M.Tech. (Quantum Computing)

Approved by All India Council for Technical Education, New Delhi,
Commissioner of Technical Education, Madhya Pradesh and
Rajiv Gandhi Technological University, Bhopal.

Affiliated to
Rajiv Gandhi Technological University, Bhopal.

About the Program

Like the first digital computers, quantum computers offer the possibility of technology exponentially more powerful than current systems. They stand to change companies, entire industries, and the world by solving problems that seem impossible today.
A recent report states that by 2023, 20% of organizations will be budgeting for quantum computing projects. As this new technology develops, organizations will face a shortage of quantum computing experts.
The time to learn about quantum computing is now. Discover the technical implications of this new frontier in computing and how you can apply quantum computing to every problem in engineering and technology.

Stake Holders

Any one interested in this area are welcomed to learn the courses. However, we prefer students with basic knowledge of programing skills, elementary Physics, knowledge of matrix operations and transforms and skills in logical operations.
We are

After Successful Completion,

You will be:

- able to access the quantum computing services provided by IBM, Amazon Brakt, D-Wave QPU, IonQ, Rigetti and other quantum computing services Simulators.
- able to think independently of quantum circuits, algorithm and applications for real-time stochastic problems in QC.
- trained to design QC ciruits and reversible logics for real-world problems.

PH66010 : LINEAR, NONLINEAR AND QUANTUM OPTICS

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

CO#1. Develop a familiarity with the ray optics and gaussian beam.

CO#2. Cultivate the fundamental understanding of electromagnetism.

CO#3. Deliver the knowledge about Fourier and nonlinear optics.

CO#4. Develop elementary problem-solving capability of quantum optics

Course Outcome

CO#1. Have deep understanding of EM wave propagation in guided medium.

CO#2. Demonstrate various fabrication and cabling techniques of optical fiber and its application.

CO#3. Solve the problems attributed spatial frequency filtering and quantum optics.

CO#4. Deliver the knowledge about the various optical nonlinear phenomena.

Syllabus

Unit 1. ***Linear Optics:*** *Postulates of ray optics, planar and spherical boundaries, Graded index optics and materials, ray transfer matrix, ABCD Matrix method for optical components, Interference of waves, Gaussian beam and its propagation through optical elements.*

Unit 2. ***Electromagnetism:*** *Refraction, Absorption and dispersion of electromagnetic waves, polarization and crystal optics, Propagation of electromagnetic waves through anisotropic media.*

Unit 3. ***Fourier Optics:*** *Correspondence between spatial harmonic functions and plane waves, transfer function and impulse response function of free space, Fourier transform in the far field, propagation of light in free space, Fourier transform using a lens, diffraction of light, image formation, spatial frequency filtering.*

Unit 4. ***Nonlinear Optics:*** *Nonlinear optical susceptibility, second-order optical susceptibilities, phase matching, sum, frequency and second-harmonic generation. Third-order optical susceptibility, two photon absorption, nonlinear refraction and absorption, four-wave mixing, optical bistability.*

Unit 5. ***Quantum Optics:*** *Quantization of single mode field, quantization of multimode fields, eigenstates, annihilation and creation operators, wave packets and time evolution, general idea of sqeezed states.*

Text Books

1. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, Second Edition, John Wiley & Sons-NY, 2007.
2. C. Gerry and P. L. Knight, Introductory Quantum Optics, Camridge Unv. Press, 2005.
3. K. Iizuka, Elements of Photonis Vol I & II, Wiley, New York, 2003.

Reference Books

1. A. Yariv and P. Yeh, Optical Waves in Crystal, Wiley, New York, 1983.
2. A. Ghatak and K. Thyagarajan, Optical Electronics, Cambridge Univ. Cambridge, 1989.
3. A. Yariv, Quantum Electronics, 2nd Edition, Wiley, New York, 1975.

PH66011 : Quantum Mechanics for Engineers

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

CO#1. To develop in the student awareness of situations in engineering, which need ideas of quantum mechanics.

CO#2. To make the student understand the basic language, apparatus and methods of quantum mechanics.

CO#3. To make the student understand the basic language, apparatus and methods of quantum mechanics.

Course Outcome

CO#1. The student will develop an informed appreciation of the paradigm shift already in evidence in technologies behind modern services and products

CO#2. The student will possess basic physics knowledge to pursue simulation and modelling of systems encountered in nanotechnologies

CO#3. The student will be prepared to pursue PG courses, research programs and industrial R & D programs in nanotechnologies

Syllabus

Unit 1. *Introduction, de Broglie's concept of matter waves, Heisenberg's uncertainty relations, Schrodinger's wave equation ; interpretation of wave function : probability current density ; one and three dimensional square well potential ; linear harmonic oscillator;*

Unit 2. *Probability density and probability current, equation of continuity; Wave function as a vector, physical variables as operators; Eigenvalues, eigenfunctions, expectation values and uncertainties*

Unit 3. *Particle in One-dimension: Infinite square well, finite potential well, GaAs quantum well between AlGaAs layers in a semiconductor heterostructure, triangular well, application to electron in a MOSFET*

Unit 4. *Quantum Tunneling: Potential barrier, tunneling, tunneling probability; Double rectangular barrier, resonant tunneling, Esaki tunnel diode; Barrier of arbitrary shape, WKB approximation*

Unit 5. *Probabilistic descriptions and Quantum systems, Schrodinger's time dependent equation, Wave nature of Particles, state vector, operators, Entanglement, Bell's theorem, Schrodinger CATS, EPR Paradox, single photon interference.*

Text Books

1. M. Suhail Zubairy, Quantum Mechanics for Beginners: With Applications to Quantum Communication and Quantum Computing, Oxford, Texas, 2020.
2. Quantum Mechanics: An Introduction for Device Physicists and Electrical Engineers, Second Edition, David K Ferry, Institute of Physics Publishing 2001.
3. Fundamental Quantum Mechanics for Engineers, Leon van Dommelen, 15 Jun 2012 Version 5.55 alpha, (Ebook: http://www.eng.fsu.edu/ dommelen/quantum/).

