Physikalisch-Technische Bundesanstalt
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EUV-Radiometrie

Unpolarized and Polarization Selective Reflectivity Data from Polarized Synchrotron Radiation Measurements

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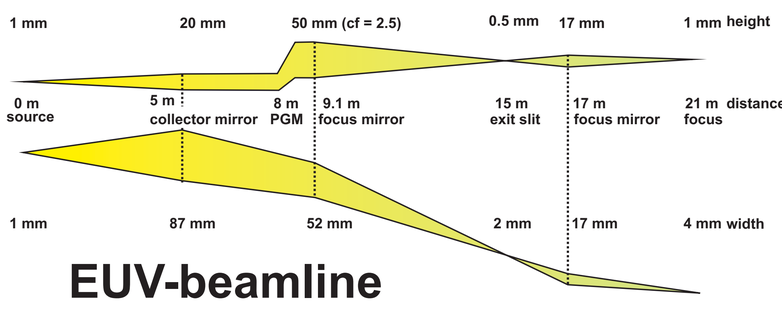
With EUV Lithography maturing, EUV optics for higher NA and consequently higher local angle of incidence are developed. These higher angles of incidence make EUV reflectivity more dependent on the polarization state of the incident light. Working in the field of EUV metrology for decades, PTB has developed measurement methods to use highly linear polarized synchrotron radiation to determine multilayer reflectivity in a polarization selective way. Depending on the size of the multilayer mirror to be investigated, we have two methods available. One is to change the polarization state of the incident beam inbetween two measurements – doubling measurement time but yielding reflectivity data as from unpolarized radiation. We are able to select the degree of linear S-polarization of the incident beam between 99 % and 50 %. This beam is used at our large reflectometer where we can characterize mirror samples with up to 50 kg in weight and 550 mm in diameter. The second method is to rotate the plane of reflection to selectively gain data from a desired polarization configuration. Using our new instrument, we can rotate the plane of reflection through 90 ° from S-polarized to P-polarized geometry. At this instrument, samples are restricted to 6 inch mask size. A polarisation sensitive detector exhibiting a suppression factor of 3 orders of magnitude allows us to achieve high selectivity using this second method.

Selecting incident Polarization



EUV-beamline

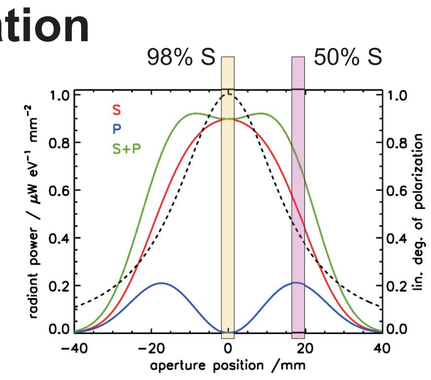
PTB's **EUV beamline** at the MLS was designed with an adjustable spotsize and a variable degree of polarization.

Accessible wavelengt range: 5 nm to 45 nm

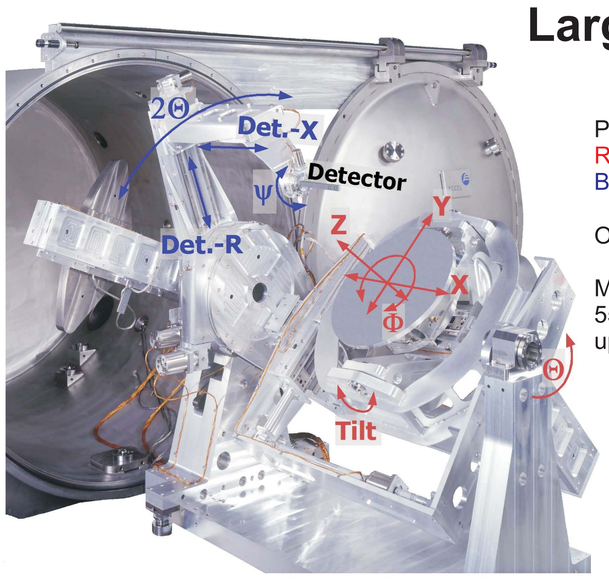
Bending Magnet Radiation

By moving the entrance aperture of the beamline across the orbital plane of the synchrotron, one can select the polarization state of the radiation entering the beamline.
On the right, the colored bars indicate the aperture positions used for 98% S-polarized radiation (orange) and 50% S-polarized radiation (violet).

