

CHEMISTRY - CHM 6180

LASERS IN CHEMISTRY

Fall 2022

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

Class times: M,W,F 12:50 PM - 13:40 PM (6th Period); F2F presentation of this class (place to be determined).

Instructor: Prof. Nicolás Omenetto **e-mail:** omenetto@chem.ufl.edu

Office: CLB201A; **Phone:** 392-9853; **Office hours:** CLB 201A, Tuesday, Thursday: 8th – 9th period (2:00PM – 4:00PM) or by appointment.

1. Course objectives.

This course will lay the foundations of the interaction between the laser radiation and atomic and molecular systems. The purpose is to provide the analytical background necessary to understand “why” lasers are unique sources of radiation, “where” they can be used, and “when” should be used. 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., single and multi-photon absorption, emission, fluorescence, ionization, Raman and scattering methods) using lasers as primary excitation sources.

2. Textbook.

No textbook suggested for this class. Handout notes covering all the material described below will be distributed.

3. Material covered and planned weekly schedule.

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).

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 and the definition of the *virtual level*).

- Diagnostics of plasmas with laser radiation. Time resolved spectroscopy. Pump and probe methods. Ultimate sensitivity and resolution achievable. Towards *absolute analysis* by laser methods.

4. Tests and Grading

Selected numerical problems from various book chapters will be given and discussed in class or during office hours. *As a preparation for the tests, typical problems/questions, including their solutions, will also be provided.*

There will be 1 *Mid-term Test*, and a *Final Test*. Mid-term Test 1 will include the material covered in Section I and II, and the Final Test will cover Sections III and IV. *Tentative* dates for the exams are planned as follows:

Mid-term Test: Monday; October 11, 2021; Time: TBA.

Final Test: Date, time: Friday, December 13, 2021; Time: 10AM-12PM.

Grading will be based on a 200 points total and on a point distribution as follows: 1/2, 1/2. *See Table on page 4* for the correspondence between points and letter grades. Note that, *for the Mid-term Test, individual discussions of the results with the students will be organized.*

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.

If justified, late Mid-term exam can be considered, with no additional penalty if taken within the next two days of the actual date 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. Policy related to COVID-19

Participation in our class is fundamental since improving oral conversation skills is a key objective of the course. Thus, students are required to have their cameras on from start to finish during our classes on Zoom. A default setting for our sessions in Zoom is that participants will be muted when they enter, so you will unmute yourself when you comment orally during our whole-group conversations and when you are in small groups. Your instructor may also ask students to reply in the chat box for specific activities. Oral comments on camera and written comments in the chat box

are considered activities for participation. If you have technical issues, please immediately consult UF IT Help to resolve them and then contact your instructor. Zoom sessions will not be recorded by the instructor and may not be recorded by students. As in all courses, unauthorized recording and unauthorized sharing of recorded material is prohibited.

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
160-169	A-
150-159	B+
140-149	B
130-139	B-
120-129	C+
100-119	C
< 100	C-