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INSTITUTE FOR NANOTECHNOLOGY

UNIVERSITY OF TWENTE.

FOM

UV spectral filtering by 3D structured EUV multilayers

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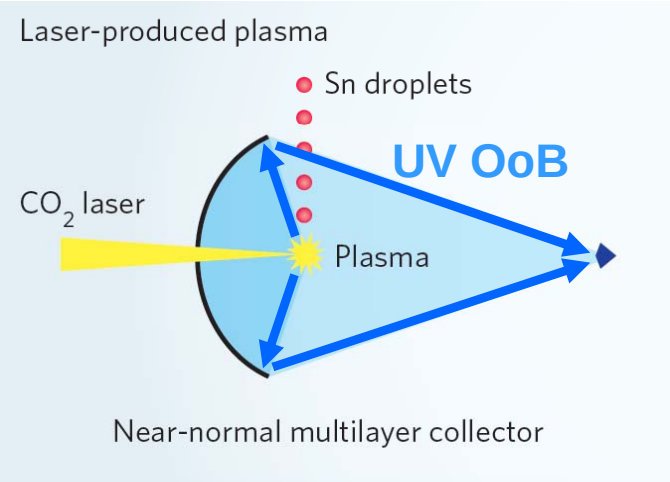
XLIV OPTICS

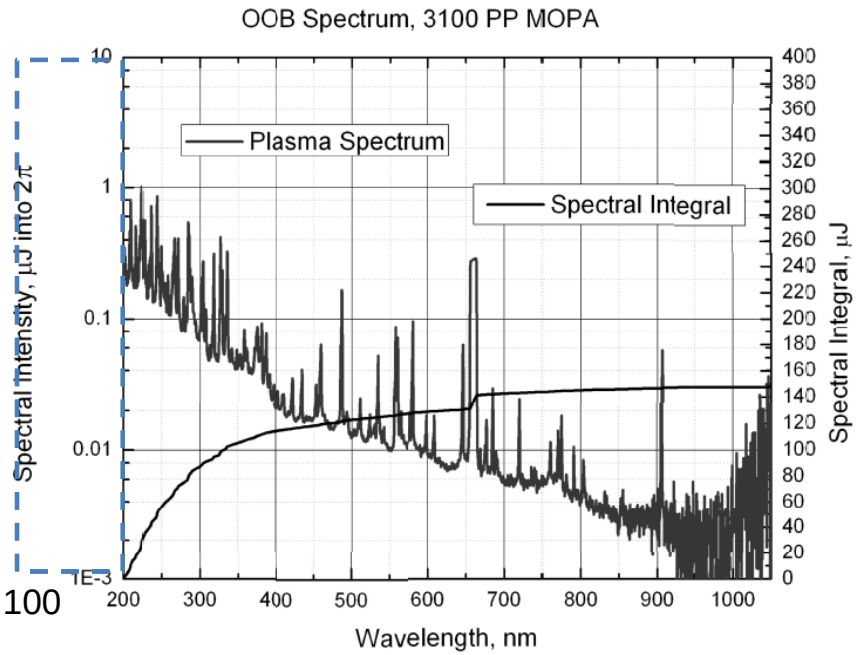
Background



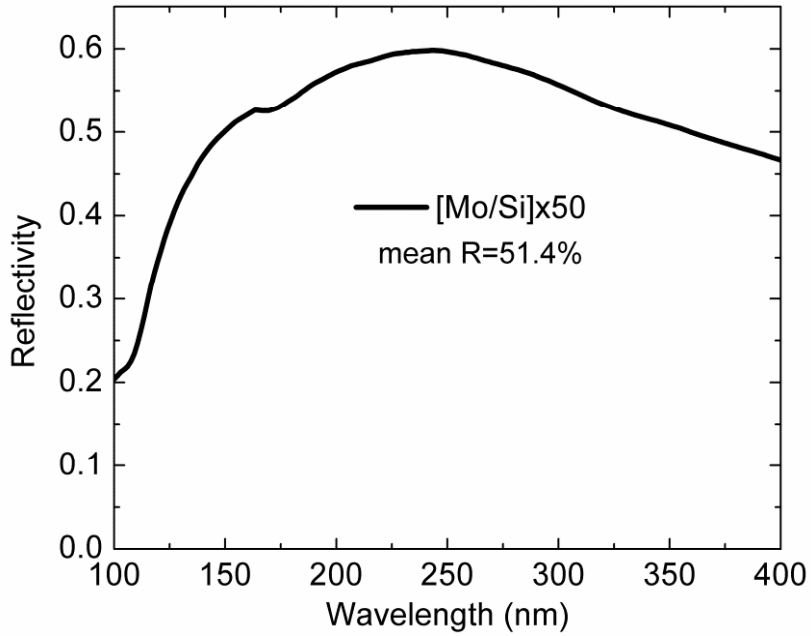
Out-of-Band UV: 100-400nm

(reflected by a single layer: Mo / Si)

Full band suppression rqd !