Please note: We could achieve higher or lower percentages of polarization but chose not to as the S/N ratio would become unfavorable



Large Reflectometer



PTB reflectometer with movements indicated
Red: Sample movements
Blue: Detector movements

Operating pressure: Below 10^{-6} hPa

Maximum sample size:
550 mm in diameter, 140 mm in height
up to 50 kg

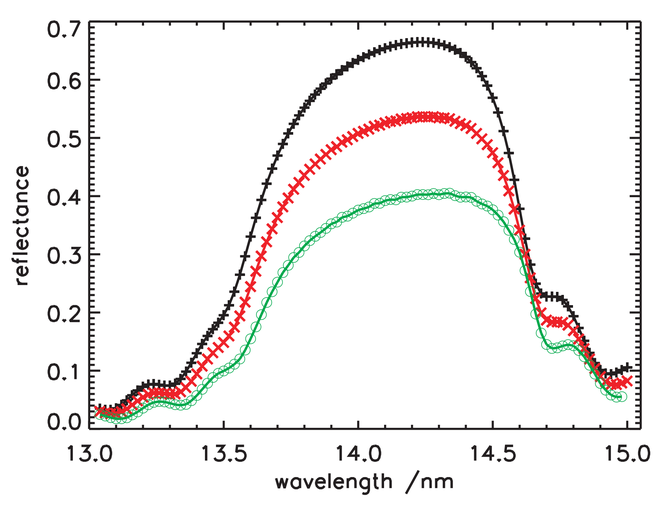
- for example an EUV-source Kollektor Mirror

The ability to change the polarization state of the light in the be experiment yields the data necessary to calculate reflectivity values for other polarization states not directly acessible to measurement. In the case where reflectivity for unpolarized light is desired, we can use measurements at maximum S-polarization (98%) and medium S-polarization (50%) to deduce unpolarized data.

$$R_{0\%\,S\text{-}pol} = R_{50\%\,S\text{-}pol} - 25/24\,(R_{98\%\,S\text{-}pol} - R_{50\%\,S\text{-}pol})$$

Example of EUV-mirror reflectivity measurement and data deduction using the polarization selection properties of PTB's EUV beamline.

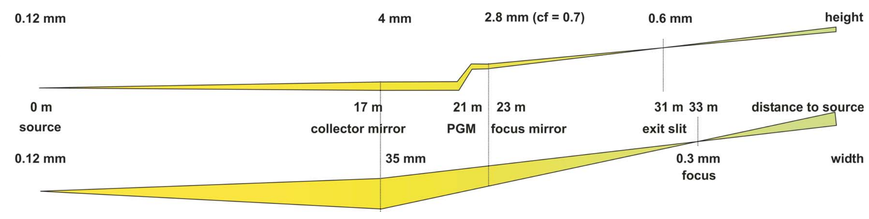
Black: 98% S-polarized light
Red: 50% S-polarized light
Green: calculated values for 0% S-polarized light



Rotating the Plane of Reflection

PTB's **soft X-ray beamline** at Bessy II was designed for maximum stability and a well collimated beam. The achieveable low beam divergence is most useful for small-angle scattering measurements. The polarization state of the radiation is optimized and fixed to 99% S-polarization.

