

0737/0738 Special Topics in Physical Chemistry:

Coherent Light-Matter Interaction

Fall 2005

415 Beury Hall; Thursday, 6:10 - 9:00 p.m.

Instructor

Dr. Dmitri Romanov

Office: 218 Barton A

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Office hours: Tuesday, 12:30-2:30 p.m., Thursday, 4:00 – 6:00 p.m.

Course objectives

The course intends to bridge the gap between text-book material and fast-expanding research literature in the field of light-matter interaction ranging from coherent and strong-field control to quantum computing and cryptography. The students will progress from learning in formal classes to acquiring knowledge in self-study of current research literature. The course topics encompass various methods in the description of the electromagnetic field, its quantization and its interaction with matter, so enabling the student to acquire essential knowledge, overview and expertise in this field.

Textbooks

(SZ) M.O.Scully, M.S. Zubairy, Quantum Optics, Cambridge University Press, Cambridge, 1997

(BS) B.W. Shore, The theory of coherent atomic excitation, V. 1,2; Wiley, New York, 1990

Additional Reading

L. Allen, J.H. Eberly, Optical resonance and two-level atoms, Dover, New York, 1987

R. Loudon, The quantum theory of light, 3rd ed., Oxford University Press, Oxford, 2000

P. Meystre, M. Sargent III, Elements of Quantum Optics, 3rd ed., Springer, Berlin, 1999

M. Orszag, Quantum Optics, Springer, Berlin, 2000

Class Procedures

Class will meet for lectures one day per week at the scheduled time. Class attendance is governed by University Policy; however, each student is responsible for all materials covered in all lecture sessions. (This means calling someone in the class before the next classtime to obtain missed material, handouts and schedule information.)

Assignments and exams

Weekly homeworks worth a total of 50% of the course grade will be given. Reading assignment will be made to assist in material assimilation. A midterm exam (October, 20; 25%) and a final exam (December, 15; 25%) will be given as in-class closed-book exams. Grade scale is as follows:

greater than 85% – A, 82-85% – A-;
78-81% – B+, 74-77% – B, 70-73% – B-;
66-69 – C+, 62-65% – C, 58-61% – C-;
you guess what happens below 60%.

There will be absolutely **NO make-up exams administered for ANY reason**. If any student finds it necessary to miss an exam due to reasons of health or other extraordinary reasons, it is the responsibility of the student to inform the instructor **in writing, prior to the exam**, of these circumstances (the student should be prepared to completely justify the reason for the absence). If the reason for the absence is approved, the appropriate course of action will be decided by the instructor on a case-by-case basis. Any student missing a scheduled exam without contacting the instructor will be assigned a grade of 0 (zero) for that exam.

Handicapped students

Any student who has a need for accommodation based on the impact of a disability should contact me privately to discuss the specific situation as soon as possible. Contact Disability Resources and Services at 215-204-1280 in 100 Ritter Annex to coordinate reasonable accommodations for students with documented disabilities.

Course Topics and Readings

1. Photons and radiation
 - a. E-M waves, Standing and propagating waves (SZ 1.1; BS 9.1-9.2)
 - b. Atom-field interaction: r-E and p-A Hamiltonians (SZ 5.1, 5A; BS 2.8, 3.11, 9.14)
 - c. Quantization and photons (SZ 1.1.2, 1.5; BS 9.3, 9.13)
 - d. Radiation modes and Fock states (SZ 1. 2; BS 9.6, 9.7)
 - e. Coherent states and classical limit; squeezed states (SZ 2.2-2.7)
 - f. Perturbative and non-perturbative approaches (SZ 5.2)
 - g. Homogeneous and inhomogeneous line broadening (BS 22.2, 23.3, 23.6)
 - h. Short pulses. Pulse shaping and representations (BS 5)

2. Two-state model
 - a. Dressed states (SZ 10.2; BS 3.5, 10.3, 10.4)
 - b. Rotating-wave approximation (SZ 5.2; BS 3.9, 3.10)
 - c. Optical Bloch equations; Bloch vector (SZ 5.B; BS 8.1, 8.4)
 - d. Rabi oscillations (SZ 5.2; BS 3.9, 3.10)
 - e. The density matrix approach (SZ 5.3; BS 9.7, 10.3, 10.4)
 - f. Strong fields (SZ 10.2; BS 4.1)
 - g. The Floquet Hamiltonian (BS 4.2)
 - h. The dynamic Stark effect (SZ 10.2; BS 4.3, 10.4)
 - i. Broadband excitation (SZ 6.5; BS 4.5)

3. Three-state atoms
 - a. RWA and analytical solution: dressed states (SZ 7.2; BS 13.1, 13.2)
 - b. Virtual states (BS 13.4)
 - c. Coherent population trapping (SZ 7.2; BS 13.7)
 - d. Electromagnetically induced transparency (SZ 7.3)

4. Continuum processes
 - a. Quasicontinuum excitation (BS 16.1)
 - b. Fano states (BS 16.2)
 - c. Continuum discretization (BS 16.3, 16.4)
 - d. Multiple continua (BS 16.5)
 - e. Atoms and molecules in strong laser field. Tunnel and multiphoton ionization: Keldysh, ADK and all that

5. Odds and beginnings
 - a. Physics of entangled photons; quantum information (SZ 18.1)
 - b. Decoherence and measurements (SZ 19.1, 19.2, 20.3)
 - c. Quantum cryptography and teleportation (SZ 18.6)
 - d. Mechanical action of light: gradient forces. Ion traps; Cold systems (SZ 17.1, 17.4)
 - e. Collective effects. Superradiance (BS 19.1)

The course content may be modified at the discretion of the instructor. The instructor will announce in class any material so affected.