# Calibrated broadband spectroscopy using transmission gratings in the EUV to DUV wavelengths

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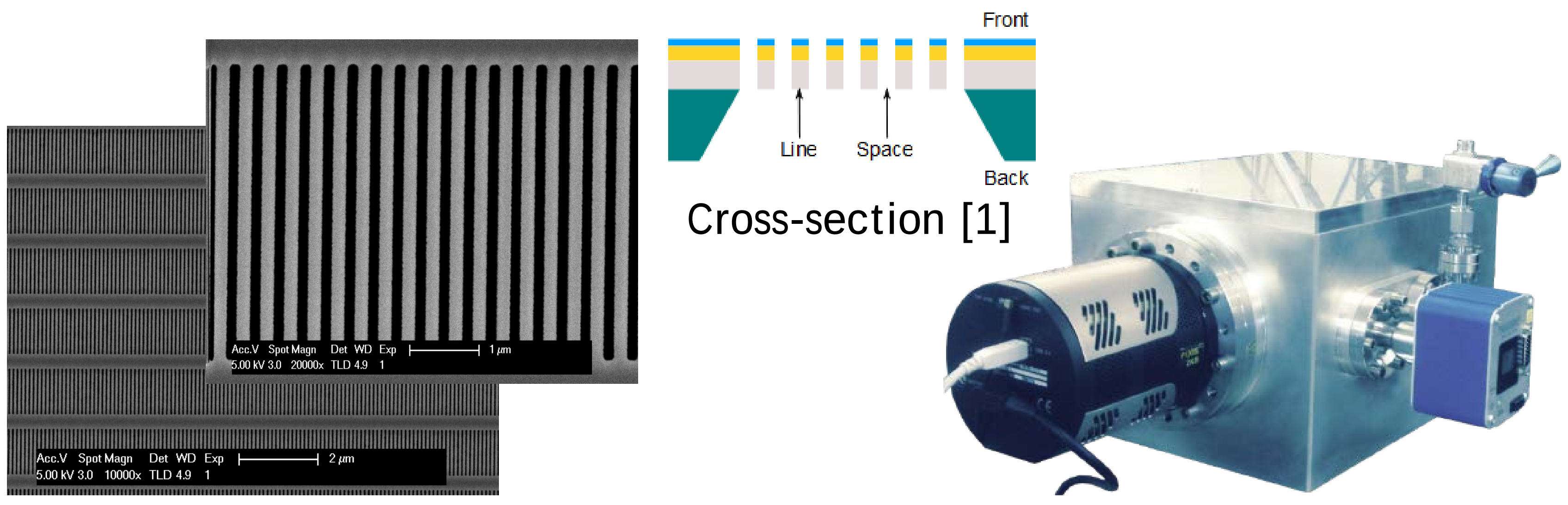
## Motivation

- EUVL source plasma emission spectrum is relevant for scanner performance
  - In-band EUV range (13.5 nm ±1%) is needed for ensuring optimal plasma emission and it influences imaging performance via coating angular and spectral dependencies
  - DUV range (130-400 nm) can cause parasitic heating of optical components and contrast loss in photoresist patterning
- Spectral characterization using transmission spectrometer was shown to provide insight about the mentioned aspects
- The spectrometer can be calibrated for accurate measurements

