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FOM

Spectral purity enhancement for EUV Lithography Systems

November 5, 2014

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XLIV OPTICS

FOM DIFFER/Rijnhuizen

Untill

1st July 2014

Multilayer R & D program

EUV & Beyond lithography

Figure 1.
The front entrance of FOM-Rijnhuizen.

University of Twente / MESA+

XUV OPTICS

Focus Group in Twente

Multilayer R & D program

University of Twente

MESA+ Institute for Nanotechnology

provincie Overijssel

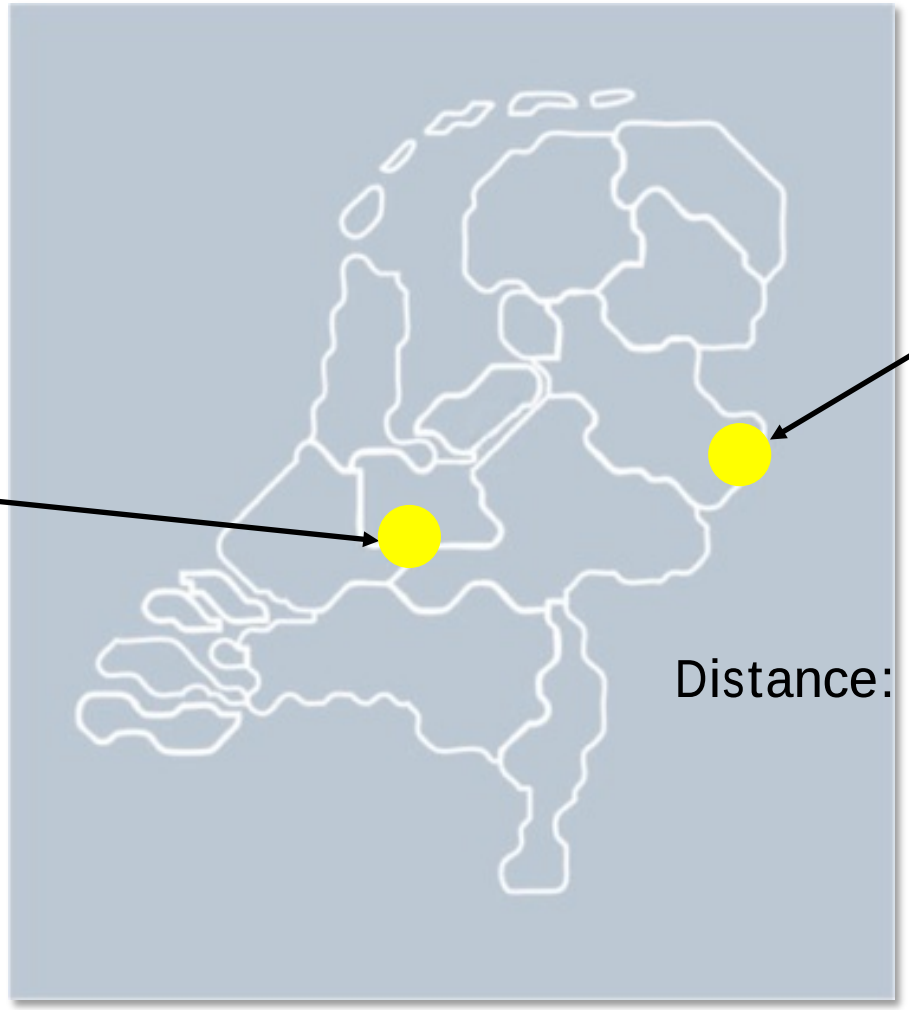
SolMateS

DEMCON

TNO

XUV FOM PANalytical ASML ZEISS MESA+ INSTITUTE FOR NANOTECHNOLOGY UNIVERSITY OF TWENTE.

Location in the Netherlands



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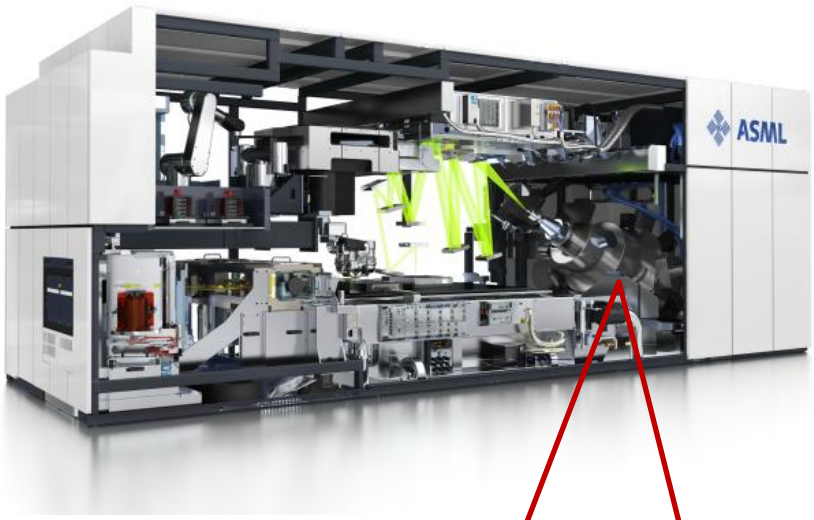
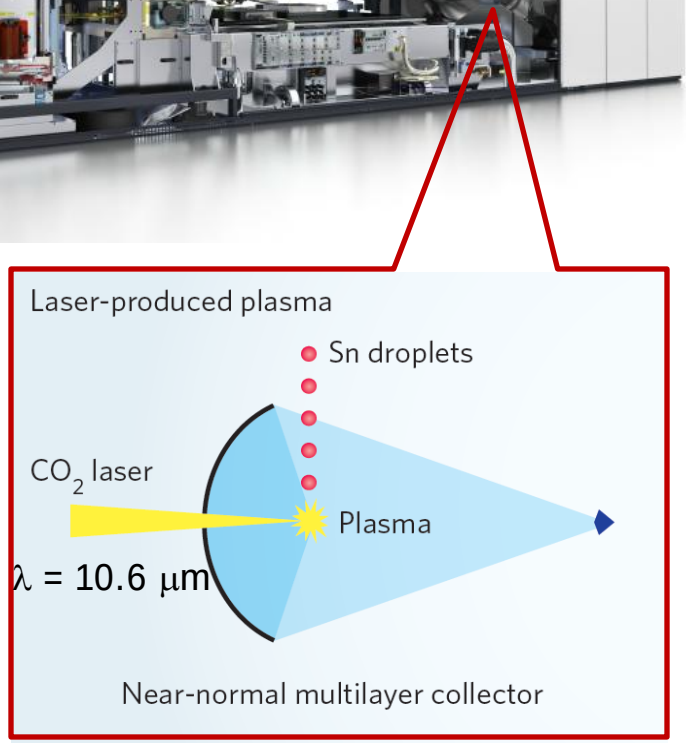
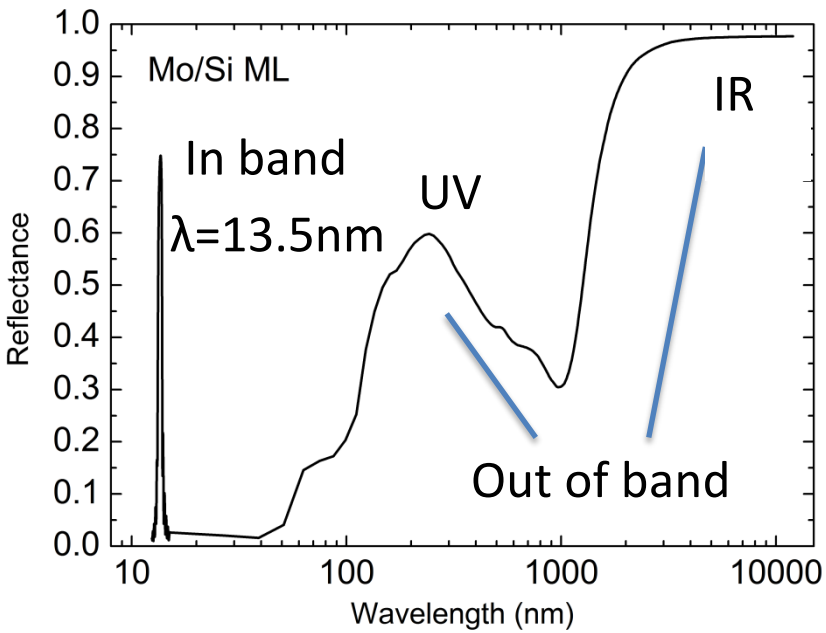
Distance: 145 km or 90 miles

