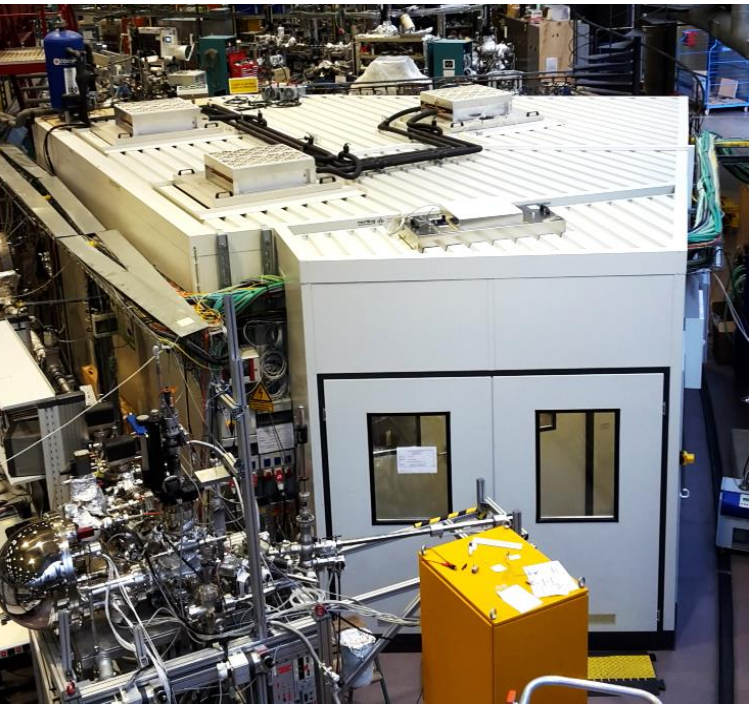
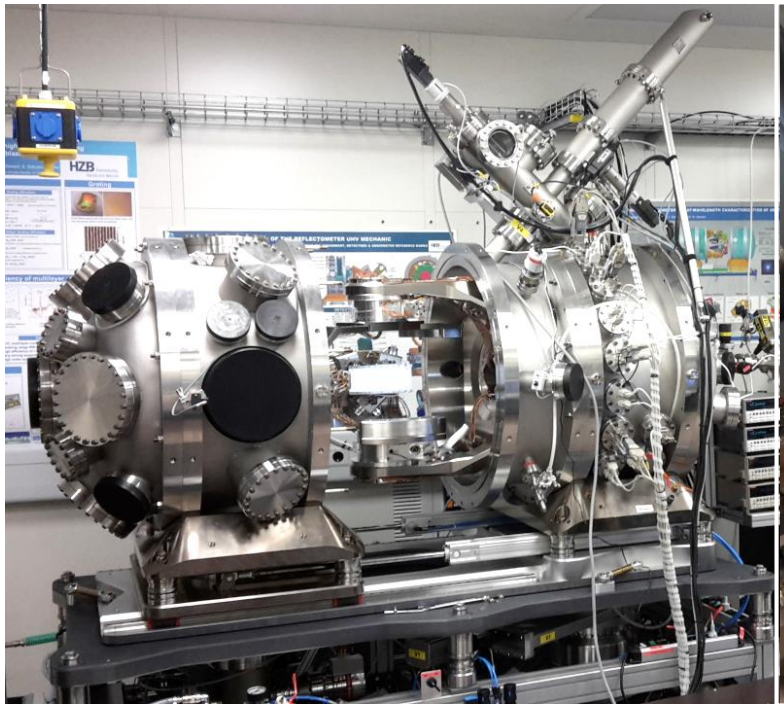
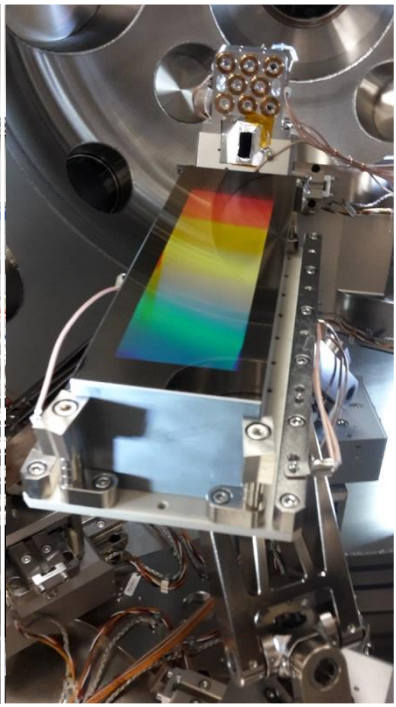
At-Wavelength Metrology facility for XUV optics at BESSY-II

A. Sokolov, M.G. Sertsu, F. Eggenstein, F. Schäfers







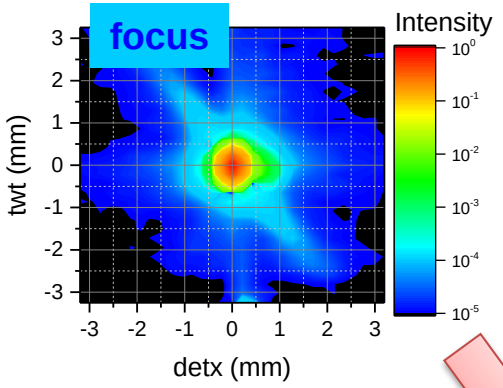
To the 13th International Conference on Synchrotron Radiation Instrumentation (SRI 2018), Taiwan, June 10 to 15, 2018

Optics beamline and Reflectometer

HZB Helmholtz Zentrum Berlin

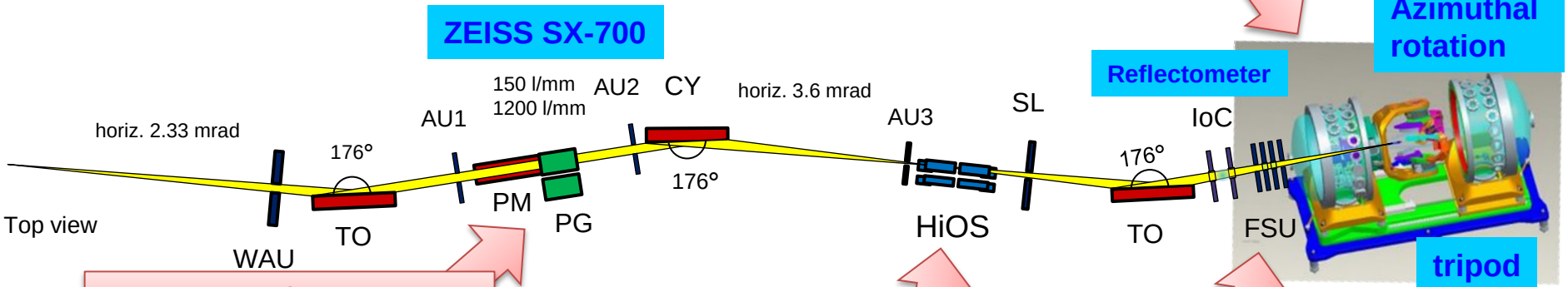
Collimated PGM

- 13.5 (<10) – 1800 (>2000) eV
- moderate resolution 2000 - 10.000
- polarization linear/elliptical
- higher order light suppression
- low divergence (0.5 x 3.6 mrad²) [v*h]
- small spot size (0.15 x 0.3 mm²) [v*h]



up to >10⁵ stray light cutoff

ZEISS SX-700

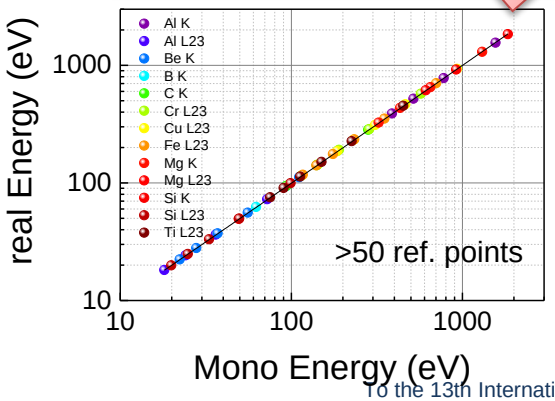


Azimuthal rotation

Reflectometer

tripod

Energy scale accuracy

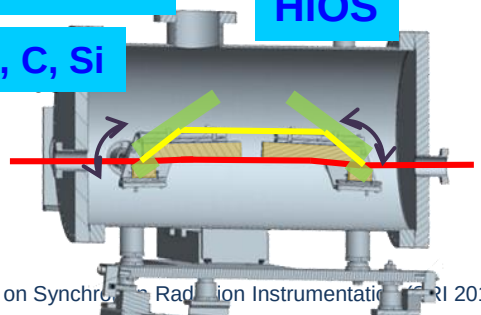


High spectral purity

x4 times reflection

HiOS

AlF_3, C, Si



FSU

FSU chamber

12 abs. filters

Double set pinholes and apertures

Working energy range

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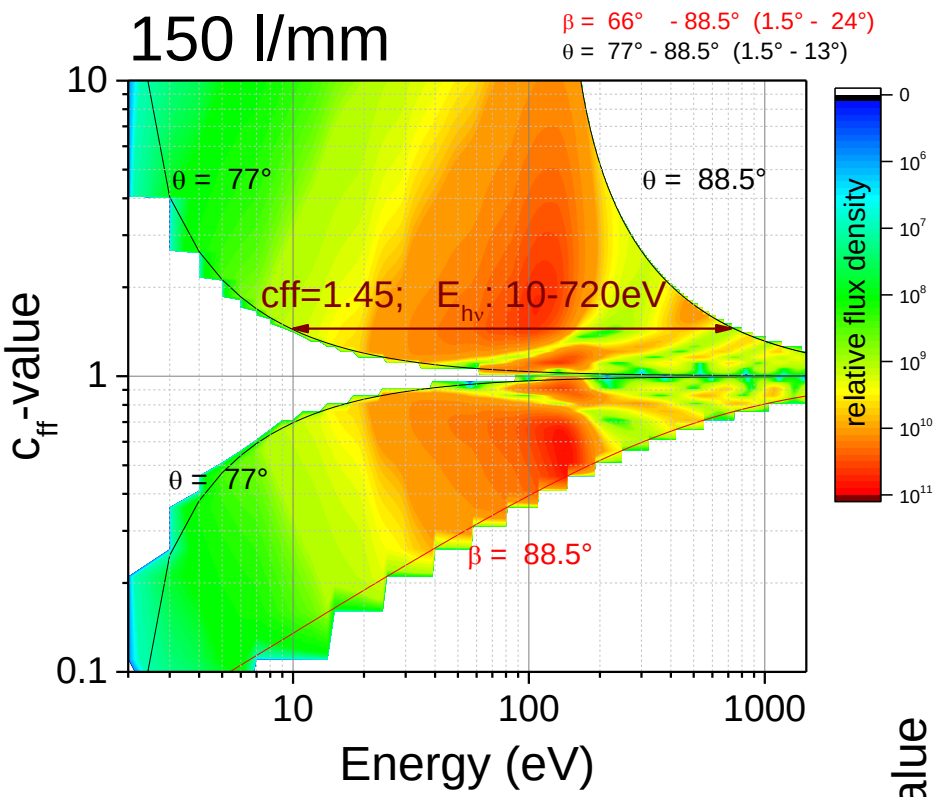
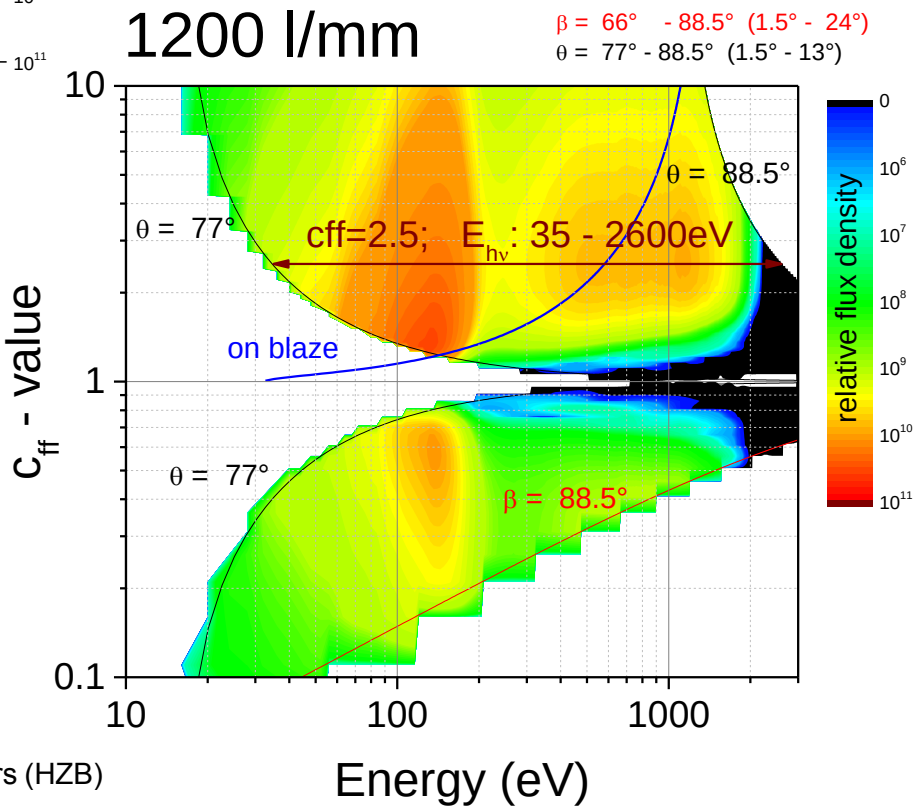


