High-accuracy EUV reflectometry at PTB

EUV Radiometry

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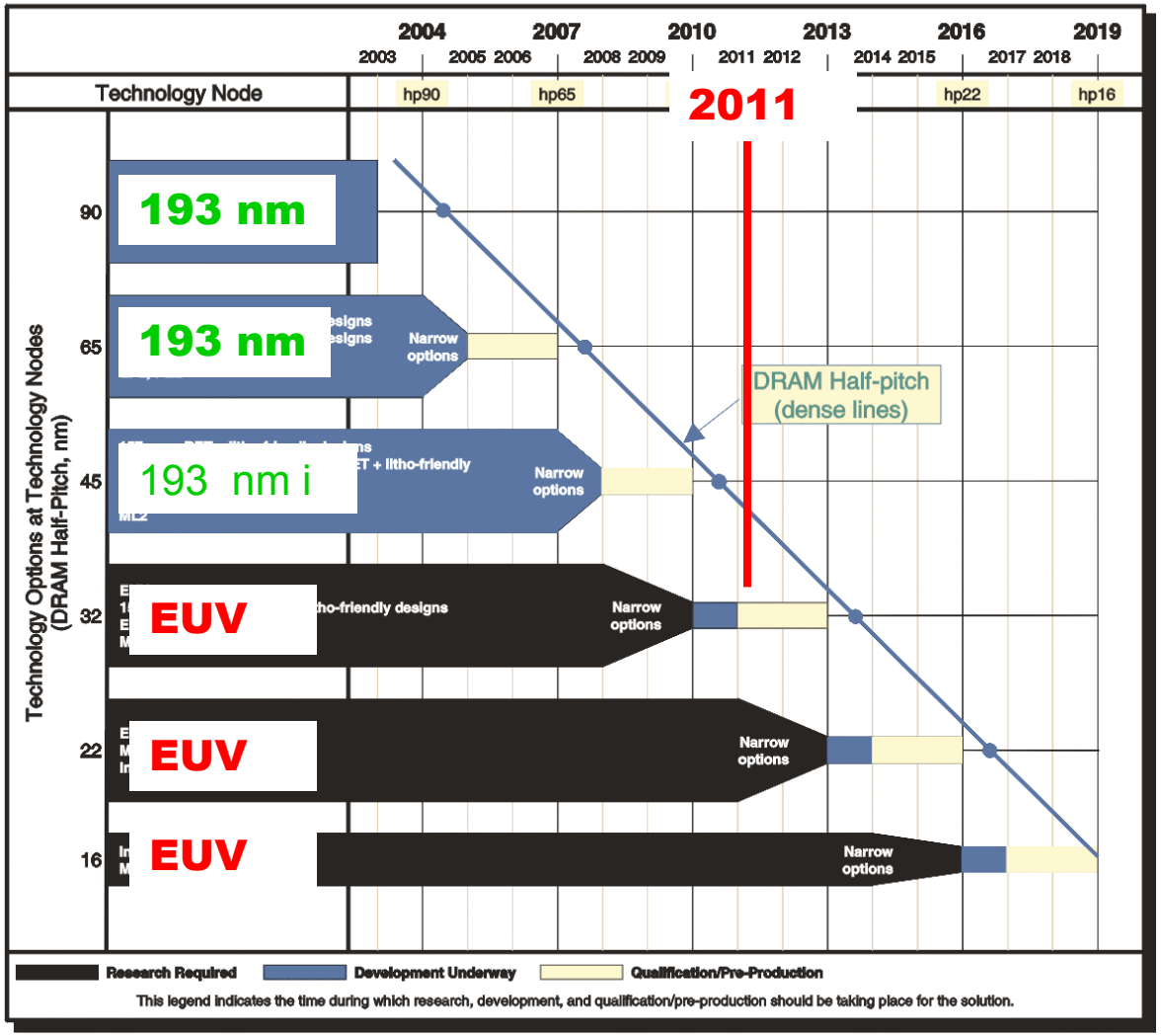
Outline

- PTB laboratory at BESSY II
- Instrumentation
- Measurement examples, uncertainties
- Micro reflectometry facility
- Future developments

ITRS: Lithographie - Roadmap

EUV Radiometry

Figure 53 Lithography Exposure Tool Potential Solutions



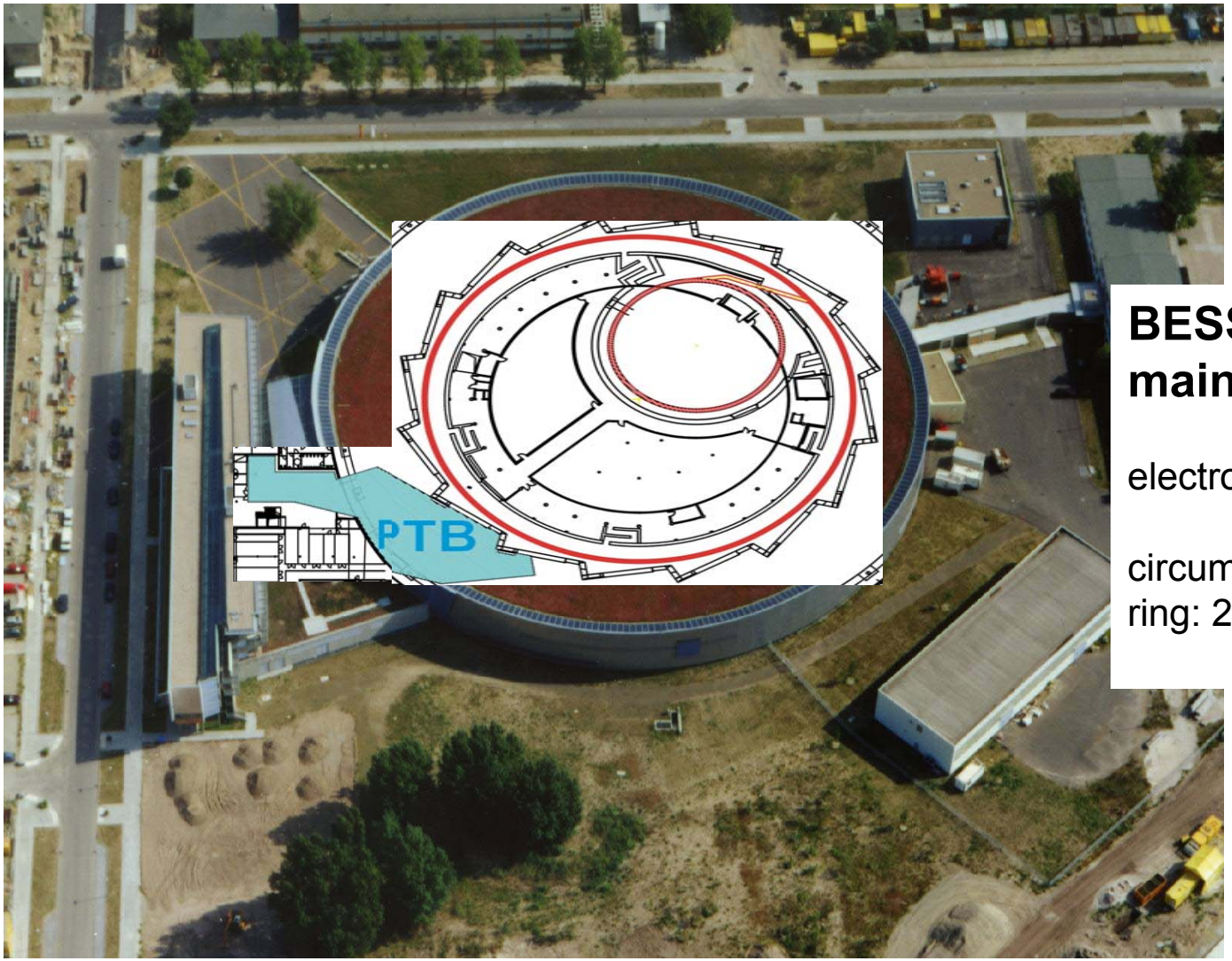
wavelength:

excimer-Laser

13.5 nm Extreme UV

PTB Radiometry Laboratory at BESSY II

EUV Radiometry



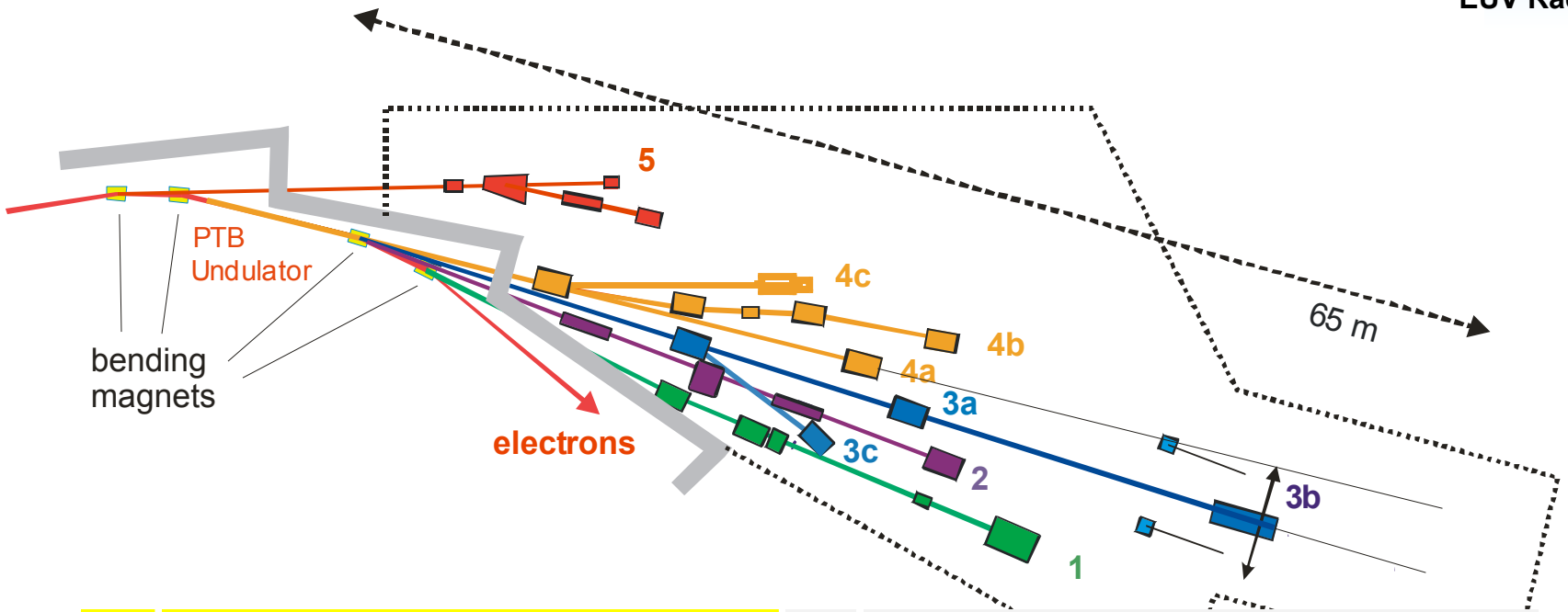
BESSY II
main parameters

electron energy 1.7 GeV

circumference of storage ring: 240 m

PTB Radiometry Laboratory

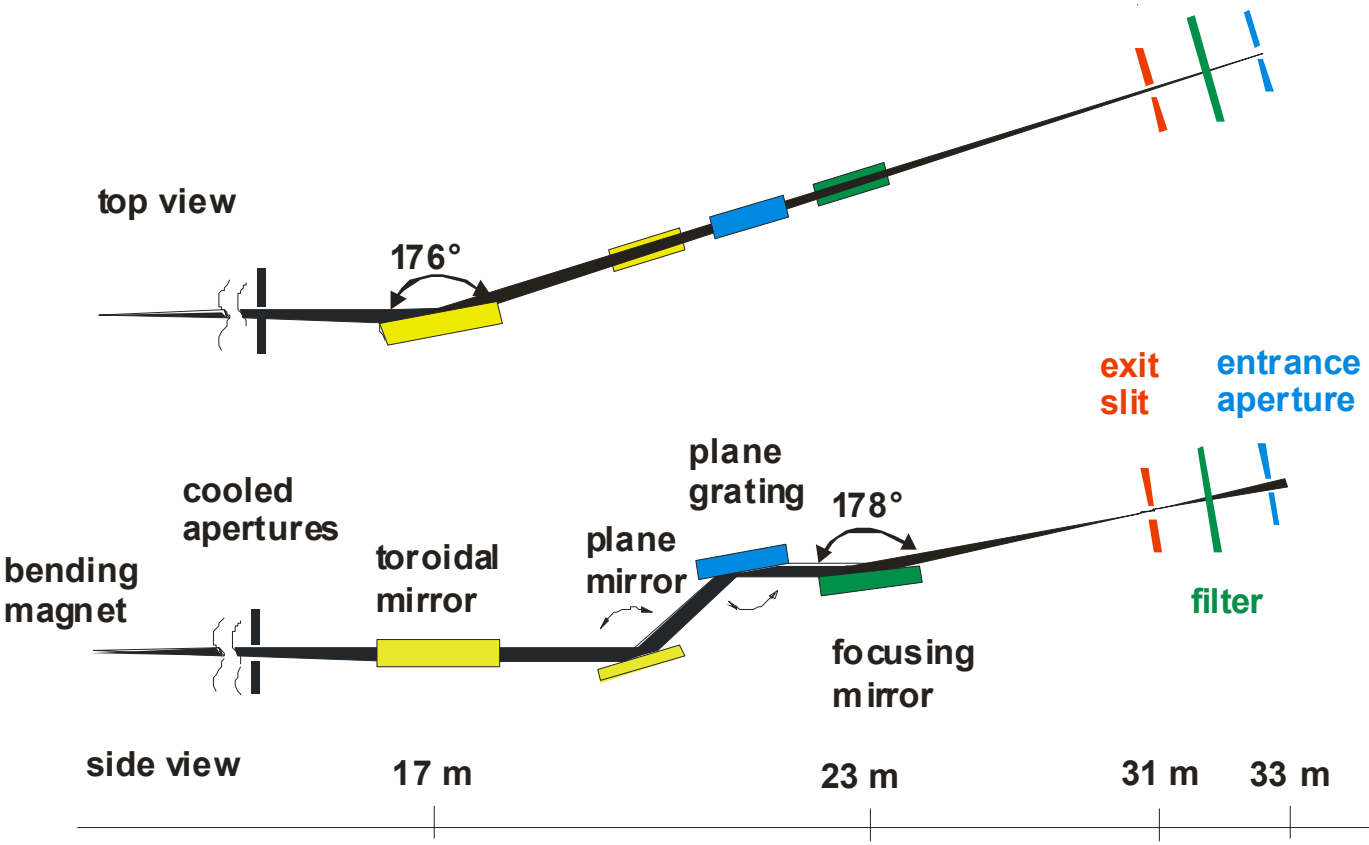
EUV Radiometry



1	plane grating monochromator 30 eV to 1800 eV	4a	undispersed undulator radiation
2	four crystal monochromator 1.75 keV to 10 keV	4b	plane grating monochromator at undulator 20 eV to 1900 eV
3a	undispersed bending magnet radiation	4c	deflected undispersed undulator radiation
3b	normal incidence monochromator radiation source calibration 3 eV to 35 eV	5	normal incidence monochromator detector calibration 3 eV to 35 eV
3c	deflected undispersed bending magnet radiation		

