Development of XUV multilayer coatings in IOF

Fraunhofer IOF

S. Yulin[1], P. Naujok[1,2], R. Müller [1,2] and N. Kaiser[1]

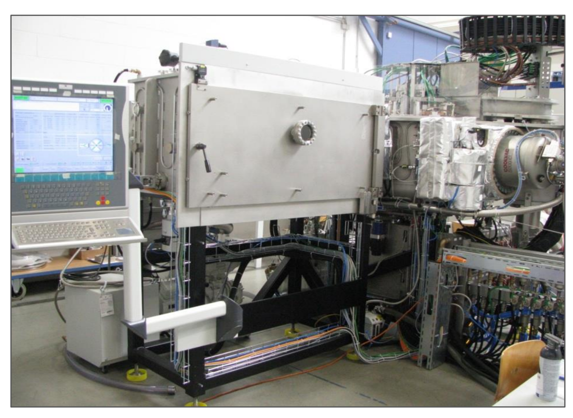
[1] Fraunhofer-Institute for Applied Optics and Precision Engineering IOF, Jena (Germany)
[2] Friedrich-Schiller-University Jena, Institute of Applied Physics, Abbe Center of Photonics, Jena (Germany)

Introduction

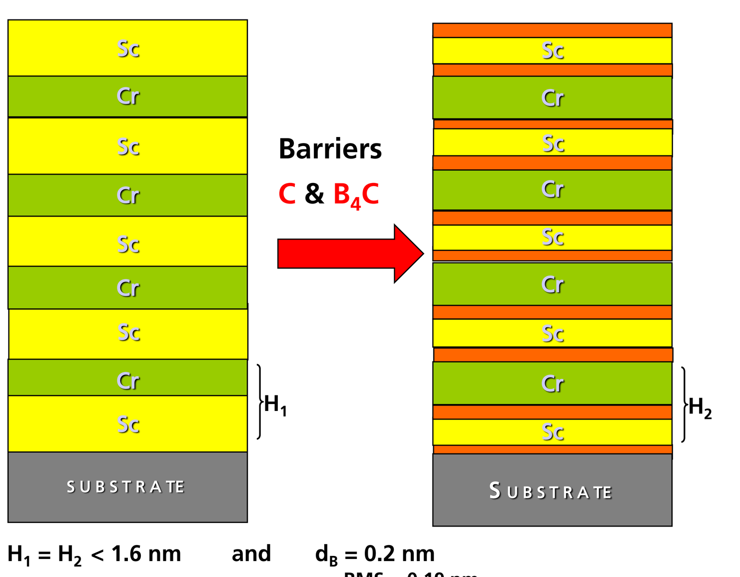
High-reflective XUV coatings are a key component for many applications including microscopy in the "water window" (2.3 - 4.4 nm), next generation lithography (λ = 13.5 nm / λ = 6.X nm), high-order harmonic generation (20 - 50 nm), astronomy and spectroscopy (5 - 80 nm) as well as plasma diagnostics and laser research.

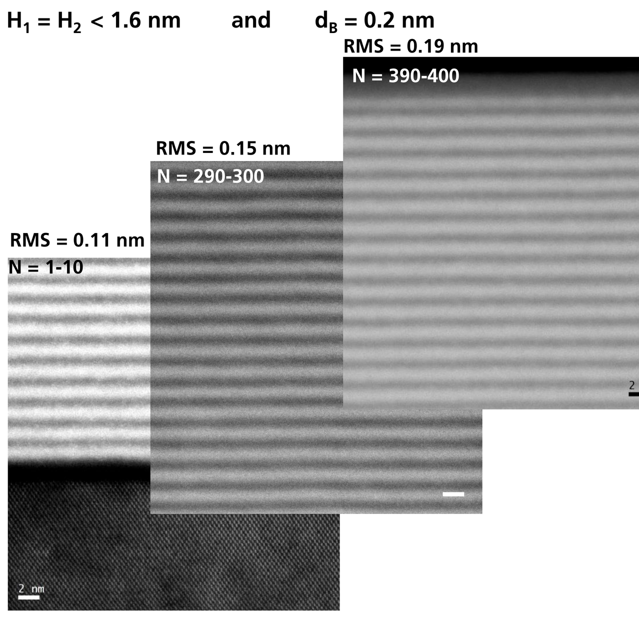
At the Fraunhofer IOF Jena multilayer coating development covers the full spectral range from 1.0 nm to vacuum ultraviolet around 200 nm. This paper considers some theoretical design considerations, prospects of modern interface-engineered strategies (interface barriers and capping layers) and deposition techniques for controlled fabrication of XUV multilayer coatings. The paper summarizes our recent progress in preparation of high-reflective multilayer coatings with regard to minimum structure imperfections, enhanced stability and different possibilities in broadening of the angular reflective response.

