UNIVERSITY OF TWENTE.

LPNO Laser Physics and Nonlinear Optics

XUV OPTICS

# Translating the Borrmann effect into narrow-band EUV transmission windows

MESA+ INSTITUTE FOR NANOTECHNOLOGY

J.L.P. Barreaux[1,*], H.M.J. Bastiaens[1], I. Kozhevnikov[3], F. Bijkerk[2] and K.-J. Boller[1]

[1]Laser Physics and Nonlinear Optics, MESA+ Institute for Nanotechnology, University of Twente, The Netherlands

[2]XUV Optics, MESA+ Institute for Nanotechnology, University of Twente, The Netherlands

[3]Institute of Crystallography, Russian Academy of Sciences, Leninsky Prospect 59, Moscow 119333, Russia

*j.l.p.barreaux@utwente.nl

nanonextnl innovating with micro and nanotechnology

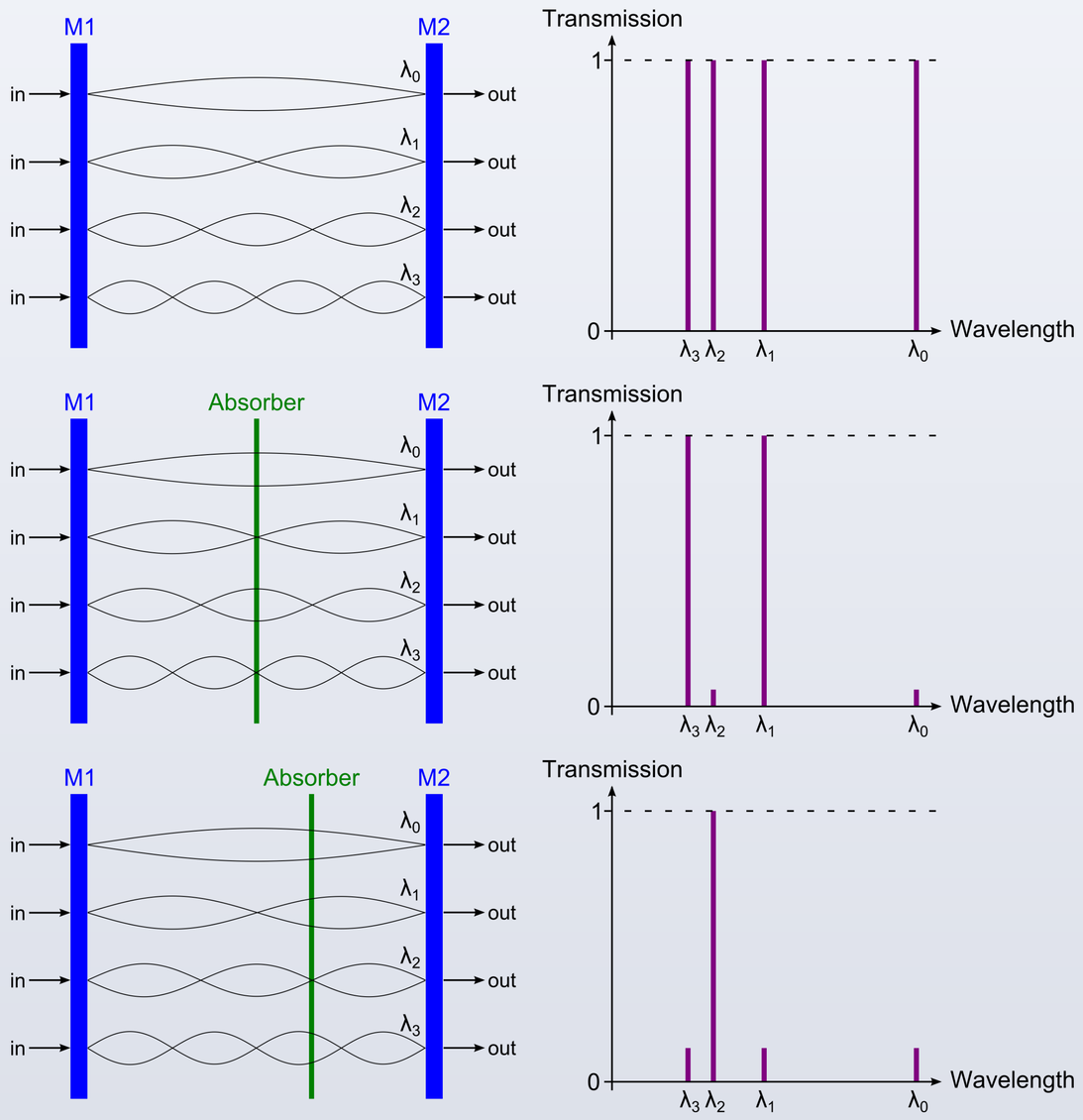
## Introduction

- EUV spectrum generated by Laser-Produced Plasma (LPP) are complex:
  - depends strongly on the excitation conditions
