Towards Nanoelectronics Metrology With A Laboratory Set-up In The Soft X-Ray Range

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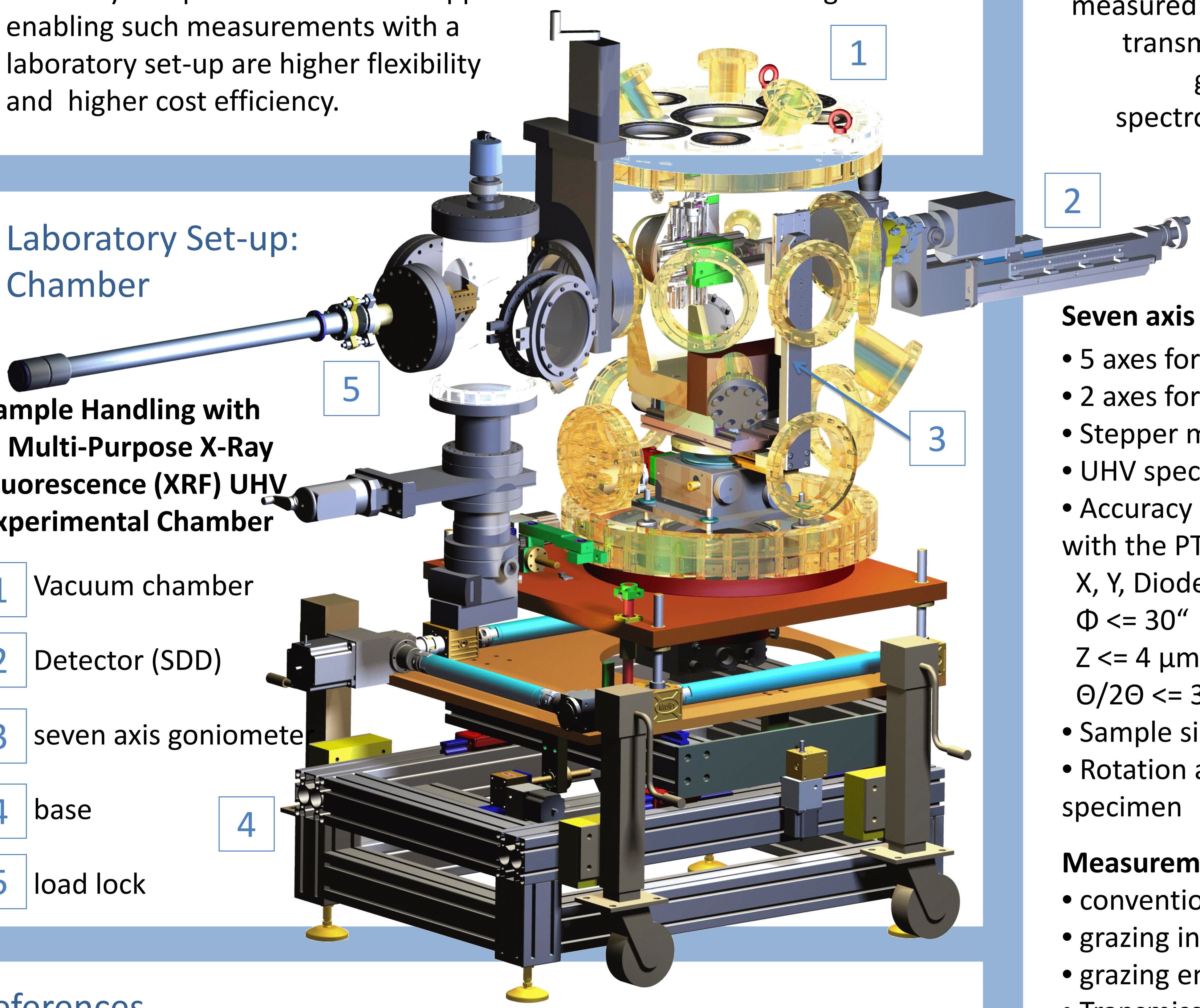
Motivation

