Probing laser-solid interactions with Small-Angle X-ray Scattering

L. Gaus [1,2], L. Bischoff [1], M. Bussman [1,3] , E. Cunningham [4], C. B. Curry [4,5] , J. E [6,1,7], E. Galtier [4], M. Gauthier [4], A. Laso García [1], M. Garten [1,2], S. Glenzer [4], J. Grenzer [1], C. Gutt [8], N. J. Hartley [4,1], L. Huang [1], U. Hübner [9], D. Kraus [1], H. J. Lee [4], E. E. McBride [4,6], J. Metzkes-Ng [1], B. Nagler [4], M. Nakatsutsumi [6], J. Nikl [10], M. Ota [11], A. Pelka [1], I. Prencipe [1], L. Randolph [8], M. Rödel [1,2], Y. Sakawa [11], H.-P. Schlenvoigt [1], M. Šmíd [1], F. Treffert [4,12] , K. Voigt [1,2], K. Zeil [1], T. E. Cowan [1,2], U. Schramm [1,2], T. Kluge [1]

1) Helmholtz-Zentrum Dresden-Rossendorf, Germany, E-mail : l.gaus@hzdr.de, 2) TU Dresden, Germany, 3) CASUS – Center for Advanced Systems Understanding, Görlitz, Germany, 4) SLAC National Accelerator Laboratory, Menlo Park, USA, 5) University of Alberta, Canada, 6) European XFEL, Schenefeld, Germany, 7) The Peac Institute of Multiscale Sciences, Chengdu, People's Republic of China, 8) Universität Siegen, Department Physik, Siegen, Germany, 9) Leibniz Institute of Photonic Technology, Jena, Germany, 10) ELI Beamlines Centre, Institute of Physics, Czech Academy of Sciences, Czech Republic, 11) Osaka University, Japan, 12) TU Darmstadt, Germany

The development of second-generation short-pulse laser-driven radiation sources requires a mature understanding of relativistic laser-plasma processes such as heating and transport of relativistic electrons as well as the development of plasma instabilities. These dynamic effects occur on femtosecond and nanometer scales and are therefore very difficult to access experimentally. However, ultrashort pulses of modern x-ray free electron lasers (XFELs) provide the necessary penetration power and a high spatial and temporal resolution for pump-probe experiments of high-intensity laser-solid interaction processes.

In a first experiment at the Matter in Extreme Conditions facility at LCLS we demonstrated that Small-Angle X-ray Scattering (SAXS) with XFEL pulses enables the measurement of plasma expansion dynamics in a direct in-situ pump-probe experiment at the relevant time and length scales [1].

In this talk, the focus will be on a follow-up experiment performed with significantly higher pump laser intensity reaching the relativistic intensity domain, improved targetry and particle diagnostics. In particular, probing at resonant X-ray energies has shown to give new insight into the ionization process, plasma opacity and density by studying asymmetries in SAXS patterns from nanostructured grating targets [2].

References

[1] Kluge et al., Phys. Rev. X 8, 031068 (2018)
[2] Gaus et al., arXiv: 2012.07922 (2021, under review)