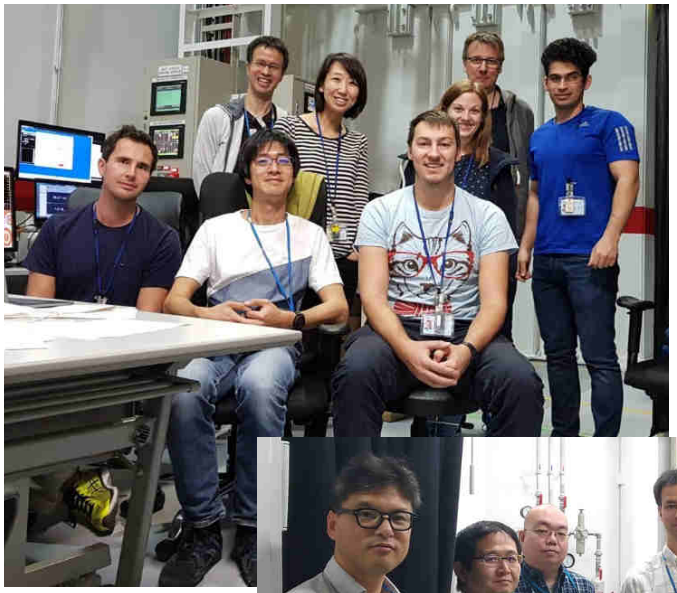
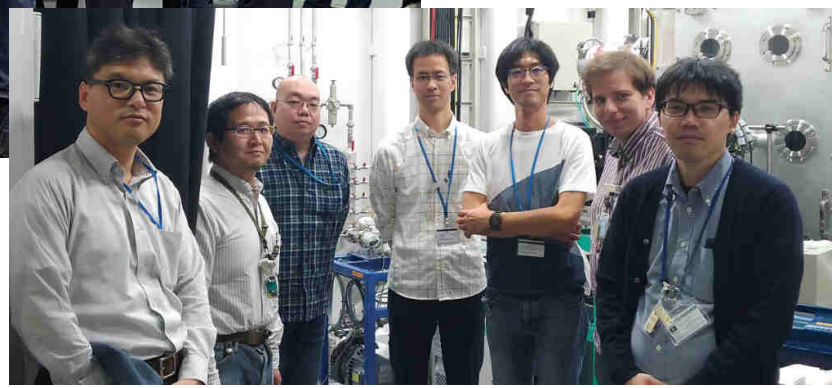
Surface dynamics of solids upon high-intensity laser irradiation investigated by grazing incidence X-ray scattering

Lisa Randolph

Team





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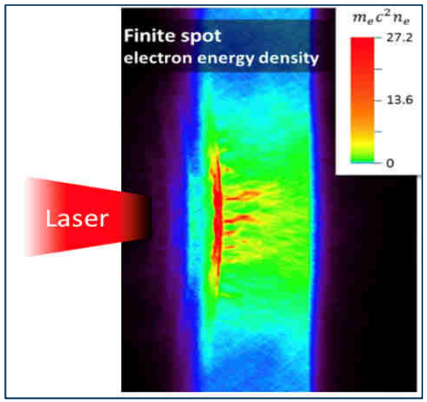
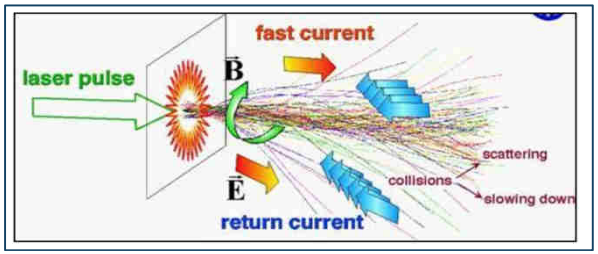
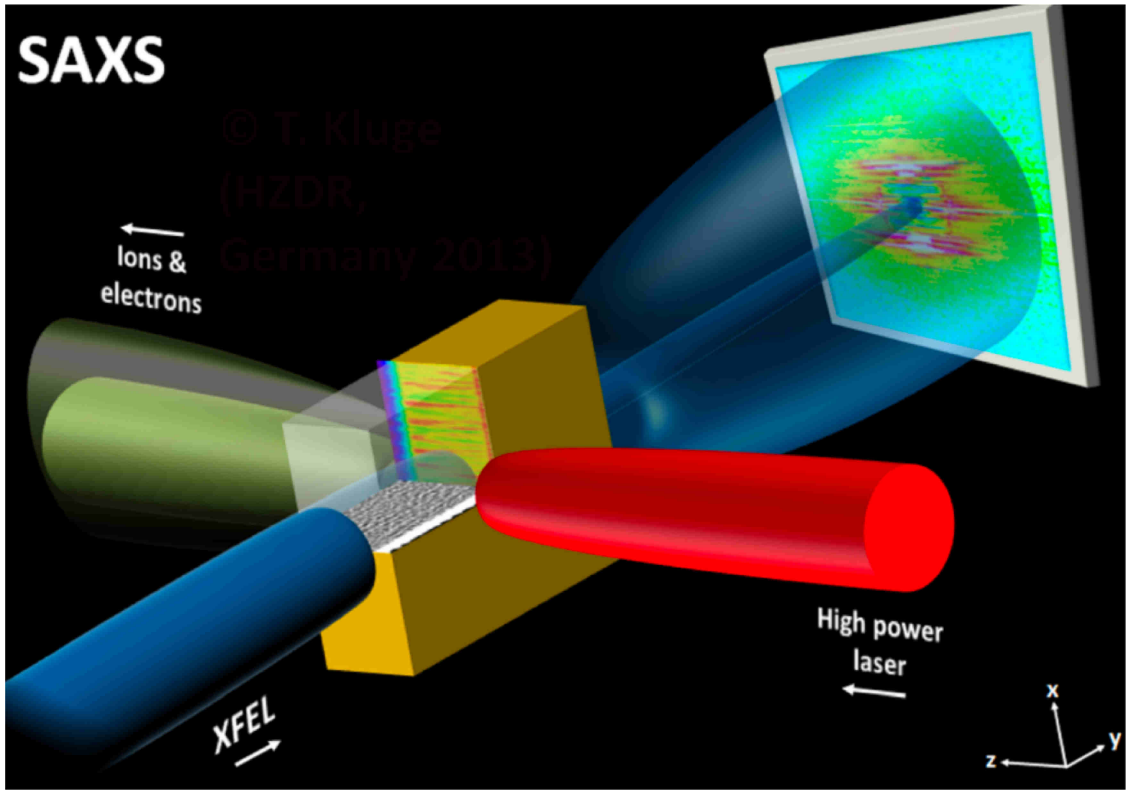
Motivation: X-ray diagnostics of solid density plasma

