ASEN 5519. Laser Remote Sensing

Fundamentals and Applications in Science and Engineering

Syllabus, Spring 2006

Lecture: ECST 1B21 Tuesday and Thursday 3:30-4:45 pm

Web page: http://cires.colorado.edu/science/groups/chu/classes/asen5519/

Instructor

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Office Hours: Monday 2 - 3 pm and Wednesday 2 - 3 pm

Prerequisites

The prerequisites for this class include a basic understanding of atomic, laser and optical physics, electromagnetic waves, statistics/probability, and signal processing. These are all topics that are covered in undergraduate physics or engineering programs. If you do not have a background in one of these areas you should expect to spend some extra time on the specific material. Note – This is a graduate class and you are expected to work independently to solve problems. There are many resources, including the library, at your disposal. If you feel that you are significantly deficient in more than one of the areas listed above then you should contact the instructor.

Course Objective

Laser remote sensing is an advanced technology that is not only replacing conventional sensors in science, engineering, and medicine, but also creating new methods with unique properties that could not be achieved before. The course will cover laser remote sensing principle, technology, and their applications in scientific research and industry engineering. Our goals are to provide students a comprehensive understanding of the fundamentals of laser remote sensing, and the necessary knowledge and ability to pursue research in the lidar and remote sensing field. Topics include lidars (Light Detection and Ranging), laser altimetry, and special lidars such as space-borne lidar, ocean lidar and ladar. For each topic, measurement principle, device technology, data inversion, and their applications will be taught in the classroom, while laboratory visits and field trips will give students hands-on opportunities to see and operate real lidars. Students will analyze real lidar data for conversion to physical parameters. Data conversion results will be discussed and connected to applications in atmosphere/space science, topography, pollution monitoring, ocean studies, and space engineering.

Objectives of the course are to provide:

(1) a comprehensive, yet easily understandable, up-to-date overview of the basics of laser remote sensing technologies and their potentials in scientific and industry research;

(2) exposure to and practical experience with existing laser remote sensing device and data reduction computer codes and algorithms;

(3) an introduction to various applications of laser remote sensing technology in science, and engineering.

Course Content

The class is broken into a number of sections, as follows:

1. Introduction and Quantum Physics Basics

Lectures will be given to introduce the general concept and basics of remote sensing, the history of laser remote sensing, and the wide applications of lasers from space to atmosphere to ocean as well as pollution, bio-mass, object

monitoring and detection. As preparation knowledge for this course, basics of quantum physics will be introduced: the quantum theory of light, atomic and laser spectroscopy, radiation propagation, laser and how it works, etc.

2. FUNDAMENTALS OF LASER REMOTE SENSING

Several lectures will be devoted to discuss laser remote sensing principles, lidar equation, physical processes involved in the interaction between light and objects, lidar system architecture, optical physics for lidar instrumentation, lidar data inversion, and lidar error analysis.

3. TOPICAL LIDARS AND THEIR APPLICATIONS

Several lidars will be discussed in considerable detail for chosen topics (aerosol/clouds, constituent densities, temperature, wind, solid target, etc). The discussions include the physical principles, device hardware, data inversion, and applications. Students will be given opportunities to visit some practical lidar systems. Real lidar data will be handed out to students for data reduction as homework projects. The results from these projects will be discussed with respect to their applications in atmosphere/space science, topography, ocean study, etc.

A. Lidars for Aerosol/Cloud Measurements

Mie/Rayleigh/Raman scattering and high-spectral-resolution lidars will be discussed. Lidar data on polar mesospheric clouds (PMC), polar stratospheric clouds (PSC), and lower atmosphere clouds will be given to students for data reduction. We will discuss how these data contribute to our understanding of cloud formation and global climate change.

B. Lidars for Constituent Measurements

Resonance fluorescence lidar, differential absorption lidar (DIAL), and Raman lidar will be introduced. Real lidar data from broadband Na and K lidars will be given to students for data reduction (resonance fluorescence). How these lidars contribute to mesosphere metal layer study will be discussed. Application examples will be given to show how people gain knowledge on atmosphere dynamics, structure and chemistry from these measurements.

C. Lidars for Temperature Measurements

Resonance fluorescence Doppler lidar, Boltzmann lidar and Rayleigh lidar for temperature measurements will be introduced. Real lidar data from the UICU and CSU Na wind and temperature lidars will be handed out to students for data reduction. Visit to the CSU Na wind/temperature lidar will be arranged. Students may have the opportunity to participate in the operation of a containerized Fe Boltzmann temperature lidar on campus. How these temperature data help in atmospheric model validation will be discussed.