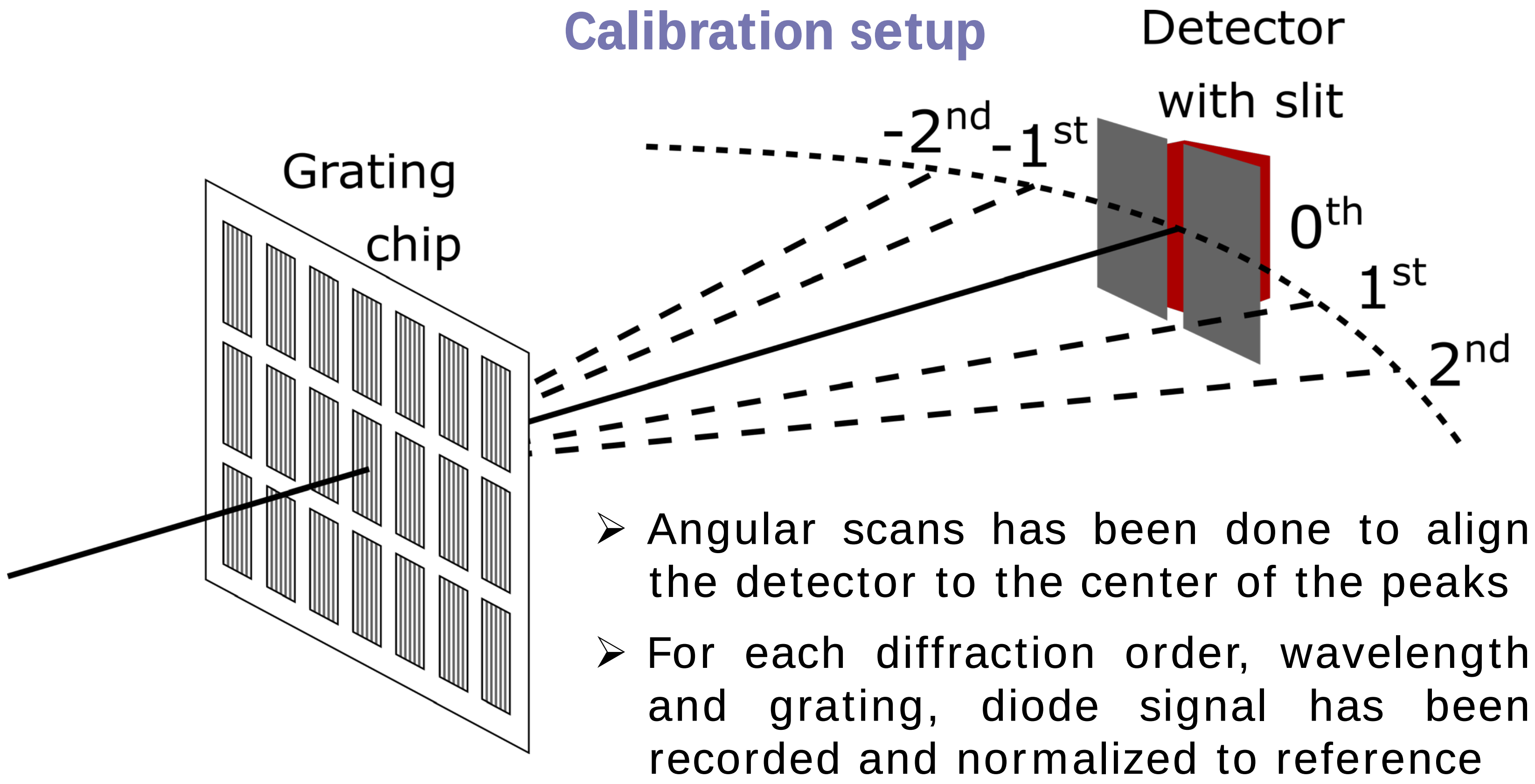
## Compact High-Resolution Spectrometer for VIS, DUV, EUV

- Grating matrix with free-standing transmission gratings
  - Lines densities from 500 lines/mm up to 10.000 lines/mm
- Diffraction efficiency in the first order ≈ 10%
- Flat diffraction efficiency curve from 10 nm to 100 nm
- Reproducible fabrication of gratings by proprietary NIL process

