

Motivation

Simple method for determining number of layers of 2D materials

- Optical methods: non-destructive, fast, and large-area capable
- Common approach: measurement of contrast between substrate and 2D material

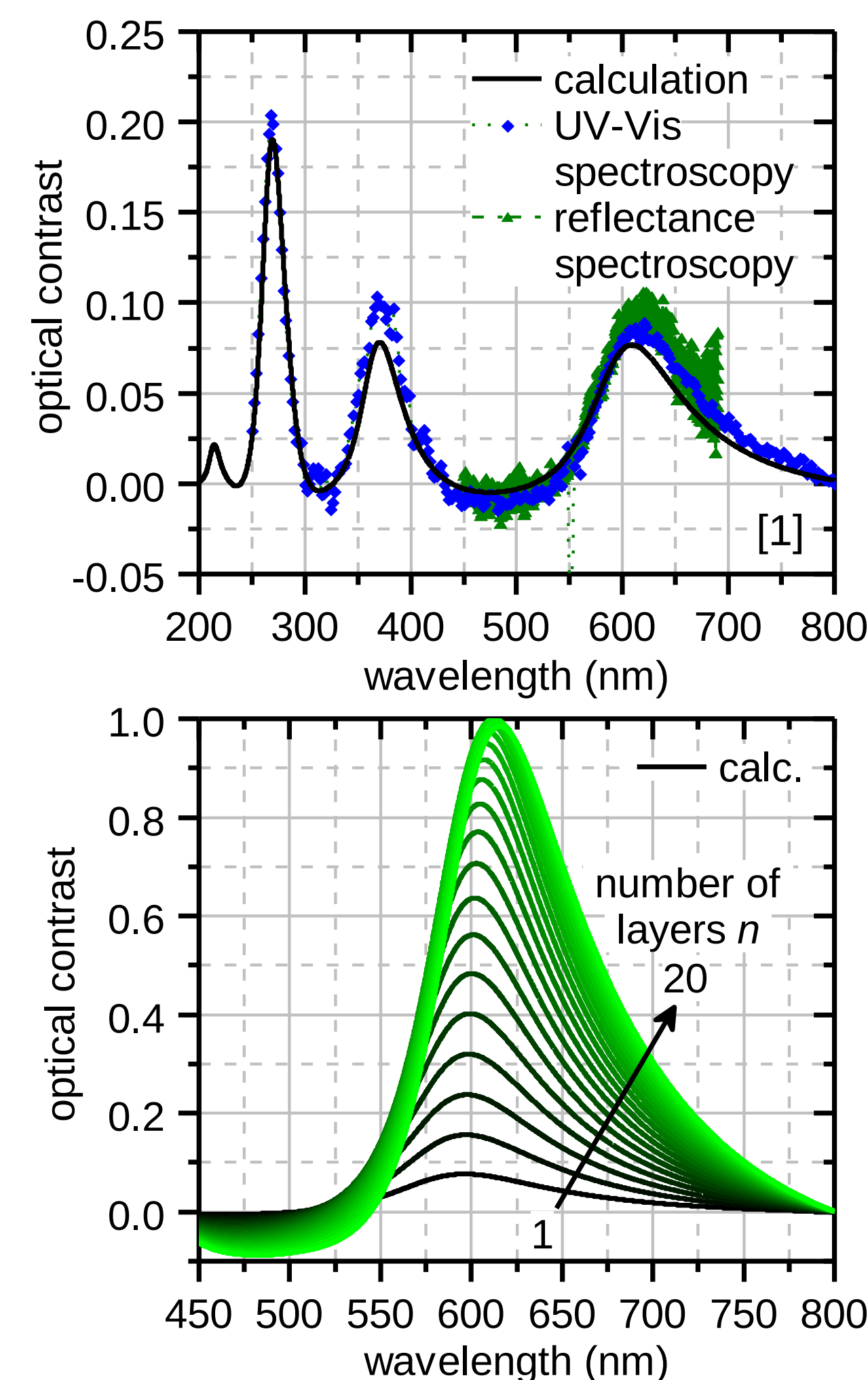
Contrast-based method for detection of 2D materials

- Optimized layer stack → high contrast between substrate and 2D material
- Standard solution: 300 nm SiO₂ on Si

Challenges

- Low contrast: < 10% within the visible spectral range for SL-graphene
- Layer stack optimized for characterizing 2D materials only but not for applications
- Contrast increases nonlinearly with n → data evaluation not straightforward
- Reference spectrum needed → relative measurement

[1] Hutzler et al., *Appl. Phys. Lett.* **110** (2017)



