17221-772(16) Optics (3l, 3p)

2017

Course summary:

Geometrical, physical and quantum formalisms, polarisation (Stokes and Jones vectors), reflection, transmission and dispersion (Fresnel, Brewster, total internal reflection, double refraction), geometric-optical description of paraxial optical systems (matrix optics), diffraction and interference (three-dimensional), interferometry, non-linear optics.

Diffraction theory. Fourier optics, diffractive optics. Anisotropy, optical modulation: Electro-optical, magneto-optical and acousto-optical modulation. Non-linear polarisation, non-linear optical coefficients, harmonic generation and phase matching.

Module relevance in programme:

This course offers a comprehensive look at the interaction between light and matter and as such the topics covered allows for eventual specialization in the field of photonics. It is also envisioned that the course permits a seamless transition of concepts to practice which are the requirements of the various laser based research undertaken at the LRI. The module requires prior knowledge in classical electromagnetism as presented in the undergraduate modules 254 and 342 and 711.

Nonlinear optics describes the interaction between light and matter in regimes where the polarization response of a medium depends nonlinearly on the electric field strength of the optical wave. This leads to diverse phenomena that allow the alteration of an optical wave's spectral properties including sum-frequency generation, difference frequency mixing, second, third- (and higher) harmonic generation, electro-optic modulation, acousto-optic modulation, super-continuum generation, saturable absorption etc., all of which are studied in this course. These phenomena allow new optical applications in many sub-disciplines in physics, among others laser physics, imaging, spectroscopy, atomic and molecular physics and biophysics.

Outcomes of course:

The outcomes of the course are to give the student an understanding of a number of the optical techniques that are available in the application of lasers.
The student should:

- understand the physical principles on which the technique relies,
- be able to apply this knowledge to special cases related to experiments in our research projects,
- have knowledge of how these techniques are applied in research and technology.

Lecturer:

Dr GW Bosman (2nd quarter)
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Dr H Uys (4th quarter)
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Mentor:

The Department of Physics has appointed a staff member as mentor for each year of its physics programme to be available to students for consultation. Students should feel free to discuss general issues related to the physics programme or specific modules in the programme with the relevant mentor, in addition to usual consultations with their individual lecturers of modules.

The mentor for the Honours programme and its modules is Prof KK Müller-Nedebock kkmn@physics.sun.ac.za.

Course content:

Formal lectures

2ND QUARTER

1. INTRODUCTION: History of optics. Wave motion. Electromagnetic theory. Propagation of light
2. CLASSICAL DISPERSION THEORY: Electron oscillator model. Refractive index and polarisability. Electric dipole radiation. Scattering and polarisation.
3. GEOMETRICAL OPTICS: Lenses, mirrors and prisms. Optical systems. Analytical ray tracing and the matrix formalism. Thick lenses and aberrations.
4. POLARIZATION: Nature of polarised light. Polarisers. Dichroism and birefringence. Stokes and Jones vectors.
5. INTERFERENCE: Addition of waves. Conditions for interference. Interferometers. Multiple beam interference.
6. DIFFRACTION: Fraunhofer diffraction. Fresnel diffraction. Kirchhoff's diffraction theory.

7. FOURIER OPTICS: Fourier transforms and optical applications.

4TH QUARTER

1. INTRODUCTION: Nonlinear properties, processes and susceptibilities.
2. CLASSICAL THEORY OF NONLINEAR OPTICS: Lorentz model with anharmonic oscillators, properties of nonlinear susceptibilities.
3. WAVE EQUATION FOR NONLINEAR OPTICAL INTERACTIONS: The wave equation applied to sum-frequency and difference-frequency generation, phase matching and energy relations.
4. OPTICAL MODULATION: Electro-optical modulation (Kerr and Pockels effects), magneto-optical modulation (Faraday effect) and acousto-optical modulation (Bragg and Raman-Nath scattering), self-phase modulation and white light generation.
5. NONLINEAR OPTICS IN THE QUANTUMTWO-LEVEL APPROXIMATION: The density matrix and von Neumann equation, steady state response and derivation of the third-order susceptibility.

Practical (Tutorials):

No formal tutorials are scheduled. Students are expected to complete tutorial problems and assignments in their own time.

Study material:

Optics, E Hecht (Fourth Edition), Addison - Wesley, Reading, 2002.
Lasers, P W Milonni and J H Eberly, John Wiley, New York, 1988.
Nonlinear Optics, RW Boyd, Academic Press, London, 1992.
Modern Optics, R Guenther, John Wiley, New York, 1990.

Learning opportunities:

Class discussions and tutorial problems.

Assessment:

Methods of Assessments
Tutorial problems, assignments and tests contribute to the continuous assessment.