Extreme conditions

understanding nanoscale structures in solid density plasmas







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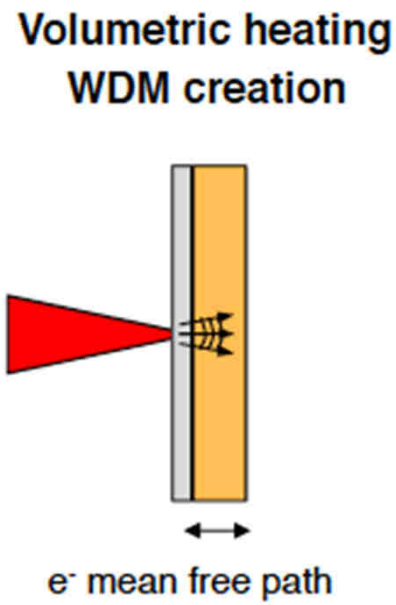
T. Kluge, et al. Physics of Plasmas 21, 33110 (2014)
T. Kluge, et al. Physics of Plasmas 23, 33103 (2016)
T. Kluge, et al. Physics of Plasmas 24, 102709 (2017)
T. Kluge, et al. Phys. Rev. X 8, 031068 (2018)

Surface dynamics

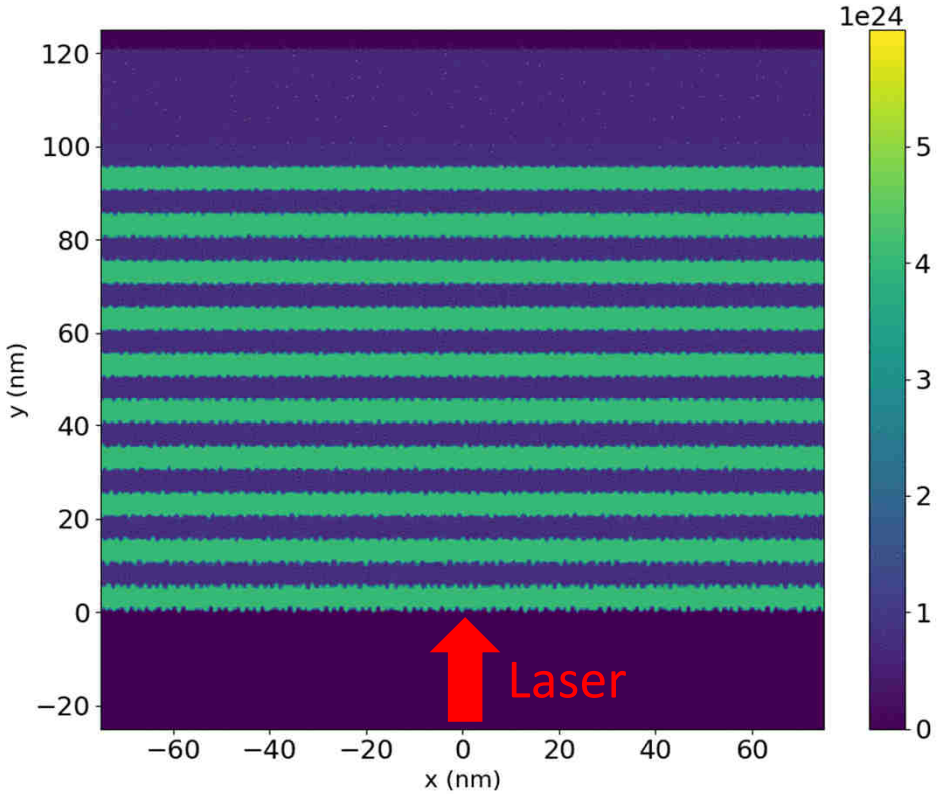
- Evolution of surface plasma expansion
- Evolution of surface roughness / ripples and its mechanisms
- Correlation between surface structures and absorption / ionization / energy transport