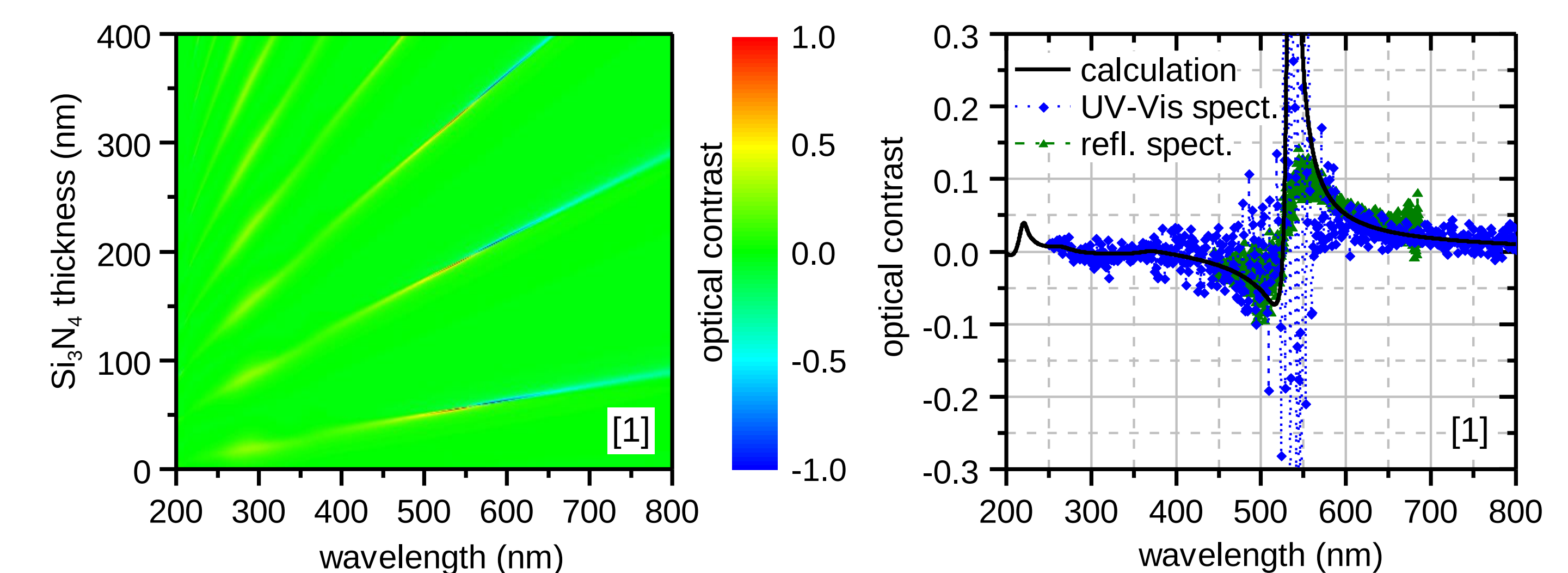
Methodology

Calculation based on the transfer-matrix method (TMM)

- Complex refractive indices → increases accuracy of the calculation
- Advanced optical layer stacks with more than one layer → Additional layers can significantly enhance obtainable contrasts

Measurement: reflectance spectroscopy (450 nm – 690 nm)

