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Concept of nanodiffraction beamline on a new 4+ generation synchrotron radiation source. Beamline capabilities for solving material science problems

Igor Likhachev

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871072.

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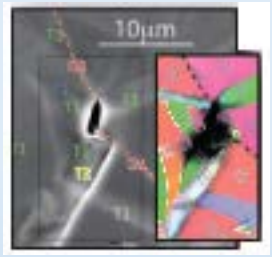
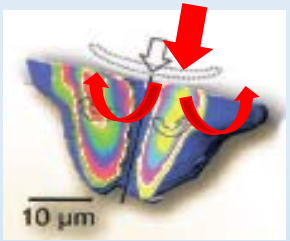
Micro- and nanoelectronics

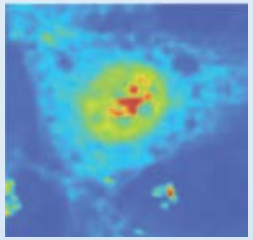
Material science



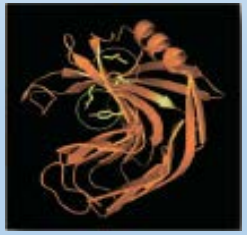
MEMS & NEMS



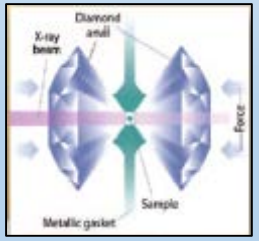
Cell biochemistry



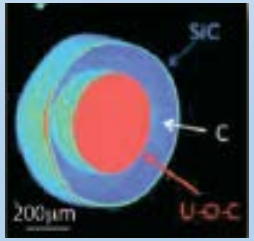
Protein crystallography



High pressure



Radioactive materials



Archeology

Bacis techniques:

- X-ray diffraction techniques
- Coherent Bragg diffraction
- Bragg ptychography

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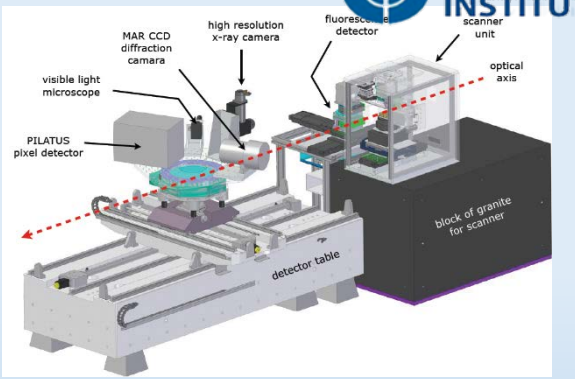
World analogues

ID01 @ESRF

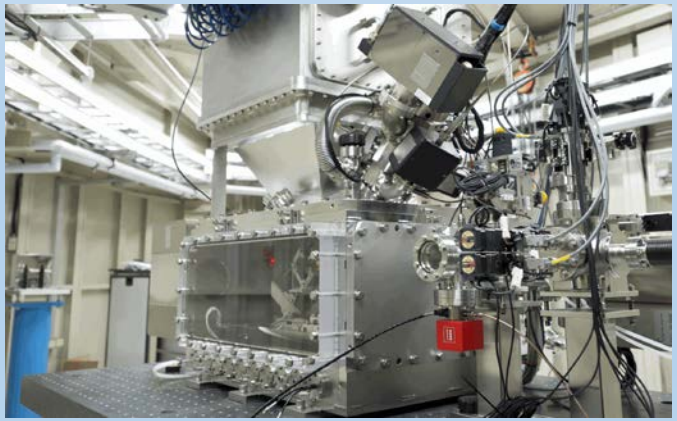
P23 @DESY



P06 @DESY

BL 12.3.2 @ALS

26-ID-C @APS



21A @TPS (Taiwan)

