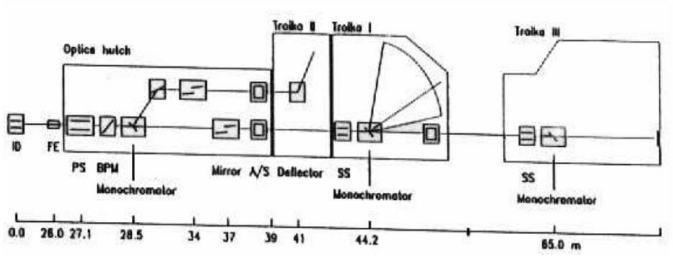
“train-like” configuration
instrumentations are used sequentially



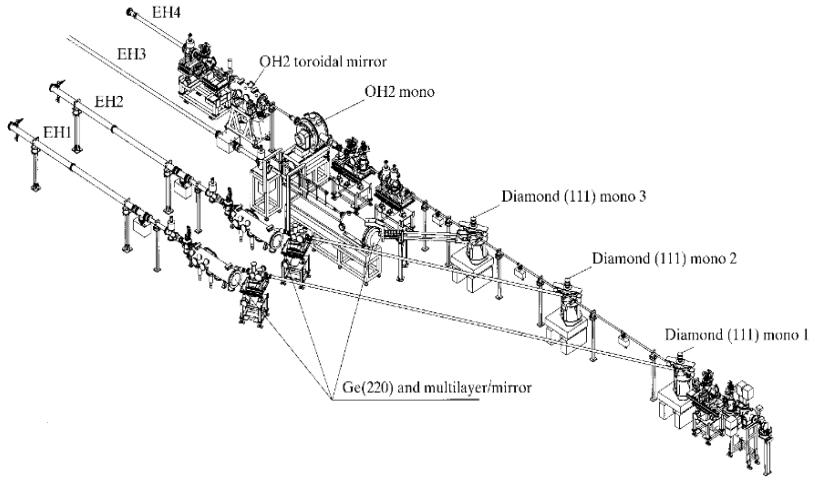
beam multiplexing
instrumentations are used in parallel

Beam multiplexing

Past



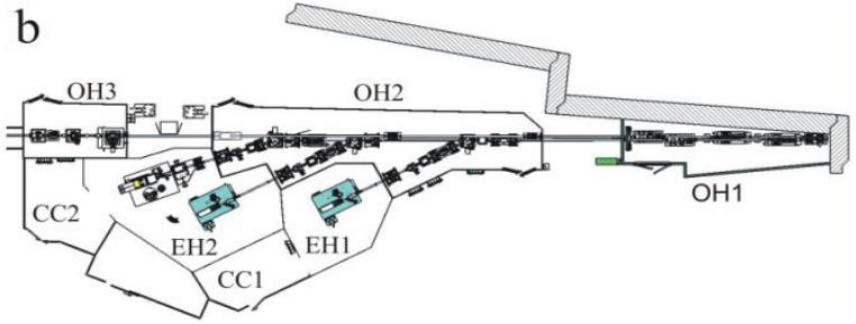
TROIKA (ESRF, 1994)



QUADRIGA (ESRF, 1998)

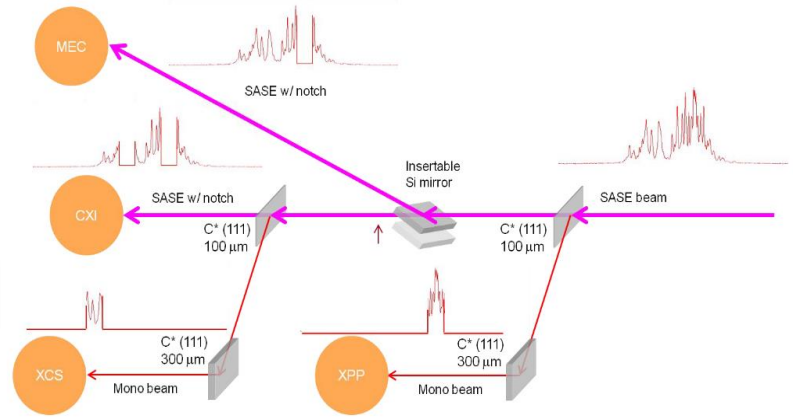
Present

LS-CAT (APS, 2007)

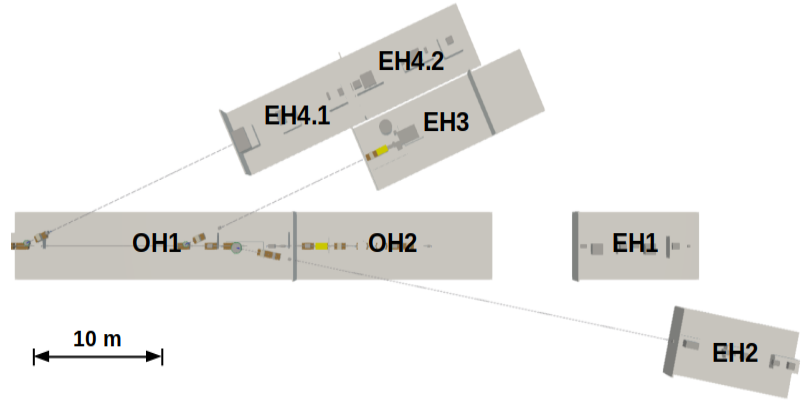


MASSIF (ESRF, 2015)

Coherent future



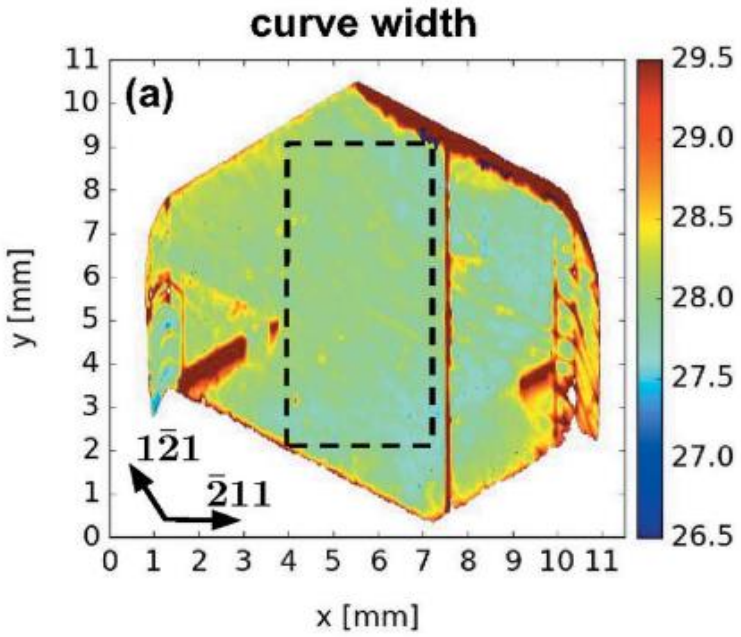
XFELs (LCLS, EuXFEL...)



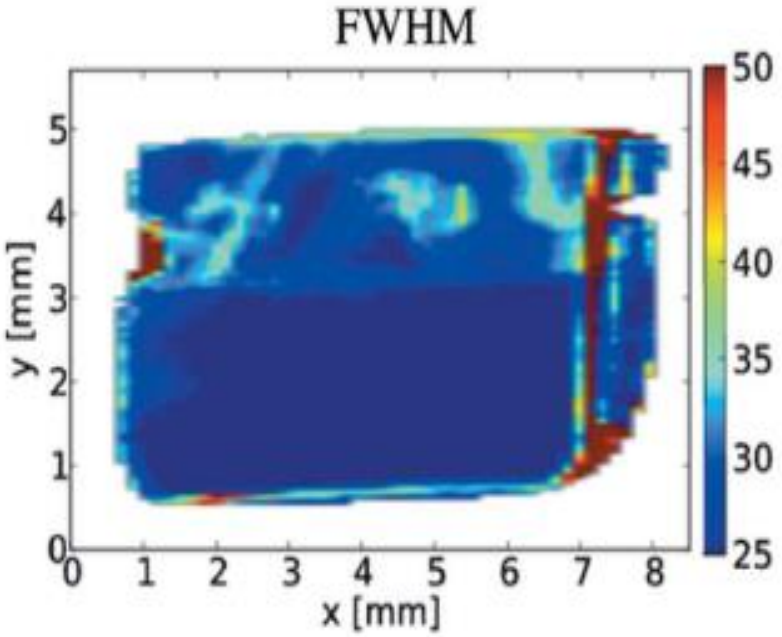
SKIF

Beam multiplexing

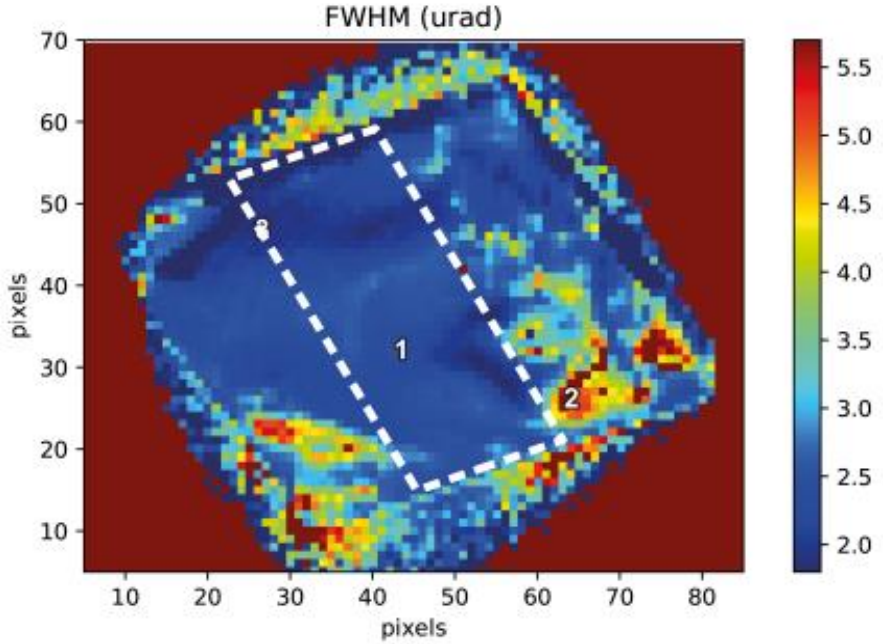
Wavefront preserving diamond beamsplitters



New Diamond Technology LLC,
Saint-Petersburg, Russia
(Stoupin *et al.* 2016)



TISNCM,
Troitsk, Russia
(Stoupin *et al.* 2014)



IGM SB RAS,
Novosibirsk, Russia
(courtesy of A. Snigirev)

Tested and used at APS, LCLS, PETRA III, *etc.*

Beamlines

- Best performance: **ID only**
- Highly **optimized set** of research techniques:
  - Fixed energy (two multi-end-station undulator beamlines with beam multiplexing)

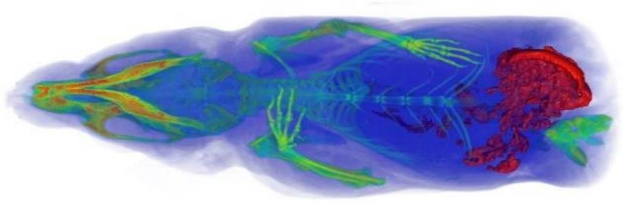
    Coherent and submicron beams beamline 1-1 (low-beta ss)
    High-resolution / *in situ* XRD and SAXS beamline 1-2 (high-beta ss)
  - Hard and soft spectroscopy (two tunable undulator beamlines)

    Hard x-ray spectroscopy beamline 1-4 (sc “tapered” undulator)
    Soft x-ray spectroscopy beamline 1-6 (switchable undulator)
  - High-energy (two wiggler beamlines)

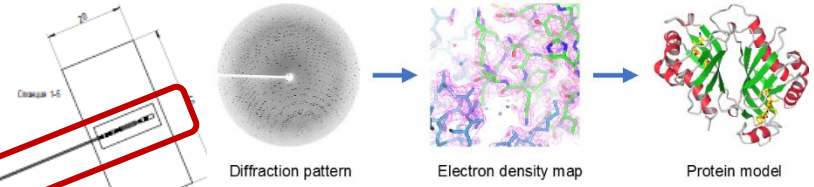
    Ultrafast high-energy diffraction and radiography beamline 1-3
    General high-energy diffraction and radiography beamline 1-5

