

**International SEMATECH
EUV Source Workshop
February 23, 2003, Santa Clara, California**

Multilayer based instrumentation developments for EUVL source metrology

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- **Inband, out of band and out of EUV metrology**
- **Off-synchrotron optics degradation analysis**
- **Off-synchrotron reference detector calibration**

With a long time experience in multilayer-based SXR and EUV metrology [1-7], we now focus efforts on development of miniature spectrally selective instruments for EUVL source diagnostics.

Devices of two types are currently in progress:

1) Detectors for inband metrology with fixed or variable sensitivity contour shape

2) Detectors for broad range spectrum survey, including out of band EUV and out of EUV intervals

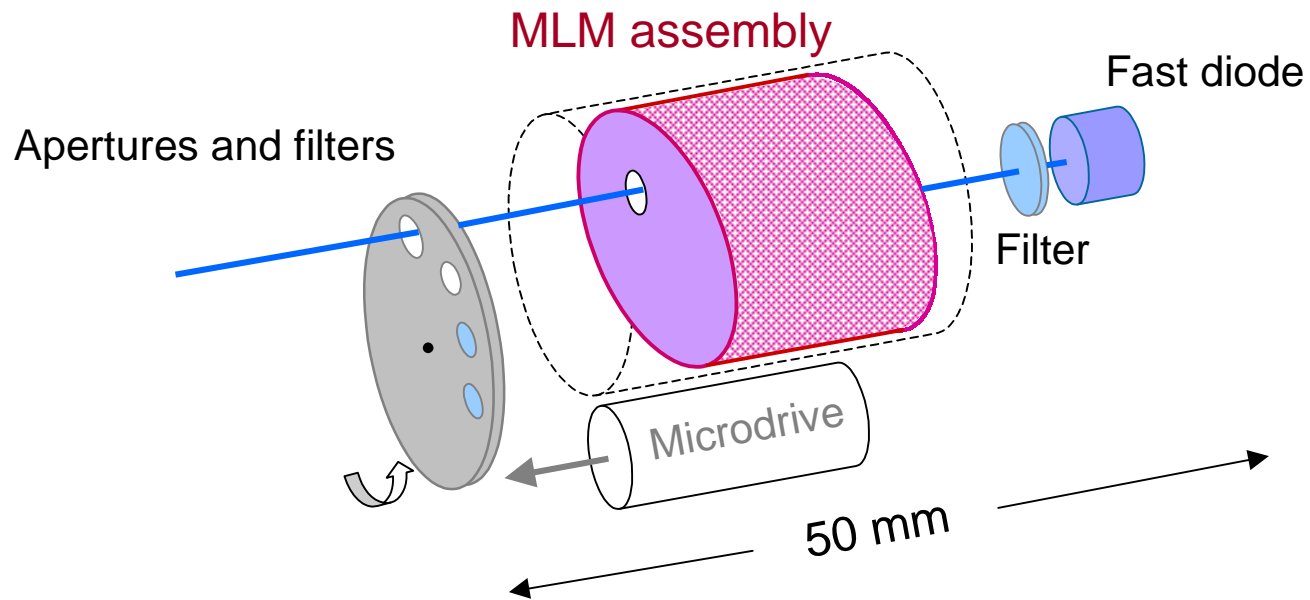
All instruments are developed to be ...

- **calibrated for absolute radiometry** with reference to national standards
- **equipped with signal procession electronics**
- **designed for mounting at arbitrary positions in and out of source chamber**
- **custom-adaptive** units based on modular design, including entrance elements changeable in vacuum