- Optical profiler Zeta 300 (*Zeta Instruments*)
- Automatic mapping possible



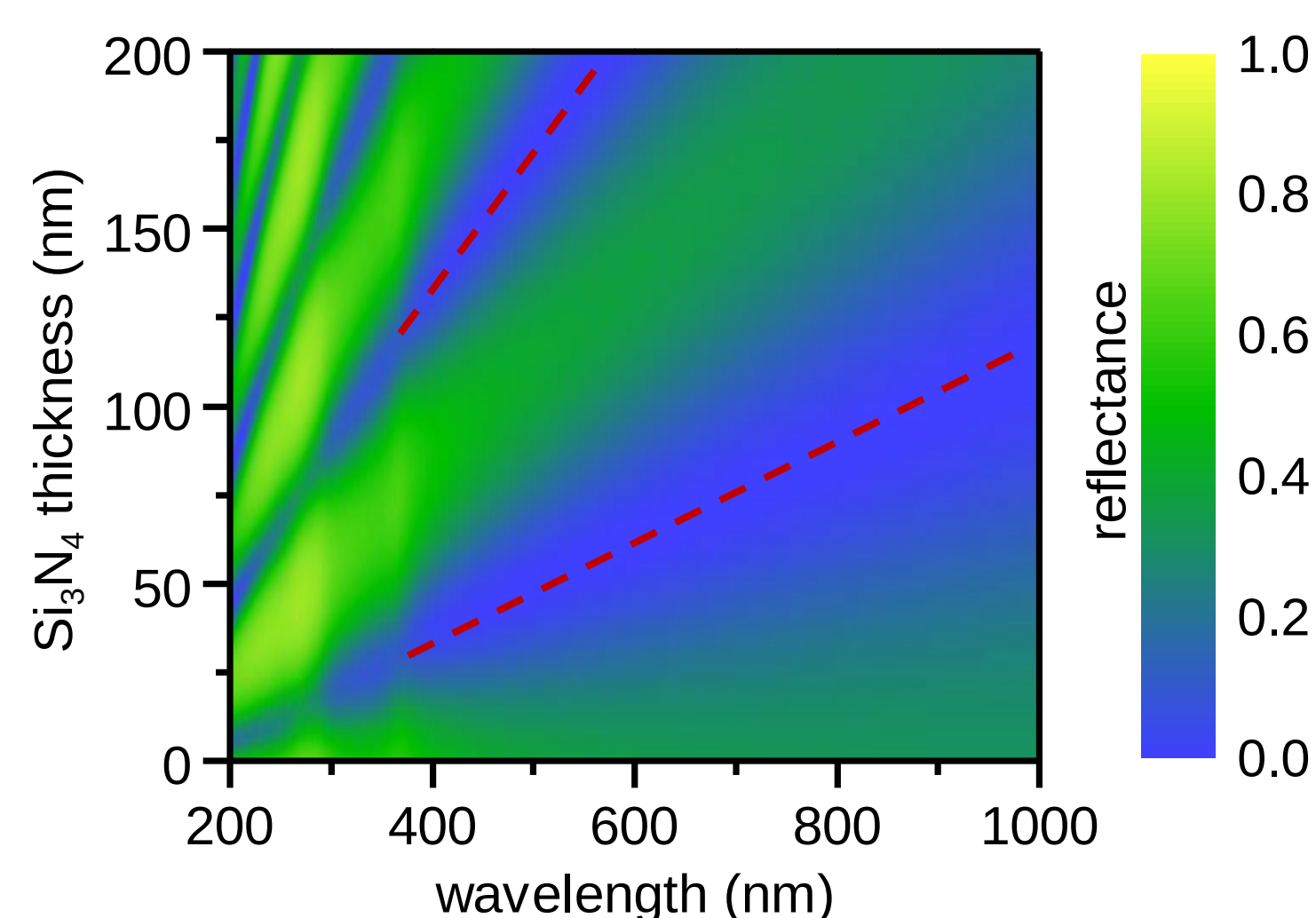
Challenge: Sensitivity / SNR of detector → limited measurement accuracy