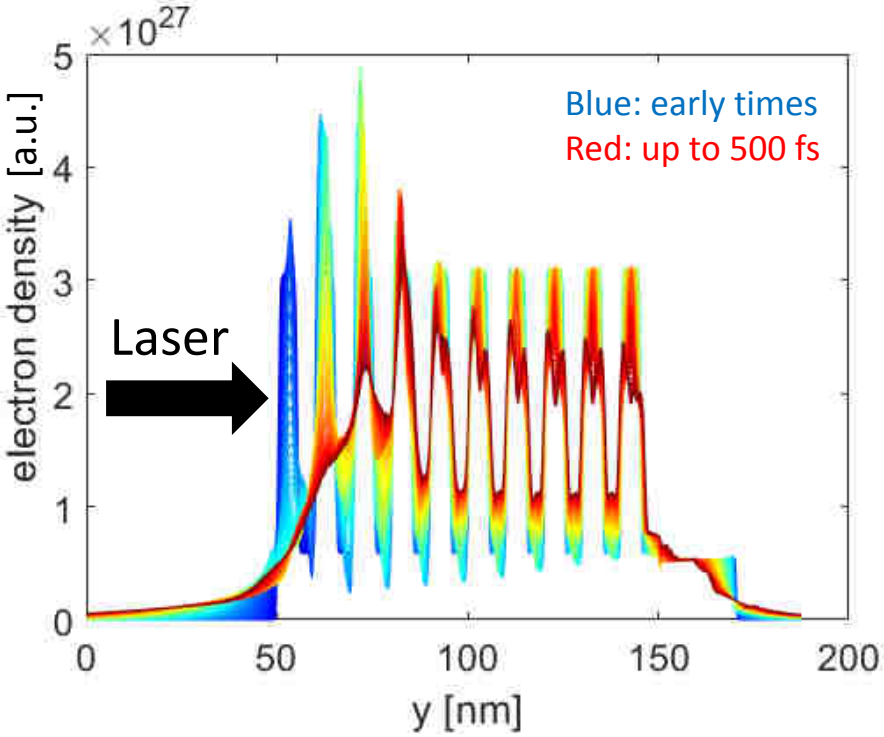
- Access to density profile of the surface is needed
- Realized by multilayer samples



PIC simulation Multilayer

Total electron density (~500 fs)

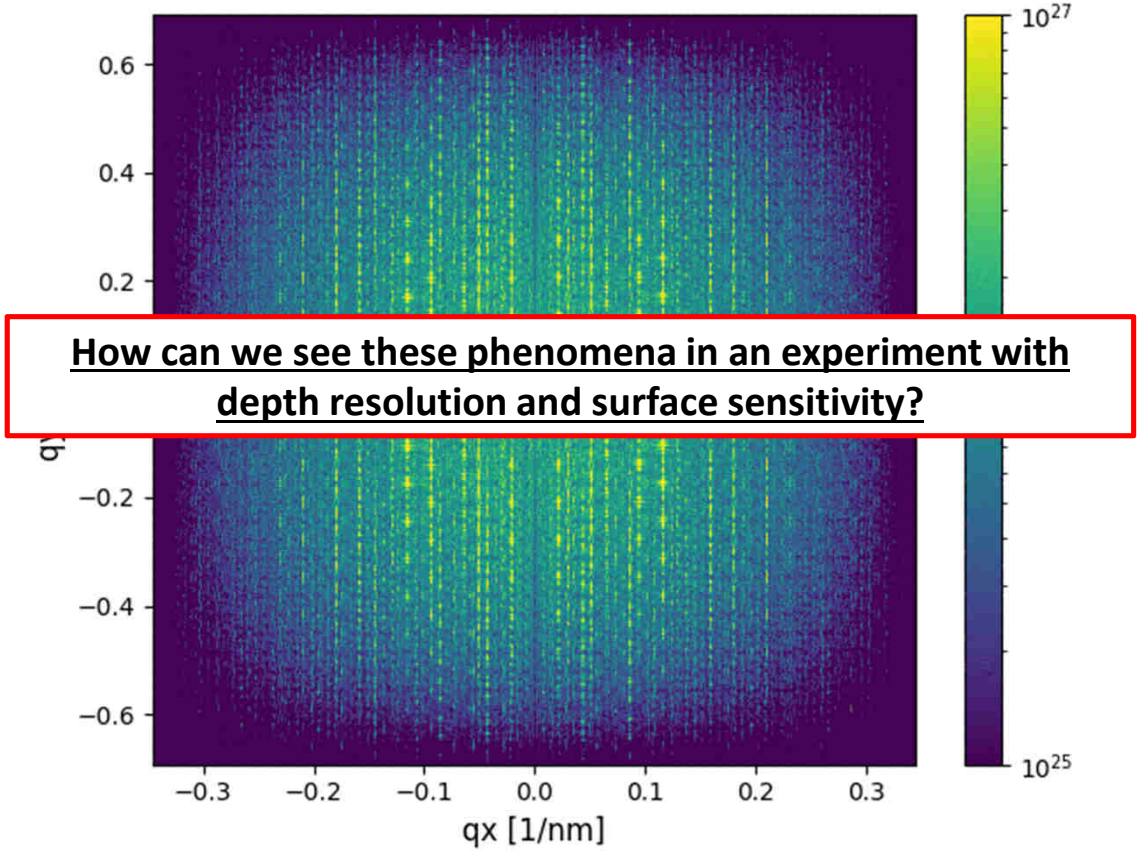




PIC simulation by M. Banjafar, Eu. XFEL

Laser intensity 10^17 Wcm^-2, λ = 800 nm, 50 fs pulse, including TF, field ionization, no binary collisions. Sample: Ta / Al multilayer, 5 nm thick each.

X-ray movie (~ 500 fs)



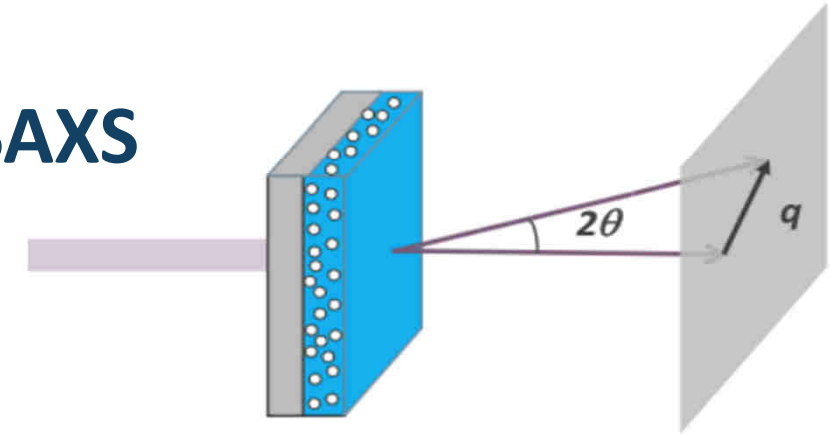
How can we see these phenomena in an experiment with depth resolution and surface sensitivity?