Pilot instrument for inband metrology

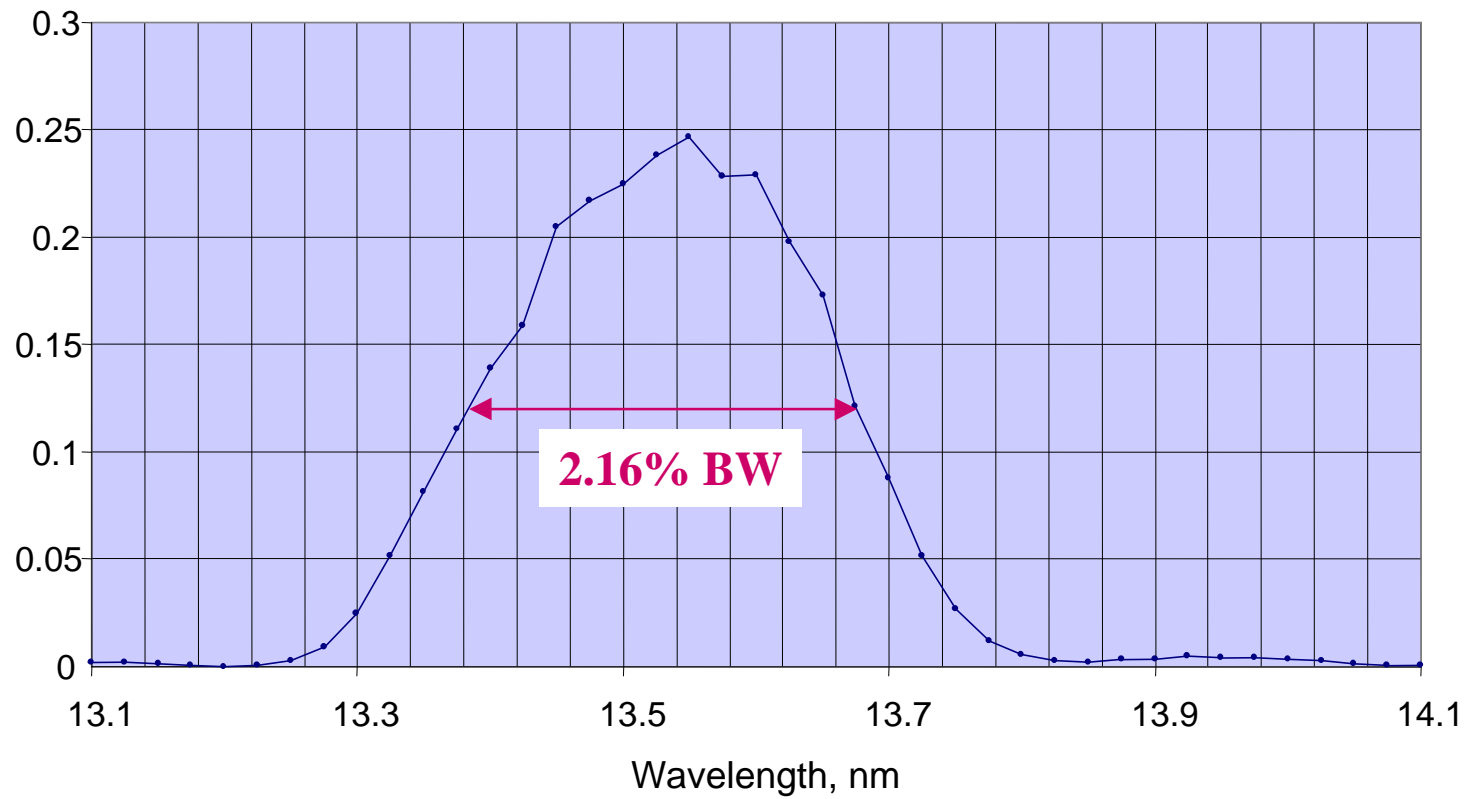
- Precision-made near normal incidence **multilayer mirror (MLM) assemblies** with optimum number of reflections
- **2%BW** (or other, ...%BW) throughput contour with well defined, reproducible shape
- Transmission filters and apertures changeable in vacuum for easy **adaptation to source** conditions
- Movable entrance window cover to **reduce degradation**
- Ultra-compact design to provide convenience of both source metrology and **(re-)calibration as complete unit**

Inband detector layout



- Modular MLM assembly design, no adjustment is needed
- $\theta < 5 \text{ deg} \gg \gg$ no polarization effects
- *Not shown: entrance unit for suppression of electrons*

Throughput contour of pilot MLM assembly



Development challenges

- Variable sensitivity contour
- Automatic selection of entrance apertures
- Adding (optional) unit for polarization analysis
- Adding entrance element for debris suppression

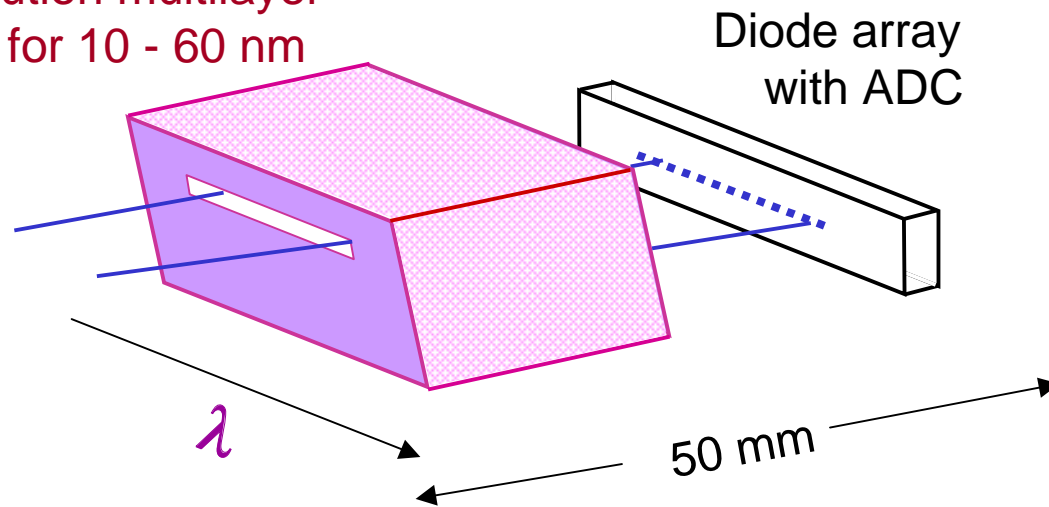
Project: inband and out of band survey

Approach to main solutions:

- Using assembly of high-resolution graded MLMs
- Set of MLM structures optimized for 10...60 nm range
- Using reflection mini-grating for longer wavelengths, including out of EUV range, from 50 to 300-350 nm
- All dispersion elements and corresponding diode arrays in a single instrument
- Ultra-compact design to provide convenience of both source metrology and (re-)calibration as complete unit