Spectral filtering: Tailoring optical response







- Heat load problem
- Imaging contrast loss

IR suppression methods

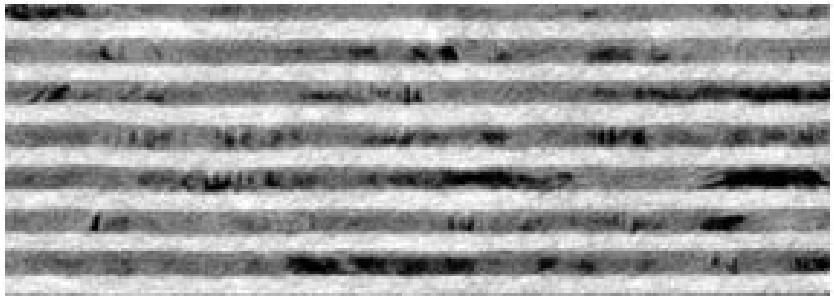
- Multilayer-based solutions for IR filtering

IR antireflecting multilayer mirrors

IR suppression + EUV reflection

IR+EUV

EUV

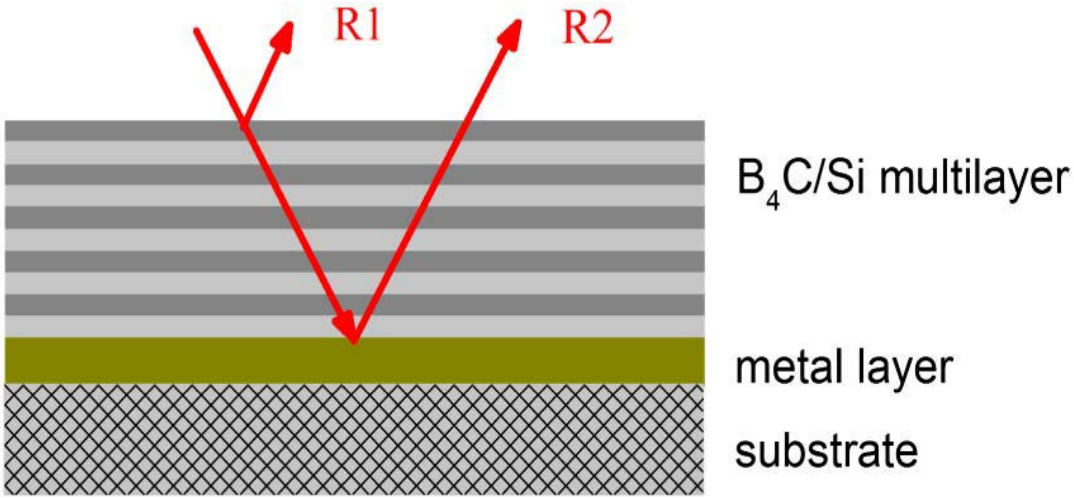


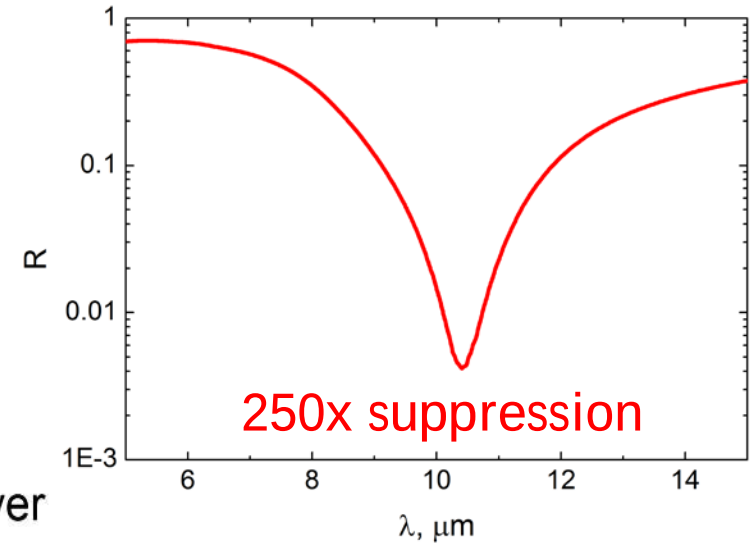
Mo/Si multilayer is opaque for IR radiation

