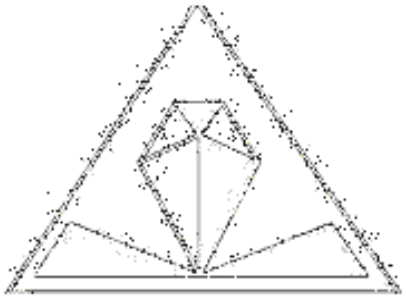


Shubnikov Institute of Crystallography
Russian Academy of Sciences

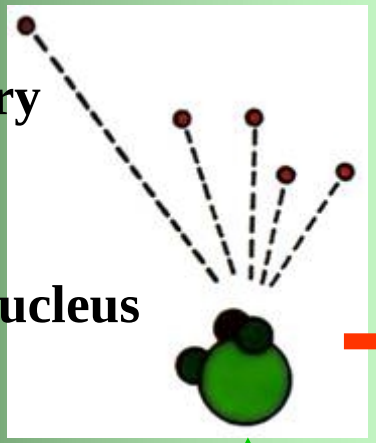
Kurchatov Synchrotron Radiation Center
RRC «Kurchatov Institute»

Synchrotron Radiation:
application in
science and technologies

M.Kovalchuk

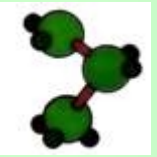
SCIENCE IN 20th CENTURY

elementary particles

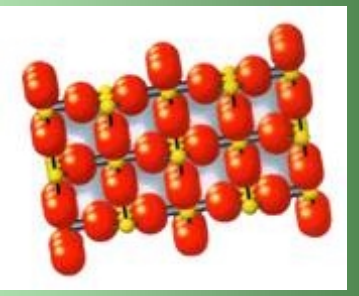


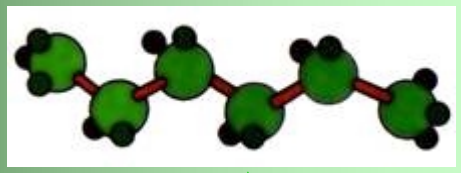
nucleus

atom

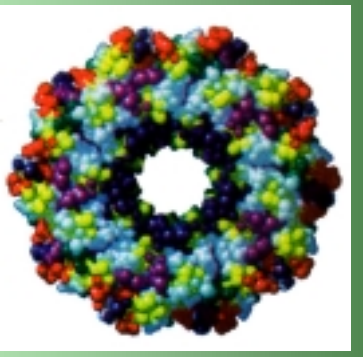


inorganic materials





molecules



organic materials

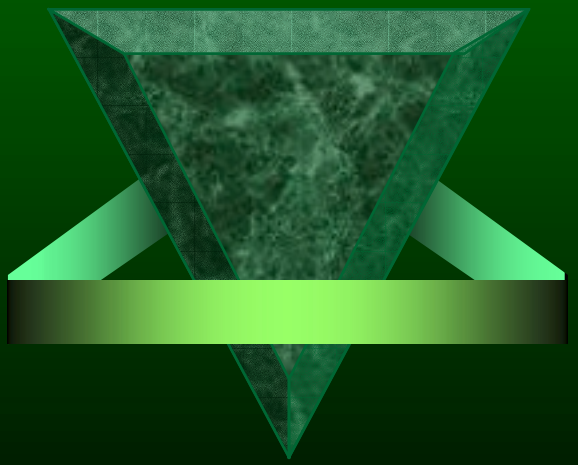
materials

From complexity to simplicity

From simplicity to complexity

SCIENCE IN 20th CENTURY
TRENDS OF DEVELOPMENT

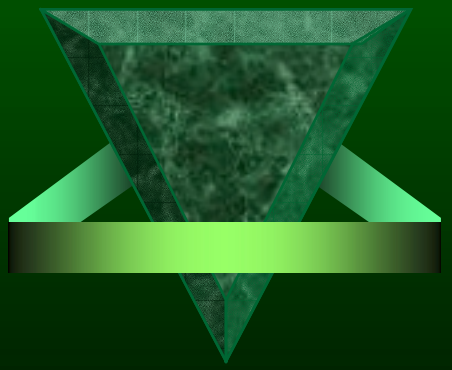
Goal: Penetration into the matter (physics of nucleus and elementary particles)



Large-scale facilities for small groups of experts

SCIENCE IN 21st CENTURY
TRENDS OF DEVELOPMENT

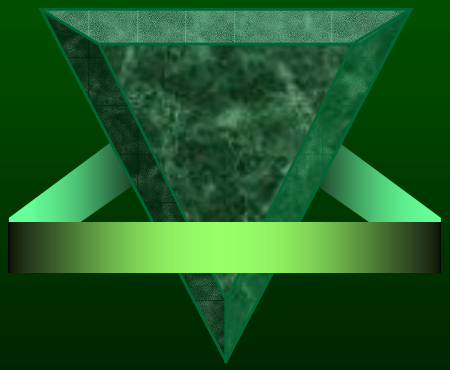
Goal: Synthesis of organic and inorganic materials with given properties



- Atomic and molecular architecture
- Adequate characterization of structure and properties

SCIENCE IN 21st CENTURY
TRENDS OF DEVELOPMENT

Methodology:
Interdisciplinary approach

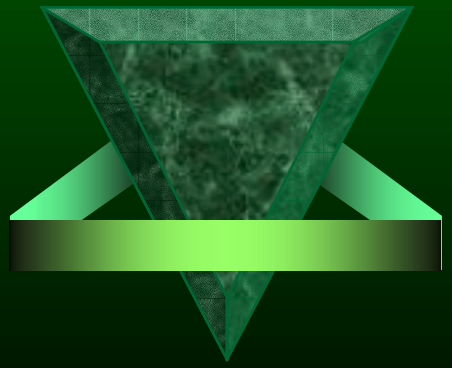


Large-scale facilities
used in different disciplines

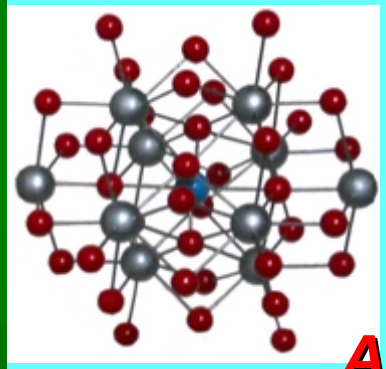
- Neutron sources
- Synchrotron radiation sources

CRYSTALLOGRAPHY

Physics | **Chemistry** | **Geology** | **Biology**

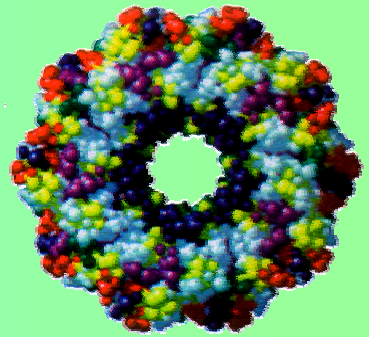


- Growth
- Structure
- Properties



Inorganic materials

Organic materials



ATOMIC and MOLECULAR DESIGN

MOLECULAR BEAM EPITAXY

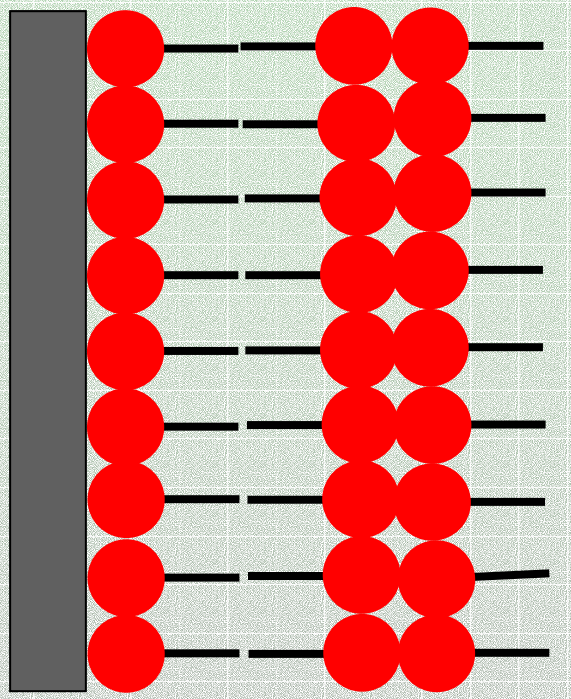
LANGMUIR-BLODGETT METHOD

SELF-ORGANIZATION

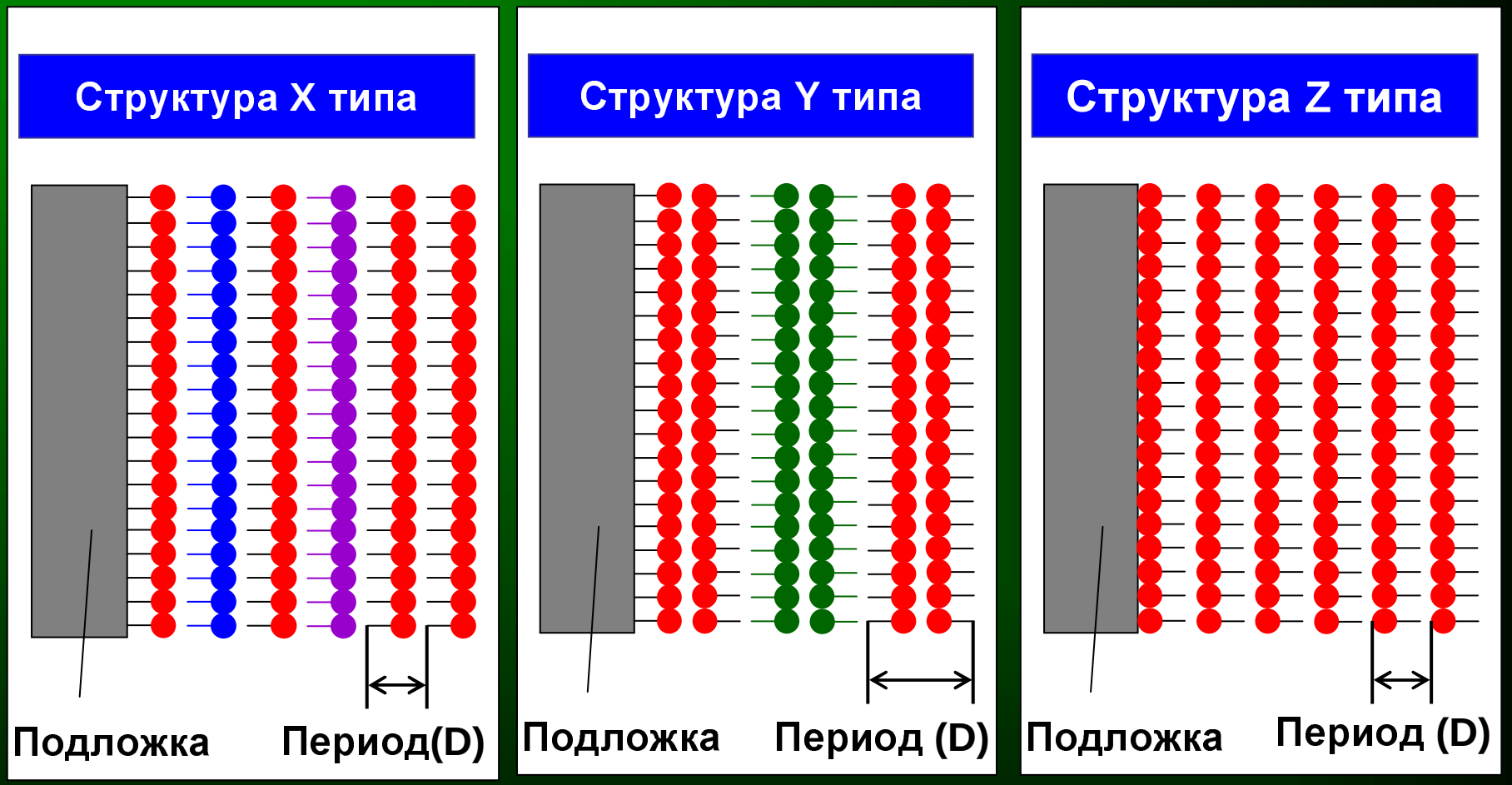
STRUCTURES WITH QUANTUM DOTS

ALIVE NATURE OBJECTS

Multilayer nanofilm

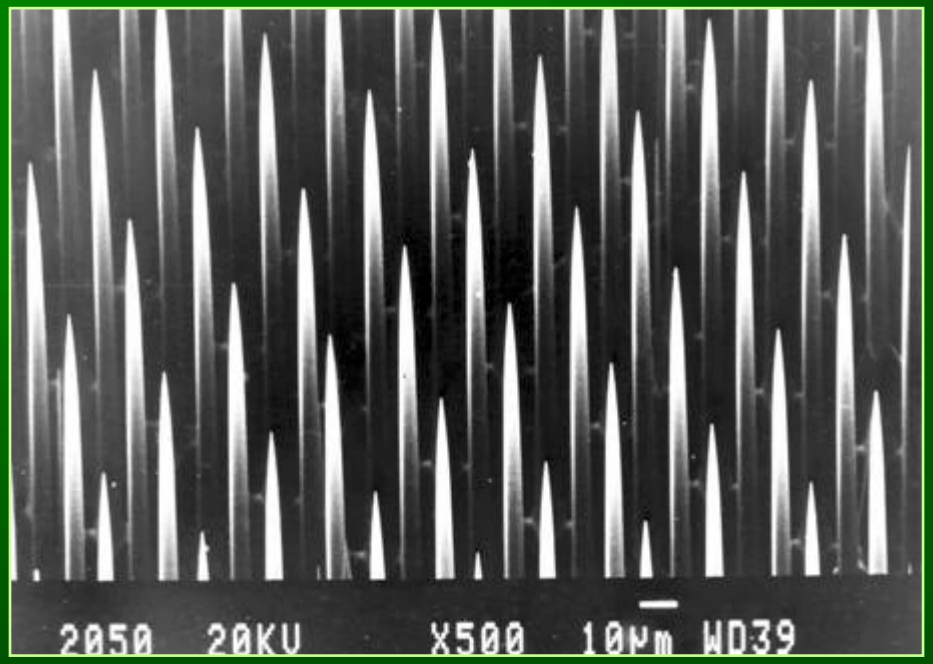


TYPES OF MULTILAYER ORGANIC NANOSTRUCTURES

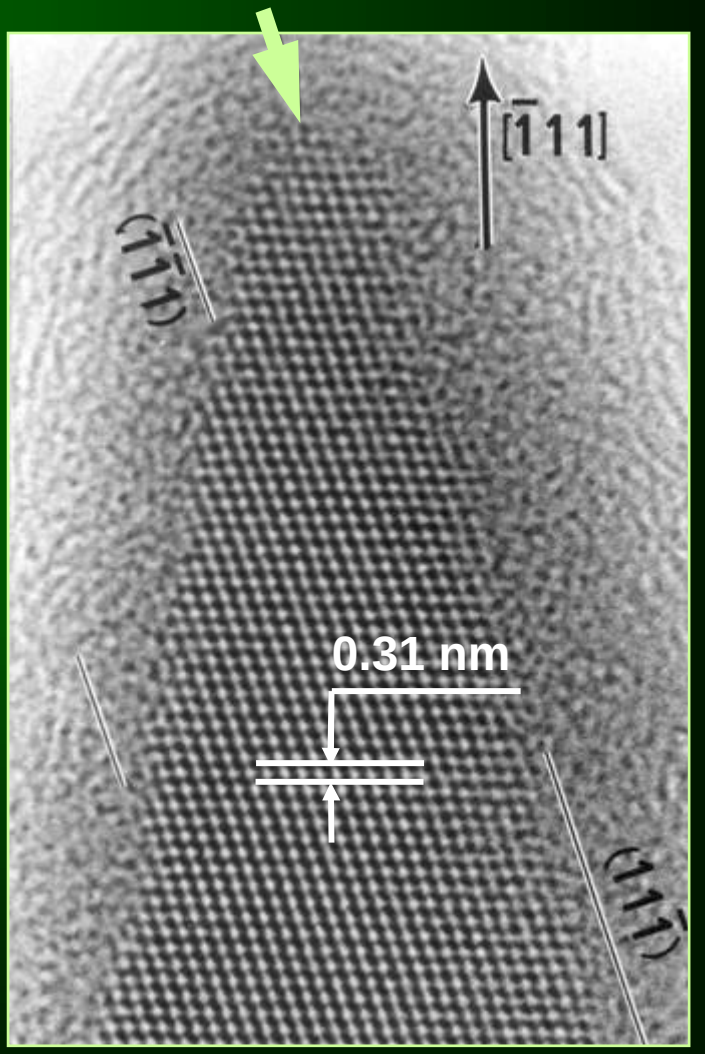


Наноструктуры с различным чередованием слоев и заданными свойствами.