Broad spectrum survey

Graded along λ axis
high resolution multilayer
assembly for 10 - 60 nm

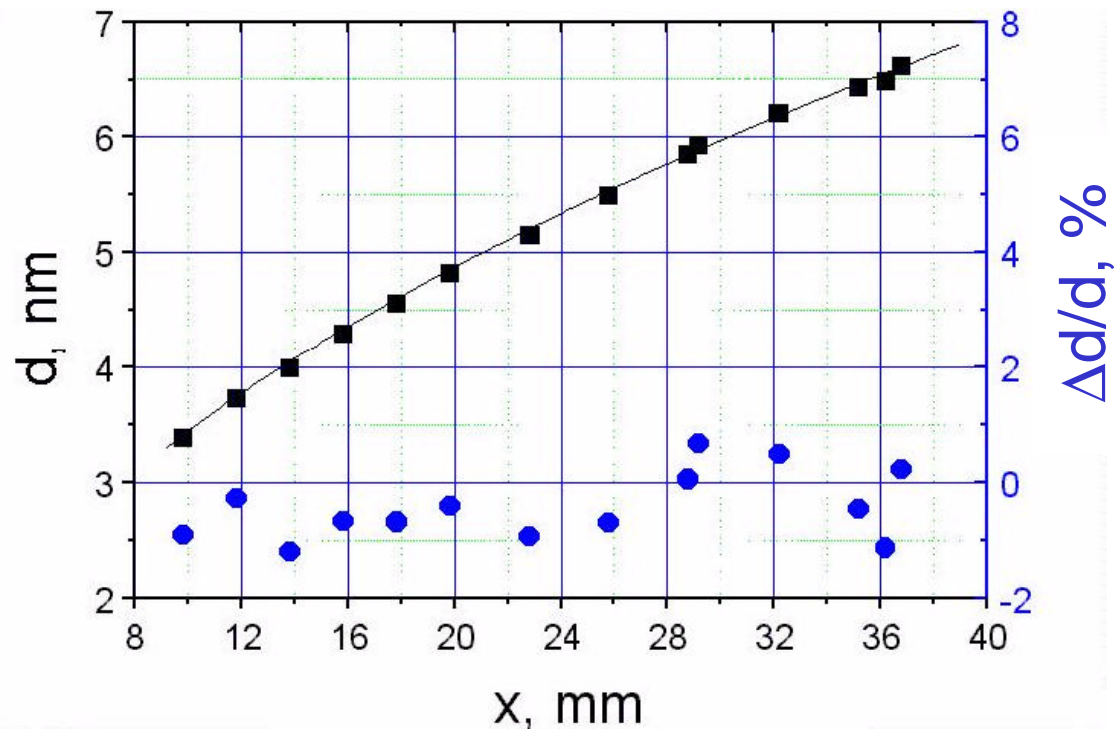


- Modular MLM assembly design, no adjustment is needed
- Time-averaged measurement mode with variable integration time

Example of graded multilayer coating technology:

MLM with d -spacing variation of 0.1 nm/mm

Deviations of about 1% from expected period variation are shown



Calibration

- **Off-synchrotron!**

Two main approaches to absolute calibration of inband and spectrum survey instruments:

- 1) Independent optics throughput measurement and diode (array) calibration against a reference diode
- 2) Complete sensitivity calibration of the whole instrument against a reference diode

- **Inhome facilities for diode sensitivity calibration:**

- a) **Inband, near band** - high throughput multilayer monochromator with x-ray tube (see next section)
- b) **Out of band, out of EUV** - laser plasma source with grating monochromators

Work plan of detector developments

- **Inband instruments**

- pilot 2%BW MLM unit: **fabricated**
- pilot instrument ready for demonstration: early **April**
- demonstration on EUV source: **April**
- instrument ready for users: end of **June**

- **Spectrum survey instruments**

- pilot dispersion element with graded MLMs ready: **May**
- pilot instrument for 10-60 nm ready for demonstration: **Oct.**
- demonstration on EUV source: **Nov.-Dec.**
- instrument for **10-60 nm** ready for users: **April 2004**
- user-oriented developments towards **out of EUV : 2004**

**Scanning reflectometer for
optics degradation analysis
and detector (re-)calibration**

Inhome reflectometry with X-Ray tubes and broad range grating monochromators has played a crucial role in multilayer optics developments at IPM [8-14]

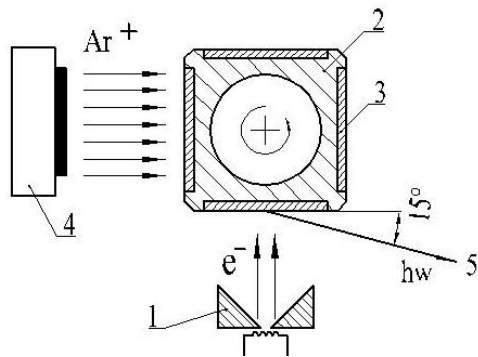


We present a new user-friendly instrument:
Scanning reflectometer with EUV source and multilayer monochromator for off-synchrotron measurements of optical elements before and after exposition to a source