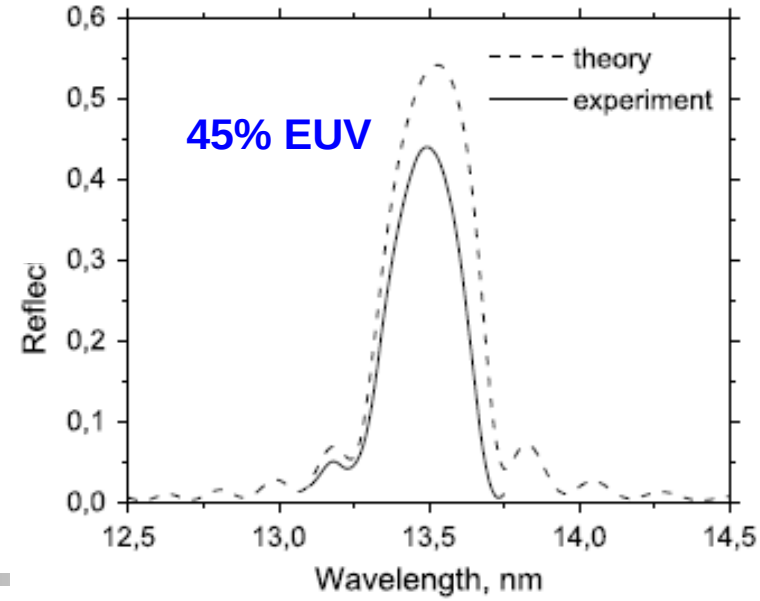
➡ IR transparent materials should be used

Infrared anti-reflectance coating

B_4C/Si multilayer reflects EUV light and is transparent for 10.6 μm radiation



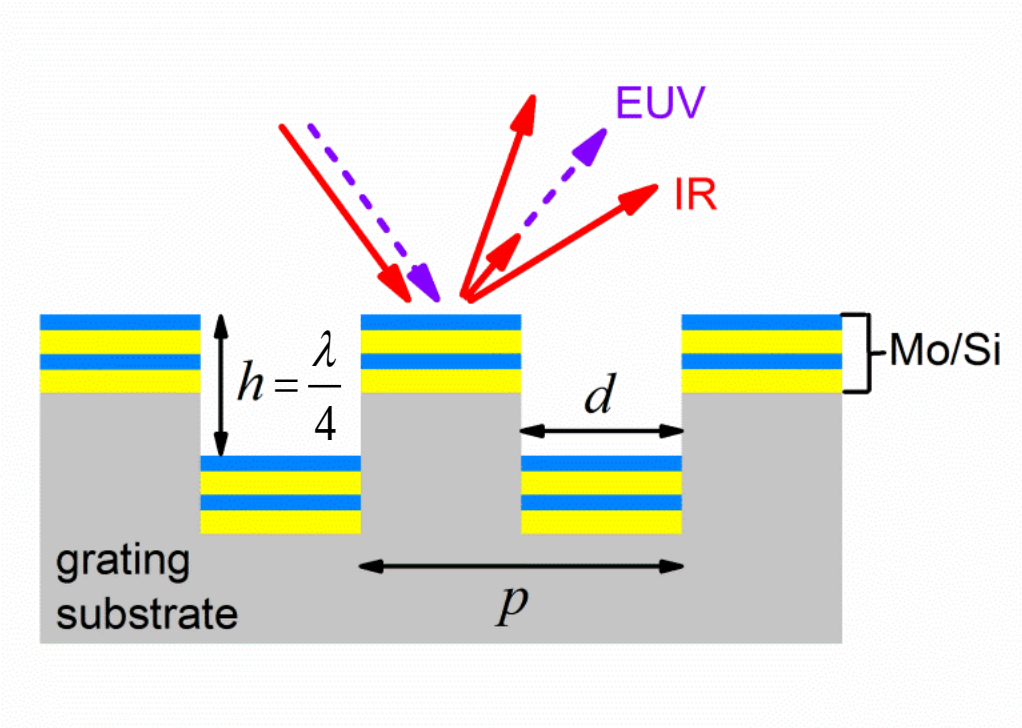




IR suppression ... at the cost of 13.5 nm EUV light..

Medvedev et al, *Opt. Lett.* **37**, pg. 1169 (2012)

Grating-based spectral purity filtering



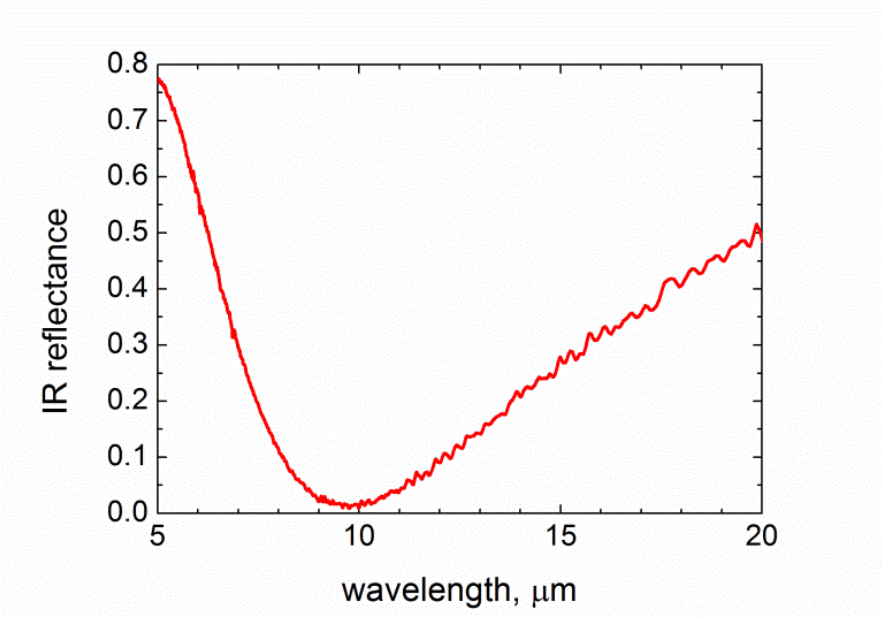
Destructive interference for the specular direction