SX700 Zeiss monochromator

Gratings: **150l/mm** and **1200l/mm**



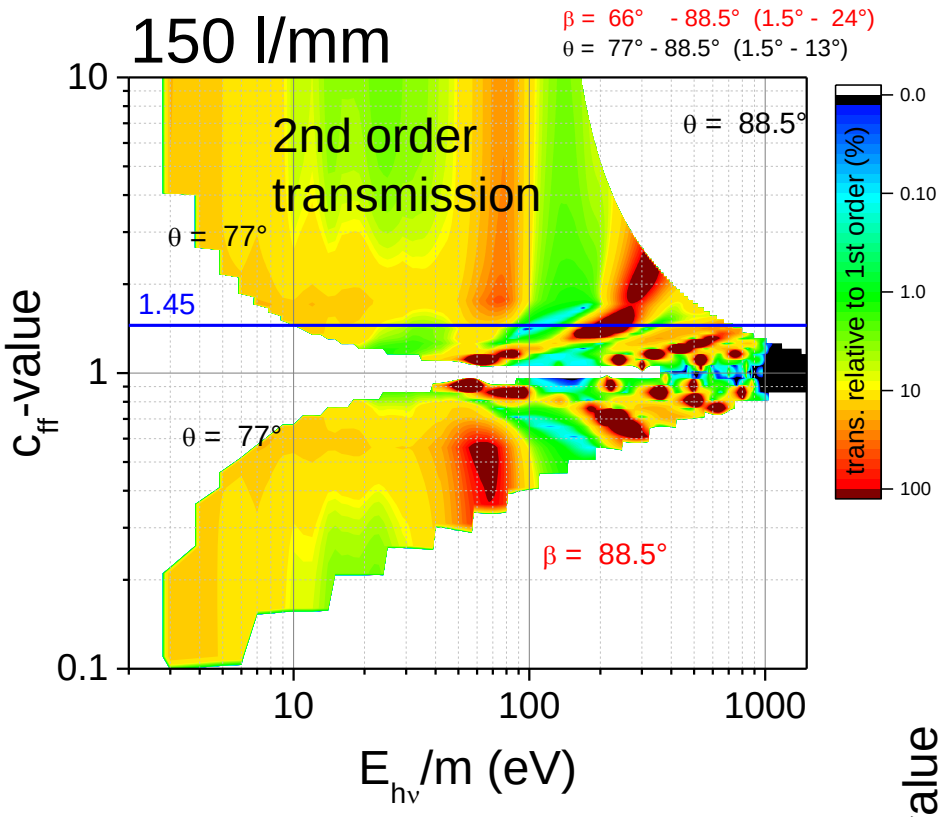
$c_{ff} = \cos(\beta) / \cos(\alpha)$

Wide energy range:

10eV – 2000eV

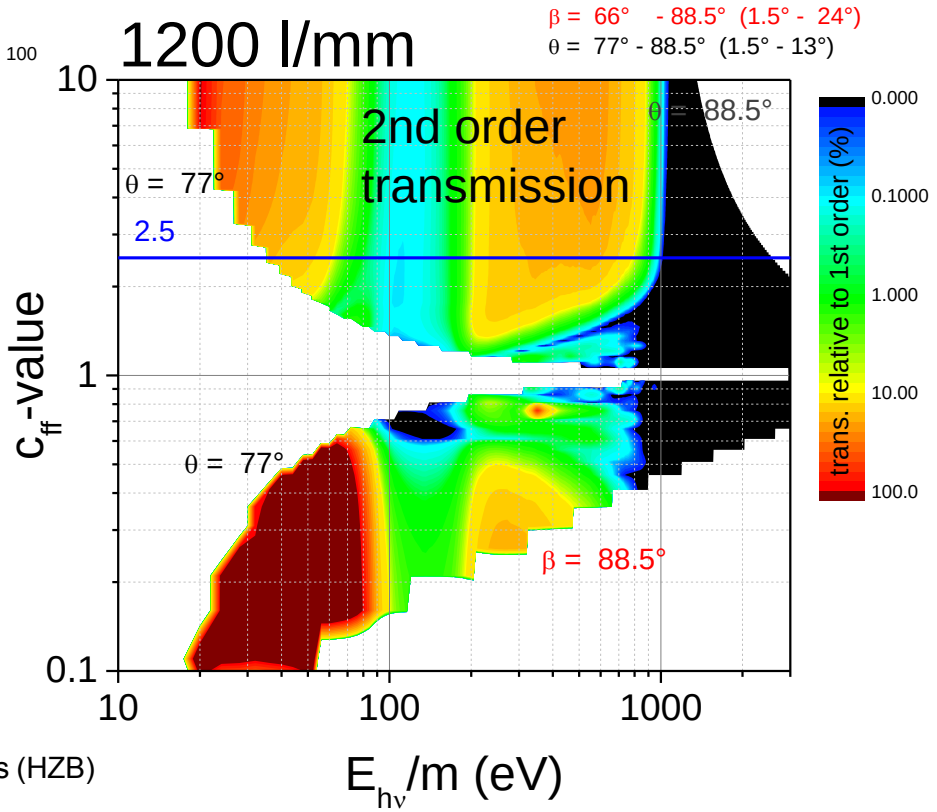
Calculations were done in “REFLEC” program designed by F. Schäfers (HZB)

2nd order amount



SX700 Zeiss monochromator

Gratings: **150l/mm** and **1200l/mm**

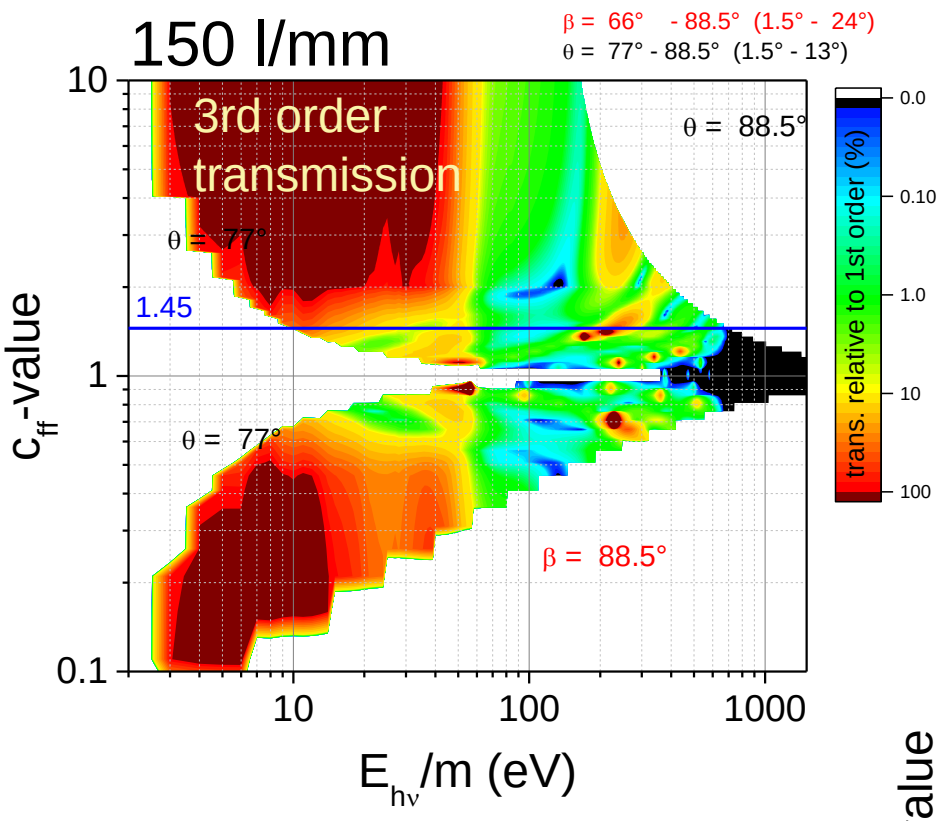


without HO suppression

up to 20% of second order

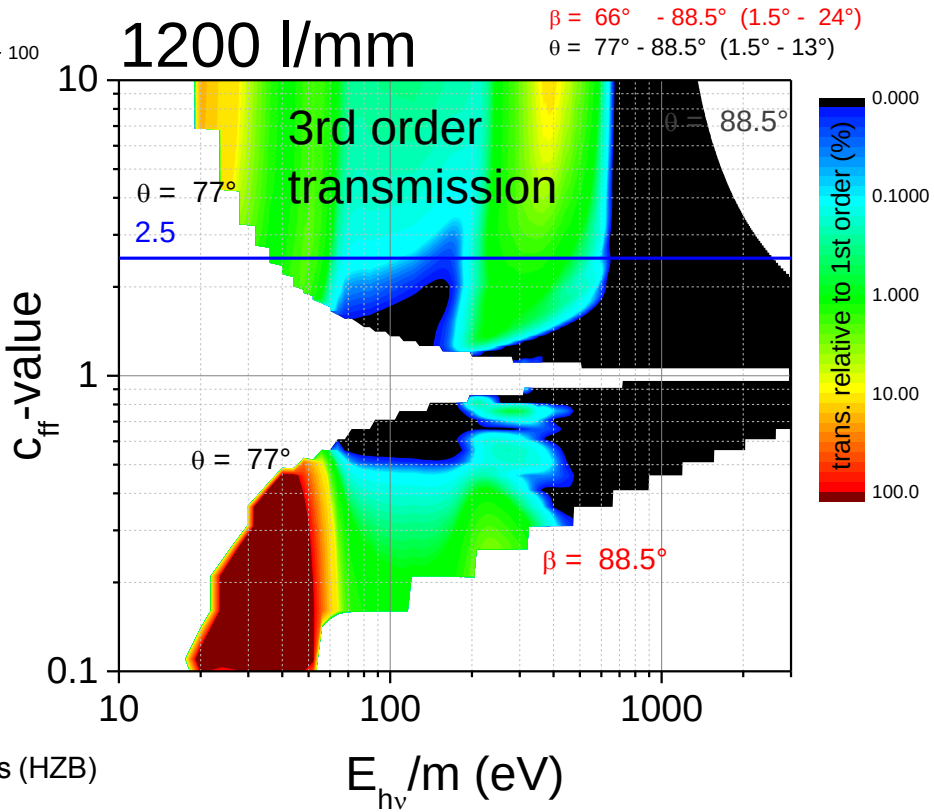
Calculations were done in “REFLEC” program designed by F. Schäfers (HZB)

3rd order amount



SX700 Zeiss monochromator

Gratings: **150l/mm** and **1200l/mm**

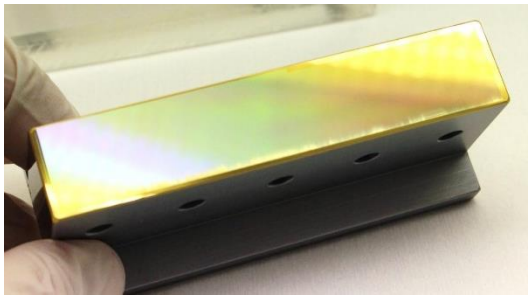


without HO suppression

up to 2% of third order

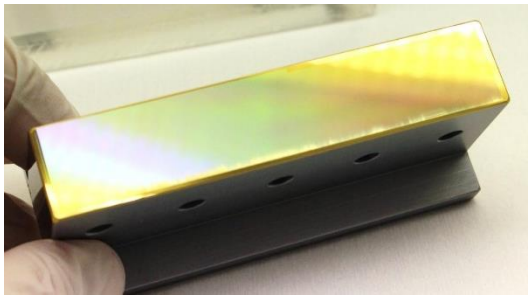
Calculations were done in “REFLEC” program designed by F. Schäfers (HZB)