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Nanofocusing

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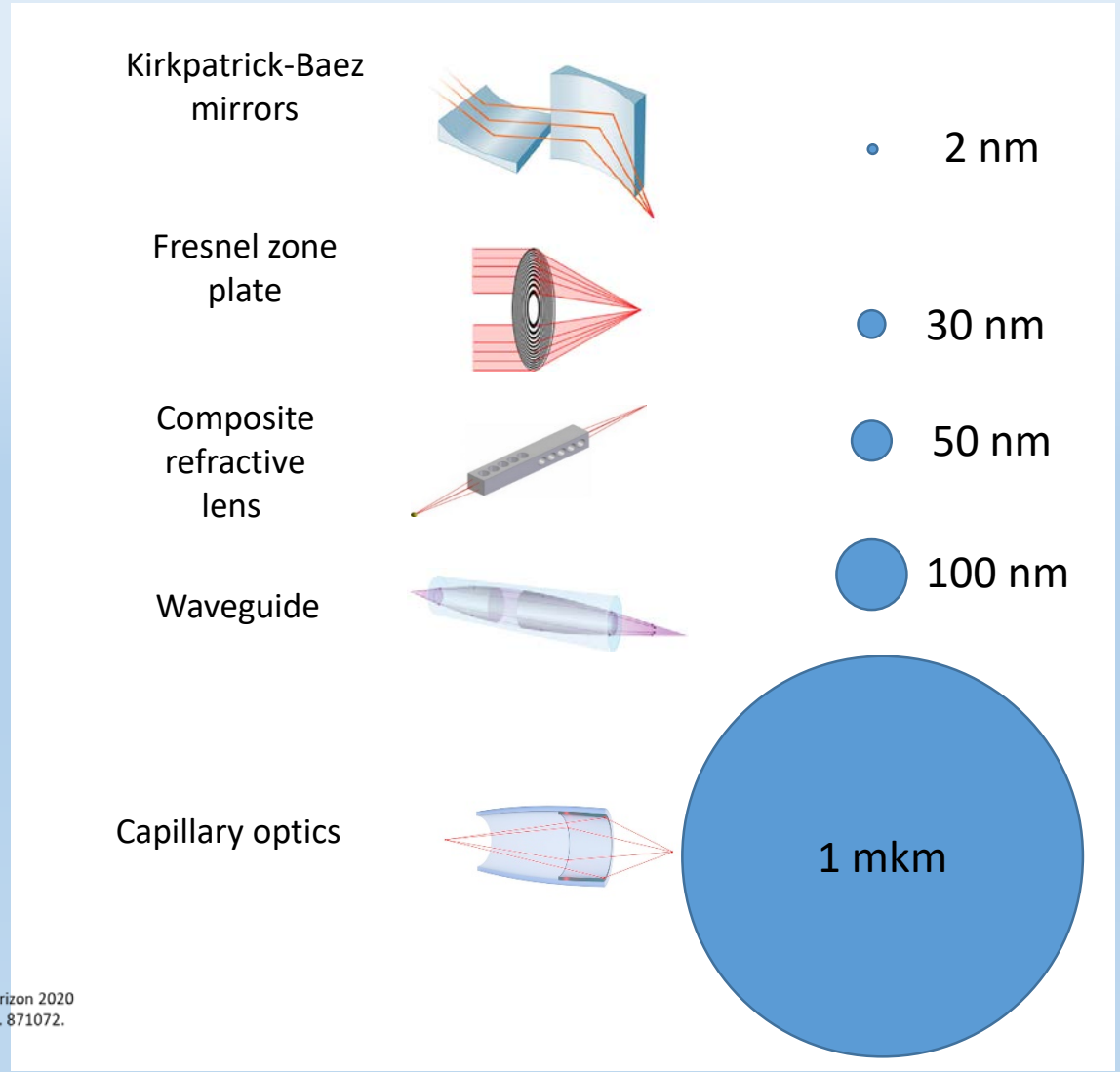
Methods for obtaining of nanosized x-ray beam	Minimum focus spot size
Kirkpatrick-Baez mirrors	2 nm
Fresnel zone plate	30 nm
Composite refractive lens	50 nm
Waveguide	100 nm
Capillary optics	1 mkm