zero order IR reflectance: $R^{(0)} = 0$

Reflected IR radiation is distributed between off-specular diffraction orders

Proof of principle: spectral characteristics

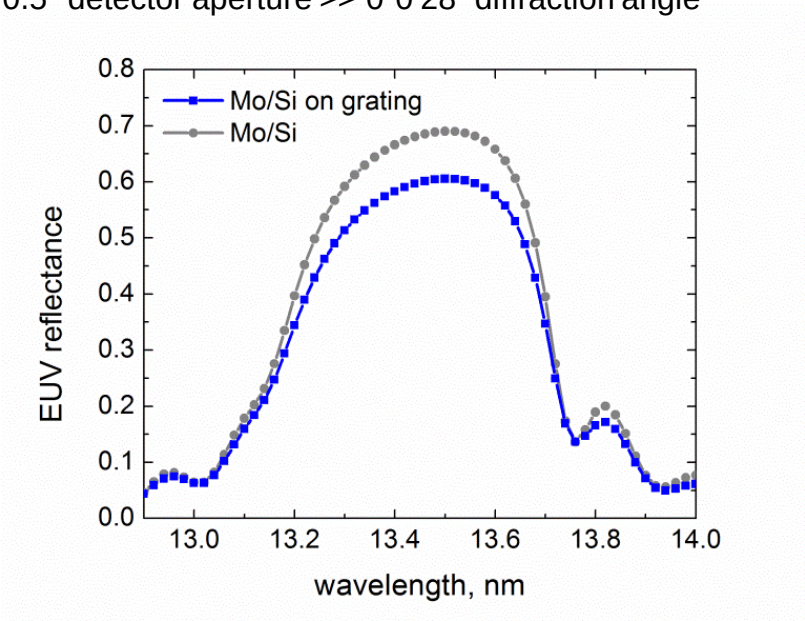
Measured with FTIR spectrometer
Off-specular reflectance filtered with diaphragm



70x IR suppression

V.V. Medvedev et al.,
Opt. Express **21** 16964 (2013)

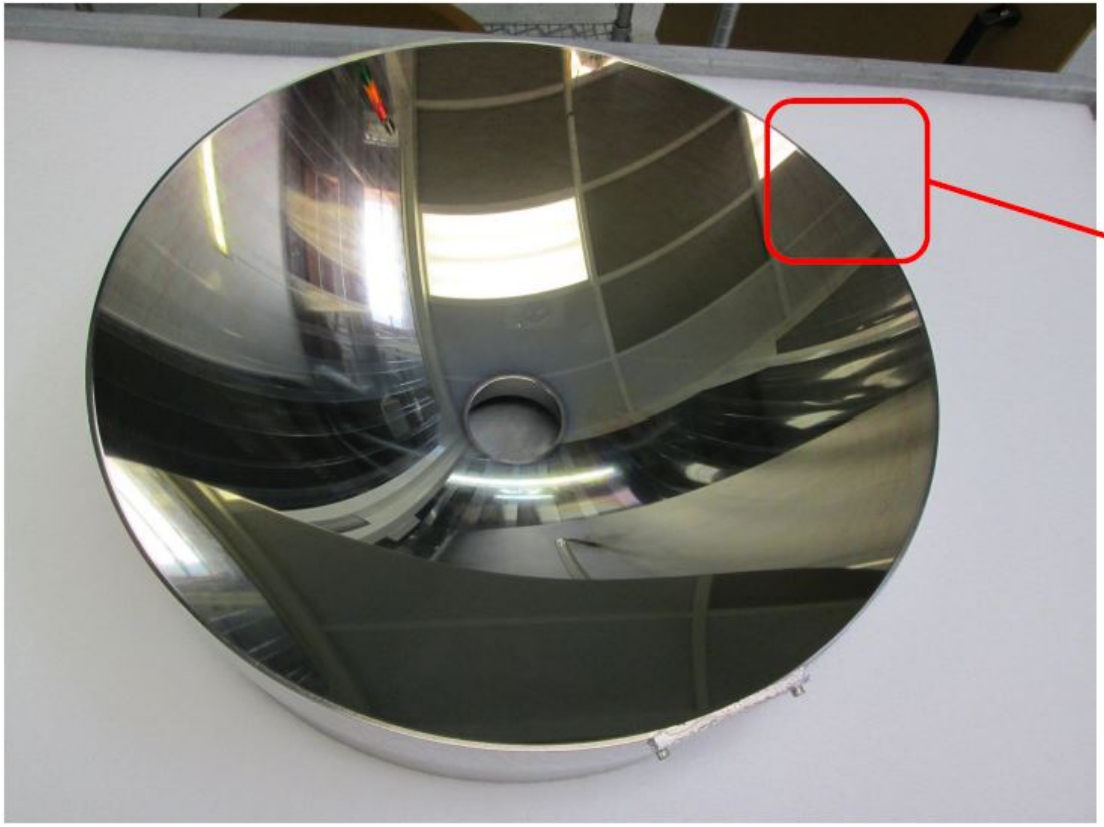
Measured at PTB
1.5º from normal
0.5º detector aperture >> 0º0'28" diffraction angle

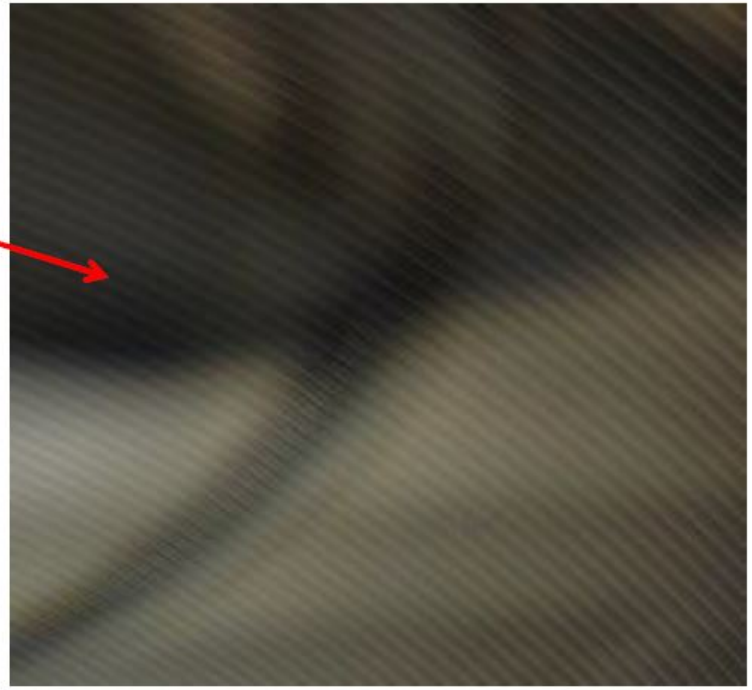


61% EUV peak reflectance

8% losses due to structure/multilayer imperfections

Demonstration Collector: ~410mm dia (NA ≳ 0.22)