Metrology on diffraction gratings



Metrology on diffraction gratings and higher orders effect

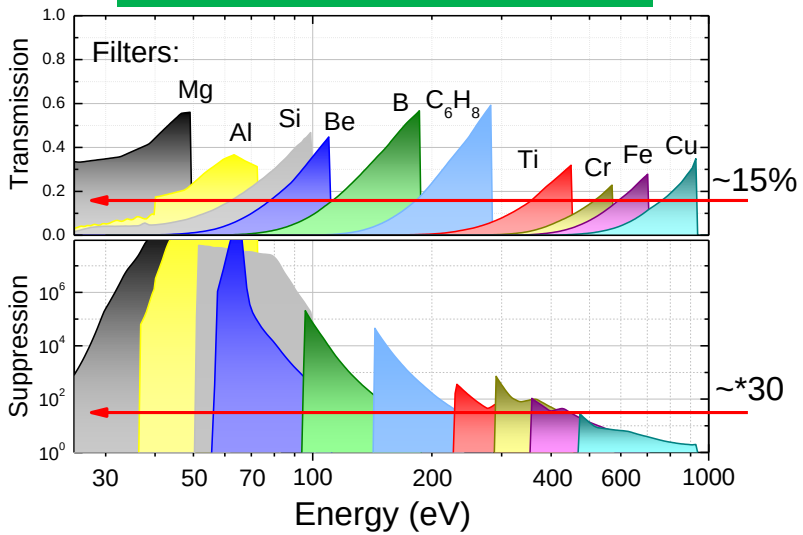
HZB Helmholtz Zentrum Berlin



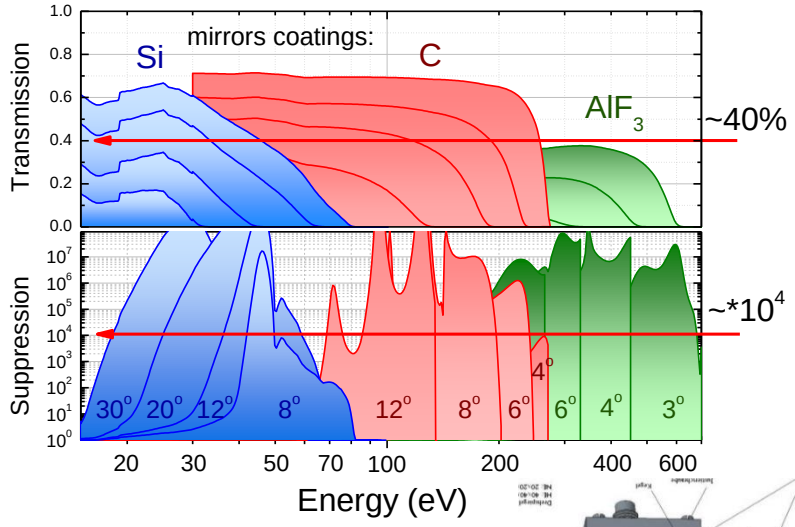
Higher order suppression system

Effective higher orders suppression will be realized by:

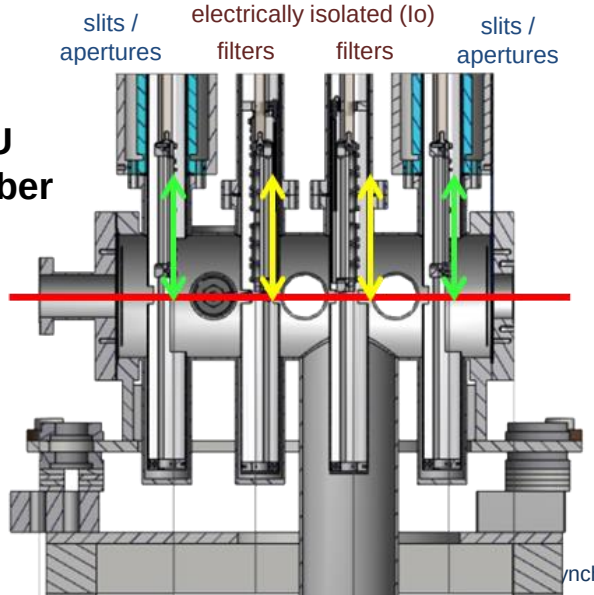
Set of 12 absorption filters



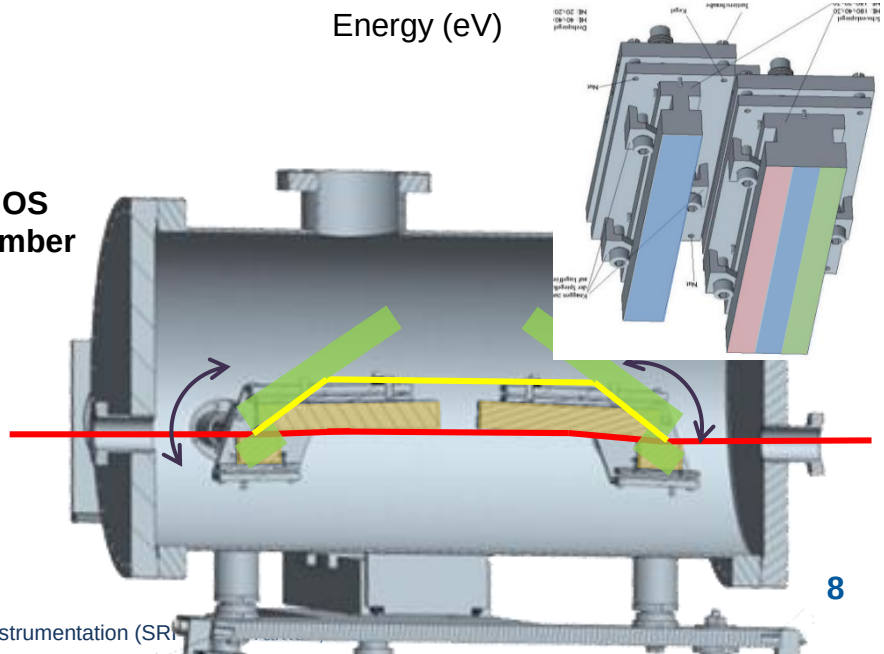
4-mirror higher orders suppression system



FSU chamber

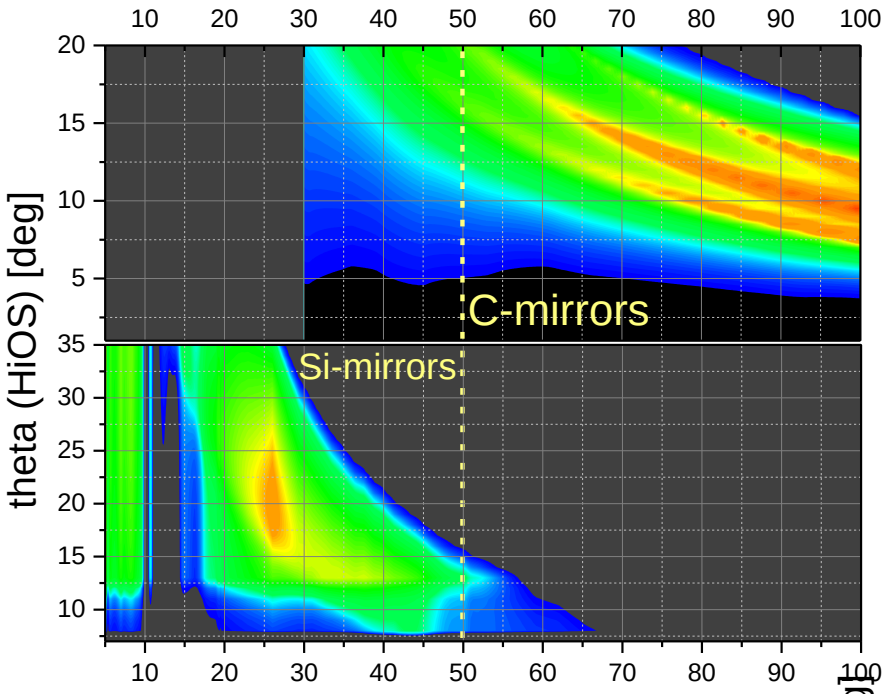


HiOS chamber

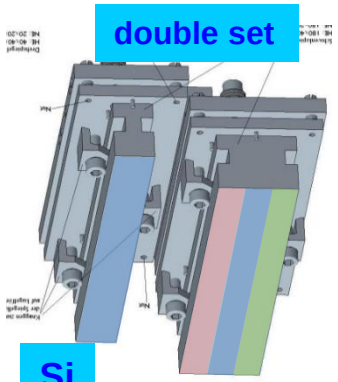


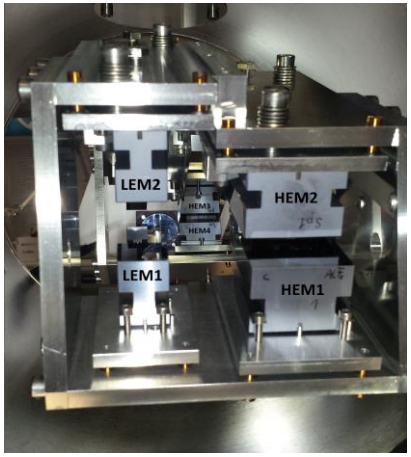
HiOS: transmission and HO suppression

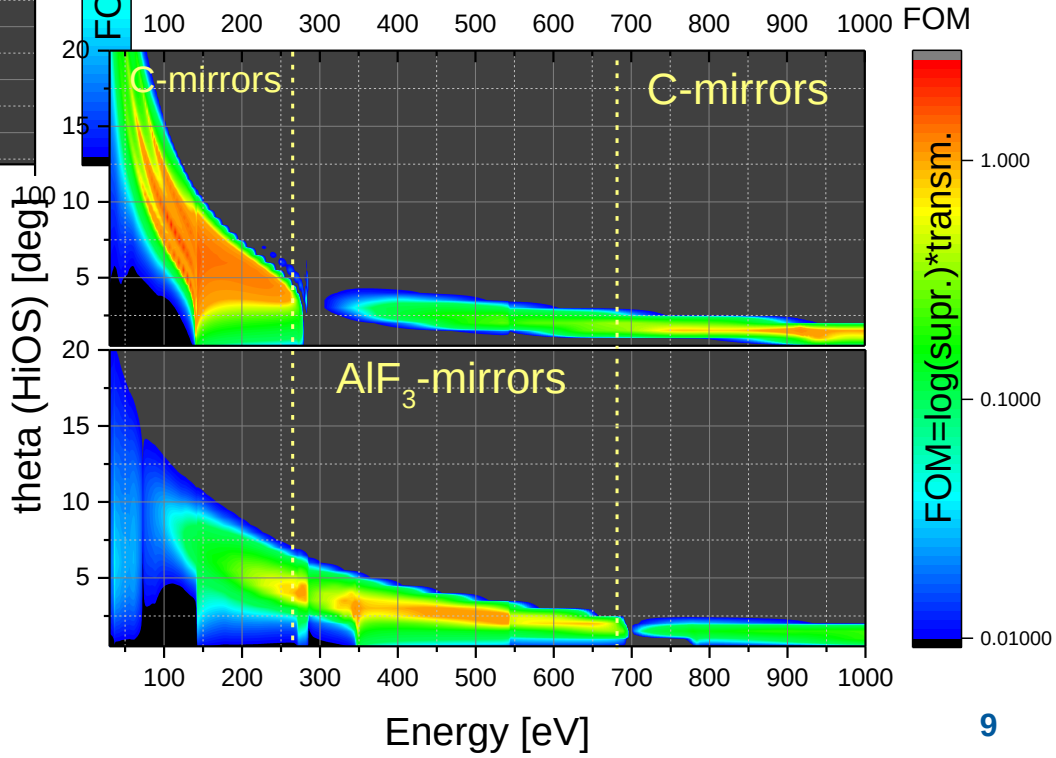
parameters	HiOS #1 (low E)	HiOS #2 (high E)
Energy range	10 – 60 eV	50 – 1000 eV
Angular range	8 – 35°	2 – 15°
Size mirrors	20 (180) x 20 mm²	40 (180) x 40 mm²
Mirror separation	22 mm	5 mm
Coating	Si	AlF_3, C, Si