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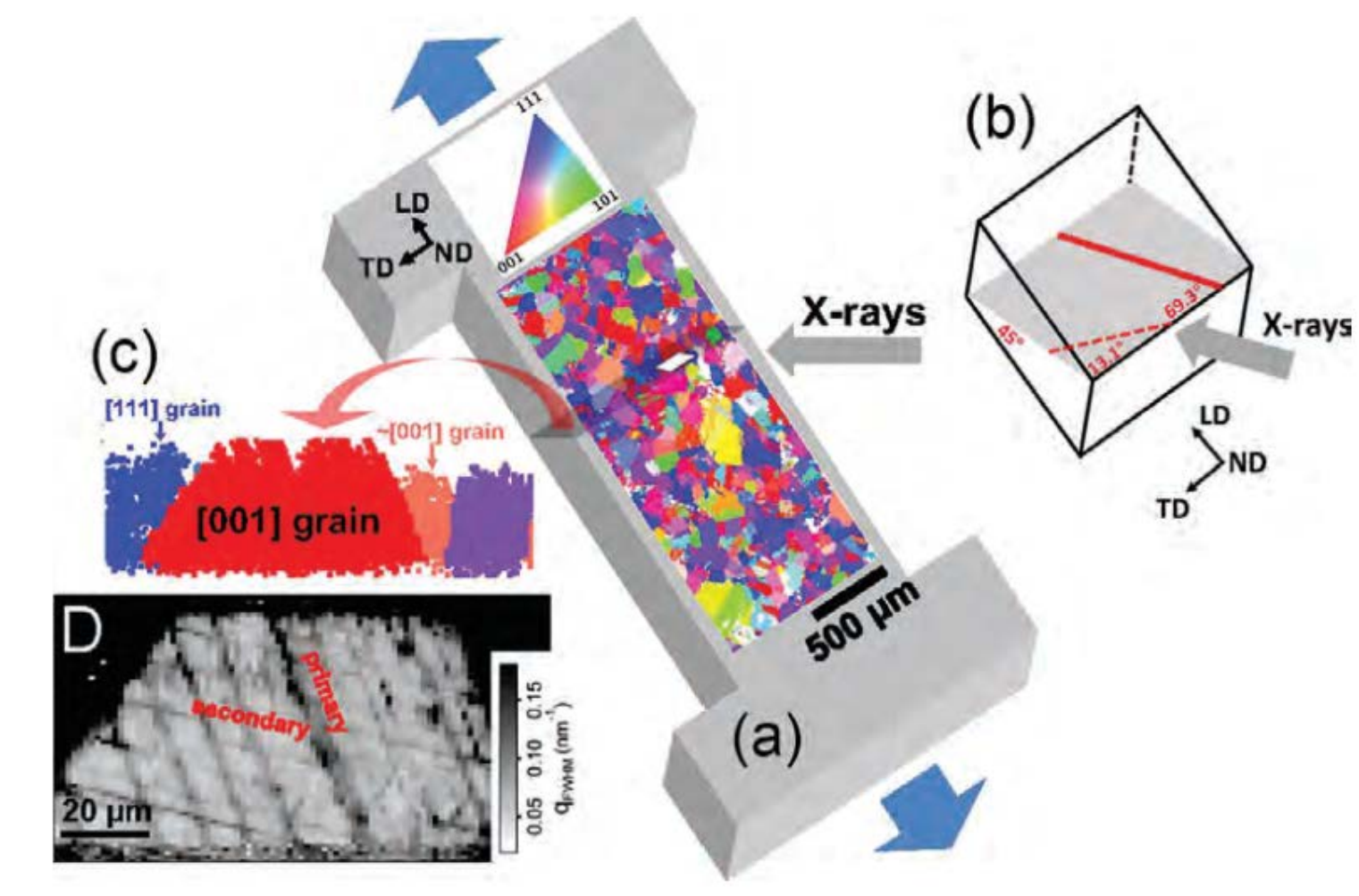
3D reconstruction of strained structure