ОСТРИЙНЫЕ НАНОСТРУКТУРЫ

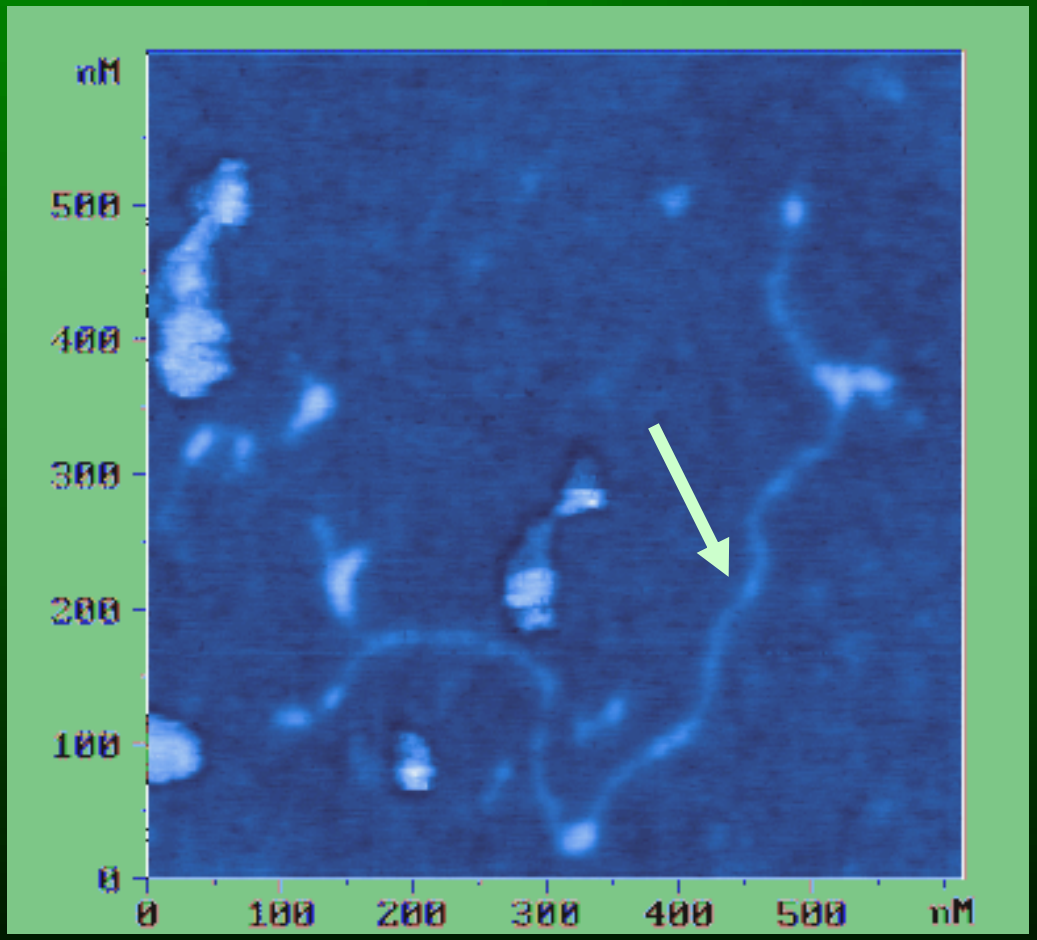


Основа принципиально новых экранов для дисплеев и телевизоров; кантилеверы для зондовой микроскопии; различные эмиттеры.



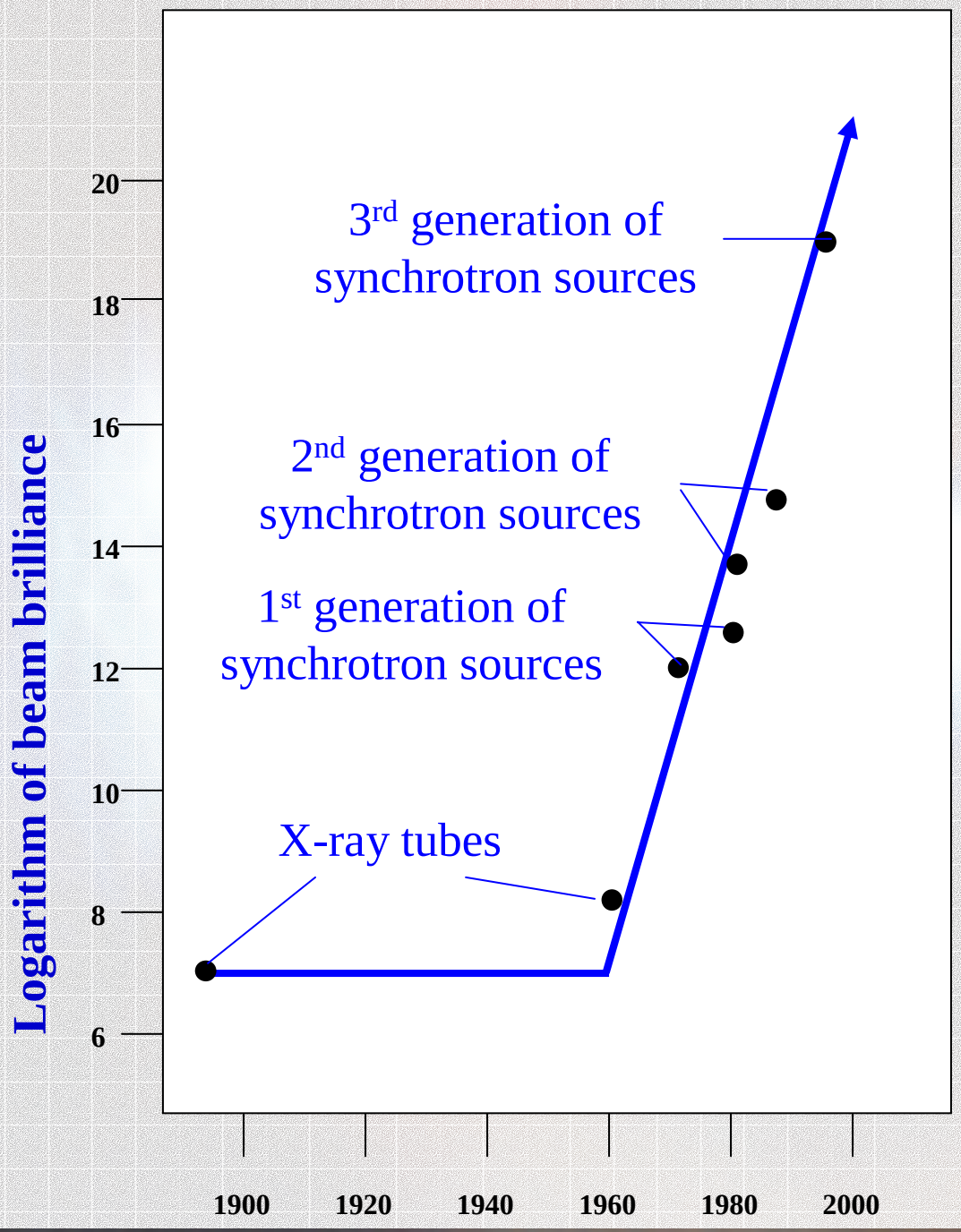
Электронная микроскопия высокого разрешения