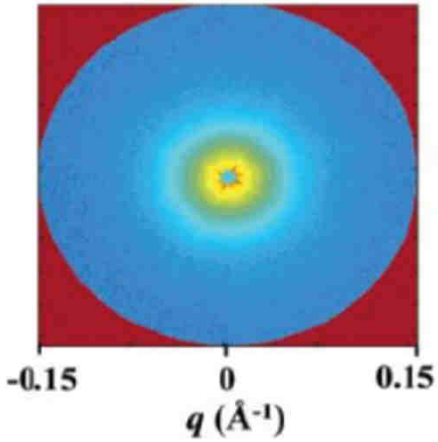
PIC simulation by M. Banjafar, Eu. XFEL

Laser intensity 10^17 Wcm^-2, λ = 800 nm, 50 fs pulse, including TF, field ionization, no binary collisions. Sample: Ta / Al multilayer, 5 nm thick each.

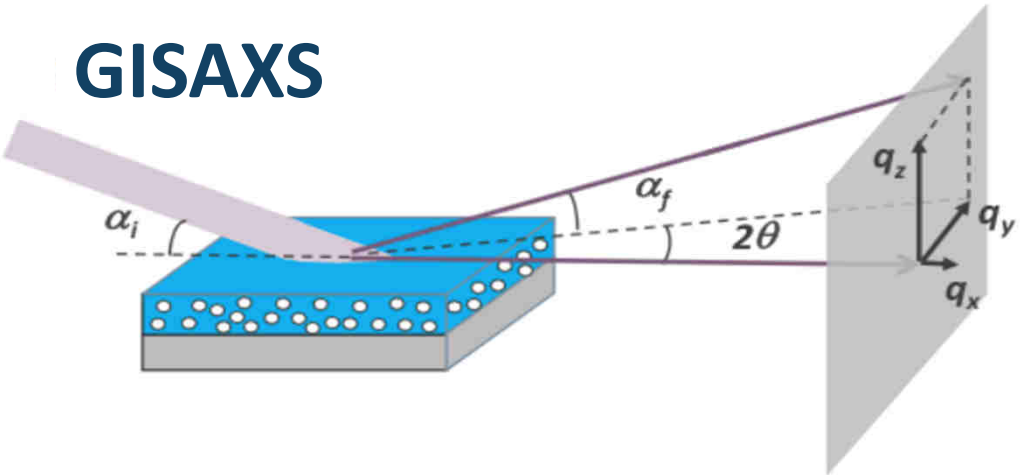
GISAXS = GI + SAXS
(Grazing Incidence Small Angle X-ray Scattering)