Anastasios Pateras et al. Mesoscopic Elastic Distortions in GaAs Quantum Dot Heterostructures. Nano Lett.2018 185 2780-2786

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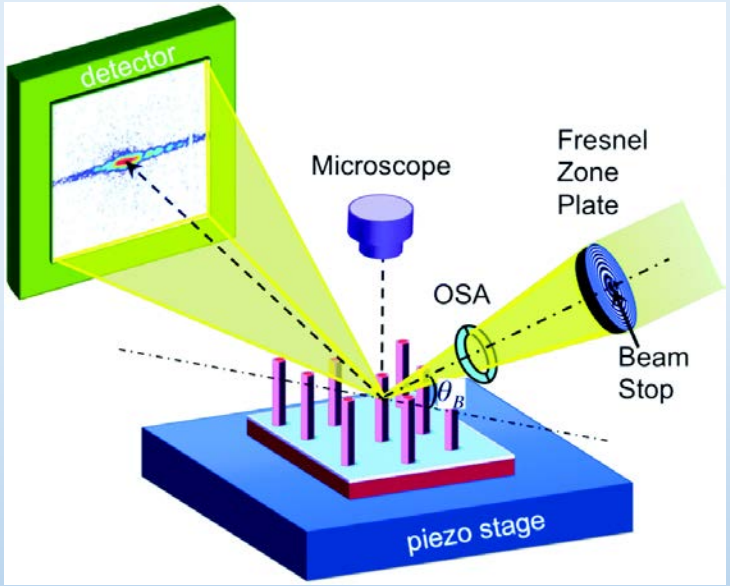
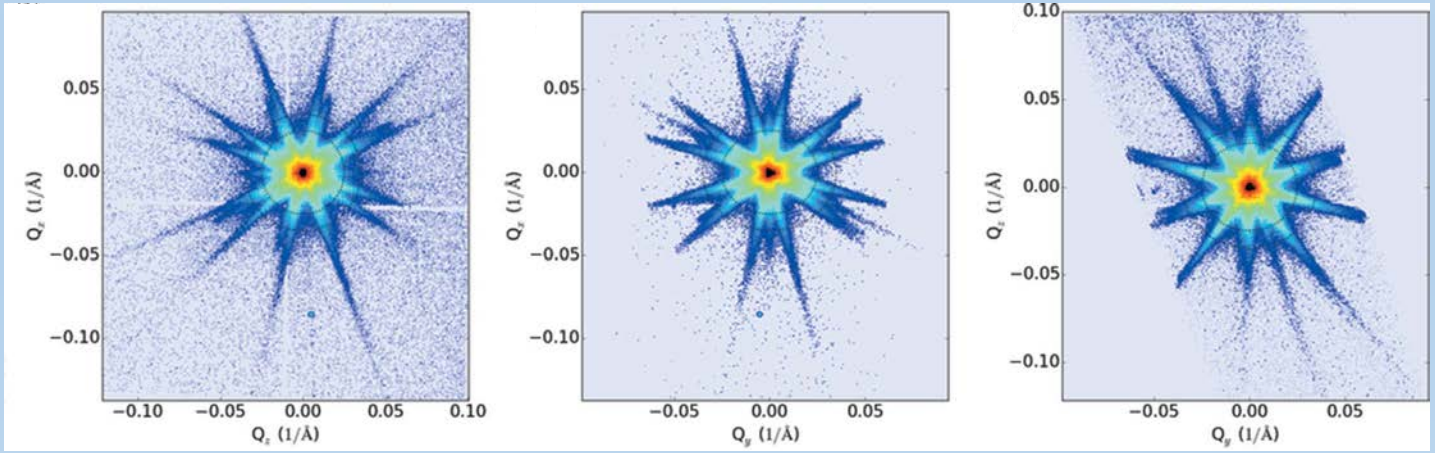
Coherent Bragg diffraction

Stéphane Labat et al. Inversion Domain Boundaries in GaN Wires Revealed by Coherent Bragg Imaging. ACS Nano 2015, 9, 9, 9210–9216



Objects:

- amorphous and disordered structures
- polymers
- crystal defects
- quantum dots and wires
- deformed structures and nanostructures
- buried layers and interfaces



Steven J. Leake et al. The Nanodiffraction beamline ID01/ESRF: a microscope for imaging strain and structure. J. Synchrotron Rad. (2019). 26, 571–584

Functions:

- imaging of displacements (deformations) fields
- 3D reconstruction of nanoobjects
- imaging of nanoparticles, etc.