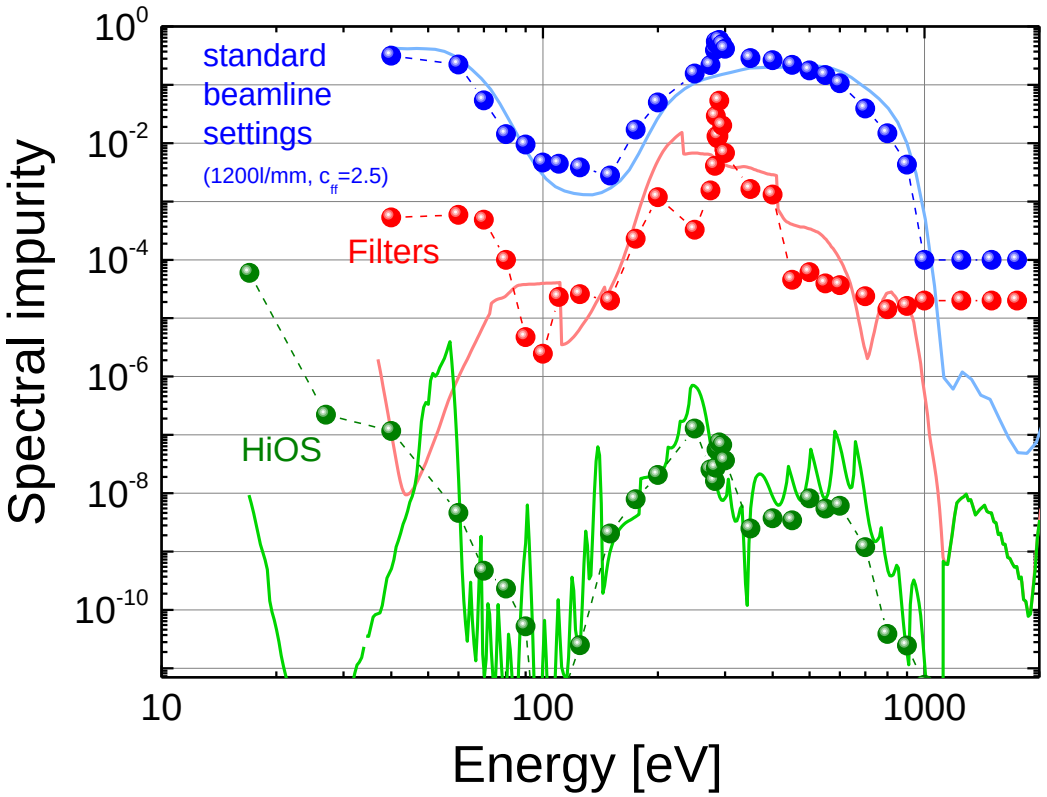
x4 times reflection

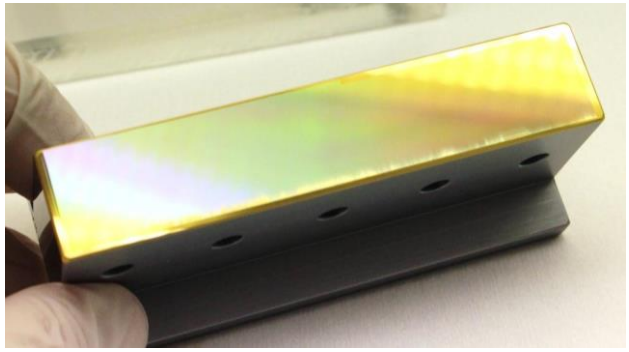


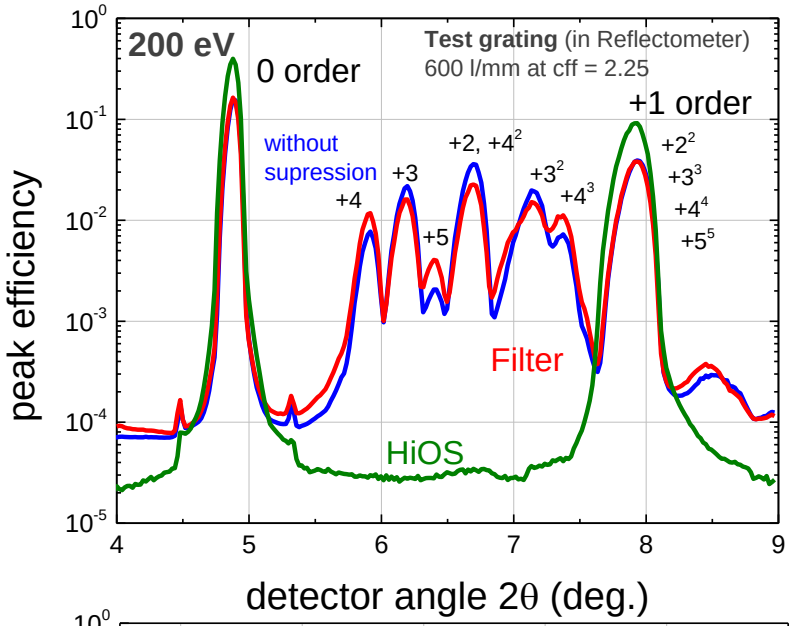


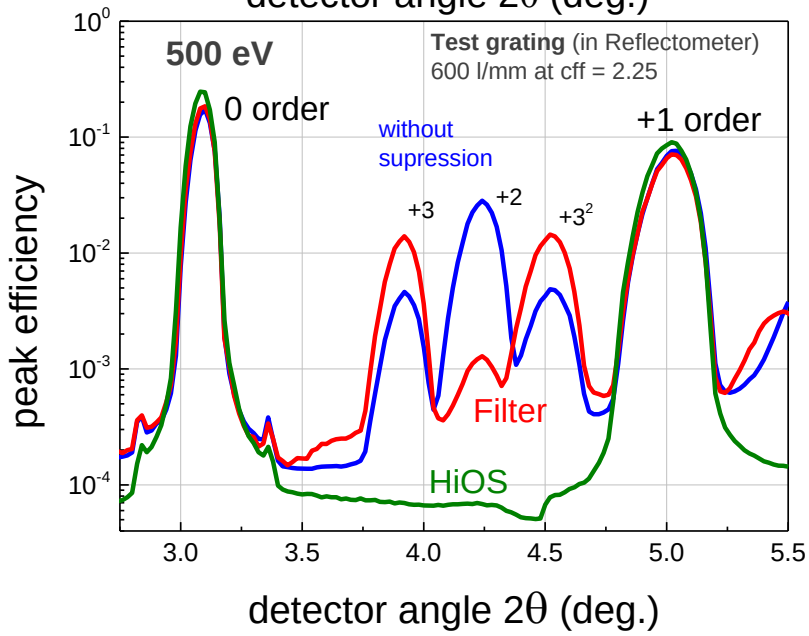


Spectral purity

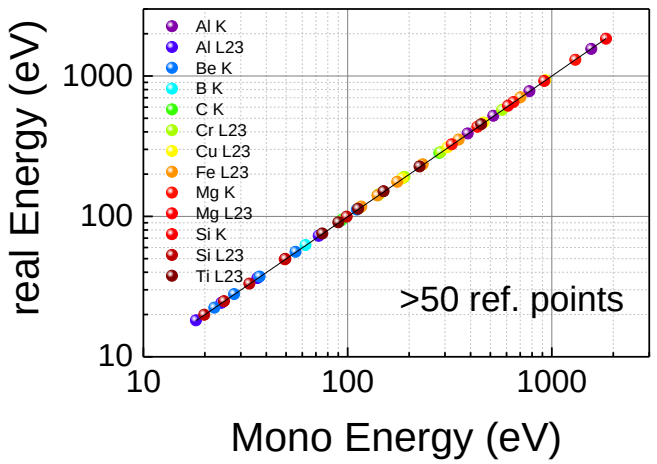


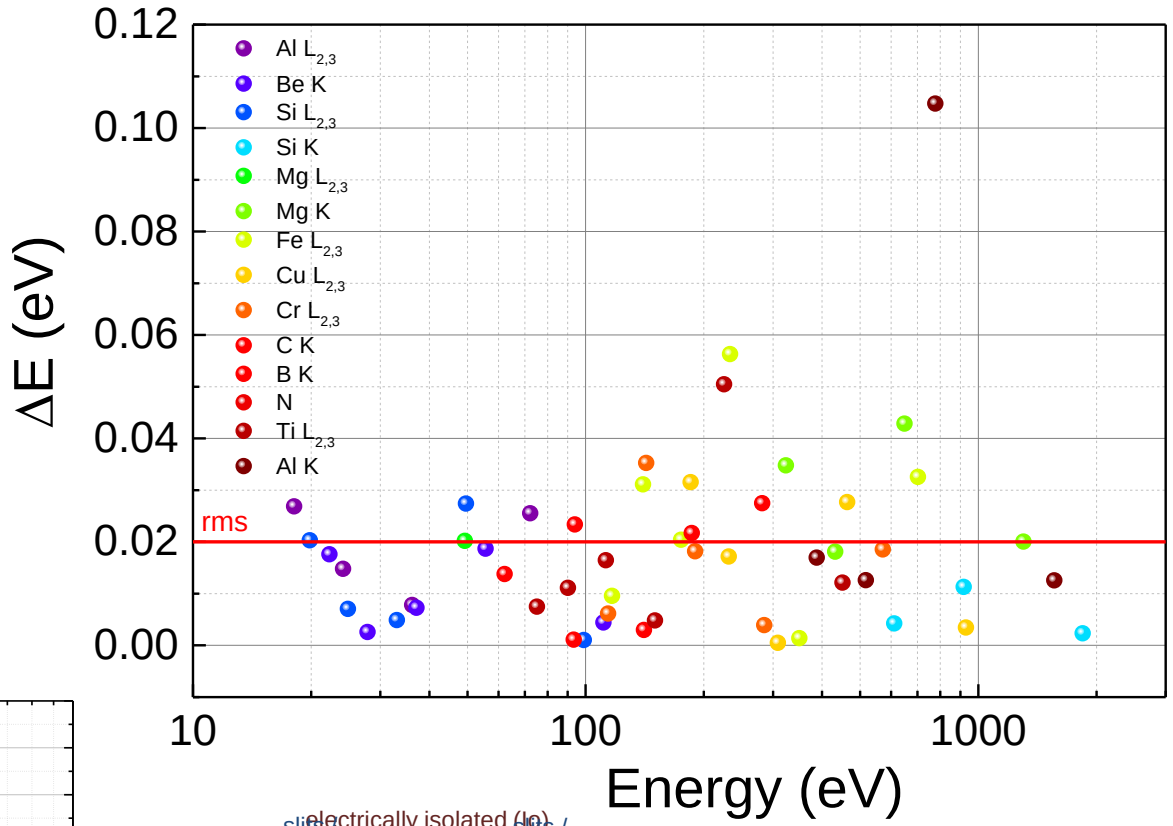




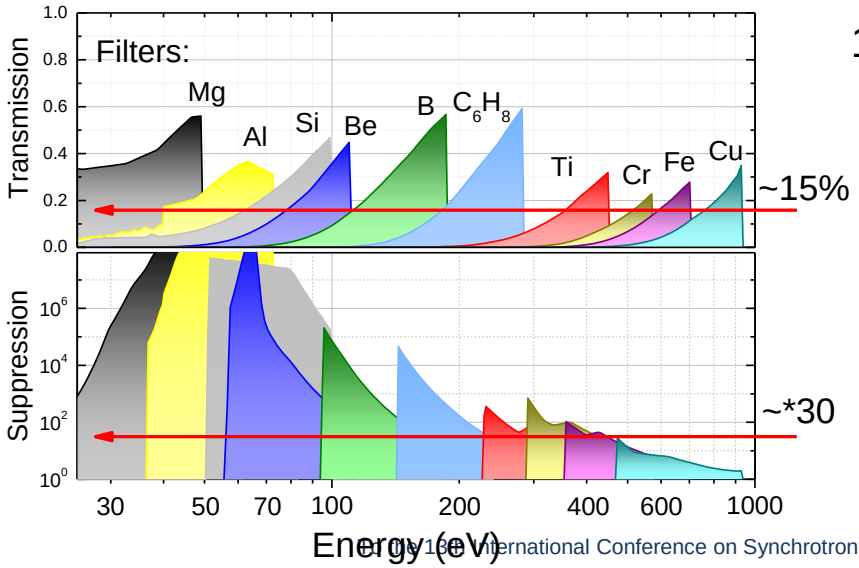


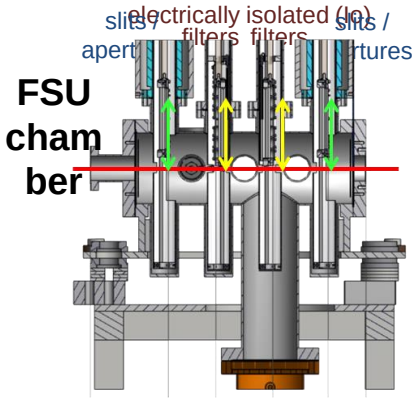
Energy scale accuracy





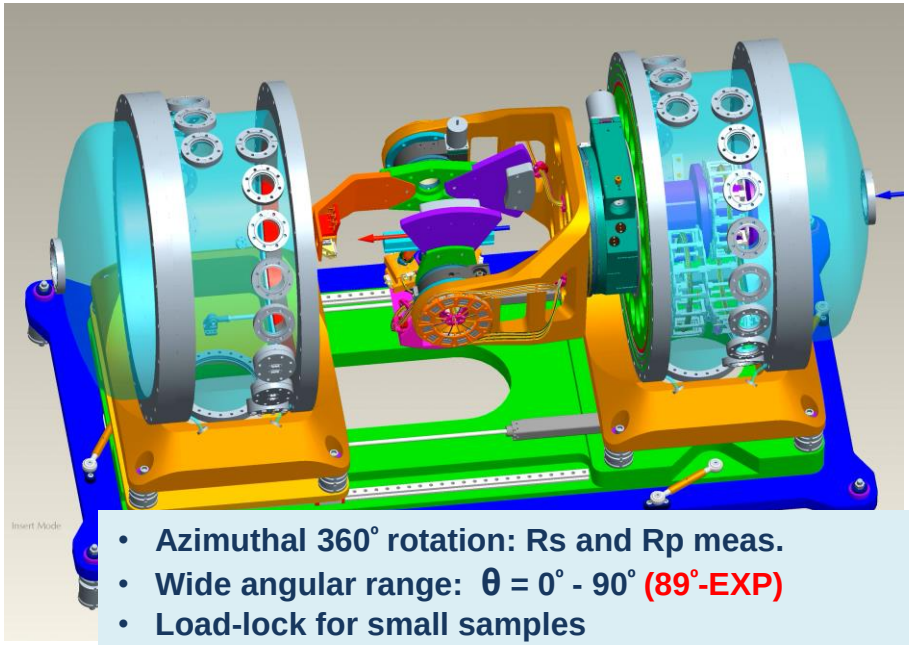
12 abs. filters in FSU

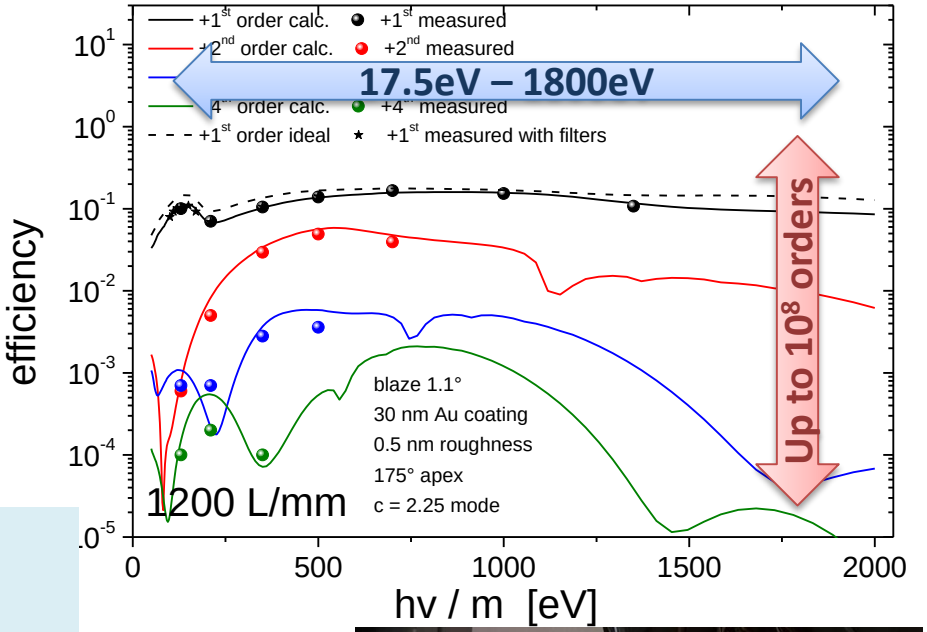




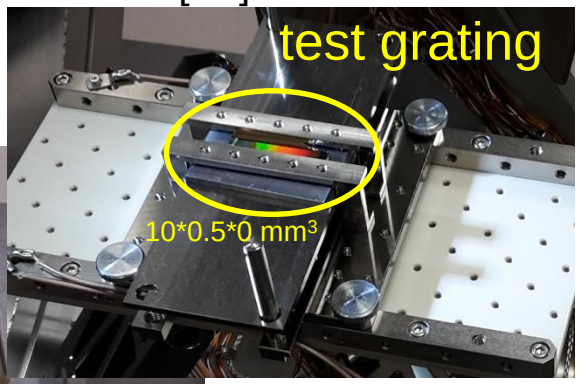
Metrology on gratings: @ energy efficiency measurements