(Igor V. Fomenkov, Proc. of SPIE, 8679, 2013)



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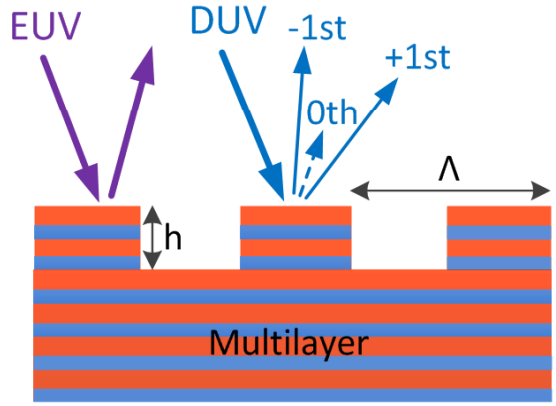
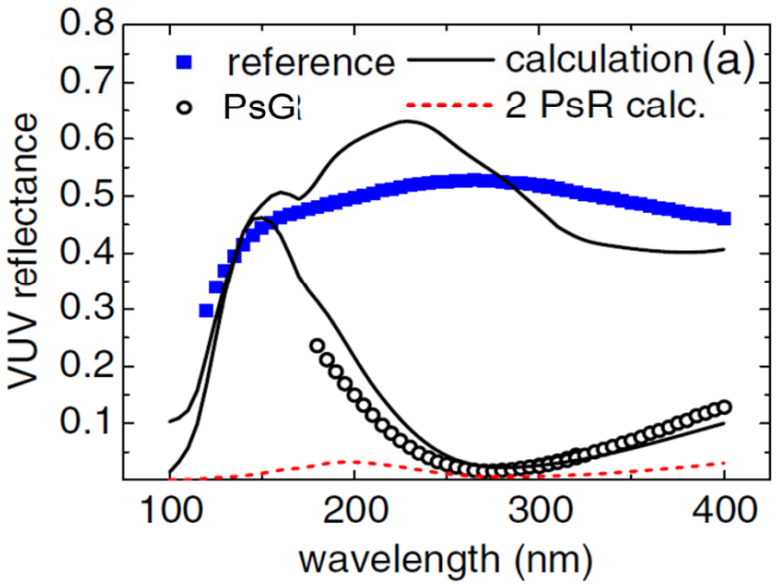
UV suppression based on ML grating

Phase shift multilayer grating

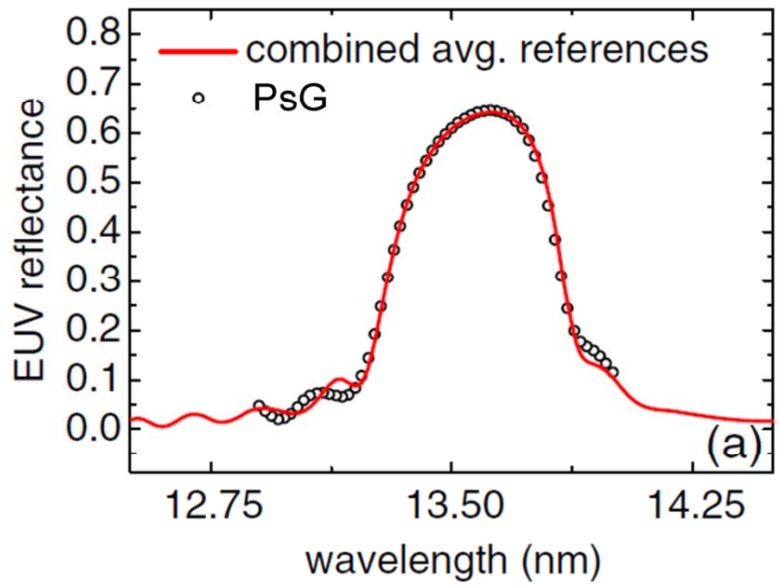
- $\Lambda >> \lambda_{EUV}$, high reflectance of EUV
- **$h = \lambda_{DUV}/4$**, destructive interference



30x Suppression (λ=280nm)



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



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

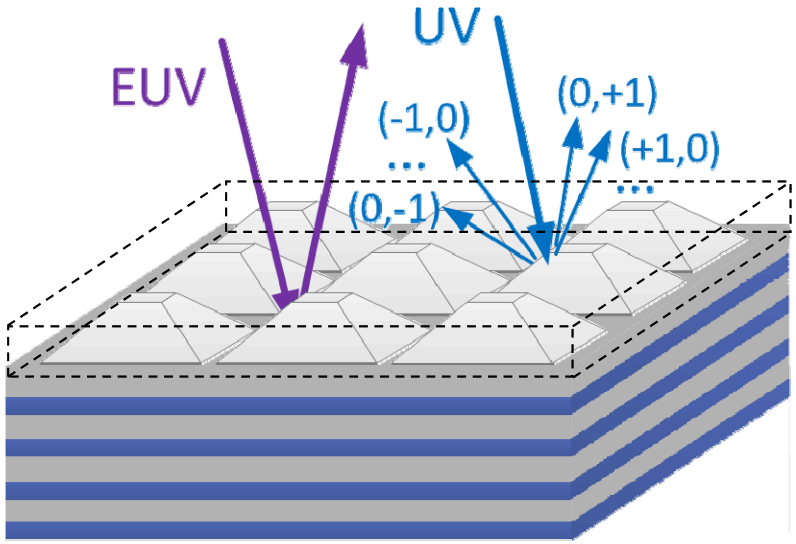
Broadband suppression – Pyramids

ML + Surface "scattering" – diffraction structure

Si pyramids (symmetric)

- reflective for DUV/UV
- "transparent" for EUV

"3D Pyramids-ML"



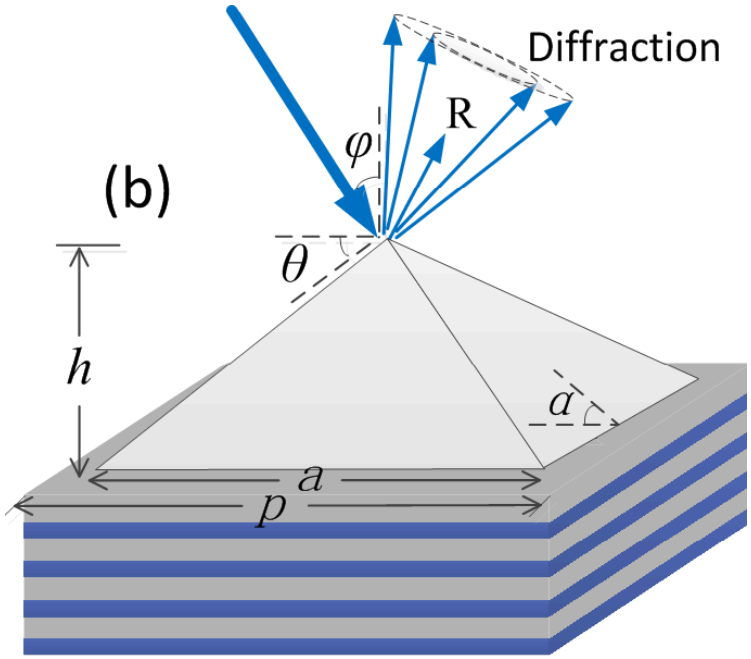
Combined suppression effects:

Blazed diffraction + interference + absorption

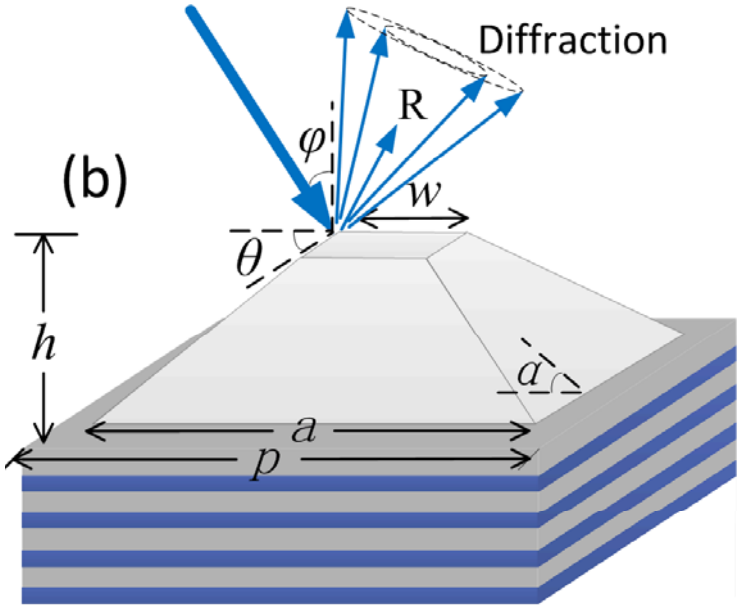
Design of 3D Si Pyramids

Structural optimization for best suppression UV & best R_{EUV}

Height h and top width w (Rigorous Coupled Wave Theory)