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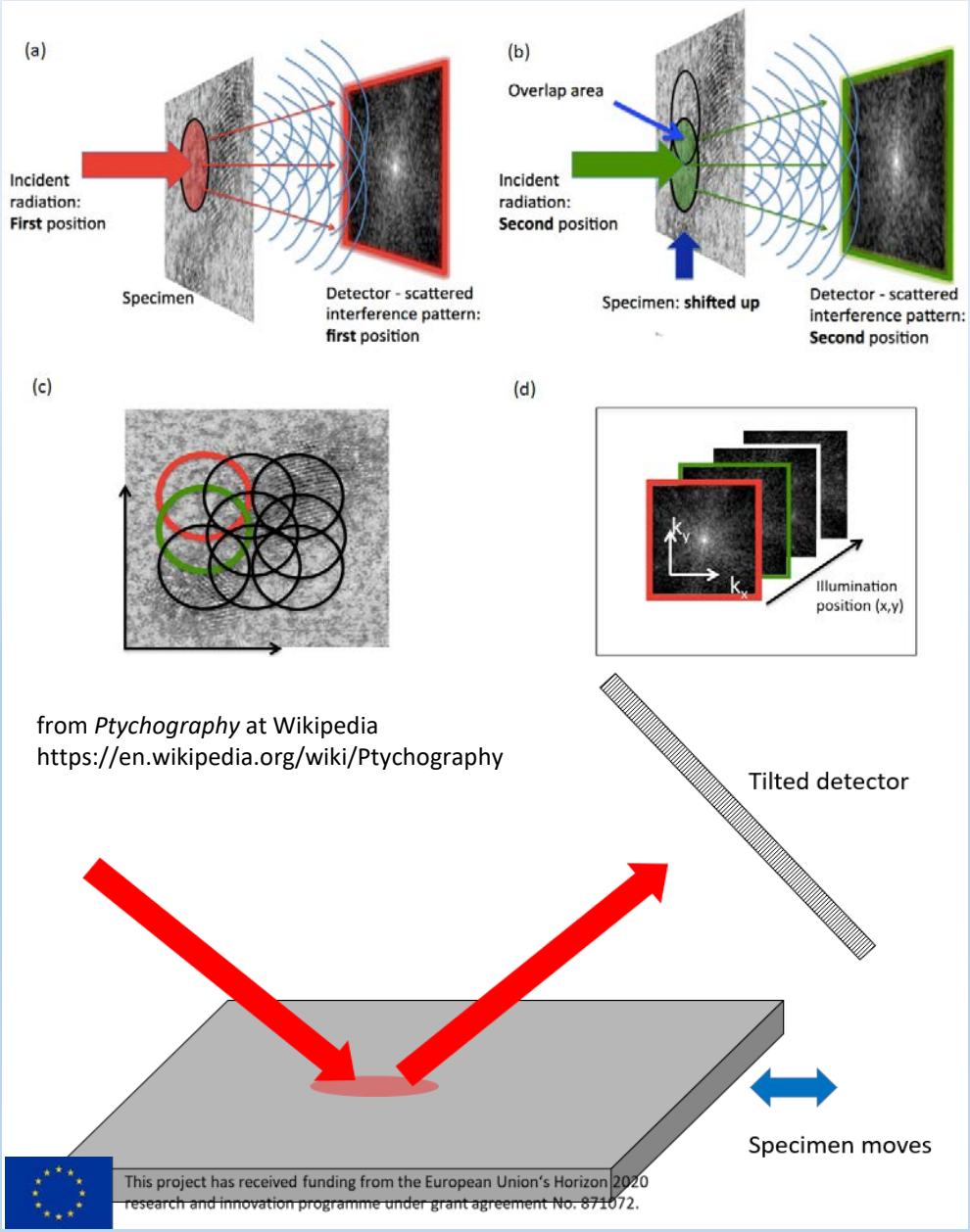