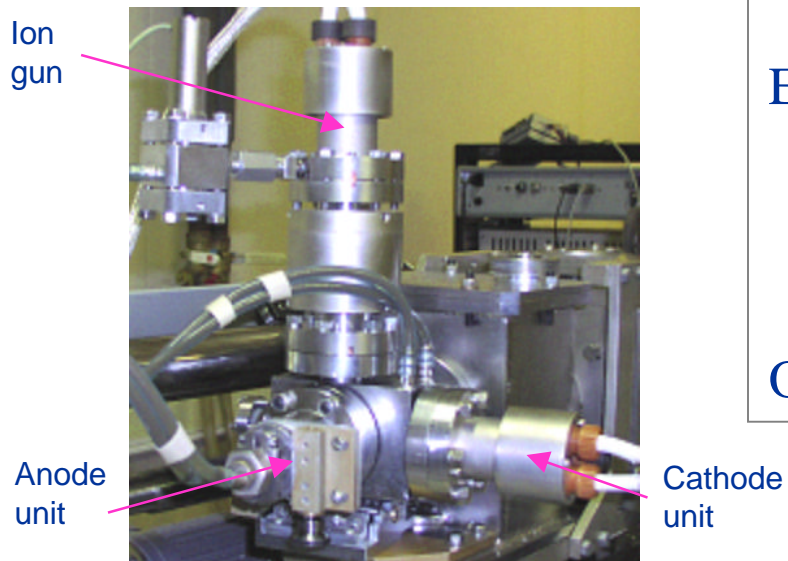
Scanning reflectometer with EUV source and MLM monochromator:

- High-precision comparative reflectivity measurements at normal and grazing incidence >>> **Analysis of debris-induced optics degradation**
- Reliable scan of sample surface due to small **incident beam width of < 0.5 mm**
- Narrow **band width of < 0.15 nm**, selected points from **12.4 nm to 16 nm**
- High output beam intensity of $> 10^7$ photons/s
- Precision **(re-)calibration of detectors with reference to national standards**
- **Fully autonomous facility**, desk-scale dimensions
- **Automated operation**, including pumping control and measurement procedure
- LabVIEW[®] based upper level service program

Inhome EUV source: dismantlable X-Ray tube



1 - electron gun, 2 - water-cooled anode holder,
3 - anode target, 4 - ion gun, 5 - X-Ray beam



Anode voltage (max.): 10 kV

Emission current (max.)

