ASEN-5519
Fundamentals of Spectroscopy for (Optical) Remote Sensing

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Introduction

1. Concepts of Spectroscopy

2. Why to Study Spectroscopy ?

3. Class Structure, Schedule, and Grading Policy

4. Lab Visit: Chu Laser/Lidar Laboratory

1. Concepts of Spectroscopy

Spectroscopy is the study of the interaction between radiation (photons, phonons, or particles) and matter.

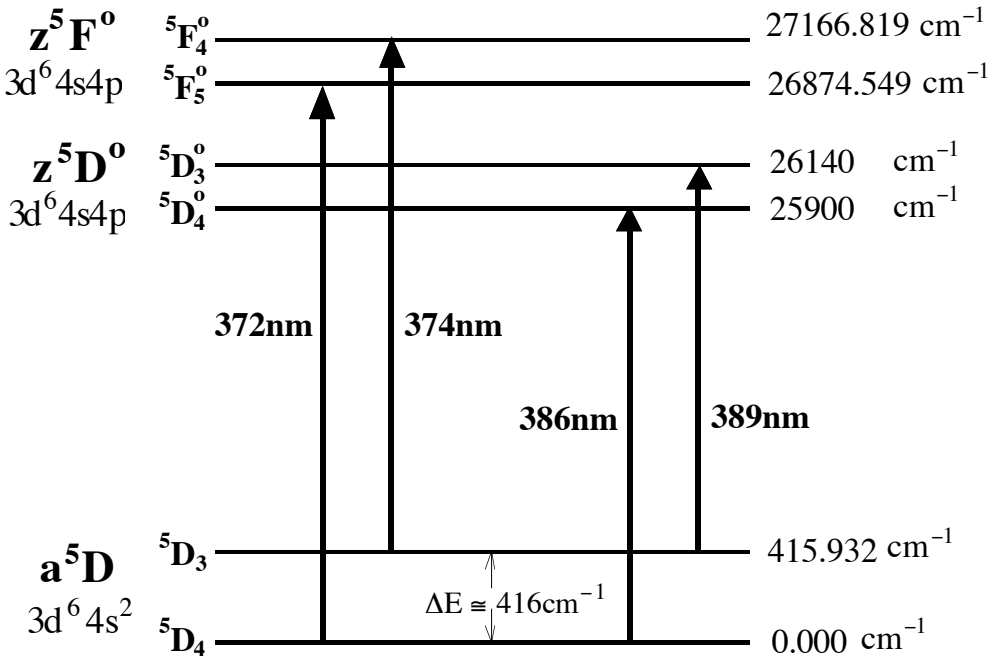
Spectroscopy is the study of matter by investigating radiation (photons, phonons, or particles) that is absorbed, emitted, or scattered by the matter under investigation.

The radiation includes all forms of electromagnetic radiation and non-electromagnetic radiation. For example,

EM radiation (photons): radiowaves, microwaves, infrared light, visible light, ultra-violet light, X-ray, etc.

