PH 585 **Spring 2024**

Celebration of the AMO Symposium

Wednesday, May 29

2:35-2:50

Resonance-enhanced Multiphoton Ionization

Presenters: Benhardt Hansen, Kim Tran

Abstract:
Multiphoton Ionization is the process when an atom or molecule absorbs simultaneously many photons, and the absorbed multiphoton energy overcomes ionization potential of atom, which leads to ionization.[1-4] Due to small multiphoton absorption cross section, a short pulse, high laser intensity, typically above 10^9 W/cm^2, is required to achieve this phenomenon. Current research in multiphoton ionization involves strong field laser-matter interaction, and a resonance-enhanced multiphoton ionization (REMPI) technique to study spectroscopic structures of gas molecules. Our talk will cover the theory and experimental set-up of REMPI. Additionally, we summarize key results from the literature paper using REMPI and DFT calculations to study excitation structure and solvent effect of flavone molecules, which has an application in sunscreen formulation.[7]

Outline:

- Multiphoton ionization
  - o Definition
  - o Brief history
  - o Use perturbation theory to derive multiphoton absorption transition rate and cross section
  - o Brief overview of current research involving in multiphoton ionization:
    - Resonance/ non-resonance multiphoton ionization
    - Strong field physics
- · Resonance enhanced MPI (REMPI): Application in spectroscopy study
  - o Experimental setup:
    - Laser set-up
    - Time-of-flight spectrometry to monitor ion signal
    - Identify Ionization energy threshold of molecule
  - o Key results when using (1+1) R2PI, and DFT calculation to study excitation structure and solvent effect of Flavone molecule

References:

1. He, Guang S., 'Multiphoton Absorption (MPA) Theories', Laser Stimulated Scattering and Multiphoton Excitation (Oxford, 2022), https://doi.org/10.1093/oso/9780192895615.003.0010
2. He, Guang S., 'Multiphoton Ionization of Atoms and Molecules', Laser Stimulated Scattering and Multiphoton Excitation (Oxford, 2022), https://doi.org/10.1093/oso/9780192895615.003.0013.
3. Mainfray, G. Manus, C. Multiphoton ionization of atoms. Rep. prog. phys. 1991, 54, 1333. DOI 10.1088/0034-4885/54/10/002.
4. Bransden, B., Joachain, C., 'Atom in Strong Laser field', Physics of Atoms and Molecules' (Pearson, 2001).
5. Göppert-Mayer, M. Elementary processes with two quantum transitions. Annalen der Physik. 2009, 18 (7-8), 466-479. DOI: 10.1002/andp.200952107-803.
6. Hall, J. L., Robinson, E. J., Branscomb, L. M. Laser Double-Quantum Photodetachment of I-. Physical Review Letters. 1965, 14 (25), 1013-1016. DOI: 10.1103/PhysRevLett.14.1013.
7. Fan, J.,Buma, W.J. 'Resonance-enhanced multiphoton ionization studies of the lower electronically excited states of Flavone', The Journal of Physical Chemistry A. 2023, 127(7), 1649–1655. DOI:10.1021/acs.jpca.3c00202.

Friday, May 31

2:00-2:15

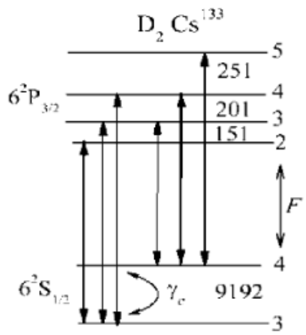
Precision Optical Measurements Using Frequency Combs

Presenters: Jackson Gessner and Jason Culley

Abstract:
Frequency combs are a new fundamental tool for measuring light based on advances in pulse lasers. They provide a way to precisely measure frequency intervals, enabling improvements to precision spectroscopy, affecting many science fields.

