Metrological station "COSMOS“. Current status.

A.D. Nikolenko P.S.Zavertkin, D.V.Ivlyushkin, M.R.Mashkovtsev
Budker Institute of Nuclear Physics SB RAS, Novosibirsk

M.A. Bublik, B.A. Zabolotko
Dukhov All-Russia Research Institute of Automatics (VNIIA), Moscow

N.A. *Makarova*
Polzunov Altai State Technical University, Barnaul

V.T. Minligareev , A. A. Nusinov Yu.M. Kachanovskiy
Fedorov Institute of Applied Geophysics, Moscow

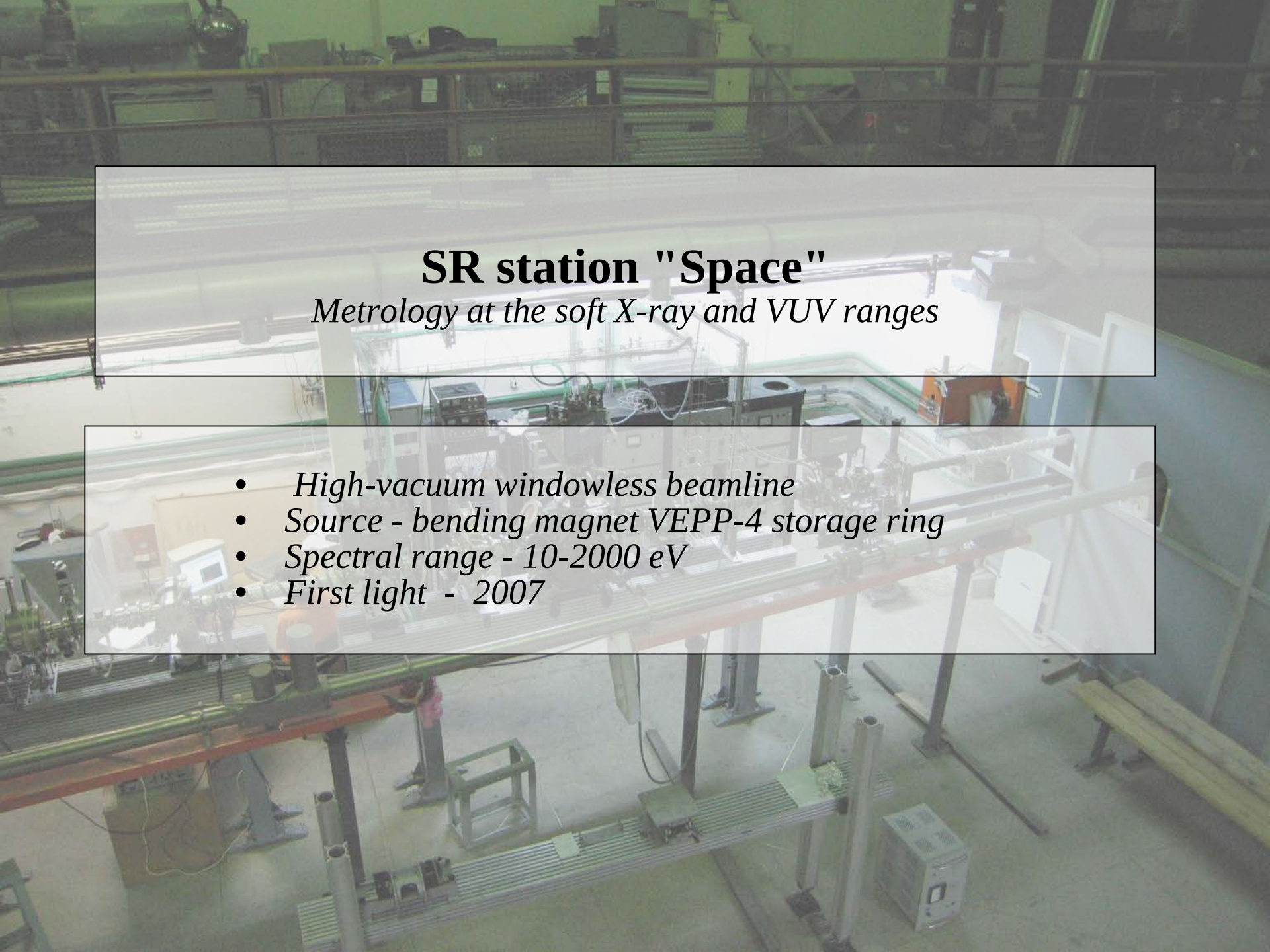
"COSMOS" beamline : The main tasks

Development of procedures and carrying out of absolute calibration in the soft X-ray and VUV (10-2000 eV) for:

- any kinds of X-ray optics (grates, mirrors etc.)
- ready-fitted appliance (spectrometers, radiometers, telescopes)
- detectors (in particular absolute spectral responsivity)

Application fields

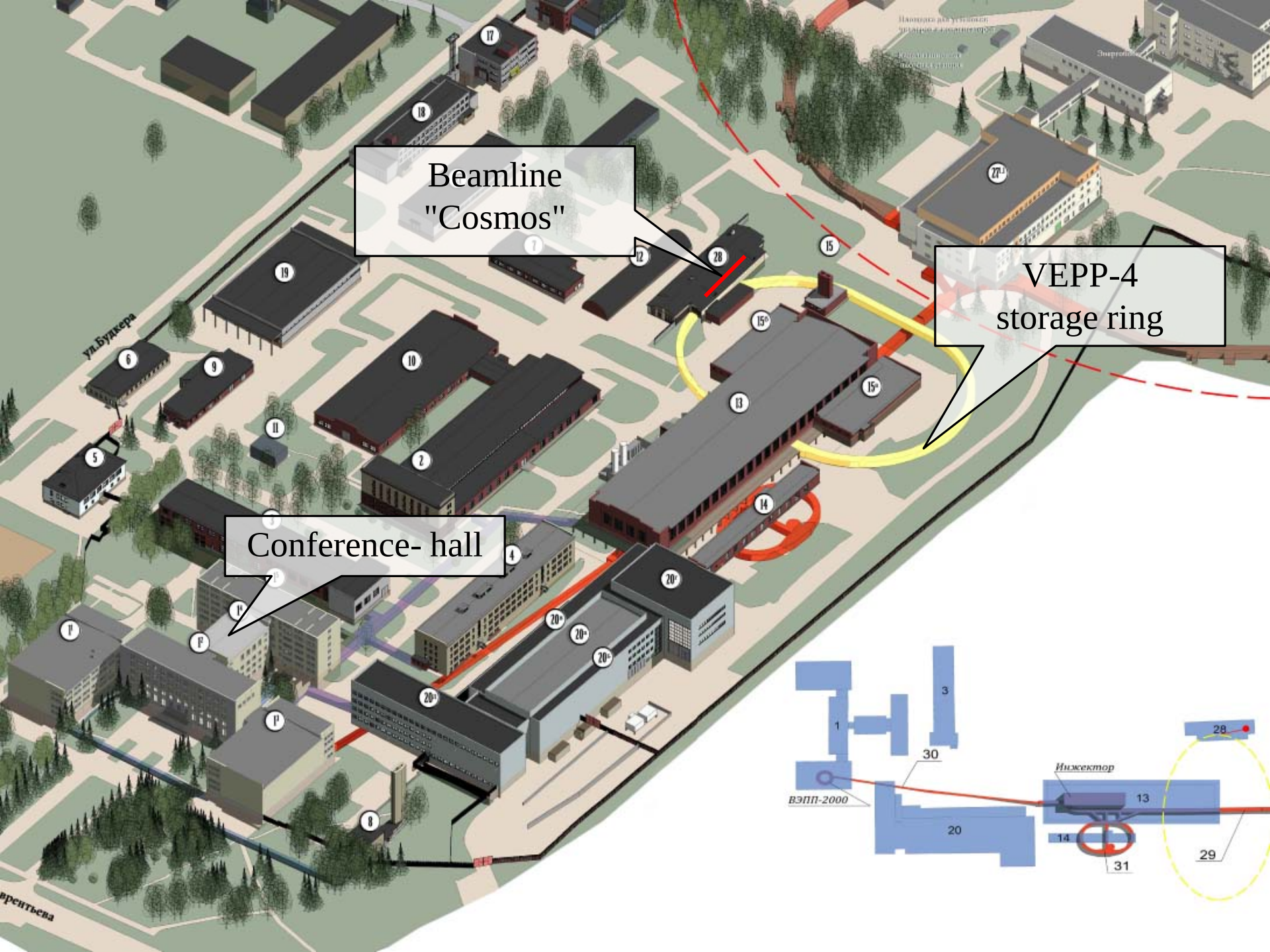
- Astrophysical observations at the soft X-ray range
- Diagnostic of high-temperature plasma
- Equipment for the EUV-lithography (λ=13 nm)