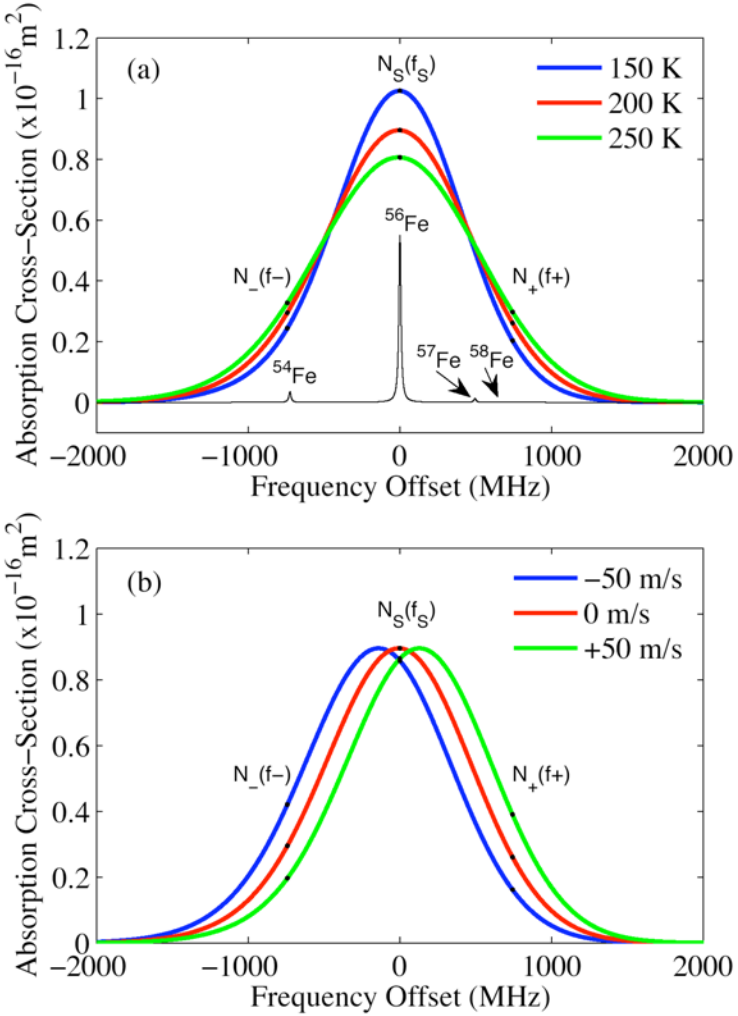
Non-EM radiation: phonons (acoustic wave), electrons, etc.

Spectroscopy in the Major Research Instrumentation (MRI) Lidar



Atomic Fe energy levels

Advanced Spectroscopy won us the MRI Award from NSF!!!



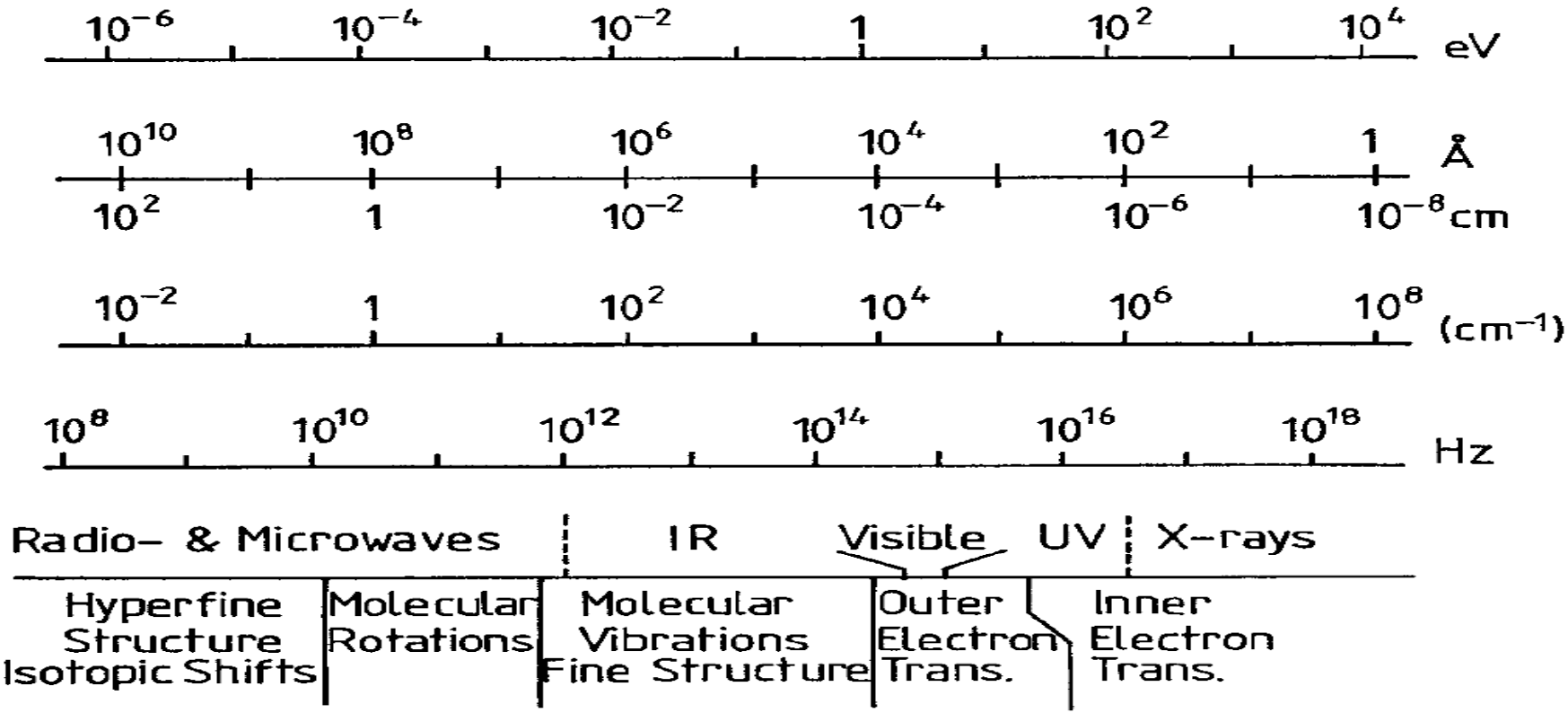
Doppler broadening and shift of Fe 372-nm absorption line