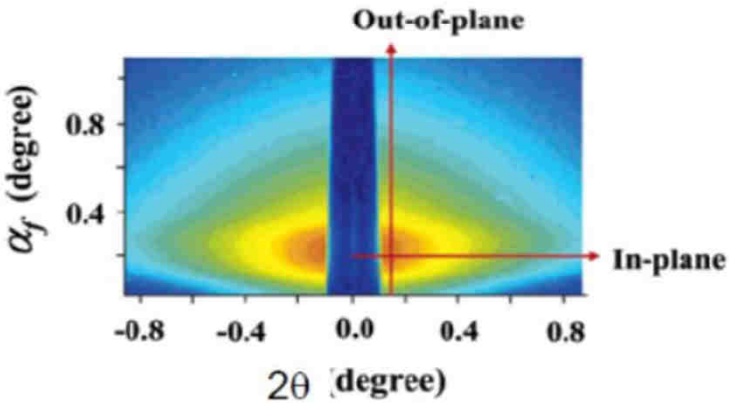
SAXS





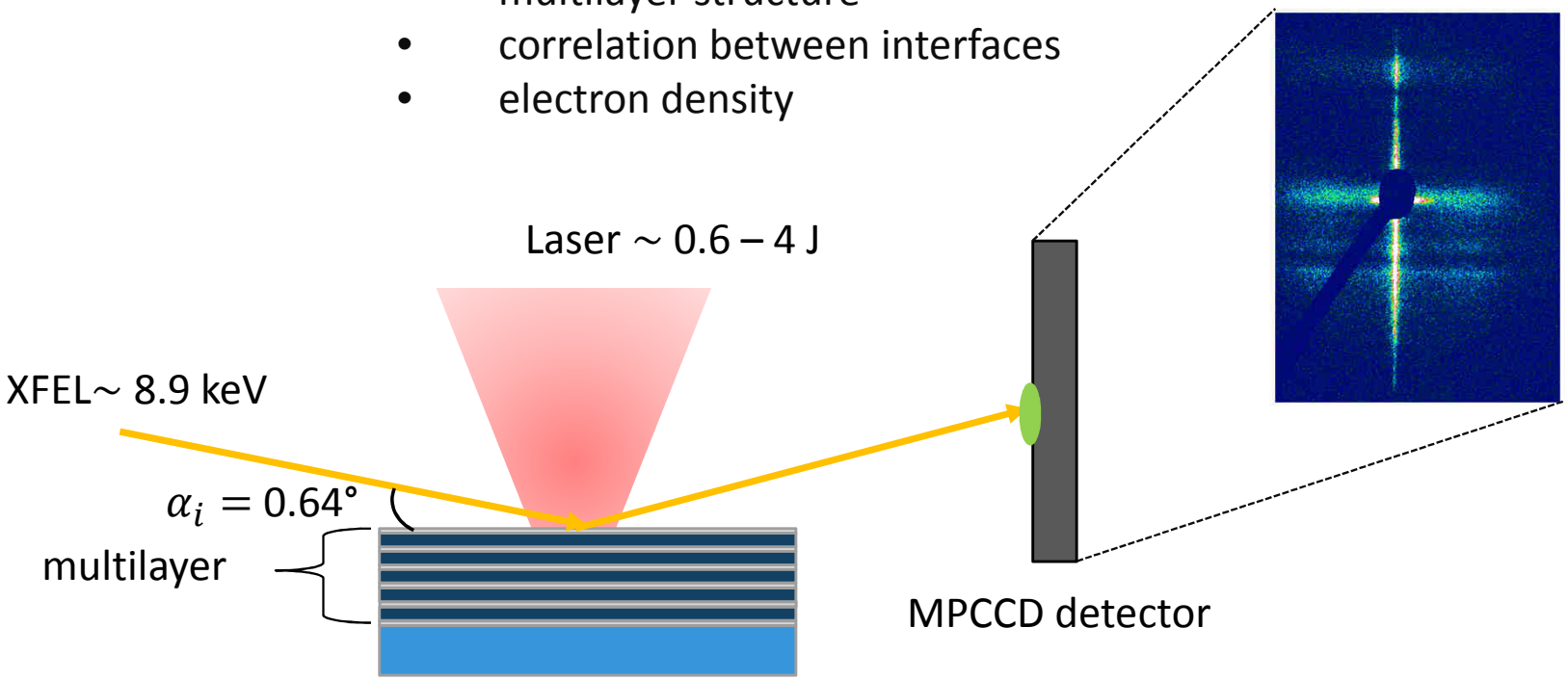
GISAXS

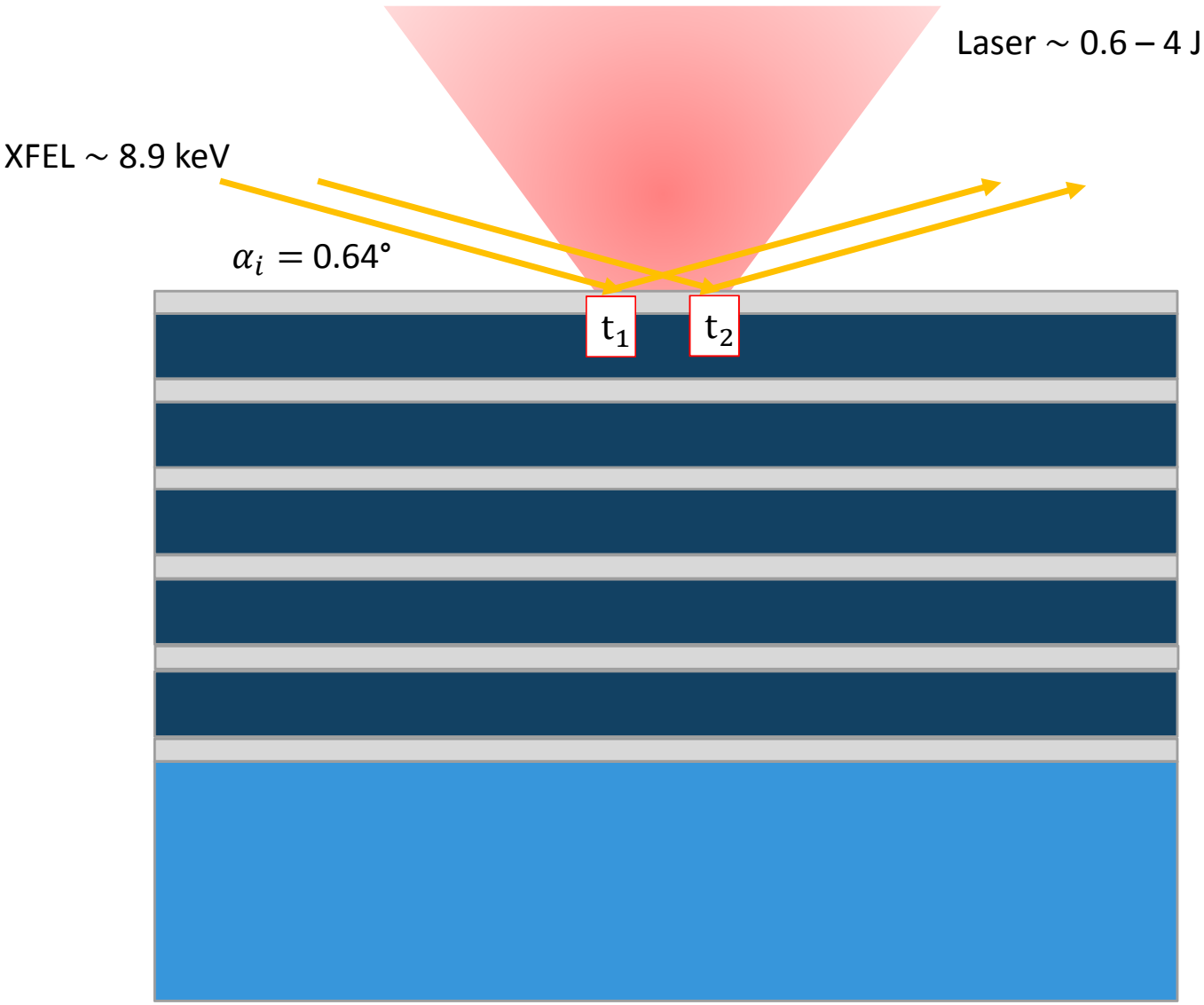




GISAXS from multilayer

- single shot compatible
- information about
  - multilayer structure
  - correlation between interfaces
  - electron density