Grazing Incidence and Grazing Exit X-ray Fluorescence (GI- and GE-XRF) analyses in the soft X-ray range are excellent non-destructive methods to investigate layers located at or near the surface. They can be used for the characterization of atomic layer deposition processes (ALD) [1] or to determine depth profiles of dopants for ultra shallow junction (USJ) applications [2,3]. For these kind of investigations the German national metrology institute (PTB) uses synchrotron radiation and calibrated instrumentation at BESSY II . We would like to show the possibility to perform such kind of angle-resolved measurements with a laboratory set-up. A new laser-produced plasma-source for the soft X-ray range was developed by the Berlin Laboratory for innovative X-Ray Technologies (BLiX) at the TUB [4]. Calculations for the laboratory set-up relying on depth-profile measurements by the PTB are carried out to demonstrate the analytical possibilities for USJ applications. The main advantages of enabling such measurements with a laboratory set-up are higher flexibility and higher cost efficiency.

Laboratory Set-up: Chamber



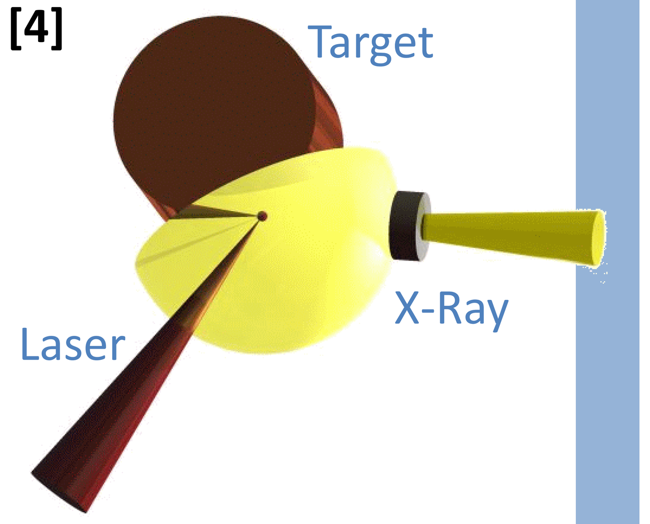
Sample Handling with a Multi-Purpose X-Ray Fluorescence (XRF) UHV Experimental Chamber

1 Vacuum chamber
2 Detector (SDD)
3 seven axis goniometer
4 base
5 load lock

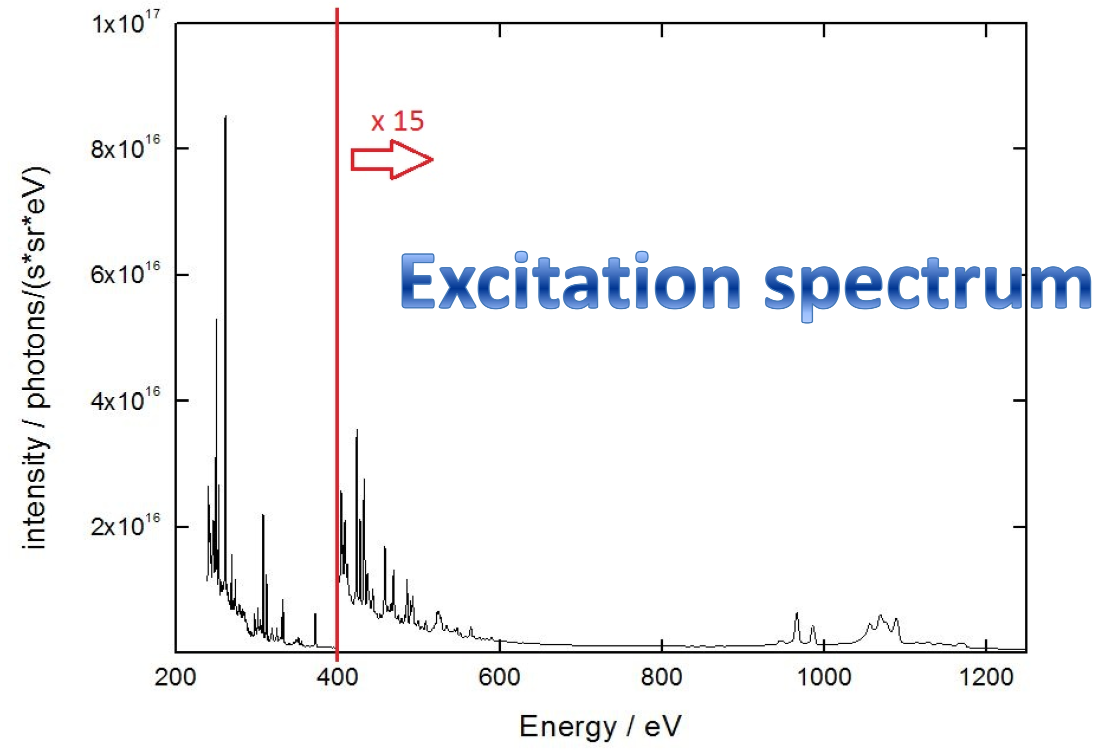
Laboratory Set-up: LPQ, Goniometer, and Detection