Accessible wavelengt range:
0.7 nm to 25 nm

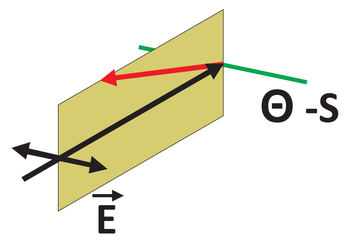


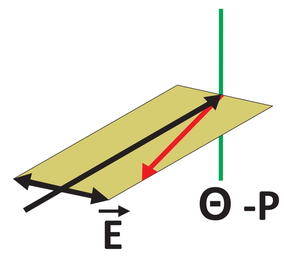
Soft X-ray beamline

Measurement Geometry

With PTB's Ellipsometer, measurement geometry is flexible. In partcular, the plane of reflection can be rotated to any attitude toward the linearly polarized incident beam. On the left, S- and P- measurement orientations are shown.
The radiation is incident from the left, the electrical field vector beeing horizontal. the main sample rotation defining AOI is indicated in green, the reflected light in red.

Top: Maximum S-polarized geometry
Bottom: Maximum P-polarized geometry
Any mixture of these extreme geometries is attainable





Ellipsometer

PTB's Ellipsometer uses no lubricants to avoid all organic contamination. Operating pressure: Below 10^{-7} hPa

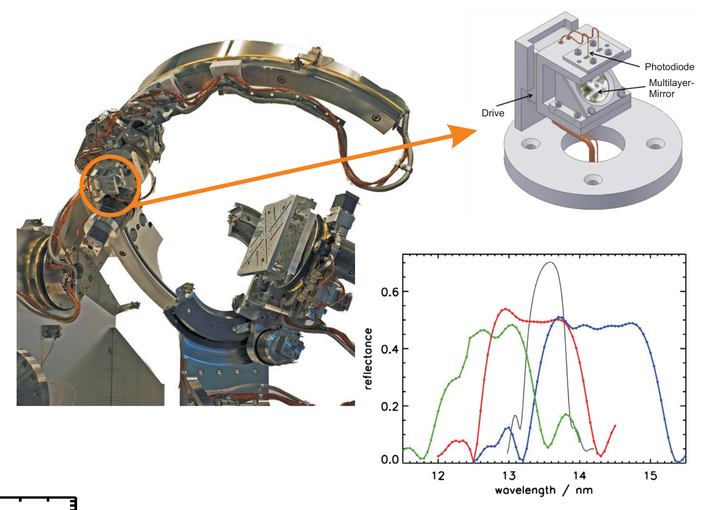
Maximum sample size:
190 mm x 190 mm x x70 mm and up to 5 kg

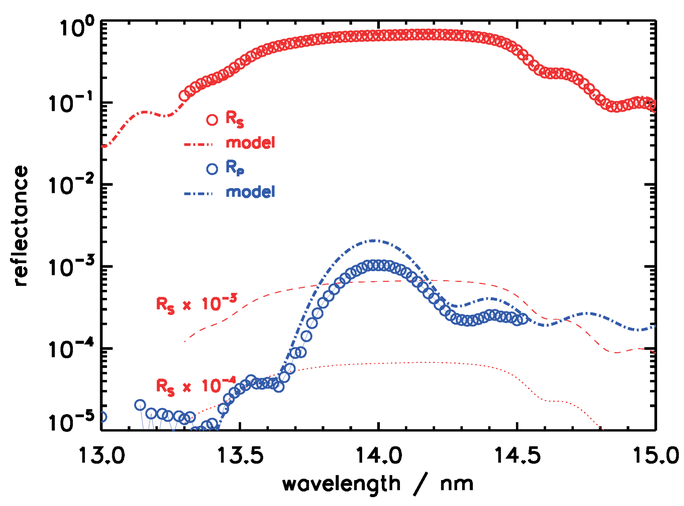
- for example: 6" Mask size

This instrument allows arbitrary rotation of the plane of reflection by providing all necessary freedom of movement of sample and detector.

Polarimeter

To detect the polarization state of the reflected light, a polarimeter detector was added to the detector suite of PTB's ellipsometer.
We use a broadband multilayer mirror at brewster angle as analyzer - see inset.
The polarimeter setup can be rotated around the measured beam.





Measurements at brewster angle:
With the incident radiation
S-polarized to 99%, the only way to access reflectance in a polarization dependent way in this geometry which yields very low reflectance for Rp is to use a polarimeter as detector.

Red: S-polarization
Blue: P-polarization

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