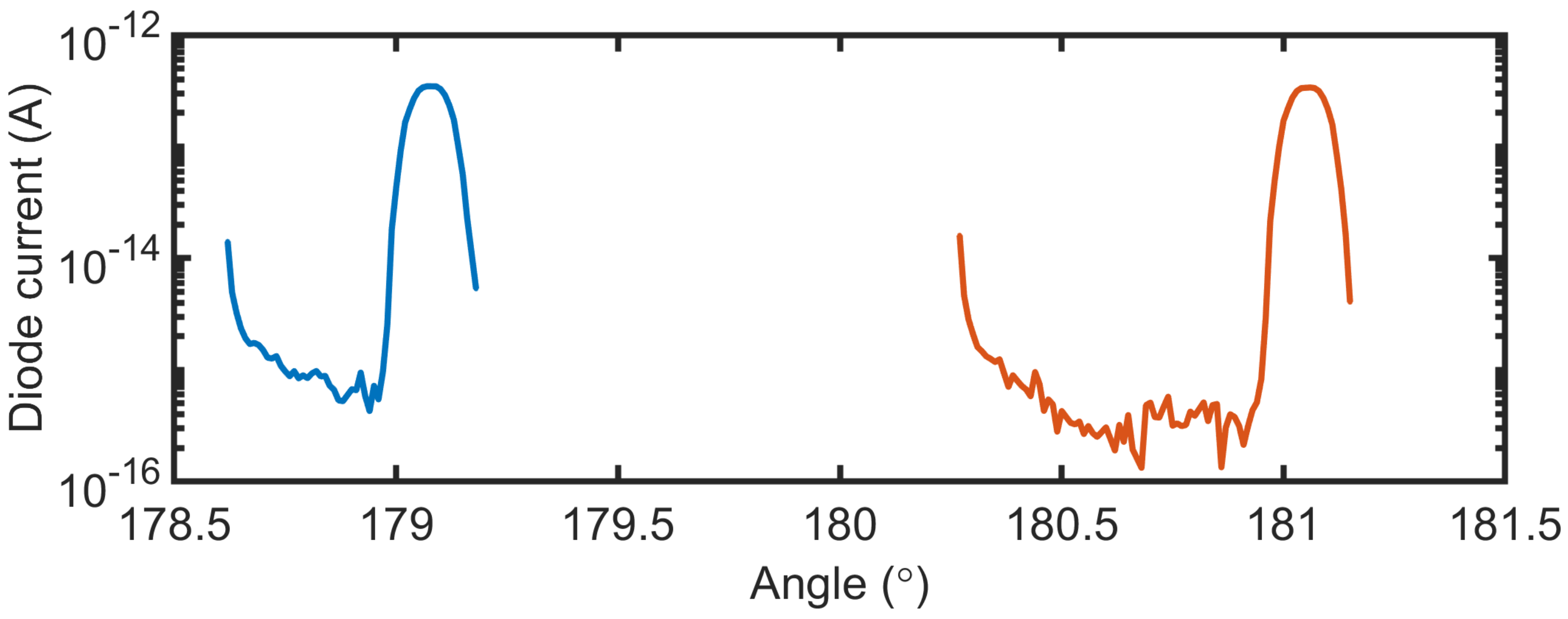


- High spectral resolution: 0.1 nm at 13.5 nm wavelength [2]
- Broad spectral coverage: 5 to 800 nm
- Fast switching between high resolution or wide spectrum
- Flat-field spectrum and higher order suppression by filters
- Easy alignment:
  - Computer-controlled positioning of components
  - GUI to control the optics and record/process spectrum