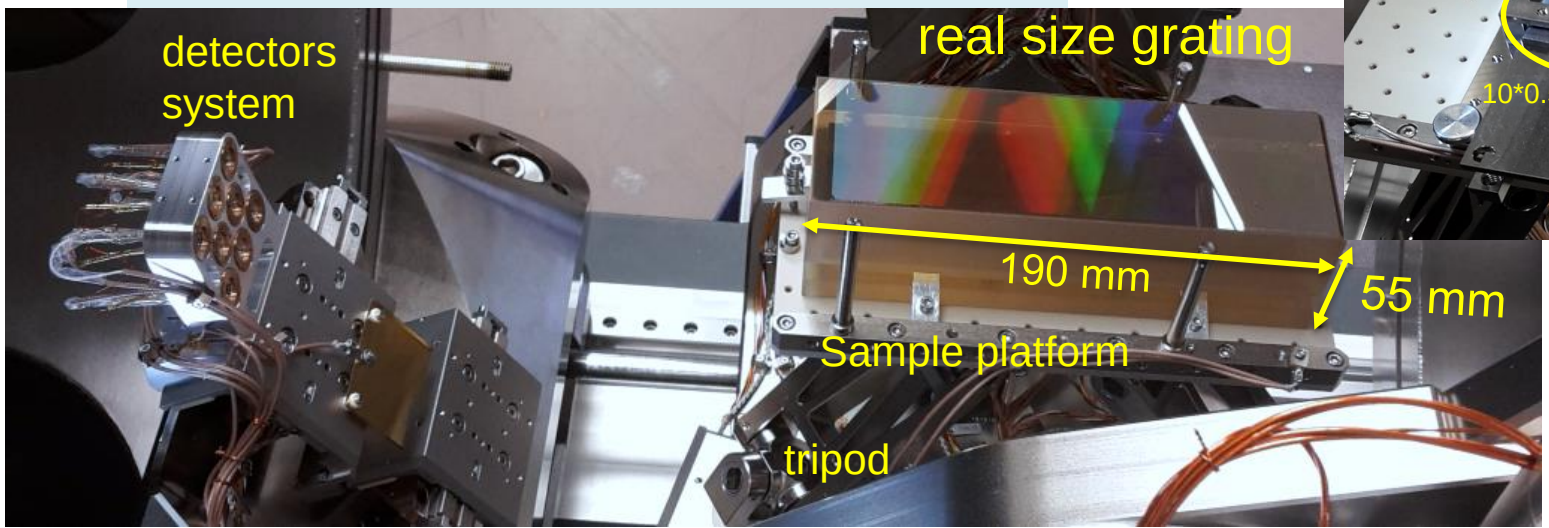
HZB Helmholtz Zentrum Berlin





- Azimuthal 360° rotation: Rs and Rp meas.
- Wide angular range: θ = 0° - 90° (89°-EXP)
- Load-lock for small samples
- Sample move in 6 degrees of freedom
- Sample weight: 4 kg
- Sample size: <300 x 60 x 55 mm³





Large area Imprinted Blazed Grating

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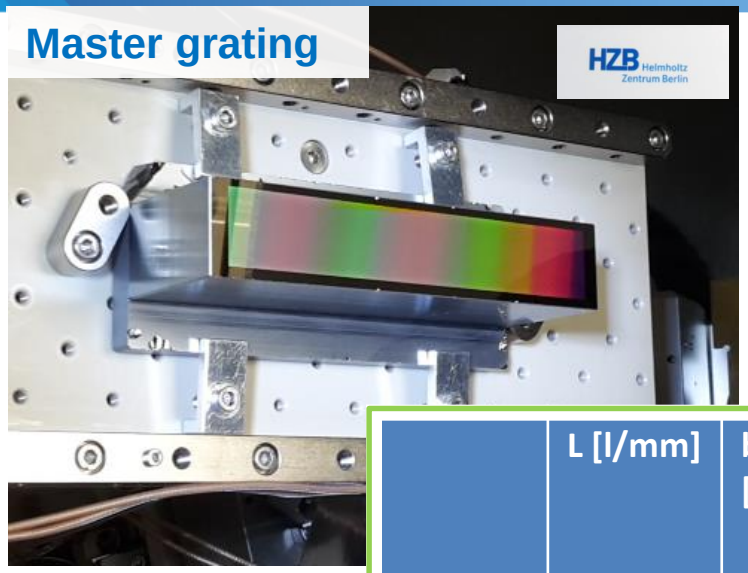
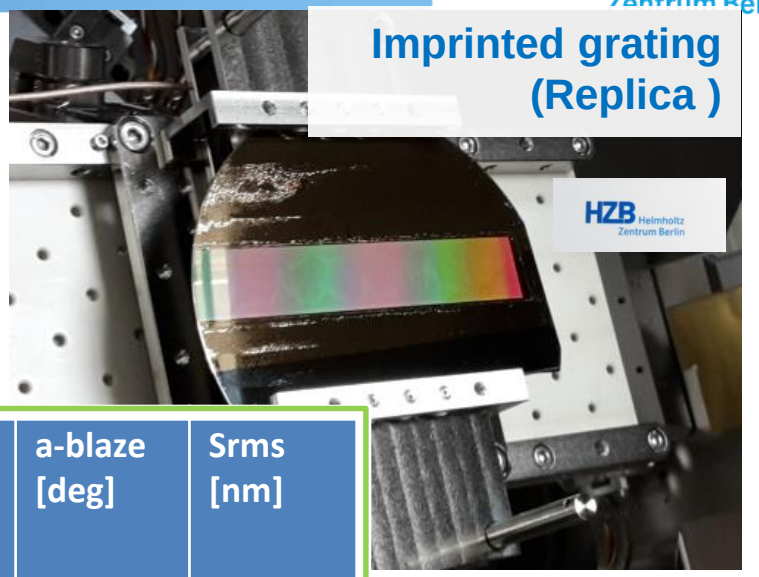
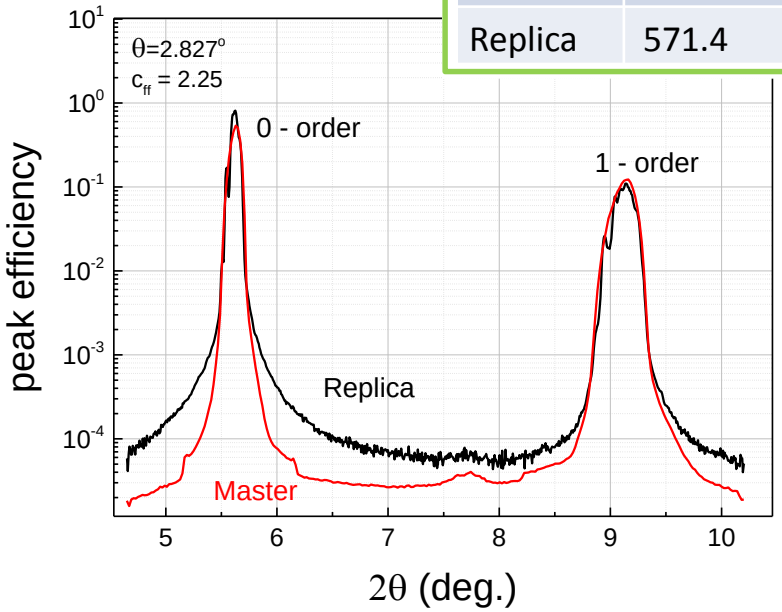
Master grating

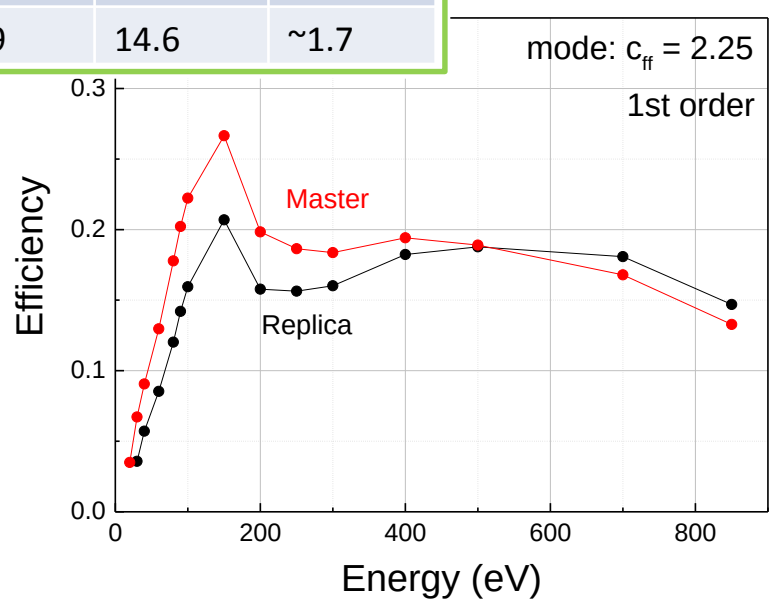


Imprinted grating (Replica)



