WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Chemistry 860
Spectroscopy of Individual Molecules and Particles
Spring 2018

Meeting Time and Location:
11 – 11:50 a.m. Mon, Wed, Fri, Rm. 8335 Chemistry
(typically two lectures/week, often on Mon and Wed)

Instructional Mode: all face-to-face.

2/3 Credits: The variable number of credits provides interested students with the opportunity of earning one extra credit by composing an original research proposal at the end of the semester.

How Credit Hours are Met:
The class meets on average each week for two 50-minute lectures. Over the course of the semester, students enrolled for two credits are expected to do at least 90 hours of learning activities, which includes class attendance, reading, studying, preparation, problem sets, papers, and an oral presentation. Students enrolled for 3 credits will have an additional 45 hours of outside work for their original research proposal.

Instructor: Prof. Randall Goldsmith (rhg@chem.wisc.edu)

Instructor Availability: after lecture with additional office hours by appointment.

COURSE DESCRIPTION

Molecules are the central actors in nearly all physical descriptions of condensed matter physics, thermodynamics, molecular and cellular biology, and chemistry. Though molecules' collective actions are often sufficient to describe a physical system, in many cases, revealing the properties and behavior of individual molecules is critical to understanding physical mechanism. This feature has made measurements on individual molecules a particularly illuminating mechanistic tool with uses spanning chemistry, biology, and physics.

The first optical measurements on individual molecules were performed in 1989 at low temperatures, but quickly proliferated to room temperature and even solution-phase measurements. Single-molecule measurements quickly coopted contemporaneous advances in microscopy, nanophotonics, and biochemistry, adding additional observational dimensions and applications. By the turn of the century, the milestones for single-molecule measurements had piled up. Basic assumptions regarding the roles of homogenous and inhomogeneous broadening in determining lineshape had been confirmed. Individual biomolecules could be observed fulfilling their biological roles, with conformational changes and single enzyme turn-overs resolved in real time, acquisition of true molecular movies a reality. Individual biomolecules could even be observed in live cells. Single molecules became favorite tools of quantum optics. The behavior of complex materials could be understood through the observations on molecular components.

Three years removed from the awarding of a Nobel Prize in chemistry where single-molecule spectroscopy figured prominently, the field continues to be vibrant, innovative, and ever-expanding. Instrumentation-development continues to produce enabling technologies to apply single-molecule observations to new places, while existing techniques have become trusted workhorse tools, particularly in biology, where they continue to reveal exciting and surprising molecular behavior. Thus, single-molecule spectroscopy has become the rare venue where researchers in physics, chemistry, biology, and materials science can all agree is a generator of observations of unique value and lasting importance.

This course will trace the history of single-molecule techniques, discuss underlying physical mechanisms, instrumentation (including theoretical and practical issues), statistics, and extremely wide range of applications spanning biology, chemistry, and physics.

Requisites
Graduate or professional standing
CHEM 562 or equivalent is recommended.

LEARNING OUTCOMES

At the conclusion of this course, students (undergraduate and graduate) will be familiar with a variety of aspects of optical measurements on single molecules and particles, including motivations, history of the field, instrumentation, limitations, and modern applications. Students enrolling in the 3-credit option will also gain experience in writing proposals.

GRADING

2-Credits	30% attendance, participation, problem sets 30% midterm paper (technique primer) 40% oral presentation
3-Credits	20% attendance, participation, problem sets 20% midterm paper (technique primer) 30% oral presentation 30% original research proposal

Midterm paper: Write a primer on a particular technique or body of work. Clear topics with Professor Goldsmith beforehand. Due second week of March.

Final Presentation: An oral presentation using powerpoint (or equivalent) on a technique or application of single-molecule or single-particle measurements that we have NOT focused on during class. Clear topics with Professor Goldsmith beforehand. To be presented late April/Early May.

REQUIRED TEXTBOOK, SOFTWARE & OTHER COURSE MATERIALS

No textbook is required. Useful/recommended books include:

M. D. Fayer, "*Elements of Quantum Mechanics*", 2001

A. Nitzan, "*Chemical Dynamics in Condensed Phases*", 2006

N. J. Turro, "*Modern Molecular Photochemistry*", 1991

J. R. Lakowicz *"Principles of Fluorescence Spectroscopy"*, 3rd ed., Springer 2006

ACADEMIC INTEGRITY

By enrolling in this course, each student assumes the responsibilities of an active participant in UW-Madison's community of scholars in which everyone's academic work and behavior are held to the highest academic integrity standards. Academic misconduct compromises the integrity of the university. Cheating, fabrication, plagiarism, unauthorized collaboration, and helping others commit these acts are examples of academic misconduct, which can result in disciplinary action. This includes but is not limited to failure on the assignment/course, disciplinary probation, or suspension. Substantial or repeated cases of misconduct will be forwarded to the Office of Student Conduct & Community Standards for additional review. For more information, refer to studentconduct.wiscweb.wisc.edu/academic-integrity/.

ACCOMMODATIONS FOR STUDENTS WITH DISABILITIES

McBurney Disability Resource Center syllabus statement: "The University of Wisconsin-Madison supports the right of all enrolled students to a full and equal educational opportunity. The Americans with Disabilities Act (ADA), Wisconsin State Statute (36.12), and UW-Madison policy (Faculty Document 1071) require that students with disabilities be reasonably accommodated in instruction and campus life. Reasonable accommodations for students with disabilities is a shared faculty and student responsibility. Students are expected to inform faculty [me] of their need for instructional accommodations by the end of the third week of the semester, or as soon as possible after a disability has been incurred or recognized. Faculty [I], will work either directly with the student [you] or in coordination with the McBurney Center to identify and provide reasonable instructional accommodations. Disability information, including instructional accommodations as part of a student's educational record, is confidential and protected under FERPA." http://mcburney.wisc.edu/facstaffother/faculty/syllabus.php

DIVERSITY & INCLUSION

Institutional statement on diversity: "Diversity is a source of strength, creativity, and innovation for UW-Madison. We value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals.

The University of Wisconsin-Madison fulfills its public mission by creating a welcoming and inclusive community for people from every background – people who as students, faculty, and staff serve Wisconsin and the world." https://diversity.wisc.edu/

Tentative Topics List: Topics will change shift depending on the evolving interests of the class.

Electronic Spectroscopy
Lineshapes and Linewidths
Dye Photophysics
Zero Phonon Lines
Spectral Hole Burning
Poisson Processes
Statistical Fine Structure
Frequency Modulation Spectrocopy
Single-Molecule Absorption Spectroscopy
Single-Molecule Fluorescence Spectroscopy
Photon Anti-bunching
Fluorescence Correlation Spectroscopy
Solution-Phase Measurements
Origins of Background
Raman Spectroscopy
Confocal Detection
Near Field Scanning Optical Microscopy (NSOM)
Point Spread Functions
Microscopy Optics
Epifluorescence
Total Internal Reflection Microscopy (TIRF)
Ergodic Principle
Detectors
Cameras
Super-Localization
Forster Resonance Energy Transfer (FRET)
Biological Applications (Enzymes, Rotors, etc.)
Surface-Enhancement Raman Spectroscopy
Single-Molecule Experiment Design

OPTIONAL TOPICS:
Single-Molecule Force Spectroscopy
Optical Tweezers
Conjugated Polymers
In vivo Measurements
Super Resolution Microscopy
Photonic Schemes (Microcavities)
Time-Series Analysis
Microfluidics, More