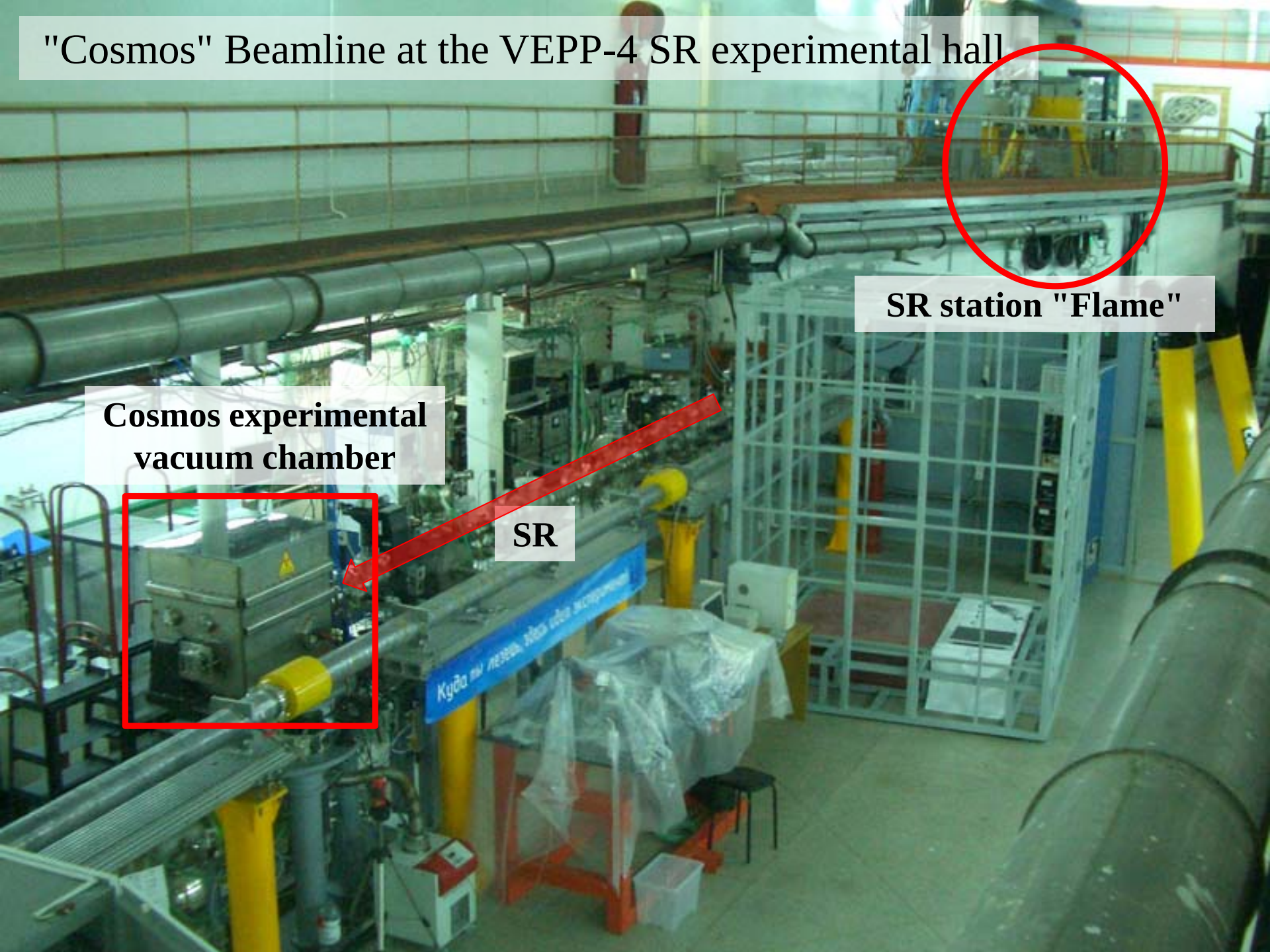


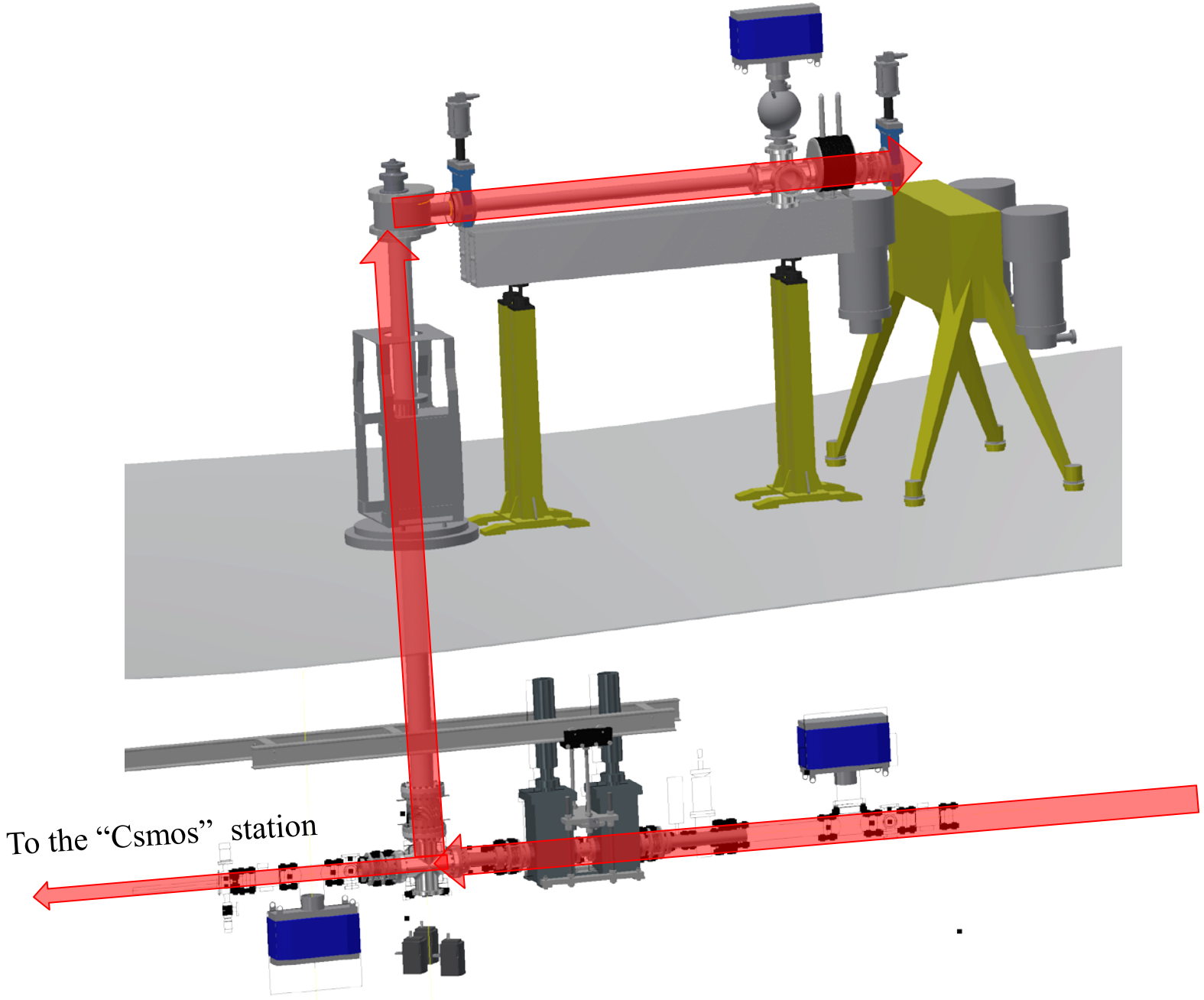
SR station "Space"

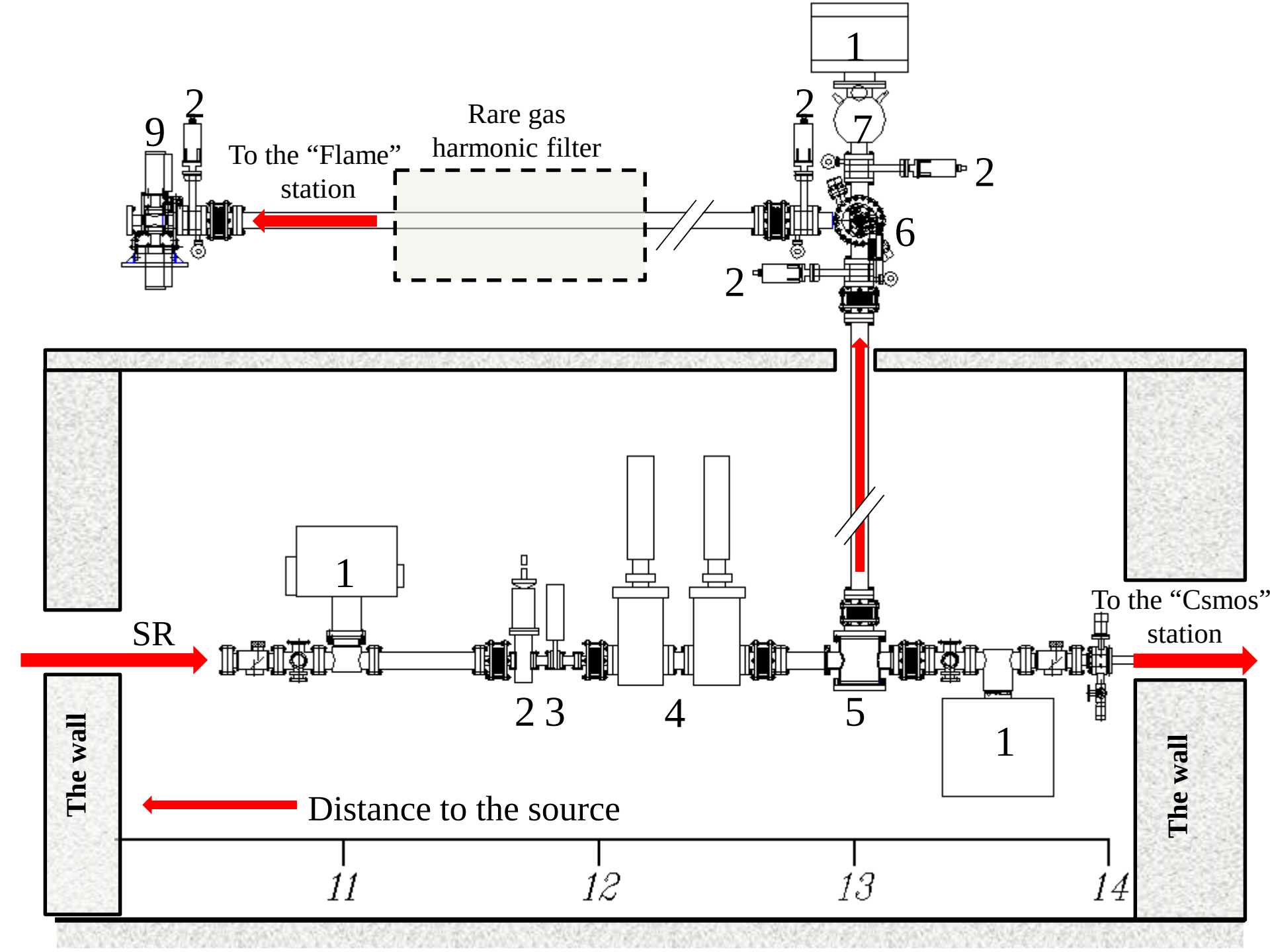
Metrology at the soft X-ray and VUV ranges

- *High-vacuum windowless beamline*
- *Source - bending magnet VEPP-4 storage ring*
- *Spectral range - 10-2000 eV*
- *First light - 2007*


Beamline
"Cosmos"
VEPP-4
storage ring
Conference- hall
ул.Будкера
ВЭПП-2000
Инжектор
1
3
30
13
20
14
28
29
31


"Cosmos" Beamline at the VEPP-4 SR experimental hall
SR station "Flame"
Cosmos experimental vacuum chamber
SR


To the “Csmos” station


1
2
9
2
To the “Flame” station
Rare gas harmonic filter
2
7
2
6
2
1
SR
2 3
4
5
To the “Csmos” station
1
The wall
Distance to the source
11
12
13
14
The wall

Project of new beamline “Flame”

Spherical mirror:

R=12 m
Substrate – quartz
Coating – gold
Roughness – 15 A
Aperture – 60x60 mm

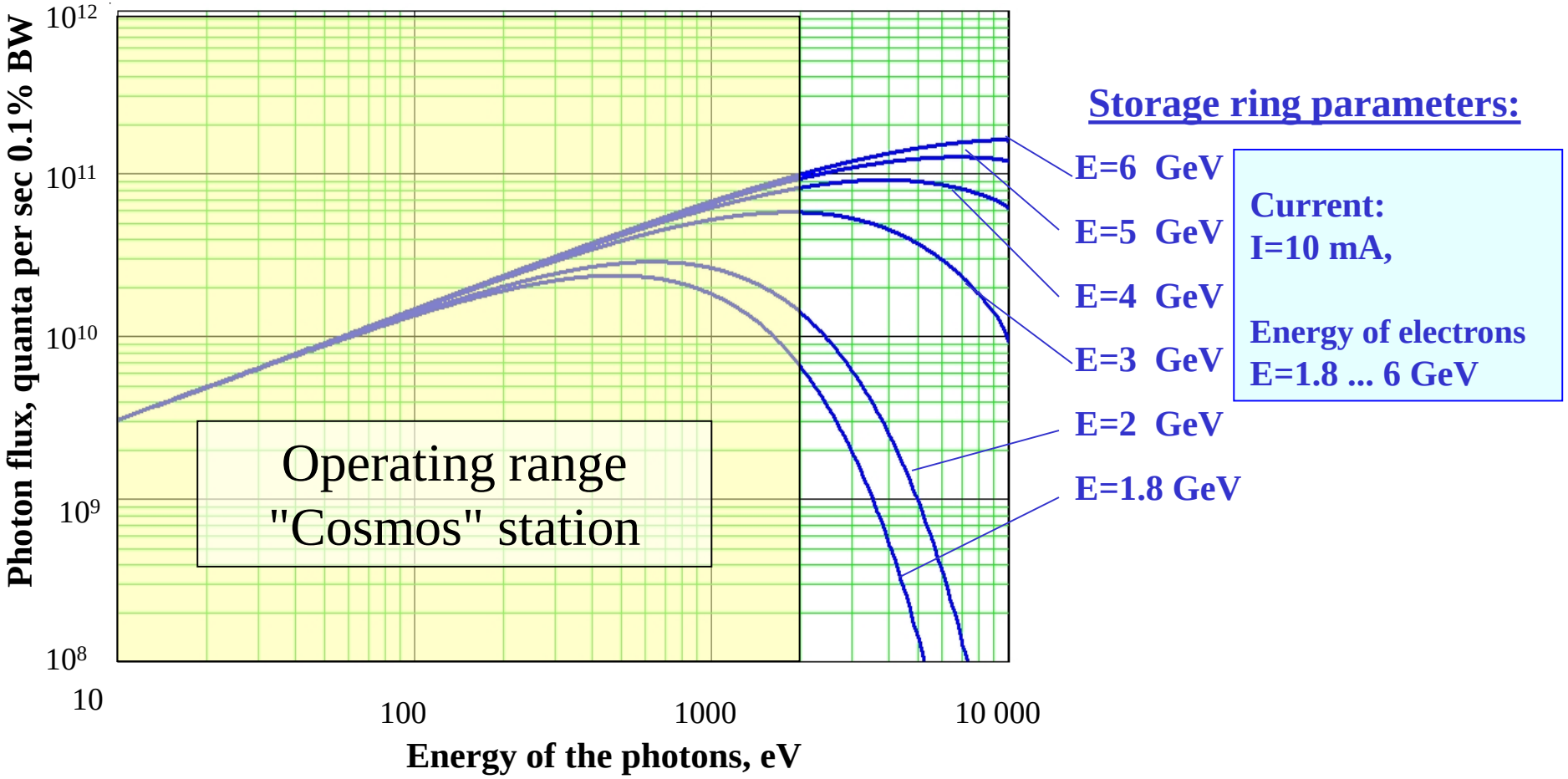
Plane grating:

Substrate – quartz
Coating – gold
Roughness – 15 A
Number of grooves – 1500 per mm
Aperture – 30x40 mm
Rotation range: 4º-16.5º
Energy range: 5-25 эВ (2000 Å - 500 Å)
Spectral resolution: E/ΔE=500-2000

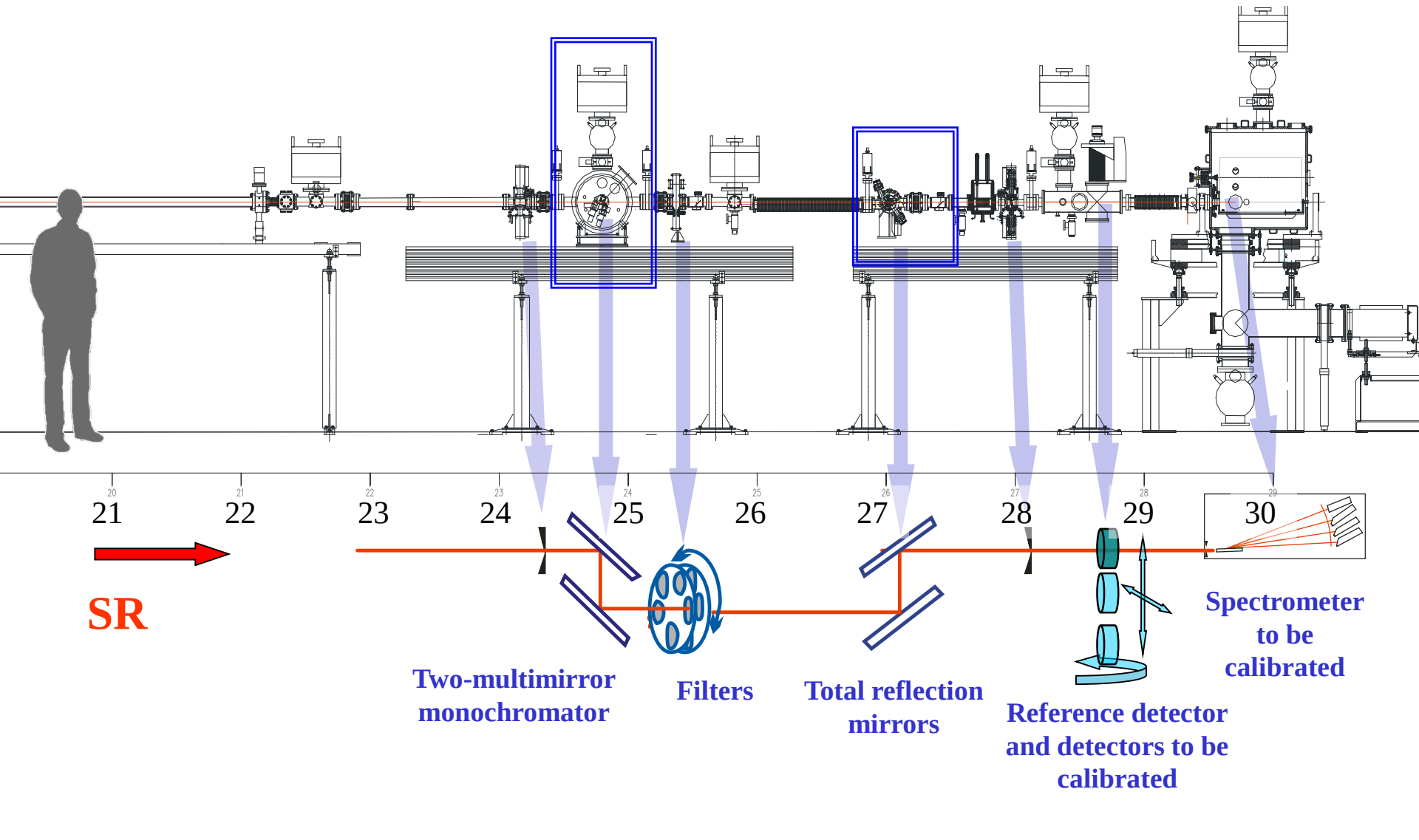
Photon flux at the «Cosmos» station for different energy of electrons in the VEPP-4 storage ring.

Beamline parameters:

aperture - 5X5 mm, distance to the source - 30 m bandwidth $\Delta E/E=10^{-3}$



Layout and optical scheme of the COSMOS station



Two-multimirror monochromator
(multilayer mirrors)

Parameters:

Angle range: **7º-80º**

Mirrors: **30x40 mm^2 (Y/Mo, Fe/C, W/Si...)**

Spectral range **- 80-2000 eV**

Spectral resolution: **0.1-10%**

Fixed position of monichromatic beam

Vacuum - 10^{-4}Pa

Two-multimirror monochromator
(multilayer mirrors)

Parameters:

Angle range: **7º-80º**

Mirrors: **30x40 mm^2 (Y/Mo, Fe/C, W/Si...)**

Crystals: **mica, KAP, CzAP...**

Spectral range **- 80-2000 eV**

Spectral resolution: **0.1-10%**

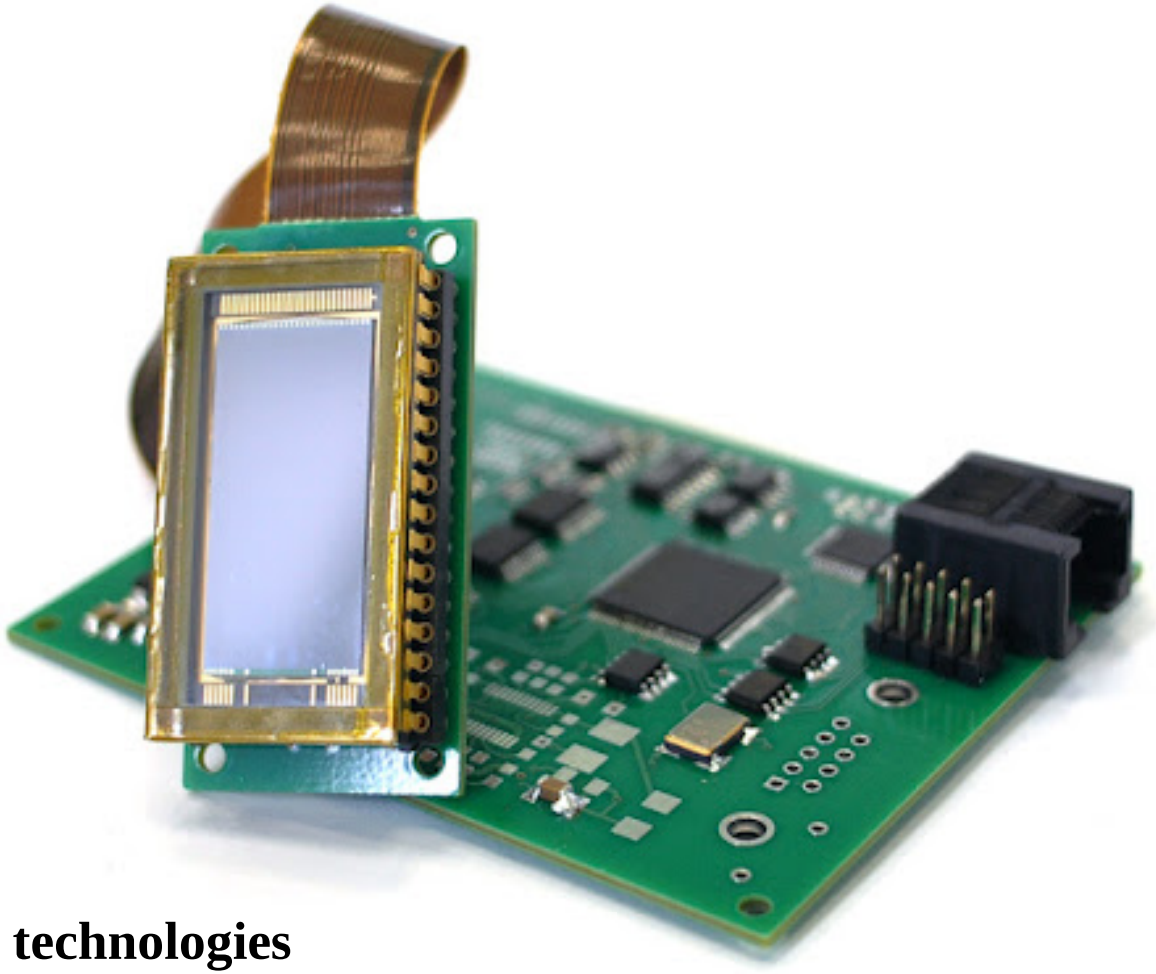
Fixed position of monichromatic beam

Vacuum - **10^{-4}Pa**

Acknowledgement to our colleagues from the Boreskov Institute of Catalysis SB RAS:
Evgeniy KOROTAEV, Lev MAZALOV, Mikhail SYROKVASHIN

Two-coordinate BI CCD –based detector

(P.N. Lebedev Physical Institute of RAS, Moscow)