	L [l/mm]	blaze [deg]	a-blaze [deg]	Srms [nm]
Master	588.2	1.04	13.8	~0.6
Replica	571.4	1.09	14.6	~1.7

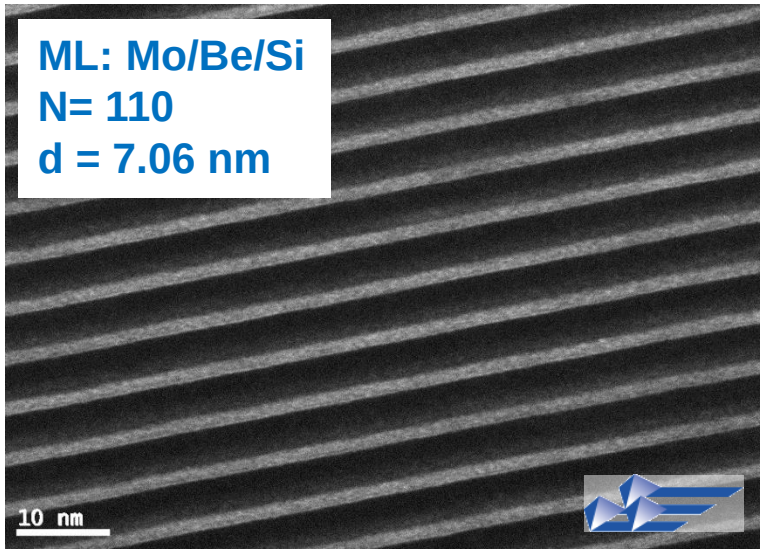




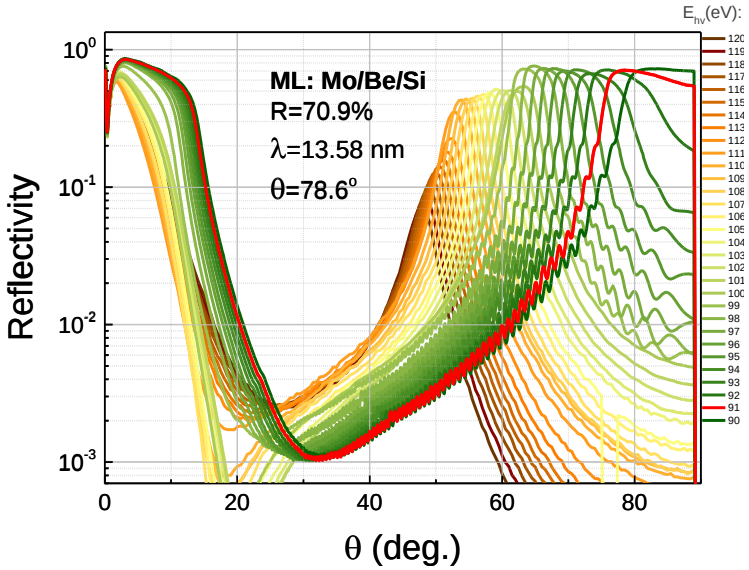
Metrology on Multilayers

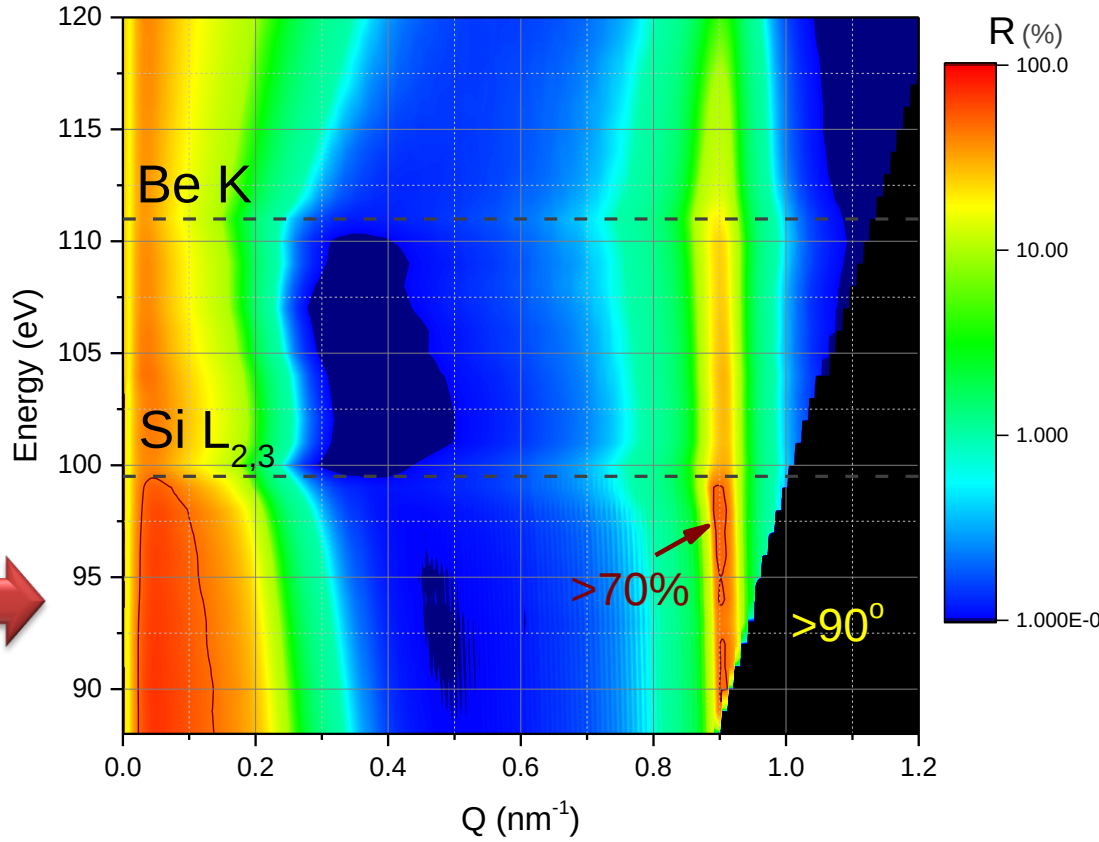
poster: Dr. Sertsu - PD2-16

HZB Helmholtz Zentrum Berlin



DFG-RSF – SO 1497/1-1





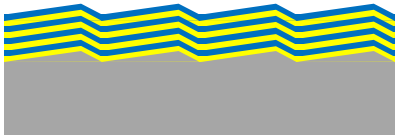
N. I. Chkhalo et al., "High-reflection Mo/Be/Si multilayers for EUV lithography". Optics Letters, 42, p. 5070 (2017)

Metrology on gratings: Multilayer Blazed Grating

poster: Dr. Huang - PD2-02

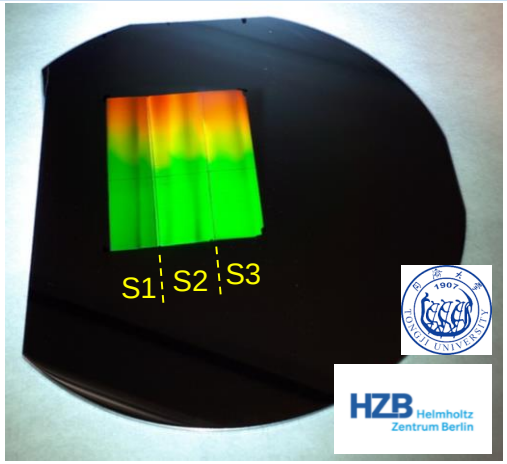
HZB Helmholtz Zentrum Berlin

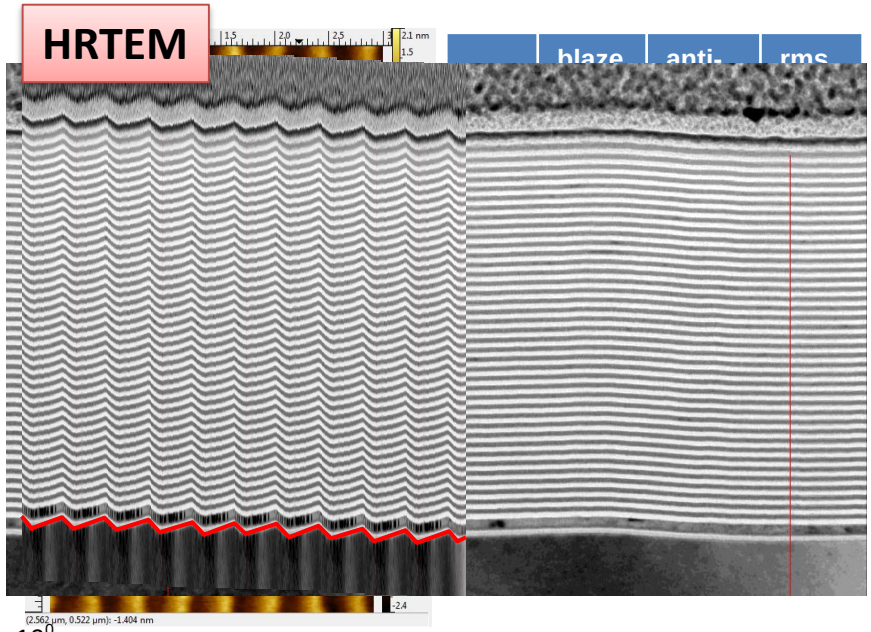
ML: Cr/C (35), d=6.3 nm,



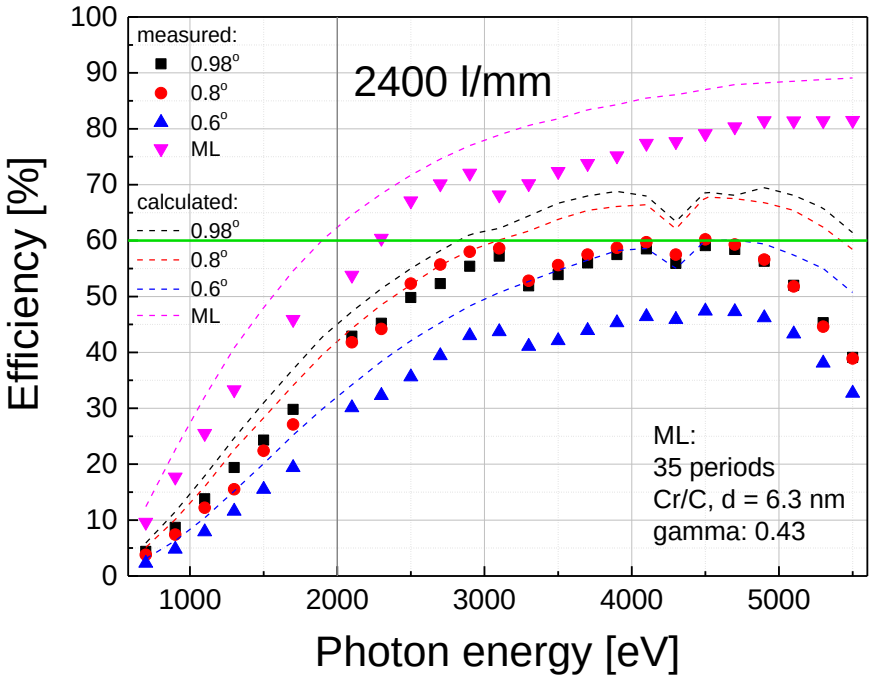
N = 2400 l/mm

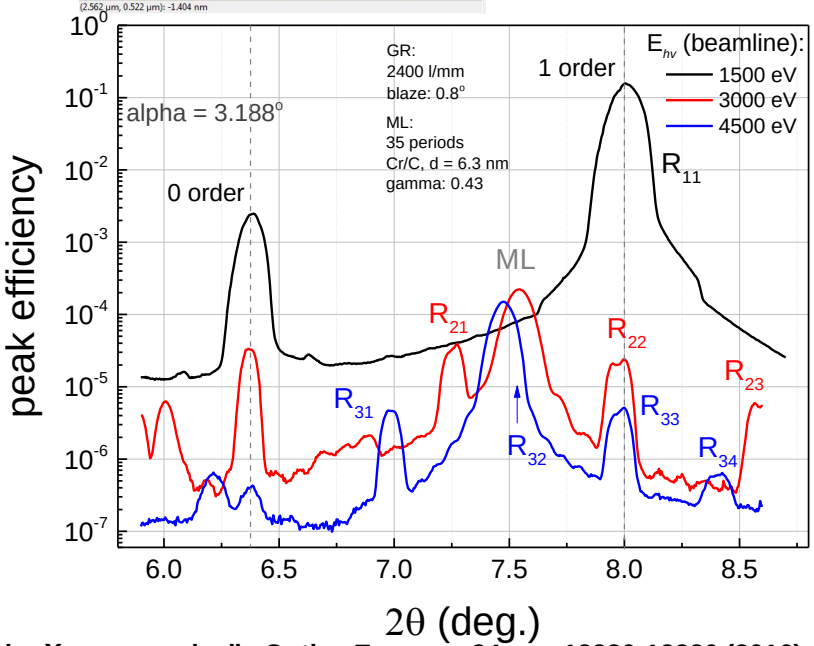
blaze = 0.6˚, 0.8˚, 1.0˚





efficiency: >40 % (2 keV) and 60 % (3-5 keV)

