Plan of Lectures

Lecture 1, August 30

- General stuff: introductions, web, homework, class presentations, e-mail list, books
- Definition of N/L optics: optical properties of the medium are modified by light
- Resonant vs. non-resonant NLO
- The $\chi^{(n)}$ formalism
- Estimates of $\chi^{(1)}$ and $\chi^{(3)}$ for non-resonant NLO
- The Kerr effect: dielectric tensor in the presence of a static field, estimate of the Kerr coefficient and comparison with experimental values

Lecture 2, September 1

- Optical modulators based on the Kerr effect; Kerr effect as a $\chi^{(3)}$ effect
- Pendulum demonstration of light propagation in birefringent medium
- Linear electro-optical (Pockels) effect; piezo-electric crystals
- An organizational question: how will this course be graded? (50% presentations in class; 50% homework). Each student is required to make at least one presentation in class, more presentations are encouraged!

Lecture 3, September 8

- Quiz on linear optics – influencing reflection by placing objects behind a highly-reflective mirror
- A brief detour (upon students' request) into Fabry-Perot resonators and spectrum analyzers
- Amplitude modulation with a Pockels cell; time-dependent modulation; spectrum of amplitude- and frequency-modulated light; sideband generation as a nonlinear frequency mixing process
- Magneto-optical effects
- Faraday rotation in a longitudinal E-field as a way to search for P and T violation

Lecture 4, September 13

- Microscopic origin of the Faraday effect – the Zeeman effect
- Diamagnetic vs. paramagnetic Faraday effect
- Intensity-dependent refractive index
- Self rotation (SR): the Maker-Terhune effect; pendulum demonstration
- SR in resonant atomic systems [see D. Budker, R.Y. Chiao, D. S. Hsiung, S.M. Rochester, and V.V. Yashchuk, Nonlinear precession of the polarization ellipse in resonant atomic media: two-level systems and Rb (QELS-2000, paper QFC4); S.M. Rochester, D. S. Hsiung, D. Budker, R. Y. Chiao, D.F. Kimball, and V.V. Yashchuk, Self-rotation of resonant elliptically polarized light in collision-free rubidium vapor, Phys. Rev. A. **63**, 043814 (2001); links are available at http://socrates.berkeley.edu/~budker/PubList.html]

Lecture 5, September 15

- More on self rotation in resonant atomic systems
- A spontaneous discussion on electromagnetically induced transparency (EIT)
- Sum Frequency Generation (SFG)
- Energy and momentum conservation in optical wave-mixing processes
- Phase matching

Lecture 6, September 20

- Presentation: Travis Beals on the ac-Stark effect
- A tangential demonstration – an AOL CD as a diffraction grating
- Estimate of how many megabytes can be stored on a CD
- Back to SFG: Derivation of the coupled-amplitude equations

Lecture 7, September 22

- Degeneracy factors in $\chi^{(2)}$ processes
- SFG without phase matching; coherence length
- Linear light propagation in anisotropic media
- Relative orientation of **H**, **D**, **E**, **k**, and the Poynting vector

Lecture 8, September 27

- Index ellipsoid (optical indicatrix)
- Uniaxial crystals; normal surfaces
- Phase matching in SHG: type I, type II, non-critical phase matching
- Interlude: the first demonstration of SHG by Franken et al and the PRL mistake
- Quasi-Phase Matching (QPM)

Lecture 9, September 29

- More on QPM: high-order QPM, advantages and limitations, how to make QPM waveguide devices, commercial periodically poled lithium niobate (PPLN)
- Introduction to laser dynamics
- Q-switching techniques
- How the laser (and many other great things) happened? (See Prof. Townes' book)

Lecture 10, October 4

- Rate equations for the number of photons in a laser cavity and population inversion
- Steps in a Q-switched pulse
- The 2^* "bottlenecking" factor
- Pumping; population buildup