АТОМНО-СИЛОВАЯ МИКРОСКОПИЯ БИОЛОГИЧЕСКИХ ОБЪЕКТОВ

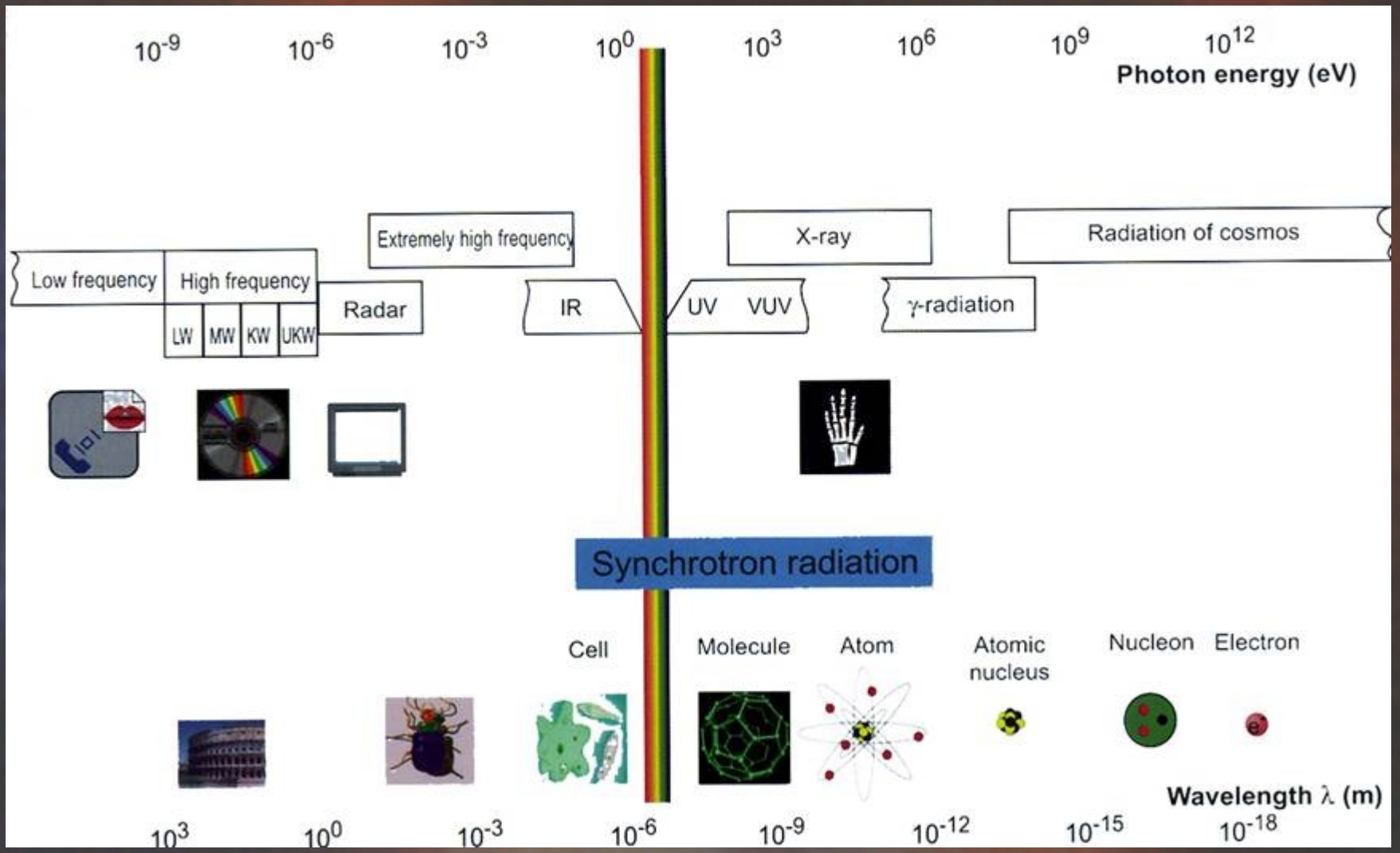


АСМ изображение молекул ДНК на поверхности свежего скола слюды

HISTORY OF X-RAY SOURCES

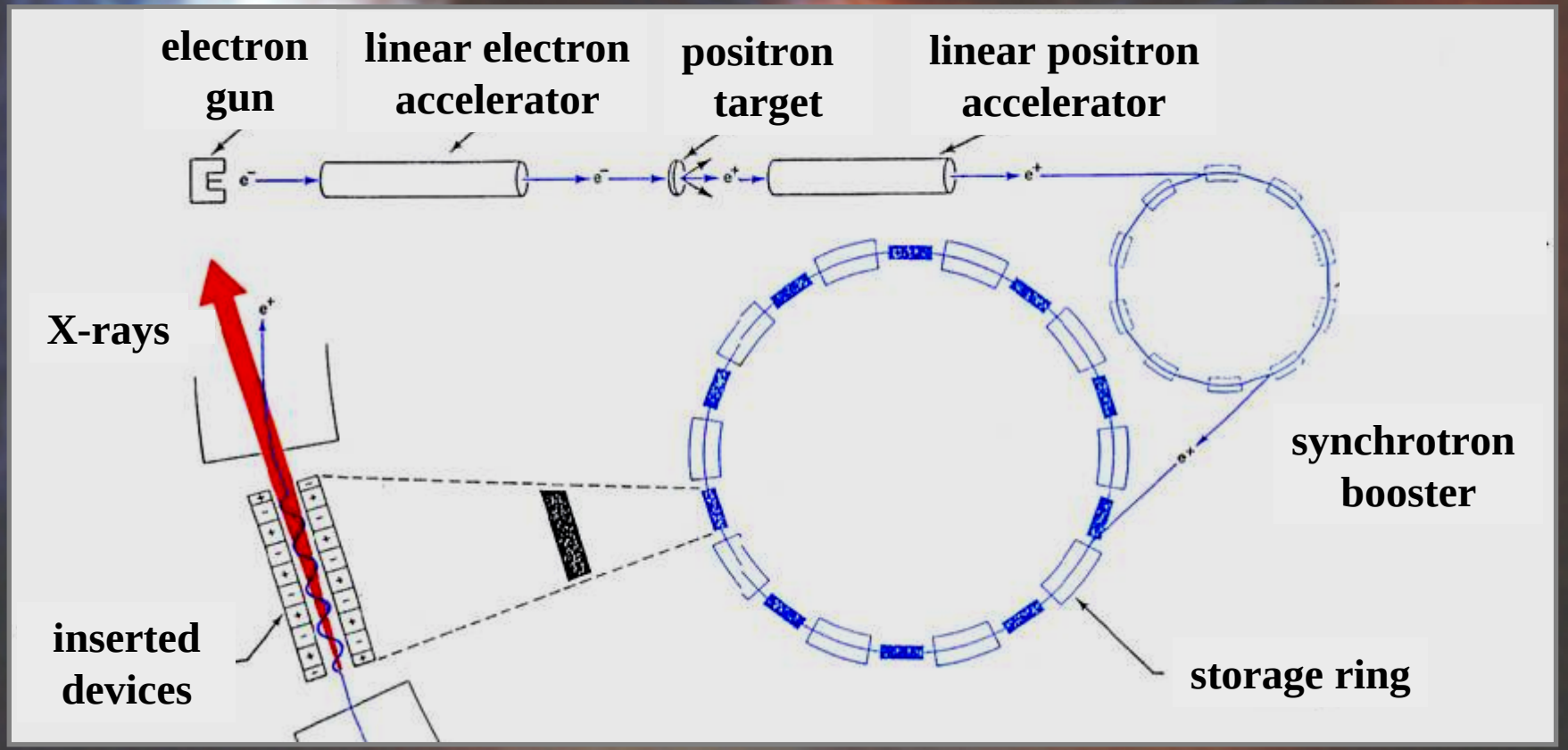


ELECTROMAGNETIC SPECTRUM

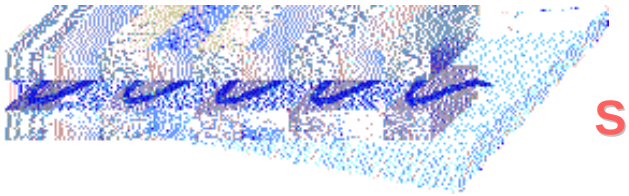


Synchrotron Radiation Sources

SCHEME OF SOURCE OF SYNCHROTRON RADIATION



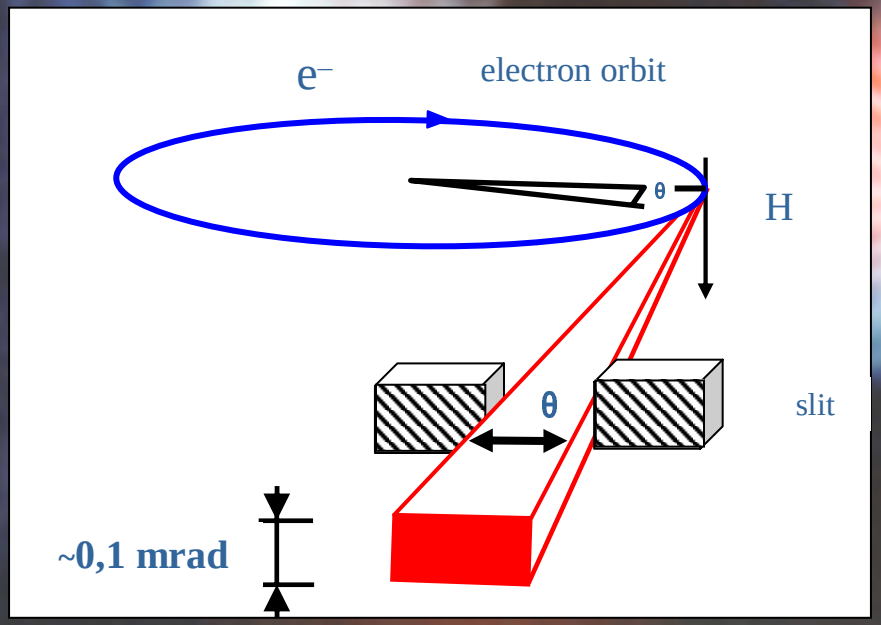
MAGNETIC SYSTEMS FOR GENERATION OF SYNCHROTRON RADIATION

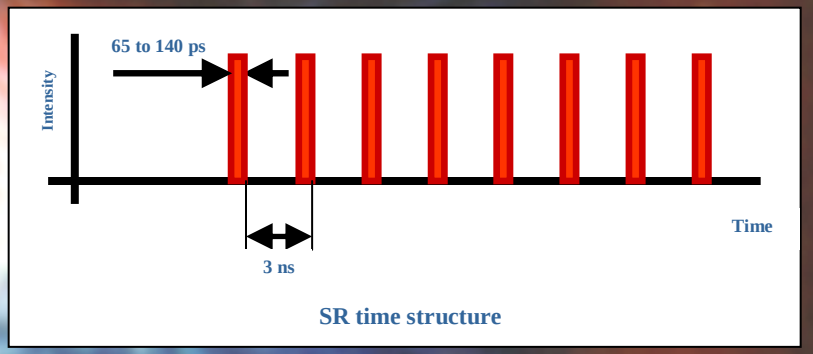


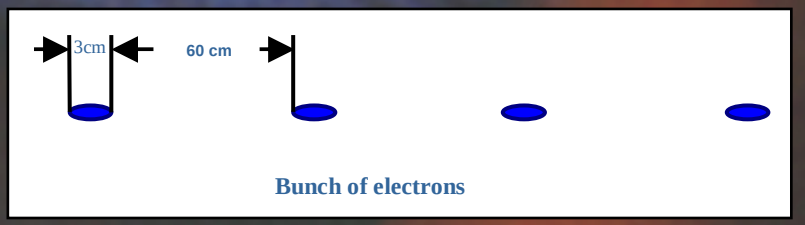
Wiggler

Undulator

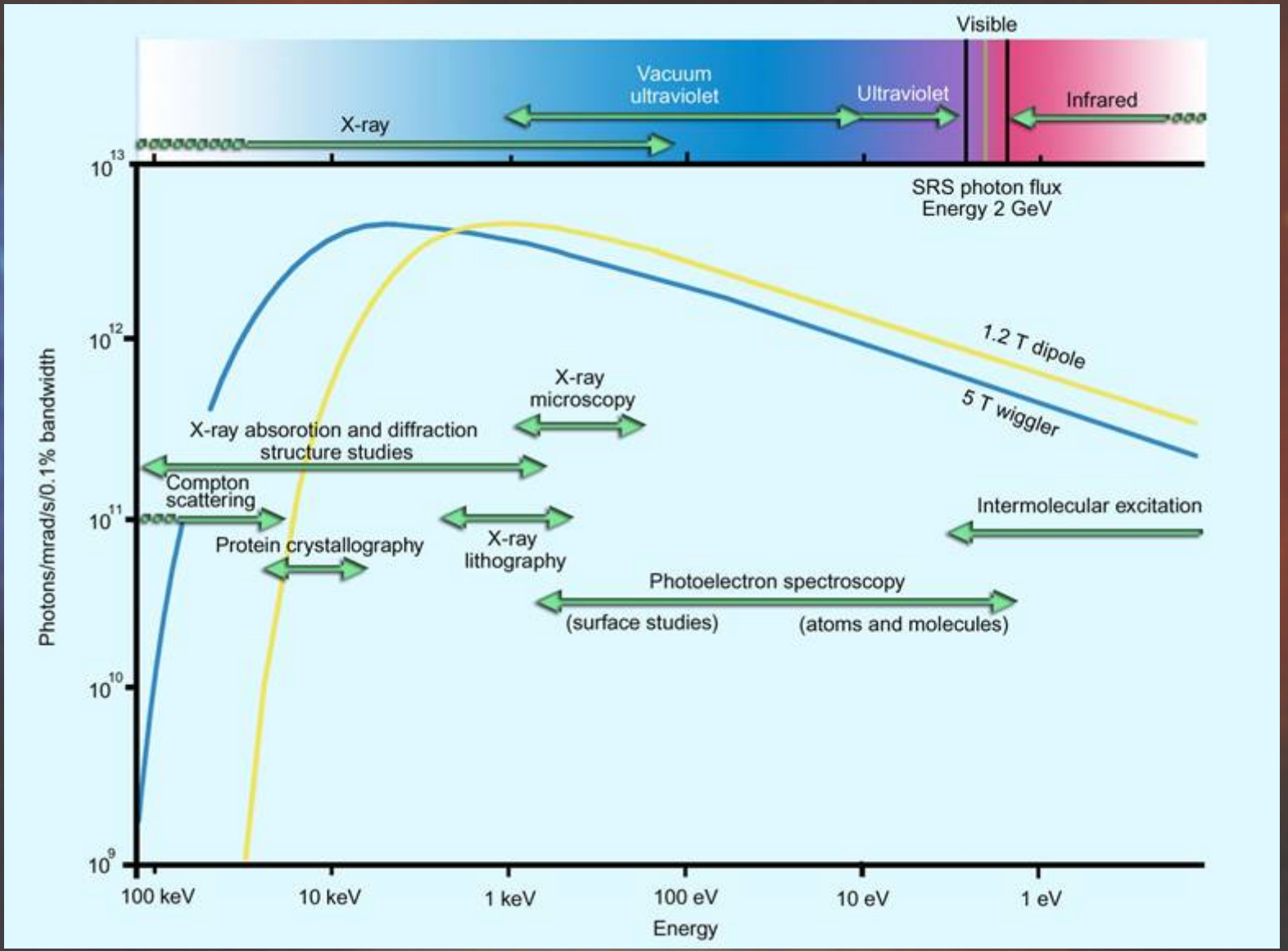
STRUCTURE OF SYNCHROTRON RADIATION





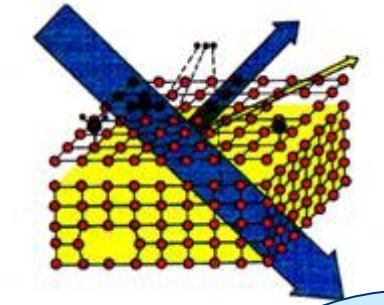


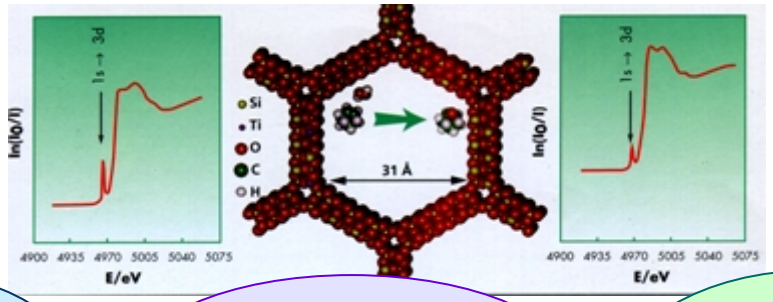
SYNCHROTRON RADIATION

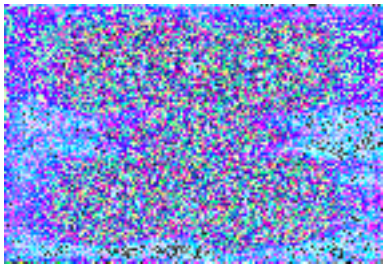


SYNCHROTRON RADIATION. ADVANTAGES

1	Wide spectral range	from infrared to hard γ-radiation
2	High brilliance	10^{10} times higher than brilliance of conventional sources
3	Polarization	polarization vector lies in the orbit plane
4	Time structure	picosecond pulses
5	Natural collimation	0,1 mrad in vertical plane
6	Ultra high vacuum	10^{-7} Pa







K_6C_{60}

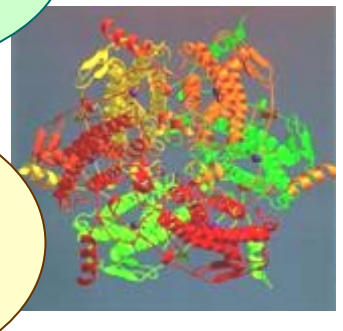
Physics

Chemistry

Materials Science

Synchrotron Radiation

Biotech-nology

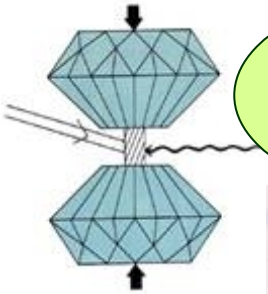


Thermus Thermophilus

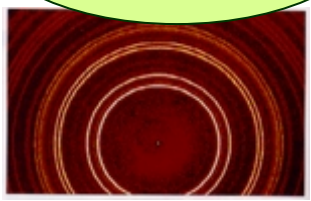
Industry

Archaeology

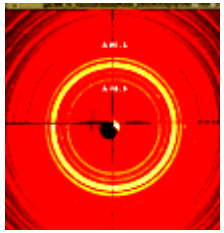
Medicine

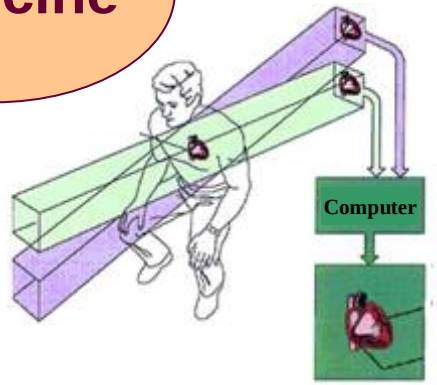


Earth Sciences



HgSe, 2,5 Gpa





SYNCHROTRON RADIATION. FIELDS OF RESEARCH

- Continuous spectrum within large wavelength range
- High flux
- High collimation
- Time structure
- High polarization

SYNCHROTRON RADIATION. FIELDS OF RESEARCH

- **Continuous spectrum within large wavelength range**
  - High flux
  - High collimation
  - Time structure
  - High polarization

- **Anomalous dispersion (scattering near absorption edges)**
- **X-ray spectroscopy near absorption edges of various chemical elements**
- **High-energy X-ray radiation (E>100 keV)**

SYNCHROTRON RADIATION. FIELDS OF RESEARCH

- Continuous spectrum within large wavelength range
- **High flux**
- High collimation
- Time structure
- High polarization

- **Study of small samples (10^{-3} - 10^{-5} μm³)**
- **Study of weakly scattering objects (surfaces, interfaces, thin films)**
- **Localization of atoms**
- **Study of bulky and strongly absorptive samples**
- **Diffraction study of imperfect crystals (diffraction at $\Theta \approx \pi/2$)**
- **Short exposures**
- **Experiments in real time (kinetics of processes)**

SYNCHROTRON RADIATION. FIELDS OF RESEARCH

- Continuous spectrum within large wavelength range
- High flux
- **High collimation**
- Time structure
- High polarization

- **High-resolution X-ray diffraction methods**
- **Interference phenomena (interferometers, waveguides, etc.)**
- **Fluorescence analysis**
- **Phase-sensitive methods and X-ray holography**

SYNCHROTRON RADIATION. FIELDS OF RESEARCH

- Continuous spectrum within large wavelength range
- High flux
- High collimation
- **Time structure**
- High polarization

- **Stroboscopy (study of fast and periodic processes)**
- ***In situ* study of processes**

SYNCHROTRON RADIATION. FIELDS OF RESEARCH

- Continuous spectrum within large wavelength range
- High flux
- High collimation
- Time structure
- **High polarization**

- **Study of magnetic structure**

RUSSIAN RESEARCH CENTER
«KURCHATOV INSTITUTE»

Kurchatov Synchrotron Radiation Center

Kurchatov sq., 1
Moscow, 123182,
Russia
Tel.: (095) 196 71 10
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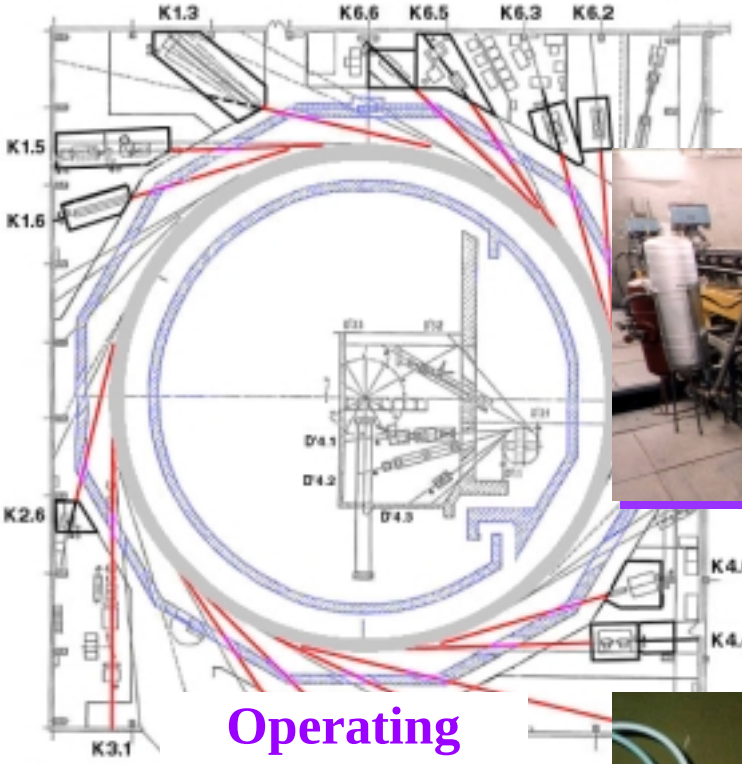
E-mail: kvard@kiae.ru

RUSSIAN RESEARCH CENTER «KURCHATOV INSTITUTE»

Kurchatov Synchrotron Radiation Center



Linear accelerator

Large storage ring

Small storage ring

Operating room

RUSSIAN RESEARCH CENTER «KURCHATOV INSTITUTE»

Kurchatov Synchrotron Radiation Center

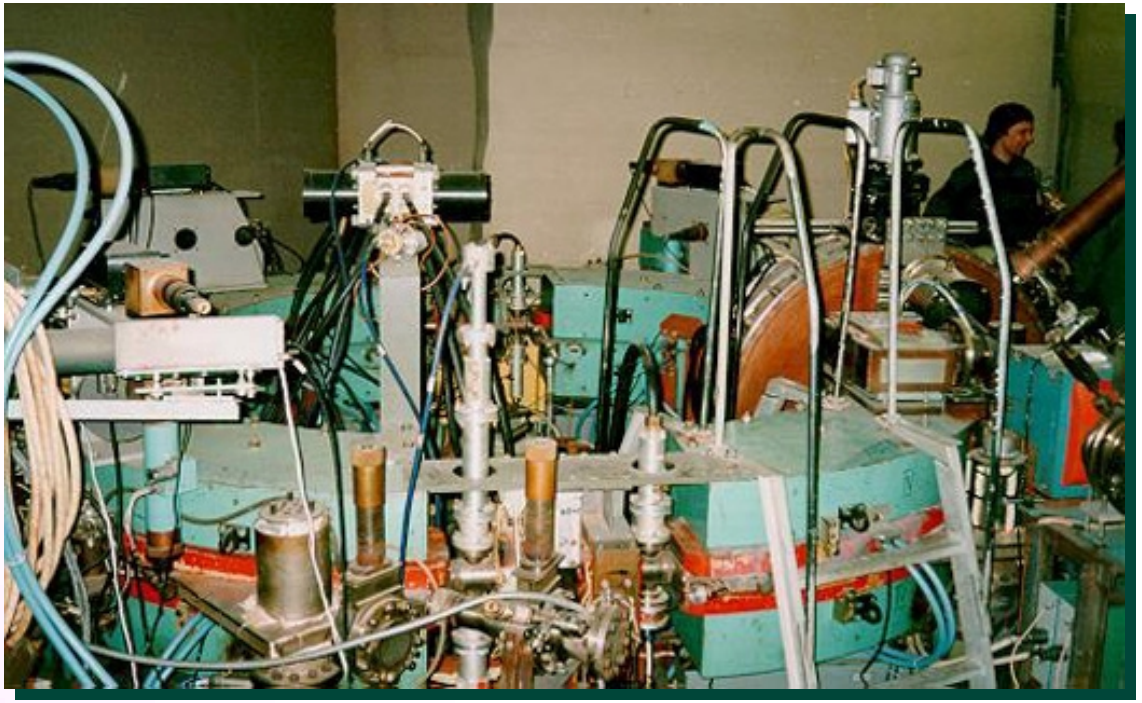
Linear accelerator

Electrons are accelerated to an energy of 100 MeV

RUSSIAN RESEARCH CENTER «KURCHATOV INSTITUTE»

Kurchatov Synchrotron Radiation Center

Small storage ring SIBERIA-1



- **The diameter is 3 m**
- **The source of SR in the VUV and soft X-ray ranges**
- **Electrons are accelerated to 450 MeV**
- **3 experimental stations**

- **The booster synchrotron injector for Siberia-2**

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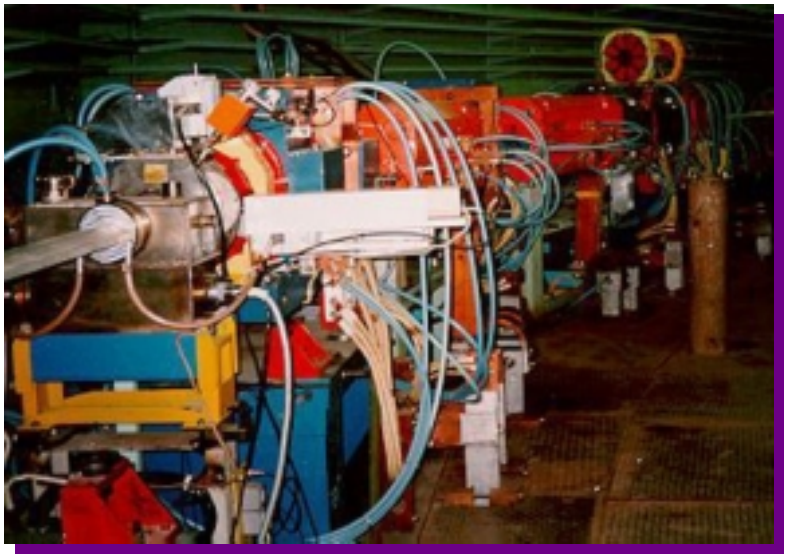
Kurchatov Synchrotron Radiation Center

Large storage ring SIBERIA-2

- **The diameter is 40 m**
- **The source of X-ray range of wavelengths**
- **Electrons are accelerated to 2.5 GeV**
- **39 points for beamlines**