Temporal resolution ~ 1 ps
→ Setup

Sample

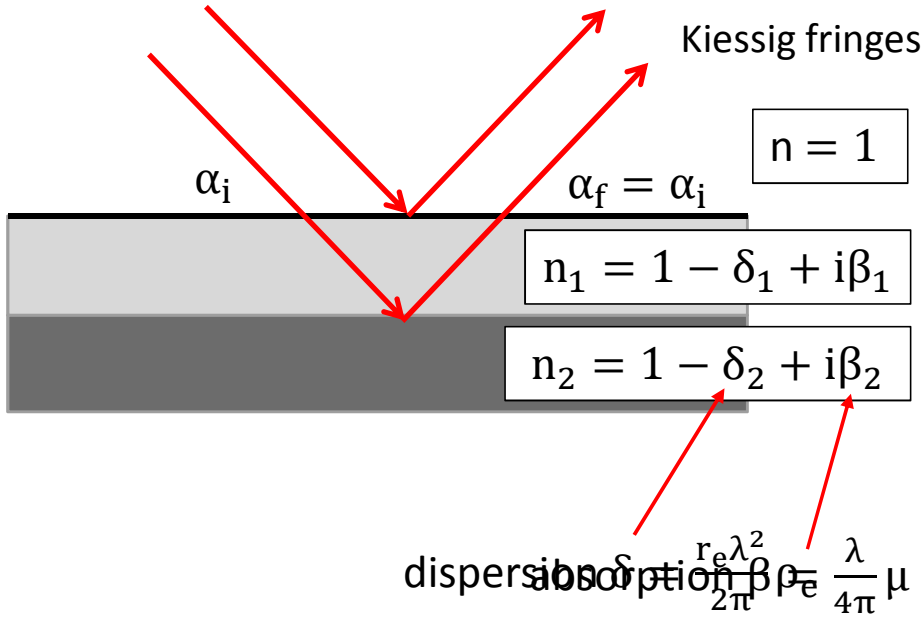
- Ta / Cu_3N multilayer
- 5 repititions

Ta – 4.5 nm

Cu_3N – 11 nm

Si substrate

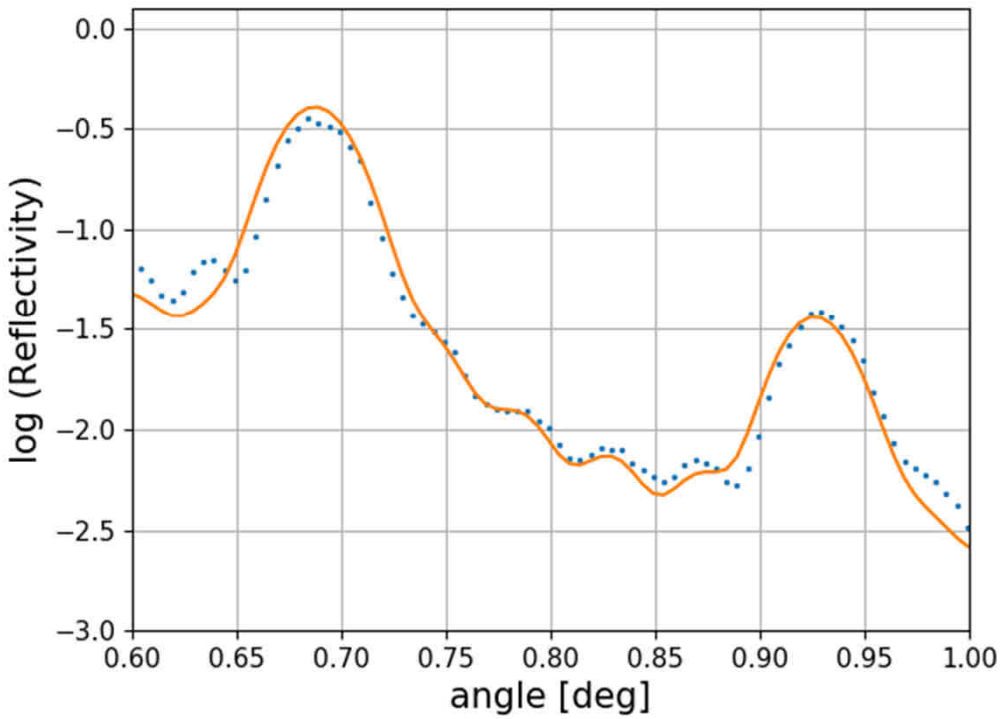
Reflection and Refraction – Perfect surface