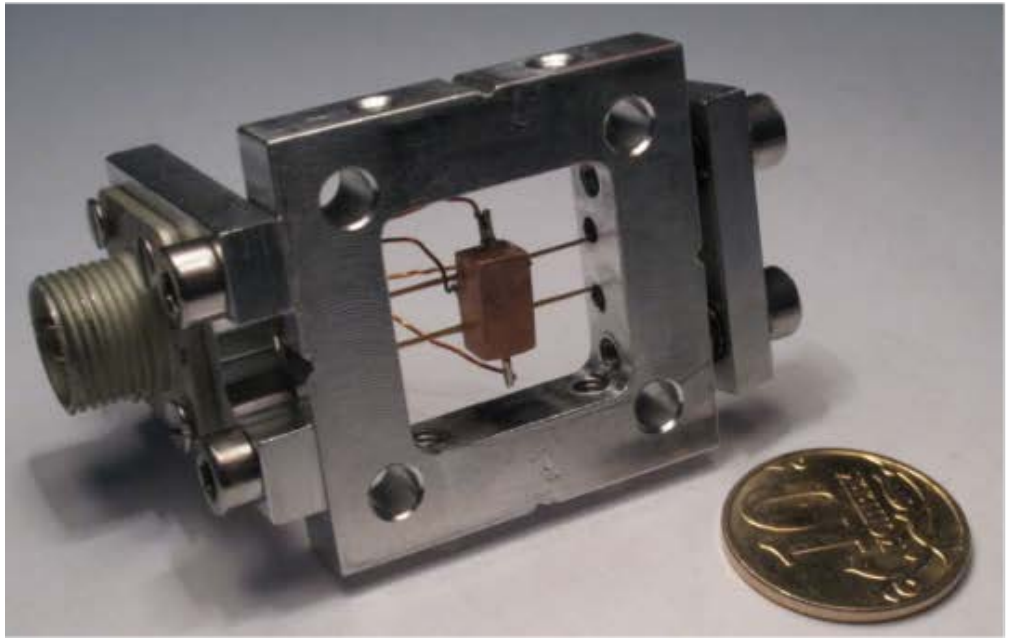


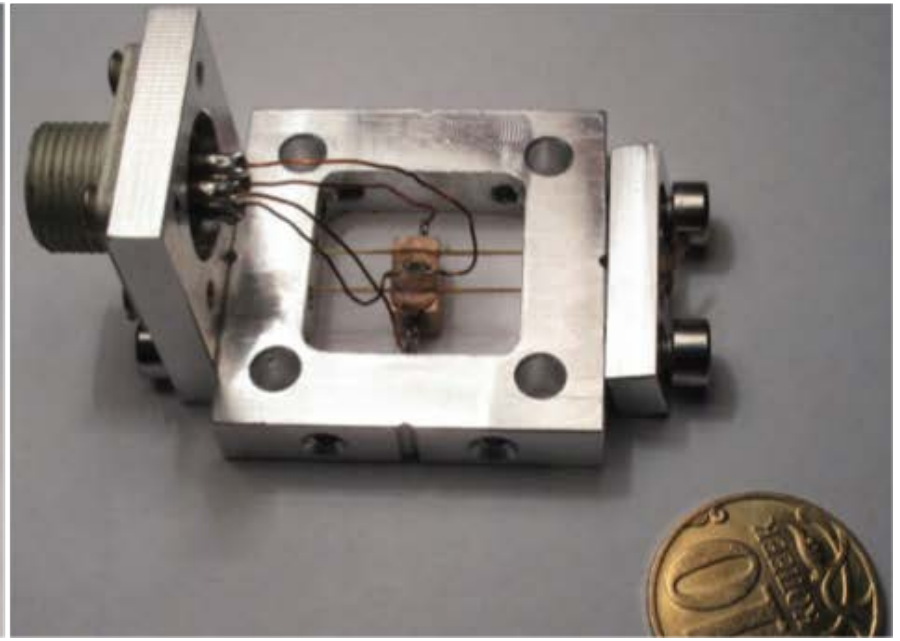
E2V technologies
Back Illuminated CCD Sensor
(Gait Britain)

Calorimeter

for the absolute measurement of the beam power of 300 μW

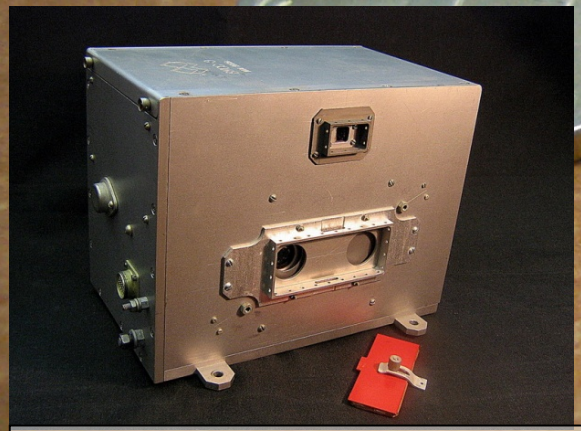
Accuracy - 2-5%



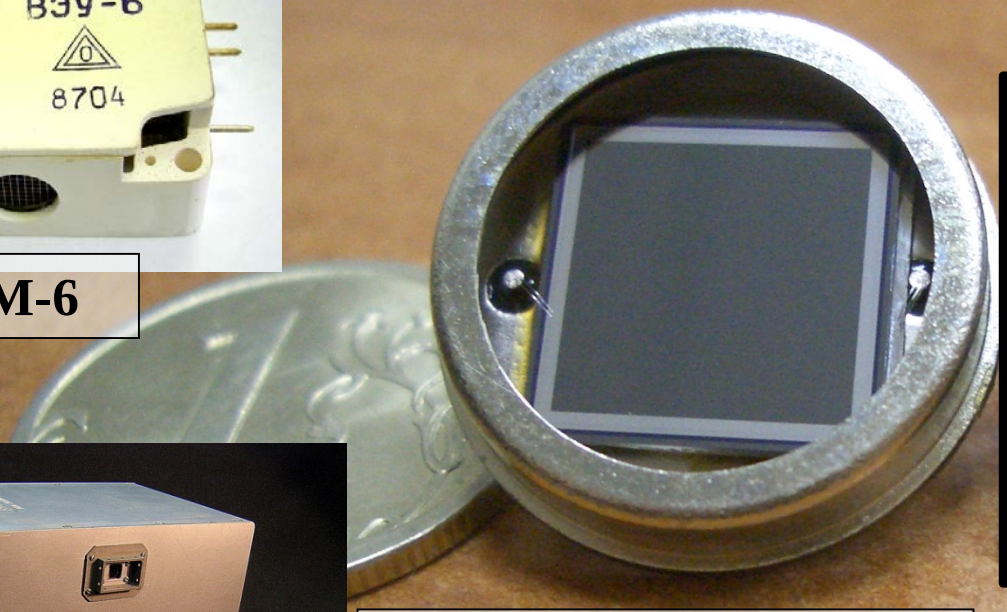


Calibrated detectors

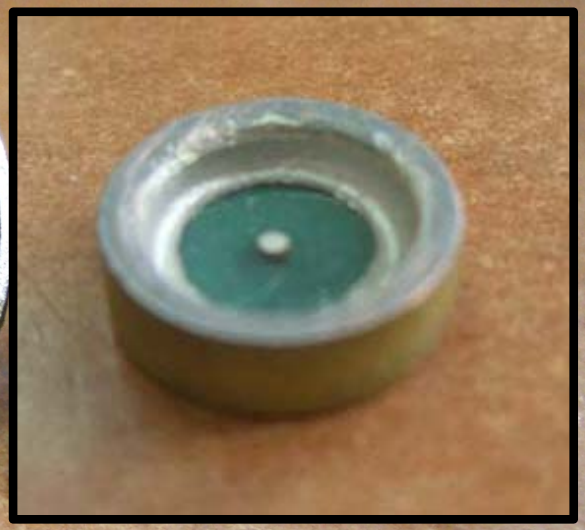
SEM-6



Solar UV radiation sensor VUSS-E
Fedorov IAG, Moscow



p-n photodiode SPD
Ioffe Institute
Saint Petersburg



ETDRI-4
coaxial diamond detector
Dukhov VNIIA, Moscow

The main consumer characteristics of detectors

- Spectral sensitivity
- Spatial sensitivity mapping
- Dark current
- Stability of characteristics
- Radiation resistance

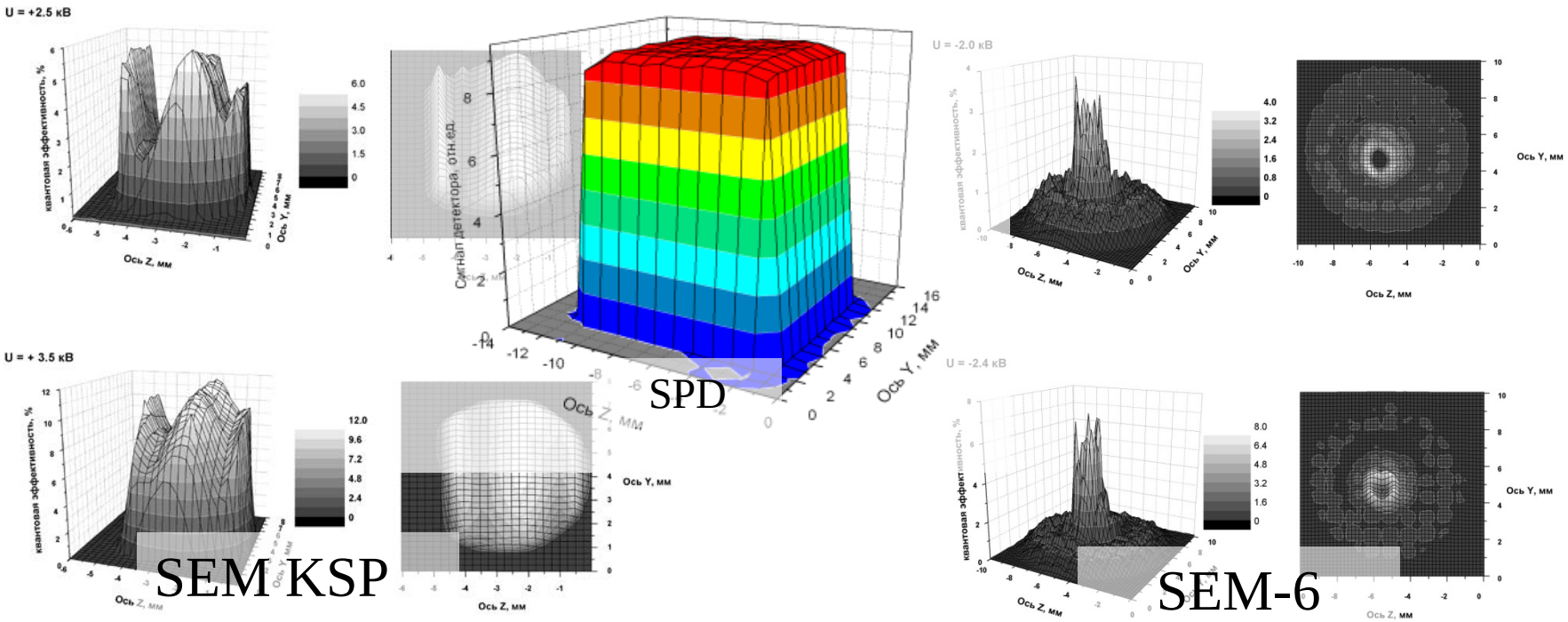
The main consumer characteristics of detectors

- **Spectral sensitivity**
  - *The method of the reference detector*
  - *Standard source method*
  - *Self-calibration method*

- Spatial sensitivity mapping
- Dark current
- Stability of characteristics
- Radiation resistance

The main consumer characteristics of detectors

- Spectral sensitivity
- **Spatial sensitivity mapping**
- Dark current
- Stability of characteristics
- Radiation resistance