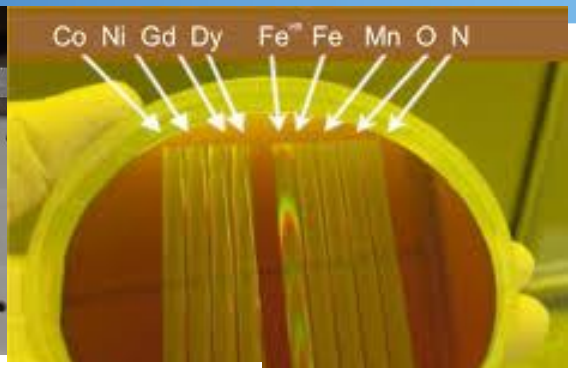


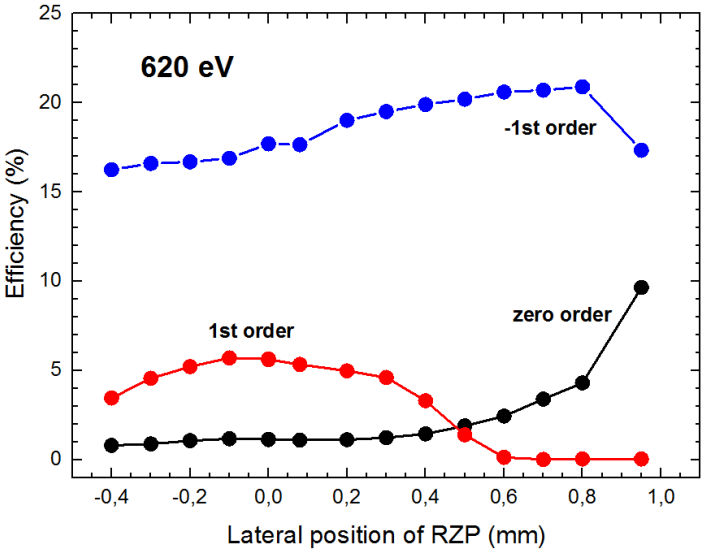


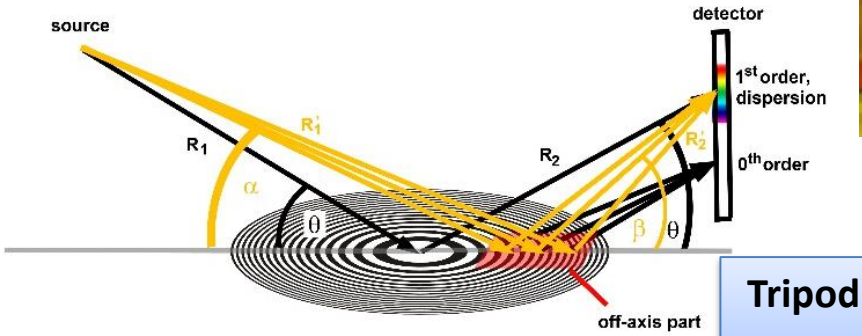
F. Senf et al., , “Highly efficient blazed grating with multilayer coating for tender X-ray energies”, Optics Express, 24, pp. 13220-13230 (2016)

Metrology on Reflection Zone Plates (RZP)

