Coherent Diffraction Imaging with Table-top XUV Sources

M. Zürch[1,2,3], A. Guggenmos[4,5], R. Jung[6], J. Rothhardt[3,7], C. Spaeth[4,5], J. Tümmler[6], S. Demmler[7], S. Hädrich[3,7], J. Limpert[3,7,8], A. Tünnermann[3,7,8], U. Kleineberg[4,5], H. Stiel[6] and C. Spielmann[2,3]

[1]*University of California, Chemistry Department, Berkeley, United States;* [2]*Institute of Optics and Quantum Electronics, Abbe Center of Photonics, Jena University, Jena, Germany;* [3]*Helmholtz Institute Jena, Jena, Germany;* [4]*Ludwig-Maximilians-Universität München, Garching, Germany;* [5]*Max-Planck-Institut für Quantenoptik,Garching, Germany;* [6]*Max Born Institute, Berlin, Germany;* [7]*Institute of Applied Physics, Abbe Center of Photonics, Jena University, Jena, Germany;* [8]*Fraunhofer Institute for Applied Optics and Precision Engineering, Jena, Germany*

**E-mail: mwz@berkeley.edu*

Abstracts: *Coherent diffraction imaging at wavelengths in the extreme ultraviolet range has become an important tool for nanoscale investigations. Employing laser driven high harmonic sources allows for lab scale applications such as cancer cell classification and phase-resolved surface studies in reflection geometry. The excellent beam properties allowed for spatial resolutions below the wavelength close to the Abbe limit, while in general the photon flux of HHG sources limits the applicability. In comparison, table-top soft X-ray laser driven by moderate pump energies were recently employed for CDI featuring excellent temporal coherence and extraordinary high flux allowing for single-shot imaging.*

The short wavelength radiation in the extreme ultraviolet (XUV) and soft x-ray range together with a high photon flux are the key elements for imaging nanoscopic structures. Coherent diffraction imaging (CDI) suits the needs for imaging in the XUV by omitting optical elements that would typically introduce high losses and limit the numerical aperture and thus the achievable resolution. For broader application of this technique laboratory light sources of various kinds have been applied.

In this report, we will focus first on recent progress achieved with high harmonic generation sources. These sources, driven by an amplified ultrafast laser system, feature high spatial coherence with sufficient narrow-band emission lines such that temporal coherence allows imaging down to the wavelength levels as has been recently demonstrated [1]. The spectral range covered with high photon flux by these sources is typically several 10eV up to 100eV. Due to the low penetration depth at these photon energies, recent applications targeted the reflection geometry [2] where CDI becomes a powerful technique yielding three-dimensional information of the surface. The surface sensitivity becomes advantageous, when nano- and microscale objects of a certain morphology are to be compared or classified. As an example, recently it was demonstrated that reflection geometry CDI at 35eV photon energy can be used to classify different breast cancer cell expression profiles solely by investigation their diffraction pattern [3]. However, a major bottleneck of HHG powered CDI experiments is the limited photon flux and the resulting long integration times. Another promising source is a laser plasma based table-top soft X-ray laser (SXRL) [4]. In a recent experiment the coherence properties of a SXRL operated in the gracing incidence pumping geometry (GRIP) and emitting 300 nJ pulses at 18.9 nm were studied [5]. The extraordinary high photon flux and the narrow line width make this source interesting for CDI, which was studied with an apparatus and samples that were tested before at a HHG beamline allowing for a direct comparison and benchmarking between these two table-top sources.

[1] M. Zürch, et al., Nature Scientific Reports **4**, 7356 (2014).
[2] M. Zürch, C. Kern, and Ch. Spielmann, Optics Express **21**, 21131 (2013).
[3] M. Zürch, et al., Journal of Medical Imaging **1**, 031008 (2014).
[4] J. Tuemmler, et al., Physical Review E **72**, 0374011 (2005).
[5] M. Zürch, et al., Spatial Coherence Limited Coherence Diffraction Imaging using a Molybdenum Soft X-ray Laser Pumped at Moderate Pump Energies, *in preparation*.