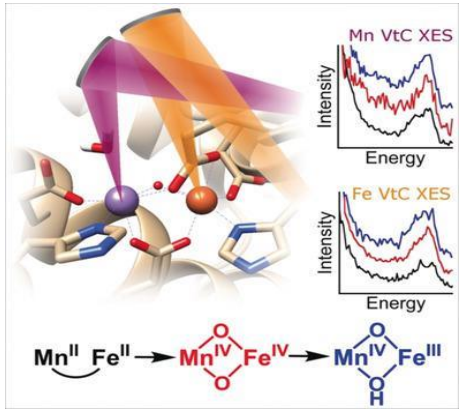
- To be complemented with more specialized energy-tunable second-stage beamlines:
  - Resonant protein crystallography (MAD)
  - Resonant small-molecule crystallography
  - Resonant SAXS
  - Multi-isotope nuclear resonance

Scientific infrastructure

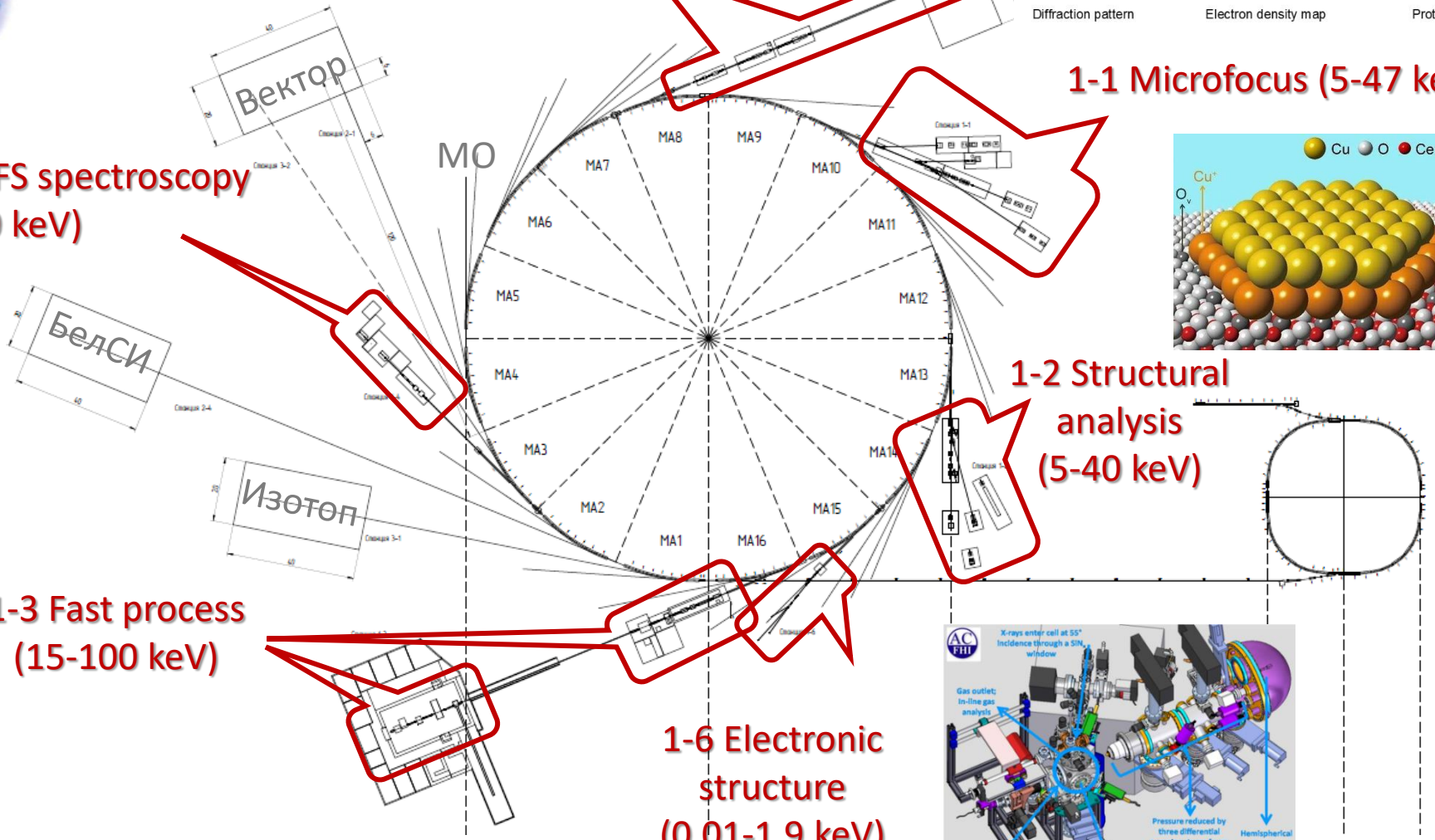


1-5 Hard X-ray diagnostics (30-150 кеV)





1-4 XAFS spectroscopy (4,5-40 keV)



1-1 Microfocus (5-47 keV)

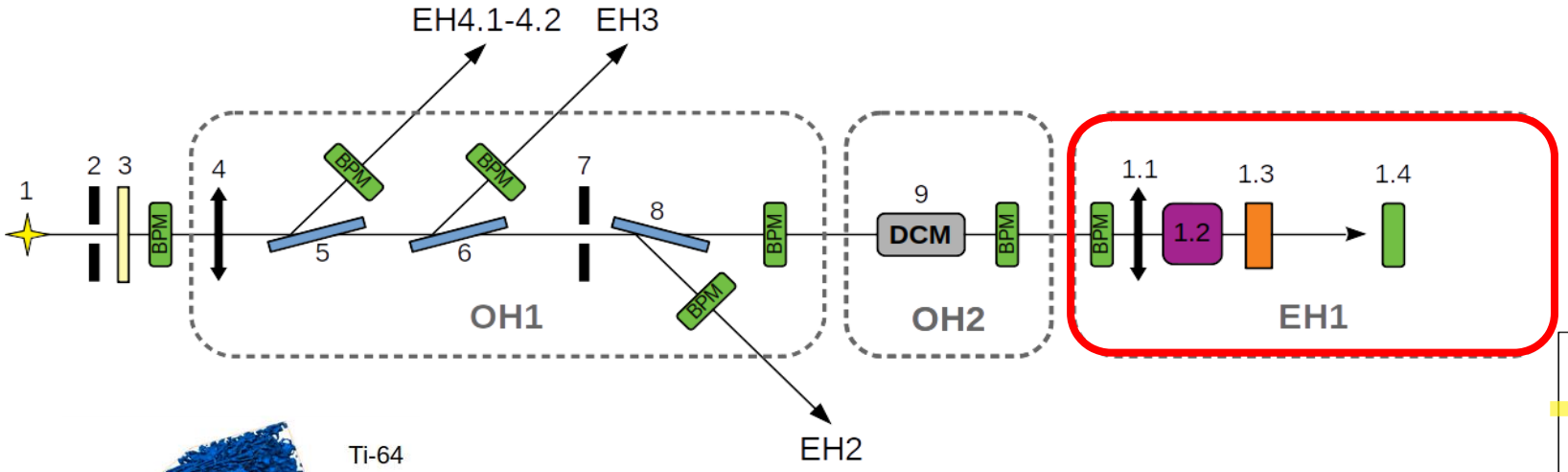
1-2 Structural analysis (5-40 keV)

1-3 Fast process (15-100 keV)

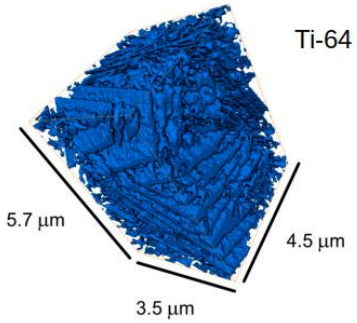
1-6 Electronic structure (0,01-1,9 keV)

Beamline 1-1 Microfocus

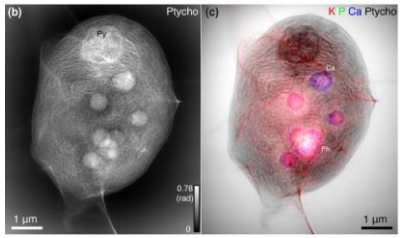
Coherent imaging of complex and hierarchical nanostructures



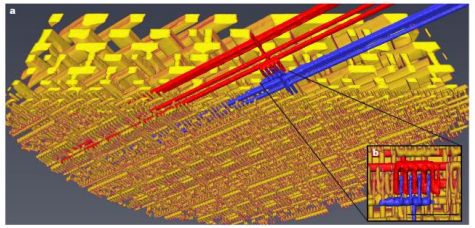
S. Rashchenko



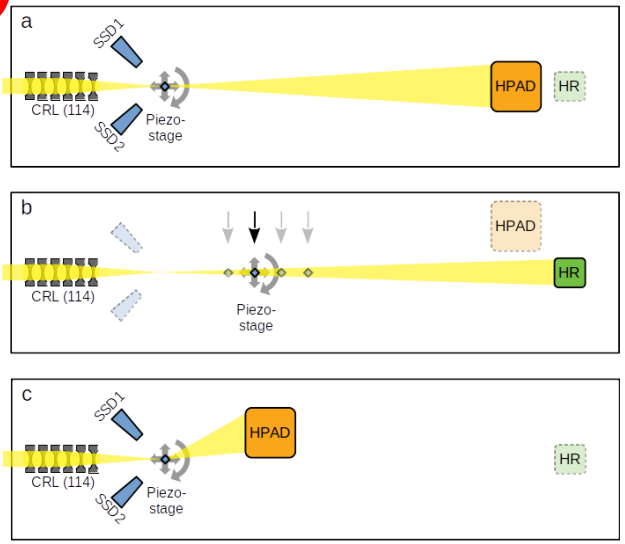
aerospace alloys

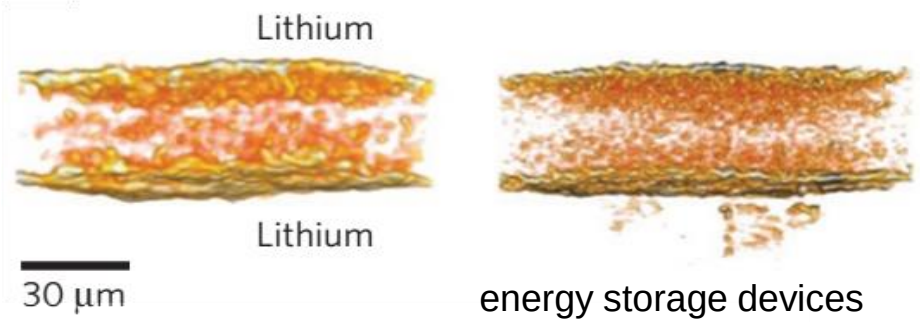


in vivo cells
(low radiation damage)



nanoelectronics

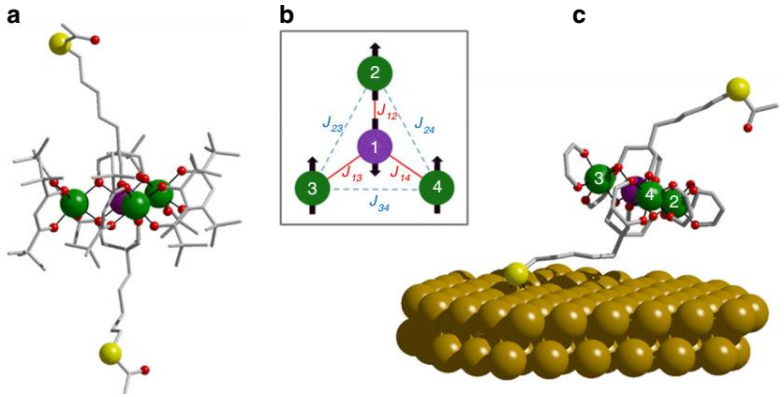




energy storage devices

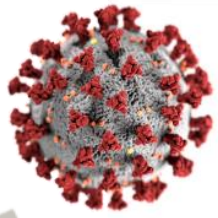
- High-energy coherent diffraction imaging and ptychography **up to 1-nm-resolution**
  - Holotomography with 150-nm-resolution
  - XRD and XRF nanotomography with 200-nm-resolution
  - Coherent flux at 27 keV up to 10^{12} ph/s in pink beam