Classification of Spectroscopy

According to radiation used in the study, spectroscopy can be classified to three main types of spectroscopy:

EM spectroscopy, Acoustic Spectroscopy, Mass Spectroscopy.

We deal with EM spectroscopy here.



2. Why to Study Spectroscopy?

1. **Spectroscopy is the fundamental for all remote sensing technologies, and also fundamental for many other modern sciences and technologies.**
2. **Spectroscopy has found very wide applications in many fields. (Spectroscopy vs. radiometry and photometry)**
3. **We want to give students the abilities and fundamental knowledge to learn other things -**

   "Teach students the skills to learn new things".
4. **Pre-requisition course for lidar remote sensing taught in Spring Semester (2009).**

2. Why to Study Spectroscopy ?

Spectroscopy is an very important approach to study the fundamental matter (fundamental particles, atoms, molecules, etc.) structure and internal interaction.

Spectroscopy is often used in physics and analytical chemistry for the identification of substances through the spectrum emitted from them or absorbed in them.

Spectroscopy is also heavily used in astronomy and remote sensing. They are used either to measure the chemical composition and physical properties of objects or to measure related environmental properties like velocities and temperatures from the Doppler shift and broadening of spectral lines.

Applications of Spectroscopy

Two main types of study of spectroscopy -

(1) Fundamental study of matter structure (e.g., atomic or molecular structure, etc.)

Spectrum study (wavelength, transition probability, etc.) is the fundamental method to study atomic and molecular structures.

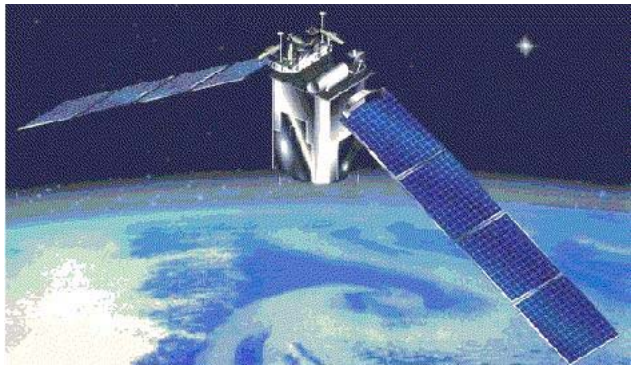
(2) Applied study of environmental properties (e.g., remote sensing of atmosphere parameters, chemical analysis)

Identification of chemical composition and measurement of their quantity using spectroscopy.