Soft X-ray radiometry beamline

EUV Radiometry



Wavelength
0.65 nm to 40 nm

At 13 nm
Radiant Power
0.5 µW

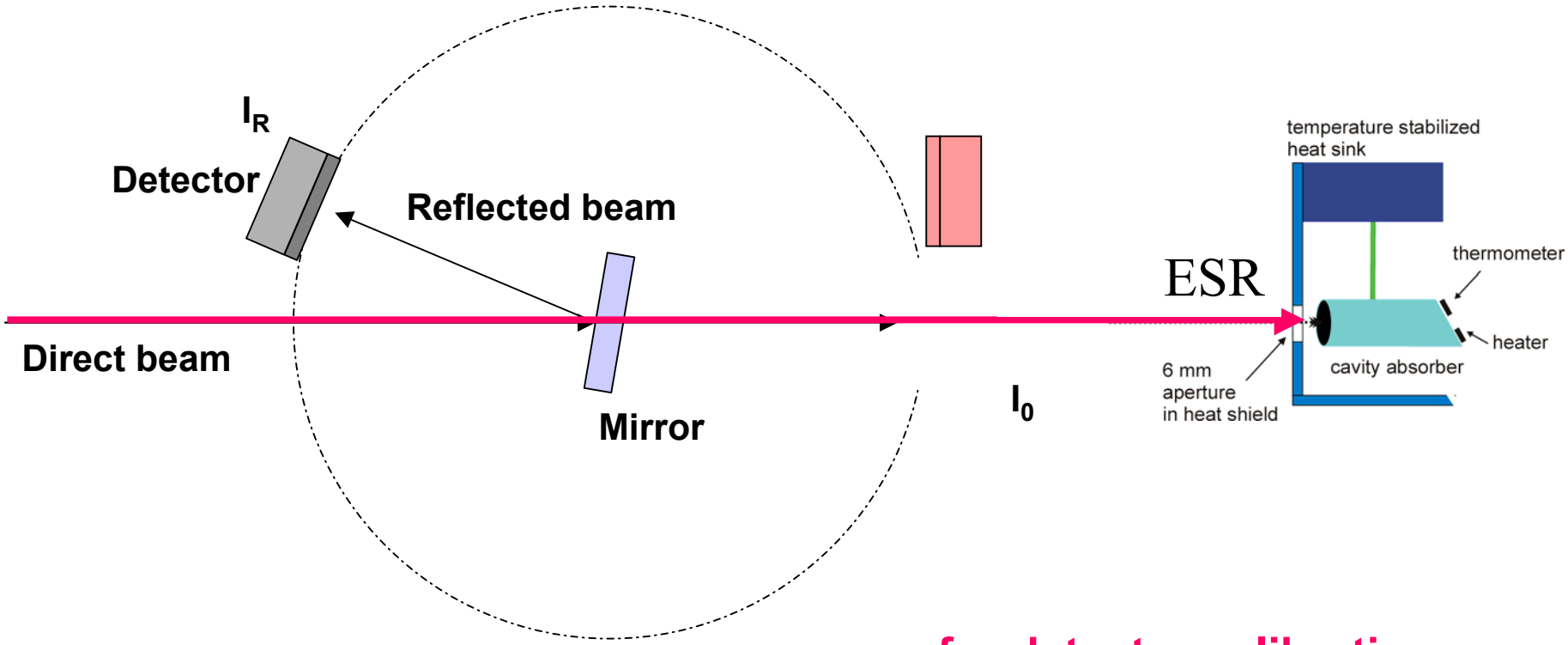
Higher diffraction orders
0.06 %

Diffuse scattered light
0.2 %

Optical scheme of the soft X-ray radiometry beamline

Reflectometry

EUV Radiometry

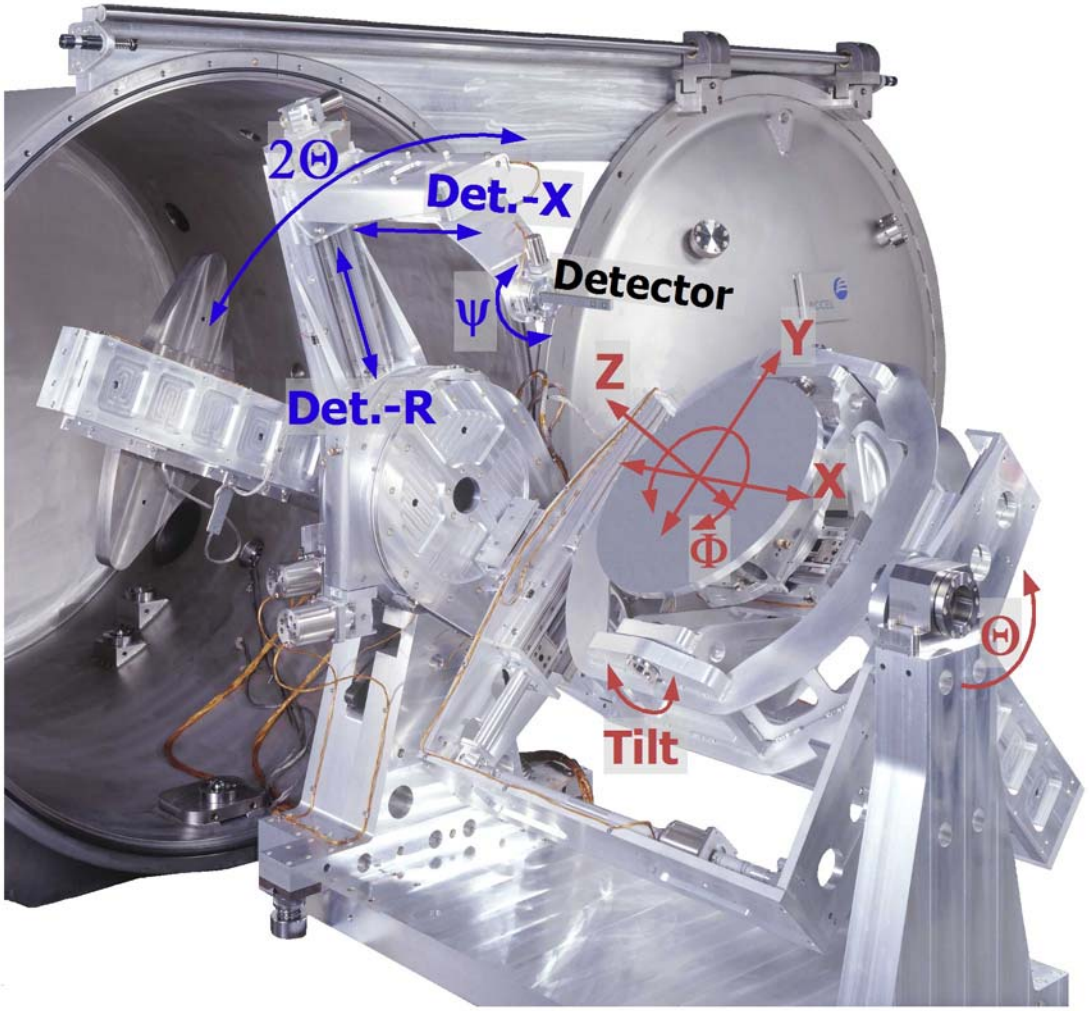


$$R = \frac{I_R/I_{Ring}}{I_0/I_{Ring}}$$

for detector calibration
see poster this afternoon

PTB Reflectometer

EUV Radiometry



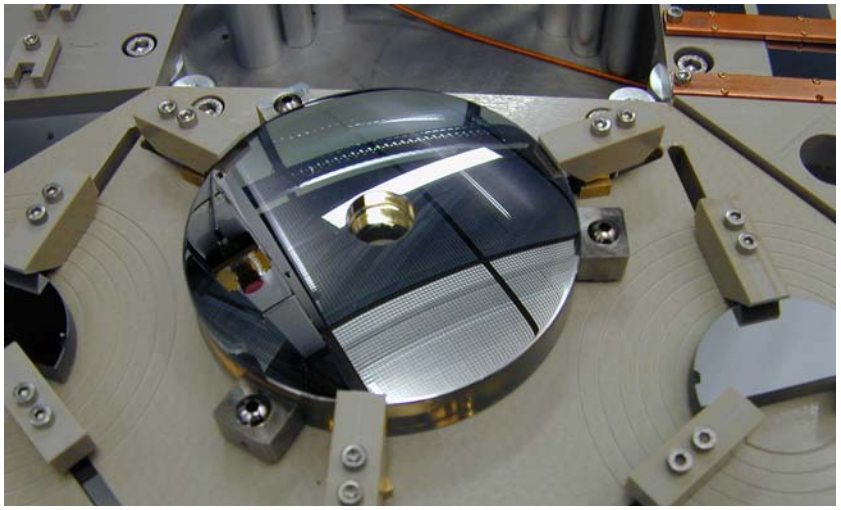
Axis	Range
Θ	-30° to 95°
Tilt	-10° to 10°
Φ	0° to 360°
X	-90 mm to 90 mm
Y	-10 mm to 300 mm
Z	-15 mm to 140 mm
Det. X	0 mm to 120 mm
Det. R	150 mm to 550 mm
Det. Ψ	0° to 180°
2θ	-5° to 190°