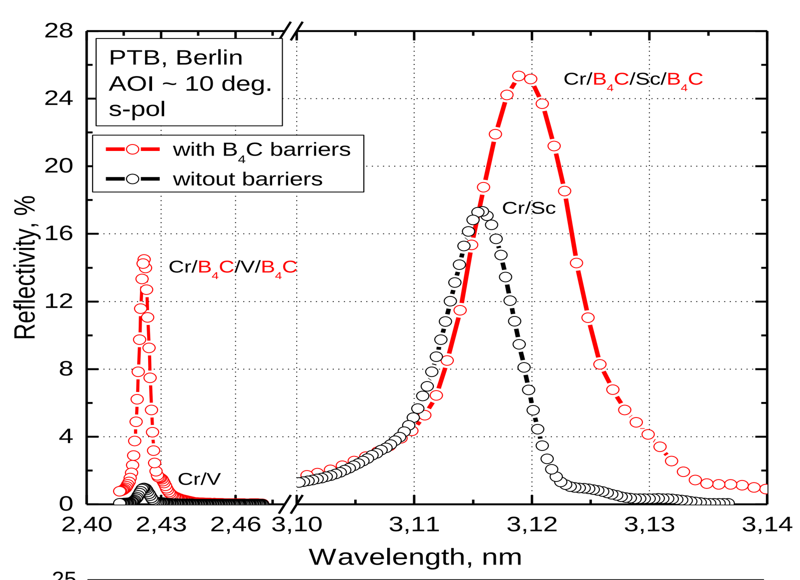
Deposition techniques

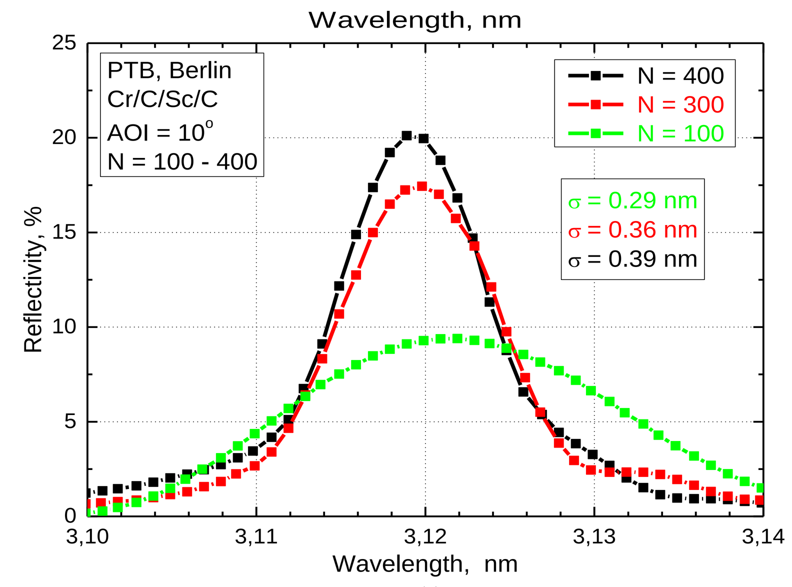
	NESSY 1 (2003)	NESSY 2 (2010)	NESSY 3 (2013)
			
Base pressure	< 10^{-8} Torr	< 10^{-8} Torr	< 8 x10^{-9} Torr
Number of targets	4	6	6
Optics size	≤ ∅ 600	≤ ∅ 600	≤ ∅ 200