Excitation With A Laser-Produced Plasma-Source [4]

- Thin Disk Laser of Trumpf Inc.
- Laser wavelength: 1030 nm
- Pulse length: 1,1 ns
- Pulse energy: max. 250 mJ
- Repetition rate: 100…200 Hz
- Focused to a 30 µm Spot on a Metal Target (Cu)
- Soft X-ray: 1…20 nm (62…1248 eV)



Output spectrum of the LPS with a Cu target measured with a transmission grating spectrograph



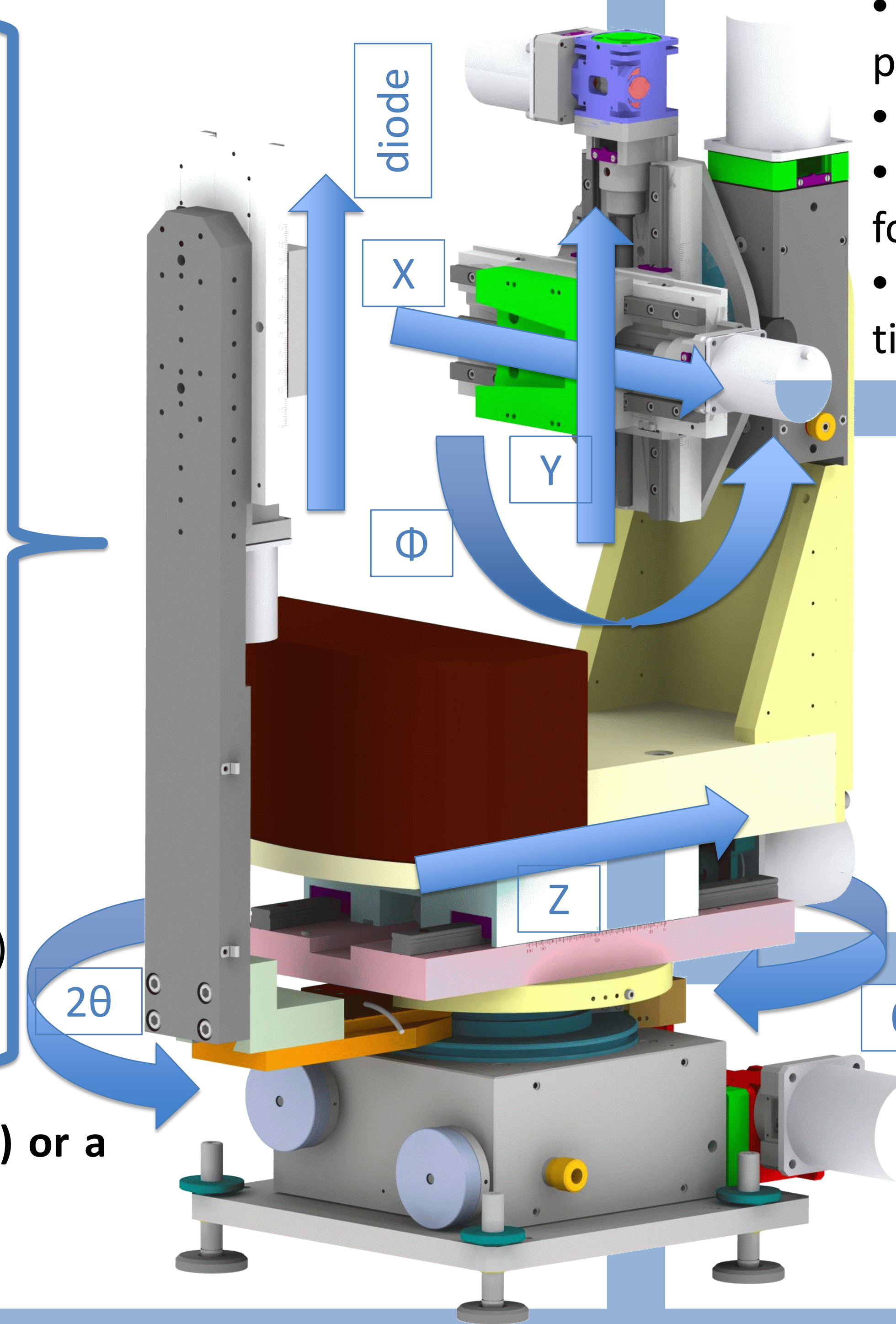
Seven axis goniometer

- 5 axes for sample positioning