Accuracy: 10µm or 0.01°

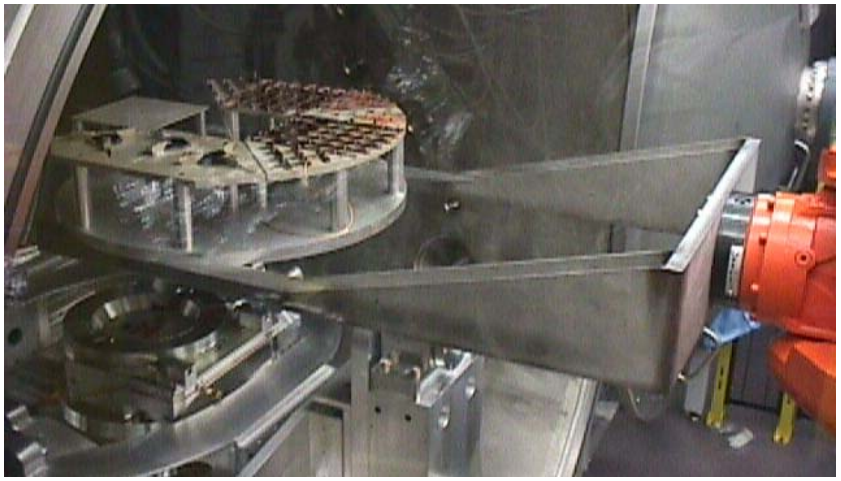
Diameter: 2 m
Length: 2.1 m
Weight: 3 t

Sample holder

EUV Radiometry

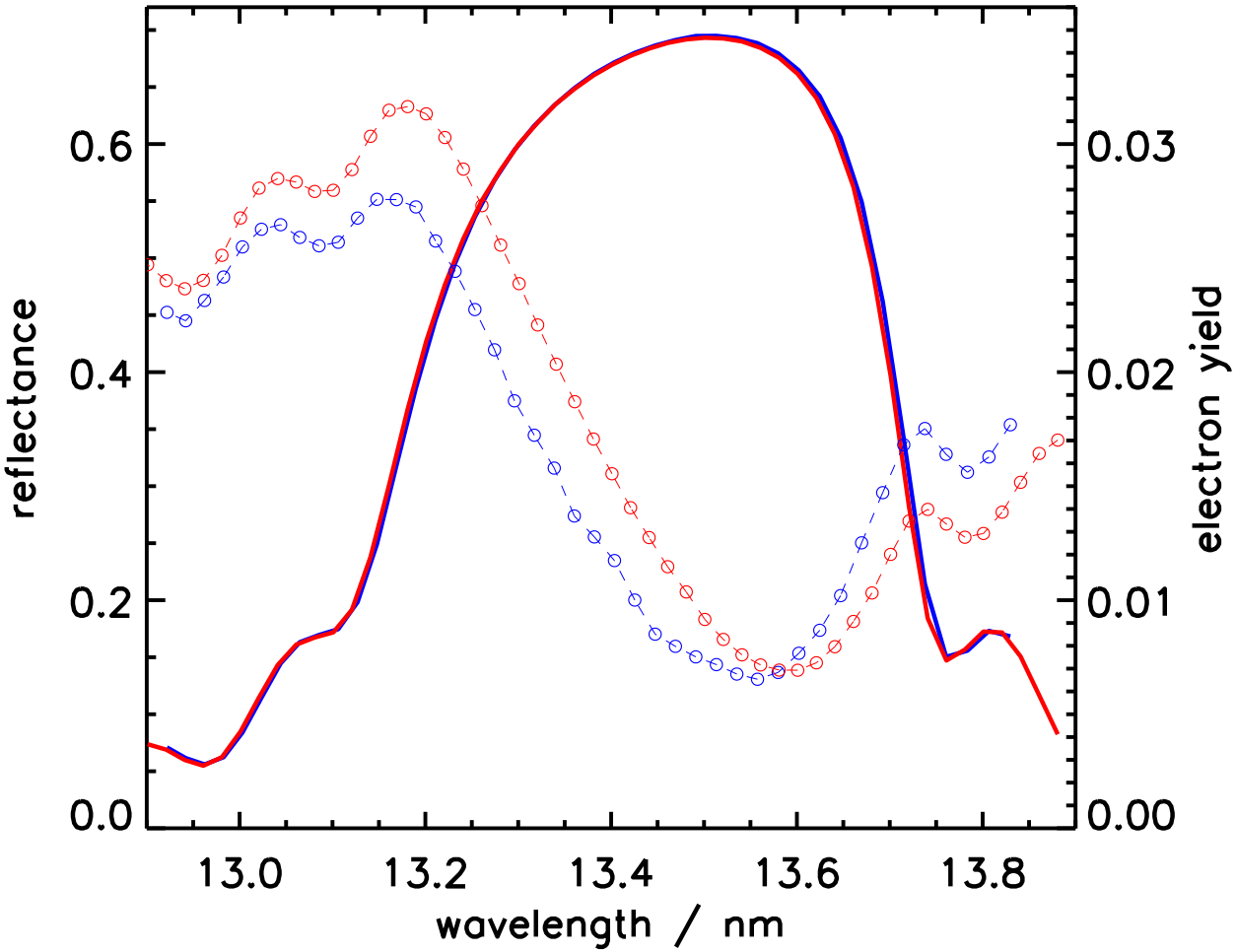


Sample mounting



Photocurrent and reflectance measurement

EUV Radiometry



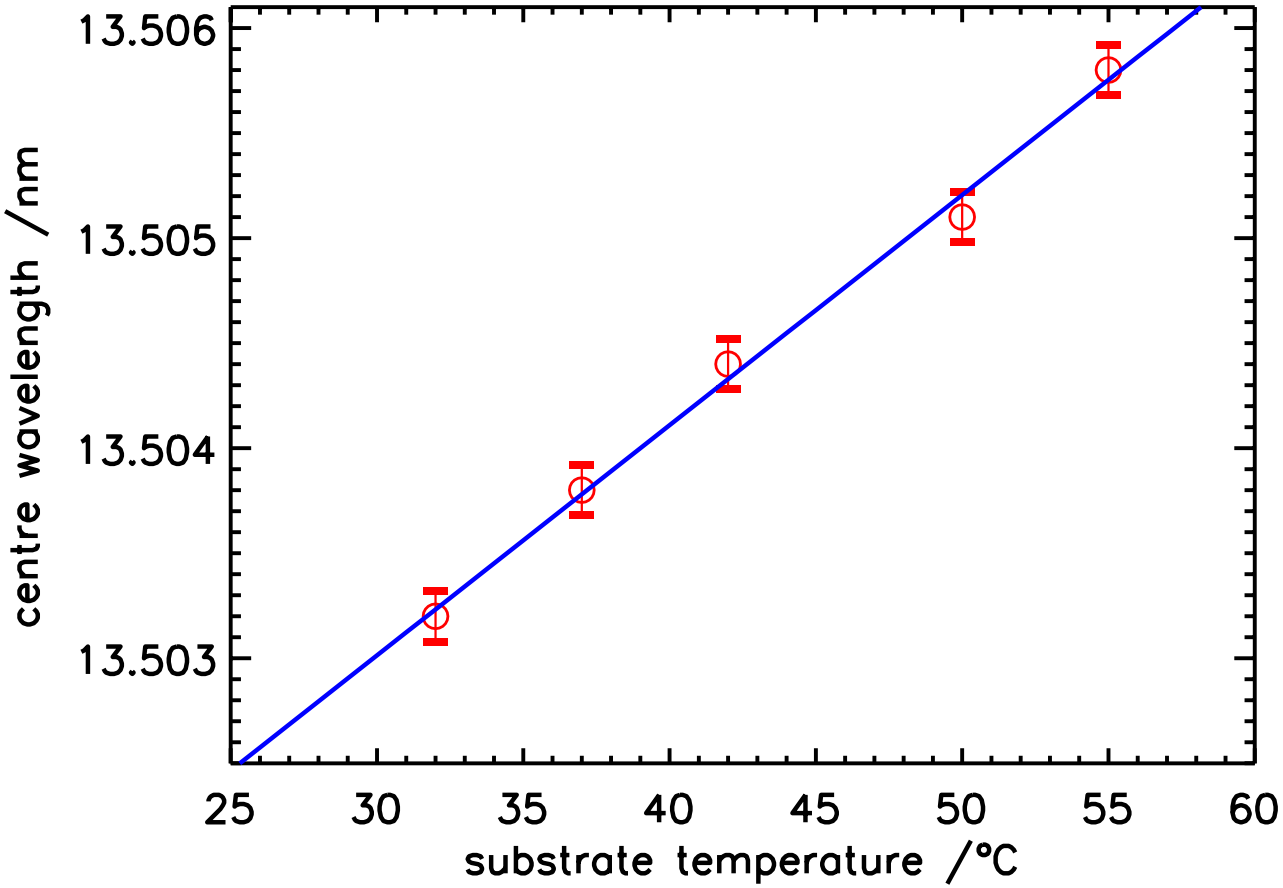
Reflectance of a mirror measured in
March 2002
August 2004

spectral reflectance