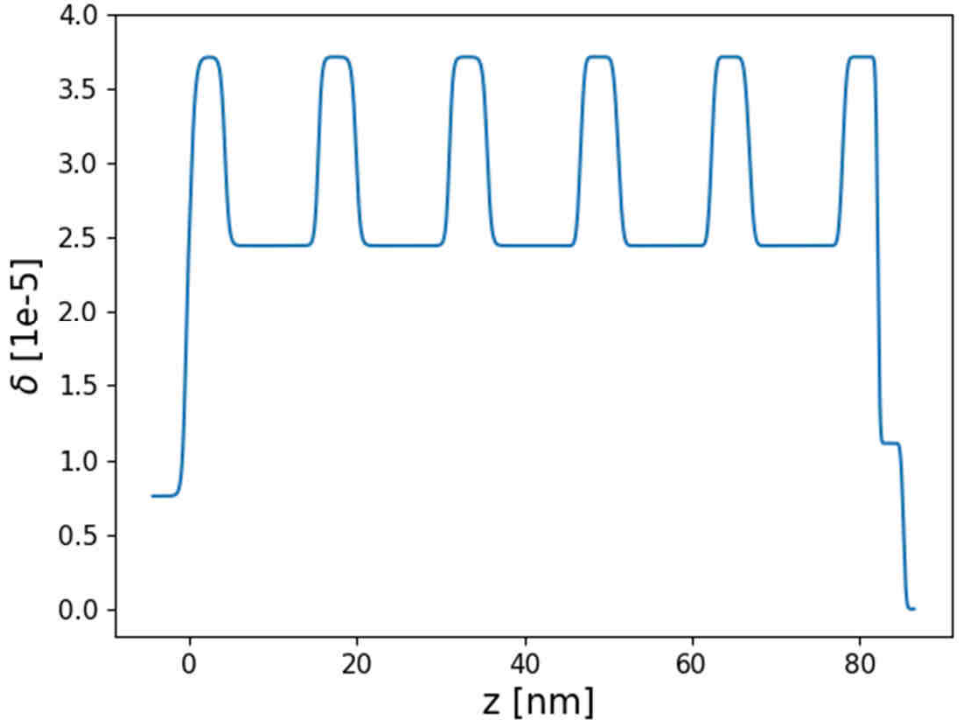


→ **dispersion profile**

X-ray reflectivity characterization

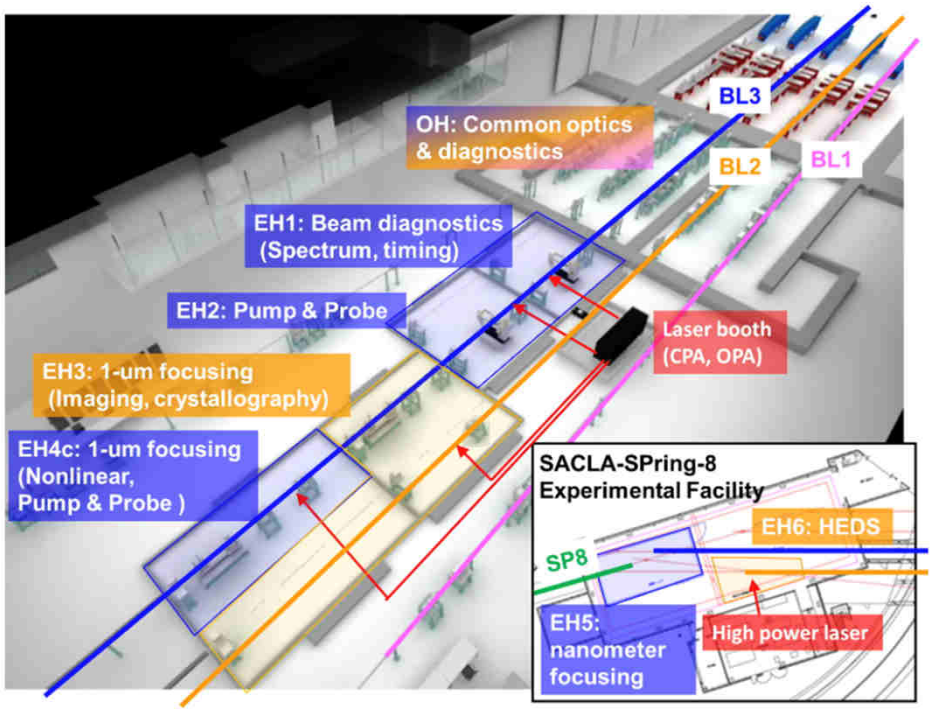
- Measured at TU Dortmund
- 4 small peaks between 2 large ones





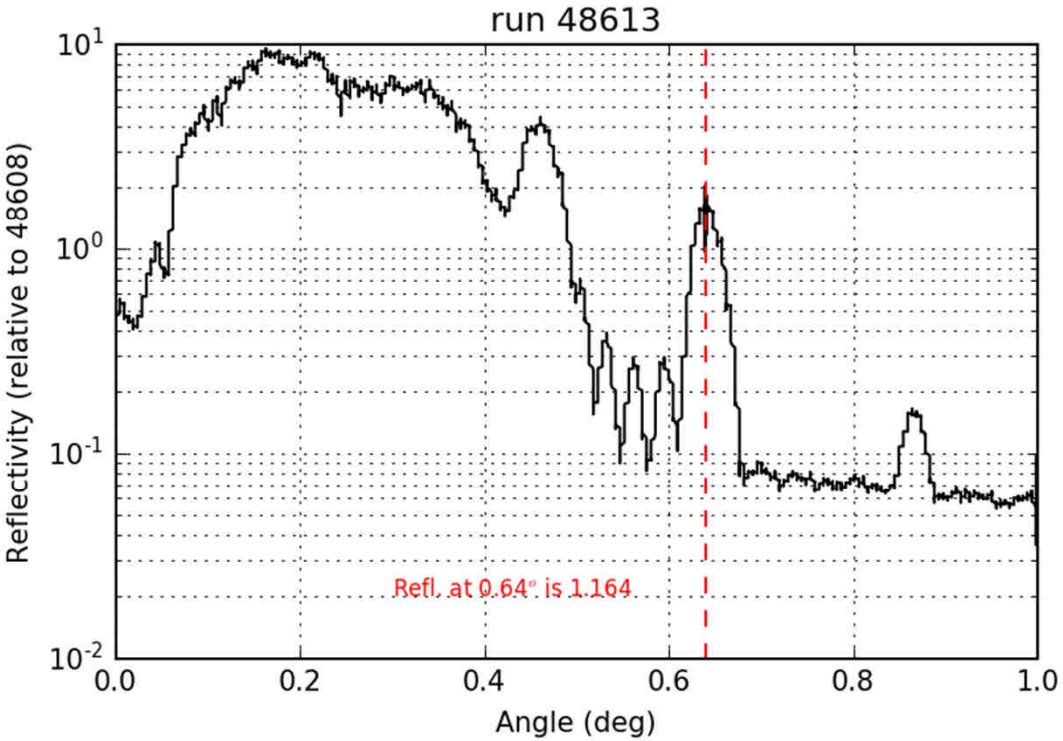
SACLA – Japanese Hard X-ray FEL facility

- Experiment in Nov. 2018
- In vacuum undulators
- Linac 8.5 GeV electron energy
- 30-60 Hz rep-rate, 0.1 mJ pulse energy
- 30 fs pulse duration
- Station: EH6 at BL3 (Toshinori Yabuuchi)

