

# Course Outline

UNIVERSITY OF CALGARY  
DEPARTMENT OF PHYSICS and ASTRONOMY

## 1. Physics 673, Quantum and Nonlinear Optics

Lecture Sections: TR 14:00-15:15, MS 205  
Instructor(s): Dr. Alexander Lvovsky

Office: SB 319, 220-4124  
Office Hours: by appointment  
Email: [lvov@ucalgary.ca](mailto:lvov@ucalgary.ca)  
<http://iqis.org/quantech/673/>  
Physics and Astronomy office: SB 605, 220-5385

## 2. PREREQUISITES: Undergraduate background in quantum mechanics, electricity and magnetism, optics

## 3. GRADING: The University policy on grading and related matters is described sections F.1 and F.2 of the online University Calendar. In determining the overall grade in the course the following weights will be used:

Homework	25%
Midterm Examination	25%
Final Examination	50%

Homework will be required prior to each class. Students with excellent classroom and homework performance will be relieved from the final examination requirement.

## 4. Missed Components of Term Work. The regulations of the Faculty of Science pertaining to this matter are found in the Faculty of Science area of the Calendar in section 3.6: <http://www.ucalgary.ca/pubs/calendar/current/sc-3-6.html>. It is the student's responsibility to familiarize himself/herself with these regulations. See also <http://www.ucalgary.ca/pubs/calendar/current/e-3.html>.

## 5. REGULARLY SCHEDULED CLASSES HAVE PRECEDENCE OVER ANY OUT-OF-CLASS-TIME-ACTIVITY. If you have a clash with this out-of-class-time-activity, please inform your instructor as soon as possible so that alternative arrangements may be made for you.

## 6. TEXTBOOKS

### Useful lecture notes

J. Preskill. *Quantum Computation* <http://theory.caltech.edu/~preskill/ph229/>

M. Lukin. *Modern Atomic and Optical Physics II* <http://lakin.physics.harvard.edu/teaching.htm>

### Nonlinear optics

Y. R. Shen. *The principles of nonlinear optics*

V. G. Dmitriev, G. G. Gurzadyan, D. N. Nikogosyan. *Handbook of Nonlinear Optical Crystals*

**R. W. Boyd. *Nonlinear optics***

### Optical coherence

**L. Mandel, E. Wolf. *Optical Coherence and Quantum Optics***

C. Gerry, P. Knight. *Introductory Quantum Optics*

### Quantum electromagnetic field

**U. Leonhardt. *Measuring the quantum state of light***

L. Mandel. *Optical Coherence and Quantum Optics*

C. Gerry, P. Knight. *Introductory Quantum Optics*

### Atomic physics

P. W. Milonni, J. H. Eberly. *Lasers*.

M. Scully and M. S. Zubairy, *Quantum Optics*.

C. Gerry, P. Knight. *Introductory Quantum Optics*

**C. Foot. *Atomic Physics***

## 7. EXAMINATION POLICY: Students are encouraged to read the Calendar, Section G, on Examinations: <http://www.ucalgary.ca/pubs/calendar/current/g.html>.

Department Approval \_\_\_\_\_

Date \_\_\_\_\_

Associate Dean's Approval for  
out of regular class-time activity: \_\_\_\_\_

Date: \_\_\_\_\_

**OTHER IMPORTANT INFORMATION FOR STUDENTS:**

- (a) **ACADEMIC MISCONDUCT** (cheating, plagiarism, or any other form) is a very serious offence that will be dealt with rigorously in all cases. A single offence may lead to disciplinary probation or suspension or expulsion. The Faculty of Science follows a zero tolerance policy regarding dishonesty. Please read the sections of the University Calendar under K. Student Misconduct (<http://www.ucalgary.ca/pubs/calendar/current/k.html>) to inform yourself of definitions, processes and penalties
- (b) **ASSEMBLY POINTS in case of emergency during class time.** Be sure to **FAMILIARIZE YOURSELF** with the information at <http://www.ucalgary.ca/emergencyplan/assemblypoints>.
- (c) **ACADEMIC ACCOMMODATION POLICY.** Students with documentable disabilities are referred to the following links:  
Calendar entry on students with disabilities: <http://www.ucalgary.ca/pubs/calendar/current/b-1.html>  
Disability Resource Centre: <http://www.ucalgary.ca/drc/>
- (d) **SAFEWALK:** Campus Security will escort individuals day or night (<http://www.ucalgary.ca/security/safewalk/>). Call **220-5333** for assistance. Use any campus phone, emergency phone or the yellow phones located at most parking lot pay booths.
- (e) **FREEDOM OF INFORMATION AND PRIVACY:** This course will be conducted in accordance with the Freedom of Information and Protection of Privacy Act (FOIPP). As one consequence, **students should identify themselves on all written work by placing their name on the front page and their ID number on each subsequent page.** For more information see also <http://www.ucalgary.ca/secretariat/privacy>.
- (f) **STUDENT UNION INFORMATION:** VP Academic **Phone:** 220-3911 **Email:** [suypaca@ucalgary.ca](mailto:suypaca@ucalgary.ca).  
SU Faculty Rep. **Phone:** 220-3913 **Email:** [sciencerep@su.ucalgary.ca](mailto:sciencerep@su.ucalgary.ca) Website <http://www.su.ucalgary.ca/home/contact.html>.  
Student Ombudsman: <http://www.su.ucalgary.ca/services/student-services/student-rights.html>
- (i) **INTERNET and ELECTRONIC COMMUNICATION DEVICE Information.** You can assume that in all classes that you attend, **your cell phone should be turned off.** Also, communication with other individuals, via laptop computers, Blackberries or other devices connectable to the Internet is not allowed in class time unless specifically permitted by the instructor. If you violate this policy you may be asked to leave the classroom. Repeated abuse may result in a charge of misconduct.

## SYLLABUS

### Some facts from linear optics

- Slow-varying envelope approximation
- Kramers-Kronig relations
- The classical theory of dispersion

### Nonlinear optics

- Nonlinear susceptibilities. Symmetries.
- Phase matching
- Second harmonic and sum frequency generation.
- Nonlinear crystals.
- Quasi phase matching

### Optical coherence

- The mutual coherence function
- Van Cittert-Zernike theorem
- Hanbury Brown-Twiss effect.
- Second order coherence for thermal and coherent light

### Quantum electromagnetic field

- Quantization of the electromagnetic field
- Single-mode quantum states of light
- Phase-space probability densities
- Beam splitter
- Homodyne tomography
- Parametric down-conversion. Squeezing. Conditional preparation of photons.

### The single-photon qubit

- Encoding and tomography
- Quantum process tomography
- Quantum cryptography
- Quantum nonlocality
- Quantum teleportation
- Quantum computing with light

### Elements of atomic physics

- Rotating wave approximation
- Two-level atom
- Jaynes-Cummings model
- Master equations
- Spontaneous emission
- Three-level atom. Dark states. STIRAP
- Electromagnetically-induced transparency. Giant optical nonlinearity
- Photon echo\*
- Memory for light\*
- Cooling and trapping of atoms\*
- Cooling and trapping of ions\*
- Cavity quantum electrodynamics\*

(\*: if time permits)