  - depends critically on surface contamination of optics
- EUV Lithography needs monitoring of in-band radiation power (13.5 nm)
- Need for a method to monitor easily the radiation power at a selected λ
  - In transmission
  - At normal incidence
  - Wavelength tunable
  - Narrow bandwidth
- Presentation of a method using the Borrmann effect in multilayer optics

## Borrmann effect in EUV multilayer optics

**How to make a broadband absorber spectrally selective?**

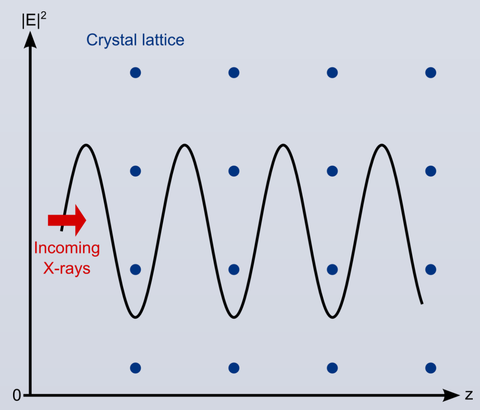
- By placing it in a spectrally selective environment!
- Consider a simple resonator:




- This is the essence of the Borrmann effect!

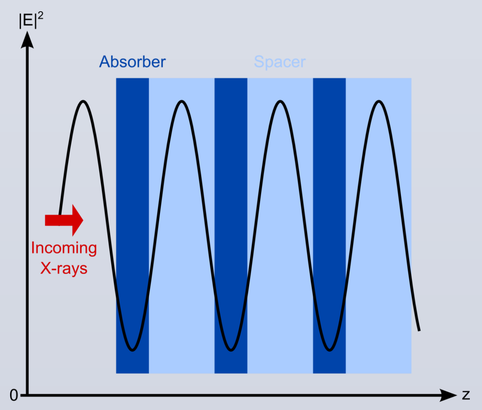
### Borrmann effect

- In a crystal [1,2]:




- Matching of the standing electric field minima with the crystal lattices
- Spectrally selective increase in X-ray transmission

- In a multilayer stack [3]:

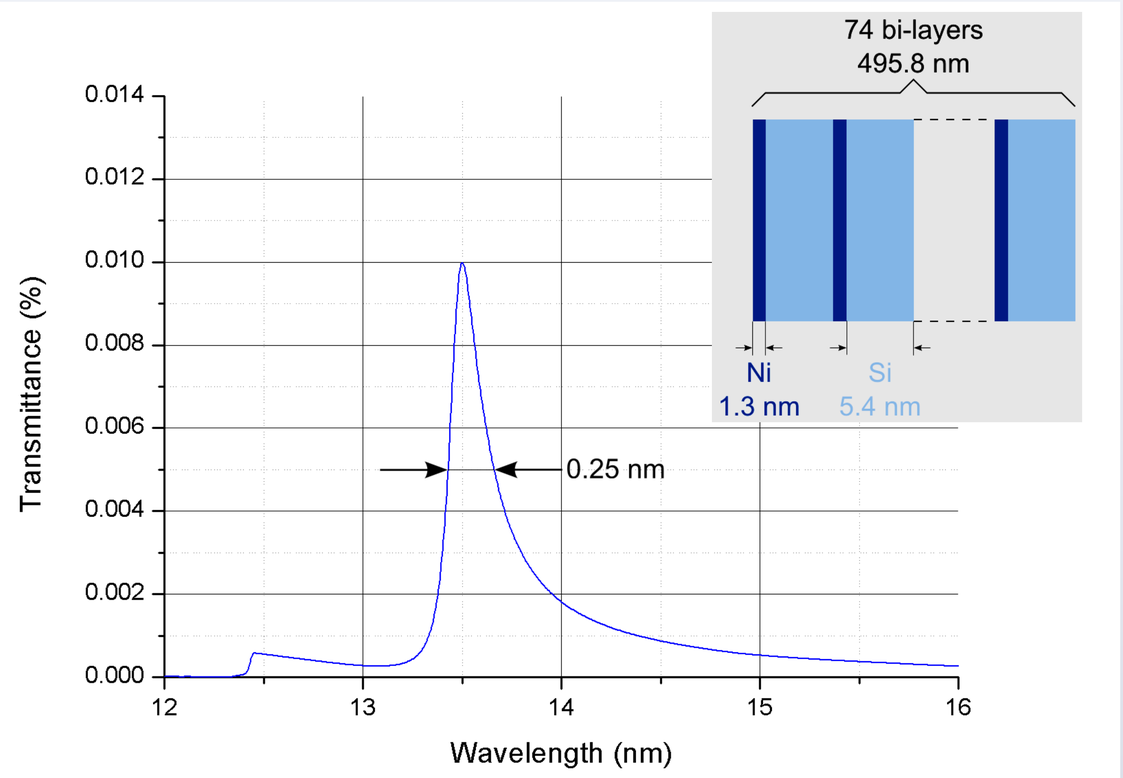



- Matching of the standing electric field minima with the thin absorbing layers
- Resonant enhancement of the transmittance for a narrow bandwidth