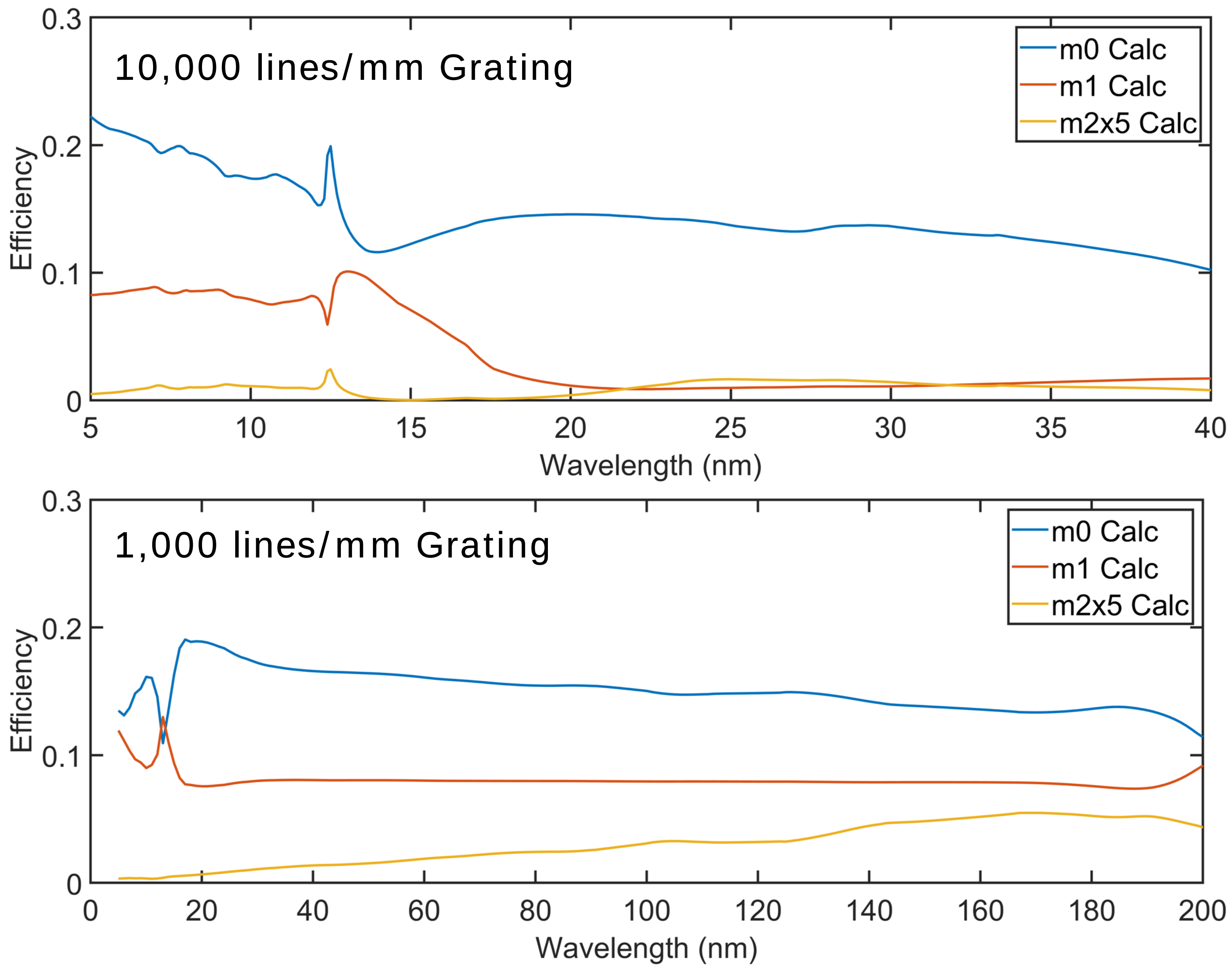
## Calibration setup



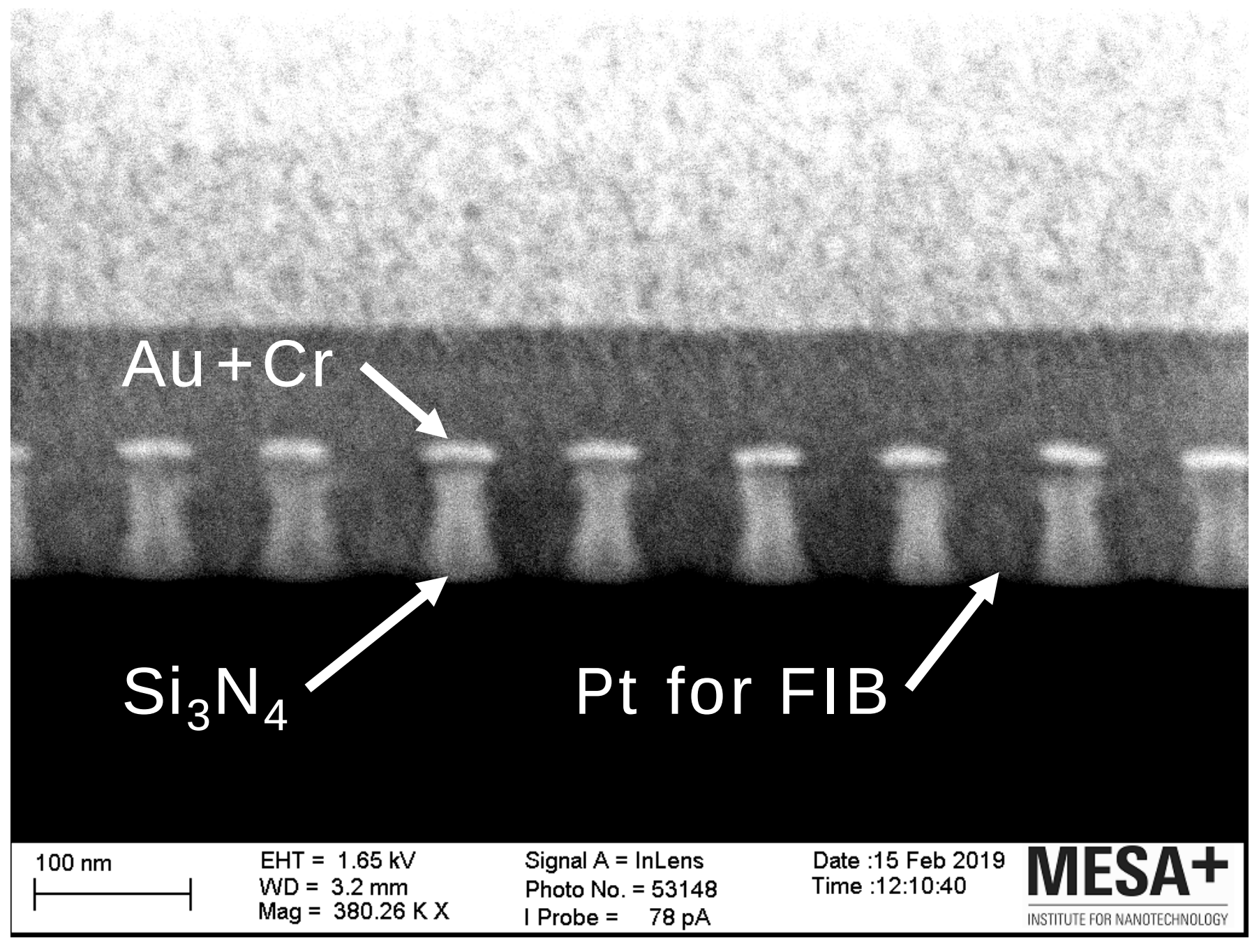
- Angular scans has been done to align the detector to the center of the peaks
- For each diffraction order, wavelength and grating, diode signal has been recorded and normalized to reference