D. Lidars for Wind Measurements

Coherent wind lidar and direct-detection wind lidars will be introduced. Real wind lidar data provided by Dr. Mike Hardesty and Dr. Alan Brewer of NOAA, will be handed out to students for data reduction. Visit to a NOAA lidar group will be arranged. How these wind measurements contribute to boundary layer study and to atmospheric model validation will be discussed.

E. Lidars for Solid Target Detection

Laser altimetry, ladar (imaging lidar), fish lidar, and coherent vibration lidars will be discussed. Some fish lidar data from NOAA lidar group will be handed to students to work with. Some data from Coherent Technology, Inc (CTI) will be used to derive coherent vibrations.

4. CONSIDERATIONS IN LIDAR DESIGN AND APPLICATIONS

After acquiring the principles of various lidar technologies, we will discuss lidars from the point-of-view of how to design new lidar systems to meet application requirements: what should be considered in the design of a lidar transmitter, receiver, interface, and methods of data acquisition and data/error analysis?

A. Transmitter Considerations

Considerations on laser wavelength, linewidth, accuracy, precision and stabilities as well as divergent angle, alignment stability.

B. Receiver Considerations

Considerations on receiver aperture, filter, and detector characteristics. Deployable telescope and polarization detection will also be introduced.

C. Interface and Data Acquisition

Considerations on interface programming and data acquisition codes.

D. Data Reduction and Error Analysis

Discussions of measurement errors (systematic and random errors) versus lidar system parameters and design.

E. Novel Lidar Applications

A few novel lidar applications will be introduced, giving examples of lidar design considerations for specific applications.

5. FUTURE OUTLOOK

Where do we go from here? Open discussions with students and experts will provide an overview for possible future development and application of laser remote sensing technologies.

Texts

Required Textbook: Laser Remote Sensing, Edited by Takshi Fujii and Tetsuo Fukuchi, Published by CRC Press, Taylor & Francis Group, ISBN: 0-8247-4256-7, 2005.

This text was chosen for its newest and frontier descriptions of modern lidars and applications. During the course of the semester chapters will be assigned for reading requirements. Supplementary material will also be provided during the course to provide more clarity or depth to a topic. There are some books on lidars that you can access through the Engineering Library to provide a different point of view on the material we will cover in class. I have placed these books on reserve at the Engineering Library:

- Laser Remote Sensing, edited by Takshi Fujii and Tetsuo Fukuchi, published by CRC Press, Taylor & Francis Group, ISBN: 0-8247-4256-7, 2005.
- Laser Remote Sensing: fundamentals and applications, by Raymond M. Measures, Wiley-Interscience, New York, ISBN: 0-89464-619-2, 1984.

Class Format

From January until late-February the class will be comprised of regular lectures two times per week. During this time, reading and homework will be assigned and group projects will be formulated. There will be an exam during this period. The exams will be a take-home-exam. More detailed information will be provided closer to the exam time. The course will also include a term project that will involve teams working on a proposed lidar system for a particular remote sensing application. The projects and teams will be formulated after about 4 weeks into the semester. From late-February to early April, we will have lectures on specific lidar systems by the instructor and invited speakers. Another take-home-exam will be given during this period. Through most of the time in April and early May, lectures on lidar design will be given and students presenting their term project. The class will terminate with a final written report. Students will participate in both the oral presentations and written reports by providing peer reviews of the work presented.

Course Grading

30	Homework	10	Homework
20	Exams (2)	60	Homework Project (x6)
30	Final Project	30	Final Project
100	Total	100	Total

Disabilities

If you qualify for accommodations because of a disability, please submit a letter to me from Disability Services in a timely manner so that your needs may be addressed. Disability Services determines accommodations based on documented disabilities. Contact: 303-492-8671, Willard 322, or

www.Colorado.EDU/disabilityservices

Religious Observances

Campus policy regarding religious observances requires that faculty make every effort to reasonably and fairly deal with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, all dates for exams, assignments and presentations are fixed in the course schedule. Please review the course schedule and let me know if certain dates conflict with your religious obligations. See policy details at

http://www.colorado.edu/policies/fac_relig.html

Classroom behavior

Students and faculty each have responsibility for maintaining an appropriate learning environment. Students who fail to adhere to behavioral standards may be subject to discipline. Faculty have the professional responsibility to treat students with understanding, dignity and respect, to guide classroom discussion and to set reasonable limits on the manner in which students express opinions.
See policies at

http://www.colorado.edu/policies/classbehavior.html and at
http://www.colorado.edu/studentaffairs/judicialaffairs/code.html#student_code