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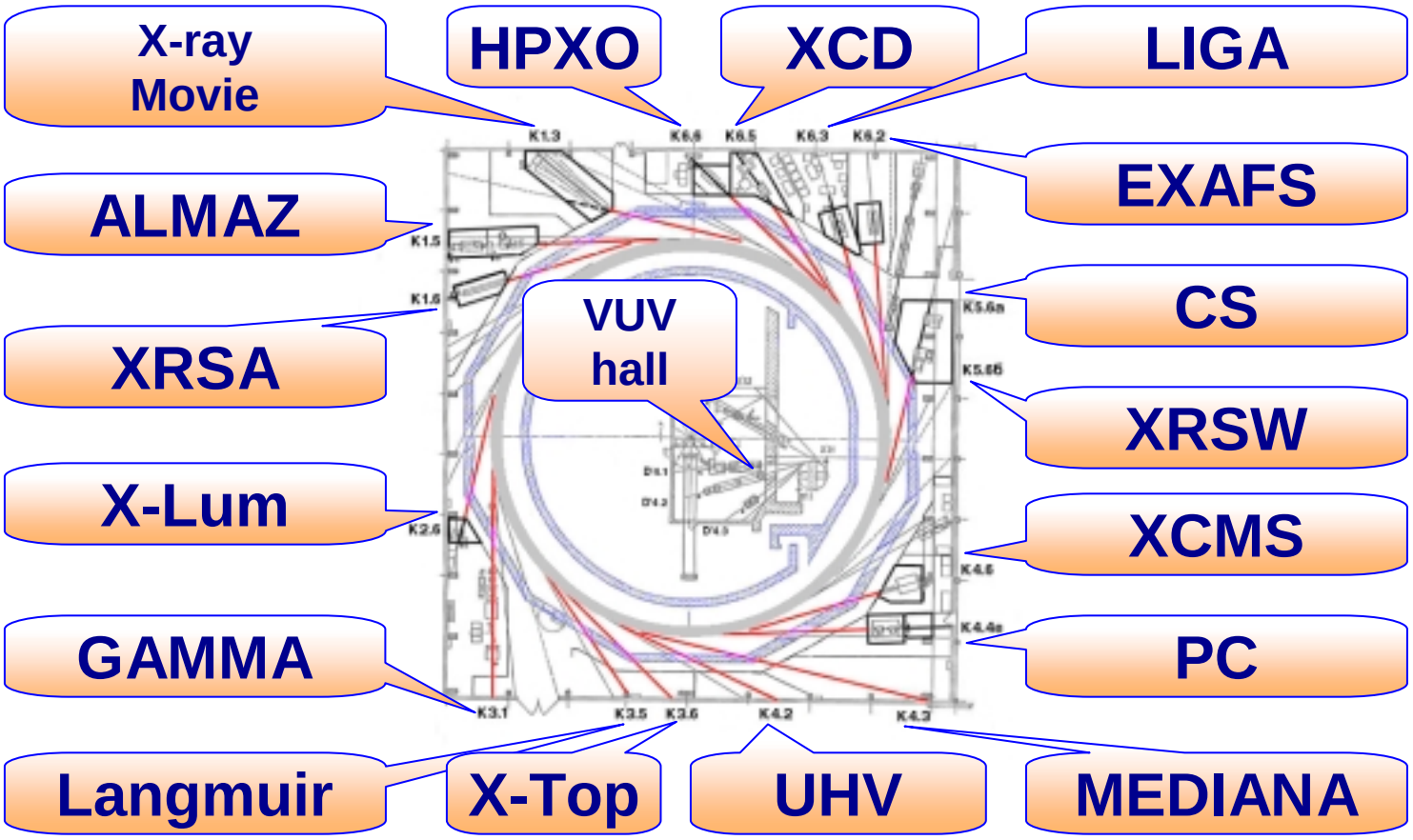
Kurchatov Synchrotron Radiation Center

EXPERIMENTAL STATIONS



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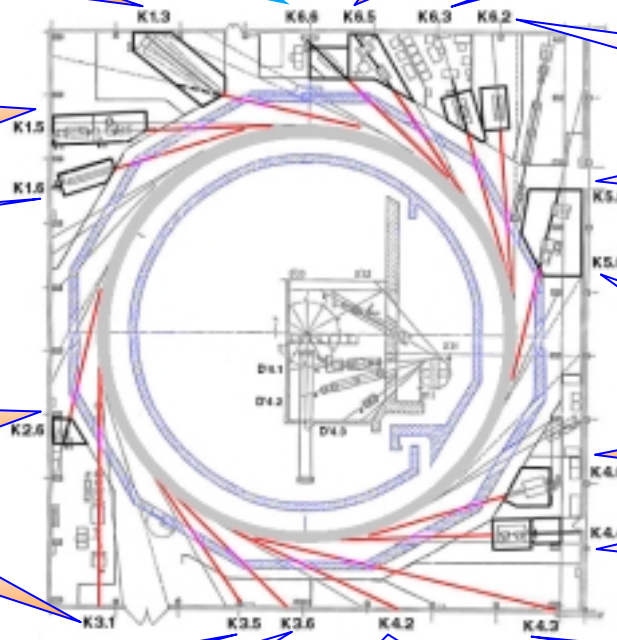
Kurchatov Synchrotron Radiation Center

HPXO

station for high-precision X-ray optics



Movie

XCD

LIGA

ALMAZ

EXAFS

XRSA

CS

X-Lum

XRSW

GAMMA

XCMS

Langmuir

PC

X-Top

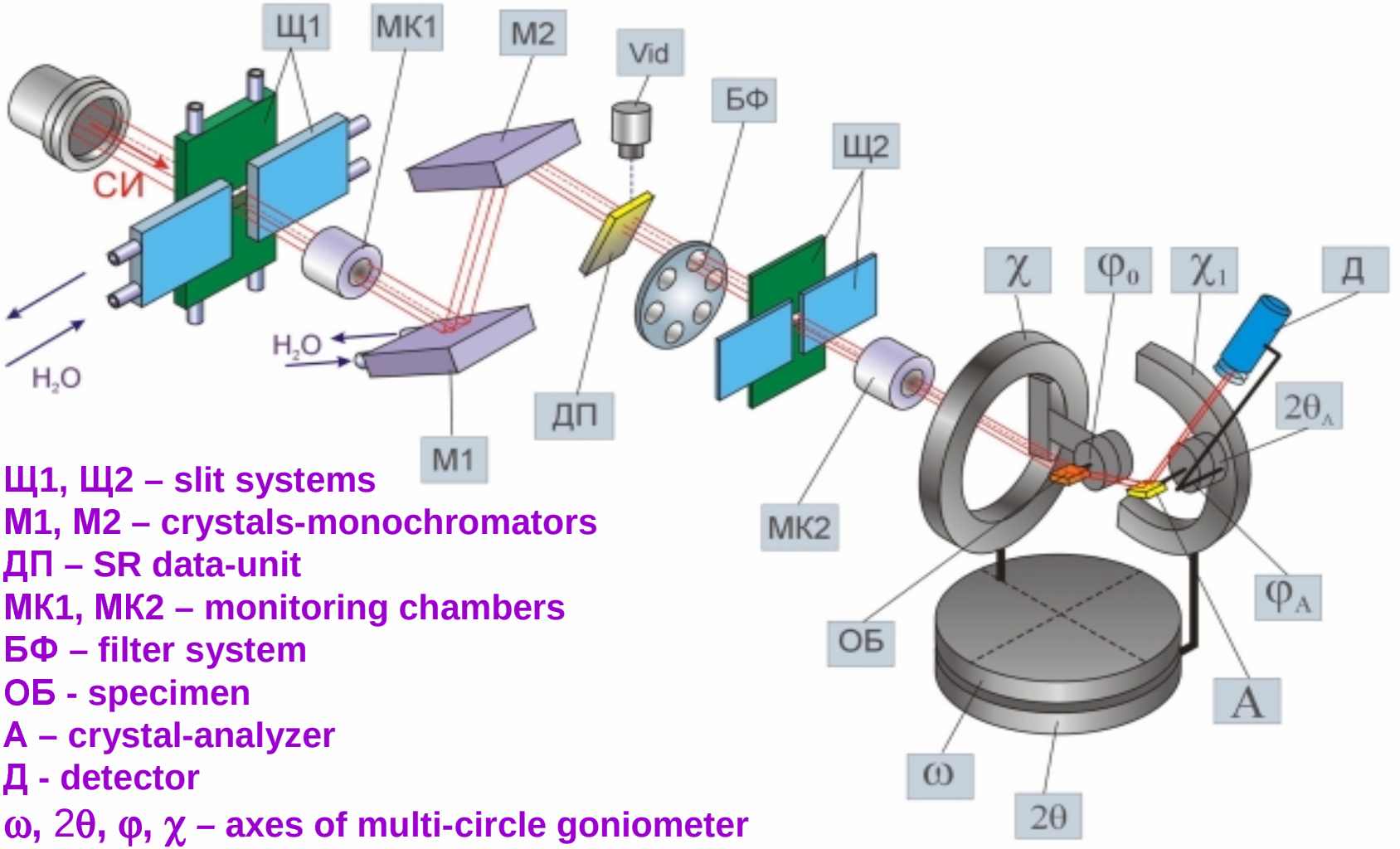
UHV

MEDIANA

STATION FOR HIGH-PRECISION X-RAY OPTICS

К 6.6

НРХО

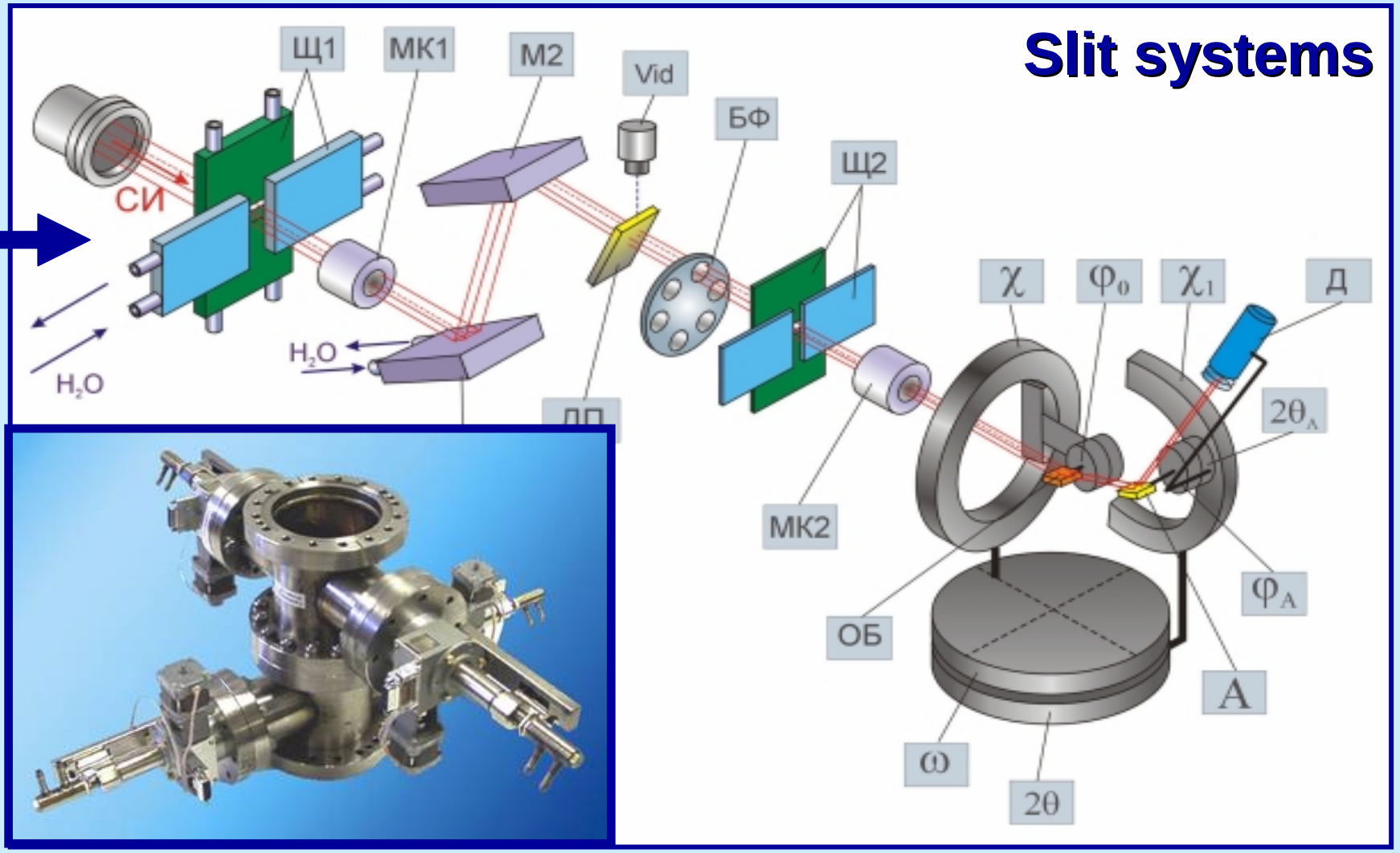


Щ1, Щ2 – slit systems
М1, М2 – crystals-monochromators
ДП – SR data-unit
МК1, МК2 – monitoring chambers
БФ – filter system
ОБ - specimen
А – crystal-analyzer
Д - detector
ω, 2θ, φ, χ – axes of multi-circle goniometer