Outline:

1. Introduction.
    a. Names, Title, Some history on frequency combs. Why are they important, when were they developed? Nobel Prize
2. How do frequency combs work?
3. Applications of frequency combs
    a. How do atomic clocks work?
        i. atomic clocks.

ii. 

iii. Previous methods of atomic clocks.
iv. Replace the microwave with a laser.
v. Frequency comb instead of quartz.
vi. Ytterbium

b. Disease detection
c. Chemical spectroscopy
d. GPS calibration
e. Telescope spectroscopy

4. Review of a specific recent paper utilizing or studying frequency combs

References:

1. Fortier and Baumann, "20 years of developments in optical frequency comb technology and applications" Comm. Phys. 2, 153 (2019)
https://www.nature.com/articles/s42005-019-0249-y
2. https://www.nist.gov/topics/physics/optical-frequency-combs Optical Frequency Combs | NIST
3. The Nobel Prize in Physics 2005 - Prize announcement
https://www.nobelprize.org/prizes/physics/2005/prize-announcement/

2:15-2:30

Spectroscopy in Astronomy: How X-ray Reflection Spectroscopy Helps To Determine Black Hole Spin

Presenters: Aidan Bagshaw and Alan Schultz

Abstract:

Black holes are interesting and useful objects for studying fundamental physics. In recent years there have been many improvements to our understanding of the physics of black holes, in the area of gravitational waves for example, but there are still many things yet to be fully understood about them. One such method to understanding more about black holes is through the use of x-ray spectroscopy. In the presentation we will provide a general outline of XRS methods, what it can and can't tell us now, and the direction of modern research in the area.

Outline:

1. What is a black hole? What is spin?
2. Brief summary of data collection and analysis

3. What is the iron K alpha line? What makes it so useful?
4. How is the iron K alpha line used in XRS?
5. Why is any of this important? Why is it cool?

References:

1. https://arxiv.org/pdf/2011.04792 Review article
2. Differential Forms and the Geometry of General Relativity, Tevian Dray
3. Textbook covering topic when found

2:30-2:45

Overview and Applications of Quantum Beat Spectroscopy

Presenters: Madalyn Riana Gragg & Vincent Vauhgn-Uding

Abstract:

Resolving energy differences between near-degenerate states poses a significant challenge in spectroscopy that limits our comprehension of molecular and solid-state energy transfer and dynamics. Quantum Beat Spectroscopy (QBS) overcomes this challenge by using short light pulses to probe coherent superpositions of energy eigenstates that reveal oscillatory decay patterns. In this presentation, the theoretical basis of QBS will be explained and modern applications within detecting near degenerate energy states under Zeeman, Stark, and Hyperfine perturbations will be analyzed. Shortcomings associated with QBS involving spectral congestion and multi-path decay will be investigated. Additionally, case studies with Rubrene single crystals and atomically thin ReS_2 will be discussed to highlight QBS's utility in studying singlet fission and novel excitons.

Outline:

1. Experimental Problems with Resolving Energy Differences Between Near-Degenerate Energy States.
2. What Are Quantum Beats and How Can They Be Used For Spectroscopy
3. Theoretical Framework of Quantum Beat Spectroscopy : Coherent Superpositions, Time Evolution, and Time to Frequency Domain Transformations
4. Sensitivity Issues Associated with Quantum Beat Spectroscopy
5. Common Applications: Zeeman, Stark, and Hyperfine (+more if time permits)
6. Case Study: Quantum Beats of a Multiexciton State in Rubrene Single Crystals
7. Case Study: Ultrafast Quantum Beats of Anisotropic Excitons in Atomically Thin ReS2
8. Future Research Frontiers & Summary

References:

[1] R. T. Carter and J. R. Huber, Chemical Society Reviews 29, 305 (2000).
[2] M. O. Scully and M. S. Zubairy, in Quantum Optics (Cambridge University Press, 1997).
[3] Eric A. Wol, Drew M. Finton, Vincent Zoutenbier, Ivan Biaggio, Applied Physics Letters,

February 20 2018
[4] Sangwan Sim, Doeon Lee, Artur V. Trifonov, Taeyoung Kim, Soonyoung Cha, Ji Ho Sung, Sungjun Cho, Wooyoung Shim, Moon-Ho Jo & Hyunyong Choi, Nature Communications, March 22 2018