→ **New evaluation technique needed**

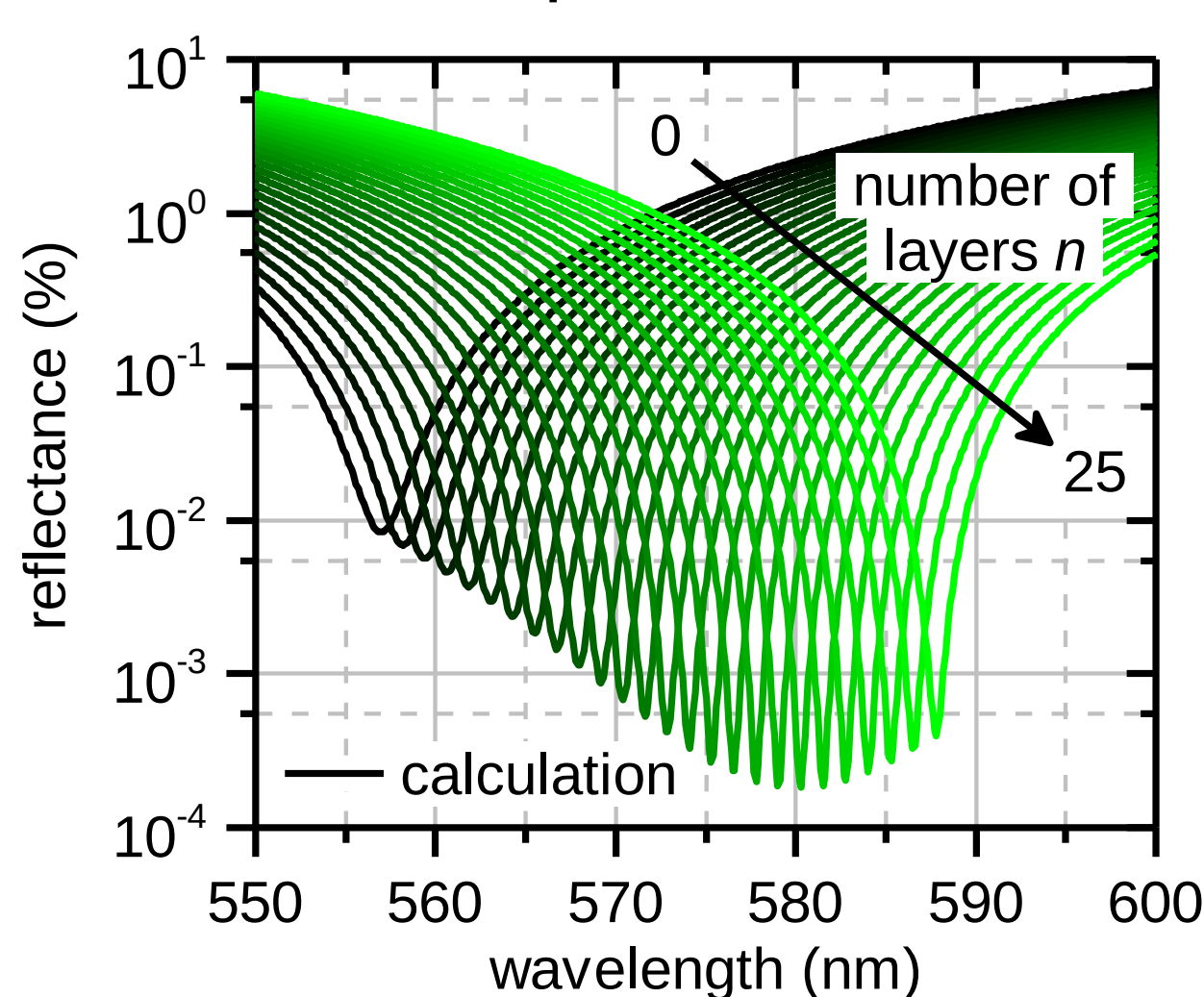
Advanced method using the wavelength shift of distinct extreme values induced by the 2D material

Design of a suitable optical layer stack

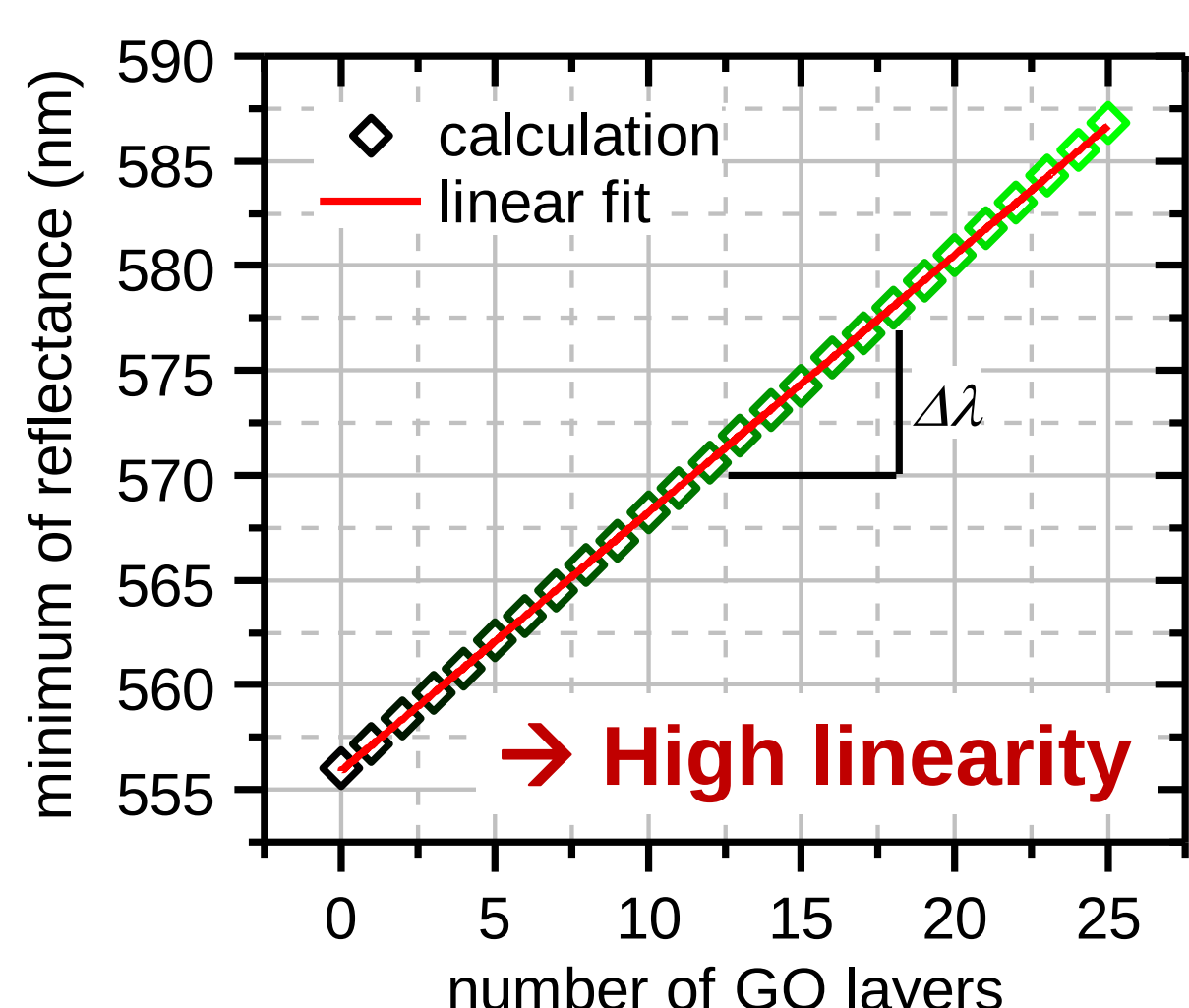
- Calculation of reflectance plot
- Choice of a suitable minimum



