Tabletop Coherent EUV Sources and Applications: Full Field Sub-Wavelength Imaging at 13.5nm and Materials Metrology

Margaret Murnane

JILA, University of Colorado at Boulder and KMLabs Inc.

High harmonic generation (HHG) is the only route for producing coherent laser-like beams spanning the UV to keV region of the spectrum (~1-60nm) in a tabletop-scale setup. HHG provides unique wavelength, polarization and bandwidth selectable, illumination beams for spectroscopy, microscopy and metrology. Over the past two years, these new quantum light sources have made the transition from the laboratory to industry: KMLabs has engineered an integrated EUV source that combines the drive laser, EUV source and beamline: the XUUS (eXtreme Ultraviolet Ultrafast Source). With record flux, pointing, wavefront and intensity stability, as well as industrial-level thermal management and laser beam pointing stabilization, these advances have enabled the first sub-wavelength resolution 13.5nm imaging using any light source,[1] small or large, as well as robust, quantitative, reconstructions of buried layers, periodic objects, and ultrathin film materials properties and electronic structure.[2-4] Real world applications will include nanomicroscopy in support of nanolithography, process control, characterization of self-assembled nanostructures and as well as real-time imaging of functioning nano-enhanced devices.

1. "Sub-wavelength coherent imaging of periodic samples using a 13.5 nm tabletop high harmonic light source," Nature Photonics **11**, 259 (2017).
2. "Full characterization of the mechanical properties of 11-50nm ultrathin films: influence of bond coordination on the Poisson's ratio", Nano Letters, Advance Online (2017). **DOI:** 10.1021/acs.nanolett.6b04635
3. "Imaging Buried Nanostructures using Extreme Ultraviolet Ptychographic Coherent Diffractive Imaging," Nano Letters **16** (9), pp 5444–5450 (2016).
4. "High contrast 3D imaging of surfaces near the wavelength limit using tabletop EUV ptychography", Ultramicroscopy **158**, 98–104 (2015).
5. "Beyond Crystallography: Diffractive Imaging with Coherent X-ray Sources", *Science* **348**, 530 (2015).

Presenting Author

Margaret Murnane is a Distinguished Professor of Physics and Electrical and Computer Engineering at the University of Colorado. She received her B.S. and M.S. degrees at University College Cork, Ireland and a Ph.D. from UC Berkeley. Her work has led to major practical advances in the technology of ultrashort-pulse lasers and coherent extreme ultraviolet and x-ray sources. Her honors include a MacArthur Fellowship, election to the National Academy of Sciences, and most recently the Ives Medal, which is the highest award of the Optical Society of America. With Henry Kapteyn, she co-founded KMLabs Inc. to commercialize laser and EUV technologies for critical applications in nanoscience and nanotechnology (kmlabs.com). She currently leads a vibrant transdisciplinary research group, and directs a new multi-university NSF Center for Real Time Functional Imaging (STROBE.colorado.edu).