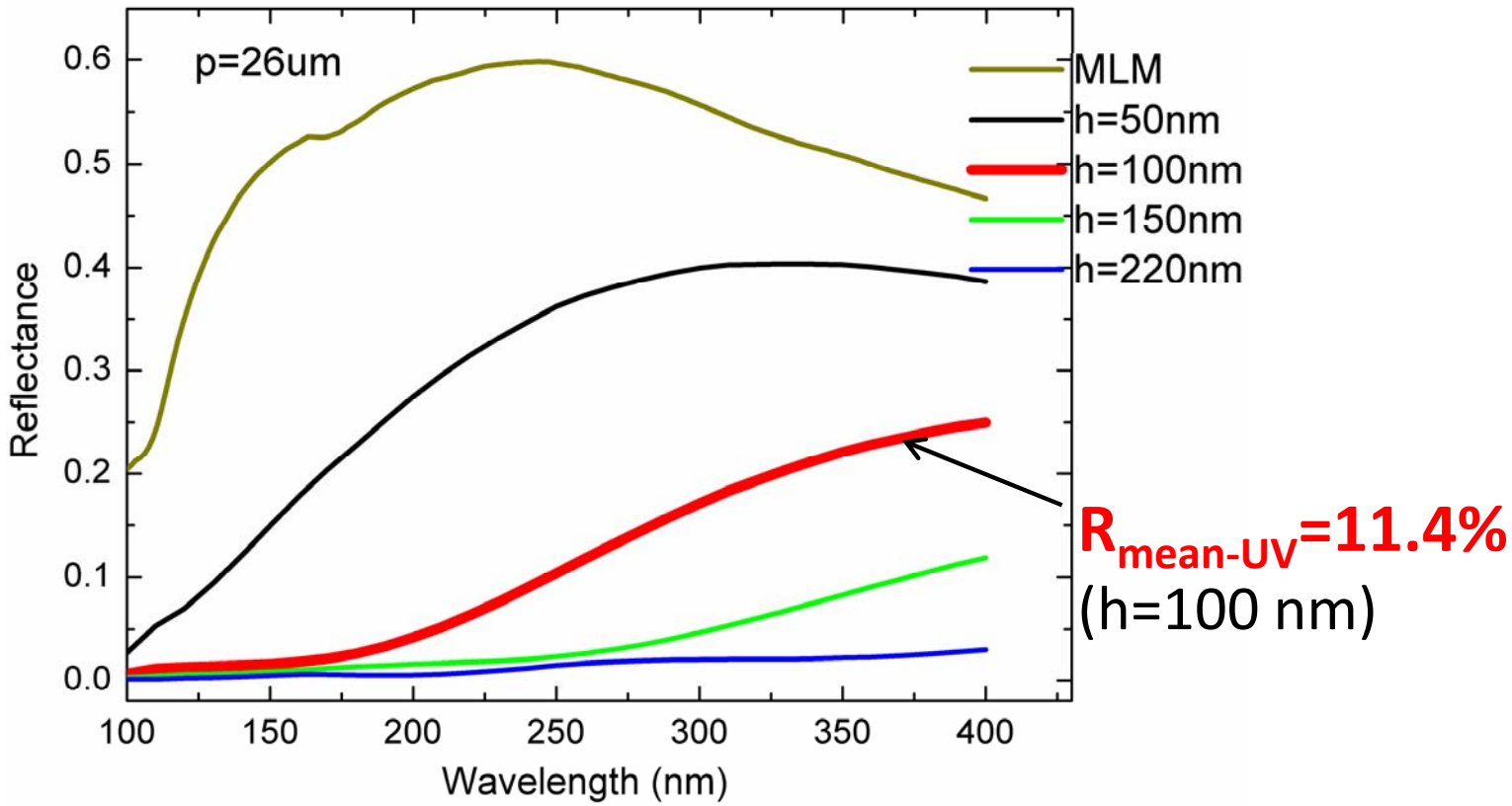


Blazed diffraction + absorption UV



Blazed diffraction + interference + absorption UV

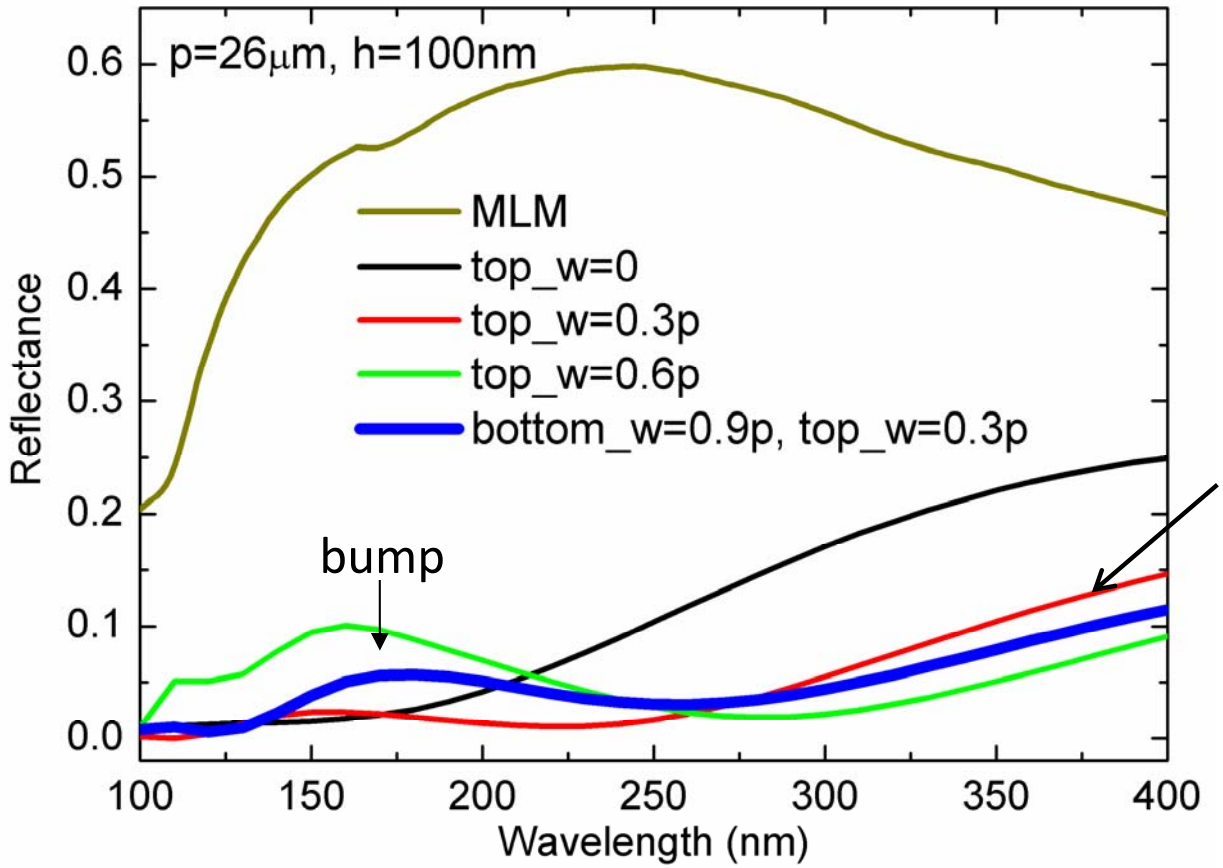
Si Pyramids – Height simulations



Increase height – better suppression

- **Larger blazed angle / more UV absorption**
  shift power to diffraction orders
- **h limited by EUV absorption**