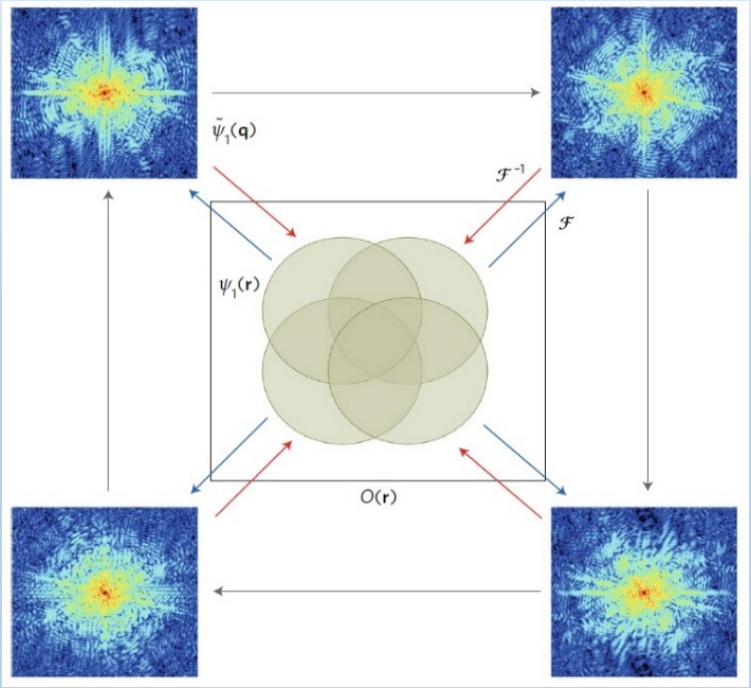
X-ray Bragg ptychography