Academic Honor Code

As a student at the University of Colorado you are bound by an academic code of honor. The purpose of an Honor Code at the University of Colorado at Boulder is to secure an environment where academic integrity, and the resulting behavior, can flourish. The Honor Code recognizes the importance of honesty, trust, fairness, respect, and responsibility and wishes these principles to be a defining part of the CU-Boulder campus. The Honor Code allows all students to have responsibility for, and the ability to attain, appropriate recognition for their academic and personal achievements. A student-run Honor Code is necessary because research indicates that these institutions are highly successful in alleviating indiscretions and promoting an academically honorable community. In addressing any proven student violations regarding the Honor Code, the student leadership of the Honor Code Council applies only non-academic sanctions, and the faculty applies academic sanctions.

- Academic Dishonesty: Any of the following acts, when committed by a student at the University of Colorado at Boulder, shall constitute academic dishonesty:
  i. Plagiarism: Portrayal of another's work or ideas as one's own;
  ii. Cheating: Using unauthorized notes or study aids, allowing another party to do one's work/exam and turning in that work/exam as one's own; submitting the same or similar work in more than one course without permission from the course instructors;
  iii. Fabrication: Falsification or creation of data, research or resources, or altering a graded work without the prior consent of the course instructor;
  iv. Aid of Academic Dishonesty: Intentionally facilitating plagiarism, cheating, or fabrication;
  v. Lying: Deliberate falsification with the intent to deceive in written or verbal form as it applies to an academic submission;
  vi. Bribery: Providing, offering, or taking rewards in exchange for a grade, an assignment, or the aid of academic dishonesty;
  vii. Threat: An attempt to intimidate a student, staff, or faculty member for the purpose of receiving an unearned grade or in an effort to prevent the reporting of an Honor Code violation.

Violations of the Honor Code are acts of academic dishonesty and include but are not limited to: plagiarism, cheating, fabrication, aid of academic dishonesty, lying to course instructors, lying to representatives of the Honor Code, bribery or threats pertaining to academic matters, or an attempt to do any of the aforementioned violations. All incidents of academic

misconduct shall be reported to the Honor Code Council (honor@colorado.edu; 303-725-2273). Students who are found to be in violation of the academic integrity policy will be subject to both academic sanctions from the faculty member and non-academic sanctions (including but not limited to university probation, suspension, or expulsion). **Any act of academic dishonesty will result in an F for this course** and will become a permanent part of the student's academic record. For more information about the University of Colorado student honor code see

http://www.colorado.edu/policies/honor.html and at http://www.colorado.edu/academics/honorcode/

Plagiarism

This course includes a research project and final written report. In constructing the research paper it is expected that ideas and concepts will come from specific reference material. It must be demonstrated that this material supports the original premise of your research project and is properly referenced. Please examine the following guidelines to avoid committing plagiarism:

What is Plagiarism?, Georgetown University
How to avoid Plagiarism, Northwestern University
Plagiarism: What it is and how to recognize and avoid it, Indiana University

Sexual Harassment Policy

The University of Colorado Policy on Sexual Harassment applies to all students, staff and faculty. Sexual harassment is unwelcome sexual attention. It can involve intimidation, threats, coercion, or promises or create an environment that is hostile or offensive. Harassment may occur between members of the same or opposite gender and between any combination of members in the campus
community: students, faculty, staff, and administrators. Harassment can occur anywhere on campus, including the classroom, the workplace, or a residence hall. Any student, staff or faculty member who believes s/he has been sexually harassed should contact the Office of Sexual Harassment (OSH) at 303-492-2127 or the Office of Judicial Affairs at 303-492-5550. Information about the OSH and the campus resources available to assist individuals who believe they have been sexually harassed can be obtained at:
http://www.colorado.edu/sexualharassment/

Other Policies

Please be respectful of others during class time. This includes turning off your cell phone before class and not talking during class unless you have the floor. Details about all of the university policies can be found on the web at http://www.colorado.edu/policies/index.htm