Laser Remote Sensing Course Schedule (Spring 2006)

Actual Course Schedule

15 weeks X 2 = 30 lectures (75 minutes each)

Instructor: Professor Xinzhao Chu

Week

1

17 Jan 2006 - Tuesday

Lecture 1. Introduction

Introduction
Concept of Remote Sensing
Concept of Remote Sensing System
Remote Sensing Aspects and Applications
Classification of Remote Sensing
Comparison of Remote Sensing
How does sodar, radar, & lidar work?
Summary

19 Jan 2006 - Thursday

Lecture 2. Laser Remote Sensing Overview

Introduction
History from searchlight to modern lidar
Basic Architecture of LIDAR
Basic Configurations of LIDAR
How does LIDAR determine range?
Basic Principle of LIDAR - LIDAR Equation
Classifications of LIDAR
Summary

2

24 Jan 2006 - Tuesday

Lecture 3. Lidar Principle Overview (Cont)

Review lidar equation & lidar architecture
An example lidar - K Doppler lidar
Classification of lidar
Comparison of Scattering
Summary

26 Jan 2006 - Thursday

Lecture 4. Quantum Physics in Lidar Principle

Overiew of quantum physics
Quantum theory of light: wave-particle duality
Wave-Particle Duality for Material Particles
QM Basic Concepts
QM Equation of Motion: Schrodinger equation
Stationary states: atomic structure
Transition: atomic spectra

3

31 Jan 2006 - Tuesday

Lecture 5. Fundamentals of Quantum Mechanics

Introduction
Principle of Uncertainty (Indeterminacy)
Principle of Superposition of States
  Eigenstates and Eigenvalues
  Wave Packet
Equation of Motion - Schrodinger Equation
Postulates of Quantum Mechanics

2 Feb 2006 - Thursday

Lecture 6. Fundamentals of Atomic Structure

QM Notation (Dirac) and Representation
Eigenvalue Equation vs. Schrodinger Equation
Atomic Structure: Coulomb Force in Hydrogen Atom
Atomic Structure: Central-Field Approximation
Atomic Structure: Pauli Exclusion Principle
Atomic Structure: Magnetic Interaction,
Atomic Structure: Influence of Nucleus
Atomic Structure: Influence of Extrenal Field

4

7 Feb 2006 - Tuesday

Lecture 7. Fundamentals of Atomic Spectra

Introduction
Perturbation Theory (time-independent)
Perturbation Theory (time-dependent)
Atomic Transition: transition probability
Atomic Transition: selection rules
Atomic Transition: oscillator strength
Atomic Transition: polarization
Atomic Transition: light intensity

9 Feb 2006 - Thursday

Lecture 8. Fundamenals of Laser Spectroscopy

Introduction
Laser Spectroscopy: natural linewidth
Laser Spectroscopy: collision broadening
Laser Spectroscopy: Doppler broadening
Classification of broadening
Voigt Integration
Effect of instrumental shape or laser shape
Saturation and saturation broadening
Saturation-absorption spectroscopy

5

14 Feb 2005 - Tuesday

Lecture 9. Fundamentals of Molecular Spectroscopy

Introduction
Molecular Structure: qualitative description
Molecular Structure: QM description
Molecular Structure: electronic motion
Molecular Structure: nuclear vibration
Molecular Structure: molecular rotation
Molecular Spectra: nonzero matrix element of dipole
Molecular Spectra: electronic spectra
Molecular Spectra: vibration-rotation spectra
Molecular Spectra: rotation spectra

17 Feb 2006 - Friday (1:30-2:45pm)

Lecture 10. Fundamentals of Scattering Theory

Introduction: Nonbound state theory
QM General Theory of Scattering
Light Scattering by particles
Elastic and inelastic scattering
Nonresonance scattering versus fluorescence
QM Calculation of Scattering Cross-section
Physics: Induced electronic dipole moment
Molecular vibration and rotation dipole moment
Rayleigh/Mie Scattering and Raman Spectra
Resonance Rayleigh/Raman Scattering