Measurement of environmental conditions like wind and temperature through spectroscopy analysis.

The SABER Instrument Aboard the TIMED Satellite

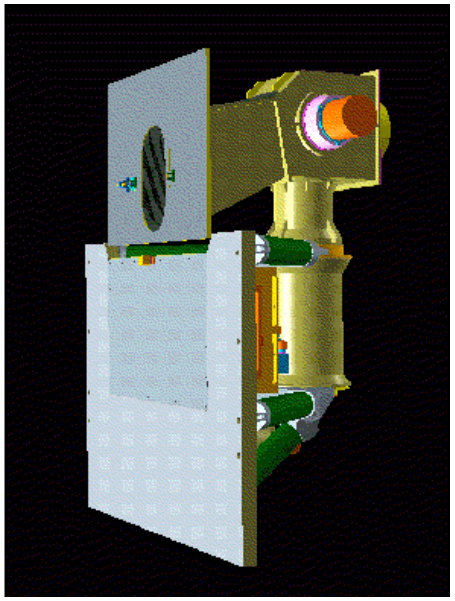
TIMED: Thermosphere, Ionosphere, Mesosphere Energetics & Dynamics



SABER: Sounding of the Atmosphere Using Broadband Emission Radiometry

SABER instrument:

- **Limb scanning infrared radiometer**
- **10 broadband channels (1.27-17 μm)**
- **Products: kinetic temperature, CO_2, O_3, H_2O, NO, O_2, OH, O, H**



[Courtesy of Dr. *Artem Feofilov et al.*, NASA, 2007]

3. Spectroscopy Course Structure

Introduction

Part I. Fundamentals of Quantum Mechanics

(QM Concepts, Principles, and Mathematic Formalism)

Part II. Fundamentals of Atomic Spectroscopy

(Atomic Structure, Radiative Transitions, Atomic Spectra)

Part III. Fundamentals of Molecular Spectroscopy

(Molecular Structure and Molecular Spectra)

Part IV. Fundamentals of Laser Spectroscopy

(High-Sensitivity and High-Resolution Spectroscopy Methods)

Summary

Course Schedule

Introduction	**1 Lecture**
Part I. Fundamentals of Quantum Mechanics	**3 Weeks**
Part II. Fundamentals of Atomic Spectroscopy	**5.5 Weeks**
Part III. Fundamentals of Molecular Spectroscopy	**2 Weeks**
Part IV. Fundamentals of Laser Spectroscopy	**3 Weeks**
Summary	**2 Lectures**

Grading Policy

45% Homework: 11 HWK (~ 4% per HWK)

15% Exam 1: Quantum Mechanics (Take-Home)

20% Exam 2: Atomic spectroscopy (Take-Home)

20% Exam 3: Molecular and laser spectroscopy (Take-Home)

± 3% Classroom Reaction:

100-point grading system for each exam and homework

Students are required to finish each homework and exam independently !!!

Textbook and Reference Books

Textbook: **"Laser Spectroscopy" by W. Demtröder**

Major Reference Books for Students:

"Quantum Mechanics I, II" by Claude Cohen-Tannoudji (Nobel Laureate)

"Atomic and laser spectroscopy" by A. 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 A. 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

Office Hours in Fall 2007

Lectures: M. W. F. 2:00-2:50pm @ KTCH 234

Office hours: Monday & Wednesday 3:00-4:00pm

@ CIRES 1B49 with Xinzhao and/or Wentao

Questions regarding

lecture contents, homework problems, & others

How to Study Spectroscopy ?

1. **Write notes and try to understand the most in classes**
2. **Review lecture notes and book chapters after class**
3. **Do homework to apply learned skills and check concepts**
4. **Discuss with instructors and classmates to get clear concepts**
5. **Visit Chu research group to get first hand experience**