- Light-pulse buildup
- Pulse output

Lecture 11, October 6

- AM mode locking
- Passive mode locking with saturable absorber
- Colliding-pulse mode locking (CPM)
- Interlude: tunable vs. fixed-frequency lasers
- How a dye laser works: electronic bands of a dye, singlet and triplet bands, absorption and emission spectra, non-radiative relaxation, Stokes shift.
- Interlude within interlude: collisional broadening and shift of spectral lines impact vs. adiabatic approximation; the cases of gases, liquids, and solids
- Synchronous-pumping modelocking
- Spectrum of a pulse train: $f_n = nf_r + f_0$; carrier-envelope phase
- Frequency Spectrum of Mode-Locked Laser animation courtesy Dr. Jun Ye (JILA)

Lecture 12, October 11

- Tom Allison: High-harmonic generation

Lecture 13, October 13

- Guest lecture by D. F. Kimball: Nonlinear Magneto-Optical Effects in Atoms

Lecture 14, October 18

- Yongmin Liu: Artifical magnetic resonator and its potential nonlinear application

Lecture 15, October 20

- Measurement of ultrashort laser pulses: spectrometers, autocorrelators, frequency resolved optical gating (FROG)
- FROG, GRENOUILLE, POLLIWOG, and other amphibian techniques

Lecture 16, October 25

- Kater Murch: Superradiance

Lecture 17, October 27

- Alex Sushkov: Photorefractive effect

Lecture 18, November 1

- Ken Tatebe: Optical information storage

Lecture 19, November 3

- Arman Cingoz: laser gyroscopes

Lecture 20, November 8

- Optical fibers
- Pulse propagation in fibers: self-phase modulation (SPM), GVD
- Optical solitons
- The Nonlinear Schrödinger Equation (NLSE)
- A bit of soliton history; solitons in other nonlinear equations; higher-order solitons

Lecture 21, November 10

- Kivin Moore: nonlinear optics with single atoms; cavity QED

Lecture 22, November 15

- Kevin Moore: more on CQED, vacuum Rabi oscillations
- Overview and review of Ultrafast Optics:
  o A bit of history
  o Generation of ultrashort pulses at different wavelengths (lasers, Thompson scattering…)

Lecture 23, November 17

- Overview and review of Ultrafast Optics (continued):
  o Stretched-pulse amplification
  o Continuum generation
  o Measuring ultrashort pulses (spectrometers, autocorrelators, FROG)
  o Spatio-temporal effects
  o Shaping ultrashort pulses
  o Connection between present and future atomic clocks and frequency combs; optical frequency standards
  o A digression into atomic clocks; general principles and precision limitations
  o Measurement of octave-spanning combs; control of both repetition frequency and carrier-envelope offset
  o Composite combs – locking a Ti-Sap and a forsterite oscillator to produce a single broadband comb

Lecture 24, November 22

- Tom Purdy: Electromagnetically Induced Transparency (EIT), and all that

Lecture 25, November 24

- Tom Purdy: Lasers Without Inversion (LWI)
- Interlude: “slow,” “fast,”, and “stopped light:” what is this all about?

Lecture 26, November 29

- Generation of ultra short pulses (following the Georgia Tech course)
- Interlude: all about flash-lamps
- Interlude: the anatomy of a dye-laser jet
- Interlude: excimer, gas-dynamic, and chemical lasers

Lecture 27, December 1

- Demonstration: oscillator assembly of a Q-switched Nd-YAG laser
- Description of short pulses (following the Georgia Tech course)
  - Instantaneous intensity and phase
  - Spectral intensity and spectral phase
  - Chirped pulses
  - First-, and second-order phases

Lecture 28, December 6

- Course/instructor evaluations
- Some topics we have not covered and where to read about them:
  - Quantum optics basic stuff: Loudon, Gerry&Night
  - Light and spin squeezing: same plus refs. On the web page

    - First- and second-order correlation functions; intensity interferometry: same + H. Brown-Twiss (a small slide show on this)
- Stimulated Raman scattering (SRS); generating tunable IR light using SRS
- Stimulated Brillouin Scattering
- Self-Induced Transparency (SIT) and solitons; Hahn's pin-ball demonstration

Lecture 29, December 8

- Travis Beals: Quantum Computing with Selectively Addressed Atoms in Optical Lattices
- If time permits: Selective Addressing of High-Rank Atomic Polarization Moments