Topics in atto- and femtosecond science **Spring 2022**

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Advanced topic lecture
Time: Mondays 2-4 pm
Place: ETHZ, HIT-H-42

Prerequisites: Quantum Mechanics 1, Basic electrodynamics
Resources: Scientific publications (references will be provided in class). The lecture will be self-contained. Some not required, but potentially useful books, are:

- Physics of Atoms and Molecules, B. H. Bransden & C. J. Joachain
- The Theory of Atomic Structure and Spectra, R. D. Cowan
- Theoretical Atomic Physics, H. Friedrich
- Solid State Physics, N. W. Ashcroft & N. D. Mermin
- Introductory Quantum Optics, C. C. Gerry & P. Knight
- Quantum Optics, D. F. Walls, & G. J. Milburn
- Nonlinear Optics, R. J. Boyd
- Atoms, Molecules, and Photons, W. Demtröder
- Attosecond and Strong-Field Physics, C.D. Lin, A.T. Le, C. Jin, & H. Wei
- Fundamental of Attosecond Optics, Z. Chang
- Atoms in Intense Laser Fields, C.J. Joachain, N. J. Kylstra, & R. M. Potvliege

Tentative list of topics:

1. Introduction
Atomic units and conversions

A. One-electron atoms in electromagnetic field
  A.1 Weak cw fields
    - Photoionization rates
    - Dipole selection rules
    - Photoelectron angular distributions
  A.2 Strong static fields
    - Tunneling ionization
    - ADK rates
    - Generalization to non-Coulombic central potentials and time-dependent fields
  A.3 Strong cw fields
    - Gauges (velocity, length, acceleration)
    - Floquet theory
    - High-frequency Floquet theory
    - Ionization stabilization (adiabatic & dynamic)
B. Two-electron atoms
  B.1 Electronic structure
    - Angular-momentum coupling
    - Autoionization (Fano resonances)

- Interactions with external XUV & IR fields

B.2 Many-electron atoms

- Central-fields approximations (Hartee Fock)
- DFT

2. Time-resolved electron emission

C. Streaking spectroscopy

C.1 Photoelectron wave packets: analytical description

- Photoemission phase shifts and time delays

C.2 Numerical calculation of wave packet dynamics

- Crank-Nicholson propagation

C.3 Atomic targets

- Streaked spectra and relative photoemission delays
- Distortions by strong streaking fields
- Coulomb-Volkov final photoelectron states

D. RABITT

D.1 Atomic targets

- Multi-sideband photoelectron spectra: a non-perturbative approach
- Applications to H, He, Ar
- Sideband amplitude- and phase-dependence on pulse parameters (XUV & IR)

D.2 Solid targets

- Pulse-dependence analysis of relative sideband amplitudes & -phases
- Influence of substrate electronic structure
- Analysis of final-state resonances

3. Nanoplasmonics

E. Mie theory

- Plasmonic near-field enhancement
- Plasmonically induced phase shifts

F. Strong-field ionization of plasmonic nanoparticles

- Photoemission spectra & cut-off energies
- Influence of electronic correlation, residual charge, & plasmonic response

G. Time-resolved photoelectron emission from plasmonic nanoparticles

- Streaked photoemission from Au, Ar, & Cu nanospheres
- Plasmonic nearfield reconstruction
- Non-linear effects in photoemission from core-shell nanoparticles

4. Diatomic molecules

H. Coupled electronic and nuclear light-induced dynamics

- (Light-induced) conical intersections

I. Pump-probe analysis of bound and dissociative nuclear dynamics

- Fragment-kinetic-energy-release (KER) specta
- Quantum-beat spectra and reconstruction of light-dressed potential curves
- Ro-vibrational coupling and dynamics in the time- and frequency domains

J. Transient absorption

- United & separated atom limits
- Towards the imaging of molecular dissociation XUV transient-absorption spectra