- line
photocurrent
- circles

Repeatability of wavelength

EUV Radiometry

measured shift of the centre wavelength as function of substrate temperature

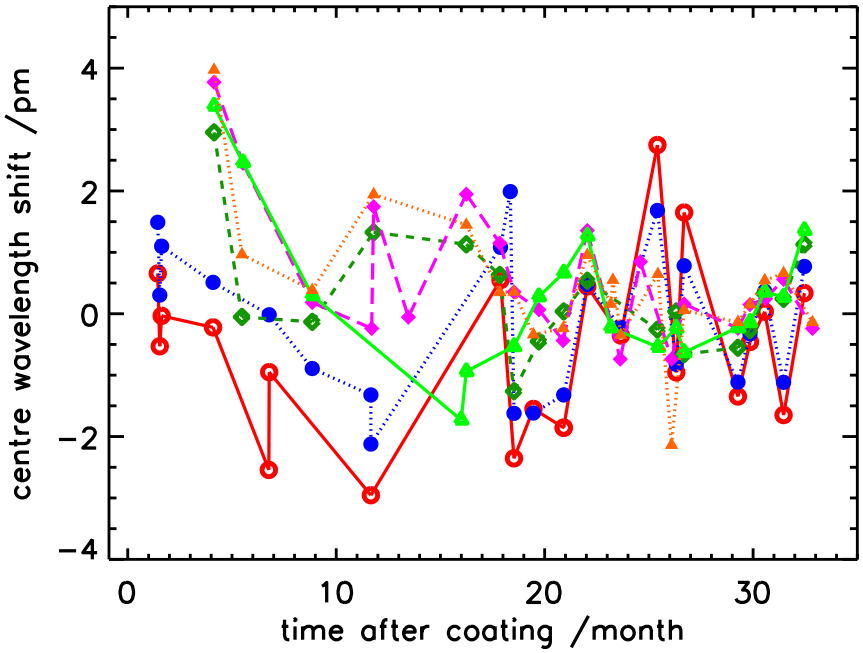


error bars:
signal statistics,
0.12 pm (2σ)

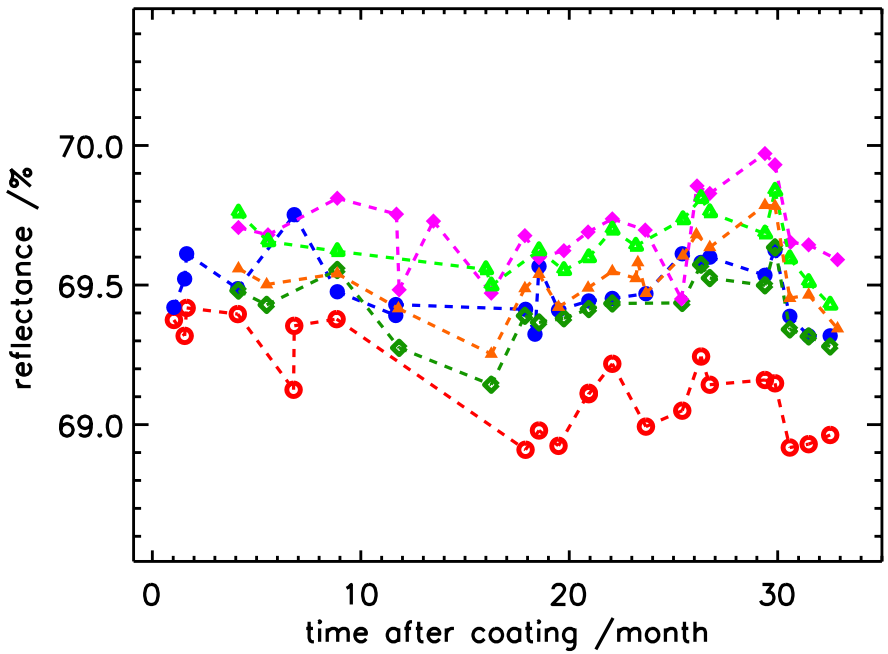
line:
linear fit with a thermal expansion coefficient of $8.1(4)10^{-6}$ K^{-1}.