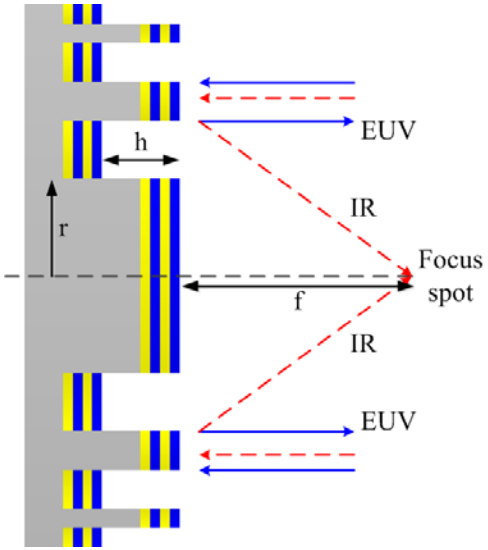


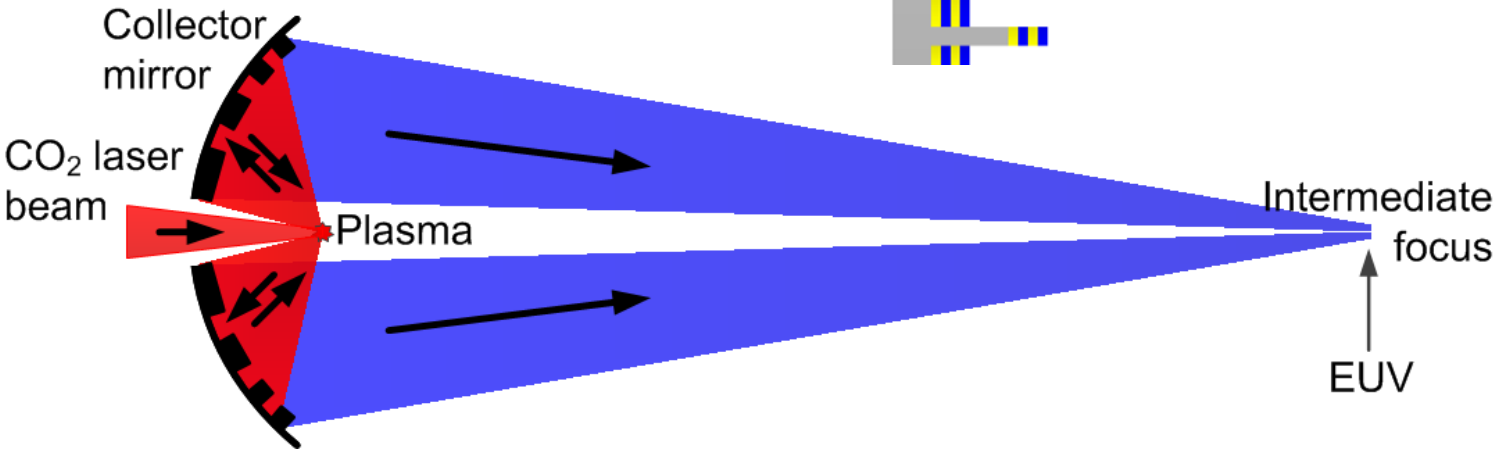


Grating structure

Courtesy of Y. Platonov and M. Kriese, Rigaku

Focusing grating: Fresnel Zone Plate





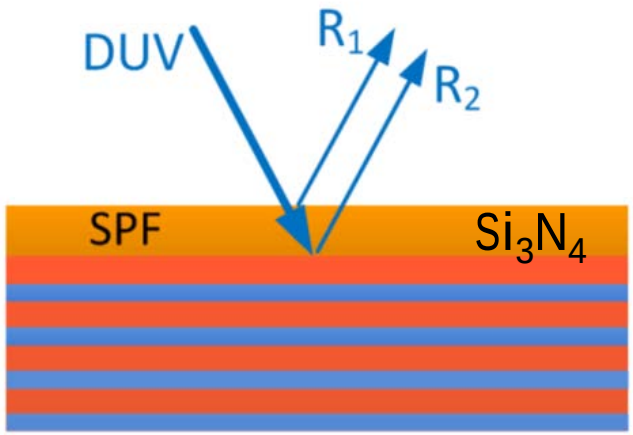
re-usage of removed IR + removal of IR from IF position

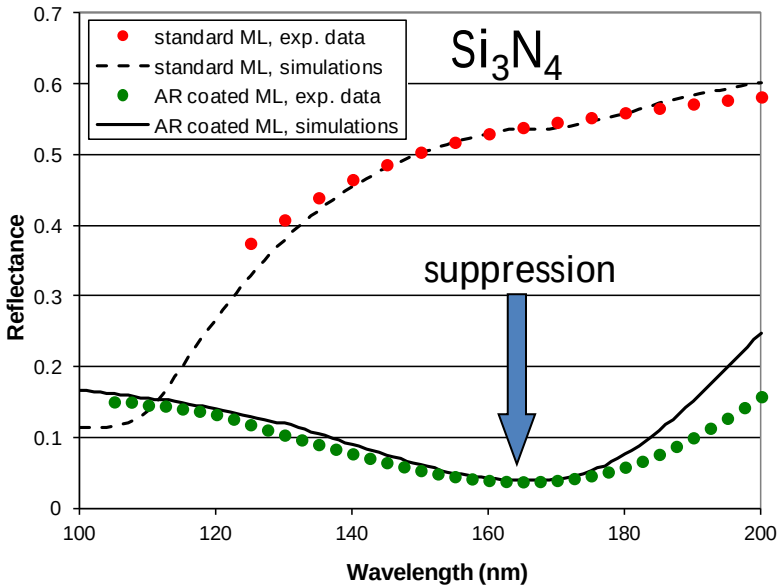
Bayraktar et al, *Opt. Express*. **22**, 7 pg. 8633 (2014)