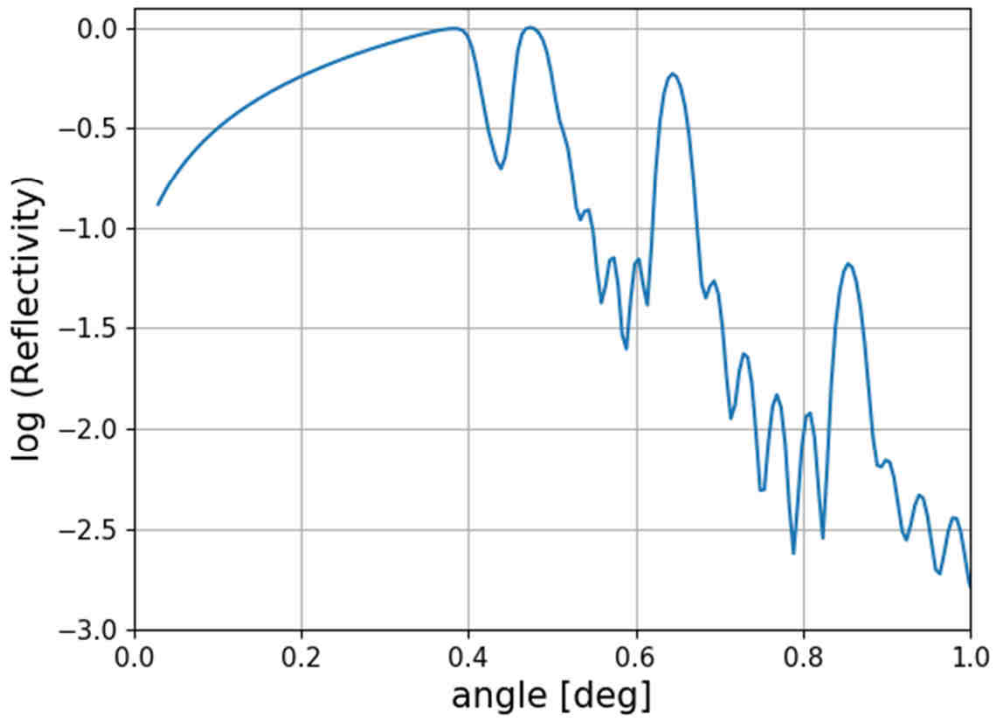


Reflectivity scans

Reflectivity measured at SACLA

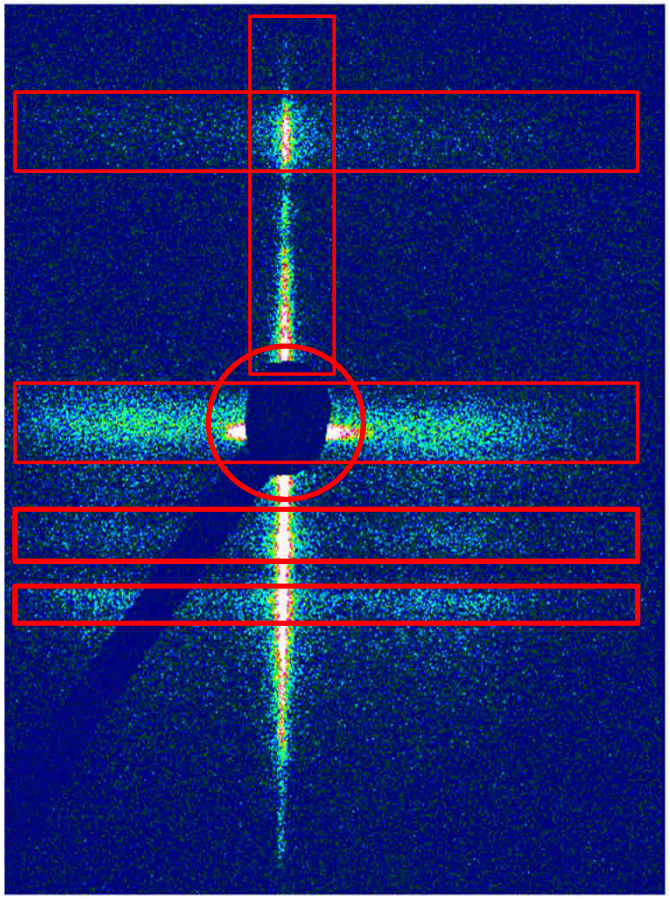


Reflectivity simulated with 'LS Fit' based on X-ray reflectivity scan from Dortmund



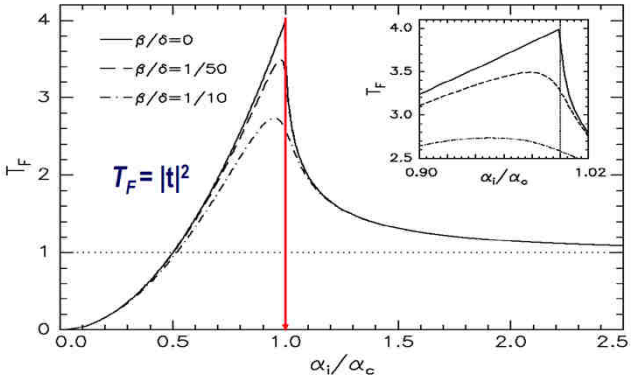
Detector image

No laser excitation



- Beam stop
- Specular reflectivity → structure of multilayer
- Bragg sheets → correlation between interfaces
- Yoneda wings →evanescent wave → critical angle, electron density

Transmission Function with absorption



Conclusion

- Experiment successful
- Surface diagnostics of plasma with GISAXS possible
- nm and ps depth resolution in laser excited multilayer

- Next steps (Experiment Nov. 2018):
  - In-depth analysis of data
  - Better time resolution: collinear laser and FEL

Thank you for your attention!