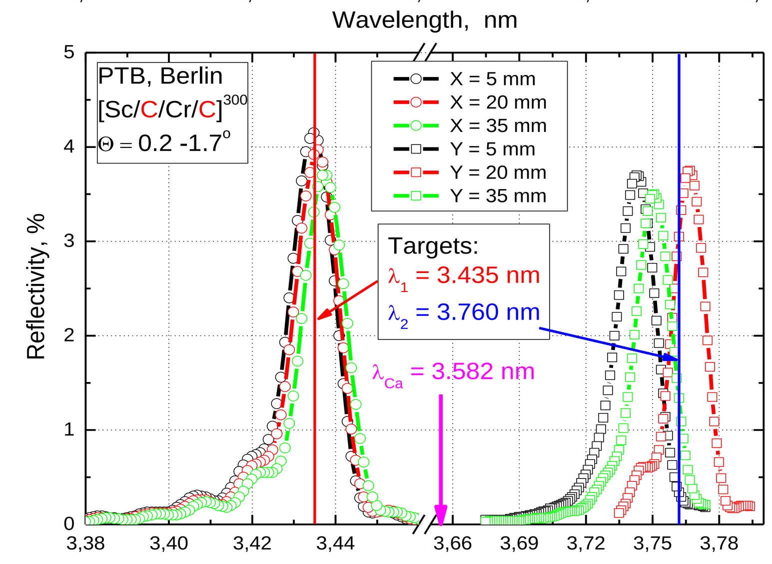
Multilayer coatings for microscopy in the water window (2.3…4.4 nm)





