OPTI 571L: Introduction to the course

Professor Miroslav M. Kolesik
*College of Optical Sciences, University of Arizona,
Tucson, Arizona 85721, USA*

(Dated: August 21, 2025)

I. ABOUT OPTI 571L

Through this course, it is expected that students will (i) develop a deeper understanding of several topics in quantum mechanics and optical physics through the ability to run their own numerical experiments; (ii) become comfortable solving problems of interest, or of relevance to their own laboratory or theoretical work in optical physics; (iii) develop skills constructing computer algorithms that relate to problems beyond optical physics, and that will potentially be useful throughout their career; and (iv) become comfortable solving problems numerically.

These skills will be particularly useful to PhD students who are specializing in optical physics, and who are interested in enhancing their research tool set with computational methods.

The OPTI 571L labs involve quantum mechanics and optical physics topics discussed in OPTI 570 and OPTI 544. While it is nominally expected that students taking OPTI 571L will have taken these two other courses, alternative graduate-level preparation in quantum mechanics (such as PHYS 570A and PHYS 570B) should be sufficient. Introductory quantum mechanics as taught at the undergraduate level or in OPTI 511R will likely not be sufficient for most students; a student with this level of preparation should discuss the suitability of enrolling in OPTI 571L with Prof. Kolesik at or prior to the beginning of the course.

It is also assumed that students have familiarity with and access to MATLAB. The use of MATLAB is required in this course. Students with no familiarity with MATLAB should talk with Prof. Kolesik as soon as possible; alternative approaches may be considered. If it seems suitable and agreeable, a student can engage in an accelerated independent learning of MATLAB basics during the first couple of weeks of the course if the student's schedule permits this additional time expenditure.

II. OPTI 571L LABS

For all labs, you will need to go through your results one-on-one with Prof. Kolesik, preferably with your computer and code available. Currently, there are 14 labs available. Each is estimated to take between 1 and 4 weeks, depending on the lab. The labs are:

- **Quantum Mechanics**
  1. Basic MATLAB for QM
  2. Bloch vector dynamics
- **Quantum Optics**
  3. Visualization of quantum states
  4. Quantum anharmonic oscillator
  5. Damped quantum harmonic oscillator
- **Particle Trapping & Manipulation**
  6. Atom diffraction & interference I
  7. Atom diffraction & interference II - updating
  8. Optical Trapping
- **Physical Optics**
  9. Novel laser beams
  10. Raman-Nath & Bragg diffraction
  11. Second-harmonic generation
- **Laser Physics**
  12. Optical resonator modes
  13. Laser pulse generation
- **Condensed Matter Physics**
  14. Quantum motion in periodic potentials

Typically, a student is expected to complete 4-5 labs over the course of the semester, depending on the labs selected. Labs 1 and 6 are required of all students, and should be completed first and in that order. Lab 1 should typically take 3-4 weeks to complete with the following broad schedule

- Week 1 - Secs. I.A & B
- Week 2 - Secs. I.B - II.C
- Week 3 - Sec. II.E

Thus, starting on Aug. 28 Lab 1 should be finished by Sept. 25. Lab 6 should typically take 2-3 weeks, and should thus be finished by Oct. 16. After that, a student can choose which labs to work on.

III. CHOOSING YOUR OWN PROJECTS

For any lab that you complete, you may extend the lab by pursuing additional calculations, tests, etc if there is something more that interests you. If you envision something that would be a significant undertaking, you should talk with Prof. Kolesik first. Otherwise, feel free to extend the lab on your own by about a week and pursue your own interests, then show your work and results to Prof. Kolesik when the lab is completed.

If you work quickly and efficiently on your first two labs, you may have the option of creating your own lab in place of completing 2 or 3 labs from the list above. You would be required to create a lab description using LaTeX, in the format of the lab descriptions that you will be given for the other labs, as well as the MATLAB code and a complete set of results that document the computational aspect of your new lab. A project of this sort takes a lot of work, but can be well worth the effort. Keep this in mind, and start talking with one of us sooner rather than later if you think this might interest you.

IV. LECTURES

The lectures for this class will be delivered as Panopto videos available through D2L. These Recorded Lectures will provide background information and material for the class, along with descriptions of the available Labs. In particular, the first recorded lecture will be available via D2L on Monday Aug. 26 and should get you underway with the required Lab 1 Basic MATLAB for QM. For on-campus students the idea is for you to watch each video lecture prior to the scheduled classroom time in Meinel 432 from 2:00-2:50 PM each Wednesday starting on Aug. 28 (For the long-distance students we can schedule Zoom meetings in place of the classroom time.) During the first part of the semester, the scheduled classroom time will be used to discuss the labs, discuss problems that you are having with computations (so it would be helpful to have your laptop computers available if you can), and to discuss MATLAB techniques. The labs each have self-contained Lab Documents, which will be available through D2L, and as the semester progresses, students will be working on different labs. Because of this, it typically becomes more efficient to cancel the scheduled classroom time and open up that time slot (or others) for office hours. We will likely not meet as a class during the last few weeks of the semester, and we will meet individually instead.

V. GRADES

Grades will be based entirely upon the weekly computational laboratory assignments. Students should expect to turn in their computer code and/or results on a weekly basis, or to show their progress and results to Prof. Kolesik during or at the completion of a lab. Grades will be determined based on the timeliness of turning in required materials, the validity of the results (ie, are they correct?), the independent completion of computer code (although working with other students may be permitted on a few projects, and discussions with Prof. Kolesik are encouraged!), and the demonstration of independence and self-motivation in the pursuit of answers to problems not specifically assigned (ie, using computer code written for the lab projects to go beyond the specific required questions of each project).

The computational laboratory assignments will account for 100% of grade. The final grade will be determined according to the cumulative percentage earned such that $90 - 100\% =$ A, $80 - 89\% =$ B, $70 - 79\% =$ C, $60 - 69\% =$ D, below $60\% =$ E.