## Calculated transmission spectra

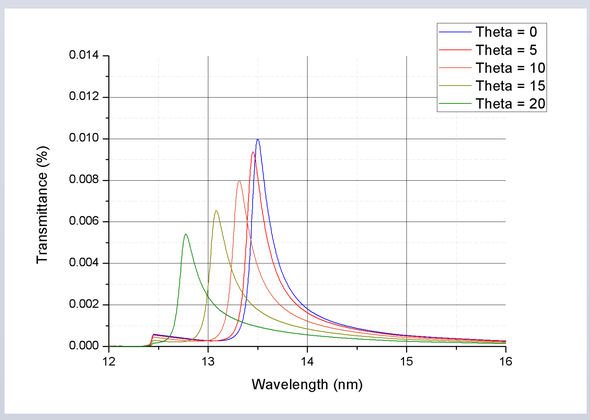
**Filter centered at 13.5 nm (Ni/Si)**

- 0.25 nm bandwidth achieved with 1% transmission

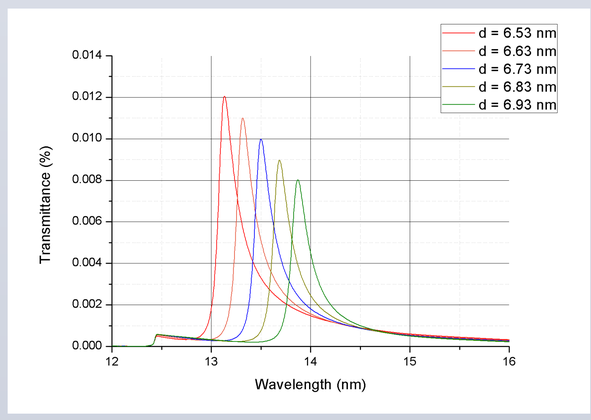



### Wavelength tunability

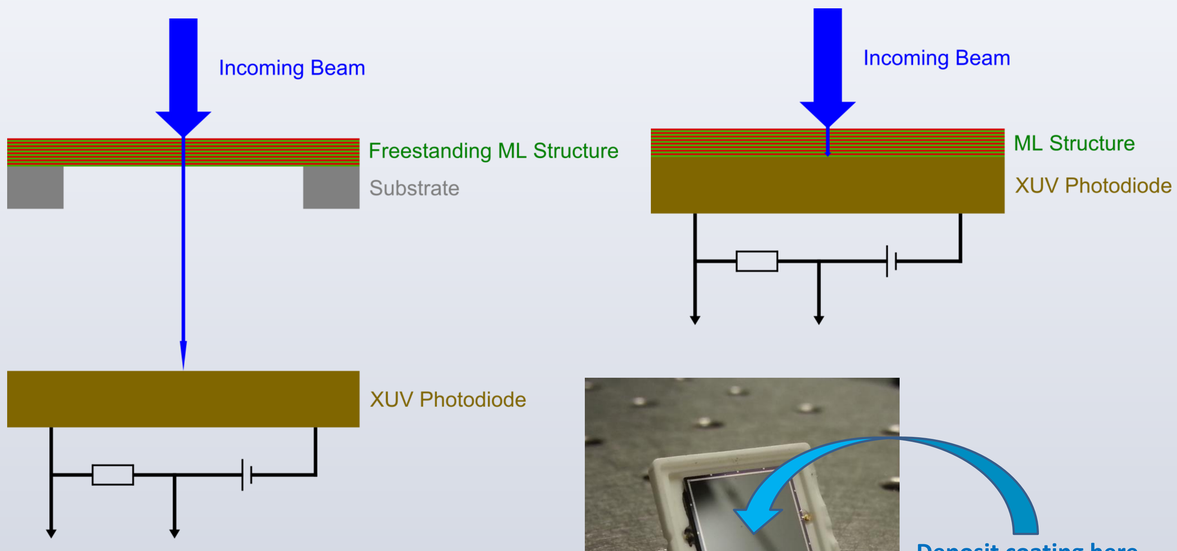
- Changing the angle of incidence:




- Changing the bi-layer thickness:




## Technical realization [4,5]




## Summary

- ✓ We present an application of the Borrmann effect in multilayer optics
- ✓ We present first calculations for XUV filters with very high resolution
- ✓ Process of deposition on the photodiode needs to be developed

[1] G. Borrmann, "Die Absorption von Röntgenstrahlen im Fall der Interferenz", *Z. Phys.*, vol. **127**, no. 4, pp. 297-323 (1950)

[2] M. von Laue, "Die Absorption der Röntgenstrahlen in Kristallen im Interferenzfall", *Acta Cryst.*, vol. **2**, pp. 106-113 (1949)

[3] I. Kozhevnikov et al., "Effect of anomalous transmittance in EUV multilayer optics," *Opt. Commun.*, vol. **281**, pp. 3025-3031 (2008)

[4] B. Kjornrattanawanich et al., "Mo/B4C/Si multilayer-coated photodiode with polarization sensitivity at an extreme-ultraviolet wavelength of 13.5 nm", *Appl. Opt.*, vol. **43**, no. 5, pp. 1082-1090 (2004)

[5] P.N. Aruev et al., "Silicon photodiode with selective Zr/Si coating for extreme ultraviolet spectral range", *Quantum Electron.*, vol. **42**, no. 10, pp. 943-948 (2012)