linear source: 150 mA

point source: 20 mA

Number of anode targets: 4

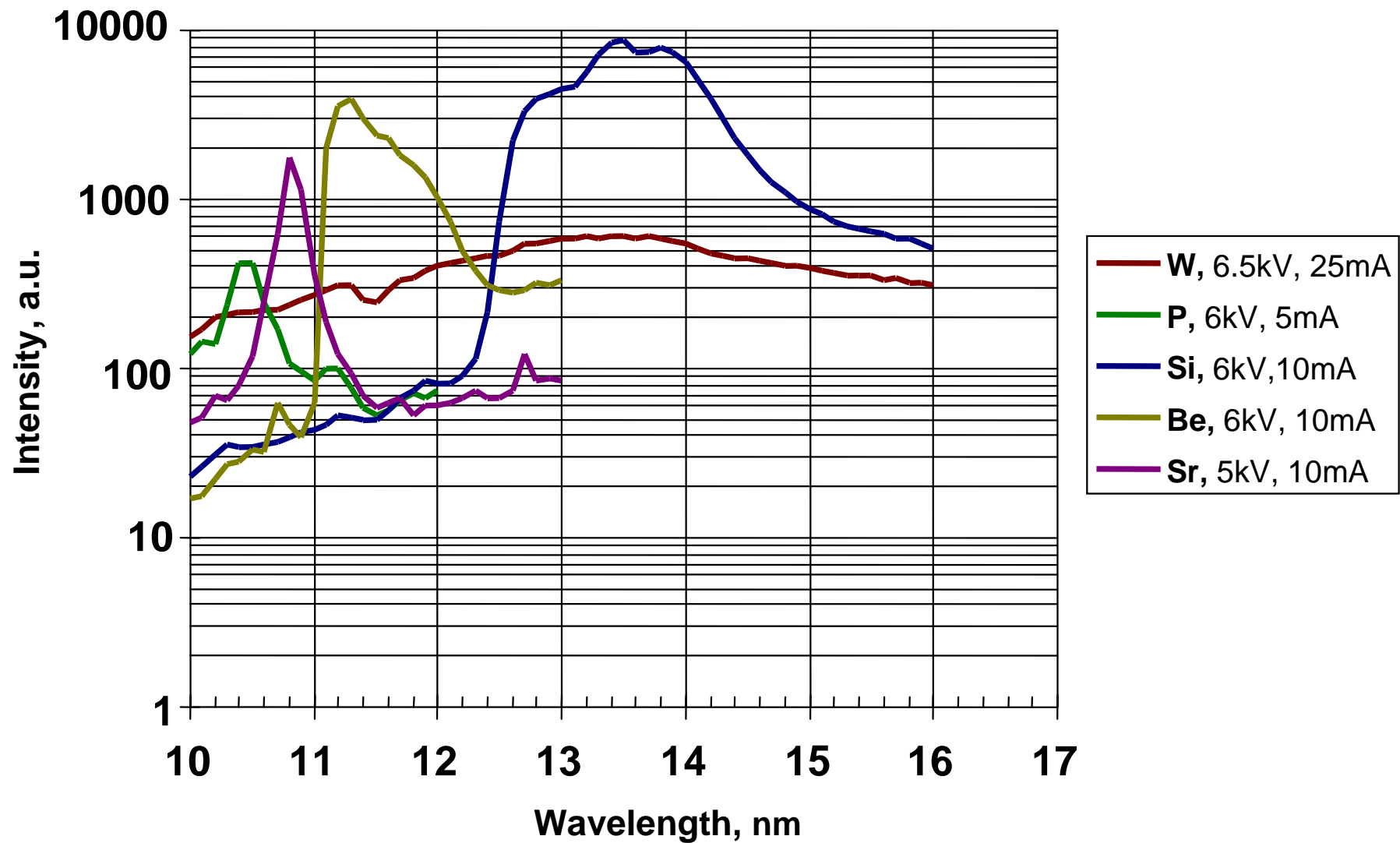
Electron beam size

linear source: 1×10 mm

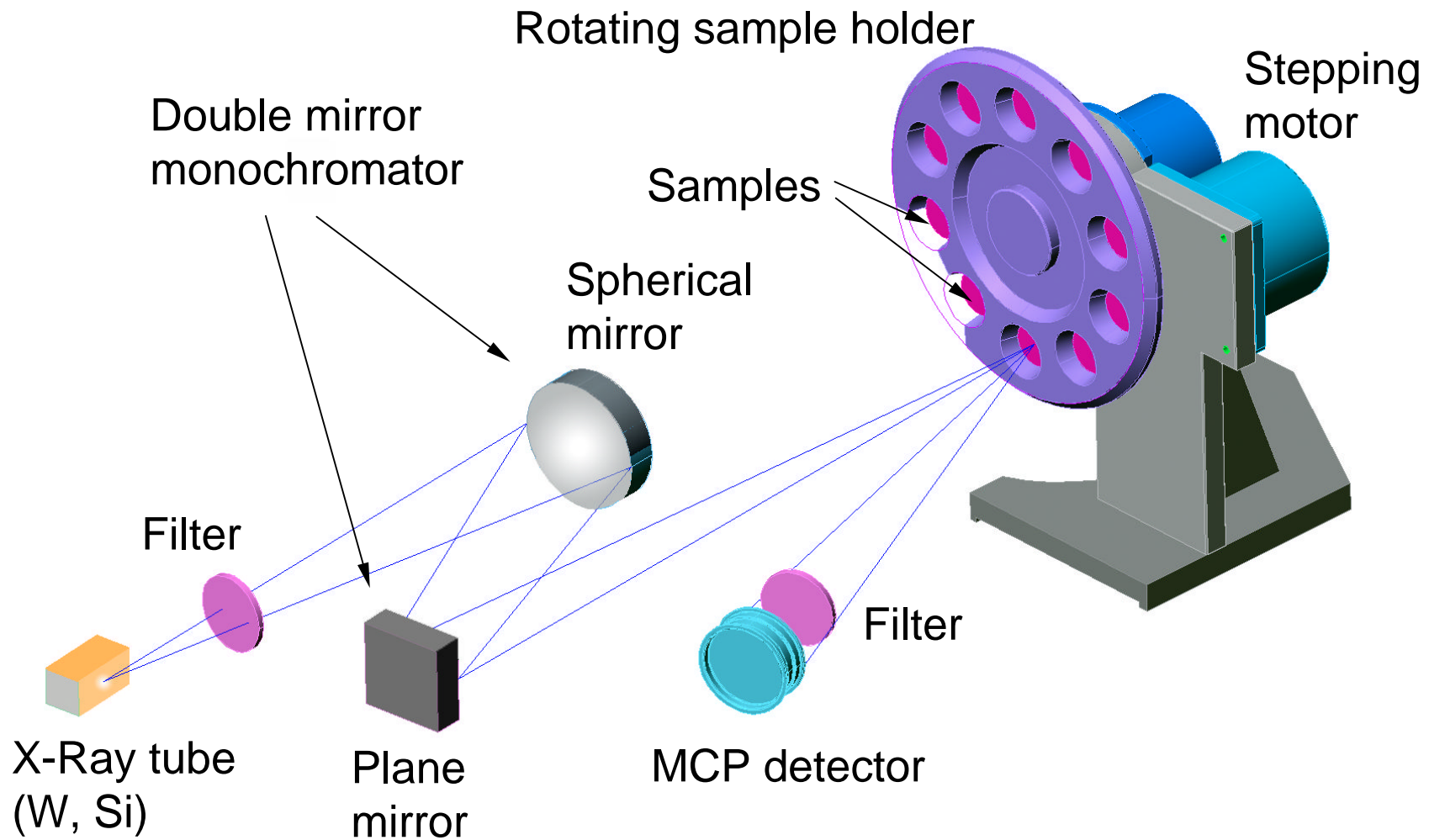
