SPRING 2016

CHM 6180

LASERS IN CHEMISTRY

(Laser Spectroscopy, with applications to chemistry, chemical analysis and diagnostics of atomic and molecular systems)

This course will lay the foundations of the interaction between the laser radiation and atomic and molecular systems (with some emphasis on atomic systems). Different types of lasers (solid, liquid and gas), modes of operation (Q-switching and mode locking), laser characteristic parameters such as wavelength coverage, temporal coherence (spectral bandwidth), spatial coherence, photon irradiance and fluence, and non-linear effects (frequency conversion and mixing) will be discussed in detail. The course will finally cover the basic principles and analytical applications of the most popular spectroscopic techniques (e.g., absorption, emission, fluorescence, ionization, Raman and scattering methods) using lasers as primary excitation sources.

1. Course outline

Section I

- Lasers and their properties. Electromagnetic waves. Cavity and cavity modes. “Thermal” and laser radiation. Einstein coefficients. Temporal and spatial coherence. Laser bandwidth (broad band versus monochromatic radiation). Single mode and multi-mode emission. Laser irradiance and diffraction limited radiation.
- Theoretical basis of absorption, emission and fluorescence. Width of spectral lines. Homogeneous and inhomogeneous broadening (Doppler, collision, power and transit time broadening). Lorentz classical electron oscillator model. Oscillator strength. Linear (single-photon) and Non Linear (Multi-photon) absorption. Saturation effects. Hole burning. High-resolution (Doppler-free) spectroscopy.
- Laser oscillation. Threshold and Gain. Gain saturation. Small-signal gain and laser output.

Section II

- Different types of lasers and their operational characteristics. 3- and 4-level laser systems. Solid state lasers. Gas lasers. Excimer lasers. Dye lasers. Semiconductor lasers. Free electron lasers. Q-switching and Mode-locking operation of lasers. Propagation of laser beams (Gaussian beams). Spatial structure and Beam Quality parameters (TEM-modes).

Section III

- Essential outline of the description of atomic and molecular systems. Levels and transitions. Introduction to the quantum mechanical treatment of the interaction between atoms, molecules and radiation. Stationary and Time-dependent Schrödinger equations. Transition moments and spectroscopic selection rules. Effects of high intensity coherent pumping: Rabi oscillations and level splitting. Density Matrix versus Rate Equations approaches in the description of the population dynamics of atomic and molecular levels.

Section IV

This section should provide the student with the analytical background needed to answer questions such as: “Why and when lasers?” and: “Which laser technique?” for the particular problem on hand.

- Analytical Laser Spectroscopy. Basic principles of selected analytical methods. Atomic and molecular absorption. Atomic and molecular fluorescence. Time resolved fluorescence. Laser-ablation and Laser-induced Breakdown emission spectroscopy. Ionization techniques. Laser Photochemistry and Photo-fragmentation. Scattering methods (Raman spectroscopy).
- Diagnostics of plasmas with laser radiation. Time resolved spectroscopy. Pump and probe methods. Ultimate sensitivity and resolution achievable. Towards absolute analysis by laser methods.

Section V

- Non-linear Optics. Polarizability, Hyperpolarizability, third order susceptibility. Non-linear electron oscillator model. Frequency doubling and mixing. Non-linear laser techniques: Coherent Anti-Stokes Raman spectroscopy. Multi-photon absorption and fluorescence.
- Laser manipulations of atoms and molecules. Radiation Pressure. Optical Chromatography. Laser cooling and trapping.

2. Classes

Monday, Wednesday, Friday: 4th period (10:40 a.m. - 11: 30 a.m.)

Room: LEI 104

3. Textbook

No textbook has been chosen. Handout Notes will be distributed.

4. Grading

There will be 2 Progress Tests and a Final Test.
Tentative dates (except for the final exam, whose date is fixed) are planned as follows:
First Progress test: 19 February 2016 (Room: TBA)
Second Progress Test: 18 March 2016 (Room: TBA)
Final Test: LEI 104 (28 April 2016, 12:30 p.m. - 2:30 p.m.)

Each test will be worth 100 points. Grading will be based on a point distribution as follows: 1/3, 1/3, 1/3. Note that each written test may also include an oral colloquium, to be arranged with the instructor.

Finally, note that all exams are given under the Honor System. The student is supposed to have checked the website for the UF policy on honesty and cheating.

The grading scale is reported in the Table below.

≥ 255	**A**
245-254	**A-**
235-244	**B+**
225-234	**B**
215-224	**B-**
200-214	**C+**
180-199	**C**
150-179	**C-**
130-149	**D+**
120-129	**D**
110-119	**D-**
≤ 110	**E**

5. Policy related to class attendance, class demeanor and make-up exams

Students are expected to attend 85% of the course. Punctuality is recommended. Cell phones should be silent during class time. Late exams are possible (if justified) with no additional penalty if taken within the next two days of the actual dates of the exam. This may not be applicable to the Final test.

6. Miscellaneous

Students are referred to the instructions given in the University of Florida website regarding the University's honesty Policy as well as phone numbers and contact sites for university counseling and mental health services. Students requesting classroom accommodation must first register with the Dean of Students Office. The Dean of Students Office will provide documentation to the student who must then provide this documentation to the Instructor when requesting accommodation.

7. Instructor

Dr. Nicoló Omenetto
Office: CLB C201A
Office hours: Tuesday, Thursday: 2:00 p.m. – 4:00 p.m.
Available for questions: Monday, Tuesday, Thursday and Friday from 9 a.m. to 4 p.m.
Phone: 392-9853
omenetto@chem.ufl.edu