Learning Activities AA 2014-2015

Module 1: Optics

Fundametals of geometrical optics. Optical waves. Polarization, diffraction, interference. Refractive index. Anisotropic and non homogenous media. Gaussian beams,Bessel beams, Laguerre Gauss beams. Singular Optics. Spectroscopy.

CFU: 3

Module 2: Nonlinear Optics

Origin of the nonlinear optical response of materials. Nonlinear Polarization. Second and third order polarization. Parametric effects. Nonlinear refractive index, focusing and defocusing of light

CFU: 3

Module 3: Laser - Quantum electronics

Basics of solid state physics - Plasmonics- Basics of light matter interaction. Lasers: c.w. pulsed, optical parametric oscillators- Q dots, photonics crystal lasers, nano-lasers, integrated emitters including optical nonlinear emitters. In/out coupling of radiation.

CFU: 5

Module 4: Optoelectronic Devices

III-V Semiconductors and compounds, homojunctions, heterojunctions, double-heterostructures, single- and multi- quantum wells. Semiconductor junction photodetectors: pn, pin, avalanche photodiodes, single photon avalanche diodes. Detection noise, signal-to-noise ratio, sensitivity, bit error rate (BER) and Q in optical photodetectors. Quantum limit of photodetection. Fiber optics: structures, electromagnetic propagation, modal, chromatic and polarization dispersion, power loss, nonlinear optical effects. Optical amplifiers: saturation, bandwidth, noise figure, semiconductor and erbium doped fiber amplifiers. Optical waveguides in organic and inorganic dielectrics. Directional couplers, X and Y jucntions, integrated optics intereformeters. Electro-optic and acousto-optic modulators. Optical logic gates.

CFU: 3

Module 5: Information Theory

Review of probability theory, random variables, stochastic processes, stationarity and ergodicity, examples: Gaussian processes and Markov chains – Shannon, Renyi and Von Neumann entropies, relative entropy, Kullback Leibler distance, mutual information, sufficient statistics, Fano’s inequality, Shannon theorem on

source coding, Kraft inequality, Huffman codes – Channel capacity, Shannon theorem on channel coding, examples: capacity of binary symmetric channel; capacity of Gaussian channel – Fundamentals of rate-distortion theory, maximum entropy principle

CFU: 3

Module 6: Quantum information I

Classical Electrodynamics: fundamental equations and dynamical variables. Quantum Electrodynamics in the Coulomb Gauge: general framework, time evolution, observables and states of the quantized free field, the Hamiltonian for the Interaction between particles and field. Coherent interaction: two state dynamics, Jaynes-Cummings model. Quantum Statistics of the field. Dissipative processes. Dressed states.

CFU: 3

Module 7: Quantum Information II

Finite-Dimensional Hilbert Spaces: Quantum bits, Multiple qubits, Quantum Tomography, Entanglement, Bell Inequality, Teleportation, No-cloning. Quantum Information Theory: Entropy and Information, the Holevo Bound, Communication over noise quantum channels, entanglement as physical resource. Quantum dense coding and quantum cryptography. Infinite-Dimensional Hilbert Spaces.

CFU: 5

Module 8: Quantum Computation

Quantum circuits. Single and multiple qbits gates Quantum Fourier transform and its applications. Quantum search algorithms.

CFU: 5

Module 9: Quantum Computation Devices

Conditions for quantum computation. Harmonic oscillator quantum computer. Optical quantum computer, Ion traps, Nuclear magnetic resonance. More implementations: other schemes

CFU: 3

Module 10: Optical systems for QI transmission and processing

Point-to-point fiber optic links, design rules, power and rise time budgets. BER, Q and system power penalties. Optical networks: ring and star architectures. Multichannel transmission. Amplified optical links. Effects of fiber dispersion and nonlinear effects on optical pulse transmission. Quantum circuits and algorithms for signal and information processing. Survey of basic architectures. Standard algorithms for data processing and search problems: Shor's algorithm and quantum FFT, Grover's algorithm and heuristic search. Quantum circuits and algorithms for computational intelligence: quantum neural networks, quantum particle swarm optimization (PSO), exhaustive search methods, quantum game theory, etc.

CFU: 5

Others Activities

Seminars (CFU: 4)

Laboratory activities (*) (CFU: 5)

Final Exam(CFU: 6)

Total CFU: 60

(*)Durante il modulo di Laboratorio di Ottica gli studenti si troveranno a contatto e studieranno sperimentalmente i fenomeni e i dispositivi ottici descritti nelle lezioni teoriche tenute negli altri moduli. In particolare:

Ottica classica: Ottica geometrica, Interferenza, Diffrazione, Interferometri di Michelson e Mach-Zehnder, Diffrazione da reticolo, Monocromatori, Fibre ottiche e perdite su canali di comunicazione in fibra. Generazione di profili di campo con singolarita.

Laser: Sistemi di pompaggio, Cavità risonanti, Fasci Gaussiani, Laser CW, Laser Q-Switch, Laser Mode-locked, Laser a semiconduttore. .Ottica Nonlineare: Generazione di seconda armonica, Effetto Pockels

Courses

1° Period (22 Aprile - 15th Giugno)

Dipartimento SBAI (Prof. Bertolotti, Ing. Belardini, Prof. C.Sibilia).

Ottica I:

Fondamenti di ottica geometrica e fisica, cenni di spettroscopia.

(Prof. M. Bertolotti/A.Belardini)

Ottica II:

Principi, processi parametrici, dispositivi

(Prof.E. Fazio/ A.Belardini)

Quantum Electronics:

Struttura della materia, principi di interazione radiazione-materia, sistemi laser

(Prof. C. Sibilia/A. Belardini)

2° Period (15th September - 30th November)

Dipartimento DIET (Prof. D'Alessandro, R.Asquini, M.Biagi).

Optoelectronics devices:

Guide, amplificatori, rivelatori, porte logiche.

(Prof. A. D'Alessandro/R. Asquini)

Information Theory:

Teoria dell'informazione classica.

(Prof. M.Biagi)

3° Period (4th December - 30th January)

Dipartimento SBAI e DIET (Prof. Bovino, Prof. R.Asquini, Prof. Panella).

Quantum Information I:

Fondamentidi meccanica quantistica e ottica quantistica

(Prof. F.A. Bovino)

Quantum II:

Principi di crittografia quantica, schemi di protocollo

(Prof. F.A. Bovino)

Computazione quantistica:

Principi, schemi

(Prof. F.A. Bovino)

Dispositivi per la computazione quantistica:

Memorie, rivelatori e dispositivi

(Prof. F.A. Bovino)

Optical Systems for QI:

Architetture circuitali e algoritmi quantistici per l’intelligenza computazionale

(Prof. R.Asquini /Prof. Panella)