from *Ptychography* at Wikipedia
https://en.wikipedia.org/wiki/Ptychography

Special requirements are imposed on mechanical and temperature stability, since the slightest mechanical noise is critical during experiments in the sample scanning mode.



Martin Dierolf et al., Ptychography & Lensing X-ray Imaging. Europhysics News, 39, 1, 22-24, 2008

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Concept of optical scheme of nanodiffraction beamline

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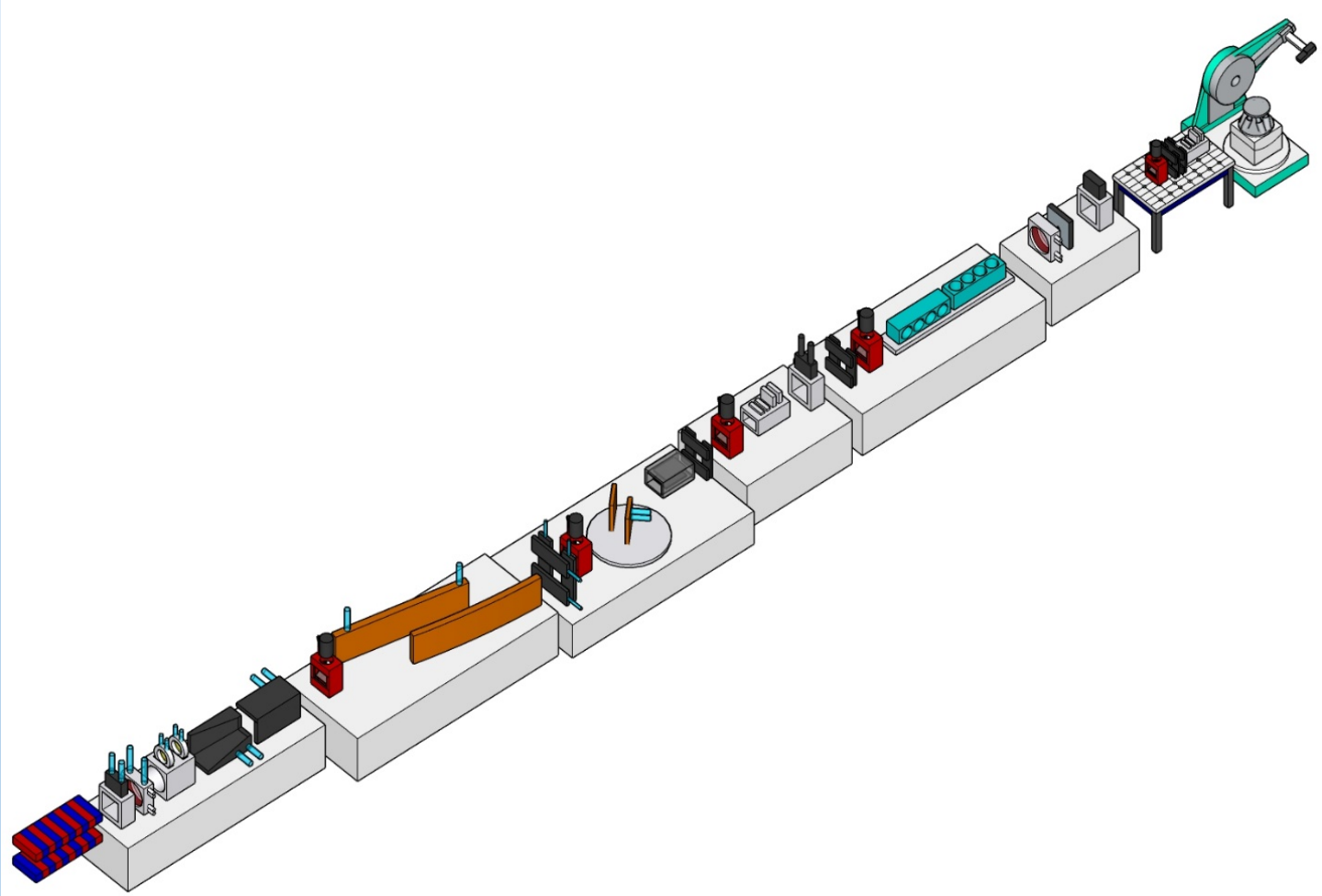

Energy range – 5-40 keV,

Source – undulator

Execution – vacuum path (before diffractometer)

Vacuum windows – diamond

Primary collimation (X-ray mirrors), monochromatization (Si (111)), focusing (CRL refractive lenses)

