Metrological station "COSMOS". Current status.
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 ($\lambda=13$ 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
"Cosmos" Beamline at the VEPP-4 SR experimental hall

SR station "Flame"

Cosmos experimental vacuum chamber
Project of new beamline “Flame”

**Spherical mirror:**
- R=12 m
- Substrate – quartz
- Coating – gold
- Roughness – 15 Å
- Aperture – 60x60 mm

**Plane grating:**
- Substrate – quartz
- Coating – gold
- Roughness – 15 Å
- Number of grooves – 1500 per mm
- Aperture – 30x40 mm
- Rotation range: 4°-16.5°
- Energy range: 5-25 eV (2000 ≤ - 500 ≥)
- 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 $\Delta E/E=10^{-3}$

Storage ring parameters:
Current: $I=10$ mA,
Energy of electrons $E=1.8 \ldots 6$ GeV

Operating range "Cosmos" station
Layout and optical scheme of the COSMOS station

- Two-multimirror monochromator
- Filters
- Total reflection mirrors
- Reference detector and detectors to be calibrated
- Spectrometer to be calibrated
Two-multimirror monochromator
(multilayer mirrors)

Parameters:

Angle range: 7º-80º

Mirrors: 30x40 mm² (Y/Mo, Fe/C, W/Si...)

Spectral range - 80-2000 eV

Spectral resolution: 0.1-10%

Fixed position of monochromatic beam

Vacuum - 10⁻⁴Pa
Two-multimirror monochromator
(multilayer mirrors)

Parameters:

Angle range: 7º-80º

Mirrors: 30x40 mm² (Y/Mo, Fe/C, W/Si...)

Crystals: mica, KAP, CzAP...

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Fixed position of monochromatic beam

Vacuum - 10⁻⁴Pa

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

ETDRI-4
c coaxial diamond detector
Dukhov VNIIA, Moscow

SEM-6

p-n photodiode SPD
Ioffe Institute
Saint Petersburg

Solar UV radiation sensor
VUSS-E
Fedorov IAG, Moscow

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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**
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Облучение фотодиода:

Схема фокусировки и фильтрации

Оптические фильтры

стекло

Рентгеновский фильтр

0.2µ Nb + 0.2µ Zr

MgF2

серый нейтральный

зркало

5 м

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/sm²) & 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. Dukhov VNIIA, 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 & $\lambda=1053$ 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
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)

Accuracy of recovery of the meander amplitude: \( \sigma = 2\% \)
Synchrotron radiation source as primary standard of soft X-ray radiation

\[ \Psi = \Psi \left( E_{\text{phot}}, \Delta E_{\text{phot}}/E_{\text{phot}}, T_{\text{beam}}, j_{\text{beam}}, \Sigma_z, B, A, L, \phi \right) \]

**Storage ring parameters:**
- \( E_{\text{phot}} \) - photon energy,
- \( \Delta E_{\text{phot}}/E_{\text{phot}} \) - spectral range,
- \( T_{\text{beam}} \) - energy of storage ring,
- \( j_{\text{beam}} \) - beam current,
- \( B \) - value of magnetic field induction in the emission point
- \( \Sigma_z \) - vertical emittance,
  \[ \Sigma_z = (\sigma_z^2 + d^2 \sigma_z^2)^{1/2} \]

**The geometrical parameters:**
- \( A = A(d\phi, d\theta) \) - receiving aperture settings
- \( L \) - distance to the emission point
- \( \phi \) - vertical angle from the median plane
Experimental setup

Reference source - VEPP-4 storage ring

Monitor of electron current

SR beamline

controlled shutter modulator

slit

Detector

filters

detector response:

$I_1$

$I_2$

$I_3$

experimental chamber

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

\[ P(E) = f(E) \psi(E) \frac{dE}{E} \]

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 - \(2.3 \cdot 10^{-5} \text{ A/W}\)

For comparison:

X-ray vacuum diode - \(1.7 \cdot 10^{-5} \text{ A/W}\)

Silicon photodiode SPD - \(0.27 \text{ A/W}\)
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)

Expected launch - 2017

based on the PMT-154
Method of the reference detector
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
Спасибо за внимание