23. Curricular Unit

Advanced Physics Topics 1

Module

Introduction to nano-optics

Type

Tutorial: Reading and Study assignment

Contact hours

18

Professor/Researcher in charge

Orlando José Reis Frazão, Manuel Joaquim Marques

Summary of Contents

1. Introduction
Maxwell´s equations and light propagation in free space. Wave equation. Electromagnetic waves. Reflection and refraction. Fresnel laws of reflection and transmission. Basic notions concerning guided propagation and waveguides.

2. Light propagation in planar waveguides
TE and TM guided modes in parallel plane guides. Guided modes and total reflection. Dispersion relation. Propagation cutoff, limits of high and low frequency, number of guided modes. Normalized parameters and normalized dispersion relation of TE and TM modes. Intermodal and intramodal dispersion. Guided power and power confinement. Radiated power. (Characterization of planar guides with a prism). Orthogonality and normalization of the modes. Expansion of an arbitrary field in normal modes. Reference the loss-gain and surface plasmons. Three-dimensional waveguides. Method of effective indices. (MMI devices; Radiation from a three-dimensional waveguide; Gaussian approximation to the fundamental mode).

3. Light propagation in optical fibers
Propagation in fibers with step index profile (SI). HE, EH, TE and TM modes. Dispersion relation. Propagation cutoff. Normalized parameters. Dispersion. Groups of modes in the limit of weak guidance; LP pseudo modes. Single mode operation. Guided power and modal power confinement. Leaky modes. Radiated power. Dispersion in single mode fibers. Control of dispersion, (and US, DS and DF fibers. Modal diameter (MFD) and equivalent step index profile (ESI)). Polarization dispersion and birefringence in optical fibers e microstructured fiber. Theoretical analysis of nanofiber confinement properties when the geometry is much reduced when compared with the wavelength.

4. Coupled mode theory
Lorentz reciprocity theorem, orthogonality of modes, expansion of an arbitrary field in eigenmodes of the unperturbed guide. System of coupled equations in the modal amplitudes; coupling coefficients. Directional coupler; phase synchronism; power transfer; spectral behavior. Optical tunable filter and optical switch. Analysis of directional coupling in terms of super modes of the structure; arrays of coupled guides. Contra directional coupling in a guide with a periodic grating; phase synchronism; reflection coefficient; spectral response of the reflector.

5. Light emission and light interactions in nanoscale environments
Quantum electrodynamics (QED) applied in a phenomenological way to study light interactions in nanoscale environments. Multipole expansion applied to the classical particle-field Hamiltonian. The radiating electric dipole. Spontaneous decay. Classical lifetimes and decay rates. Dipole-Dipole interaction. Delocalized excitations. Entanglement.

6. Nano-optics Applications
Forces in optical near-field, Maxwell´s stress tensor and radiation pressure. Dielectric probes. Tapered optical fibers and tips. Light propagation in a conical dielectric probe. Power transmission. Near-field distribution. Enhancement of transmission and directionality. Optical properties in metals. Surface plasmon polaritons at plane interfaces. Surface plasmons in nano-optics. Two and three dimensional periodic structures. Photonic crystals with a square lattice. Band structure for photonic crystals with square lattice. Waveguides with photonic crystals. Photonic crystal fibers.

References

Evaluation

The evaluation will assess to write a report and also may be published in a book chapter. The student still has to present his work in an oral presentation.

Juri

Orlando Frazão, Manuel J. Marques, Mário Ferreira