Secondary focusing - CRL, KB-mirrors, beam size less than 50 nm

Research Instrument - High Precision Diffractometer

Sample environment cameras

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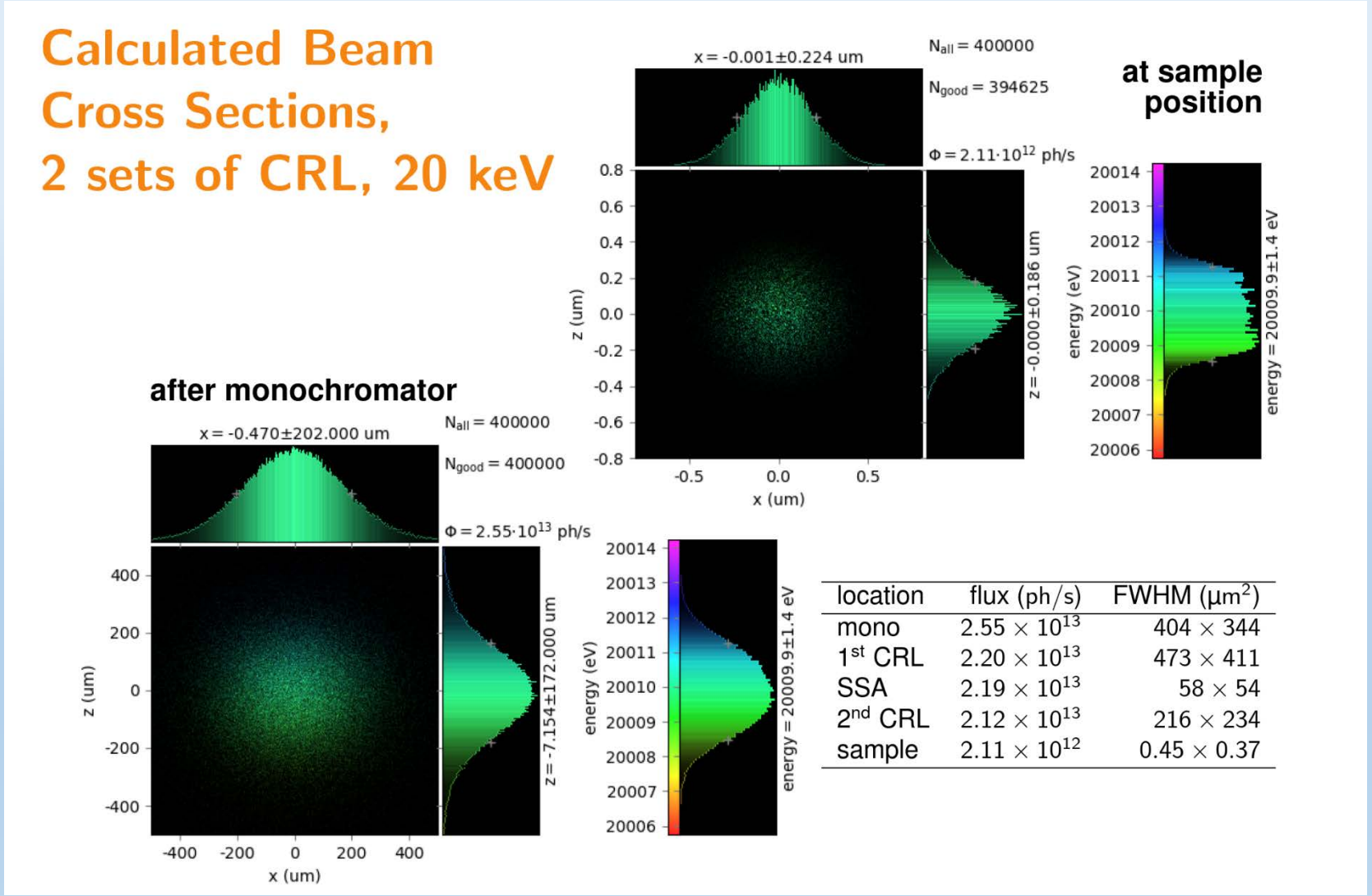
Concept of optical scheme of nanodiffraction beamline



location	flux (ph/s)	FWHM (μm²)
mono	2.55×10^{13}	404×344
1st CRL	2.20×10^{13}	473×411
SSA	2.19×10^{13}	58×54
2nd CRL	2.12×10^{13}	216×234
sample	2.11×10^{12}	0.45×0.37

M. Nentwich et al. Conceptual design of a scattering/diffraction beamline for the Russian synchrotron USSR // IUCr Congress, Prague, 2021

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Conclusion

The nanodiffraction beamline is aimed to carry out structural studies of various materials and nanoscale objects, nanoparticles and microcrystallites, to identify individual defects and structural formations, microstresses and microdeformations with a time resolution of up to fractions of microseconds.

Applications of the beamline's capabilities: materials science, micro- and nanoelectronics, X-ray optics, etc., materials science, physics of nanosystems, physics of condensed matter, nanotechnology, development of new materials with specified characteristics.

The research results are potentially interesting for industry of microelectronics, instrument and mechanical engineering, metallurgy, energetics, space technologies, etc.

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Thank you for your attention

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