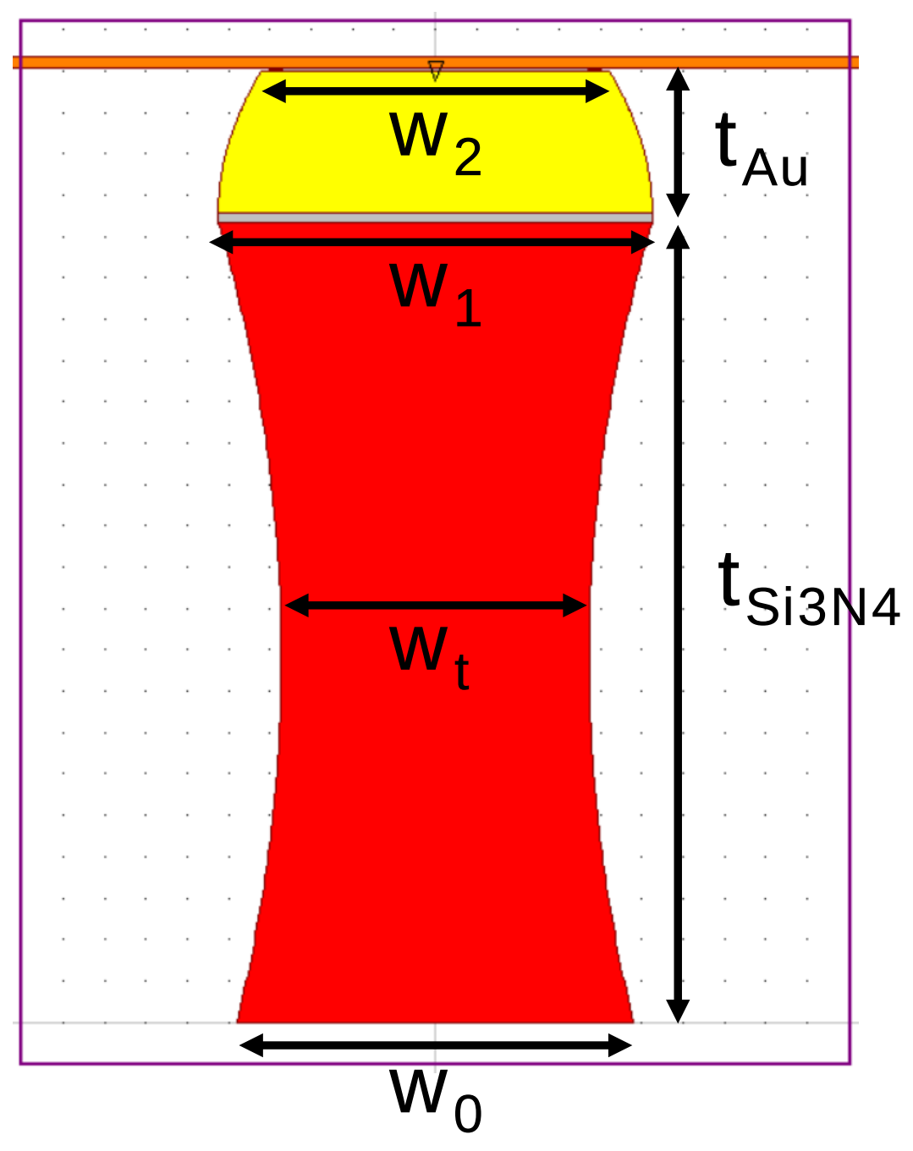


## Calculation results



## Grating Structure and Model





- SEM images reveal that the structure has strong periodicity
- Cross-sectional images show that the 10.000 lines/mm grating has tapering in the $Si_3N_4$ layer
- The grating has been modeled by taking into account the cross-section of the gratings

| | $t_{Si3N4}$ (nm) | $t_{Au}$ + $t_{Cr}$ (nm) | $w_0$ (nm) | $w_t$ (nm) | $w_1$ (nm) | $w_2$ (nm) |
|---|---|---|---|---|---|---|
| SEM (μ) | 193.5 | 36.63 | 47.96 | 37.33 | 52.48 | |
| SEM (σ) | 8.30 | 4.79 | 4.21 | 6.27 | 6.99 | |
| Model | 196.9 | 21.28+4 | 48.98 | 19.42 | 72.53 | 78.88 |

- Thicknesses from SEM and model closely match, whereas widths shown variations that can be due to edge roughness

## Conclusions and outlook

- Developed spectrometer was shown to measure EUV, DUV and VIS spectra at nominal operation conditions of EUVL sources
- The spectrometer can be straightforwardly calibrated using synchrotron sources such as in PTB in broad wavelength range
- Benefitting from SEM cross-sectional images, calibration data can be closely fitted with RCWA modeling
- Plans: Including edge roughness for a better match in widths

  Modeling 1.000 lines/mm grating for calculating the polarization dependence of the diffraction efficiencies

[1] M. Bayraktar, et.al. *NEVAC Blad*, vol. **54**, no. 1, pp. 14-19 (2016).
[2] S.J. Goh, et.al. *Opt. Express.*, vol. **23**, no. 4, pp. 4421-4434 (2015).
[3] I. Fomenkov, *EUV Source Workshop*, Dublin, Ireland (2017).

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