STATION FOR HIGH-PRECISION X-RAY OPTICS

К 6.6

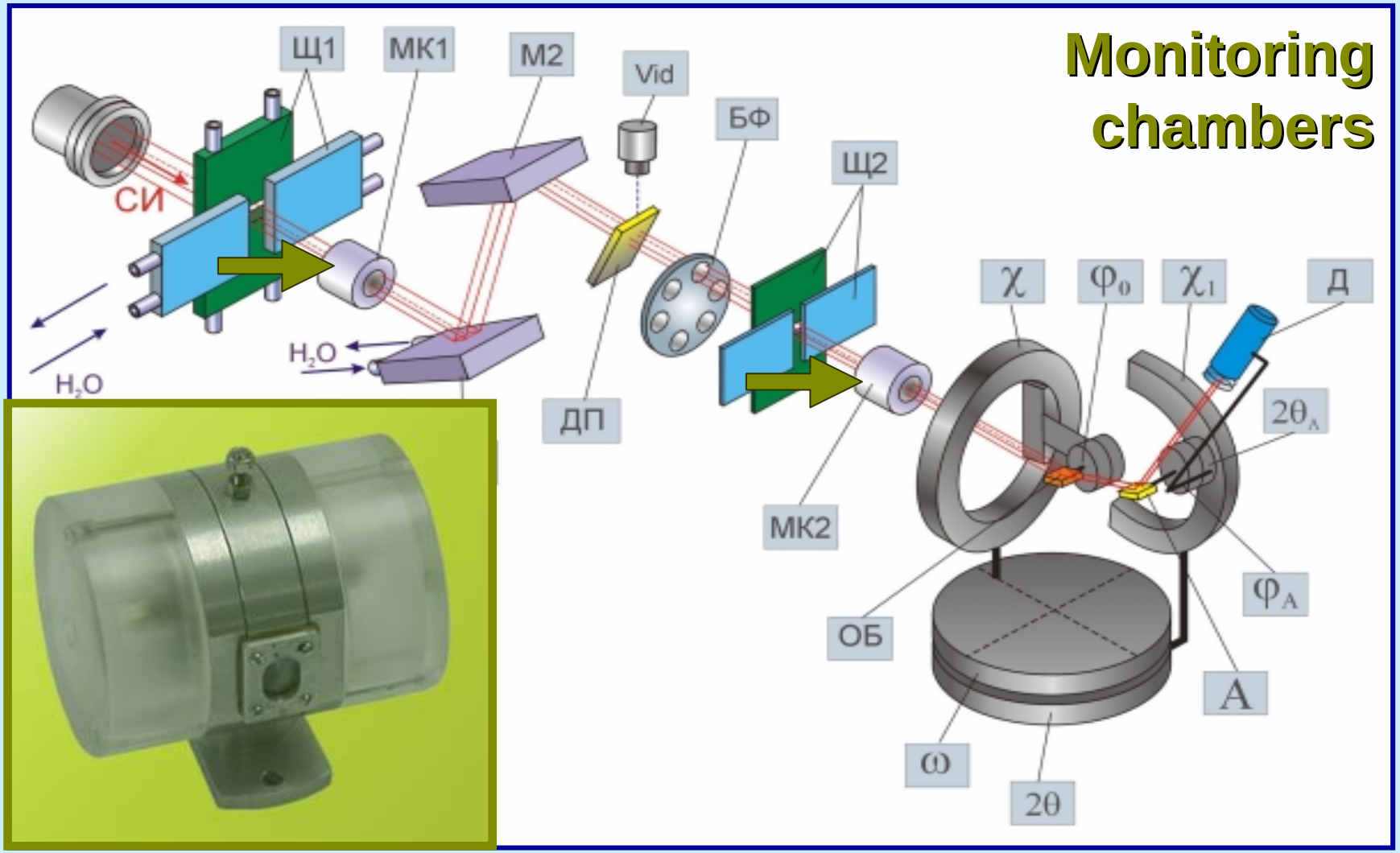
НРХО



STATION FOR HIGH-PRECISION X-RAY OPTICS

К 6.6

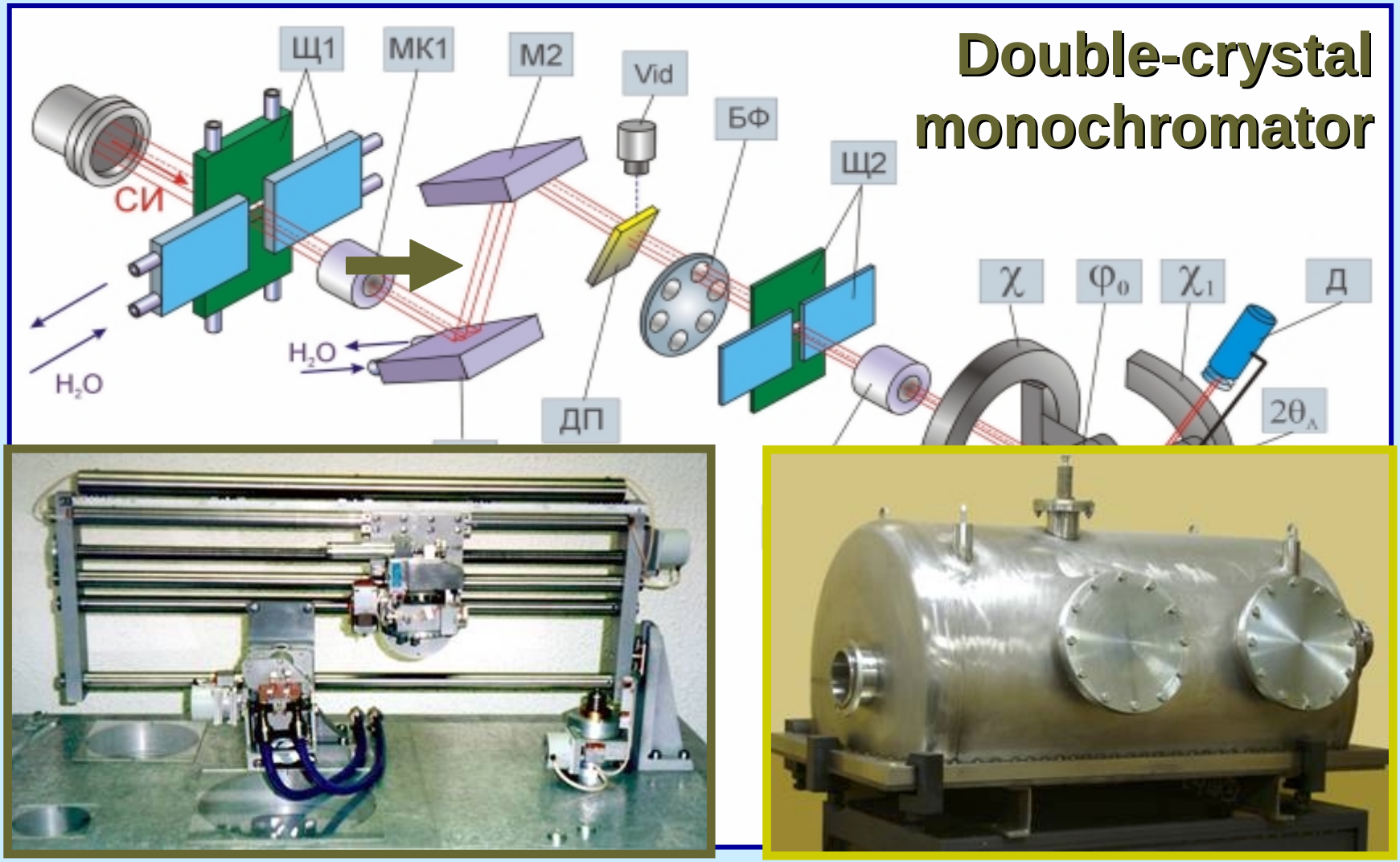
НРХО



STATION FOR HIGH-PRECISION X-RAY OPTICS

К 6.6

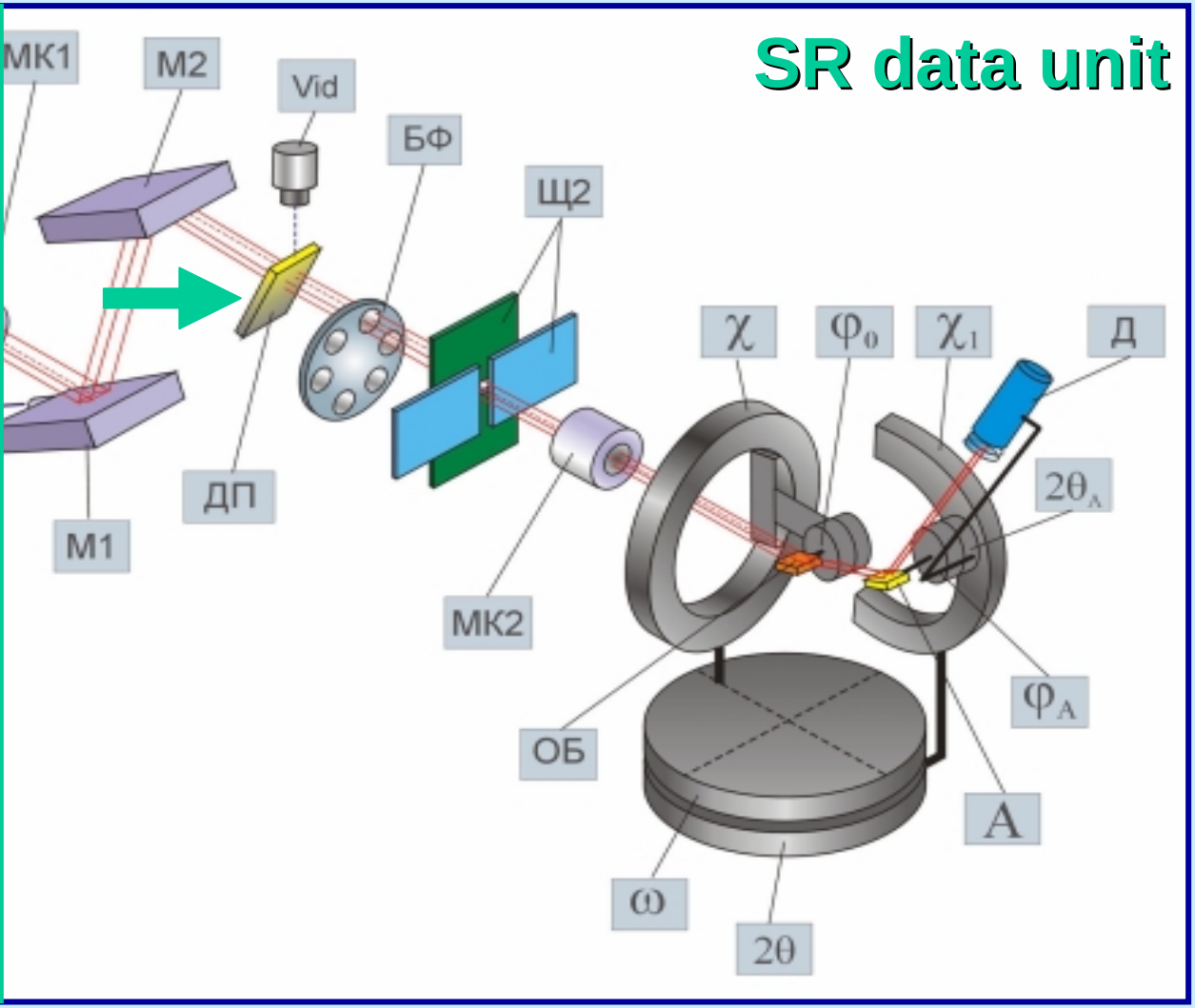
НРХО



STATION FOR HIGH-PRECISION X-RAY OPTICS

К 6.6

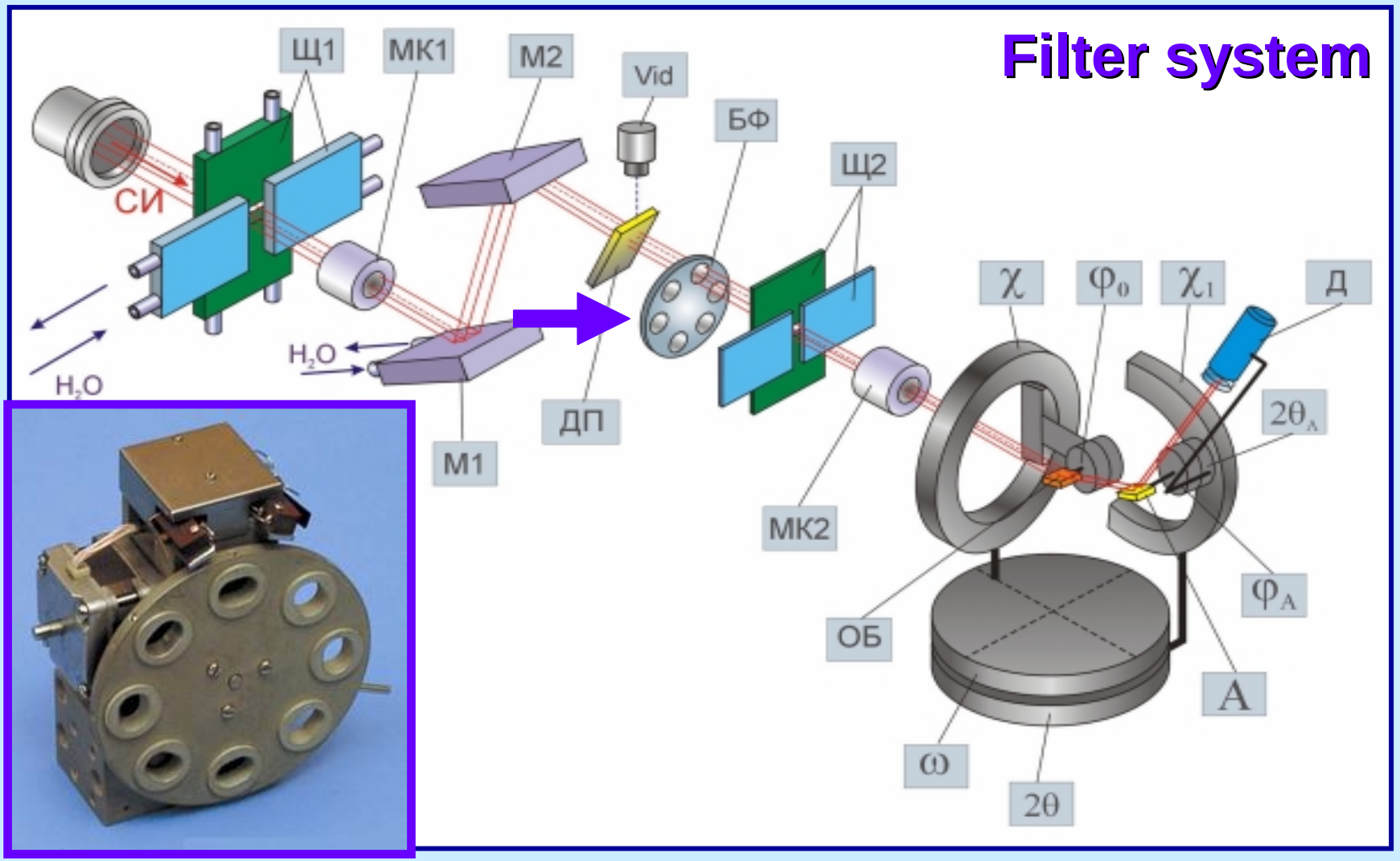
НРХО



STATION FOR HIGH-PRECISION X-RAY OPTICS

К 6.6

НРХО



STATION FOR HIGH-PRECISION X-RAY OPTICS

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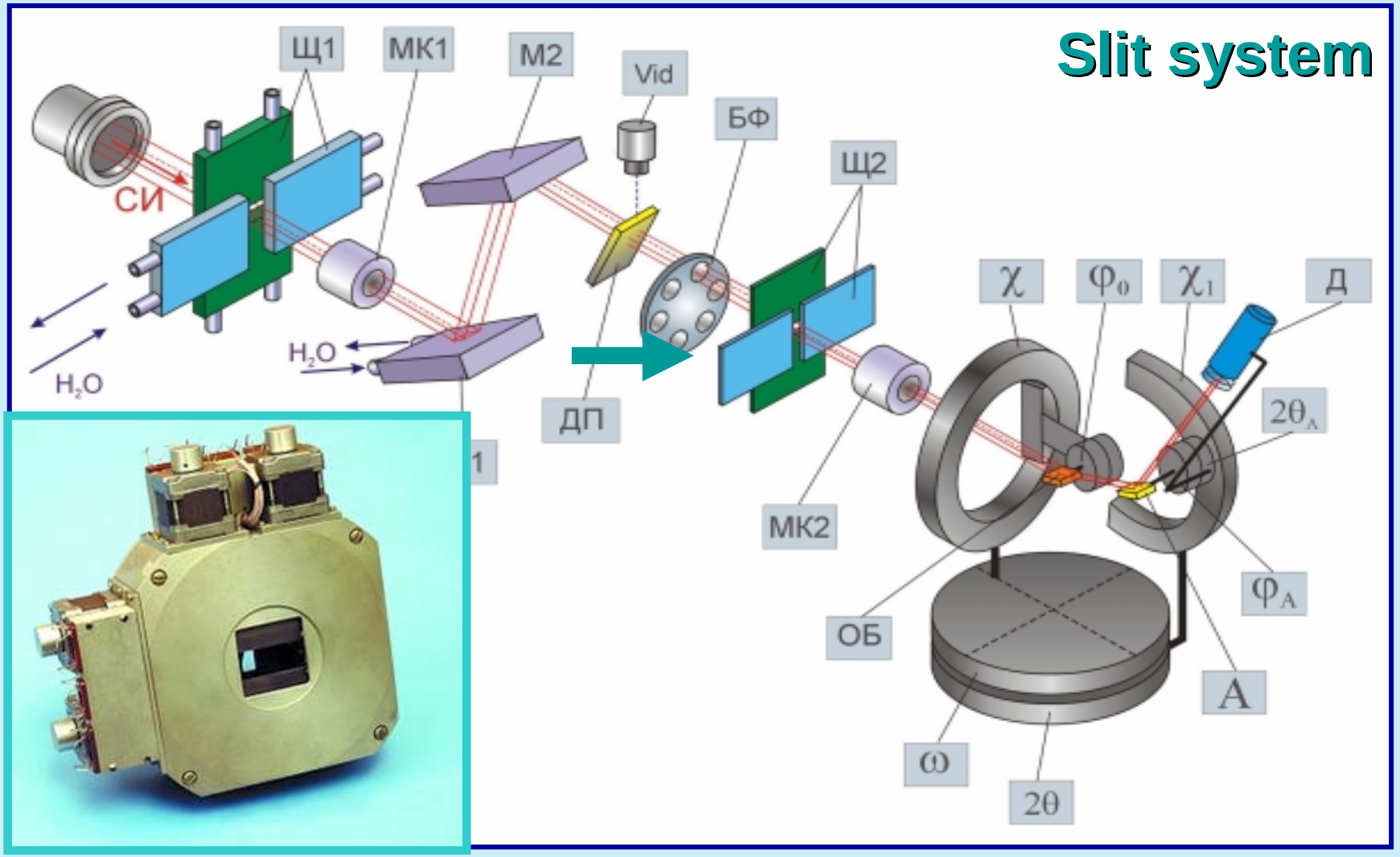
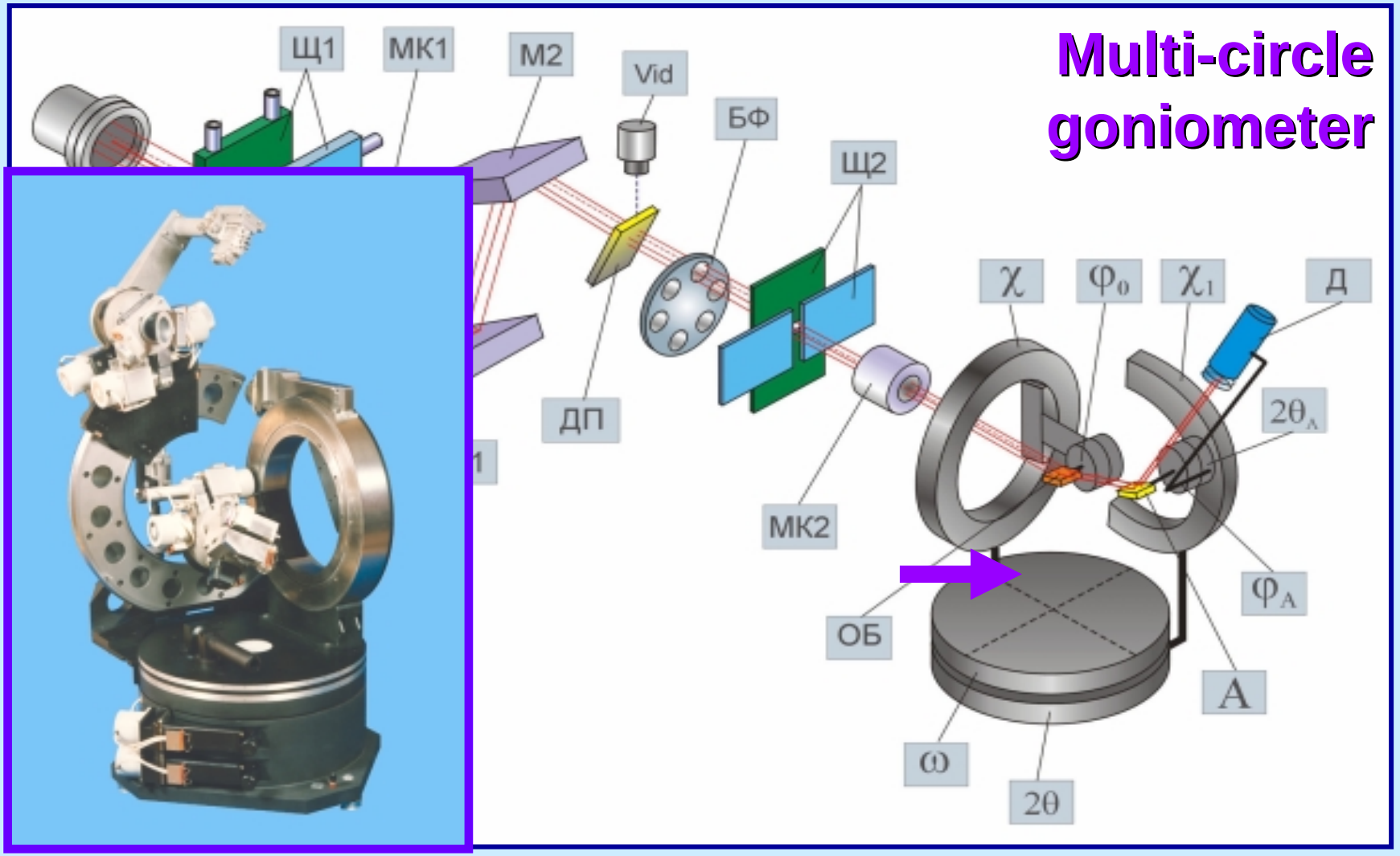