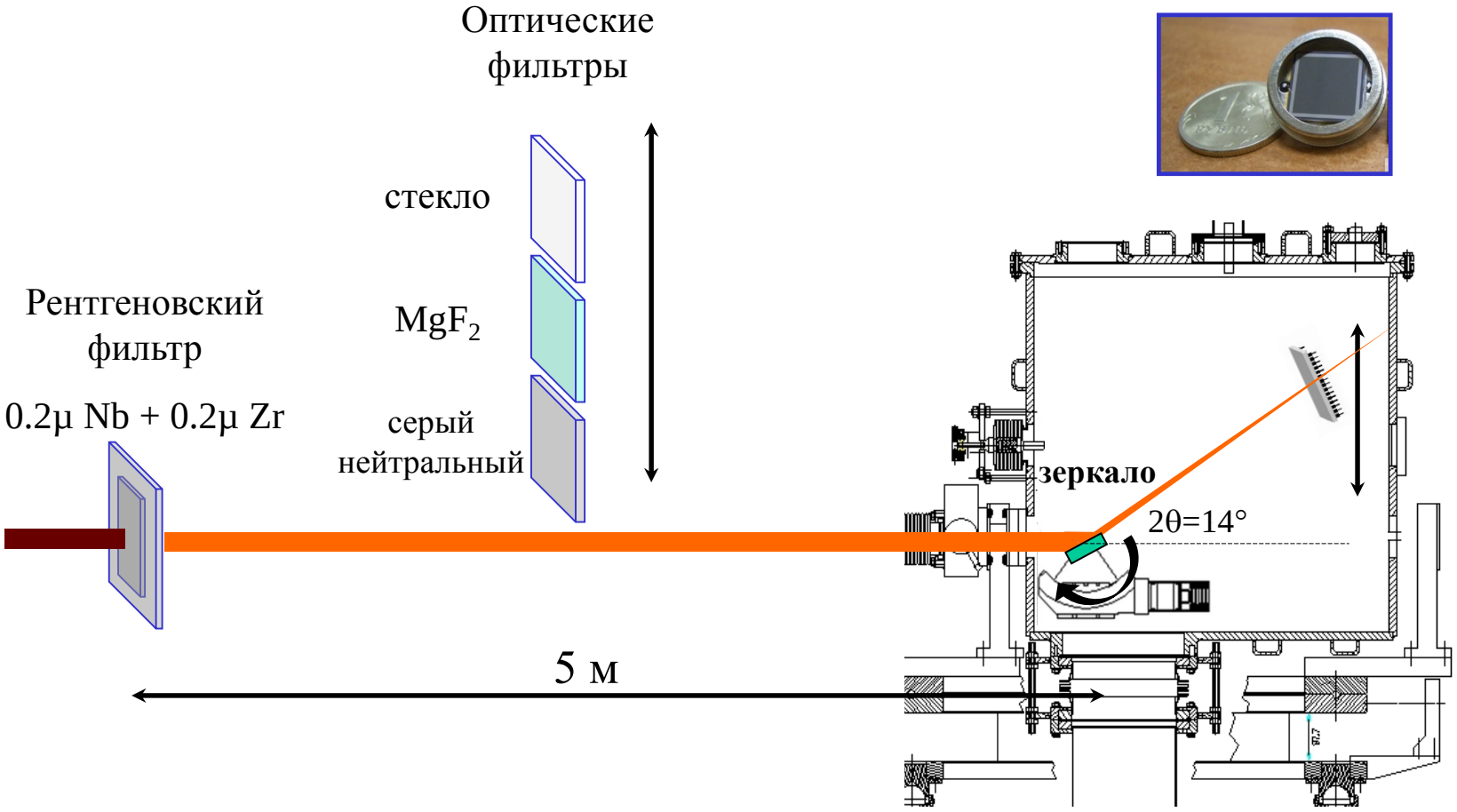


The main consumer characteristics of detectors

- Spectral sensitivity
- Spatial sensitivity mapping
- Dark current
- Stability of characteristics
- **Radiation resistance**

Облучение фотодиода:

Схема фокусировки и фильтрации

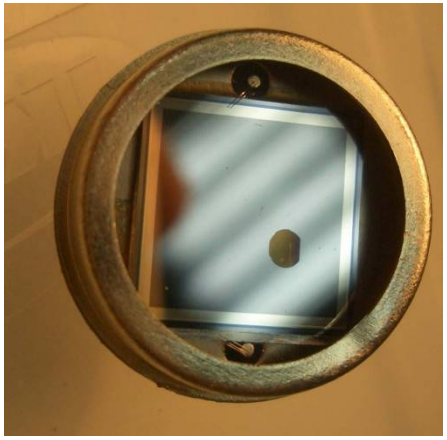


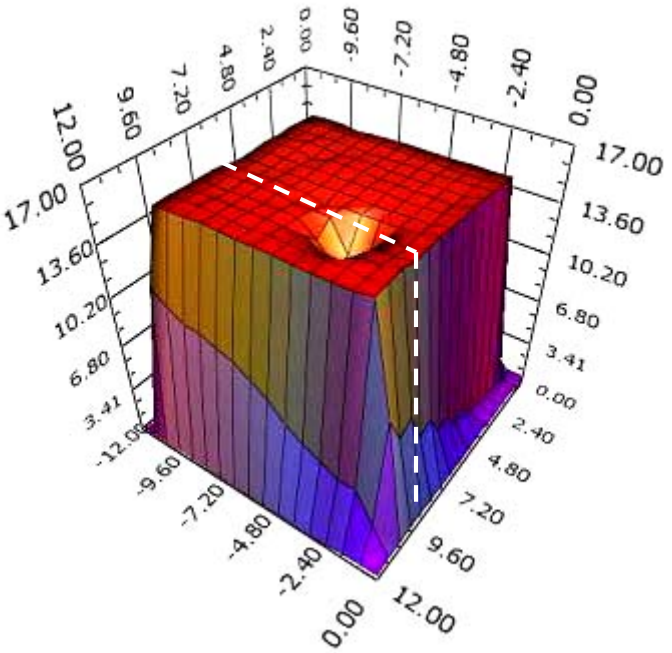
Фокусировка сферическим зеркалом R=10 м, θ=7°. Выигрыш - в 5 раз.

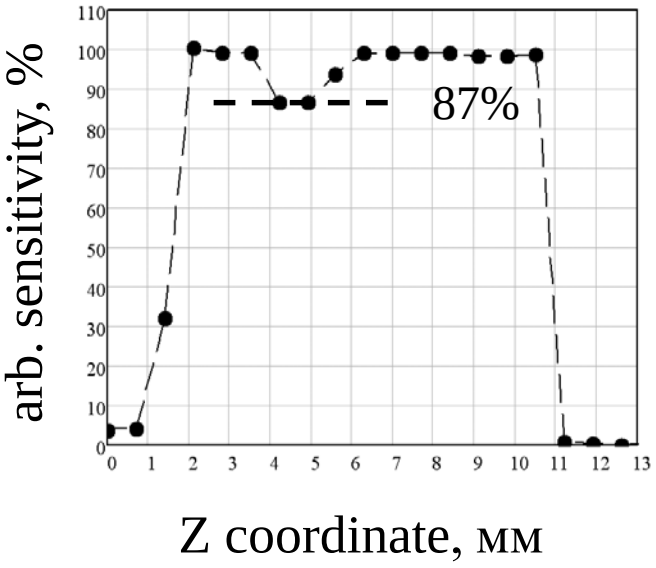
Одновременно работает как зеркало ПВО

Radiation hardness of the SPD photodiode:

appearance and sensitivity map after irradiation with 1.8 MGy dose



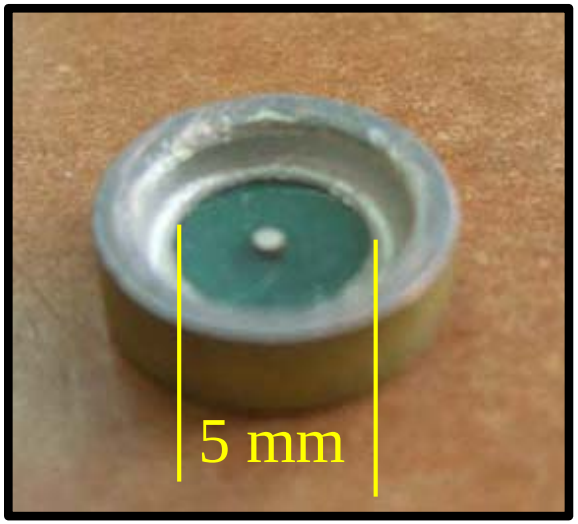




Dose: 1.8 MGy (123 J/sm^2) & 80-160 eV

Surface scan was provided at the photon energy 100 eV. The magnitude degradation - 13% and does not vary substantially within the spectral range 97-130 eV.

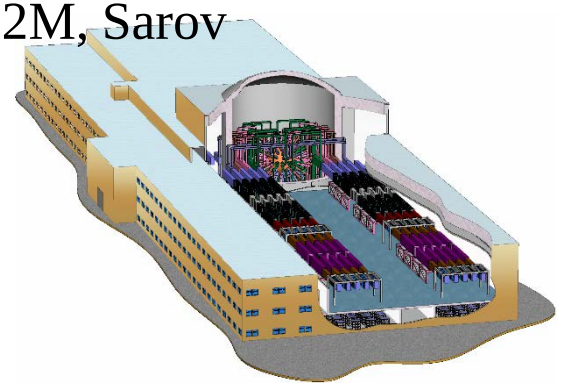
Preliminary calibration of the sensitivity of the diamond detector ETDRI-4



Developer L.M. DukhovVNIIA, Moscow

Coaxial diamond windowless detector

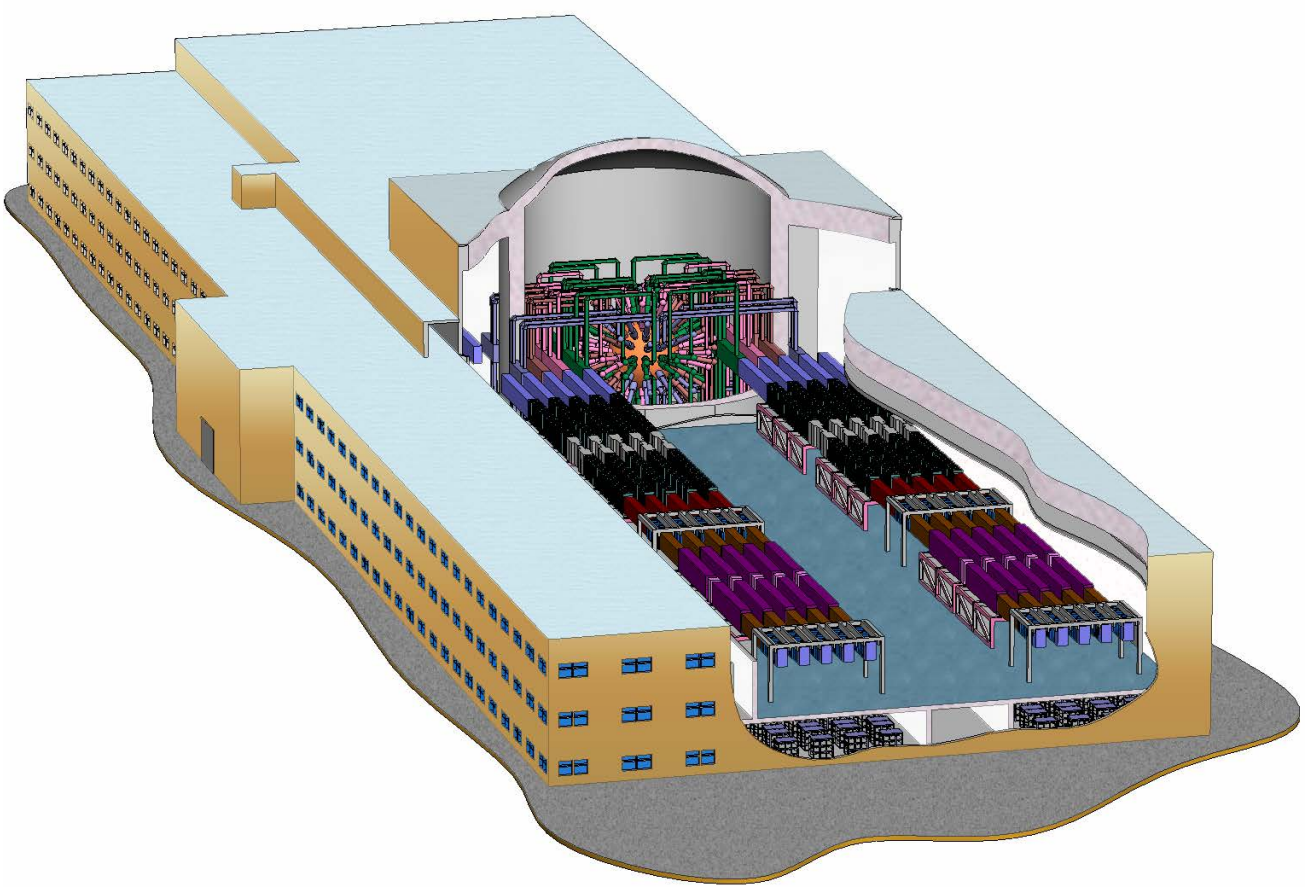
It is supposed to use at the megajoule laser facility UFL-2M, Sarov



