ASEN 6265. Fundamentals of Spectroscopy for Optical Remote Sensing

Syllabus, Spring 2024

Lecture: AERO 232 MWF 11:45am−12:35pm

Instructor

Professor Xinzhao Chu
Office: CIRES 241 / iPhone: 720-938-6643
Email: Xinzhao.Chu@Colorado.edu

Assistant

Jackson Jandreau
CIRES 1B56
Email: Jackson.Jandreau@colorado.edu

Office Hours: TBD (over Zoom and in person)

Prerequisites

The prerequisites for this class include basic understandings of general physics and modern physics (e.g., optical and atomic physics, optical electronics, and some laser basics). These are topics that are covered in undergraduate physics or engineering programs. If one does not have a background in some of these areas, one may expect to spend extra time on the related materials. This is a graduate class and students are expected to work independently to solve problems. There are many resources, including the library, at your disposal.

Course Objectives

Optical (especially laser) remote sensing has become one of the most important approaches in scientific research, space exploration, environmental monitoring and protection, and industry applications. It is not only replacing conventional sensors but also creating new capabilities with unique properties that could not be achieved before. Two major aspects of optical remote sensing (especially lidar – light detection and ranging) are the fundamental knowledge of **spectroscopy** and the primary principles and skills of **photonics**. In particular, extensive knowledge in atomic, molecular, and laser spectroscopy is crucial to the studies and advancement of optical and laser remote sensing technologies as well as their applications.

One of the goals of this spectroscopy course is to provide a comprehensive preparation for the laser remote sensing (lidar) class offered at CU. It will cover the fundamental knowledge from *quantum physics to atomic spectroscopy, and from molecular spectroscopy to laser spectroscopy*. Meanwhile, these contents are also very important parts of modern physics and technology, so they have very wide applications in many fields. Further goals of this spectroscopy course are to expose students to these modern physics and technologies, and to prepare them with the necessary knowledge and ability to pursue research and application in spectroscopy-related fields.

Objectives of the course are to:

(1) Provide a comprehensive overview of the fundamentals of quantum physics, atomic spectroscopy, molecular spectroscopy, and laser spectroscopy.

(2) Expose students to the spectroscopy applications in modern optical and laser remote sensing.

(3) Help students to develop the fundamental knowledge and skills for learning new things.

Course Contents

The class contains 4 major sections:

1. INTRODUCTION OF QUANTUM PHYSICS AND SPECTROSCOPY

Quantum Concepts and Experimental Facts

Wave-Particle Duality

Basics of Quantum Mechanics (Postulates, Principles, and Mathematic Formalism)

2. FUNDAMENTALS OF ATOMIC SPECTROSCOPY

Atomic Structure

Radiative Transition

Atomic Spectra

3. FUNDAMENTALS OF MOLECULAR SPECTROSCOPY

Rotational Spectroscopy

Vibrational Spectroscopy

Raman Spectroscopy

Electronic Spectroscopy

4. FUNDAMENTALS OF LASER SPECTROSCOPY

Laser Spectroscopy Basics

-- How to detect atoms and molecules?

-- How to obtain high detection sensitivity?

-- How to obtain high spectral resolution?

Doppler-limited Spectroscopy

Sub-Doppler (Doppler-free) Spectroscopy

Time-Resolved Spectroscopy

New Development

Fascinating Applications of Laser Spectroscopy

Textbooks

Textbook: Laser Spectroscopy, by Wolfgang Demtröder. (The 4th edition is acceptable.)

Laser Spectroscopy 1: Basic Principles, 5th Edition (2014)

ISBN 978-3-642-53858-2 ISBN 978-3-642-53859-9 (eBook)
DOI 10.1007/978-3-642-53859-9
Library of Congress Control Number: 2014938249
Springer

Laser Spectroscopy 2: Experimental Techniques, 5th Edition (2015)

ISBN 978-3-662-44640-9 ISBN 978-3-662-44641-6 (eBook)
DOI 10.1007/978-3-662-44641-6
Springer Heidelberg New York Dordrecht London

Major Reference Books for Students:

"Quantum Mechanics I, II" by Claude Cohen-Tannoudji (Nobel Laureate)
"Atomic and laser spectroscopy" by Alan Corney
"Structure and Spectra of Atoms" by Richards and Scott
"Molecular Spectroscopy" by John M. Brown
"Atomic Spectra" by T. P. Softley

Instructor's Reference Books:

"Quantum Mechanics I, II" by Claude Cohen-Tannoudji etc
"The Principles of Quantum Mechanics" by P. A. M. Dirac
"Quantum Mechanics" by Landau and Lifshitz
"The Quantum Theory of Light" By Rodney Loudon
"Atomic and laser spectroscopy" by Alan Corney
"Quantum Theory of Atomic Structure I, II" by Slater
"Atomic Spectra and Radiative Transitions" by Sobelman
"The Theory of Atomic Spectra" By Condon and Shortley
"Molecular Spectra and Molecular Structure I, I, III" by Herzberg
"Atomic Structure and Atomic Spectra" by Lemin Zheng and Gengwu Xu
"Atomic Physics" by Lemin Zheng
"Atomic Physics" by Fujia Yang
"Laser Spectroscopy" by Lemin Zheng
"Progress in Experimental Atomic Physics" by Taiqian Dong
"Principles of Quantum Frequency Standard" by Yiqiu Wang, Qingji Wang, Taiqian Dong and Jishi Fu

The textbook was chosen for its comprehensive descriptions of quantum physics, lasers, and laser spectroscopy. There are many books on spectroscopy, photonics, laser, optics, and optical electronics. You can access them through CU Libraries.

Class Format and Expectations

The class will be comprised of regular lectures three times per week. Reading and homework will be assigned. There will be two take-home exams (CU honor code applies). Guest lectures may be introduced to illustrate some novel applications of spectroscopy in modern optical and laser remote sensing. Laboratory trips may be arranged to see the real applications in Professor Chu's Group if the schedules and conditions work out.

Besides attending/listening to lectures and studying lecture notes well, graduate students are expected to study the textbooks and lecture chapters carefully, gaining deeper understandings than just finishing homework/exam assignments. It is these deep understandings that will enable our students to acquire the abilities for spectroscopy research and/or applications of spectroscopy to discover the world.

Course Grading

40	Homework (~8 HW planned but the actual number may vary)
30	Exam 1 (Quantum Concepts and Atomic Spectroscopy)
30	Exam 2 (Molecular and Laser Spectroscopy)
100	Total