STATION FOR HIGH-PRECISION X-RAY OPTICS

К 6.6

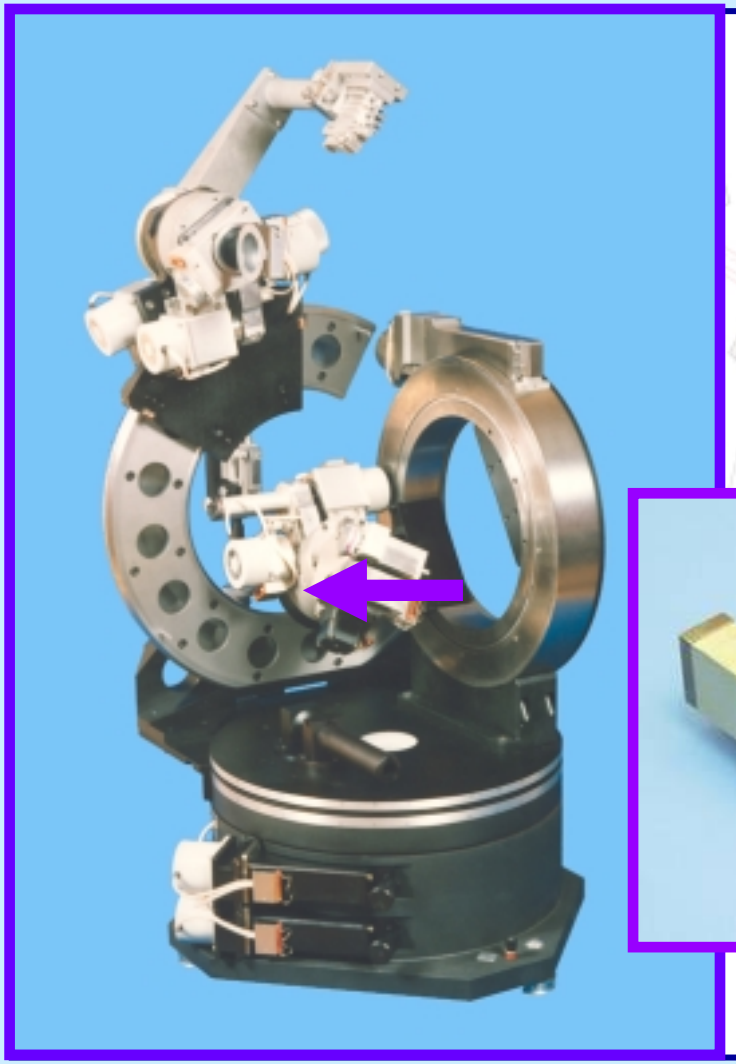
НРХО



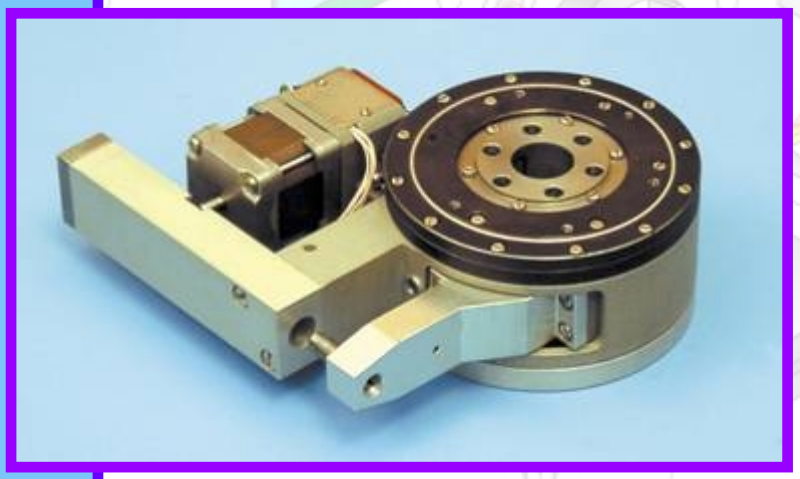
STATION FOR HIGH-PRECISION X-RAY OPTICS

К 6.6

НРХО



High-precision one-circle torsion goniometer



STATION FOR HIGH-PRECISION X-RAY OPTICS

K 6.6

HPXO

INTERACTION OF X-RAYS WITH CONDENSED MATTER

MAIN FEATURES

- Scattering on electrons
- Big penetration depth
- Absorption – photoeffect

Reflection index < 1

⇩

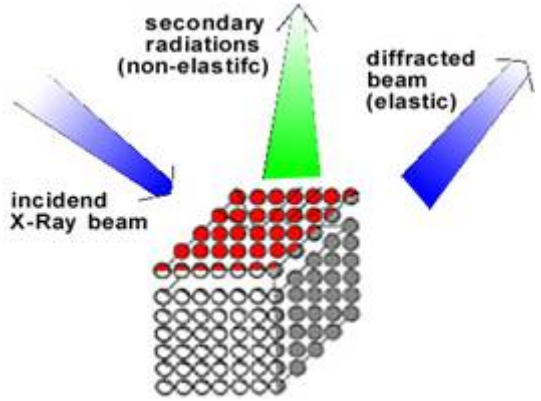
TOTAL EXTERNAL REFLECTION

Wave length (λ) – crystal lattice parameter

⇩

DIFFRACTION

SPECTROSCOPY



DIFFRACTION

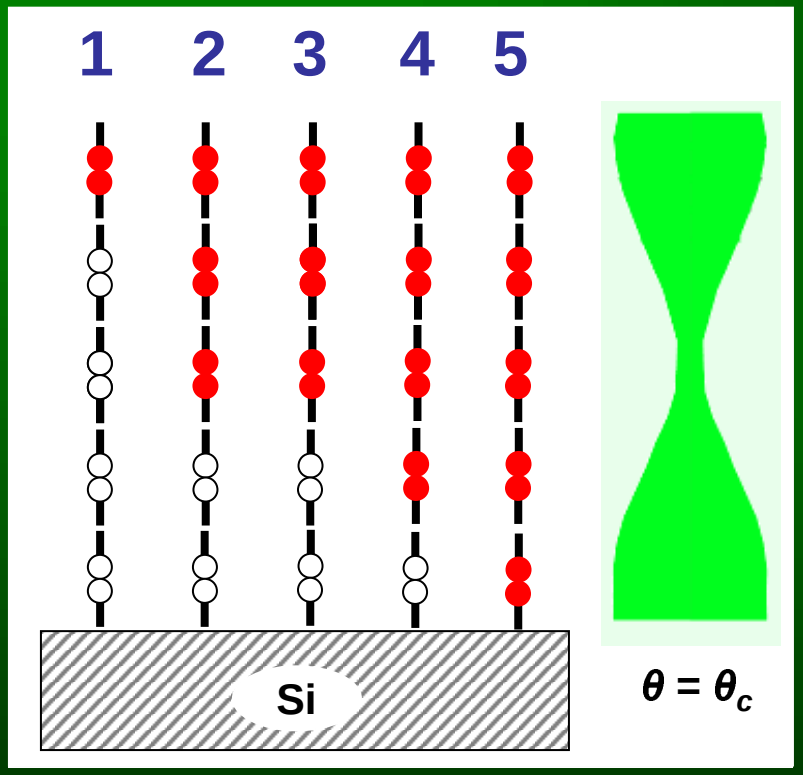
PROBLEMS

Separation of weak surface signal on the high X-ray scattering back-ground from the bulk

Weak signal measurement: ultra thin layer, very mall scattering volume, small amount of atoms

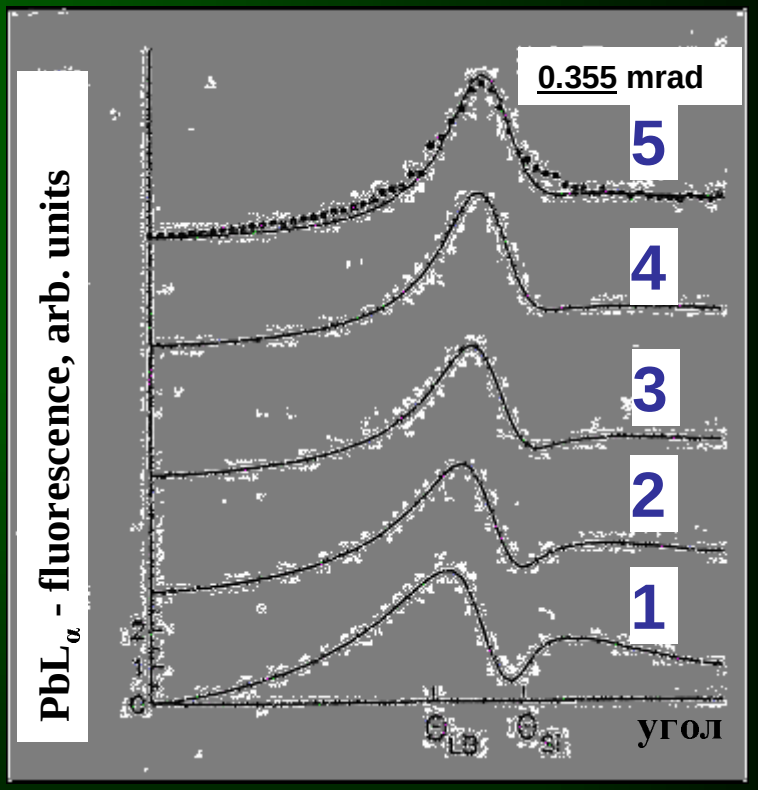
Combination of spectroscopy and diffraction

LOCALIZATION OF ATOMS IN ORGANIC LAYERS ON SOLID SUBSTRATES



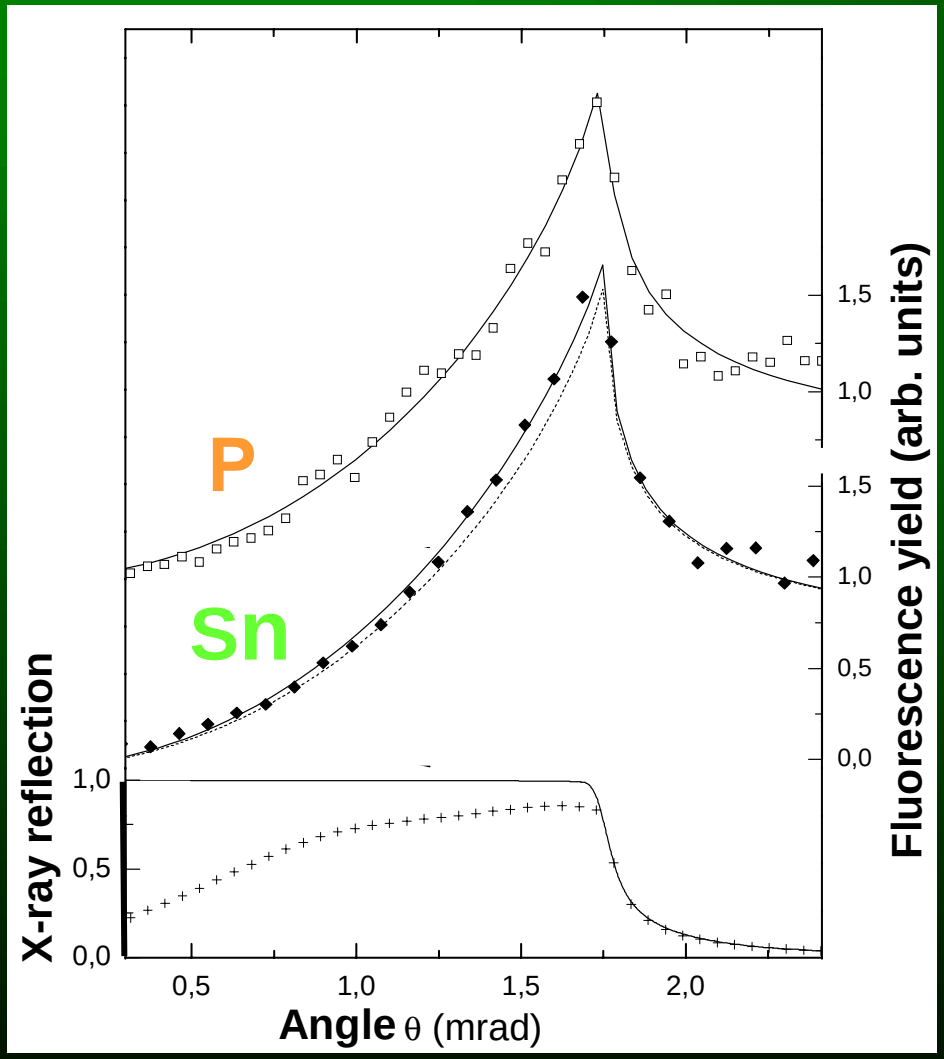
Organic Langmuir-Blodgett filns:
(8 monolayers of stearic acid on Si – substrate) + $PbSt_2$ bilayer

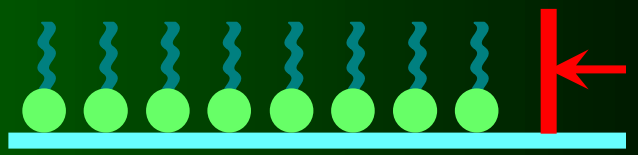
Where are Pb^{2+}?

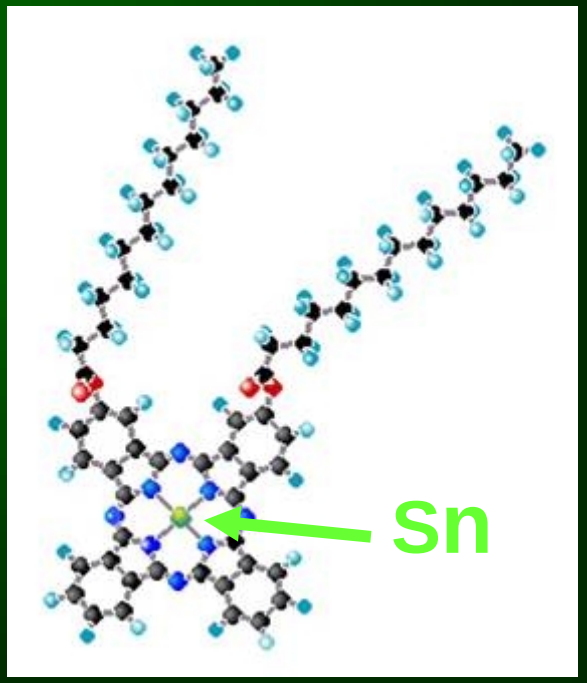


Angular dependence PbL_α – fluorescence at different distributions of Pb^{2+}

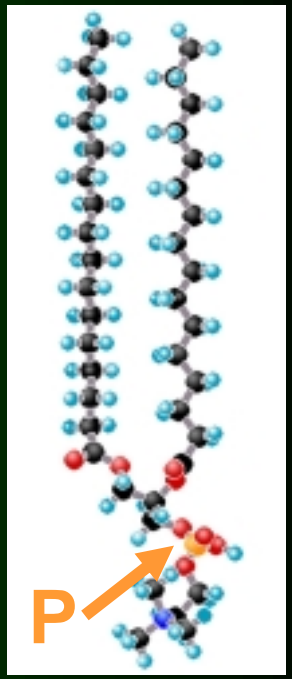
LOCALIZATION OF ATOMS IN MONOLAYER ON THE SURFACE OF A LIQUID



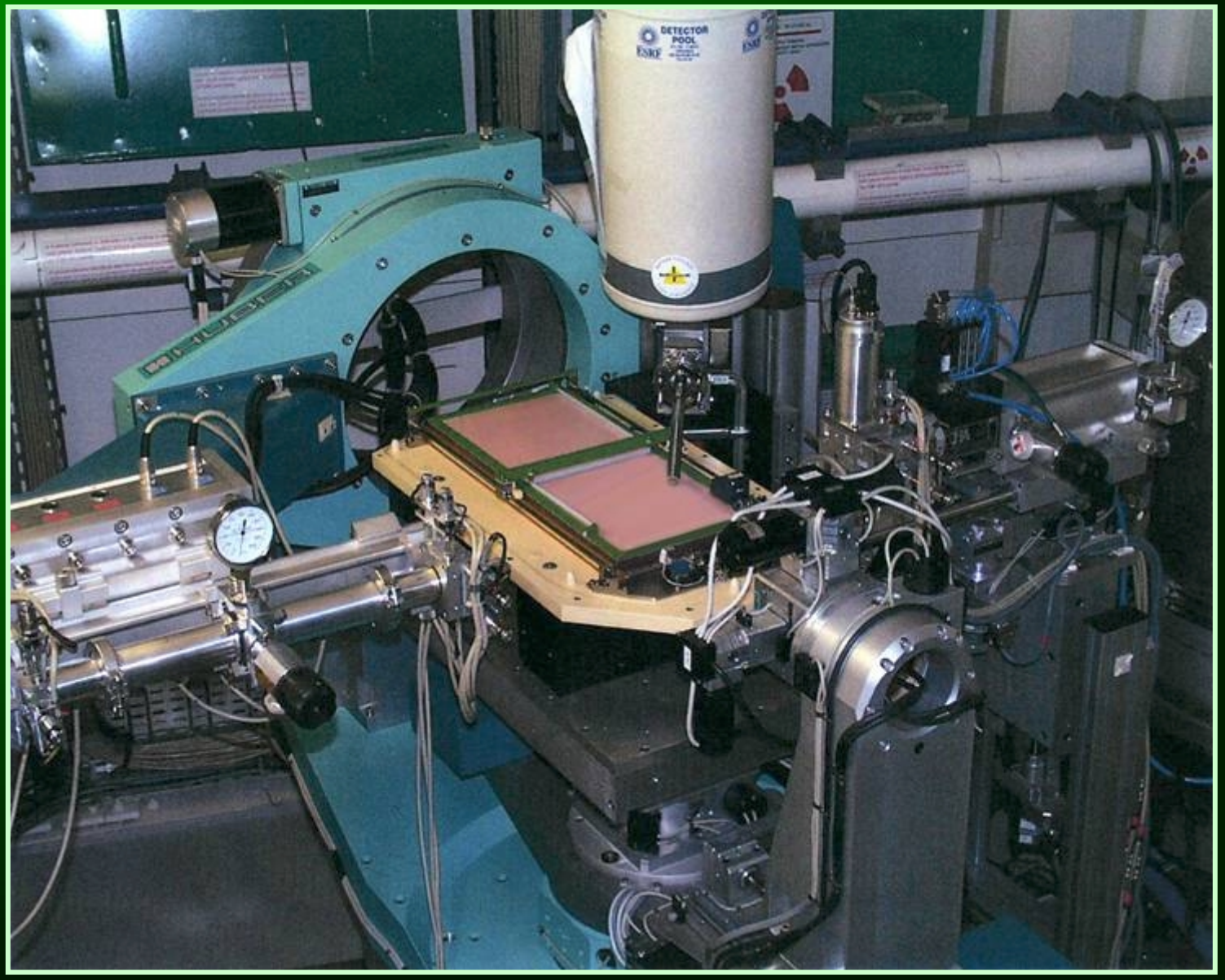




Phthalocyanine



Phospholipide (DPPC)