point source: 0.8×1.2 mm

Operating pressure: $< 3 \times 10^{-6}$ torr

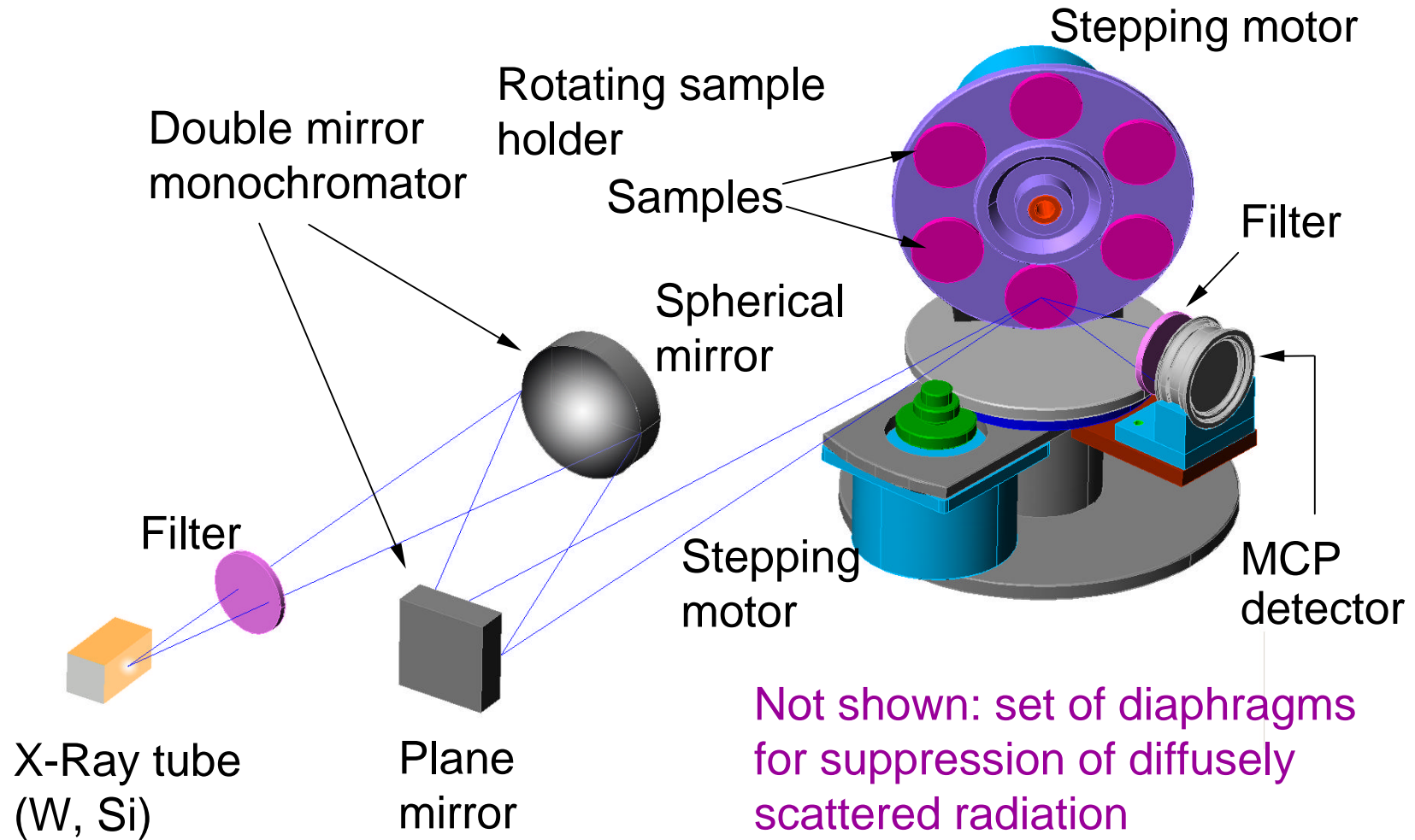
Emission spectra with W, P, Si, Be and Sr anodes