UV suppression methods

- Multilayer-based solutions for UV/DUV filtering

DUV antireflective coating

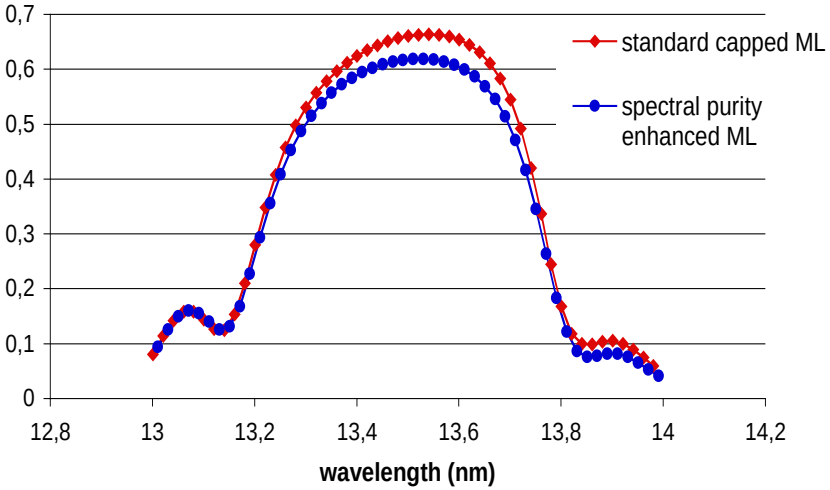




Only 4.5 % EUV loss

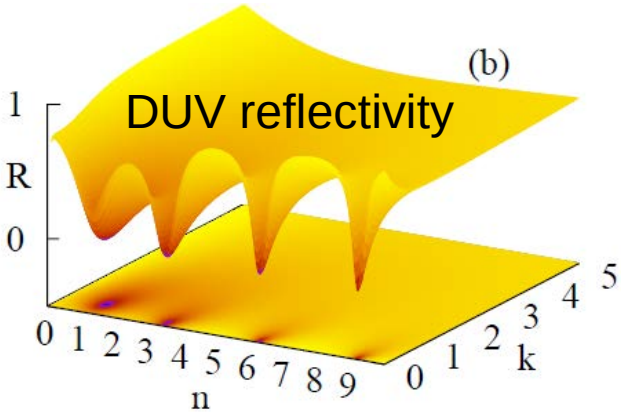
→ Works fine for

100 nm < λ < 200 nm

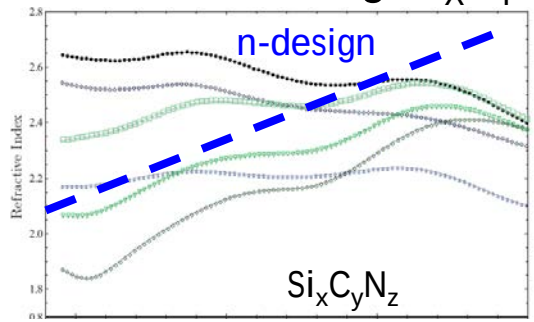


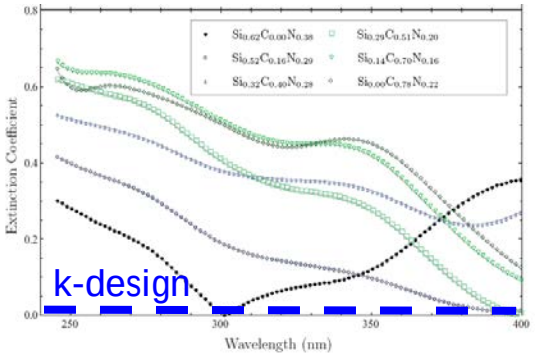
Louis et al, *SPIE 6151, 2006*

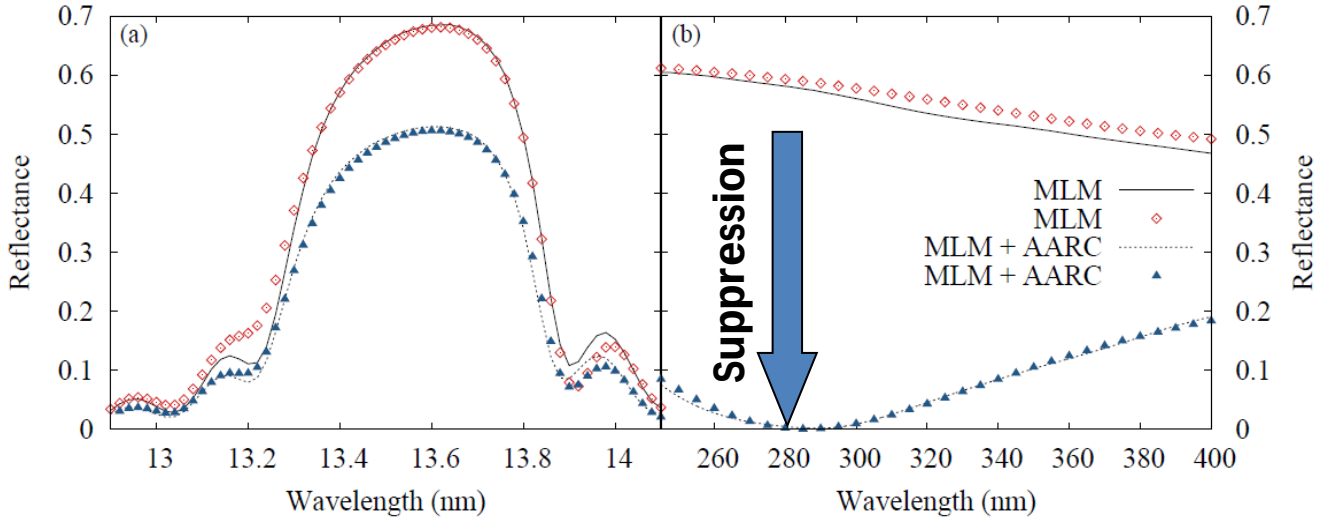
Tailoring optical constants for λ > 200 nm



Ex. : Tailoring $Si_XC_YN_Z$ to suppress 280 nm







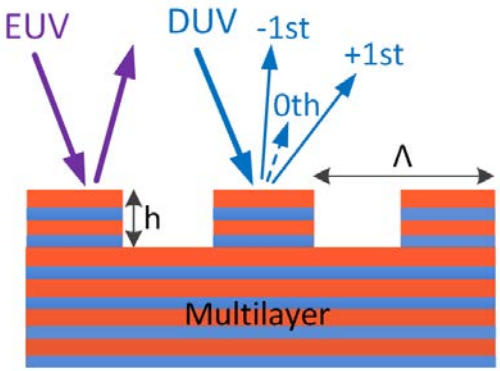
S. Huber et al, *Opt. Express, 22, 1, 2014*