Week	Tuesday	Thursday
6	21 Feb 2006 - Tuesday **Lecture 11. LIDAR Equation** Introduction Physical processes in lidar remote sensing General form of lidar equation Considerations on efficiency and geometry Scattering form of lidar equation Fluorescence form of lidar equation Differential absorption form of lidar equation Solutions of lidar equation Summnary	23 Feb 2006 - Thursday (5:00-6:15pm) **Lecture 12. LIDAR Data Inversion** Introduction From photon counts to beta, n, T, V_R to science Considerations for lidar data inversion Preprocess procedure Process to retrieve beta and n Process to retrieve T and V_R Summary **(HW Project#1: process Na lidar density data)**
7	28 Feb 2006 - Tuesday **Lecture 13. LIDAR Architecture** Introduction Basic Architecture Basic Configuration Basic Arrangement Considerations on Lidar Instrumentation Example: Na Doppler Lidar Example: Fe Boltzmann lidar Summary	2 Mar 2006 - Thursday (5:30-6:45pm) **Lecture 14. LIDAR Architecture (2)** Introduction Na Doppler Lidar: 3-frequency technique Laser Principle in general Ring Dye Laser and frequency/bandwidth control Wavemeter (Michelson Interferometer) Na saturation-absorption spectroscopy Acousto-Optical modulator Pulsed dye amplification Faraday filter Summary **(Field trip: visit CSU lidar site on Sunday)**
8	7 March 2006 - Tuesday **Lecture 15. LIDAR Architecture (3)** CSU field trip review Lidar Transmitter Dual-AOM, PDA, Injection seeding Lidar Receiver Faraday filter Multiple beam interference F-P etalon and interference filter More on laser basics	9 March 2006 - Thursday **Lecture 16. Review on LIDAR Fundamentals** Review of ldiar principle and architecture Review of lidar data retrieval Review of QM, spectroscopy, and lasers Open discussions
9	14 March 2006 - Tuesday **Lecture 17. Temperature Lidar (1)** Introduction to topical lidars Motivations to measure temperature and wind Techniques for temperature measurements Doppler technique for T and W measurements Resonance fluorescence Na Doppler lidar (Principle, Metrics, and Calibration) Na Doppler lidar instrumentation Summary **(Homework: Project-2 Na Lidar T and W)**	16 March 2006 - Thursday **Lecture 18. Temperature Lidar (2)** Review of Doppler technique Procedure to derive T/W from Na lidar data Resonance fluorescence Fe Boltzmann lidar (Principle, Metrics, Calibration) Fe Boltzmann lidar instrumentation Sensitivity analysis of temperature lidars Summary
10	21 March 2006 - Tuesday **Lecture 19. Temperature Lidar (3)** Review of Doppler and Boltzmann techniques Doppler Ratio Technique Accuracy versus Precision Error analysis of Na Doppler lidar (Accuracy, Precision, Error Propagation) Rayleigh Integration technique Error Analysis of Rayleigh Integration Lidar Rayleigh lidar instrumentation Summary	23 March 2006 - Thursday **Lecture 20. Temperature Lidar (4)** Review of Rayleigh Integration Technique High-Spectral-Resolution Lidar Rayleigh Doppler Technique Rotational Raman Technique DIAL Temperature Profiling Comparison of Temperature Lidar Techniques Newly Developing Temperature Lidars (K Doppler, Solid-State Na and Fe Doppler) Summary
11	**28 Mar 2006 - Spring Break**	**30 Mar 2006 - Spring Break**

Week	Tuesday	Thursday
	4 April 2006 - Tuesday	6 April 2006 - Thursday
12	**Lecture 21. Wind Lidar (1)** Motivations to Measure Global Wind Techniques for Wind Measurements (Doppler wind, direct motion detection, geostrophic wind) Direct Motion Detection Technique (Tracking aerosol/cloud motion, transit time) Direct Detection Doppler Wind Lidar (Atomic absorption lines, Edge Filters, Fringe Imaging) Wind Technique Comparison Summary	**Lecture 22. Wind Lidar (2)** **Guest lecture on Coherent Doppler Lidar** **By Dr. Sara Tucker** **(Homework: Project-3 Coherent)**
	11 April 2006 - Tuesday	13 April 2006 - Thursday
13	**Lecture 23. Wind Lidar (3)** Review of Wind Lidar Techniques (Direct Motion Detection & Doppler Wind Lidar) Vector and Horizontal Wind Determination (VAD, DBS, and Modified DBS) Wind Technique Comparison Coherent Detection Doppler Lidar Architecture Direct Detection Doppler Lidar Architecture GroundWinds Doppler Lidar Summary	**Lecture 24. Aerosol Lidar (1)** **Guest lecture on CALIPSO Lidar** **By Dr. Carl Weimer**
	18 April 2006 - Tuesday	20 April 2006 - Thursday
14	**Lecture 25. Middle Atmosphere Lidar** **Guest Lecture on Temp Lidar Comparison** **By Dr. Chester S. Gardner**	**Lecture 26. Aerosol Lidar (2)** Motivations to Study Aerosols and Clouds Lidar Detection of Aerosol/Cloud Properties Single-channel vs Multi-channel lidar (Elastic-scattering lidar, Raman lidar and HSRL) Polarization Detection Multi-wavelength detection Lidar detection of PMC and PSC Summary
	25 April 2006 - Tuesday	27 April 2006 - Thursday
15	**Lecture 27A. Aerosol Lidar (3)** Review of Aerosol Lidars Multi-wavelength and polarization Detection of Aerosols Comparison of Aerosol Lidar Techniques **Lecture 27B. Constituent Lidar (1)** Motivations to Study Atmosphere Constituents Lidar Detection of Constituents (essentially spectroscopic detection to distinguish species) Metal Atoms by Resonance Fluorescence Lidar DIAL Detection of Molecules and Pollutant (DIAL equation, solution, water vapor measurement) Summary	**Lecture 28. Constituent Lidar (2)** Review of Constituent Lidars Raman Scattering Lidar for Constituent Detection (Example: water vapor measurement) Raman DIAL (Example: ozone measurement) RVR Raman DIAL Summary
	2 May 2006 - Tuesday	4 May 2006 - Thursday
16	**Lecture 29A. Constituent Lidar (3)** Conventional Raman DIAL vs. RVR Raman DIAL Multiwavelength DIAL Comparison of Constituent Lidar Techniques Summary for DIAL and Raman **Lecture 29B. Target Lidar** Motivations for Target Lidar Laser Altimeter GLAS on ICESat Fluorescence Lidar for Liquids and Solids More Target and Imaging Lidars Summary of Target Lidar Techniques	**Lecture 30. Review of Lidar Class** Concept and Picture of Lidar Remote Sensing General Lidar Equation and the Ideas behind it Physical Processes involved in different Lidars Lidar Architecture Altitude Determination for Different Lidars Topical Lidar Technique Summary (Temp, Wind, Aerosol, Constituent, Target) Classifications of Lidars Challenges in Different Categories of Lidars Novel Lidar Technology and Application Outlook on Lidar Remote Sensing

Conclusion on May 4, 2006

---

10 May 2006 - HW Projects Due Wednesday **Final Grade on 12 May 2006 Friday**