Si Pyramids – top flat simulations

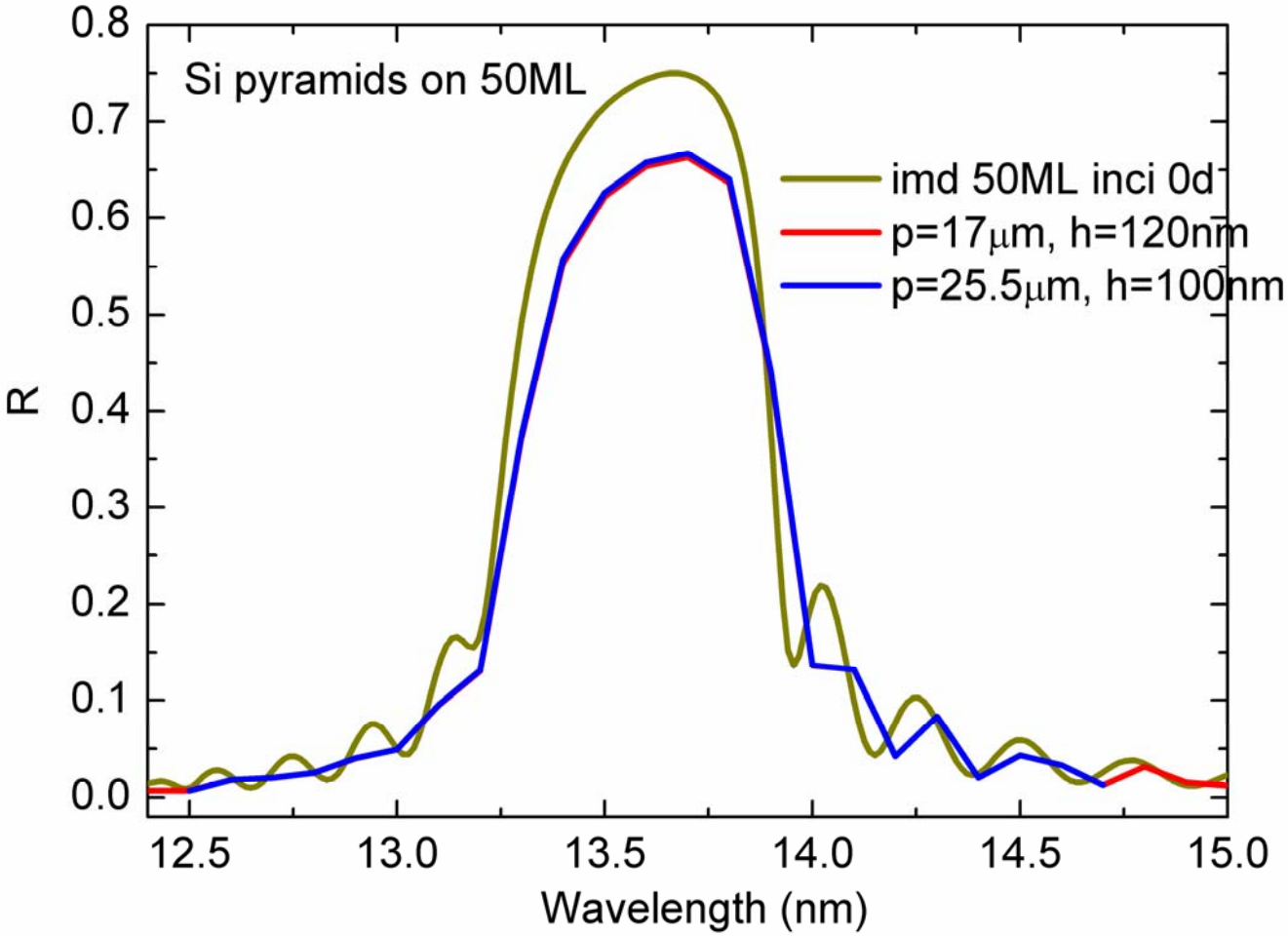


$R_{mean\text{-}UV}$=5.0%
(h=100nm, w=0.3p)

Larger top width (w) :

- Destructive interference at longer λ & constructive at shorter λ
- Suppression due to larger blazed angle