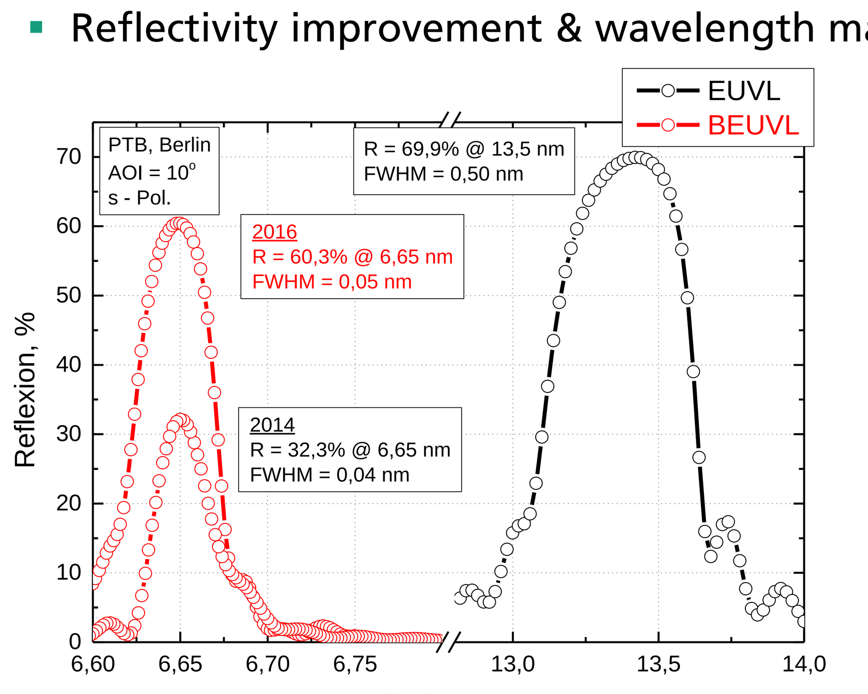


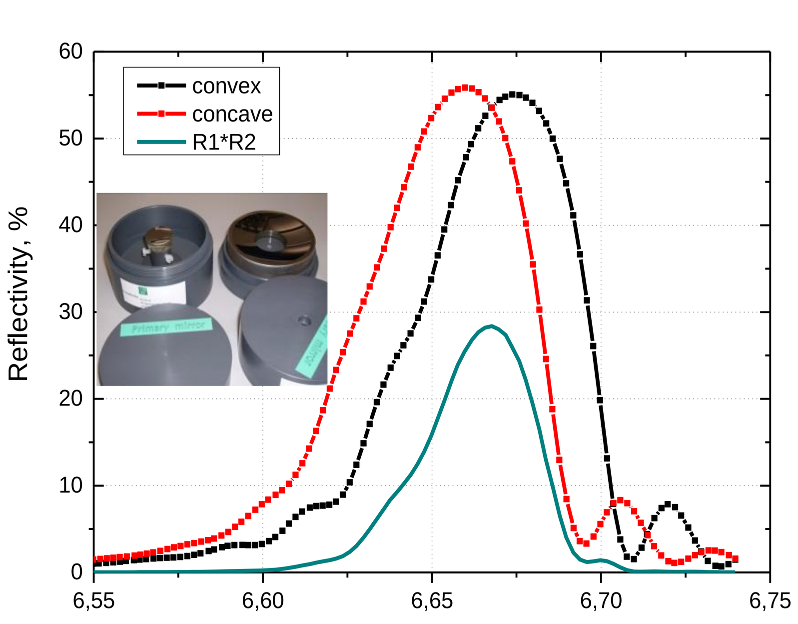




Multilayer coatings for next generation lithography (6.X and 13.5 nm)

- Reflectivity improvement & wavelength matching (Schwarzschild objective @ 6.67 nm)



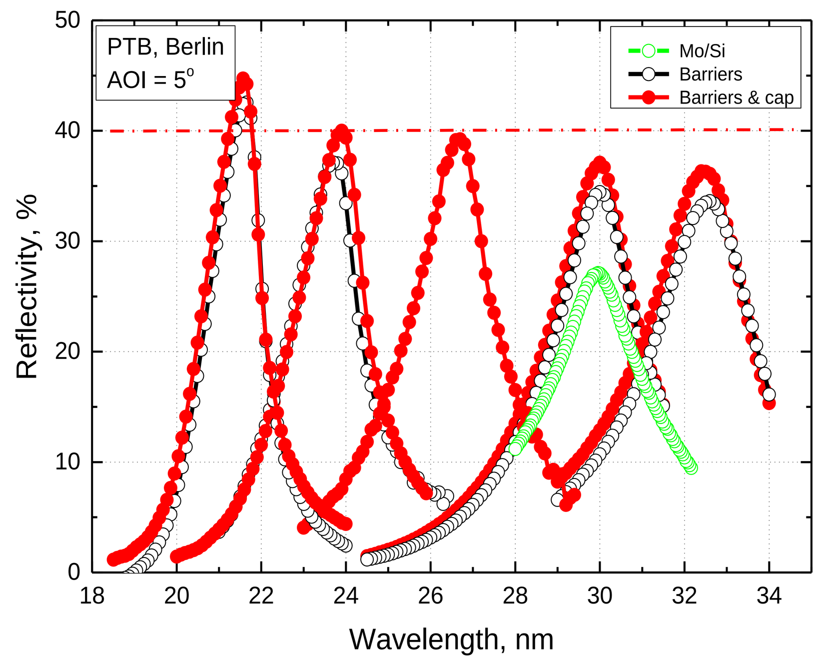


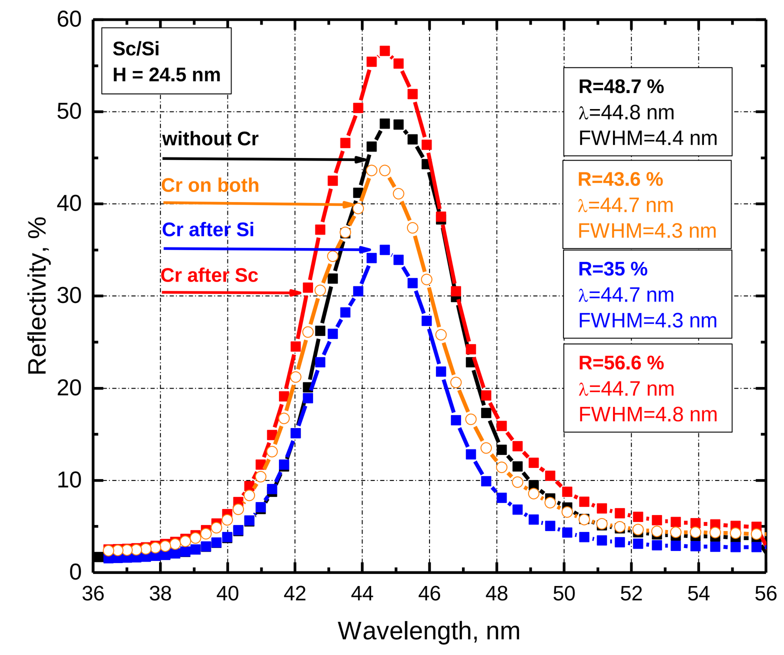
Actual challenges:

- R > 72% @ 13.5 nm and R > 65% @ 6.65 nm
- FWHM > 0.1 nm @ 6.65 nm
- Efficient grazing incidence coatings for 6.7 nm

Multilayer coatings for high harmonics generation (15… 60 nm)

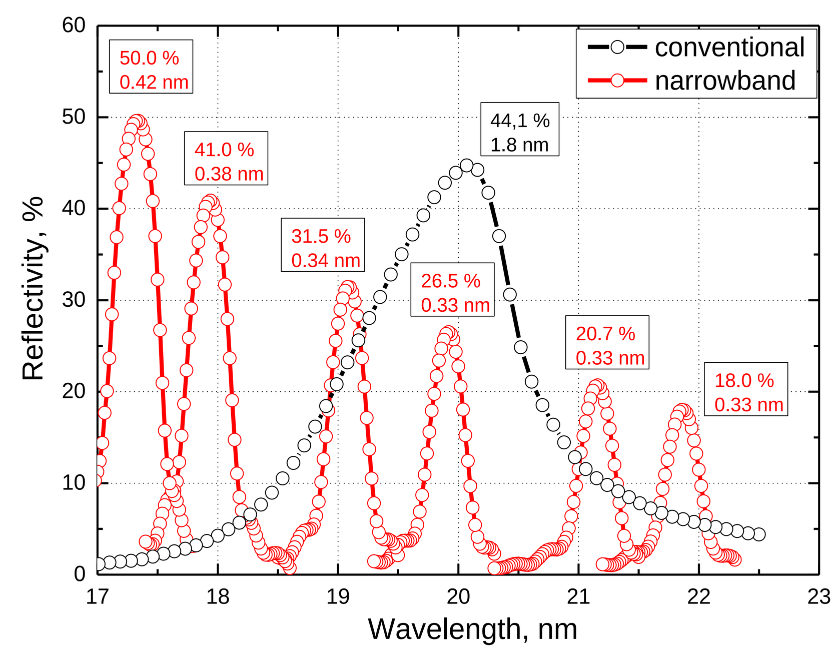
- Reflectivity enchantment by interface-engineering (barriers & capping layers)

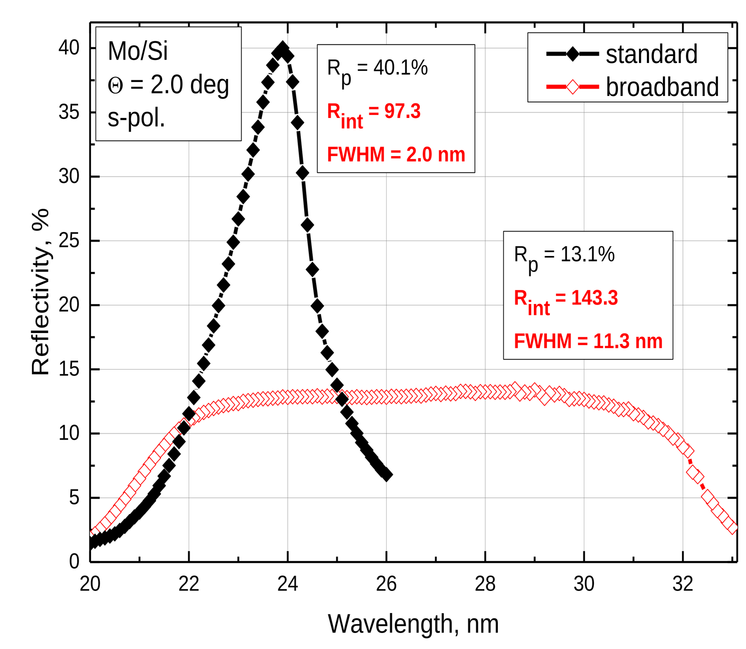




Actual challenges:

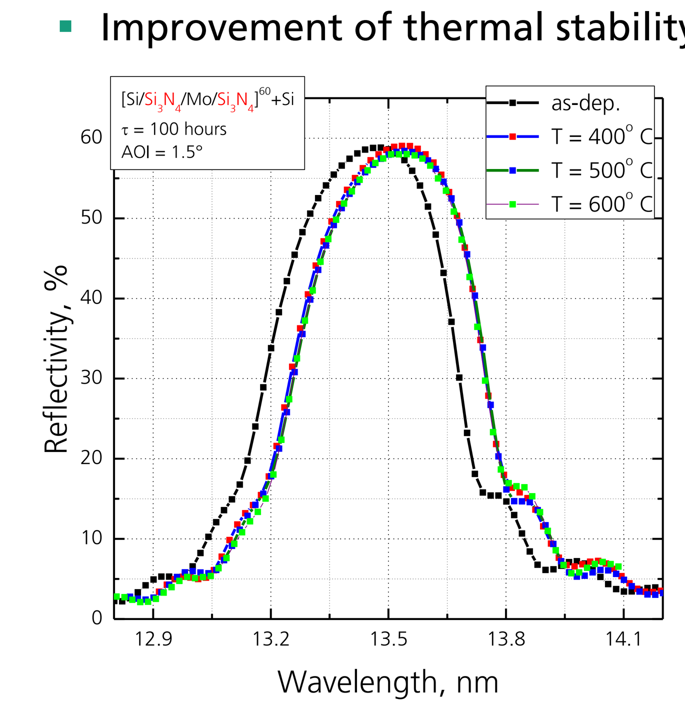
- narrowband (FWHM < 1.0 nm) and broadband (FWHM > 5.0 nm) coatings
- radiation stability



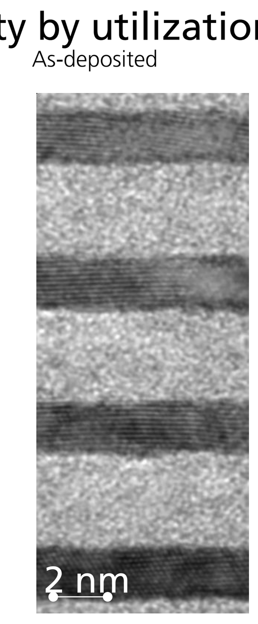


Multilayer coatings with enhanced stability

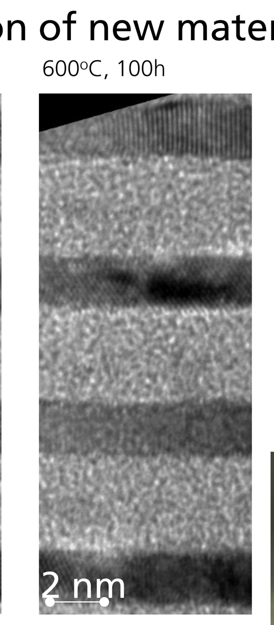
- Improvement of thermal stability by utilization of new materials and diffusion barriers