→ Still too much reflectance EUV loss

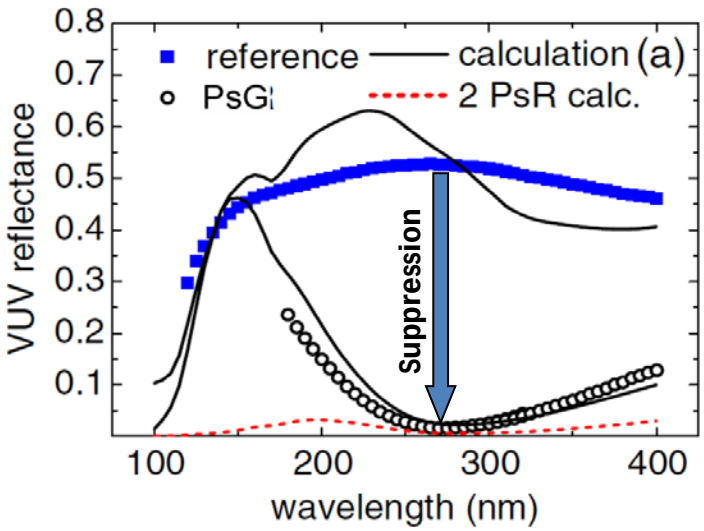
Diffractive suppression of λ = 280 nm

Phase shift multilayer grating

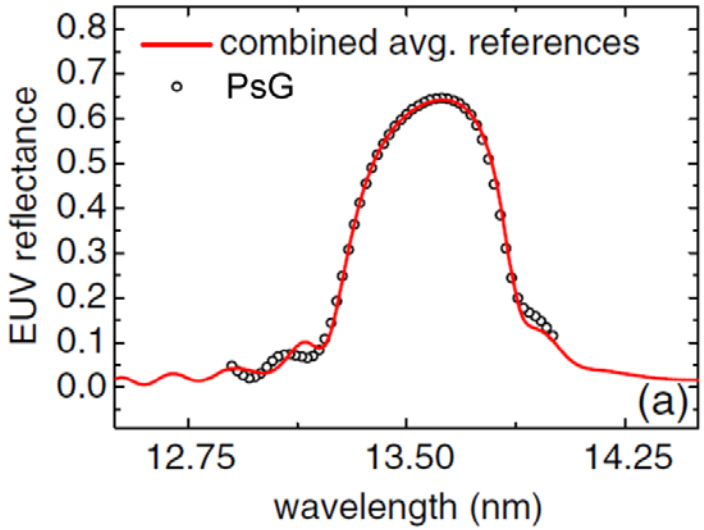
- $\Lambda >> \lambda_{EUV}$, high reflectance of EUV
- **$h = \lambda_{DUV}/4$**, destructive interference



30x Suppression (λ=280nm)

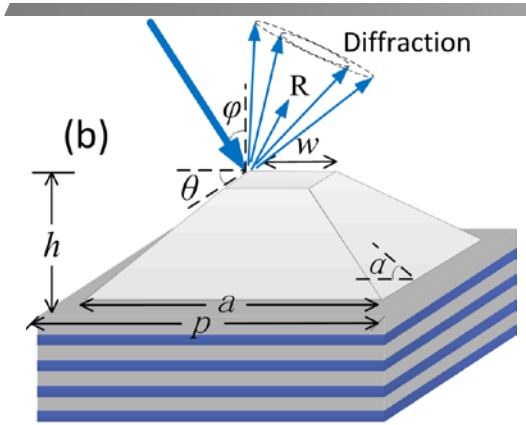


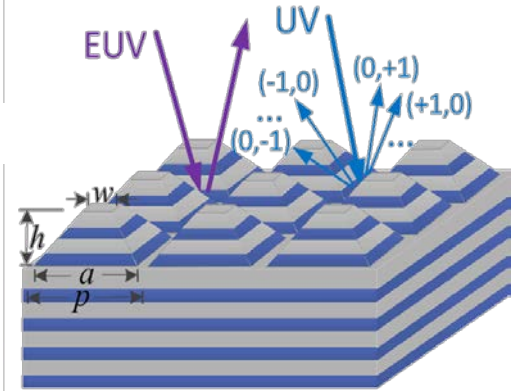
R_{EUV}=64% (MLM-68%)

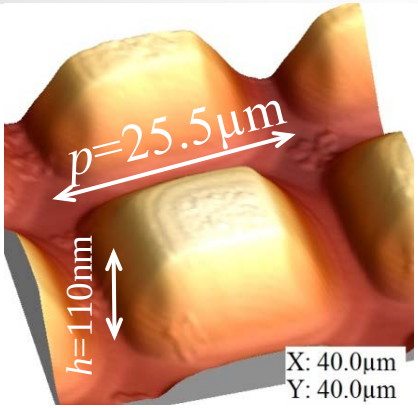


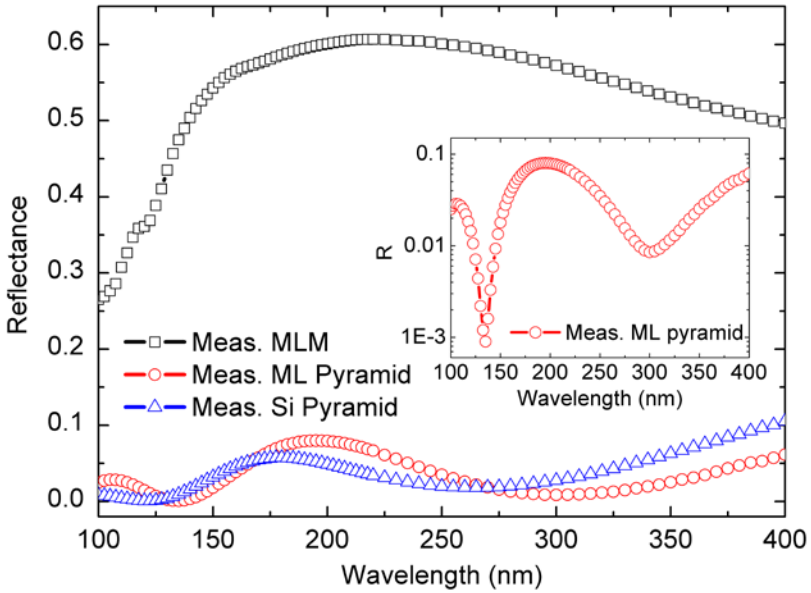
A. J. R. van den Boogaard et al, Optics Letters, 37, 2012