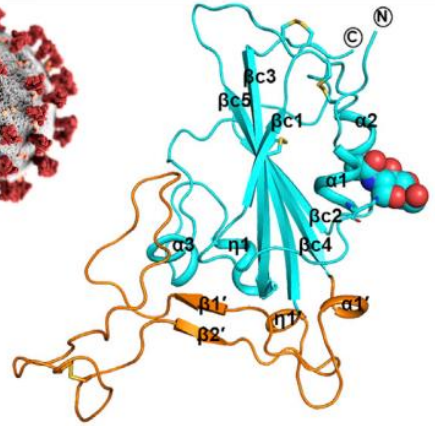
Beamline 1-1 side end-stations

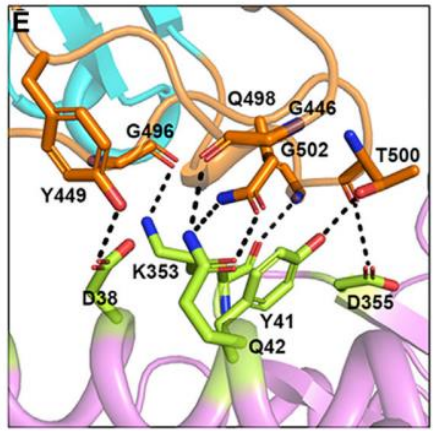


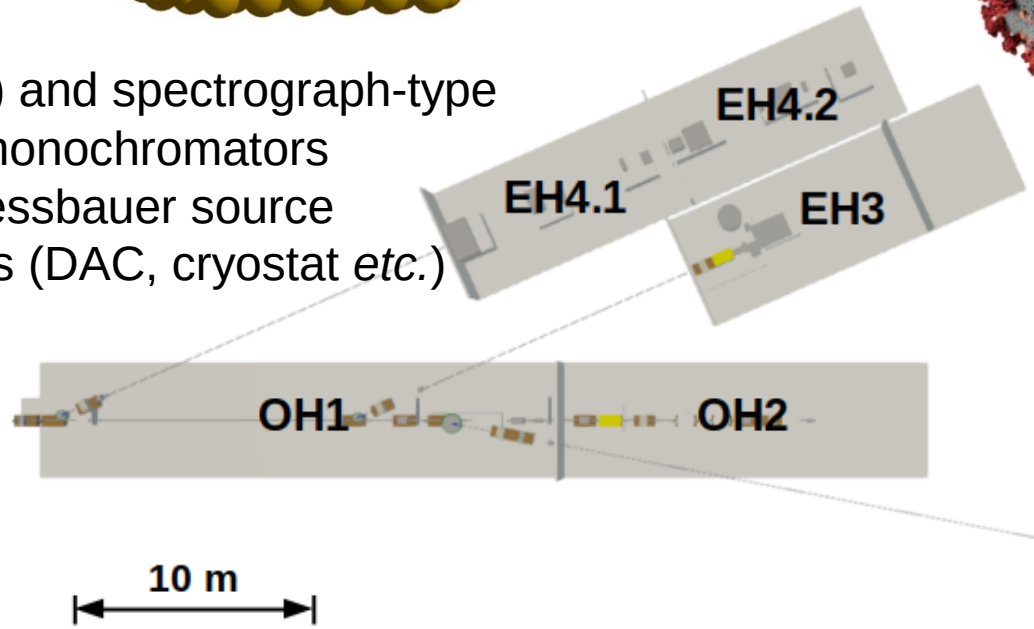
- Nested (~2 meV) and spectrograph-type high-resolution monochromators
- Synchrotron Moessbauer source
- *In situ* techniques (DAC, cryostat *etc.*)

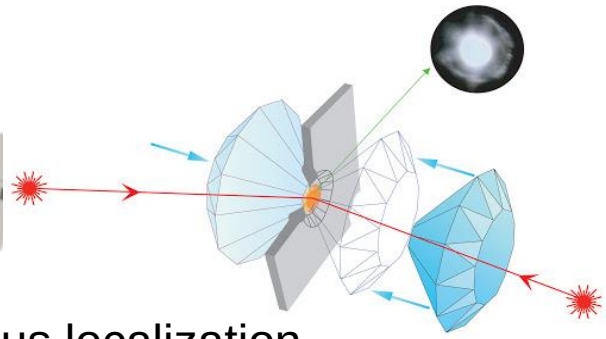
- Submicron serial and time-resolved protein crystallography
- Phase-contrast sample imaging
- 2×10^{12} ph/s at ~14 keV down to 0.6-μm spot







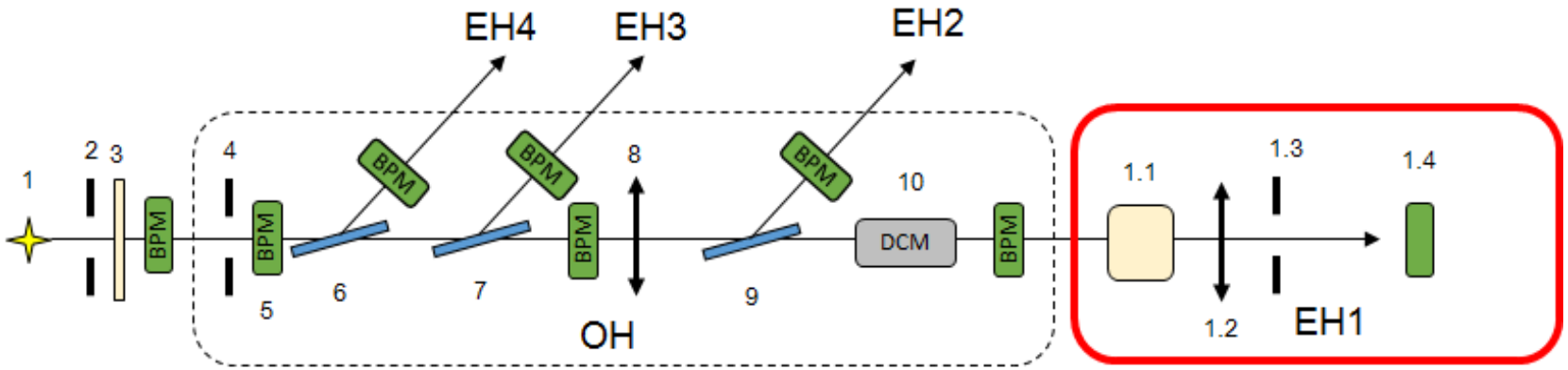




- High-energy x-ray diffraction and total scattering at extreme conditions
- Innovative scheme of phase-contrast sample imaging combined with sub-μm focus localization
- 10^{10} ph/s in monochromatic 31 keV beam focused to 300-nm spot

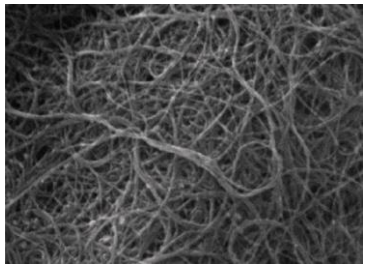
Beamline 1-2 Structural diagnostics

Application of X-ray diffraction techniques to solve a wide range of research and technological problems

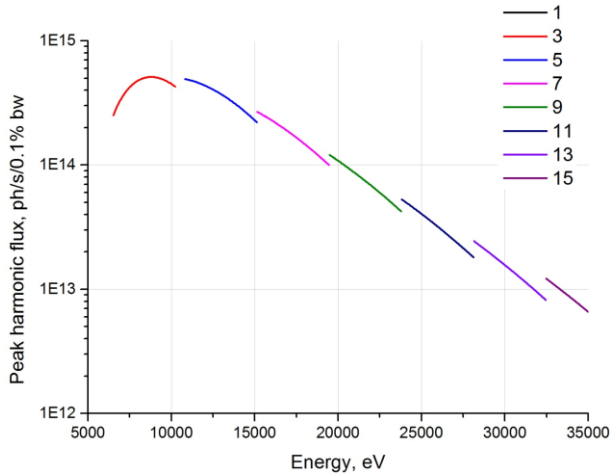


fuel cells

catalysis and *in situ* reactions



nanomaterials and polymers

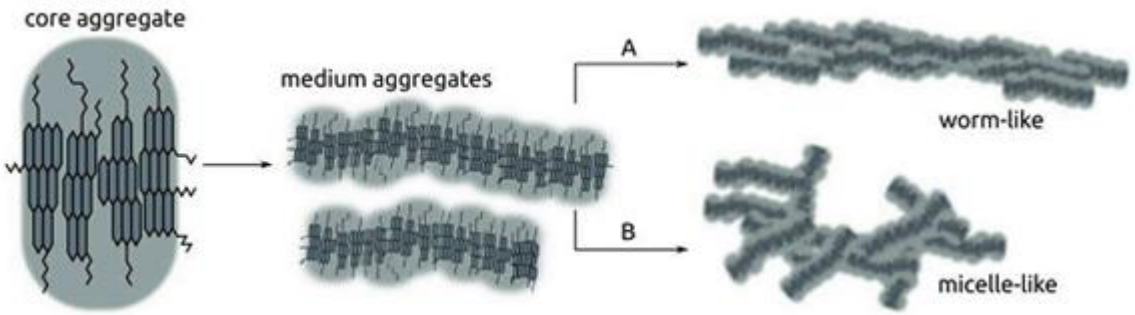


SCU Peak flux (1 x 1 mm^2 at 26 m)

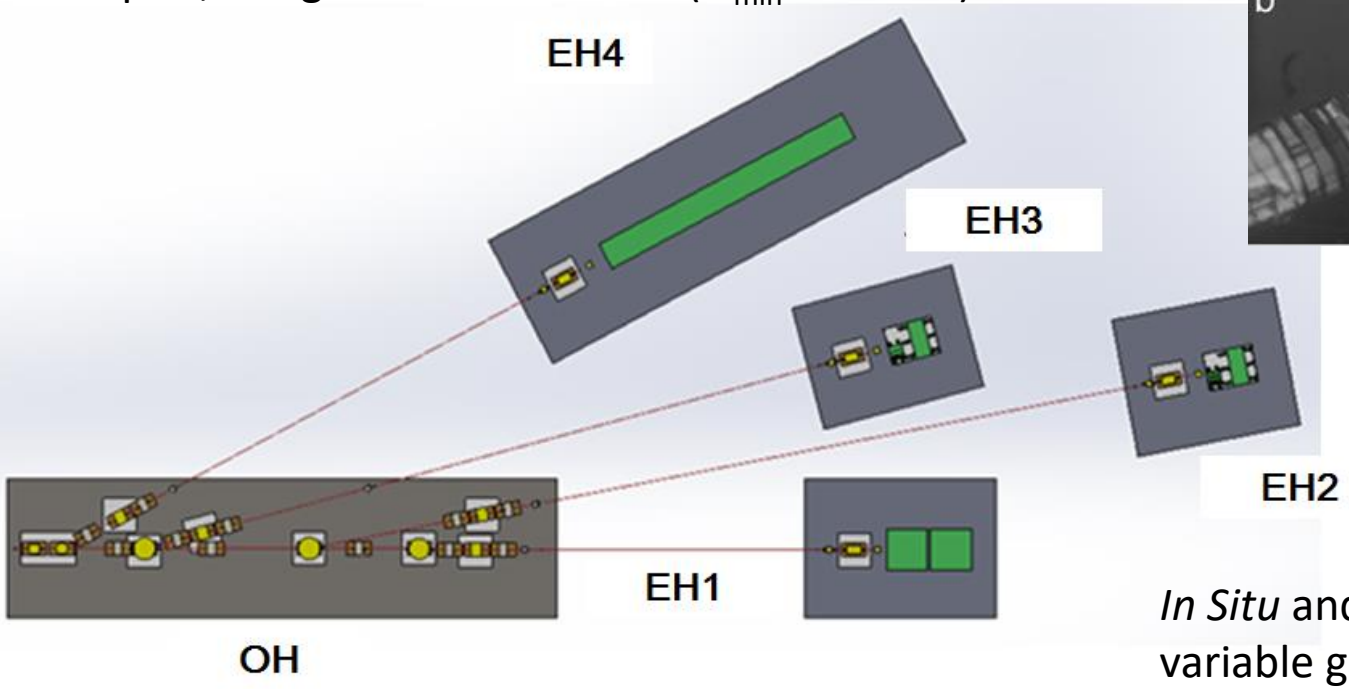
B. Zakharov

- High-resolution X-ray diffraction techniques at variable energies of SR (6.5-35 keV, resolution ~0.003 at 30°)
- Variable temperature experiments, climate chambers, variable gas environment