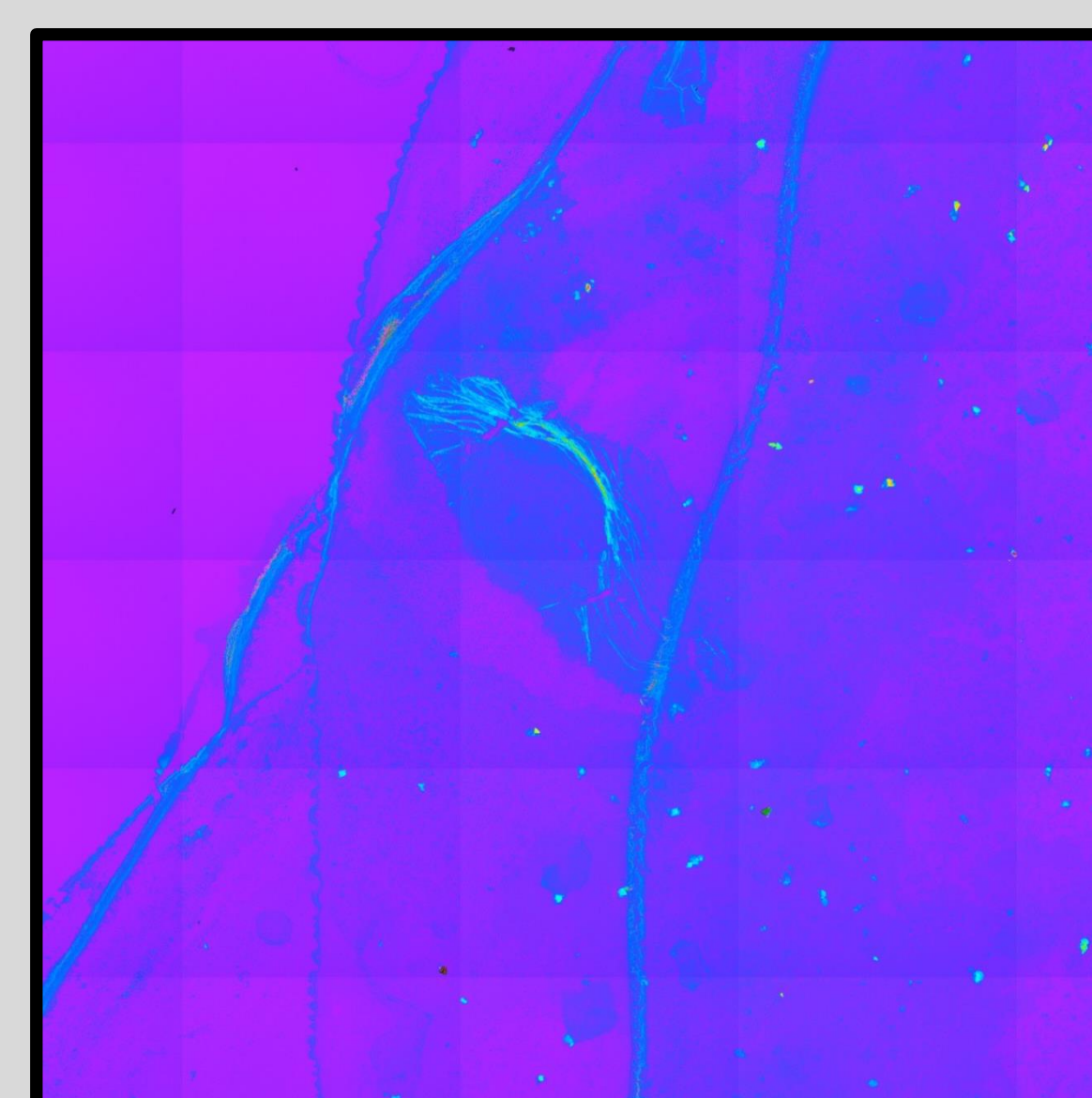
- Calculation of reflectance of layer stack with 2D material (different number of layers)
- Determination of positions of the minima