Long-term reproducibility

EUV Radiometry



measured shift of centre wavelength of EUV mirrors after coating.



measured reflectance of EUV mirrors after coating.

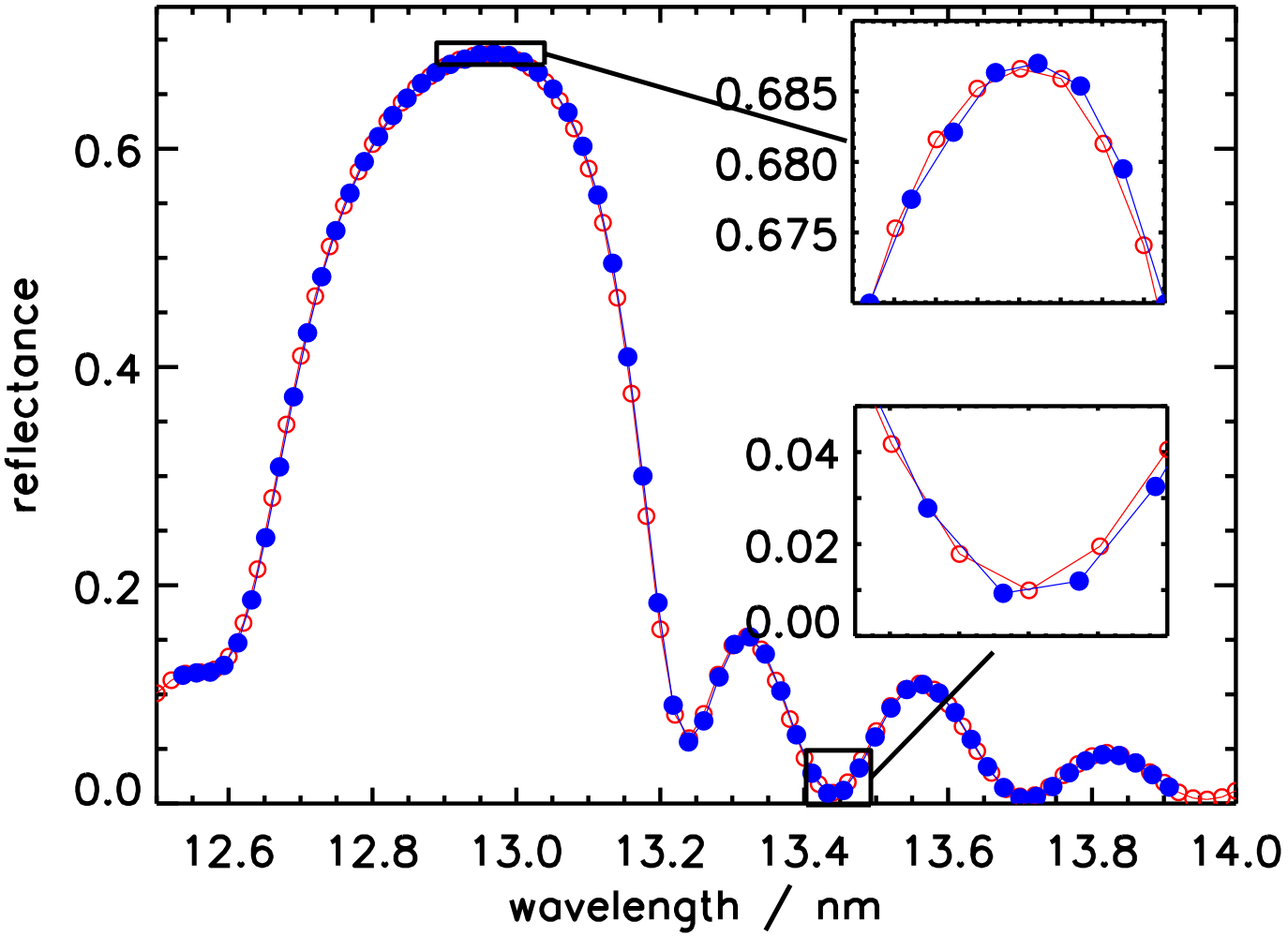
Compilation of uncertainties

EUV Radiometry

Peak reflectance	Uncertainty contribution u /%	Peak wavelength	Uncertainty contribution u /pm
Stability of normalised intensity	0.02	Repeatability of wavelength	0.06
Inhomogeneity of the detector	0.04	Reproducibility of wavelength (reference to Be K-edge)	1.1
Higher diffraction orders	0.02	Kr resonance wavelength	1.6
Diffuse scattered light	0.08		
Total uncertainty of peak reflectance	**0.1**	**Total uncertainty of peak wavelength**	**2.0**

Comparison between CXRO and PTB

EUV Radiometry



reflectance

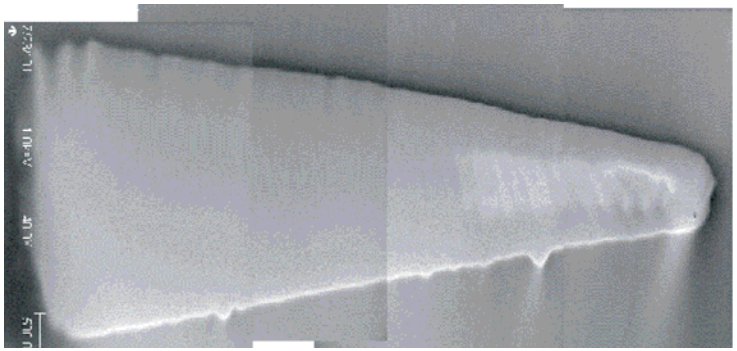
at PTB (blue)

and CXRO (red)