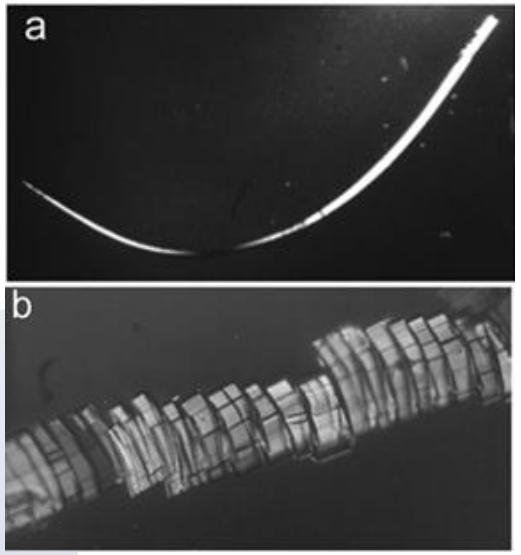
Beamline 1-2 side end-stations



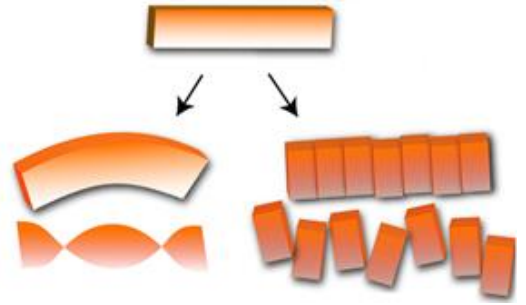
SAXS for wide range of objects including biological samples, inorganic materials *etc.* (Q_{min} ~ 10^{-4}Å^{-1})



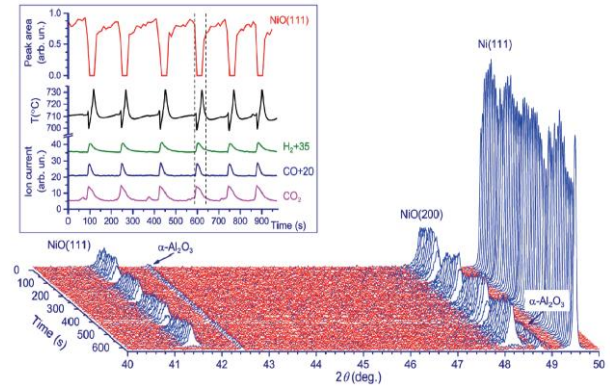
Single-crystal X-ray diffraction for the samples which are not suitable for conventional laboratory diffractometers (small size, unstable samples *etc.*), up to *ē*-density resolution



single crystals



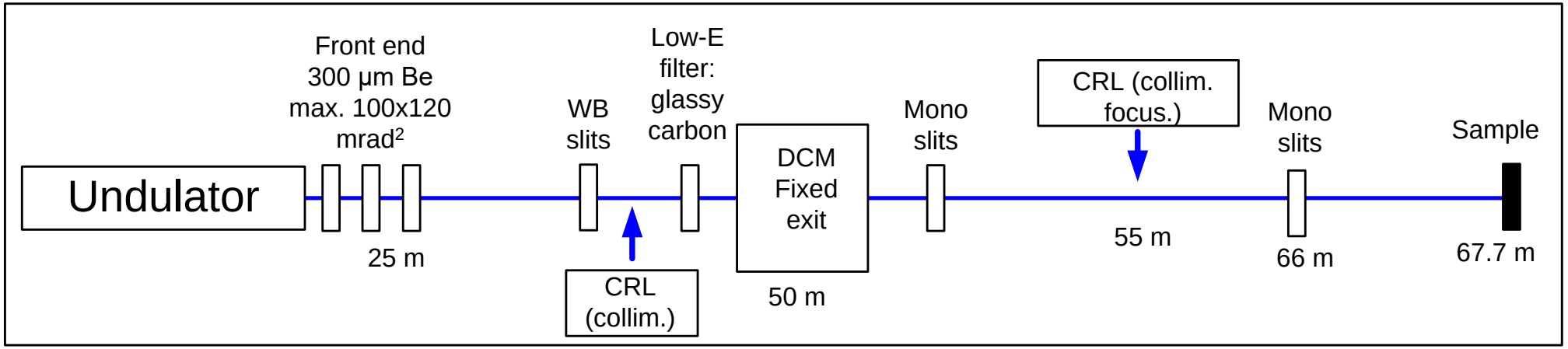
in situ reactions



In Situ and *Operando* studies at high temperatures and in variable gas atmospheres, including catalytic processes and chemical reactions (32.5 keV hard X-rays)

Beamline 1-4 XAFS spectroscopy

Designed to study the local spatial, electronic and magnetic structures of crystalline and amorphous materials, etc…



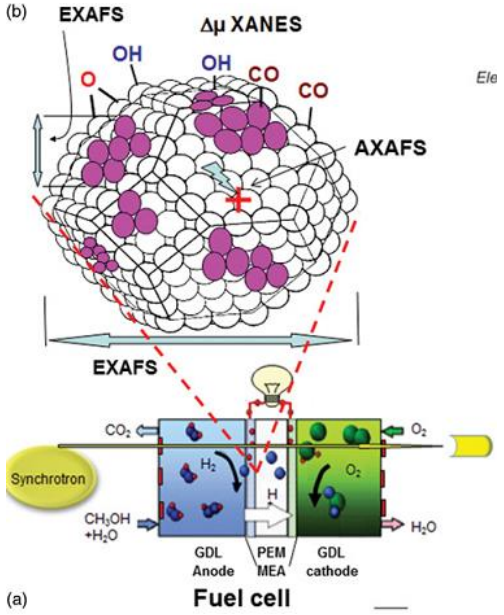
A. Saraev

Features:

- New SR source – SC tunable undulator (BINP)
- DCM in "fly" mode (1 s per EXAFS spectrum)
- Two XES spectrometers (JJ X-ray)
- Focusing – CRL and/or multilayer optics (for XES)
- $\Delta E/E < 2 \cdot 10^{-4}$ (unfocused mode for XAS)
- **$\Delta E/E \approx 7 \cdot 10^{-5}$ (collim.+focus. mode for XES)**

Opportunities:

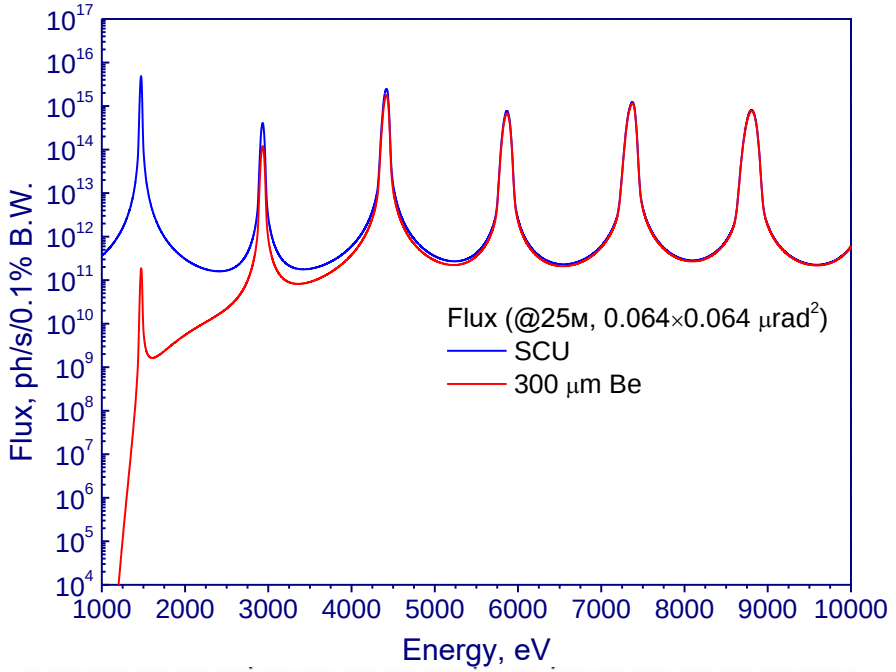
- From Ti to Ce (K-edge)
- Wide range of sample environment equipment for in situ/operando study (for example DRIFTS-XAS study)
- XES: resolution at K-edge up to 100 meV and high flux up to 10^{15} ph/s

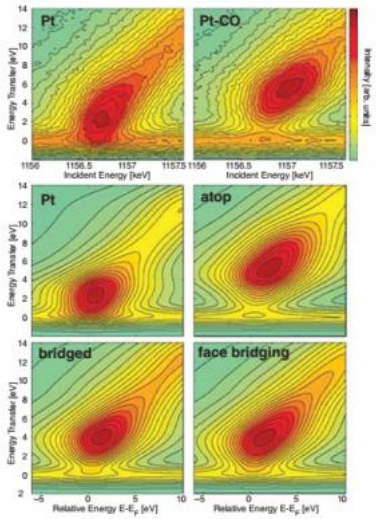


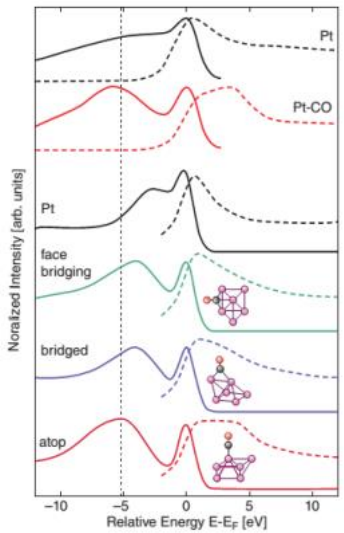
Beamline 1-4 XAFS spectroscopy

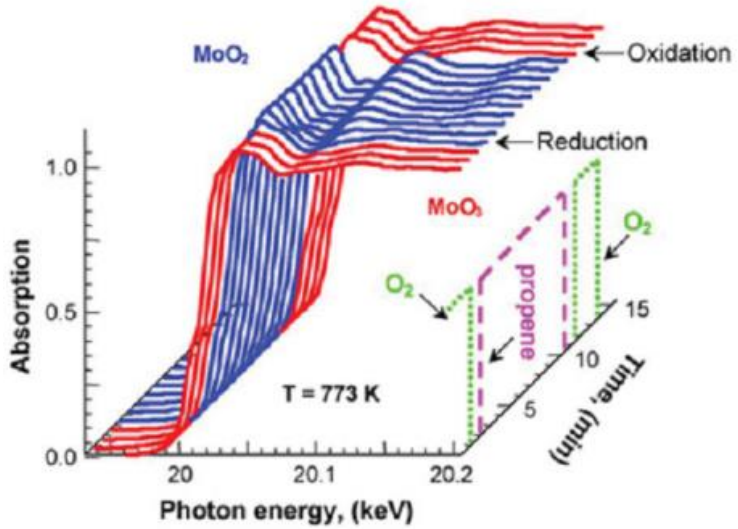
superconducting “tapered” undulator

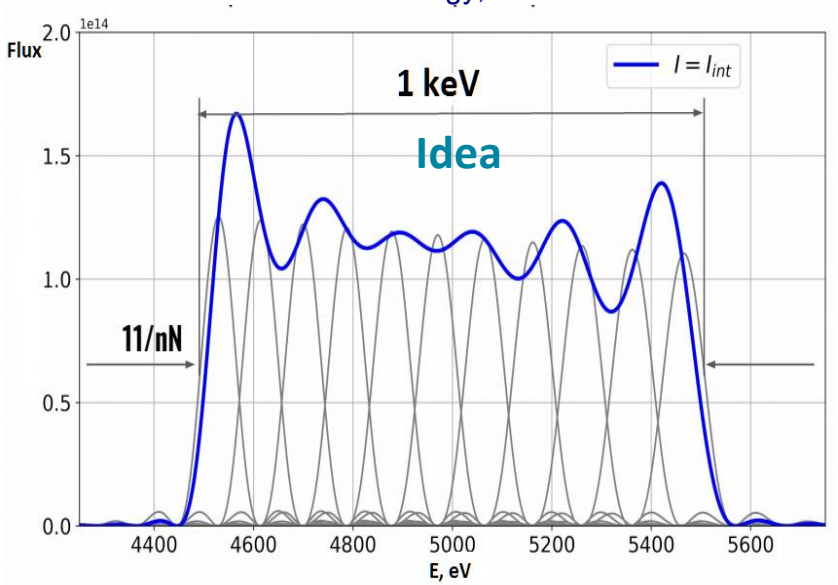
Parameter	
Period, mm	18
Number of periods	128 (more than 10 sections)
Magnetic field, T	0.1-1.25
Phase error, degree	< 3
Power, kW	< 8.2