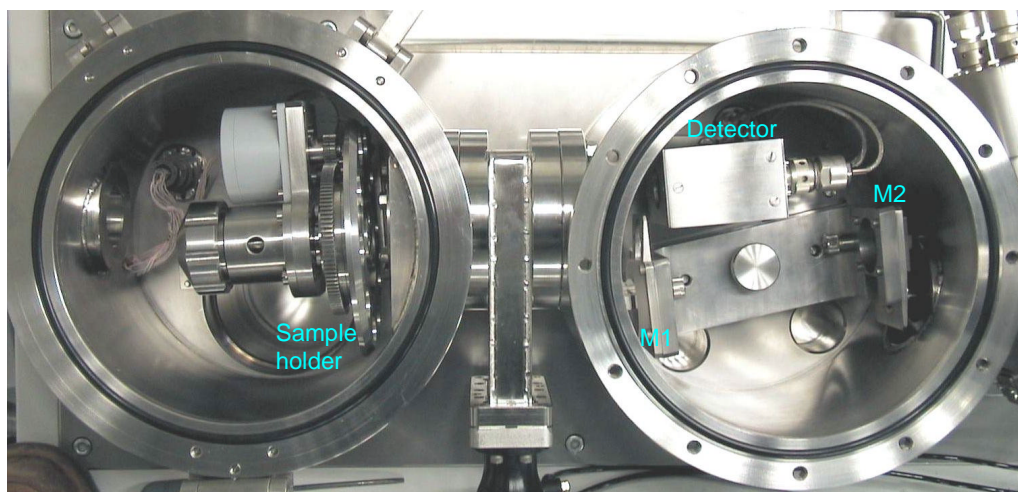
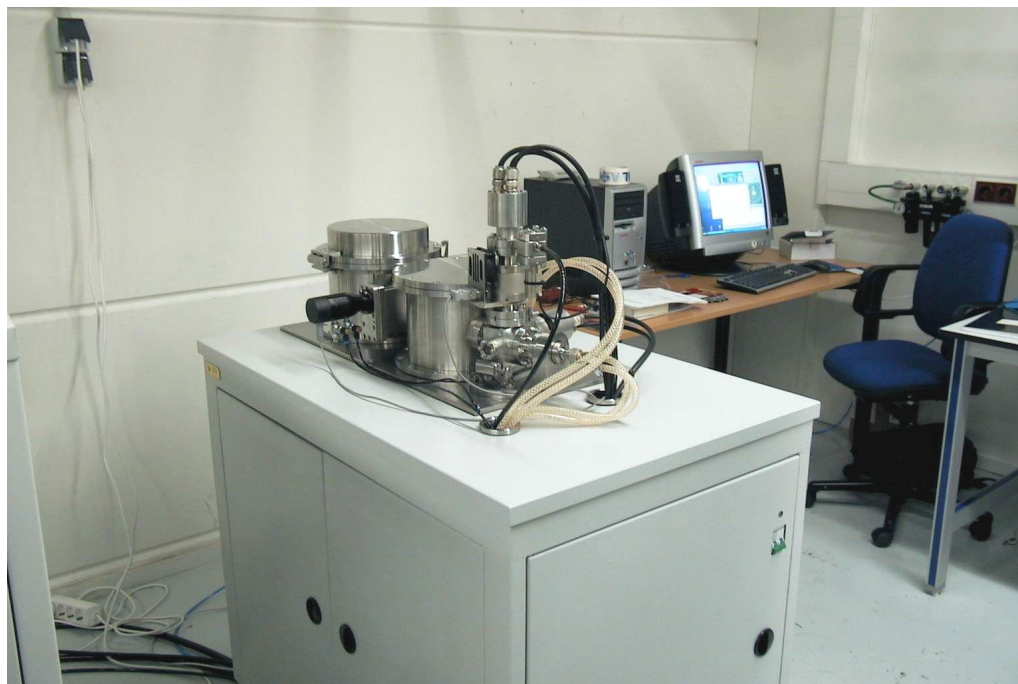