DETECTOR
POOL
ESRF

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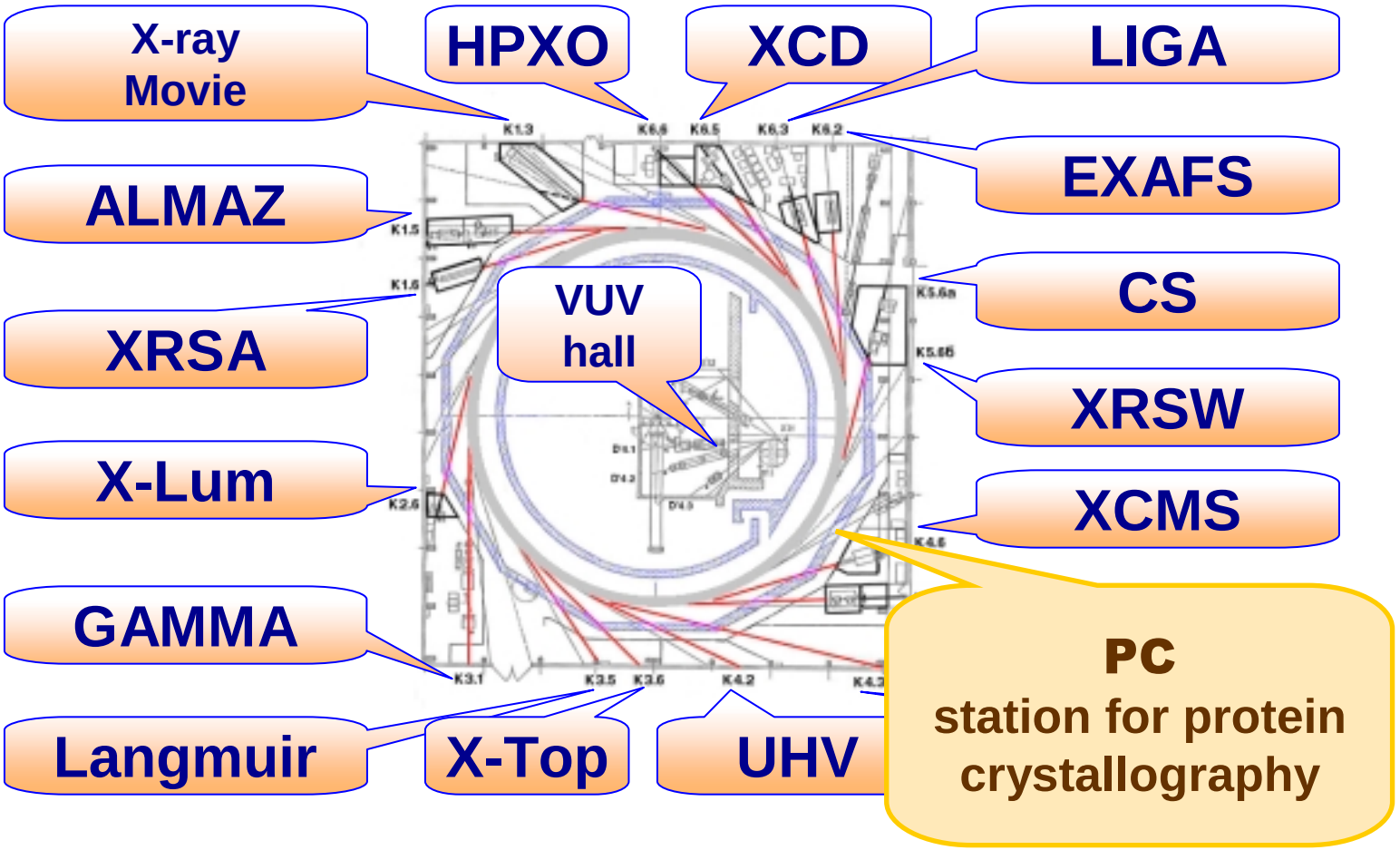
Kurchatov Synchrotron Radiation Center

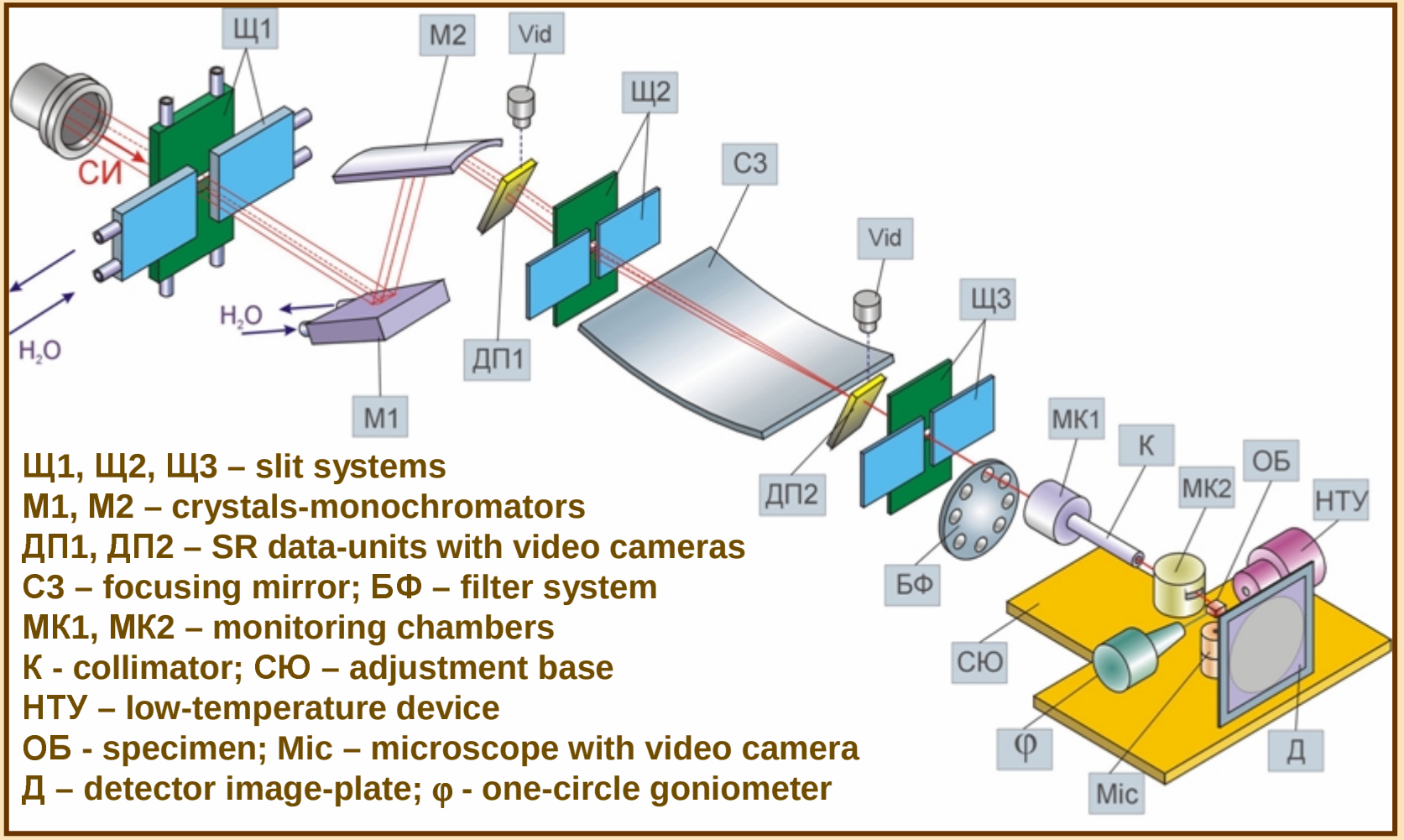
EXPERIMENTAL STATIONS



STATION FOR PROTEIN CRYSTALLOGRAPHY

К 4.4 е

РС



Щ1, Щ2, Щ3 – slit systems
М1, М2 – crystals-monochromators
ДП1, ДП2 – SR data-units with video cameras
С3 – focusing mirror; БФ – filter system
МК1, МК2 – monitoring chambers
К - collimator; СЮ – adjustment base
НТУ – low-temperature device
ОБ - specimen; Mic – microscope with video camera
Д – detector image-plate; φ - one-circle goniometer

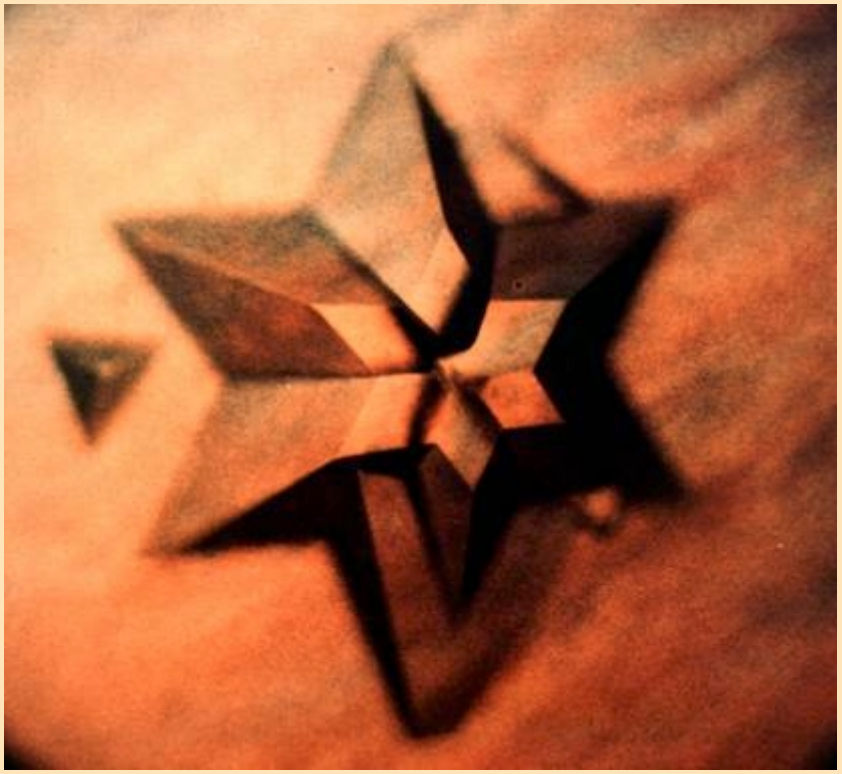
STATION FOR PROTEIN CRYSTALLOGRAPHY

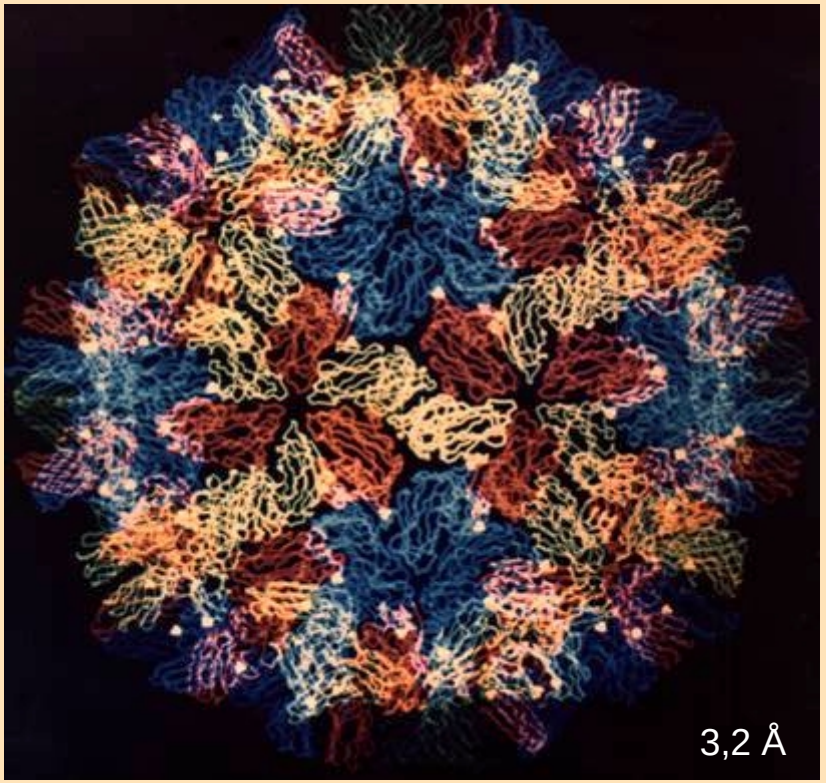
К 4.4 е

РС

APPLICATION OF SYNCHROTRON RADIATION

Carnation Mottle Virus





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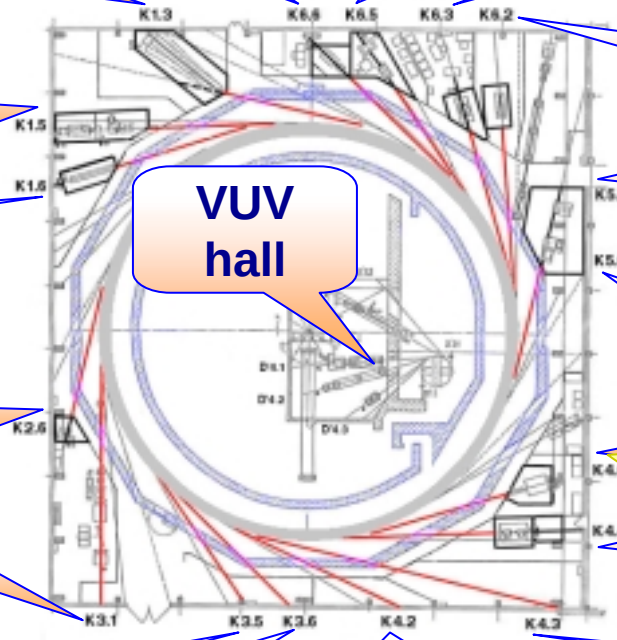
EXPERIMENTAL STATIONS



