EUV and Soft X-ray Sources Short Course - October 24, 2021 (Online)

Course Overview

This short course on EUV and Soft X-ray Sources will give an overview of underlying physics associated with EUVL and plasma sources. Instructors for the short course are Prof. David Attwood (UC Berkeley), and Prof. Gerry O'Sullivan (UCD).

Registration Link

[2021 EUV Soft X-ray Sources Short Course Registration]

Intended Audience

This short course is intended for anyone who is involved in the development of EUV Lithography and/or other emerging lithography or metrology techniques for lithography, biology or material science or any other applications that involve EUV or Soft X-ray photons. This course will help students understand the fundamentals, technology requirements, current and future trends. Those who are responsible for the development of the technology roadmaps and making technology decisions as well as students and engineers will find this course valuable.

Detailed Course Outline

1. Physics of EUV and Short Wavelength Sources with Focus on Atomic Physics (Prof. Gerry O'Sullivan, School of Physics, UCD, Dublin) (3+ Hours)

This module will cover basic properties of laser produced and discharge produced plasmas and plasma models. We will review experimental factors determining plasma parameters and ion stage distributions, emission processes, line and continuum emission and UTA (unresolved transition array) emission. Topics covered also include: basic properties of H-like and He-like systems, coupling schemes and spectroscopic notation, transition probabilities and line intensities, calculations of atomic structure and spectra, complex spectra and UTAs, configuration interaction effects, opacity and radiation transport, UTA emission in sources for EUV and BEUV lithography, optimizing UTA emission, evolution of UTA emission with atomic number; implications for water-window operation, 3d-4f versus 4d-4f UTAs as water-window sources and a survey of short wavelength emission spectra.

Module will cover:

1. Basic plasma properties and processes
2. Physics of EUV radiation processes
    - Line and continuum spectra
    - Transition probabilities
    - Unresolved transition arrays (UTA)
    - Opacity issues
    - Scaling of emission with ion stage and atomic number

3. Optimization of emission from 13.5 nm and BEUV lithography sources
4. Challenges for EUV and short wavelength operation, comparison of LPP and DPP sources.
5. Brief introduction to modeling
6. Exploration of potential sources for Blue-X (1 – 6.x nm range)

2. Physics course: EUV/x-ray interaction with matter, sources, optics, and applications
Prof. David Attwood, University of California, Berkeley (3+ Hours)

This short course will provide a brief outline of several aspects of the underlying physics associated with extreme ultraviolet lithography (EUVL). Among these will be the basic mechanisms of EUV/x-ray interaction with matter, describing the interaction of short-wavelength electromagnetic radiation with electrons and atoms; electromagnetics at short wavelengths, including a simple but very useful, semi-classical formulation of refractive index, absorption, and reflection; EUV/x-ray optics and multilayer interference coatings, the enabling technology for EUV ; basic plasma physics and plasma parameters, a description of laser-plasma interactions and its importance as the power source for EUVL; spatial and temporal coherence at short wavelength; undulator radiation and the evolution to free electron lasers (FELs); and laser high harmonic generation (HHG). Applications sprinkled throughout will include nanoscale and solar scale imaging, and probing of atoms, molecules and solids on time scales extending from seconds to femtoseconds and attoseconds.

This module will provide an overview of EUV Physics in the following areas:

1. Physics of EUV/x-ray Interaction with matter
2. Electromagnetics at short wavelengths
3. EUV/x-ray optics and multilayer interference coatings
4. Hot, dense plasmas for EUV and x-ray radiation
5. Laser produced plasmas for EUV lithography
6. Coherence at short wavelengths
7. Undulator radiation and the evolution to FELs
8. Laser high harmonic generation (HHG)

Recommended Text Books

EUV Sources for Lithography (Vivek Bakshi)

EUV Lithography – 2nd Edition (Vivek Bakshi)

X-ray and Extreme Ultraviolet Radiation (David Attwood)

Instructor's Bio

David Attwood

David Attwood is Professor Emeritus at the University of California, Berkeley, and a member of the Nano-X group at Stanford's SLAC National Accelerator Laboratory. He received his PhD in Applied Physics from New York University in 1972. After his PhD, he joined Lawrence Livermore National Laboratory to work on laser fusion. He was the first scientific director of the Advanced Light Source (1985-1988) and the founding director of the Center for X-Ray Optics at Lawrence Berkeley National Laboratory, He co-founded the Applied Science and Technology (AS&T) PhD program at UC Berkeley. His interests involve x-ray optics, the generation of coherent radiation at EUV and x-ray wavelengths, and applications to nanoscale imaging. He is co-author with Anne Sakdinawat of the text "X-rays and Extreme Ultraviolet radiation" (www.cambridge.org/xrayeuv).

Gerry O'Sullivan

Gerry O'Sullivan obtained his B. Sc. in Experimental Physics in 1975 from University College Dublin where he subsequently completed his PhD in atomic spectroscopy under the supervision of Prof. Kevin Carroll in 1980. After brief periods at NIST, the University of Maryland and a longer stint at Dublin City University, he returned to UCD as a lecturer in 1986 and was Head of the School of Physics from 2002 to 2008. He is currently a Professor and director of the Atomic and Laser Physics Research (Spectroscopy) Group. His research interests include spectroscopy of laser produced plasmas, spectroscopy of ion gas collisions and the development of laser produced plasma based light sources for applications ranging from ionic photoabsorption studies to lithography and 'water window' microscopy. For the source development work his group have been involved in a number of very productive collaborations with both academic and industrial research groups in Ireland, the US, the Czech Republic, Germany, Italy, Poland, China and especially, Japan. For his contribution to research he was elected to Membership of the Royal Irish Academy in 2004. In 2018 he was presented with a Lifetime Achievement Award for his contribution to EUV source development by EUV Litho Inc.