- 2 axes for monitoring diode positioning
- Stepper motors
- UHV specified
- Accuracy measured in cooperation with the PTB:
  X, Y, Diode <= 15 µm
  Φ <= 30“
  Z <= 4 µm
  Θ/2Θ <= 30”
- Sample size up to 10x10 cm²
- Rotation around sample axis for structured specimen

Measurement geometries:

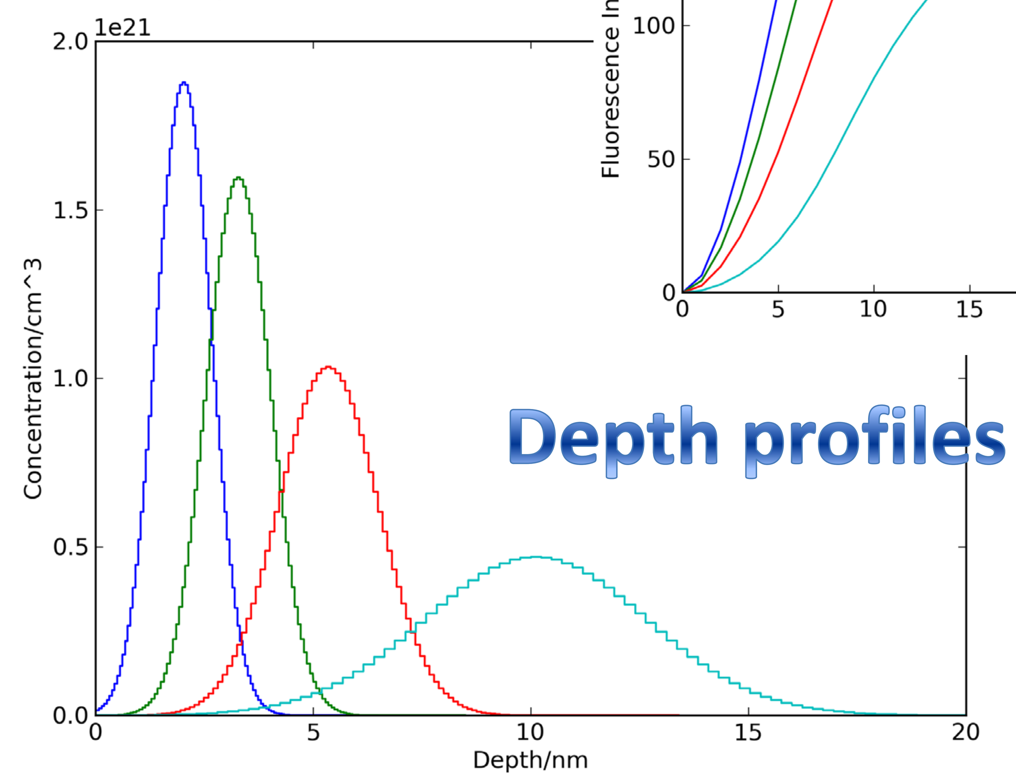
- conventional 45°/ 45° XRF
- grazing incidence X-ray fluorescence (GIXRF)
- grazing emission X-ray fluorescence (GEXRF
- Transmission XRF