Effect on EUV Reflectance



Typical EUV reflectance loss: 9%

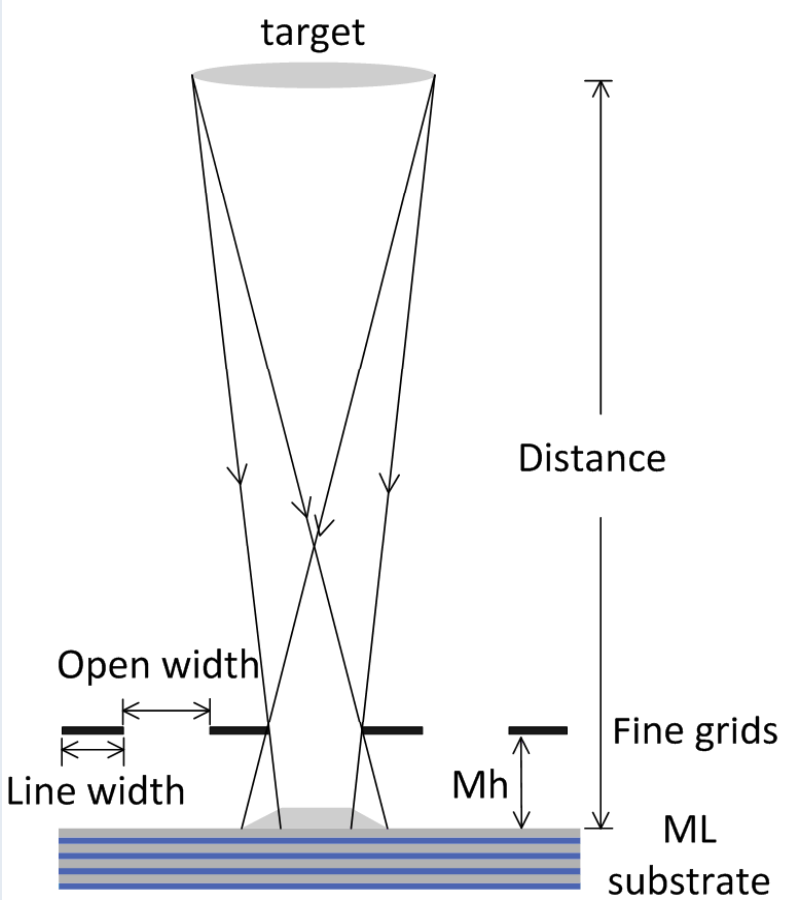
Fabrication of pyramids

Half-Shadowing Deposition Scheme

- "line-of-sight" deposition
- Shadowing from "floating" grids

↓

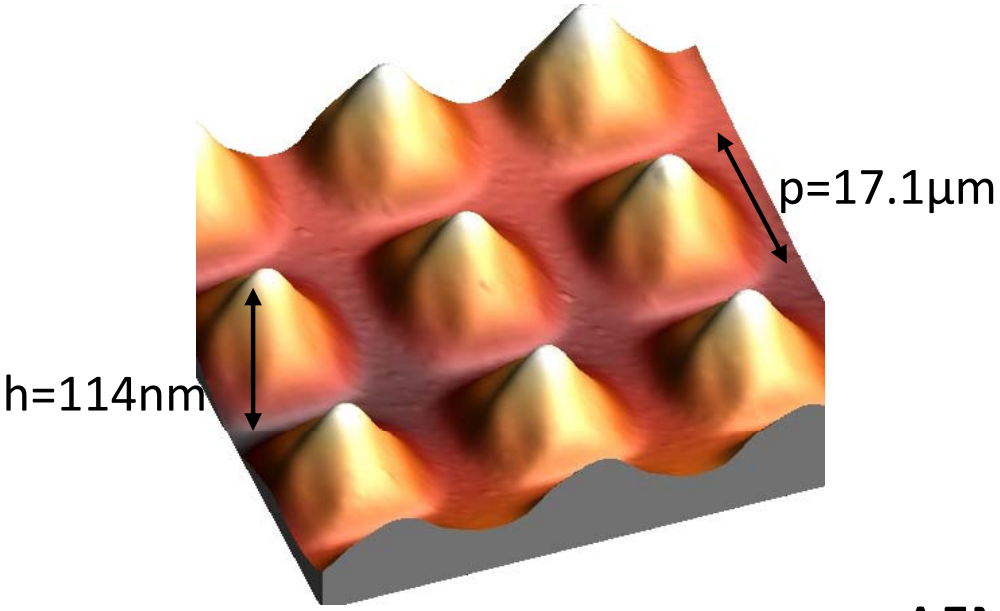
Symmetric gradient of rate

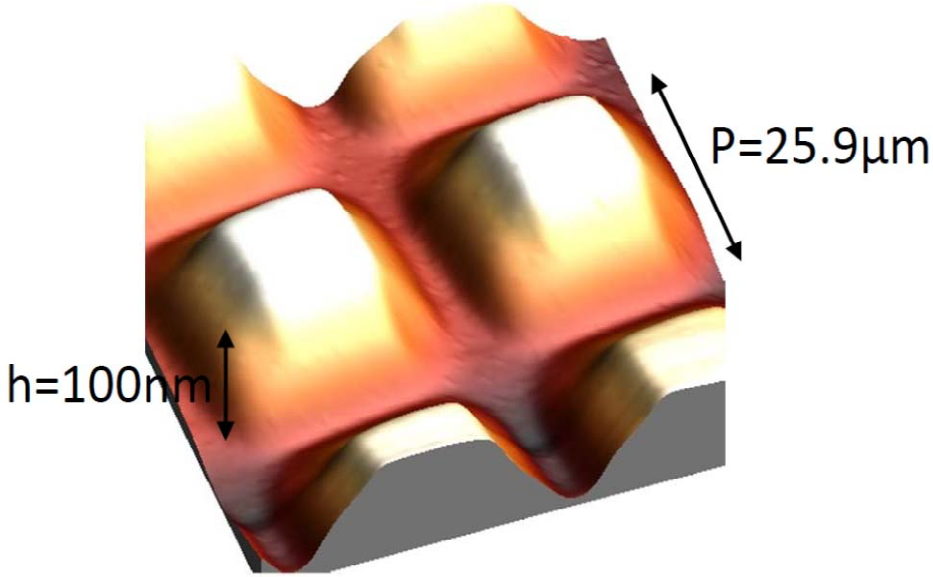


Scheme parameters:

- Target size
- Grids height
- Grids sizes: open width/line width

Atomic Force Microscopy images





AFM

Without top flat area

With top flat area

Shadowing deposition – simple surface structuring

Other microfabrication methods are possible…

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UV reflectance measurement

Measured at PTB, Berlin:

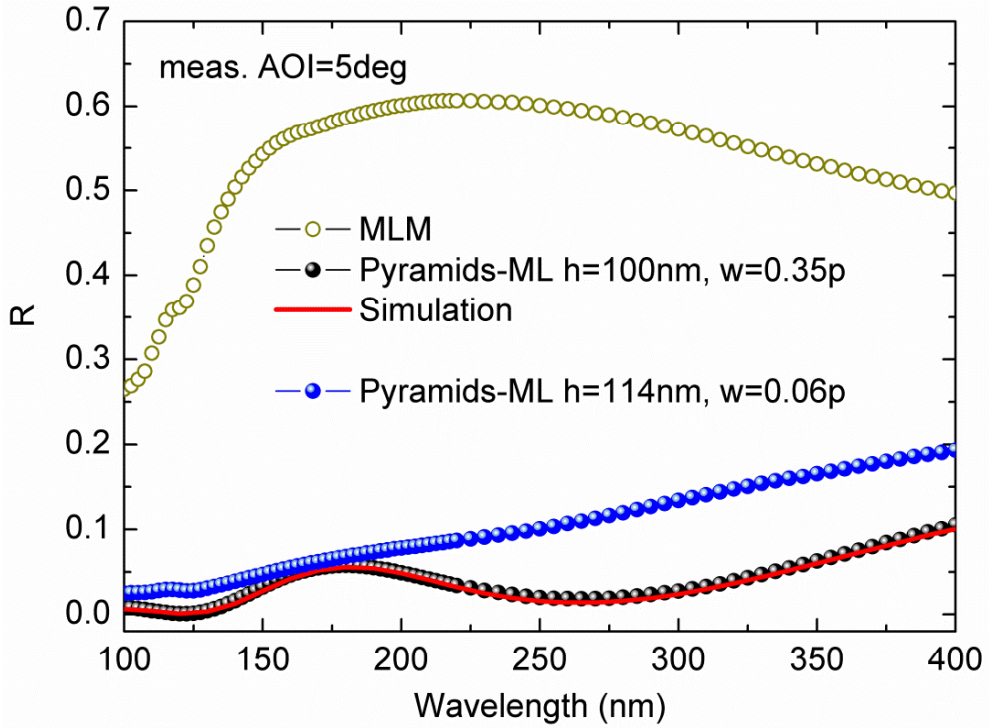
λ=100-400nm

No top flat: h=114nm

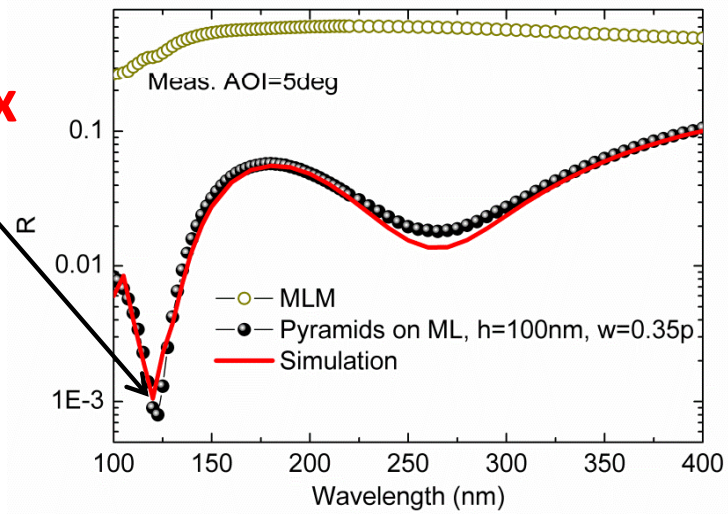
R_{UV} = 2.5%-19.3%

With top-flat: h=100 nm

R_{UV} = 0.1%-10.5%



Maximum=370x



Full band suppression of UV light, but tunable to a specific λ !

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EUV reflectance Measurement

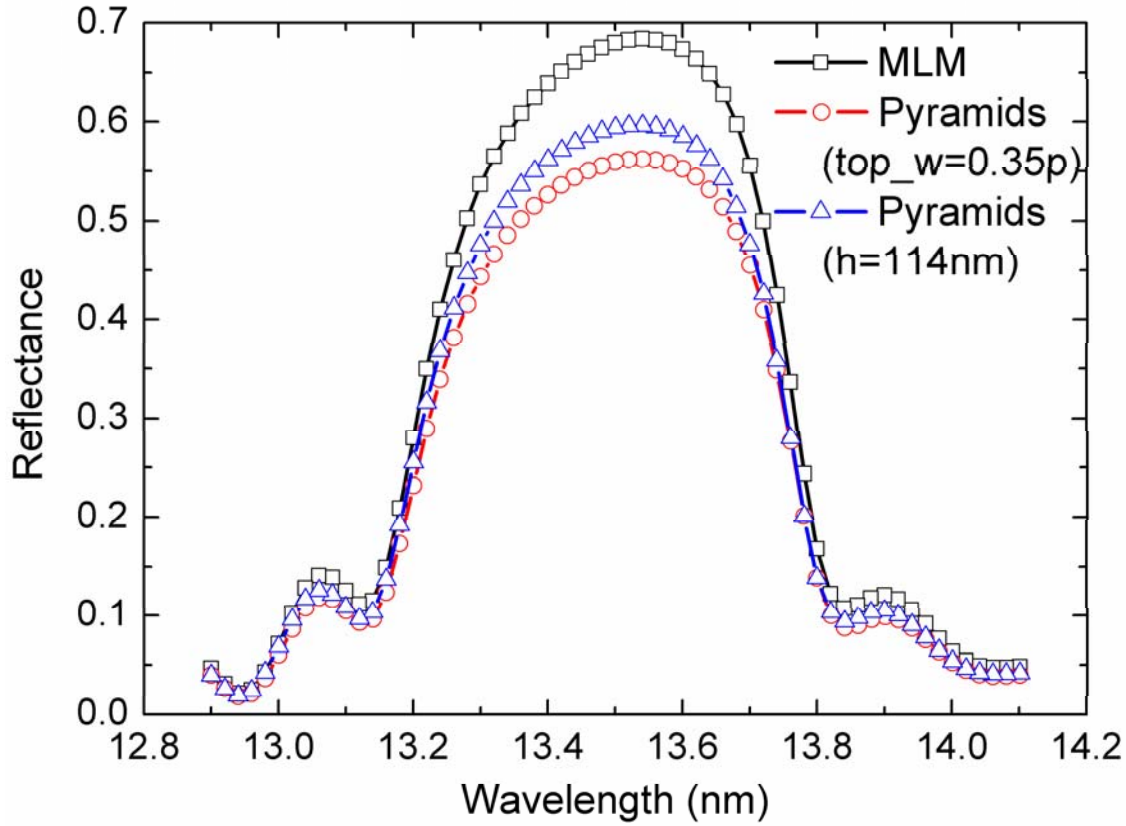
Measured at PTB, Berlin: EUV (at 1.5° off normal)

With h=114nm:
$R_{13.5nm}$ = 60.0%

With top_flat:
$R_{13.5nm}$ = 56.2%

EUV loss: 8%-12%

Reference:
no structure: R = 68.4%



→ Further optimization to balance UV suppression & EUV loss…

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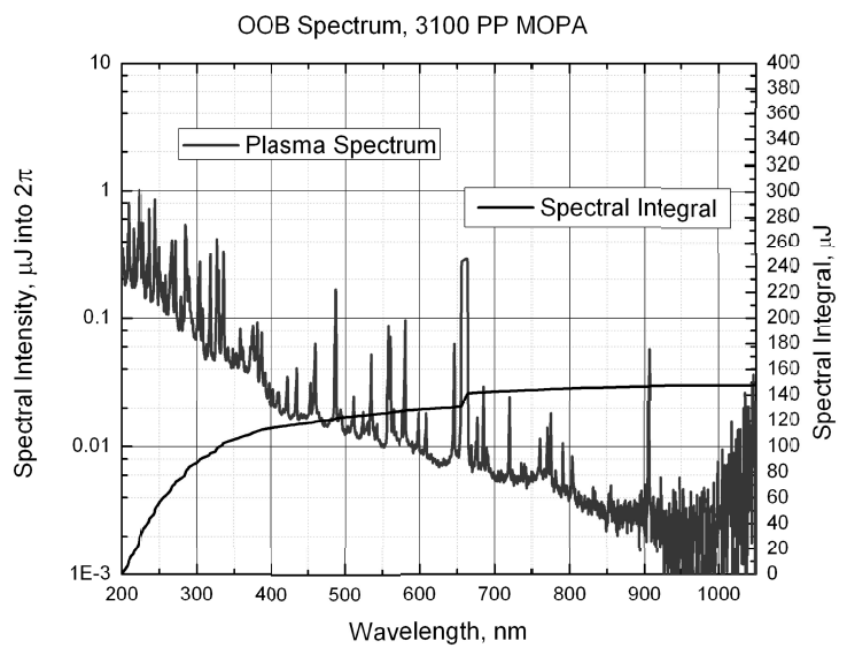
Tuning to source emission spectrum