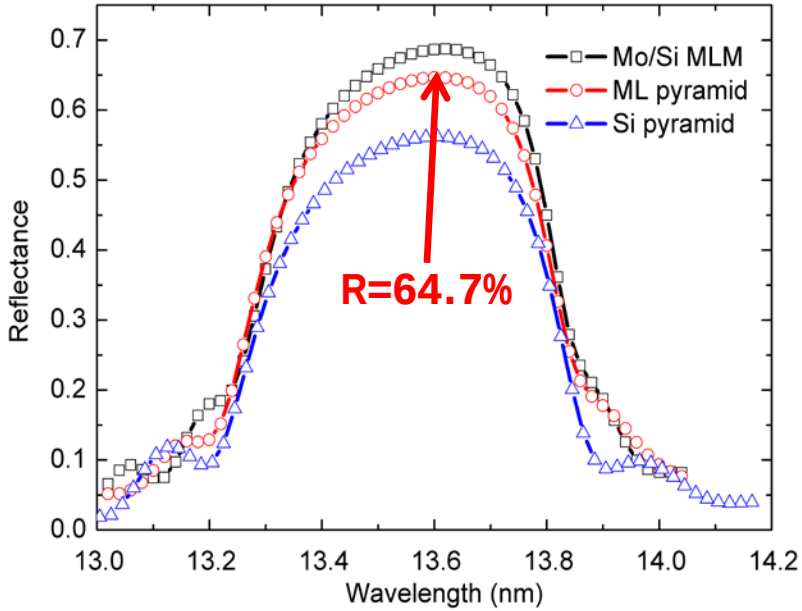
Combining diffractive and ARC











Q. Huang et al, Optics Express Vol. 22, No. 16, 2014

Summary

Multilayer based spectral purity enhancement methods

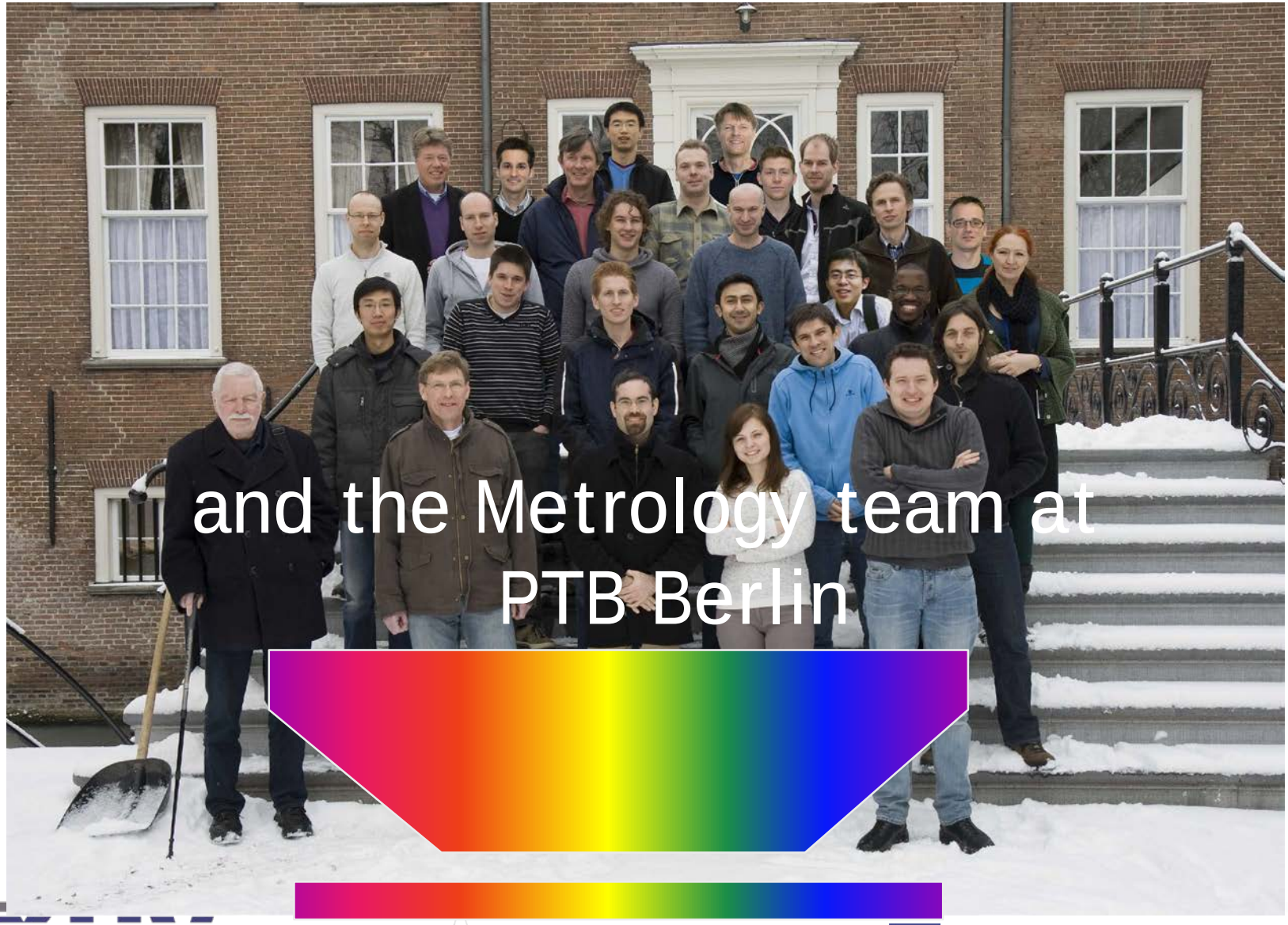
❑ Suppression of IR light

- Anti-reflection multilayer: 250 x suppression of 10.6 μm radiation, but only 45 % EUV reflectance (to be optimized)
- multilayer coated grating: 70 x suppression of 10.6 μm radiation, > 61% EUV reflectance (to be optimized)
  IR light can be refocused at the plasma position.

❑ Suppression of DUV/UV light

- Anti-reflection layer: low UV reflectance < 10 % achievable, but EUV reflectance only 50% if broadband UV suppression is required (to be optimized)
- Multilayer coated grating: strong suppression of UV reflectance obtained, but for limited λ-range. 64 % EUV reflectance
- Multilayer pyramids: broadband UV suppression (R < 10%) at 65 % EUV reflectance

Thanks to the XUV optics team



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