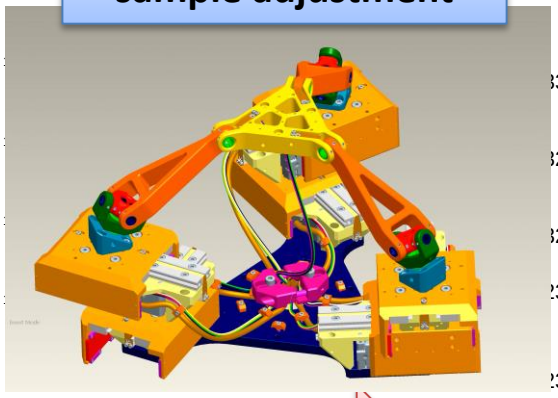
HZB Helmholtz Zentrum Berlin

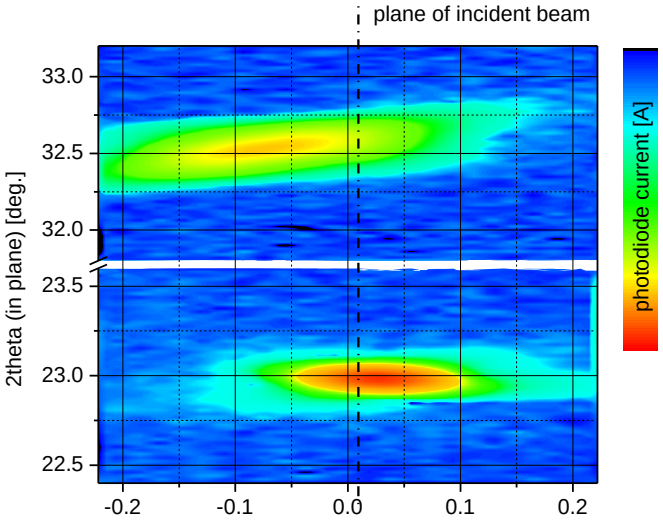




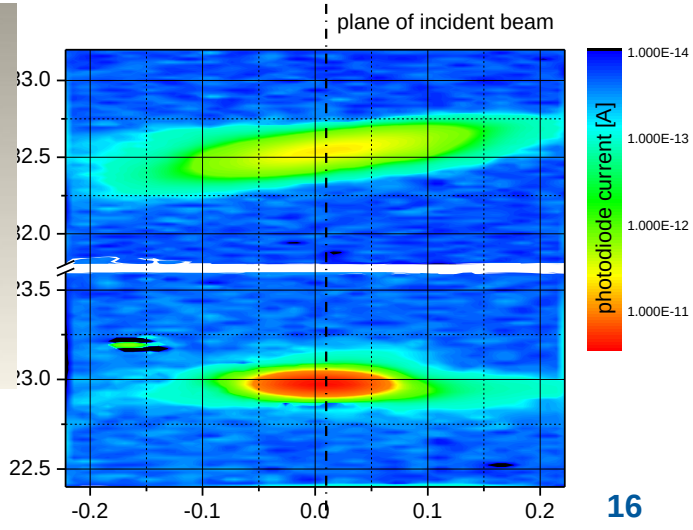


Tripod unit for precise sample adjustment

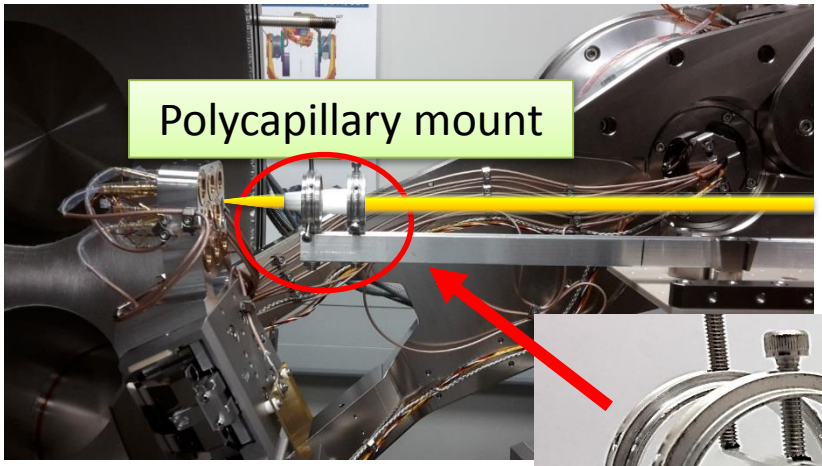


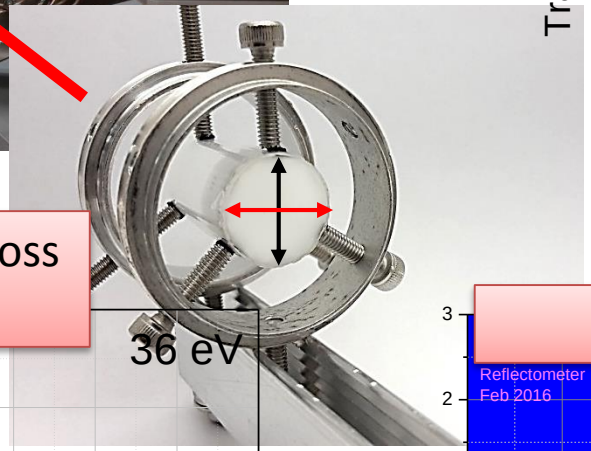


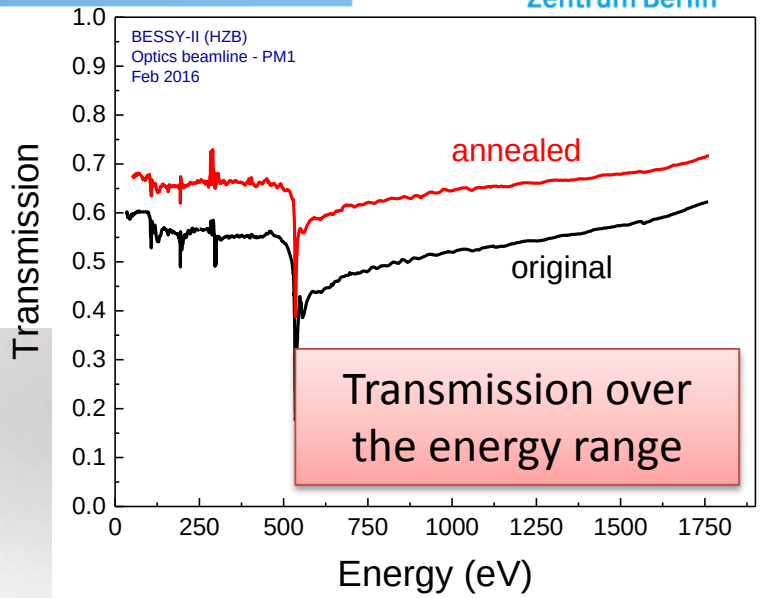
after realignment



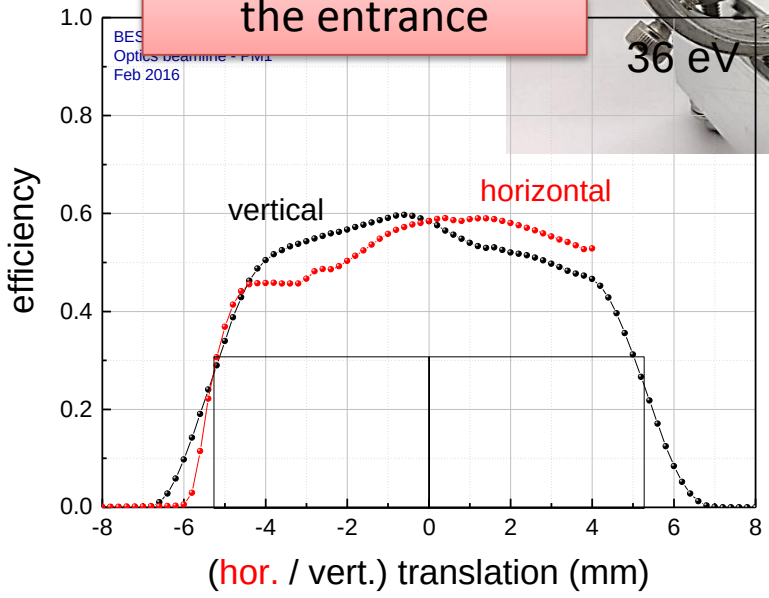
Metrology with polycapillaries



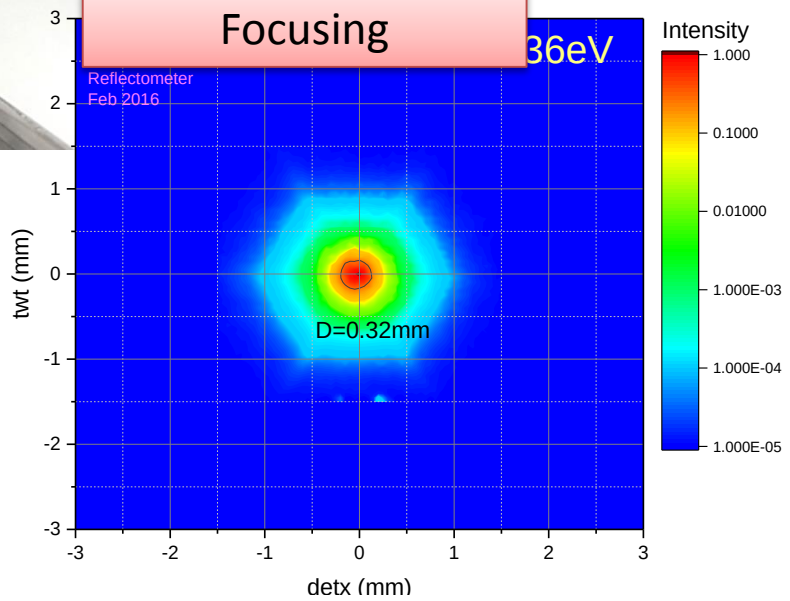




Transmission across the entrance



Focusing

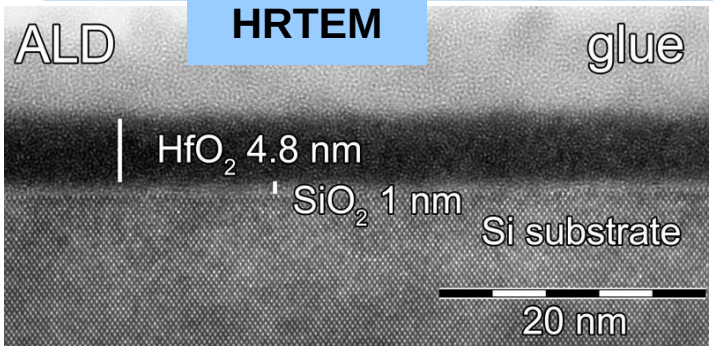


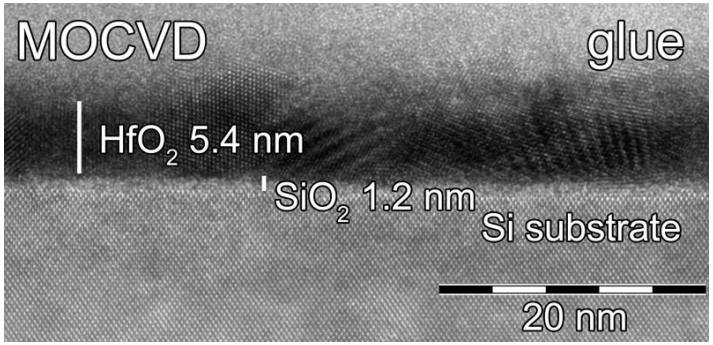
Ch. Braig, et al., "Polycapillary-boosted instrument performance in the extreme ultraviolet regime for inverse photoemission spectroscopy", Optics Express Vol. 25, Issue 25, pp. 31840 (2017)

Investigation of HfO_2 thin layered systems

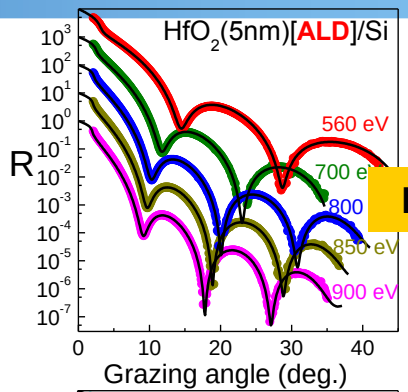
HZB Helmholtz Zentrum Berlin

HRTEM

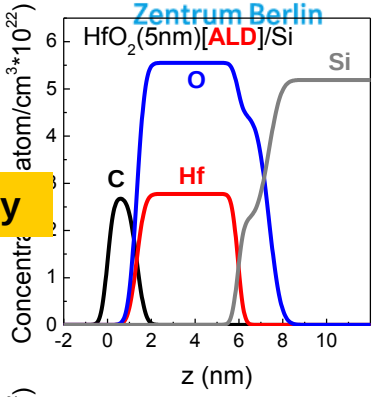


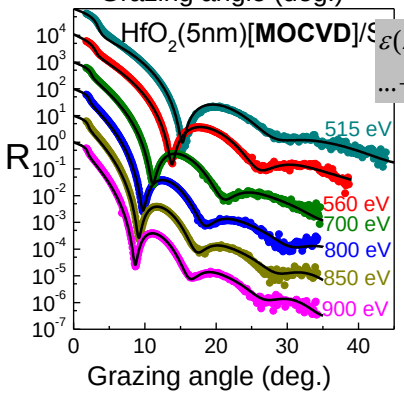


Reflectometry

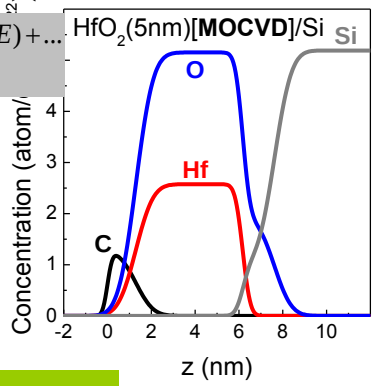


$$\varepsilon = (1-\varepsilon_1) + i\varepsilon_2$$



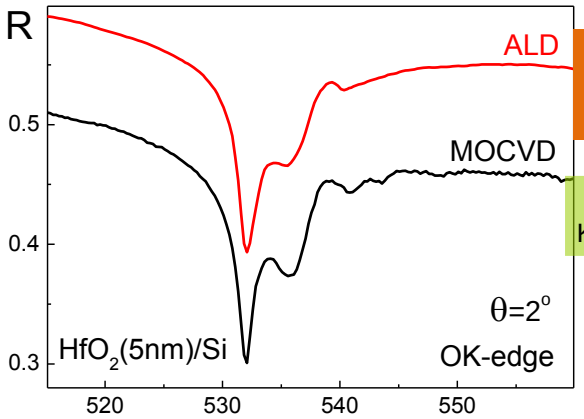


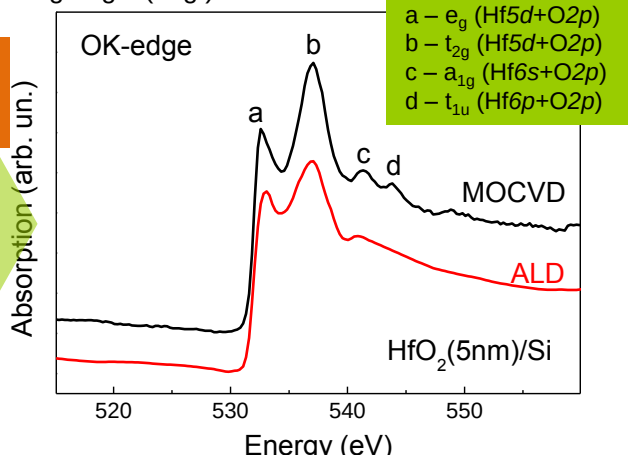
$$\varepsilon(z,E) \sim E^{-2}[C_A(z)\,f_A(E) + \ldots + \ldots + C_N(z)\,f_N(E)]$$



Reflection spectroscopy

calculation with Kramers-Kronig equation





a – e_g (Hf5*d*+O2*p*)
b – t_{2g} (Hf5*d*+O2*p*)
c – a_{1g} (Hf6*s*+O2*p*)
d – t_{1u} (Hf6*p*+O2*p*)

E.O. Filatova, A.A. Sokolov, I.V. Kozhevnikov, "High-k Gate Dielectrics for CMOS Technology" (Ed. by Prof. Gang He, Prof. Zhaoqi Sun), 2012, Wiley-VCH, Ch. 7, pp. 225-271

Other experimental stations
Beamtime / user operation

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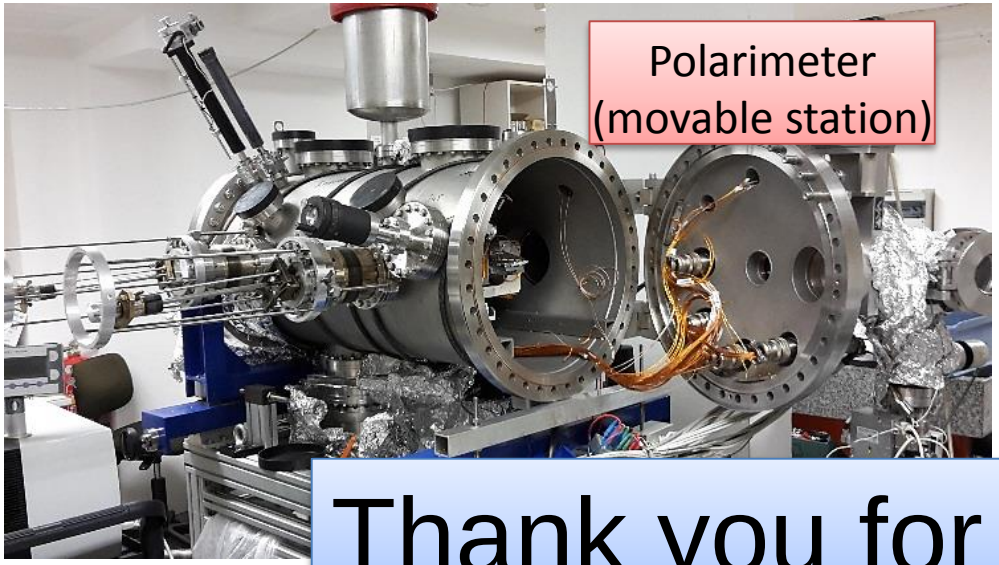
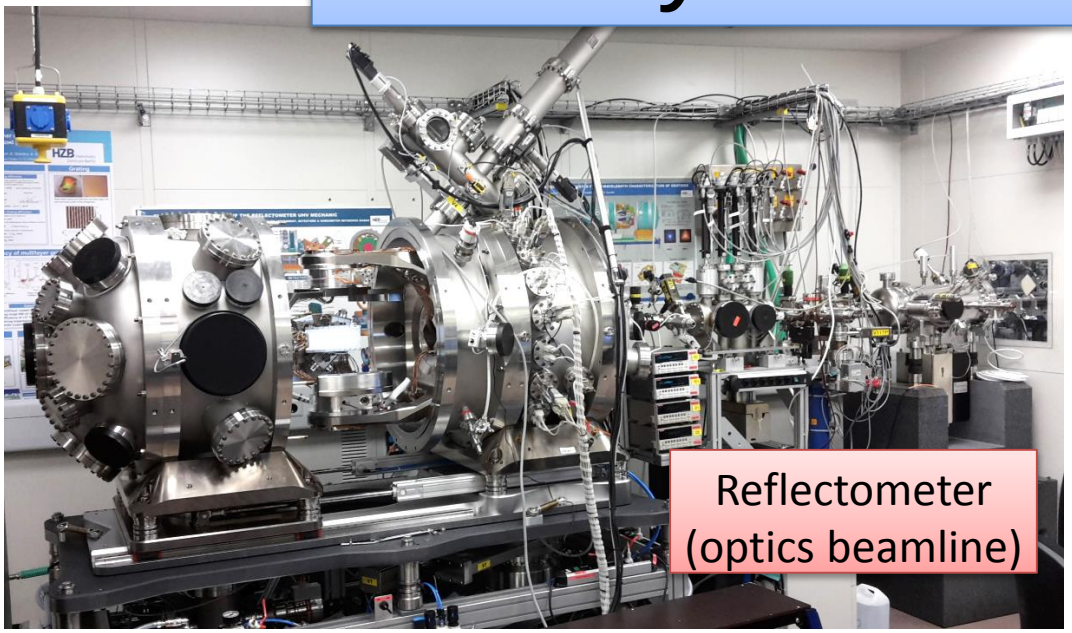


Polarimeter
(movable station)

Small Reflectometer
(movable station)

Thank you for attention!



Reflectometer
(optics beamline)