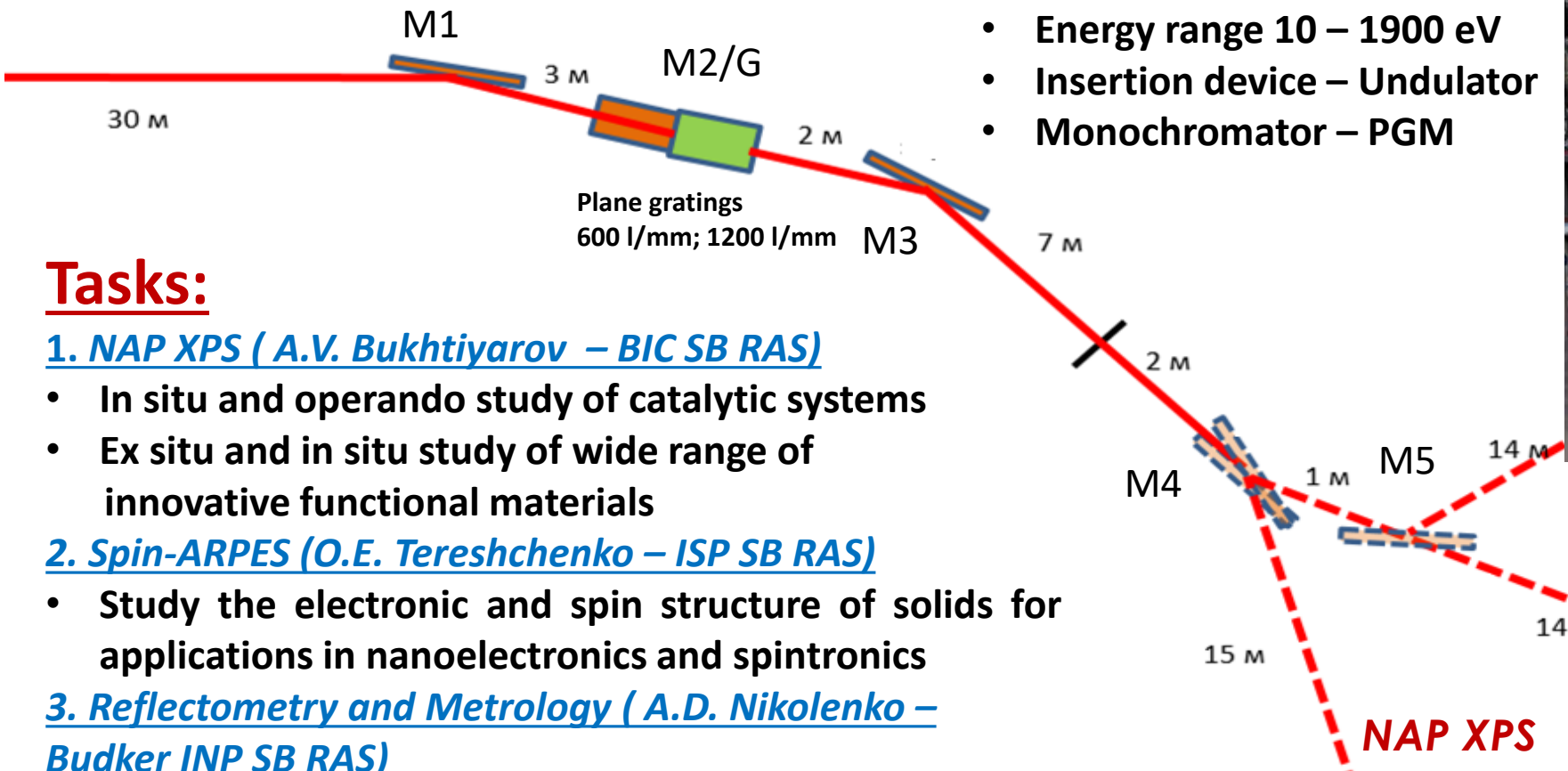








Beamline 1-6 Electronic structure



Parameters:

- **Energy range 10 – 1900 eV**
- **Insertion device – Undulator**
- **Monochromator – PGM**

Tasks:

1. NAP XPS (A.V. Bukhtiyarov – BIC SB RAS)

- **In situ and operando study of catalytic systems**
- **Ex situ and in situ study of wide range of innovative functional materials**

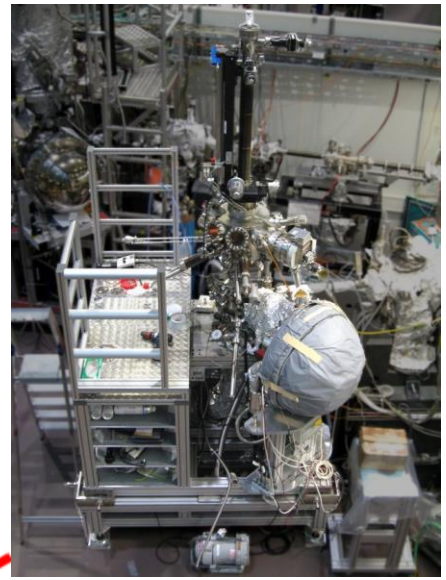
2. Spin-ARPES (O.E. Tereshchenko – ISP SB RAS)

- **Study the electronic and spin structure of solids for applications in nanoelectronics and spintronics**

3. Reflectometry and Metrology (A.D. Nikolenko – Budker INP SB RAS)

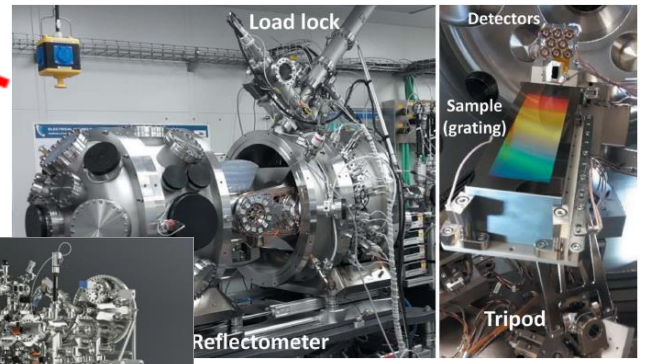
- **certification of spectral optical elements, focusing elements and X-ray detectors**
- **reference detector method for absolute calibration of the spectral sensitivity of various kinds of X-ray radiation receivers in the VUV and Soft X-Rays ranges**