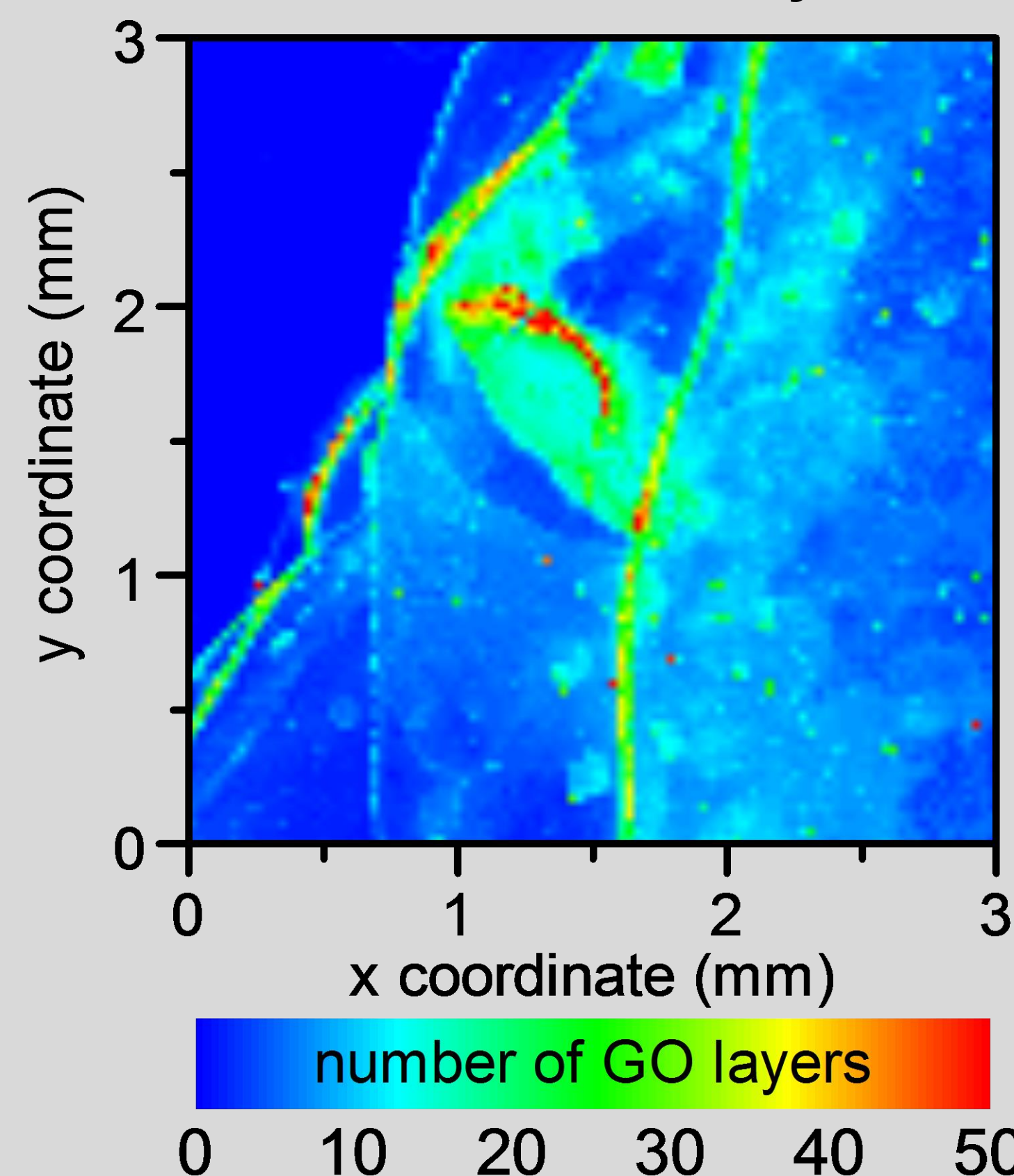
- Determination of magnitude and linearity of $\Delta\lambda$