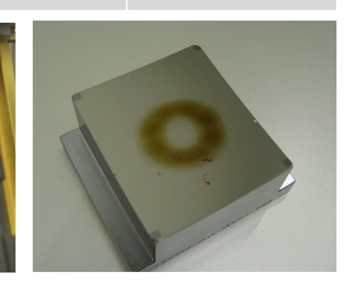
As-deposited



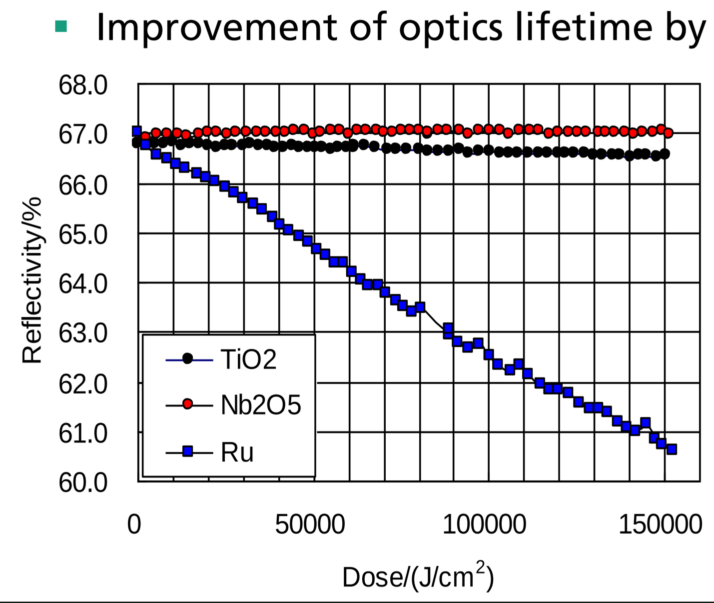
600°C, 100h

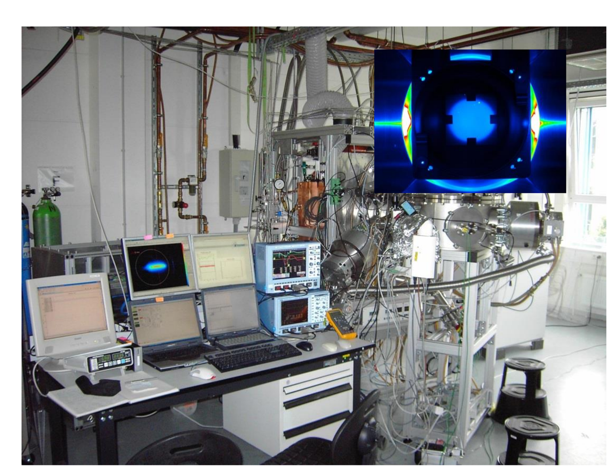


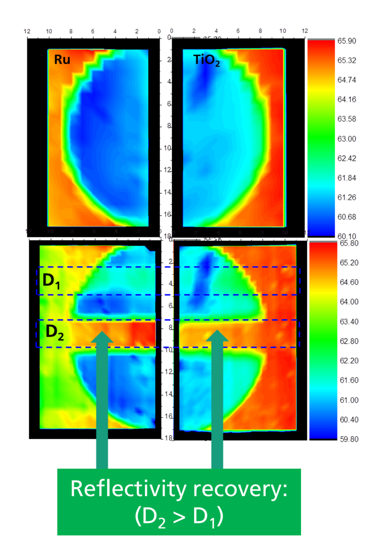
System	T_{max}, °C	R_{max}, %
Mo/Si	< 100	69
Mo_2C/Si	≤ 350	67
Mo/C/Si/C	≤ 400	60
$MoSi_2/Si$	≤ 600	42
$Mo/Si_3N_4/Si/Si_3N_4$	≤ 600	60



- Improvement of optics lifetime by utilization of capping layers and surface cleaning technologies







Summary

- Remarkable progress has been made in Fraunhofer IOF in the field of XUV multilayer coatings for different applications
  - Microscopy
    - Cr/V and Cr/Sc multilayers — 14.2% @ 2.42nm and 25.2%@ 3.11 nm
  - Lithography
    - LaN/B and Mo/Si multilayers — 60.3%@ 6.65 nm and 69.9% @13.5 nm
  - HHG and astrophisics
    - Mo/Si and Sc/Si multilayers — > 40 % @ 20…50 nm & narrowband / broadband
- Interface-engineering (barriers & capping layers) is the key-technology for improvement of optical performance and environmental stability of XUV multilayer coatings

Acknowledgment

Financial support: MAVO-project 601004 (Fraunhofer-Gesellschaft)
EUV reflectometry: Frank Scholze and Christian Laubis (PTB, Berlin)
Technical support: Steffen Schulze, Thomas Müller und Michael Scheler