Spin-ARPES

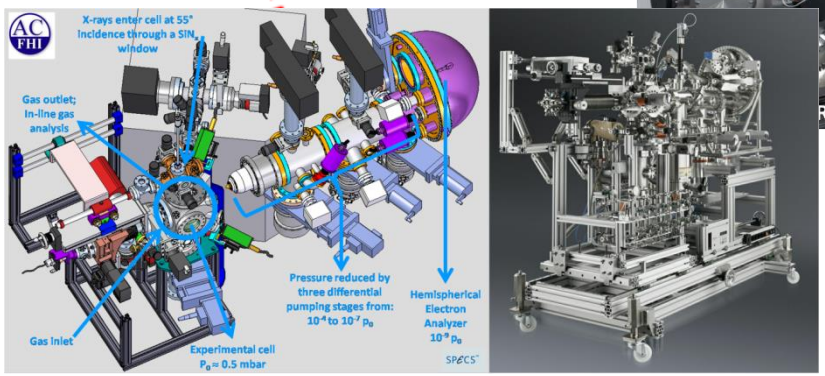


A. Bukhtiyarov

Reflectometer

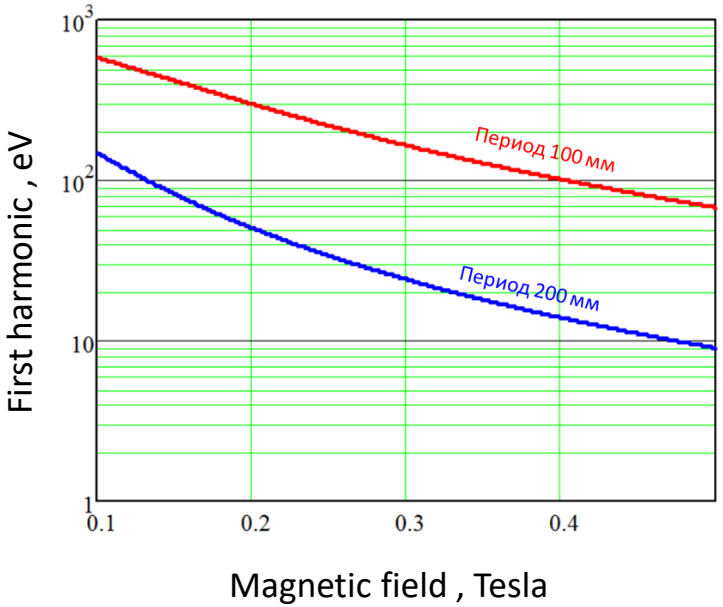


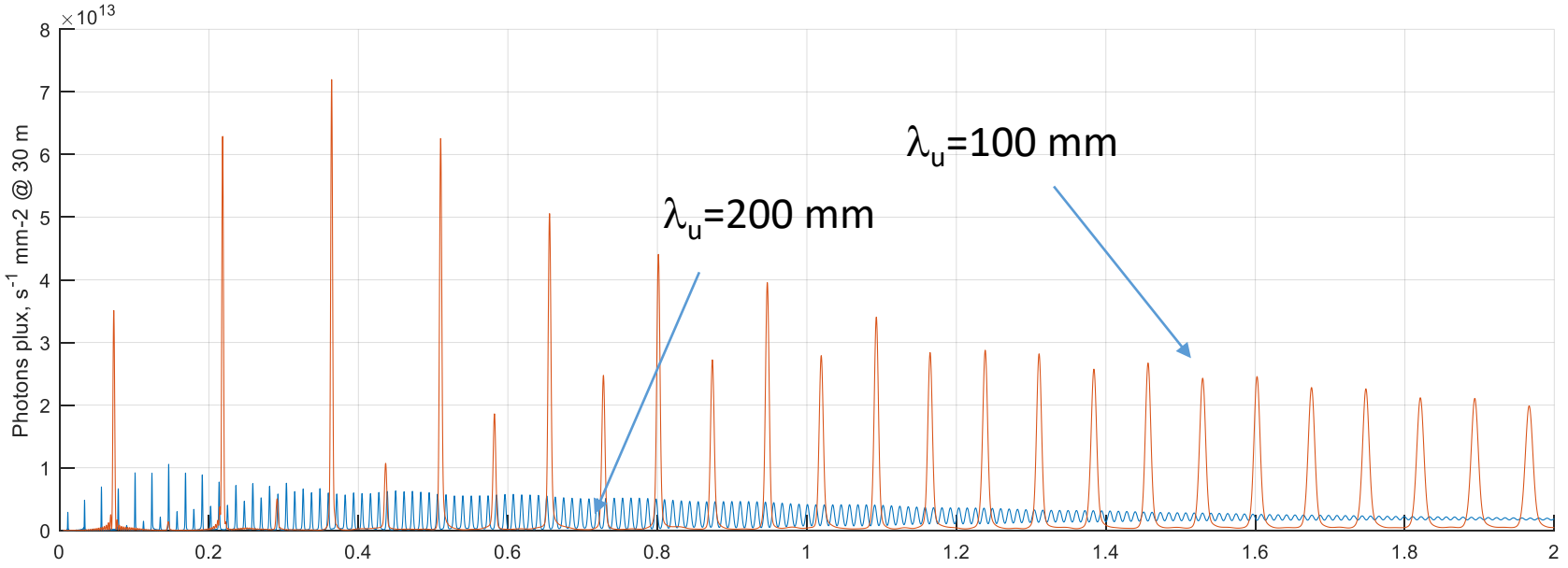
NAP XPS



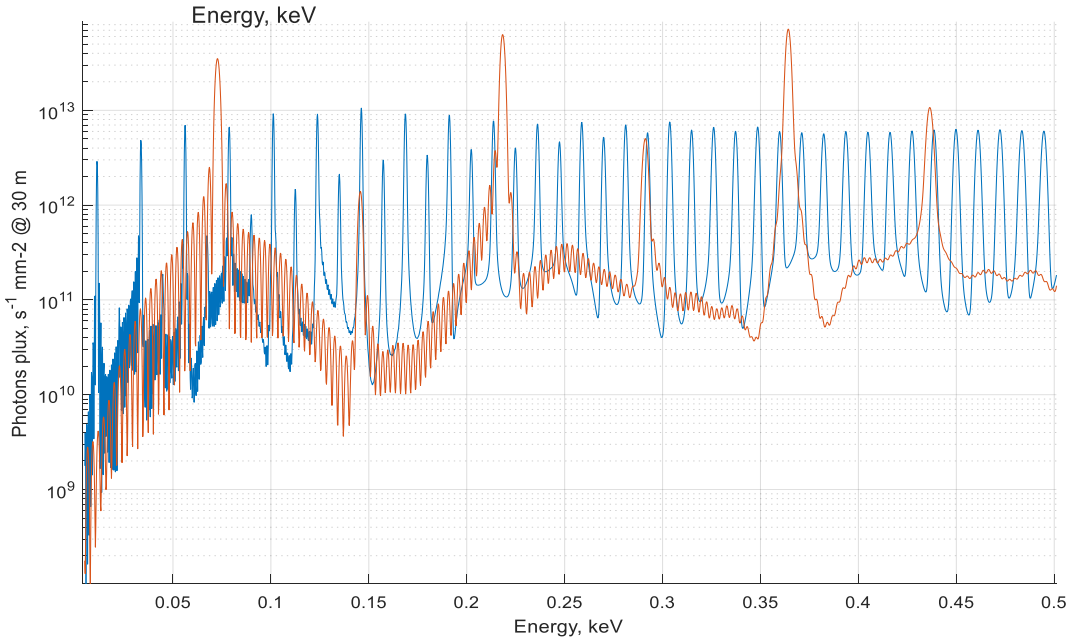
Beamline 1-6 Electronic structure

switchable undulator





The main parameters	Undulator	"Wiggler"
Period, mm	100	200
The number of periods	26	13
The total amount of poles	56	56
Total length, mm	2900	2900
Magnetic field, Tesla	0.05 - 0.5	0.05 - 0.5
Max phase error	2º	2º
First harmonic (Lowest photon energy), eV	67.6	9

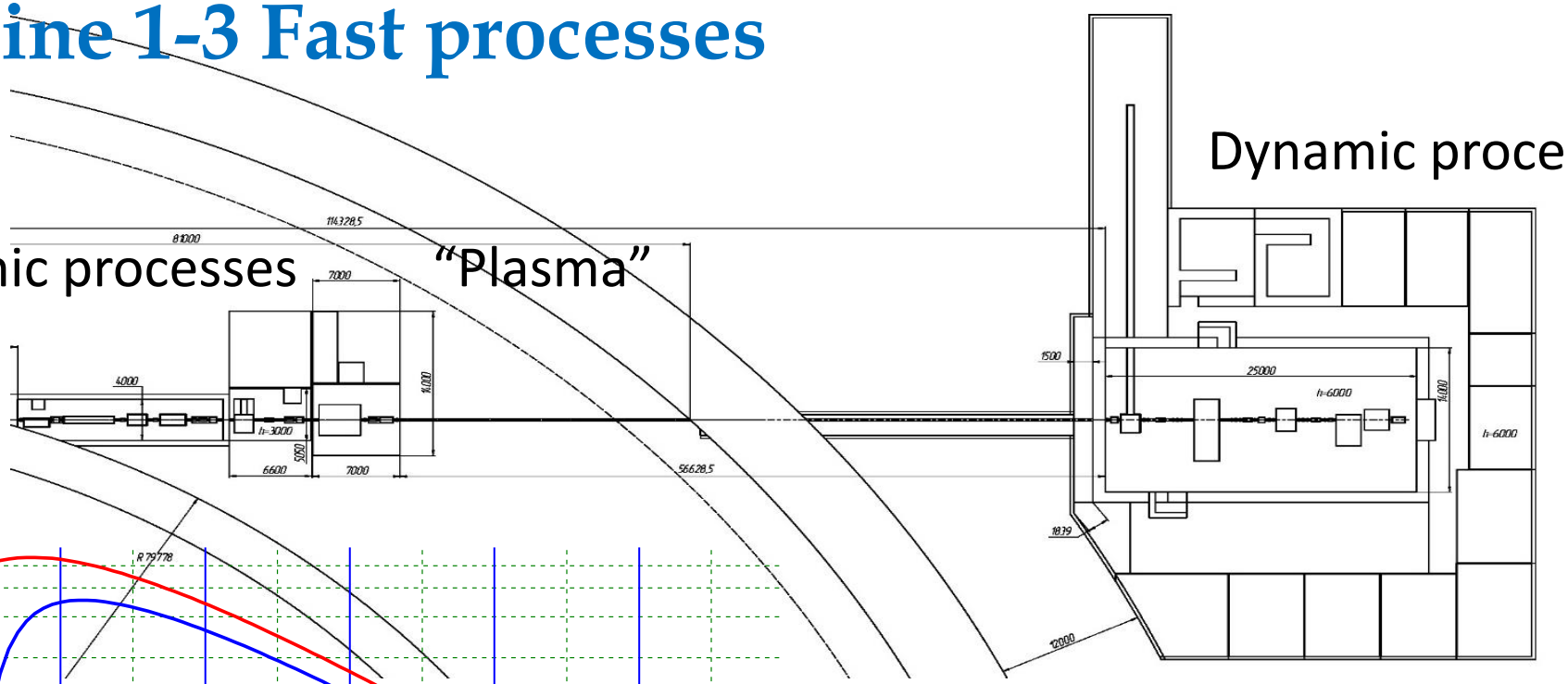


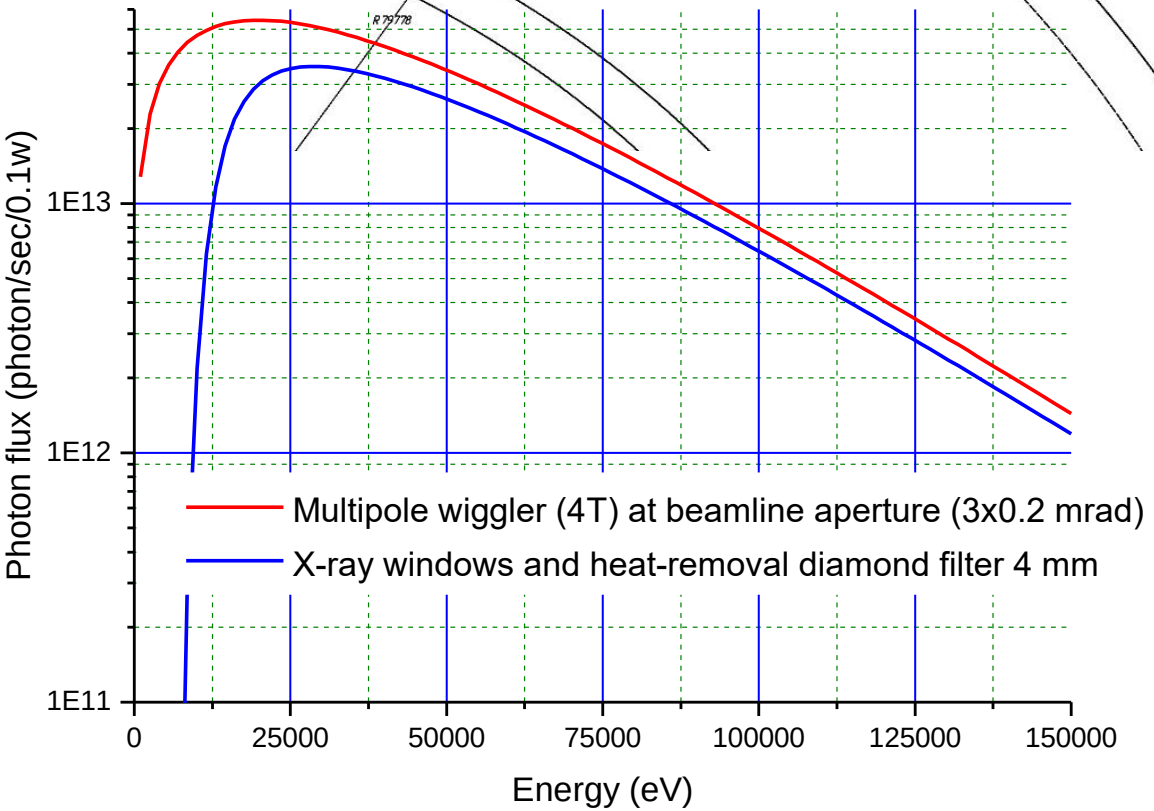
Beamline 1-3 Fast processes

Dynamic processes

"Plasma"

Dynamic processes





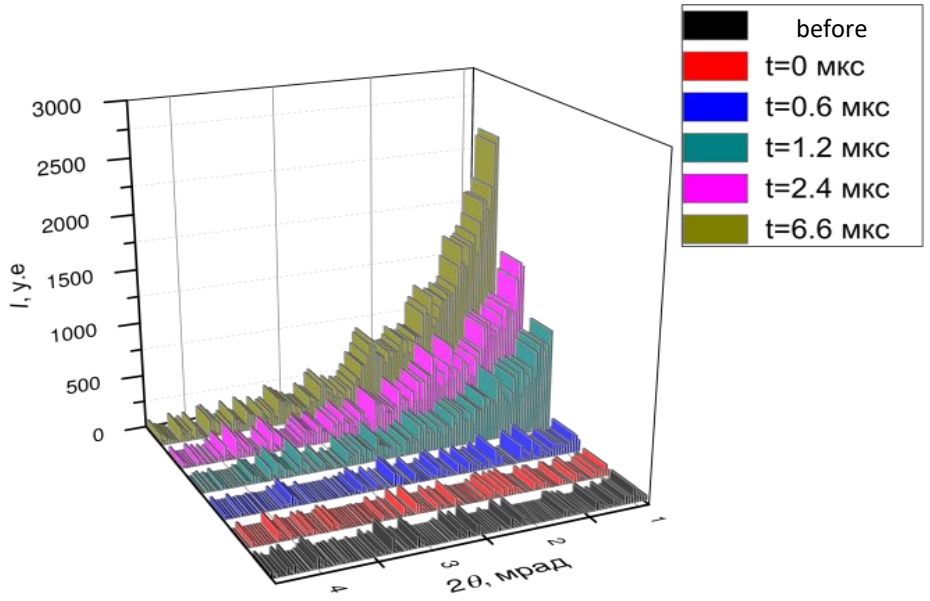
I. Rubtsov

- Measurement of deformation parameters inside the material,
- Measurements with spatial resolution in depth below the surface,
- Dynamic measurements with a temporal resolution of the order of 10 μs.