Large-field micrograph of drop-casted GO flakes on Si₃N₄/SiO₂/Si

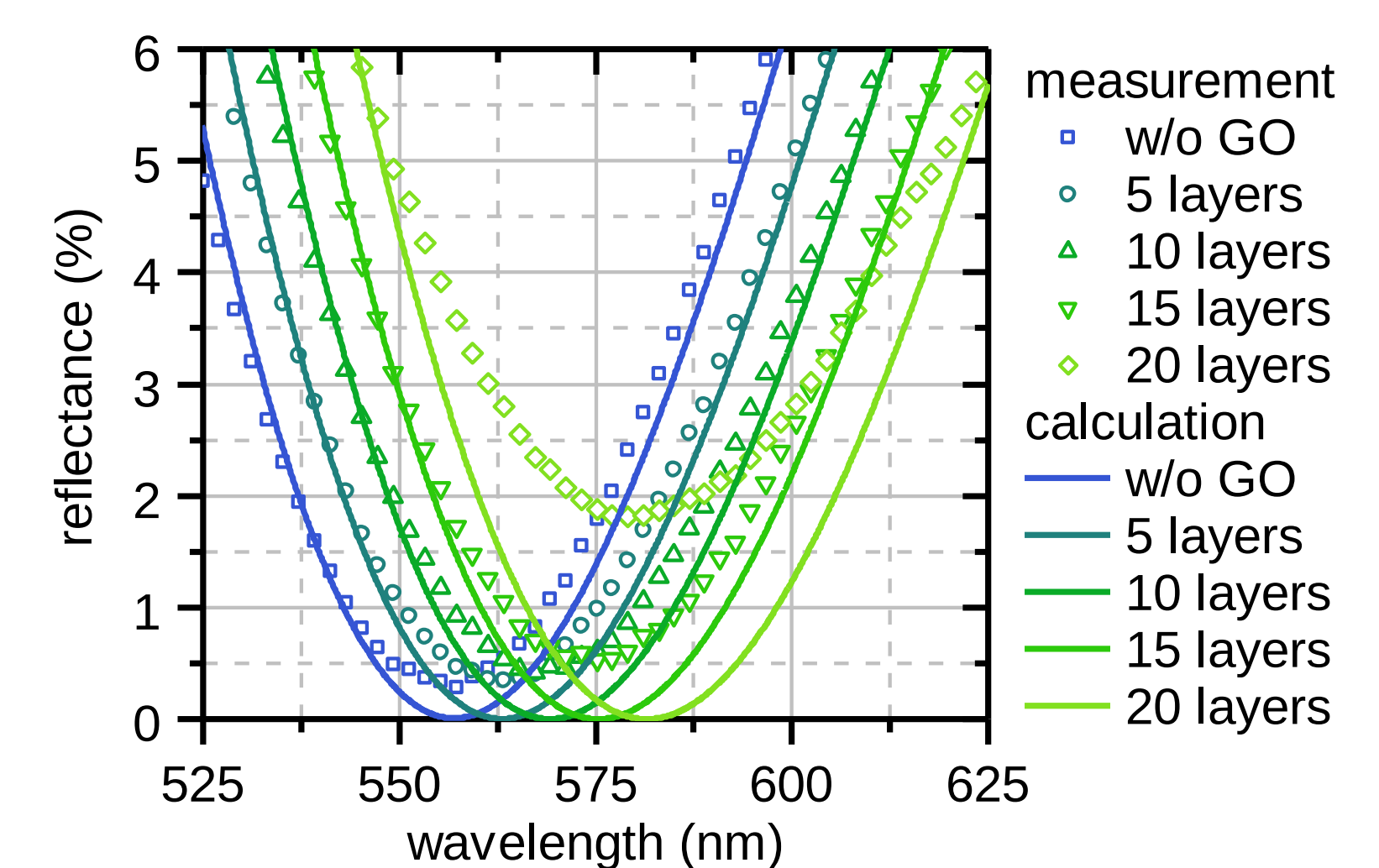


Map with corresponding number n of GO layers

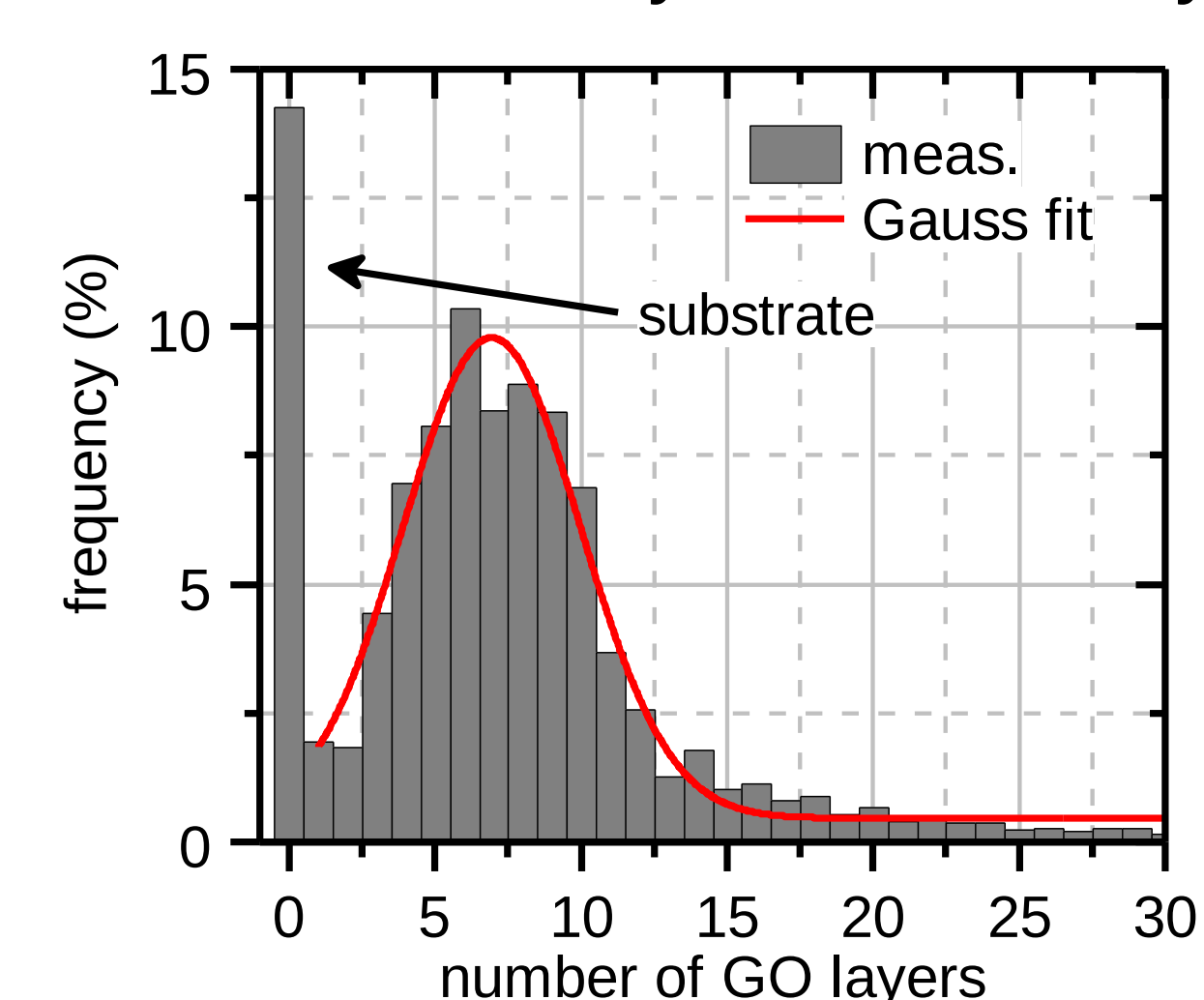


Measurement of reflectance spectra

- Mapping of area of interest
- Determination of the positions of λ_{min}



- Correlation of minima with its corresponding number of layers using characteristic $\Delta\lambda$
- Sample for demonstration reveals a mean number of GO layers of 7 ± 3 layers



- High conformance between measurement and calculation for GO and graphene demonstrated

Next steps

- Application to other 2D materials (TMDs, hBN, black phosphorus, etc.)
- Application to 2D heterostructures

→ **Advanced optical method for determining the number of layers of 2D materials**

Acknowledgement and contact

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