Measurement at near normal incidence

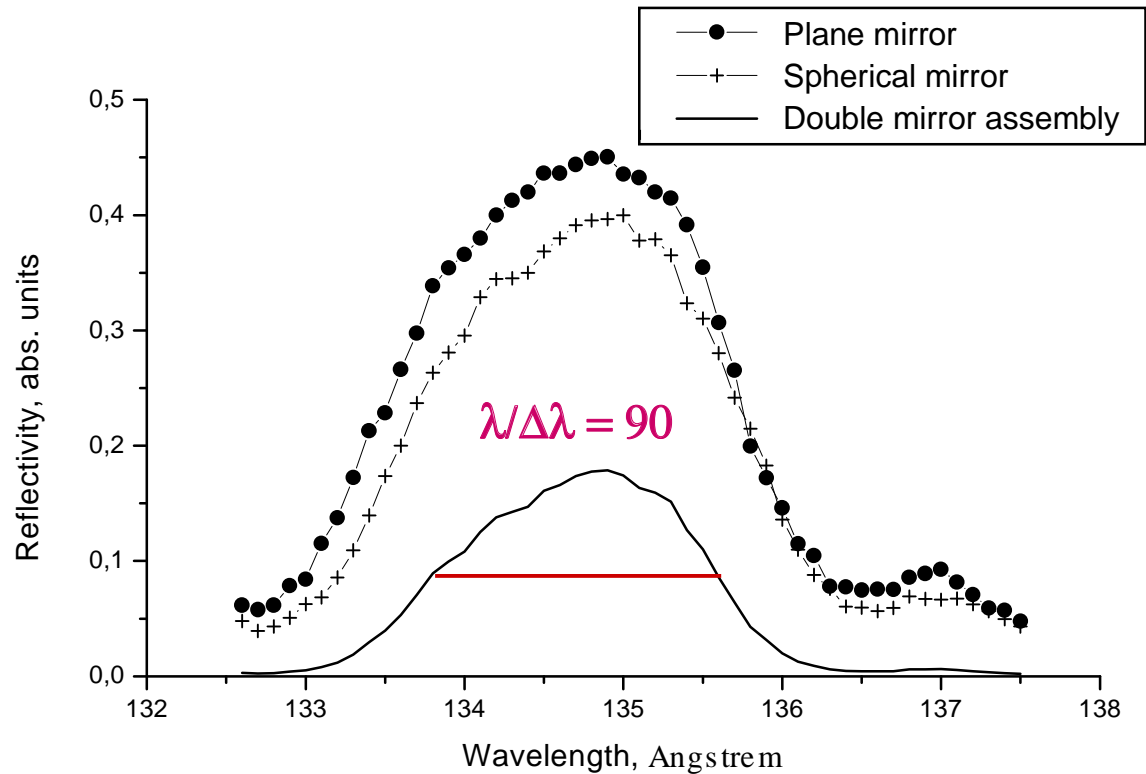


Measurement at grazing incidence



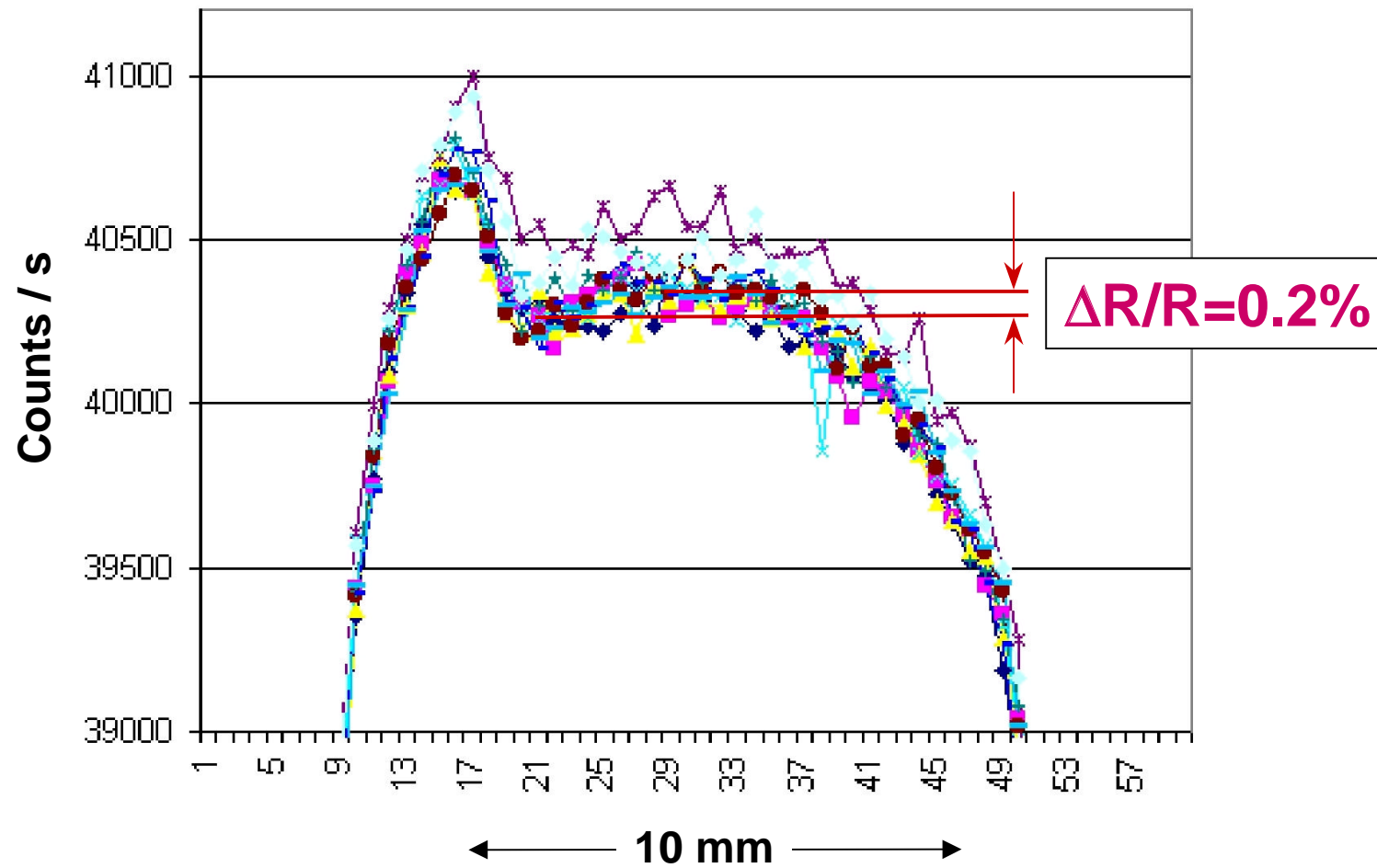


Resolution of MLM monochromator



- Changeable double mirror sets for selected points from 12.4 to 16 nm can be installed without adjustment

Reflectivity scan of test sample



Calibration of inband detectors with reference to national standards (in progress):

- **Based on high stability and intensity of monochromatized EUV beam ($> 10^7$ photons/s)**
- **Using changeable multi-position unit in sample chamber**
- **Expected precision - close to that of reflectivity measurements**

Work plan of instrument upgrade

- **Reflectometry**

- ready for users (to measure at **normal** incidence): **now**
- ready for users (to measure at **grazing** incidence): **June**

- **Reference calibration of detectors**

- concept developed: **May**
- pilot unit ready for tests: **July**
- ready to fabricate **for users: end of 2003**

Acknowledgment:

The authors are grateful to **Vadim Banine, ASML**, for permanent interest, efficient support and fruitful discussions concerning all presented developments

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