- Considering OoB power and spectrum

Integral suppression

$$= \frac{\int I(\lambda)\cdot R_{ML}(\lambda)\cdot d\lambda}{\int I(\lambda)\cdot R_{pyra.}(\lambda)\cdot d\lambda}$$



(Igor V. Fomenkov, Proc. of SPIE, 8679, 2013)

Poster SO P63:Transmission grating spectroscopy in the EUV and VUV

Less UV suppression, more EUV remains!

Applicable for different methods!

Summary

→ **UV OoB suppression for EUV sources**

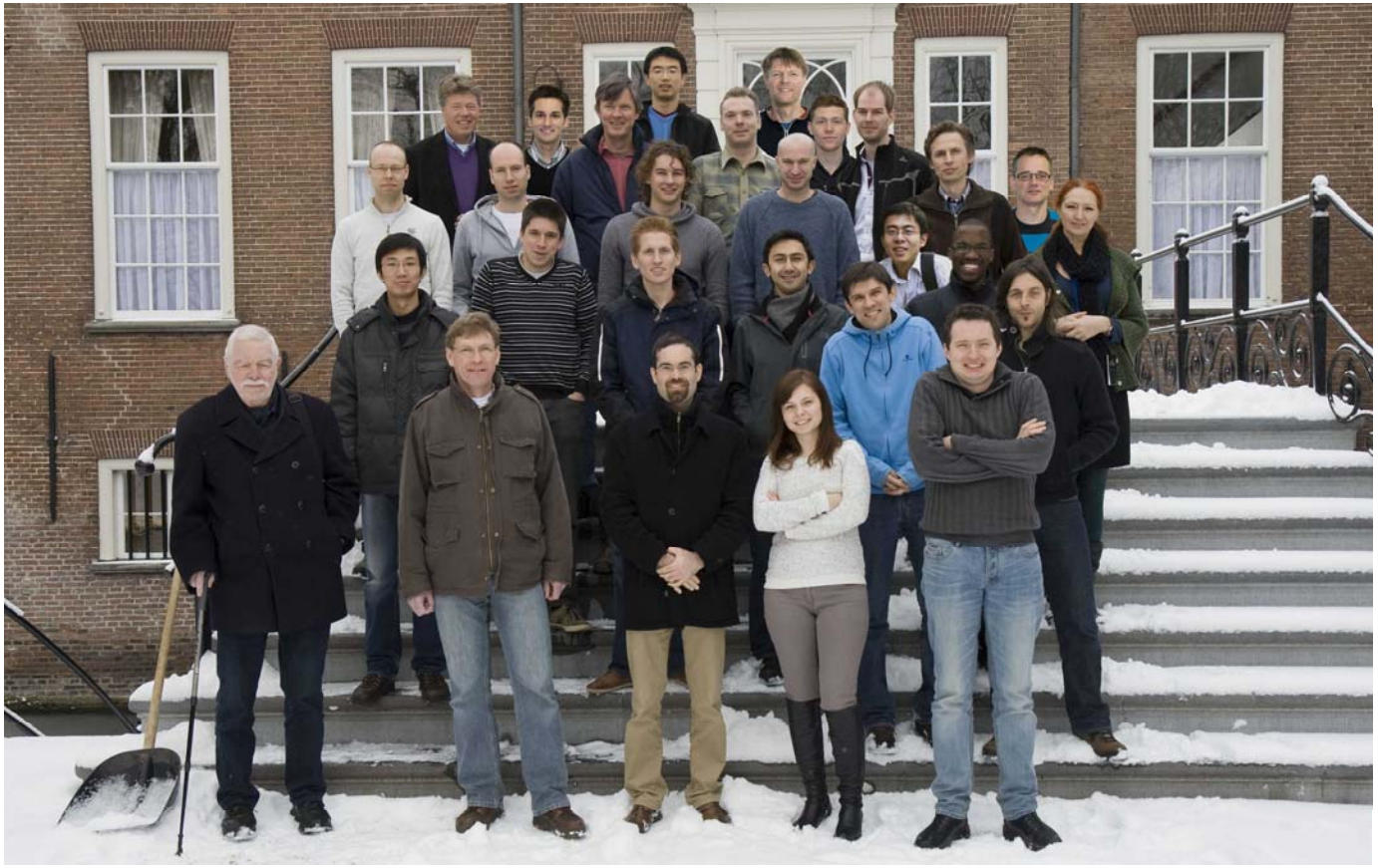
❑ Phase-shift multilayer grating

- **UV suppression, optimized for a specific λ (30x suppression at 280 nm), broad minimum, but no full band suppression.**
- **EUV loss 4 %**

❑ *3D Si Diffraction Pyramids*

- **Full band UV suppression to < 10% reflectance**
  → with top flat tunable to specific λ (370 x suppression)
- **EUV loss 8 -12 %**

Acknowledgements



And the team at PTB Berlin for reflectometry