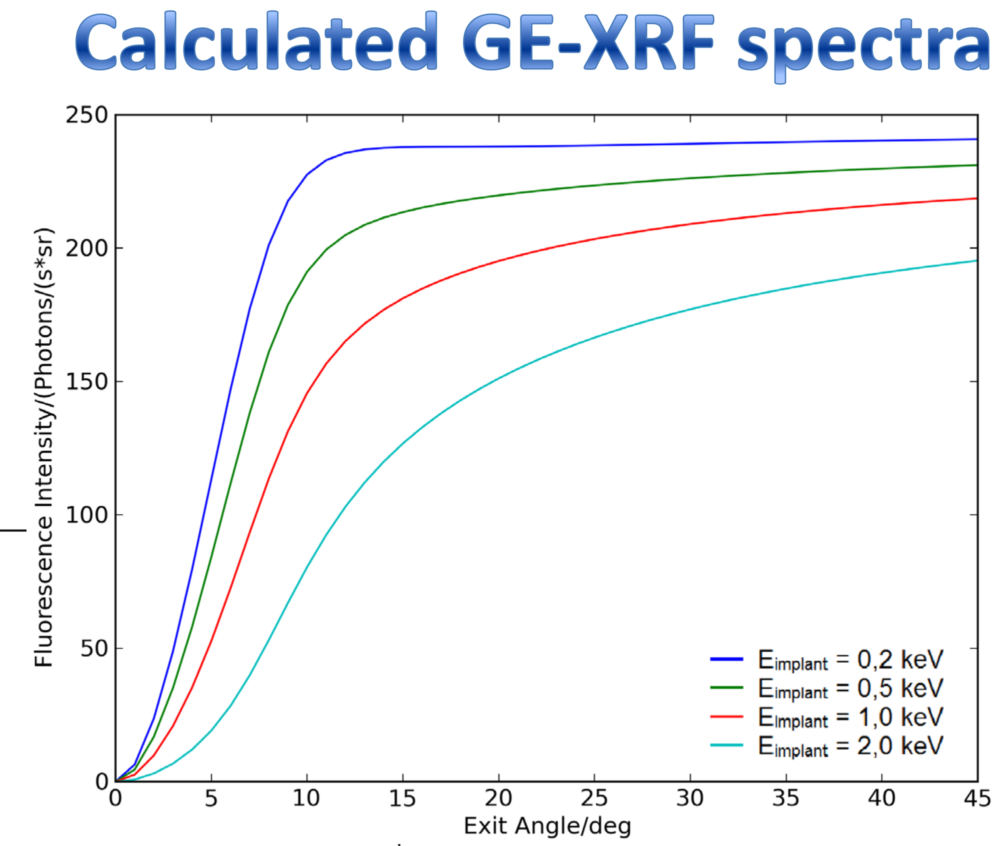
Detection with a silicon drift detector (SDD) or a reflection grating spectrometer



Calculations

Boron implant profiles with **varying implant energy** according to the samples measured at the PTB [3]





- Fluorescence intensities were calculated using a fundamental-paramater approach based on the Sherman equation
- angle dependency is calculated as shown by Urbach and De Bokx [5]
- Angular resolution: 1,5° at 5° exit angle (11° at 45° ea) for 2 x 4 cm² footprint on sample (depth resolution in the range of some nm)
- to differ the shown depth profiles with 3 x σ distance, measuring time of max. 800 s (per point) is necessary $(\sigma = \sqrt{n})$

Discussion and Outlook

- the dopant profiles of Boron, as a challenging element, with varying depth is discriminable
- the analyses of CIGSe layers will be also a challenge
- flexible and cost effective use in the laboratory
- new opportunities to analyze dopant profiles or nanolayers

References

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