PHYS-4240H-A: Modern Optics
2020FA - Peterborough Campus

Instructor:

Instructor: Rayf Shiell

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Office Hours: Wednesdays 12 -1 (by Zoom)

Meeting Times:

Wednesdays, 08:00 - 09:50, online synchronous zoom meeting; Fridays, 13:00 - 14:50, online synchronous zoom meeting.

Department:

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Description:

Coherence and fluctuations of light sources: interferometers. Interaction of light with matter: Einstein coefficients and quantum-mechanical treatment of matter. Basic laser theory: absorption and gain, saturation, three and four-level laser systems. Longitudinal and transverse modes, Gaussian beams. Specific laser systems. Concepts in modern optics.

Prerequisite: PHYS 2620H, Atomic, Molecular and Nuclear Physics
Co- or pre-requisite: PHYS-COIS 3200Y Electricity and Magnetism; PHYS-MATH 3150H, Partial differential equations

Learning Outcomes:

Upon successful completion of this course, a student should:
- have an understanding of ray/geometrical optics, electromagnetic wave optics, and scalar wave optics
- understand the physical principles behind, and perform calculations based on, superposition, beats, wave packets, interference and coherence
- analyze the Fabry-Perot interferometer, multilayer films and light incident on a conducting surface
- understand and apply Einstein's rate equations that describe laser operation
- have a good understanding of laser operation and applications, including analysis of a four-level laser system
- understand mode structure, and homogeneously- and inhomogeneously-broadened lasers
- appreciate aspects of modern optics, such as fiber optics, photovoltaics, and the use of lasers in medicine

Texts:

Required : F. L. Pedrotti, L. S. Pedrotti & L. M. Pedrotti, Introduction to Optics, 3rd edition (2007)

Readings:

This course will closely follow parts of the required text book (denoted in brackets below) in covering much of the material from chapters 1 - 9., and Chapter 26 The sequence of the schedule of topics is listed below:

Theme I: Fundamentals of Light: Its Nature, and a Scalar Field Approach

1. Light: An Introduction
1.1 Some History (1-1)
1.2 Particles and Photons (1-2)
1.3 The Electromagnetic Spectrum (1-3)
1.4 Radiometry (1-4)

2. A Ray Perspective: Geometrical optics
2.1 Huygens' Principle (2-1)
2.2 Fermat's Principle (2-2)
2.3 Principle of Reversibility (2-3)
2.4 Reflection From Plane Mirrors (2-4)
2.5 Refraction Through Plane Surfaces (2-5)

3. A Wave Perspective
3.1 One-Dimensional Wave Equation (4-1)
3.2 Harmonic Waves (4-2)
3.3 Harmonic Waves as Complex Functions (4-4)
3.4 Plane Waves (4-5)
3.5 Spherical Waves (4-6)
3.6 Other Harmonic Waveforms (4-7)

4. Superposition of Waves
4.1 Superposition Principle (5-1)
4.2 Superposition of Waves of the Same Frequency (5-2)
4.3 Random and Coherent Sources (5-3)
4.4 Standing Waves (5-4)
4.5 The Beat Phenomenon (5-5)
4.6 Phase and Group Velocities (5-6)
4.7 Two-Beam Interference (7-1, but as a scalar relationship only)

5. Interference: Time-averaged superposition of a countable number of waves
5.1 Young's Double-Slit Experiment (7-2)
5.2 Double-Slit Interference with Virtual Sources (7-3)
5.3 Stokes Relations (7-8)
5.4 Interference from Dielectric Films (7.4)
5.5 The Michelson Interferometer (8-1)
5.6 Applications of the Michelson Interferometer (8-2)
5.7 Variations of the Michelson Interferometer (8-3)
5.8 Gravitational Wave Detectors (8-10)

6. Interference in practice: Including multiple reflections
6.1 Multiple-Beam Interference in a Parallel Plate (7-9)
6.2 The Fabry-Perot Interferometer (8-4)
6.3 Fabry-Perot Transmission: The Airy Function (8-5)
6.4 Scanning Fabry-Perot Interferometer (8-6)
6.5 Variable-Input-Frequency Fabry-Perot Interferometers (8-7)
6.6 Lasers and the Fabry-Perot Cavity (8-8)

7 Coherence
7.1 Fourier Analysis (9-1)
7.2 Fourier Analysis of a Finite Harmonic Wave Train (9-2)
7.3 Temporal Coherence and Line Width (9-3)
7.4 Partial Coherence (9-4)
7.5 Spatial Coherence (9-5)
7.6 Spatial Coherence Width (9-6)

Theme II: Lasers and Laser Beams

8. Laser Operation
8.1 Einstein's Theory of Light-Matter Interaction (6-4)
8.2 Essential Elements of a Laser (6-5)
8.3 Simplified Description of Laser Operation (6-6)
8.4 Characteristics of Laser Light (6-7)
8.5 Laser Types and Parameters (6-8)
8.6 Rate Equations (26-1)
8.7 Absorption (26-2)
8.8 Gain Media (26-3)
8.9 Steady-State Laser Output (26-4)
8.10 Homogeneous Broadening (26-5)
8.11 Inhomogeneous Broadening (26-6)
8.12 Time-Dependent Phenomena (26-7)
8.13 Pulsed Operation (26-8)
8.14 Some Important Laser Systems (26-9)
8.15 Diode Lasers (26-10)

Theme III: A Miscellany of Applications

9. Presentations – Concepts in Modern Optics
9.1 Fiber Optics (Ch 10)
9.2 Ray Tracing Software (3Dwin, Optical Design etc.)
9.3 CMOS Image Sensors
9.4 Solar energy/photovoltaics
9.5 Laser-induced fusion
9.6 Lasers in medicine (28-2)
9.7 Metamaterials and photonic crystals

The order of topics will follow that given above and I shall regularly communicate both in class and through Blackboard about the pacing of the classes. Thus it is important to attend each online class and also to log into Blackboard regularly.

Assessments, Assignments and Tests:

There will be four components to the grading scheme:
1. Weekly, computerized, auto-graded, in-class quizzes based on pre-class readings and on solved examples from the textbook, delivered via the WeBWork platform and submitted during each Wednesday class. Exceptions will be made only if technical or health issues arise and are communicated to me by the beginning of the relevant class. Worth 5% of grade.
2. Bi-weekly assignments based on the readings, discussion in class, and on questions from the textbook. These are to be submitted through a high-quality, and readable, scan of your answers sent to me by email. Worth 55% of grade.
3. A mid-term examination during the November 4 class, and written remotely. Worth 20% of grade.
4. A final examination, written during the December exam period, and written remotely. Worth 20% of grade.

Grading:

Weekly in-class online quizzes: 5%
Bi-weekly assignments: 55%
Midterm during November 4 class: 20%
Final exam: 20%

University Policies:

Academic Integrity

Academic dishonesty, which includes plagiarism and cheating, is an extremely serious academic offence and carries penalties varying from failure 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.

Access to Instruction

It is Trent University's intent to create an inclusive learning environment. If a student has a disability and documentation from a regulated health care practitioner and feels that they may need accommodations to succeed in a course, the student should contact the Student Accessibility Services Office (SAS) at the respective campus as soon as possible.

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