X-ray Movie

HPXO

XCD

LIGA

ALMAZ

EXAFS

VUV hall

CS

XRSA

XRSW

X-Lum

XCMS

GAMMA

PC

Langmuir

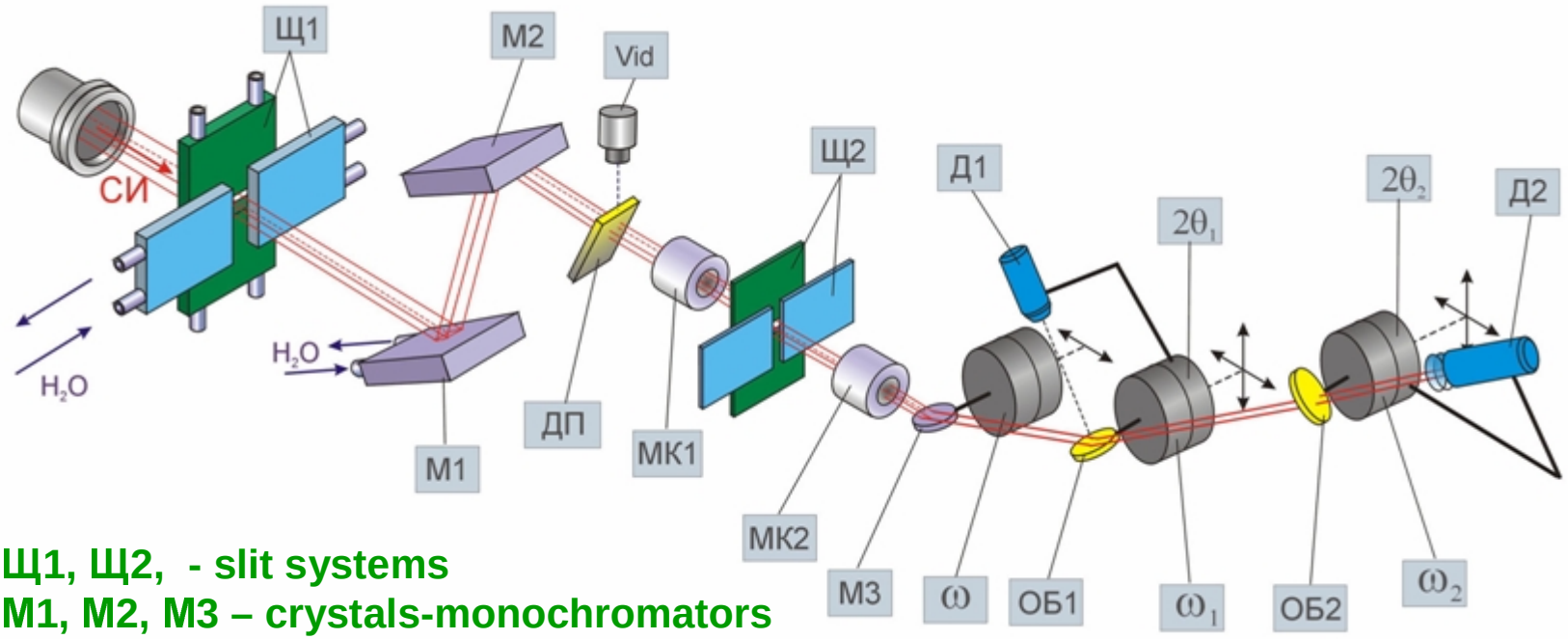
X-Top

UHV

MEDIANA

К 4.6

STATION FOR X-RAY CRYSTALLOGRAPHY AND MATERIAL SCIENCE XCMS



Щ1, Щ2, - slit systems
М1, М2, М3 – crystals-monochromators
ДП – SR data unit
МК1, МК2 – monitoring chamber; ОБ - specimen
Д1, Д2 - detectors
ω, ω_1, ω_2, $2\theta_1$, $2\theta_2$ – axes of goniometer

K 4.6

STATION FOR X-RAY CRYSTALLOGRAPHY AND MATERIAL SCIENCE XCMS

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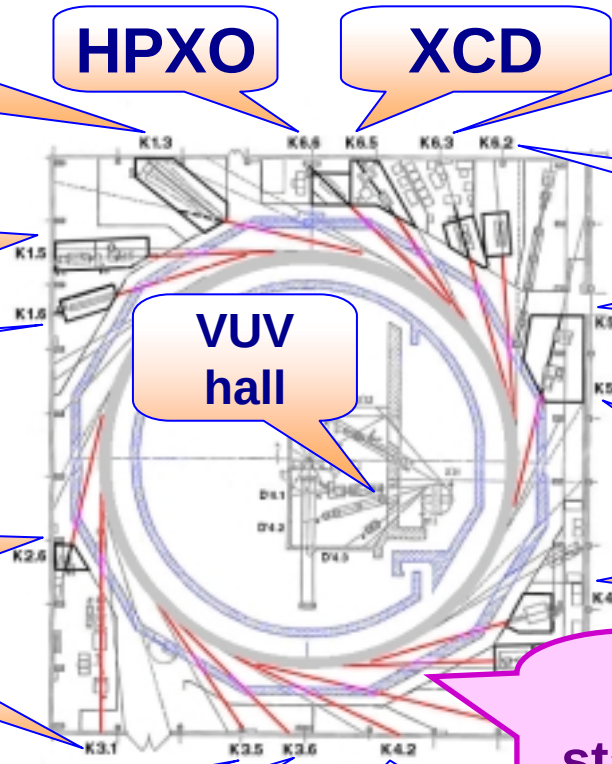
Kurchatov Synchrotron Radiation Center

EXPERIMENTAL STATIONS



X-ray Movie

HPXO

XCD

LIGA

EXAFS

ALMAZ

CS

VUV hall

XRSA

XRSW

X-Lum

XCMS

GAMMA

MEDIANA
station for multi-purpose medical applications

Langmuir

X-Top

UHV

STATION FOR MULTI-PURPOSE MEDICAL APPLICATIONS

К 4.3

MEDIANA

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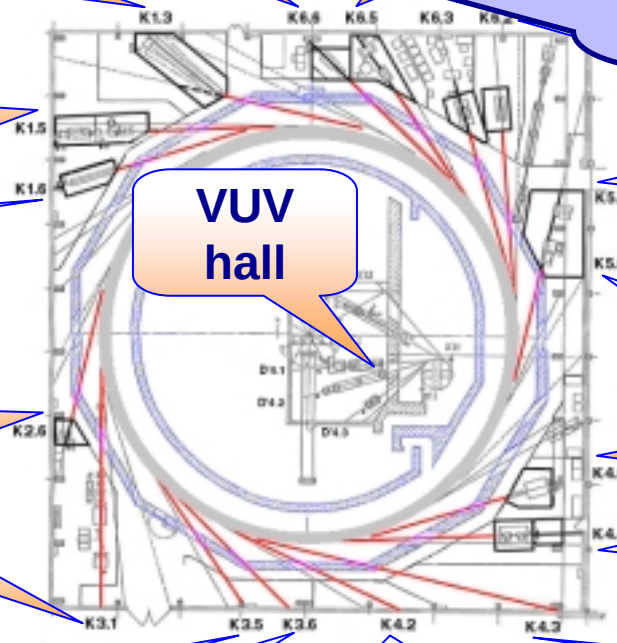
Kurchatov Synchrotron Radiation Center

EXPERIMENTAL STATIONS



LIGA
station of deep
X-ray lithography

X-ray
Movie

HPXO

XCD

EXAFS

ALMAZ

VUV
hall

CS

XRSA

XRSW

X-Lum

XCMS

GAMMA

PC

Langmuir

X-Top

UHV

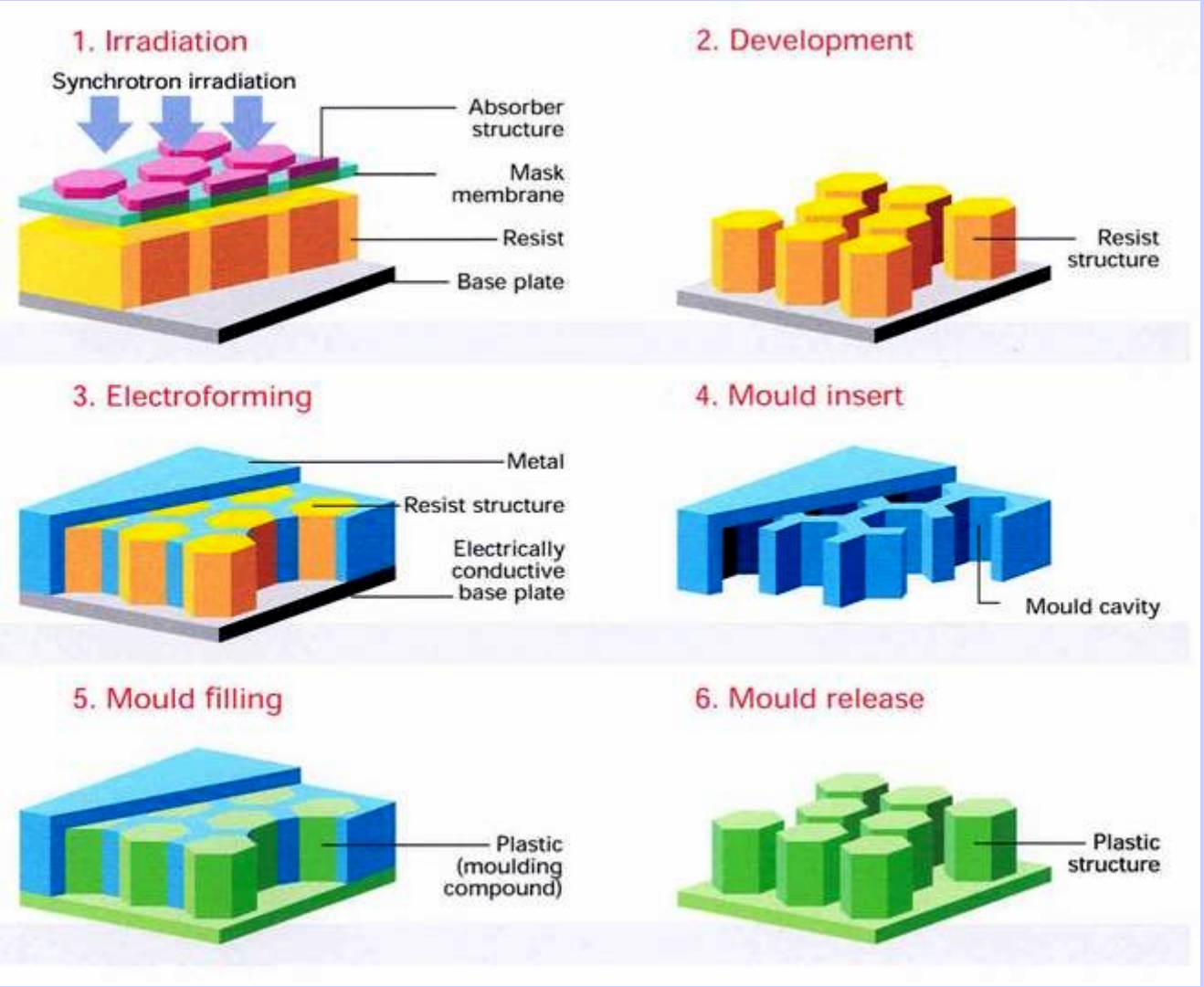
MEDIANA

STATION FOR DEEP X-RAY LITHOGRAPHY

K 6.3

LIGA

LIGA - TECHNOLOGY



Roentgen
LIthography-
Galvanik-
Abformung

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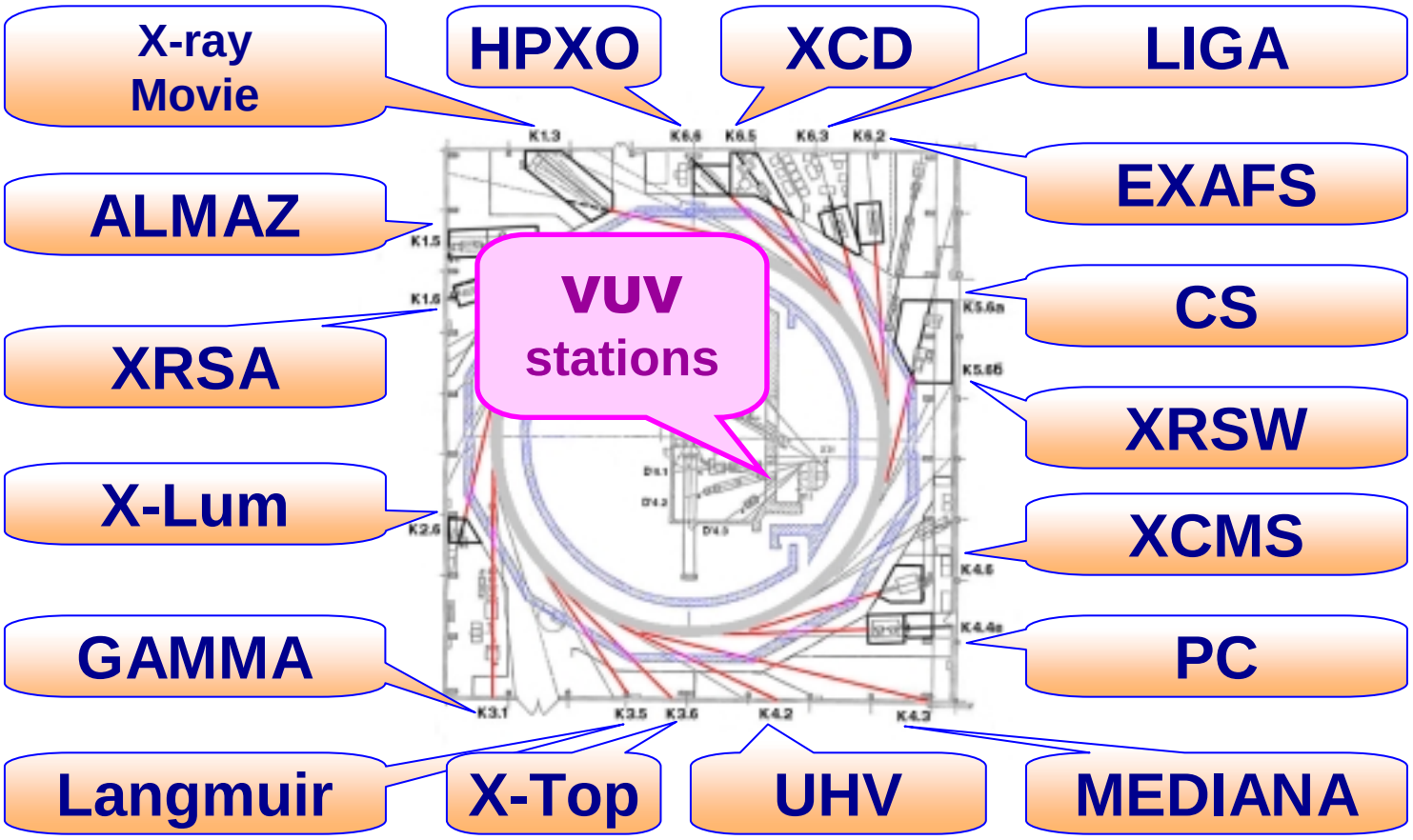
Kurchatov Synchrotron Radiation Center

EXPERIMENTAL STATIONS



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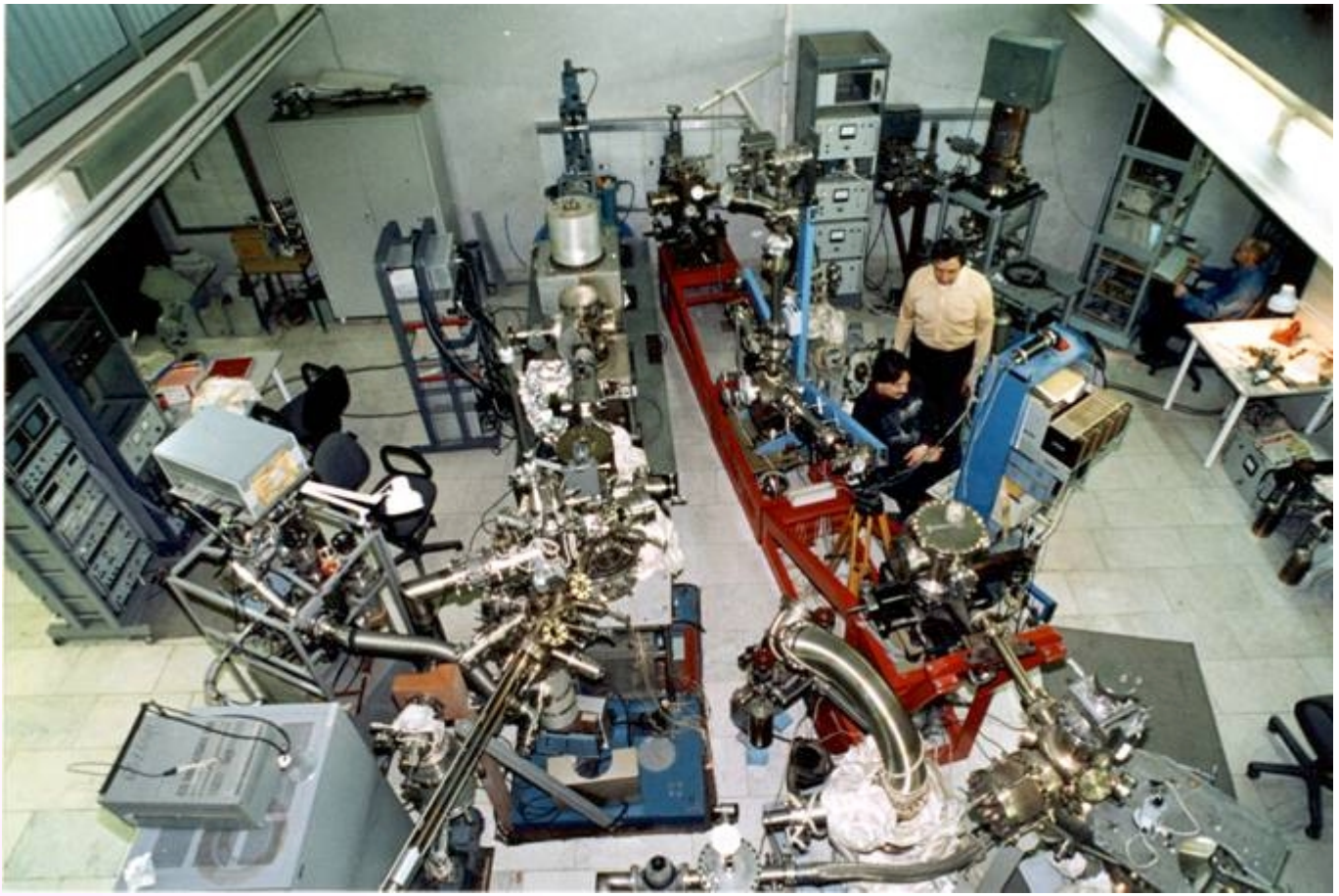
Kurchatov Synchrotron Radiation Center

HALL FOR VUV STUDIES



APPLICATION OF SYNCHROTRON RADIATION

FLUORESCENCE ANALYSIS

Fluorescent intensity distributions from the cross section of a human hair:
a) optical micrograph
b) sulphur
c) potassium
d) copper
e) zinc