Megajoule laser facility UFL-2M (Sarov)

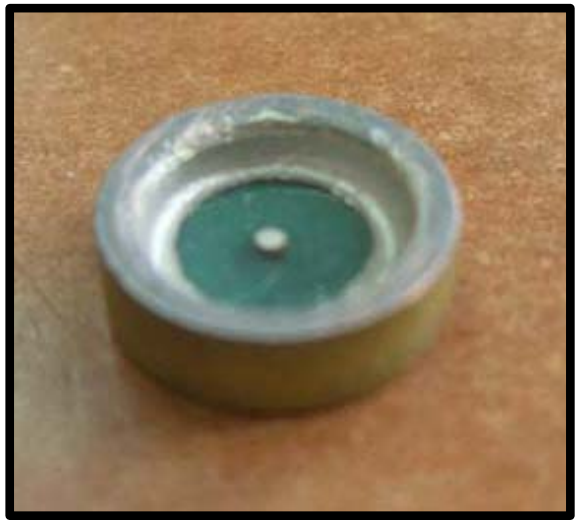
for the study laser thermonuclear fusion

- 192 lazer beam
- 4.6 MJ & λ=1053 nm
- Impulse profiled with a duration of 5-10 ns
- Power - 500 TW



Features of the detector:

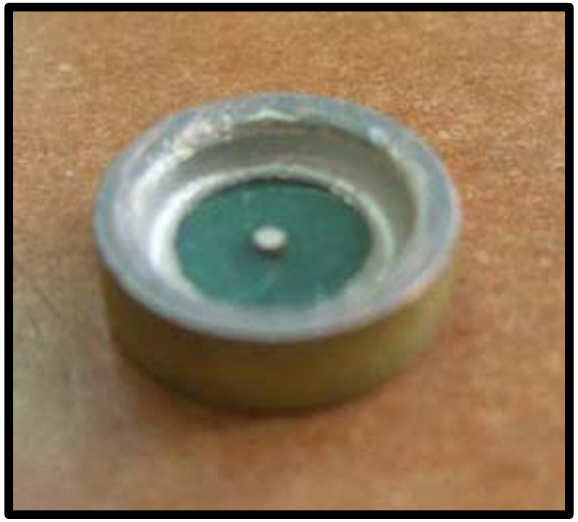
- High radiation resistance
- Solar blind
- The flat spectral response
- High time resolution (100-150 ps)
- Low sensitivity



ETDRI-4

Features of the detector:

- High radiation resistance
- Solar blind
- The flat spectral response
- High time resolution (fractions of a nanosecond)
- **Low sensitivity**

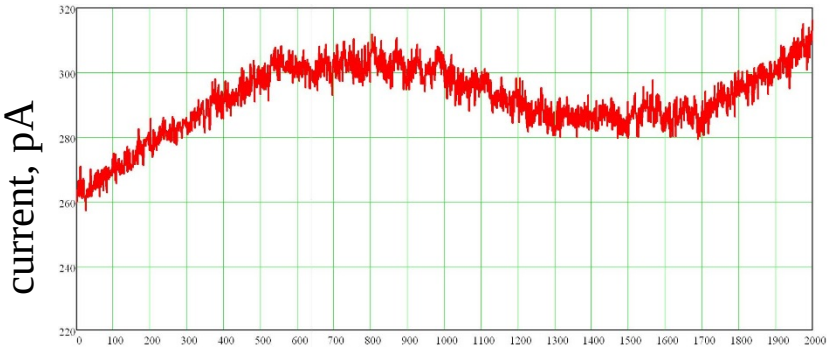


ETDRI-4

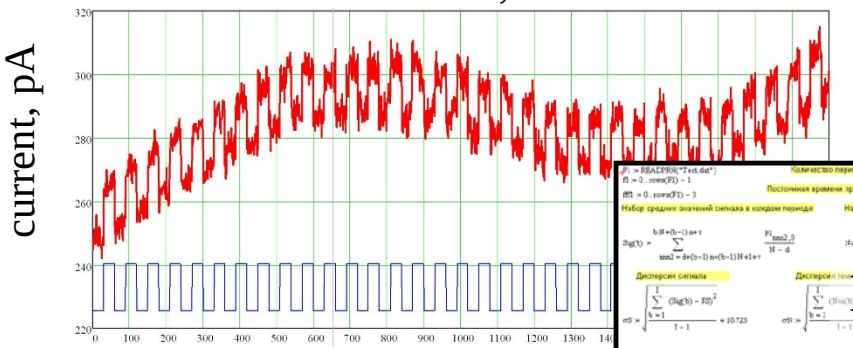
A low signal to noise ratio

Testing signal-noise discrimination procedure for the ETDRI-4

(computer simulation)

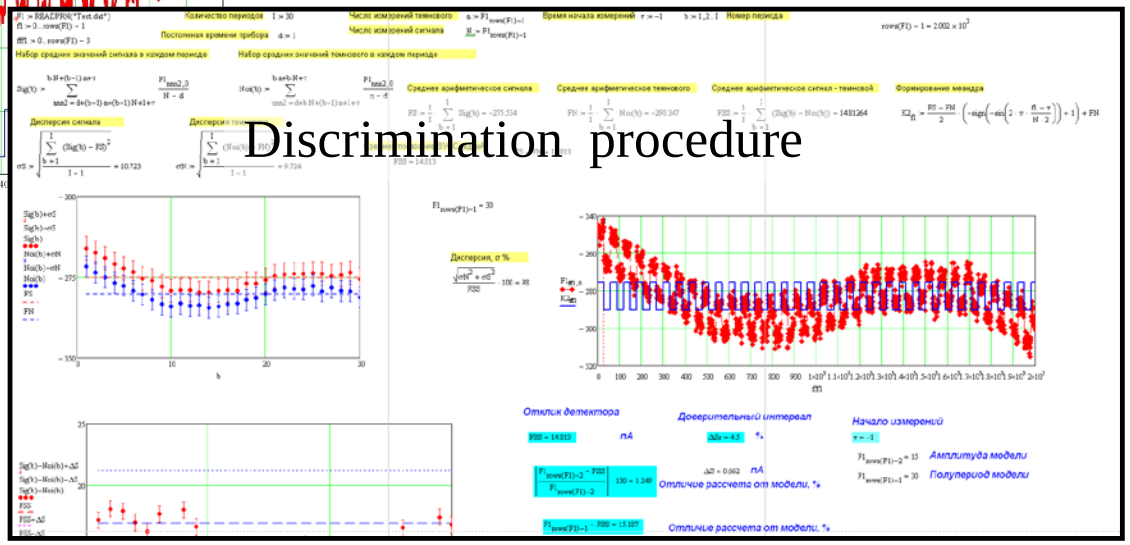


dark current
(real measurements)



dark current
+ meander

Discrimination procedure



accuracy of recovery of the meander amplitude :

$\sigma = 2\ \%$

Synchrotron radiation source as primary standard of soft X-ray radiation

$$\Psi = \Psi\,(E_{phot}, \Delta E_{phot}/E_{phot}, T_{beam}, j_{beam}, \Sigma_z, B, A, L, \varphi)$$

Storage ring parameters:

E_{phot} - photon energy,

$\Delta E_{phot}/E_{phot}$ - spectral range,

T_{beam} - *energy of storage ring*,

j_{beam} - *beam current*,

B - value of magnetic field induction in the emission point

Σ_z - vertical emittance,

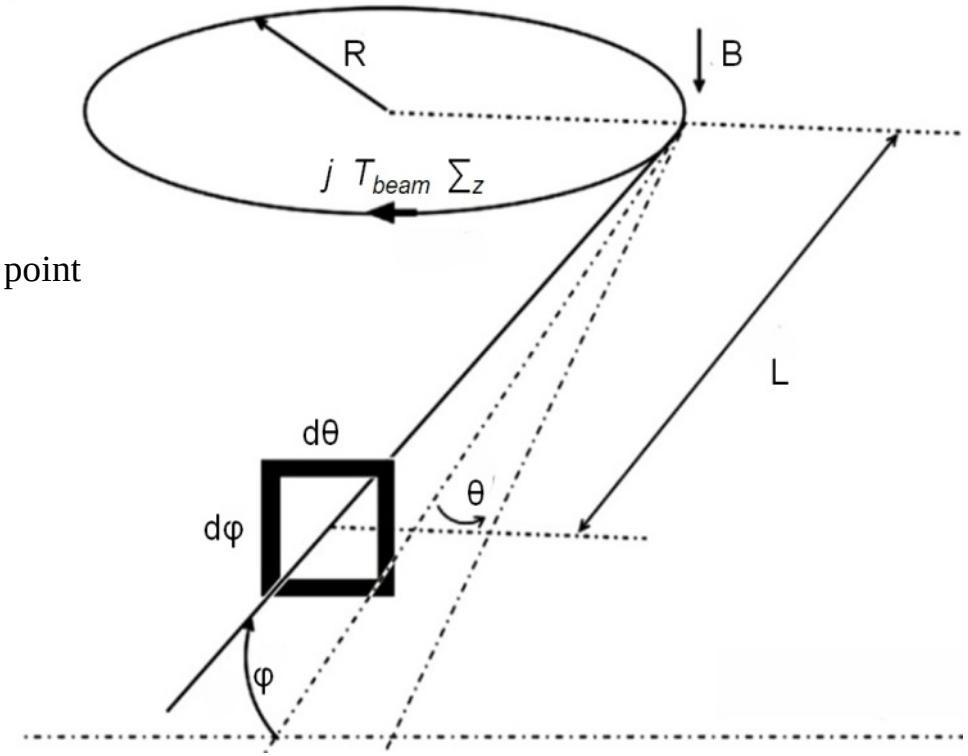
$$\Sigma_z=(\sigma_z^2+d^2\,\sigma_{z'}^2)^{1/2}.$$

The geometrical parameters:

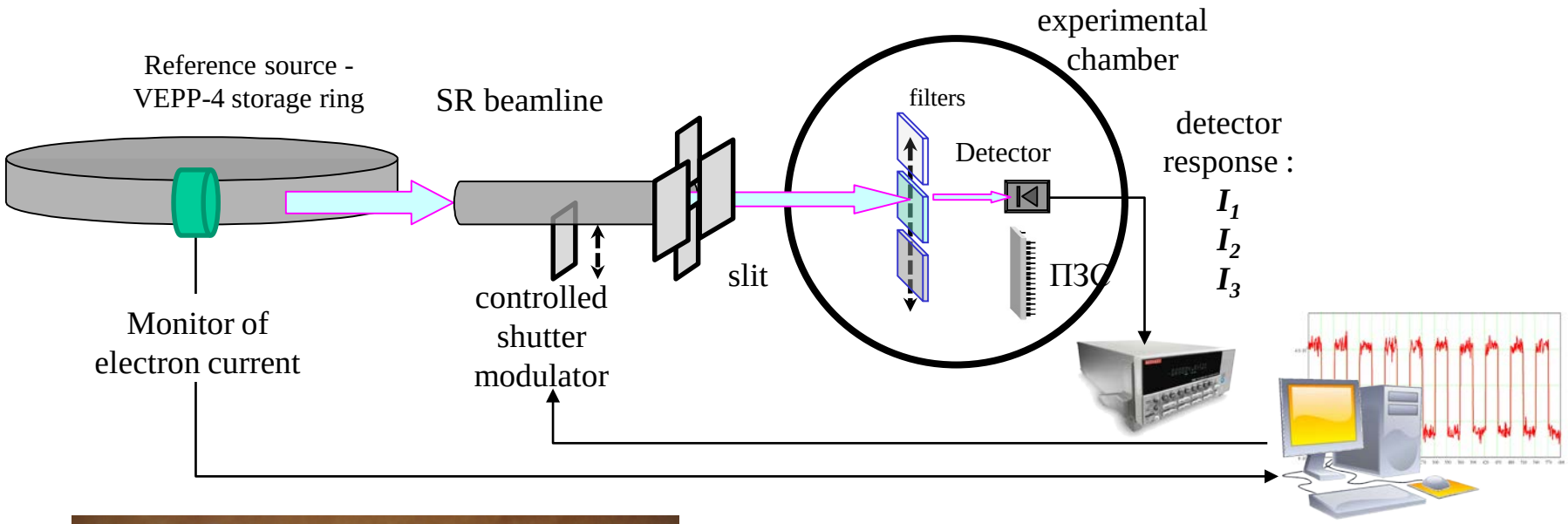
$A = A(d\varphi, d\theta)$ - receiving aperture settings

