FALL 2020

CHM 6180

LASERS IN CHEMISTRY

(Laser Spectroscopy and its applications to chemistry and chemical analysis)

1. Course outline

This course will lay the foundations of the interaction between the laser radiation and atomic and molecular systems. The course is divided in two major parts: the first part, after introducing the *basic physical principles* of the laser, will cover in detail 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).

The second part of the course will provide the *analytical background* necessary to understand "*why*" lasers are unique sources of radiation, "*where*" they can be used, but also "*when*" should be used.

Finally, selected analytical applications of the most popular spectroscopic techniques (e.g., single and multi-photon absorption, emission, fluorescence, ionization, Raman and scattering methods) using lasers as primary excitation sources will be presented. Students are encouraged to suggest specific applications of interest to their current or future work.

PART 1

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 (e.g., Rabi oscillations and level splitting).

PART 2

Section IV

This section should provide the link between the unique characteristics of lasers and their use in different fields of applied and fundamental research.

- 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. Laser cooling and Trapping. Optical Chromatography.

2. Classes (100% online)

Monday, Wednesday, Friday: 7th period (1:55 p.m. - 2:45 p.m.)

The instructor will be available for further discussions ("office hours") Tuesday and Thursday, usually between 2:00pm and 4:00 pm.

3. Textbook

No textbook has been chosen. Handout Notes, published articles and ppt presentations will be provided.

4. Tests and Grading

As a preparation for the tests, typical problems/questions, including their solutions, will be provided 2-3 weeks before the test. There will be *one mid-term Test* and a *Final Test*. *Tentative* date for the Mid-term test: 26 October; *Tentative* date for the Final Test: 16 December.

Each test will be worth 100 points. Grading will be based on a 200 point distribution as follows: 1/2, 1/2. *See Table on page 4 below for point-grade correspondence*. Note that *the graded mid-term test* will also include an *individual* oral discussion, to be arranged with the instructor.

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.

Students are expected to provide feedback on the quality of the instruction in this course by completing on-line evaluations at https://evaluations.ufl.edu. Evaluations are open two or three weeks before the end of the semester.

6. Miscellaneous

Students are referred to the instructions given in the University of Florida website regarding the University's honesty Policy (http://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/), as well as phone numbers and contact sites for university counseling and mental health services.

CORRESPONDENCE POINTS - LETTER GRADES

≥ 170	A
163-169	A-
157-162	B+
150-156	B
143-149	B-
133-142	C+
120-132	C
100-119	C-
87-99	D+
80-86	D
73-79	D-
≤ 73	E