Trent University: MTSC 6260H – Topics in Materials Science: Optics and Optical Properties of Materials

Course Outline 2011-2012

1. Course Summary

Light and light sources. Interaction of light with matter: Einstein coefficients and basic laser theory. Absorption and gain, saturation, three and four-level laser systems. Specific laser systems. Nonlinear optics.

Prerequisites: PHYS 2620H (203H) *Atomic, Molecular and Nuclear Physics* (or equivalent)
Pre/Co: PHYS-COIS 3200Y, or PHYS-COSC 321 *Electricity and magnetism* (or equivalent)
PHYS-MATH 3150H, or PHYS-MATH 305H *Partial differential equations* (or equivalent)

2. Instructor Information

Ralph Shiell, Department of Physics and Astronomy (lab SC214, office SC213),
ralphshiell@trentu.ca 748 1011 x7023
Secretary: Gina Collins, SC 327 Physics Building, gcollins@trentu.ca, 748-1011 x7715.

3. Course Timetable

The course will be delivered in a reading class format with readings, and twelve 2 hour meetings for discussion.

4. Required Text and Course Materials

Required : F. L. Pedrotti, L. S. Pedrotti & L. M. Pedrotti, *Introduction to Optics*, 3rd edition (2007)
Recommended : Mark Fox, *Optical Properties of Solids*, 2nd edition (2010)
: G. R. Fowles, *Introduction to Modern Optics*, 2nd edition (1975)
: O. Svelto, *Principles of Lasers*, 4th edition (1998)
: E. Hecht, *Optics*, 4th edition (2002)
: B. E. A. Saleh & M. C. Teich, Fundamentals of Photonics (1991)
Course webpage: http://www.trentu.ca/academic/physics/rshiell/PHYS4240Hdir/PHYS4240H.html

5. Course Format

Pre-class reading will be assigned from the notes.
I will summarize the main points of the reading, and we will work on short, ungraded assignments designed to develop a strong understanding of the material. Take-home assignments requiring more in-depth quantitative analysis will be submitted for marking. A 2-3 page submitted paper, followed by a 10-minute presentation completed 2/3 of the way through the course, summarizing a journal article describing recent experimental or theoretical optical physics research will also be part of this course. There will be one final exam for this course.

6. Course Evaluation

Assignments	35 %
Journal paper	20 %
Presentation	5 %
Final Exam	40 %

7. Topics Covered (with sections of Pedrotti[3], or Fox where relevant, *in italics*)

1. Light (*parts of Chapters: 1, 2, 4, 5, 7, 8 and 9*)
    1.1 Ray/Geometrical Optics (*1; 2-1 to 2-5*)
    1.2 Electromagnetic Wave Optics (*4-1 to 4-8*)
    1.3 Scalar Wave Optics (*4-1 to 4-8*)
    1.4 Brief Description of Quantum Optics
    1.5 Useful Units in Optics (*1*)
    1.6 Polarization of Light (*4-9*)
    1.7 Superposition; Beats (*5-1 to 5-6*)

2. Interactions Between Light and Matter (*parts of Chapters: 7, 8, 22, 25 and 26*)
- 2.1 Static ***E***-fields: Polarizability, α, Susceptibility,χ, and Relative Permittivity ε_r (*from Phys321: E&M*)
- 2.2 Classical Model of a Dielectric: Refractive Index (*25-1; 25-2*)
- 2.3 Single Interface at Normal Incidence (*7-4; 7-9; 8-4 to 8-5; 22*)
- 2.4 Light Incident on a Conducting (Metal) Surface (*25-4 to 25-5*)
- 2.5 Sources of Light
- 2.6 Characteristics of Common Light Sources: Spectral Lineshapes (*26-5; 26-6*)
  - 2.6.1 Homogeneous Broadening
    - (a) Lifetime Broadening and Inelastic Collisions
    - (b) Pressure Broadening: Elastic Collisions
  - 2.6.2 Inhomogeneous Broadening
    - (a) Gas Lasers: Doppler Broadening
    - (b) Solid State Lasers: Amorphous Crystal Broadening

3. Laser Operation (*Chapters 6 & 26*)
- 3.1 Amplification of Light: Einstein Rate Equations (*26-1*)
- 3.2 Laser Requirements and Gain Saturation
- 3.3 Four Level System at Steady State: Laser Output (*26-3*)
- 3.4 Example of Four-Level Laser System: Nd:YAG Laser
- 3.5 Amplification in an Active Medium (*26-3; 26-4*)
  - (a) Simplest Case: Ring Laser
  - (b) More Common Case: Two Mirror Laser Cavity
- 3.6 Mode Structure From a Laser Cavity (*26-5; 26-6*)
  - (a) Inhomogeneously Broadened Lasers
  - (b) Homogeneously Broadened Lasers
- 3.7 More Examples of Lasers and Laser Types
  - 3.7.1 Gas Lasers: atoms
  - 3.7.2 Gas Lasers: molecules
  - 3.7.3.Liquid Lasers: Dye lasers
  - 3.7.4 Solid State Lasers
  - 3.7.5 Semiconductor Lasers

4. Non Linear Optics (*Fox, Chapter 11*)
- 4.1 The Nonlinear Susceptibility Tensor
- 4.2 The Physical Origin of Optical Nonlinearities
- 4.3 Crystal Symmetry
- 4.3 Second-order Nonlinearities: Frequency Doubling and Pockels Effect
- 4.4.Third-order Nonlinearities: : Frequency Tripling and Kerr Effect

Late Policy: Within 24 hours: the mark awarded will be the percentage marked minus 10. More than 24 hours late: a zero mark.

8. Academic Integrity

Academic dishonesty, which includes plagiarism and cheating, is an extremely serious academic offence and carries penalties varying from a 0 grade on an assignment to expulsion from the University. Definitions, penalties, and procedures for dealing with plagiarism and cheating are set out in Trent University's Academic Integrity Policy. You have a responsibility to educate yourself – unfamiliarity with the policy is not an excuse. You are strongly encouraged to visit Trent's Academic Integrity website to learn more – www.trentu.ca/academicintegrity.

9. Access to Instruction

It is Trent University's intent to create an inclusive learning environment. If a student has a disability and/or health consideration and feels that he/she may need accommodations to succeed in this course, the student should contact the Disability Services Office (BH Suite 132 , 748-1281, disabilityservices@trentu.ca) as soon as possible. Complete text can be found under Access to Instruction in the Academic Calendar.