Beamline 1-3 Fast processes

Dynamic processes instrumentations

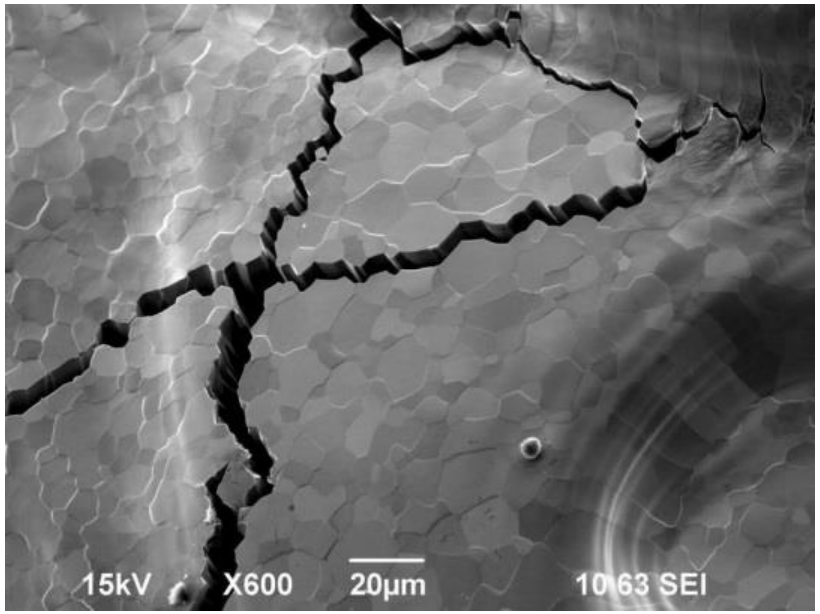
The properties of energetic materials, the structure of the shock and detonation fronts, the equation of state, phase transitions under compression, chemical reactions, the dynamic formation of nanostructures, high-speed deformation and fracture of materials.



SAXS dynamics during detonation of TNT/RDX charge.

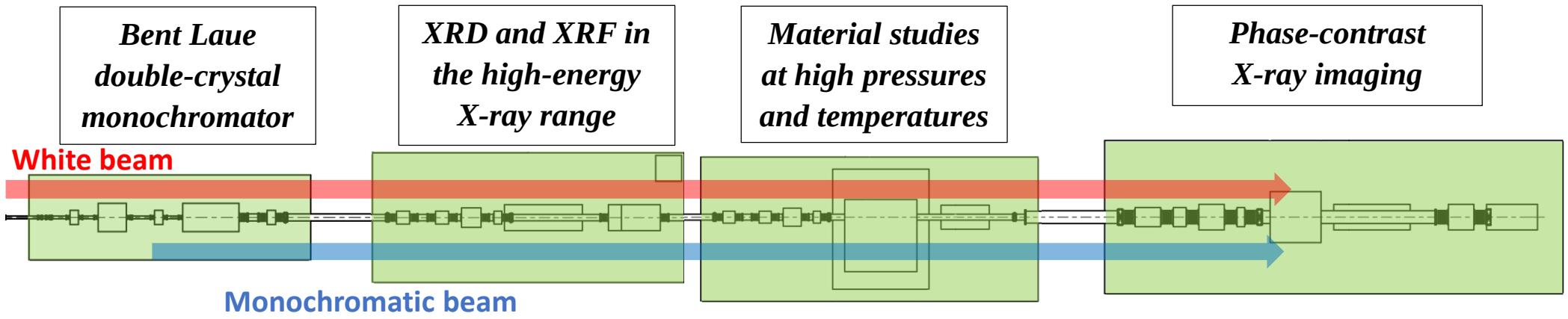
“Plasma” instrumentations

Investigation of the effects of high temperature and plasma on materials in a fusion reactor. Using diffraction techniques, the change in the crystal structure of the samples and the deformations arising in them will be investigated.



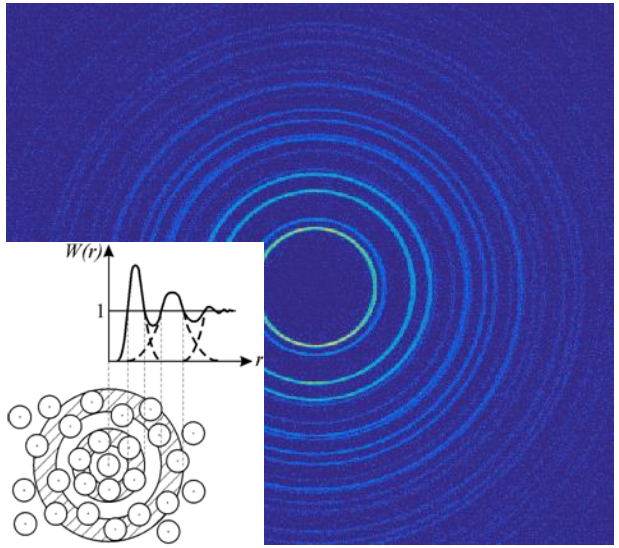
Tungsten crack after pulsed plasma loading

Beamline 1-5 Hard X-ray diagnostics



K. Kuper

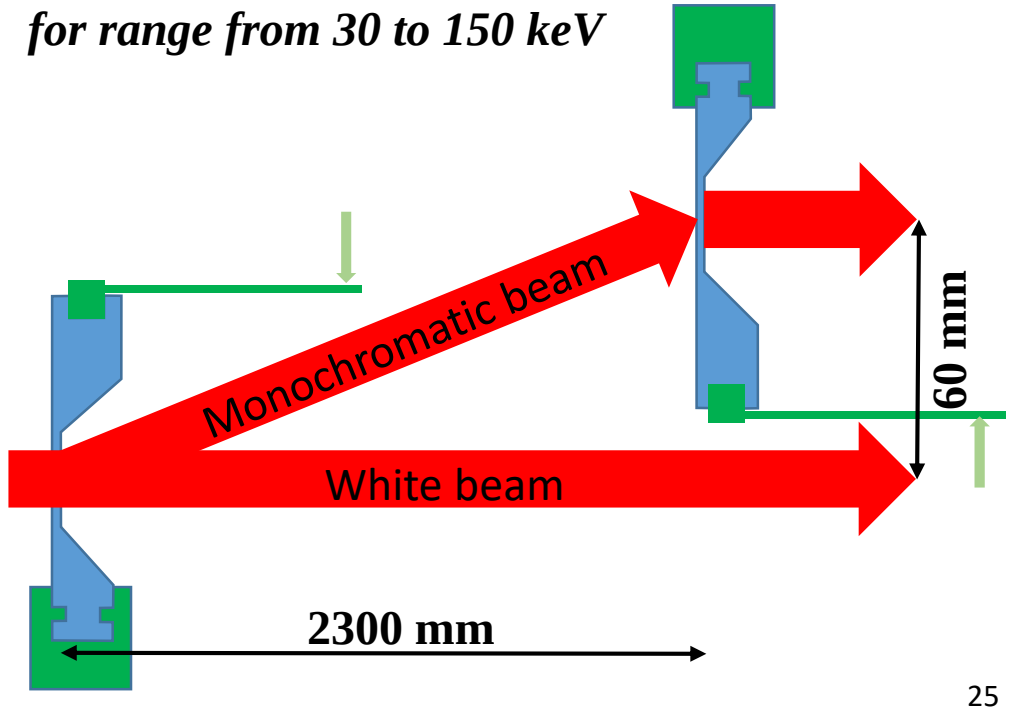
XRD and XRF in the high-energy X-ray range



The basic tasks:

- The study of the synthesis of high temperature materials
- Analysis of the processes of melting and subsequent crystallization in metals
- XRF analysis for geoscience

Bent Laue double-crystal monochromator for range from 30 to 150 keV

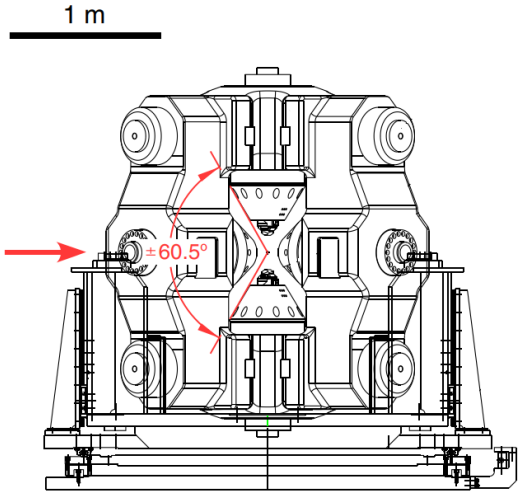


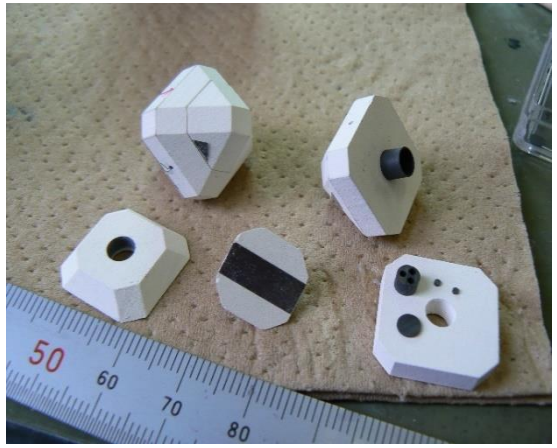
Beamline 1-5 Hard X-ray diagnostics

Material studies at high pressures and temperatures

The basic tasks:

- **Phase diagrams of crystalline substances (rocks, minerals) in the coordinates of pressure and temperature.**
- **P-V-T equations of state of crystalline phases**
- **Ultrasonic interferometry at high pressures and temperatures.**
- **The study of the rheological properties of rocks at extreme pressures and temperatures.**
- **Characterization of functional materials at pressures ranging from 3 to 10 GPa and temperatures up to 2000°K**

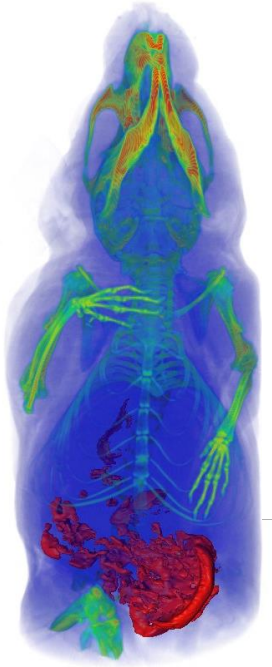


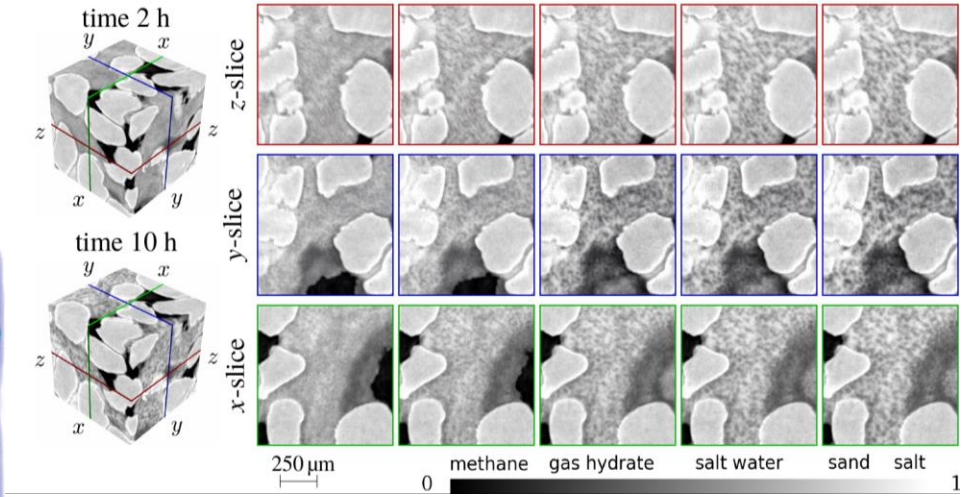


Phase-contrast X-ray imaging

The basic tasks:

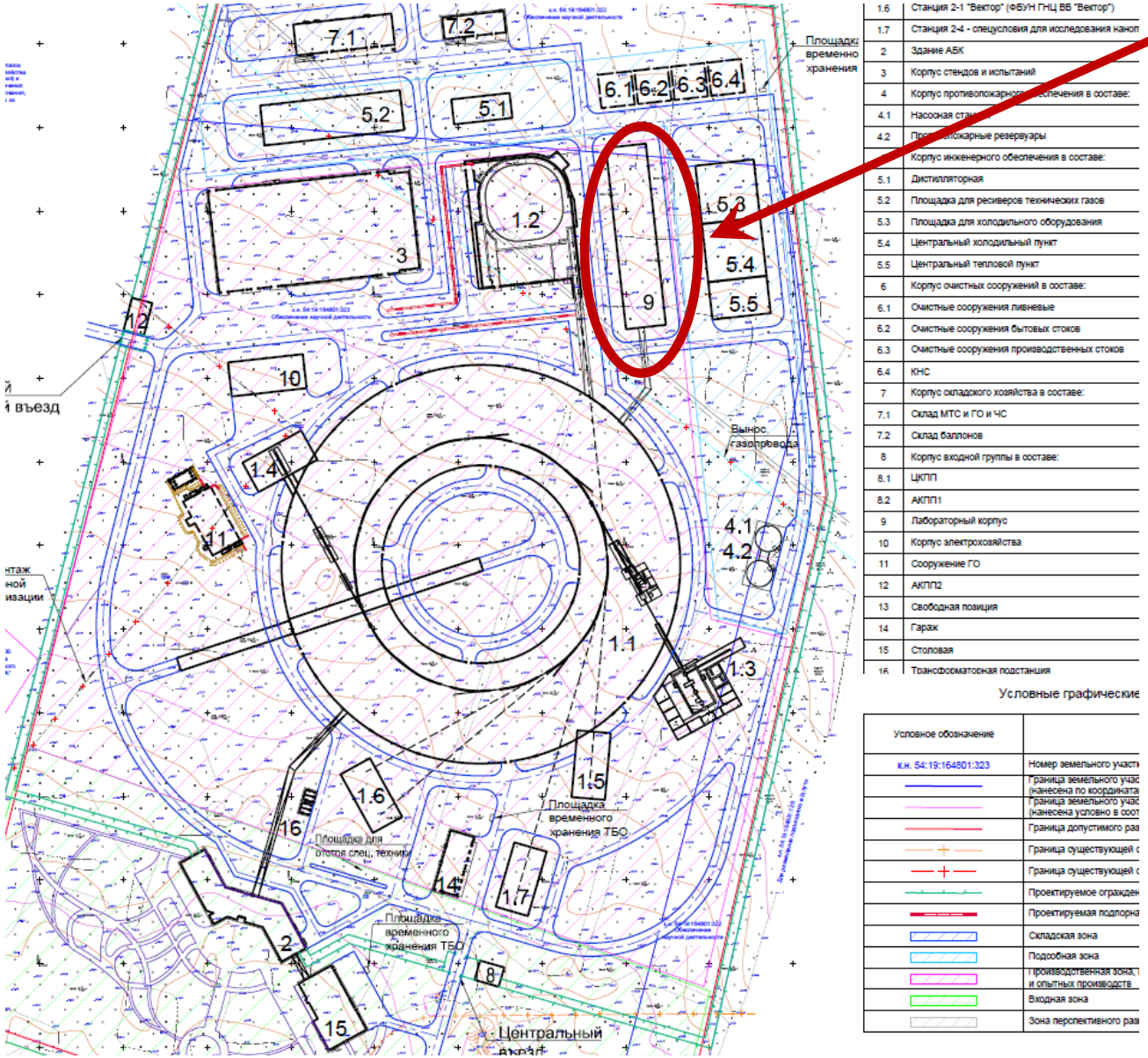
- **X-ray imaging for biological and medical application**
- **Development of the radiation therapy methods**
- **3D inspection mechanical components after extreme mechanical and thermal loading**
- **Time resolve tomography for material and geology sciences**





Dynamic in-situ imaging of methane hydrate formation and self-preservation in porous media

Scientific infrastructure



1.6	Станция 2-1 "Вектор" (ФБУН ГНЦ ВБ "Вектор")
1.7	Станция 2-4 - спецусловия для исследования нанот
2	Здание АБК
3	Корпус стендов и испытаний
4	Корпус противопожарного обеспечения в составе:
4.1	Насосная стан
4.2	Противопожарные резервуары
5	Корпус инженерного обеспечения в составе:
5.1	Дистилляторная
5.2	Площадка для ресиверов технических газов
5.3	Площадка для холодильного оборудования
5.4	Центральный холодильный пункт
5.5	Центральный тепловой пункт
6	Корпус очистных сооружений в составе:
6.1	Очистные сооружения ливневые
6.2	Очистные сооружения бытовых стоков
6.3	Очистные сооружения производственных стоков
6.4	КНС
7	Корпус складского хозяйства в составе:
7.1	Склад МТС и ГО и ЧС
7.2	Склад баллонов
8	Корпус входной группы в составе:
8.1	ЦКПП
8.2	АКПП1
9	Лабораторный корпус
10	Корпус электрохозяйства
11	Сооружение ГО
12	АКПП2
13	Свободная позиция
14	Гараж
15	Столовая
16	Трансформаторная подстанция

Условные графические

Условное обозначение	
к.н. 54:19:164801:323	Номер земельного участ
	Граница земельного учас (нанесена по координата
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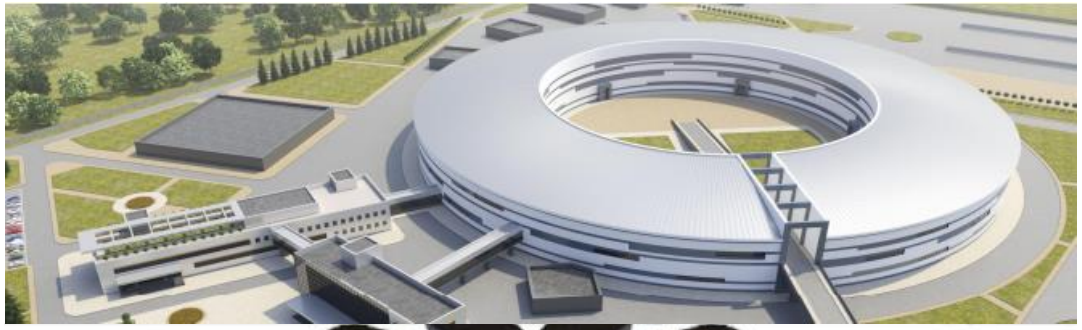
	Граница существующей с
	Проектируемое огражден
	Проектируемая подпорна
	Складская зона
	Подсобная зона
	Производственная зона, и опытных производств
	Входная зона
	Зона перспективного раз

Supporting Laboratory

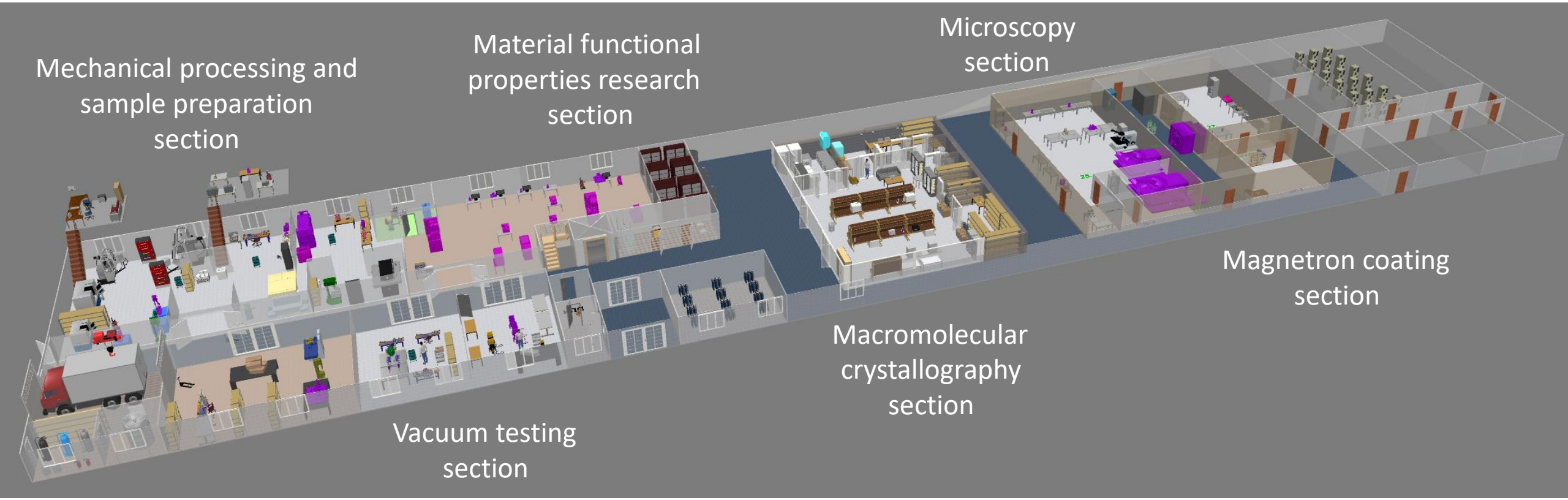
The SRF «SKIF» will offers for users a unique array of support services and laboratories for the experiment preparation, instrumentations and the analysis of resulting data.

B. Goldenberg



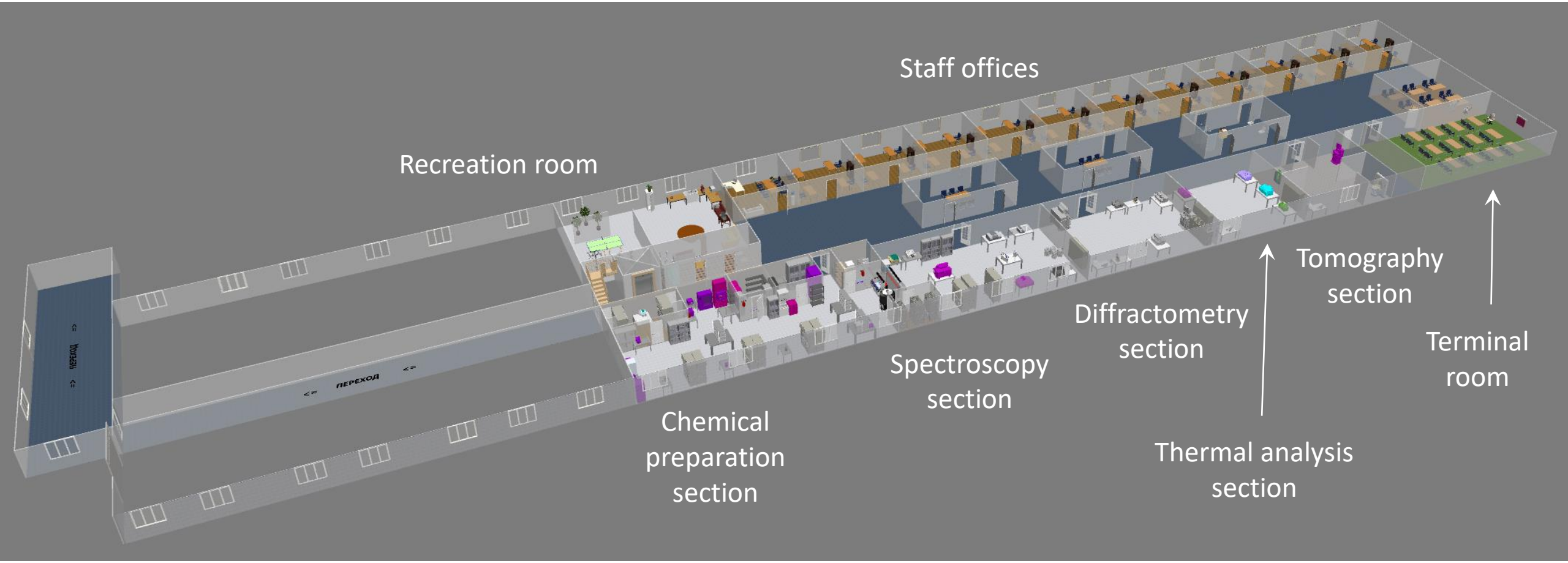
Scientific infrastructure

Supporting Laboratory, ground floor



Scientific infrastructure

Supporting Laboratory, first floor



Thank you for kind attention !