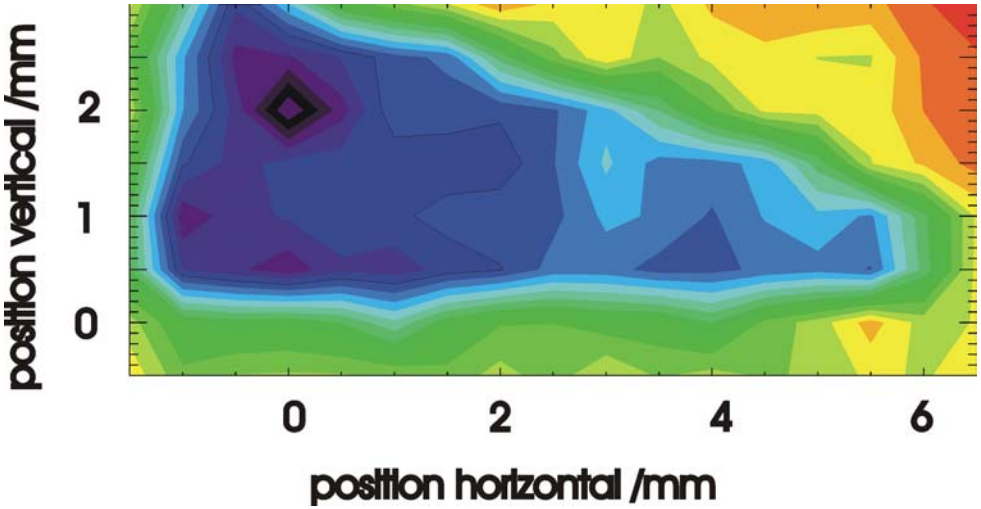
Irradiation testing

EUV Radiometry

carbon contamination by EUV irradiation



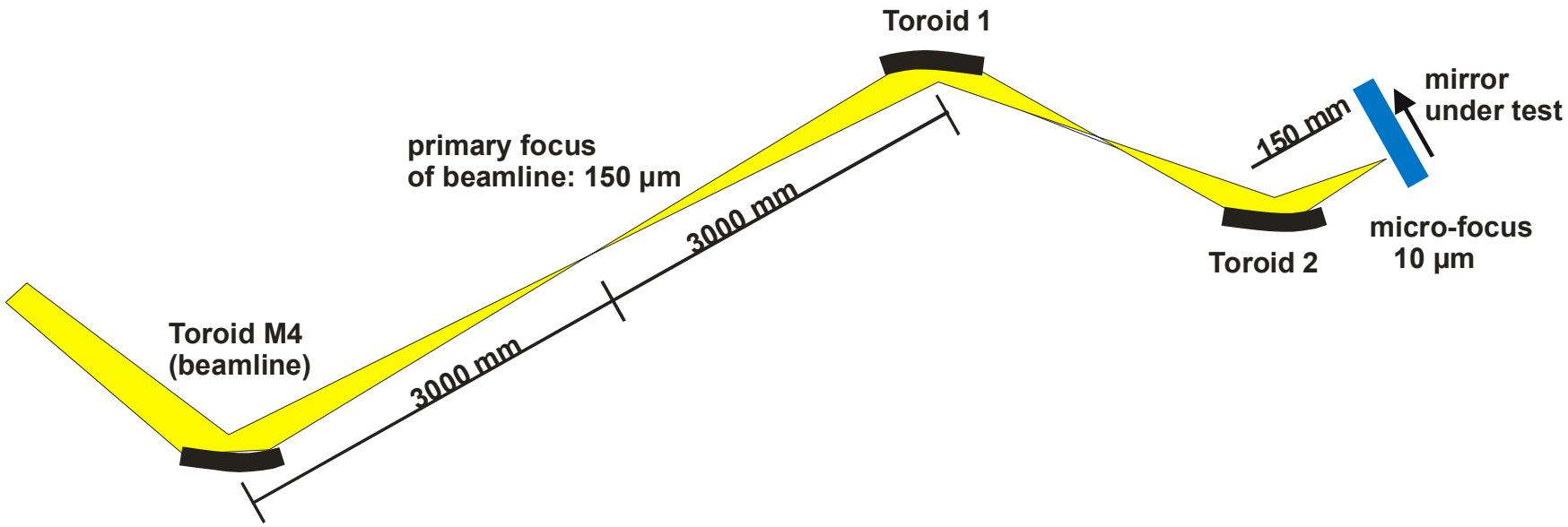
scanning electron microscope



spot in reflectance scan

Micro reflectometry

EUV Radiometry

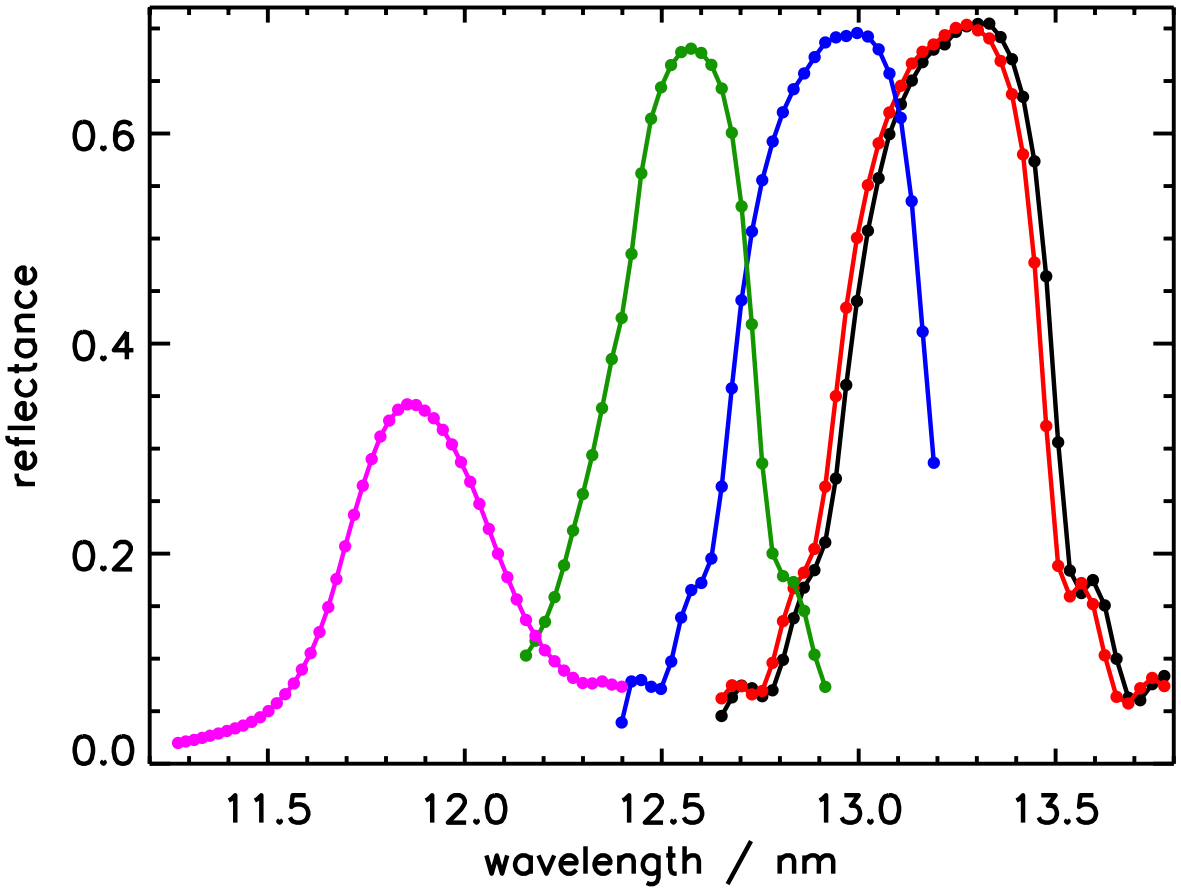


At the undulator beamline of PTB, a refocusing unit with 10 µm focal spot is installed. Using a reflectometer for sample sizes up to 160 mm, micro-reflectometry with about 10 µm spatial resolution can be done at mirrors and masks.

Micro reflectometry

EUV Radiometry

Characterization of multilayer coating close to the substrate edge



Reflectance as function of wavelength

centre of the mirror (black).
and radii of
9.5 mm (red)
10.55 mm (blue),
10.7 mm (green), and
10.8 mm (magenta).