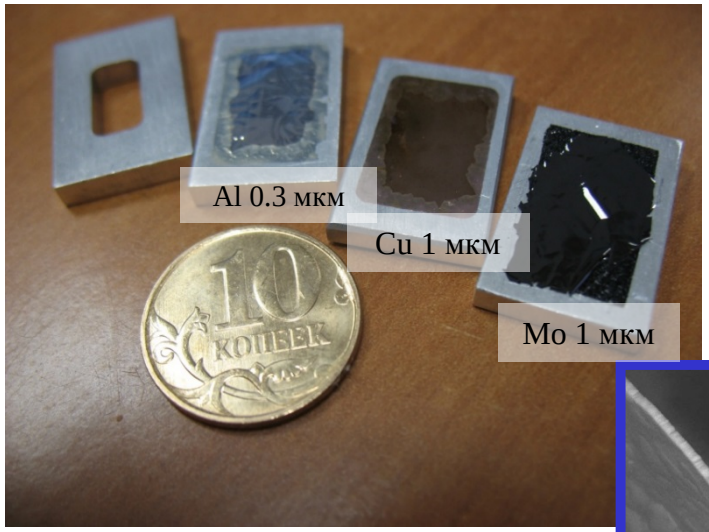
L - distance to the emission point

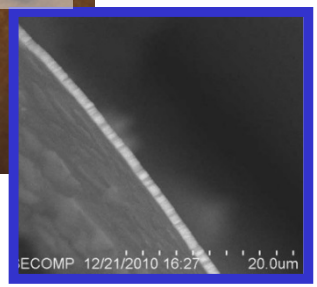
φ - **v**ertical angle from the median plane



Experimental setup



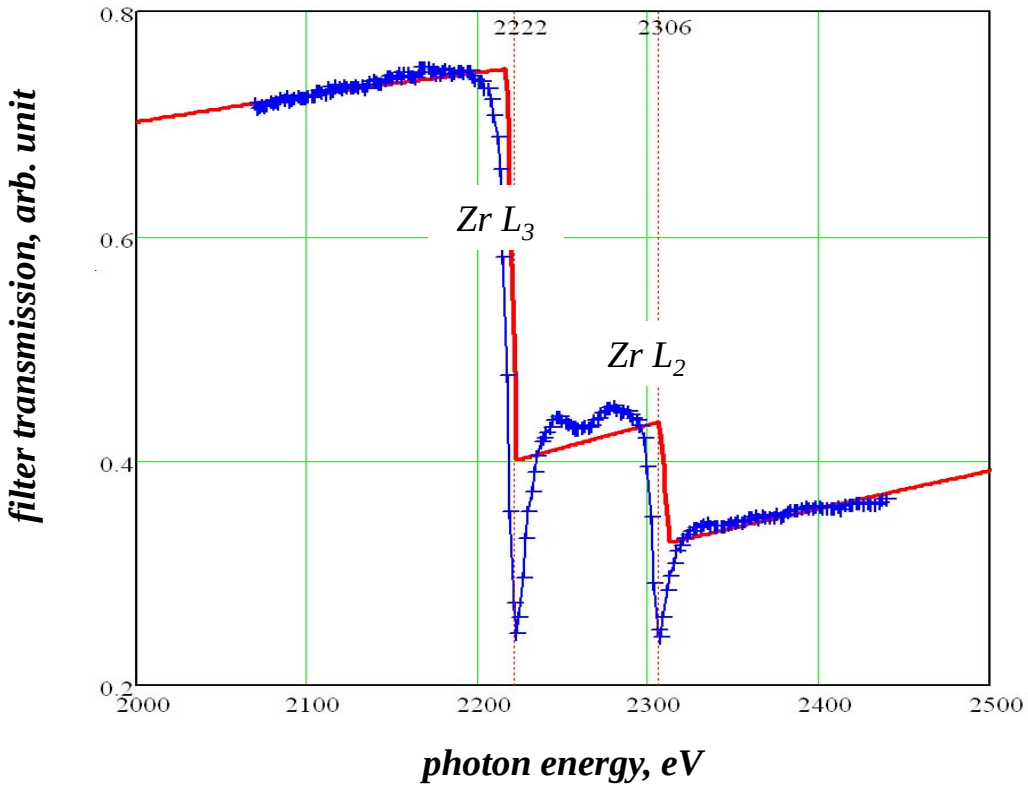




Filters

Certification of the selective filters

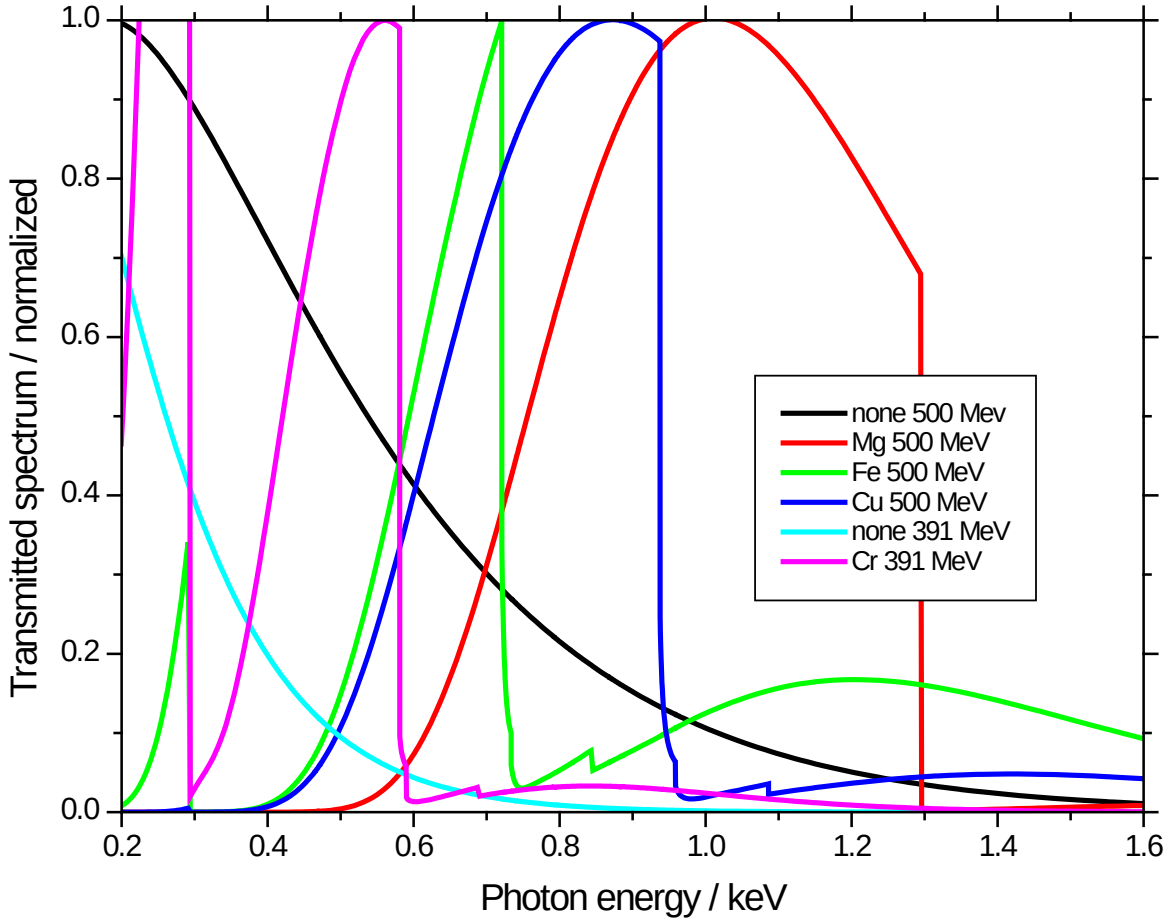
measurement of the transmission near the K or L-edges of the filter material



Measurement transmission of the Zr filter (monochromator crystals - mica).
Comparison with the CXRO data base (red graph) gives the thickness of the filter - 0.54 μm
http://henke.lbl.gov/optical_constants/

The estimated power spectral density of the SR after the filters

$$P(E) = f(E)\,\psi(E)\;dE/E$$



Filters are polymer film with metal coating or the thin metal film
Fe, Cu, Mg, Cr, Al etc.
the thickness of the filter should be certified

Solution of a system of integral equations

$$I_i = \int_0^{\infty} P_i(E) \cdot S(E)\, dE + \xi_i$$

P_i - spectral power distribution of the SR after i-th filter

$S(E)$ – spectral sensitivity of the detector

The system is solved by the limited optimization of Boxing (a type of flexible polyhedron method).

