Syllabus

Spring Semester 2013

PHYS 491/891: Introduction to Extreme Light

Format: 3-credit lecture
Meets: TBA
Instructor: Professor Donald Umstadter <donald.umstadter@unl.edu>, 472-8115

Scope: The focused light of UNL's petawatt-peak-power *Diocles laser* produces extremely high electromagnetic field strengths. One of the hallmarks is this *extreme light* is the acceleration of electrons to relativistic velocity, by both the electromagnetic field directly, as well as by laser-driven electrostatic plasma waves. This leads to emerging area of *relativistic optics*, as well as new classes of laser-driven electron accelerators and x-ray light sources. These in turn allow matter to be probed with sub-angstrom-spatial and femtosecond-temporal resolution, both of which are the natural scale-lengths of atomic dynamics. The development of novel gamma-ray photon energy light sources is relevant to another incipient area, namely, *nuclear photonics*. Applications of this research include advanced radiology, materials science, biomedicine, nuclear physics and engineering, defense, and homeland security.

Topics to be covered (as time allows):

1. Electrostatic and electromagnetic waves in vacuum, atomic media, and plasma
2. Gaussian optics and Fourier-transform limited light pulses
3. Generation of ultra-short pulses and ultra-high-power laser-light
4. Diagnostics and control of high-power laser-light: spatial and spectral phase measurements
5. Single-particle motion in high intensity EM fields, ponderomotive forces, and scattering
6. Relativistic corrections
7. High-field photo-ionization models
8. Relativistic optics in plasmas: *e.g.*, self-focusing, laser wakefields
9. Laser-driven charged-particle acceleration
10. Laser-driven synchrotron x-ray generation
11. Atomic, nuclear and biomedical applications of tunable, narrowband, ultrafast x-rays
12. Numerical models and simulation codes
13. Generation of other types of laser-driven secondary radiation: THz, ions, high-order harmonics
14. Special topics: *e.g.*, radiation damping, vacuum pair production

Student preparation: This course is intended as an introduction to the subject for graduate students and advanced undergraduate students in physics, chemistry, materials, and engineering. The recommended preparation is a strong foundation in electromagnetism, modern physics, relativity and optics, such as obtained in PHYS 213 (General Physics III), PHYS 343 (Physics of Lasers & Modern Optics), PHYS 451 (Electromagnetic Theory), PHYS 452 (Optics & Electromagnetic Waves), PHYS 480 (Intro to Lasers & Laser Applications). Please consult the instructor if you are unsure about your preparation.

Pedagogy: Participants will acquire the essential concepts, knowledge, and current state of the art of the subject matter, through lectures, readings, discussion, problem solving, and presentation.

Grading:

Homework:	20%
Midterm exam:	20%
Class participation:	15%
In-class presentation:	20%
Final exam:	25%

Recommended reading:

- G. Mourou and D. Umstadter, "Extreme Light," *Scientific American* (May, 2002), p. 81.
- D. Umstadter, "Topical Review: Relativistic Laser-Plasma Interactions," *J. Phys. D: Appl. Phys.* 36, R151–R165 (2003).
- G. Mourou, T. Tajima, and S. V. Bulanov "Optics in the relativistic regime, "*REVIEWS OF MODERN PHYSICS*, VOLUME 78, p. 309, APRIL–JUNE 2006.
- E. Esarey, C. B. Schroeder, and W. P. Leemans, "Physics of laser-driven plasma-based electron accelerators," *REVIEWS OF MODERN PHYSICS*, VOLUME 81, p. 1229, JULY–SEPTEMBER 2009.
- S. Corde et al., "Femtosecond x rays from laser-plasma accelerators," *REVIEWS OF MODERN PHYSICS* (accepted, Aug 9, 2012).