Customers of PTB for EUV radiometry

EUV Radiometry

Major scientific cooperations:

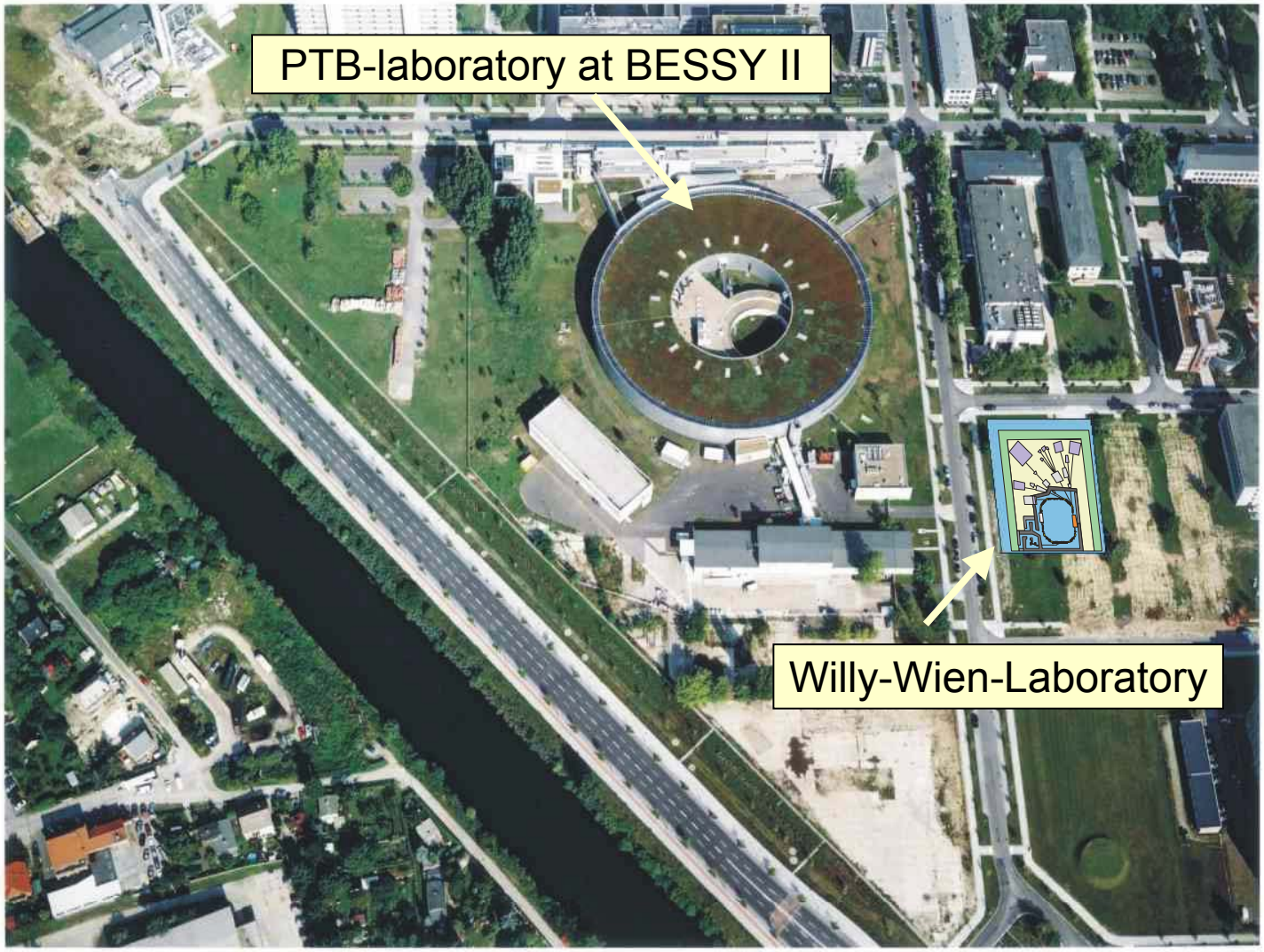
partner	**task**
Carl Zeiss SMT AG	at-wavelength-metrology for EUV lithography
XTREME	EUV source characterization tools
AMTC	Charact. of EUVL masks

about 75% usage of available beam time, ~1000 mirrors /year

other research contracts with various partners from research and industry

Outlook: Metrology Light Source for EUV radiation

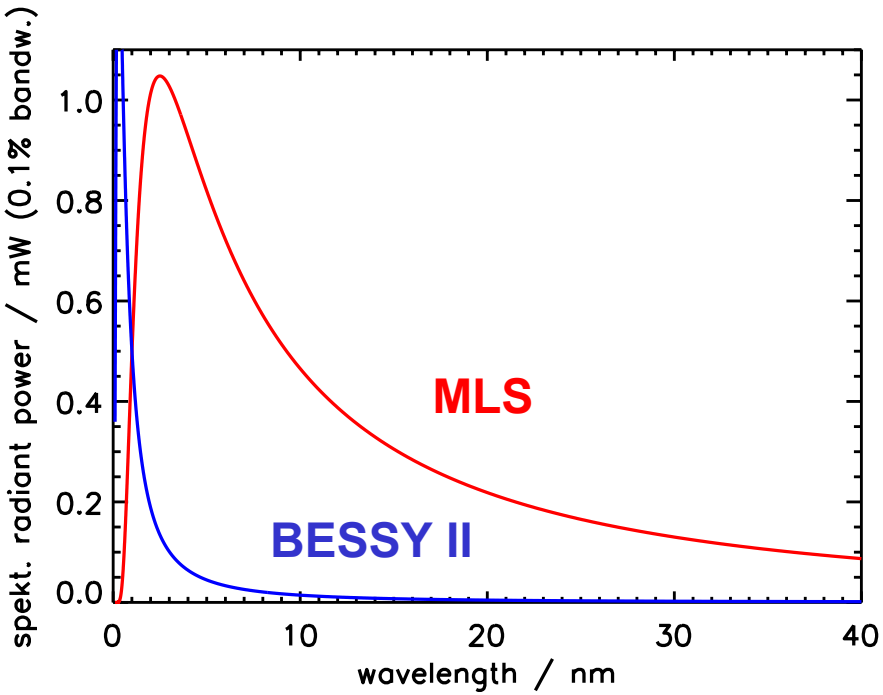
EUV Radiometry



New Options

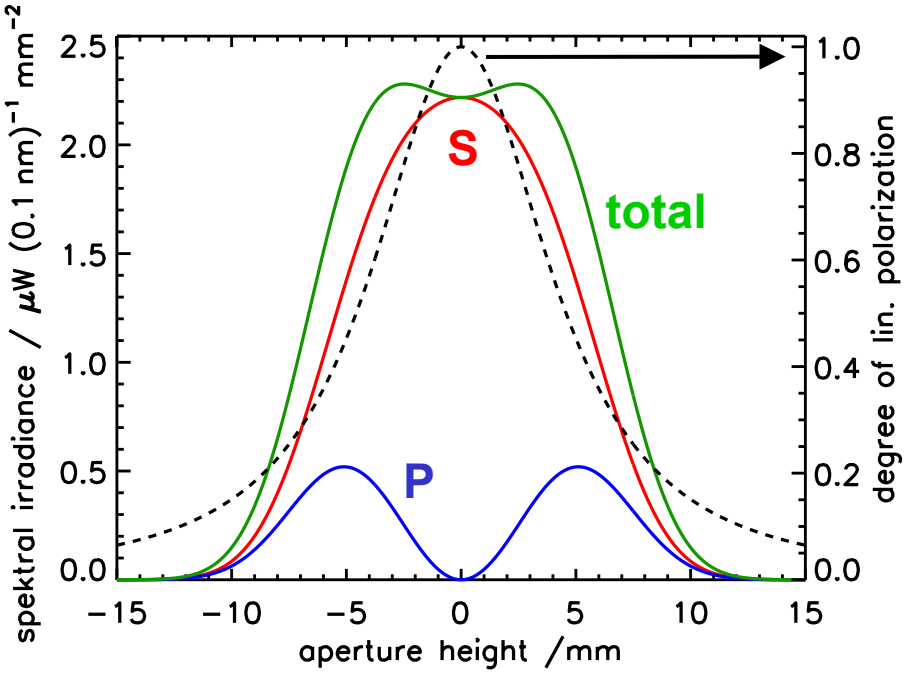
EUV Radiometry

- high radiant power



100-times increase as compared to BESSY II

- variable polarization



usage of off-axis radiation at the MLS

Conclusion

- EUVL development requires high-accuracy, high-volume reflectometry
- PTB serves the European industry at a dedicated beamline
- excellent long term reproducibility is achieved
- new options for micro reflectometry are available
- future use of the MLS will enable new applications