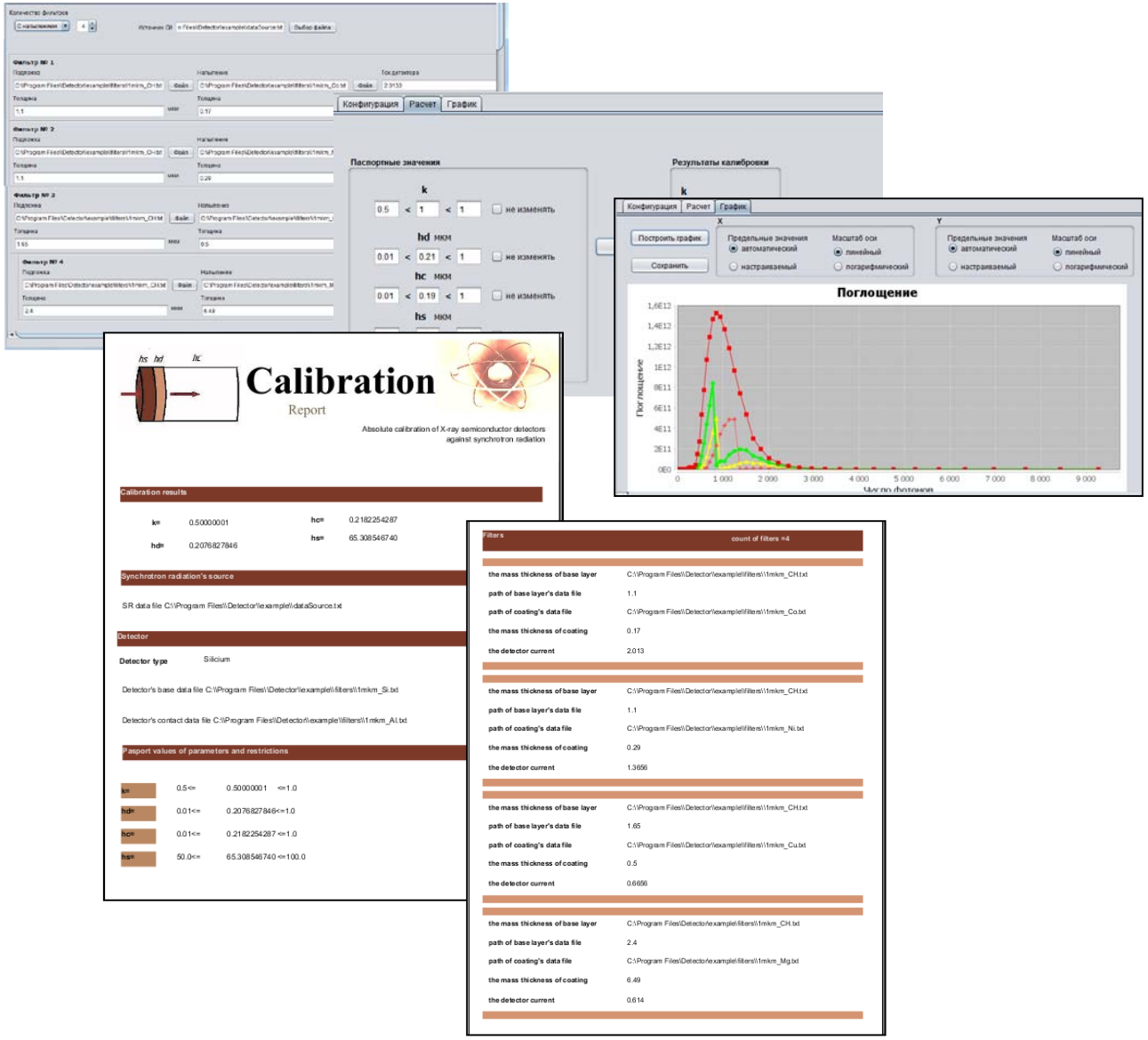
To stabilize the solution we use parametric definition of the functions S(E).

$$S(E) = \frac{e}{w} \cdot k \cdot \exp\left[-\mu_c(E) h_c\right] \cdot \exp\left[-\mu_d(E) h_d\right] \cdot \left(1 - \exp\left[-\mu_s(E) h_s\right]\right)$$

h_c h_d h_s - variable parameters: the deposition thickness of the dead and the active layers of the detector

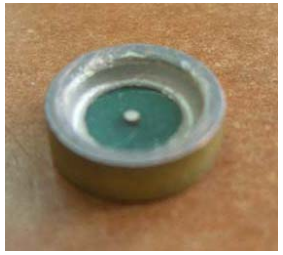
k - charge collection efficiency of the detector

The appearance of the interface window for solving the system of equations *written by our colleagues from Polzunov Altai State Technical University, Barnaul*



Preliminary sensitivity calibration result & 1000 eV :

ETDRI-4 - **$2.3 \cdot 10^{-5}$ A/W**



For comparison:

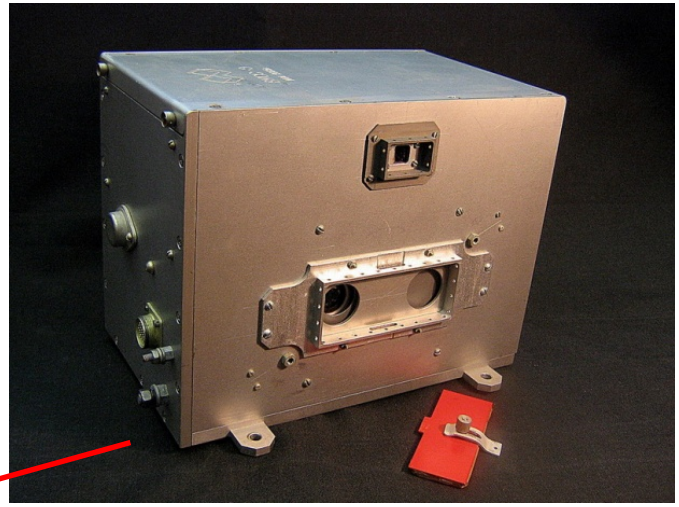
X-ray vacuum diode - **$1.7 \cdot 10^{-5}$ A/W**

Silicon photodiode SPD - **0.27 A/W**

Calibration of the Solar UV radiation sensor VUSS-E for the geostationary satellite "Electro-L №3"

Customer - Fedorov IAG, Moscow

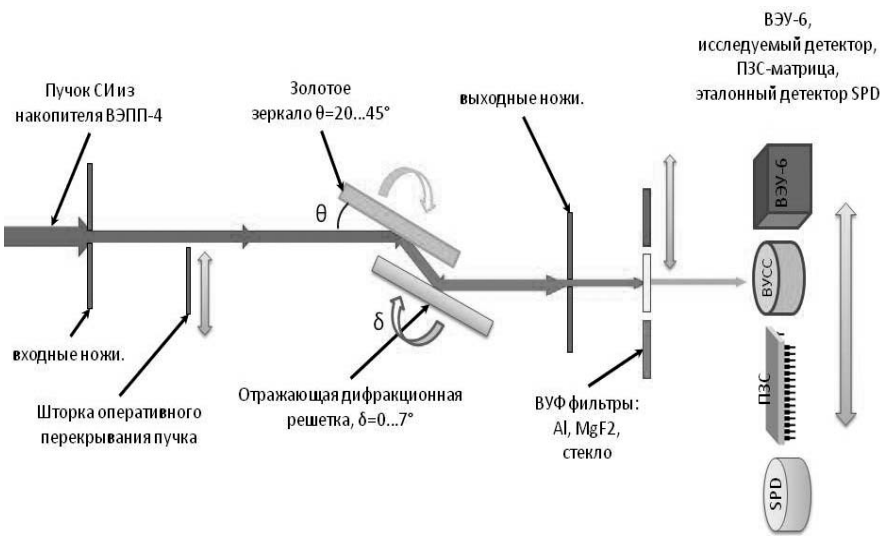
Fluxmeter to measure the intensity at 121.6 nm (H Lyman alpha-line)

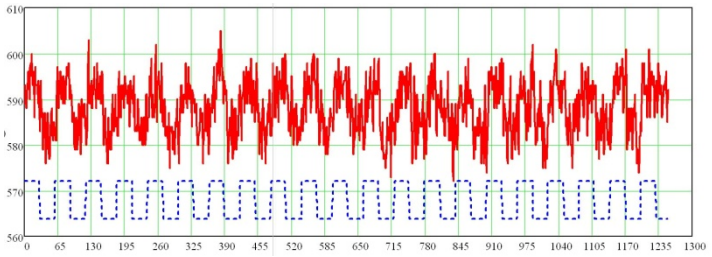


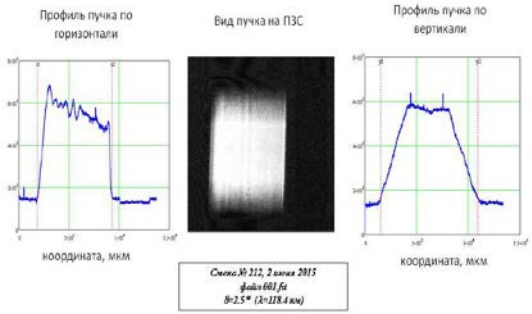
based on the PMT-154

Expected launch - 2017

Method of the reference detector







Calibration certificate

Номер сертификата 1-2015 Страница 1 из 2

Федеральное государственное бюджетное учреждение науки Институт ядерной физики им. Г.И. Будкера Сибирского отделения Российской академии наук ИЯФ СО РАН

Федеральное государственное унитарное предприятие «Сибирский государственный Ордена Трудового Красного Знамени научно-исследовательский институт метрологии» ФГУП «СНИИМ»

Budker Institute of Nuclear Physics Siberian Branch Russian Academy of Sciences BINP SB RAS

Federal state unitary enterprise «Siberian State Scientific Research Institute of Metrology» FSUE «SNIIM»

Сертификат калибровки

Calibration certificate

Номер сертификата **1-2015** Дата калибровки **10.07.2015** Страница 1 из 2

Объект калибровки: *измеритель ультрафиолетового излучения Солнца типа ВУСС геликогеофизического аппаратурного комплекса ГГАК*

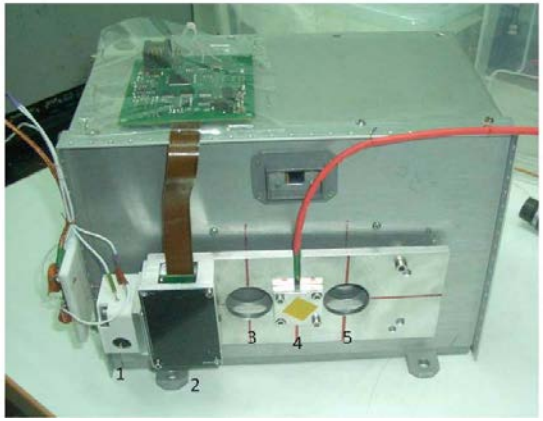
Заказчик: *Заказчик: ФГБУ "ИПГ" 129128, г. Москва, ул. Ростокинская, д.9 ИНН 7716823812*

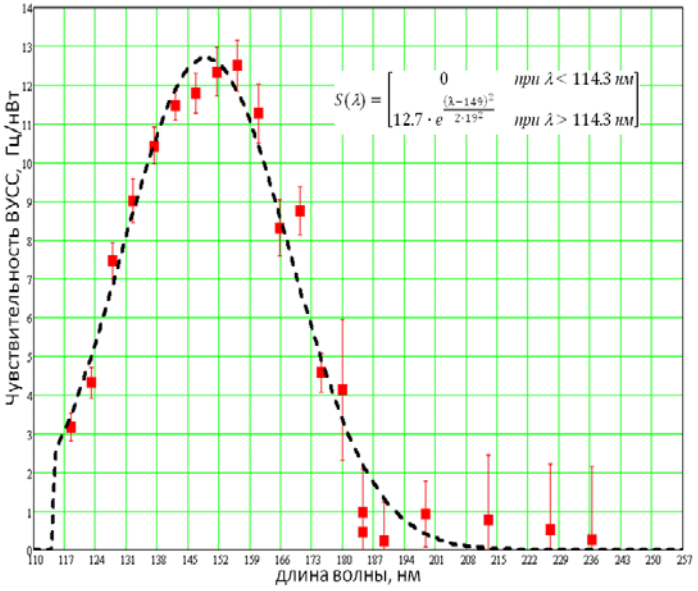
Метод калибровки: *Косвенное определение чувствительности при измерении мощности излучения с помощью эталонного детектора*

Калибровка выполнена с помощью: *Детектор SPD-100 UV, пикоамперметра Keithley 2502, станции синхротронного излучения "Космос", накопителя ВЭПП-4 (ИЯФ СО РАН)*

Условия калибровки: *Температура 25°С, отн.вл.воздуха 60 %, атм.давление 99,8 кПа*

Утверждающая подпись: Директор Г.В. Шувалов; Заместитель директора ИЯФ СО РАН Е.Б. Левичев





Conclusions

At the station Cosmos worked out a number of procedures for certification of basic consumer qualities of different kinds of detectors :

- Spectral sensitivity (calibration accuracy 1-10%)
  - *method of the reference detector*
  - *standard source method*
  - *self-calibration method*
- Spatial sensitivity mapping
- Dark current
- Stability of characteristics
- Radiation resistance


XVI МЕЖДУНАРОДНАЯ КОНФЕРЕНЦИЯ ПО
ИСПОЛЬЗОВАНИЮ СИНХРОТРОННОГО ИЗЛУЧЕНИЯ
10 – 15 июля 2006 г.
СИ-2006
К502АМ54

Спасибо за внимание