Reference Books

1. D.J. Griffith, Introduction to Quantum Mechanics, 2nd Ed. Prentice Hall, 2004.
2. L. I. Schiff, Quantum Mechanics, 3rd Rev. Edition, McGraw Hill, 1968.

PH66012 : Quantum Computing - I

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

CO#1. To introduce the fundamentals of quantum computing

CO#2. The problem-solving approach using finite dimensional mathematics

Course Outcome

CO#1. Basics of complex vector spaces

CO#2. Quantum mechanics as applied in Quantum computing

CO#3. Architecture and algorithms

CO#4. Fundamentals of Quantum computations

Syllabus

Unit 1. *Complex numbers and its geometrical representations, Complex vector spaces, inner products and Hilbert spaces, Hermitian and unitary matrices, Tensor products of vector spaces Deterministic Systems*

Unit 2. *Dirac formalism, superposition of states, entanglement Bits and Qubits. Qubit operations, Hadamard Gate, CNOT Gate, Phase Gate, Z-Y decomposition, Quantum Circuit Composition, Basic Quantum circuits.*

Unit 3. *Quantum Algorithm - I: Quantum parallelism, Quantum Evolution, Deutsch's Algorithm, Deutsch-Jozsa Algorithm, Simon's periodicity algorithm.*

Unit 4. *Quantum Algorithm - II: Grover's search algorithm, Shor's Factoring algorithm. Application of entanglement, teleportation, superdence coding.*

Unit 5. *Quantum programming languages, Probabilistic and Quantum computations, introduction to quantum cryptography and quantum information theory.*

Text Books

1. Quantum computing explained, David McMahon, Wiley-interscience, John Wiley & Sons, 2008
2. Quantum computing for computer scientists, Noson S. Yanofsky, Mirco A. Mannucci, Cambridge University Press 2008

Reference Books

1. Quantum computation and quantum information, Michael A. Nielsen and Isaac L. Chuang, Cambridge University Press 2010
2. Introduction to Quantum Mechanics, 2nd Edition, David J. Griffiths, Prentice Hall New Jersey 1995

PH66204 : QUANTUM COMMUNICATION & INFORMATION SYSTEMS (ELECTIVE-I)

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

CO#1. To infix mathematical background for communication signal analysis, information theory and coding.

CO#2. To equip students with knowledge of performance evaluation parameters in presence of channel noise.

Course Outcome

CO#1. The students will be able to perform the time and frequency domain analysis of the signals in digital communication.

CO#2. They will be capable of analyzing and evaluating the performance of baseband/bandpass systems in terms of error rate and spectral efficiency.

Syllabus

Unit 1. ***Signals and Spectra:*** *Fourier transform and properties, Digital communication signal processing, spectral density, autocorrelation, random variable, probability density function, Gaussian & Rayleigh probability density, noise, bandwidth of digital data.*

Unit 2. ***Quantum Fourier transform*** *and its applications, the quantum Fourier transform, Performance and requirements, Applications: order-nding and factoring, General applications of the quantum Fourier transform.*

Unit 3. ***Base Band and Band Pass Systems:*** *sampling theorem, quantization, pulse code modulation, detection of binary signal in Gaussian noise, matched filter, intersymbol interference, Digital modulation techniques, detection of signal in the presence of noise, coherent and non coherent detection.*

Unit 4. ***Channel Coding:*** *Linear block codes: generator matrix, systematic linear block codes, parity check matrix, cyclic codes, Hamming codes, Convolutional Codes: Encoder representation, maximum likehood decoding.*

Unit 5. ***Quantum Information Theory:*** *Communication channels; mutual information, channel capacity and entropy; Shannon's theorems; Quantum communication, dense coding and teleportation; von Neumann entropy.*

Text Books

1. B. Sklar, Digital Communications, Pearson Education.2/e, 2005.
2. J.G. Proakis, Digital Communications, McGraw-Hill Higher Education, 4/e, 2001.

Reference Books

1. Michael A. Nielsen & Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press
2. B. P. Lathi, Modern Digital & Analog Communications Systems, Oxford University press, 3/e, 1998.

PH66207 : QUANTUM SENSORS AND APPLICATIONS (ELECTIVE-I)

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

CO#1. To understand basics of sensors, actuators and their operating principle.

CO#2. To educate the students on different types of micro fabrication techniques for designing and developing sensors (Several applications from Electronics to Biomedical will be covered).

Course Outcome

CO#1. To explain working of various types of electrochemical sensors and actuators.

CO#2. To provide information about interfacing of sensors and signal conditioning circuits to establish any control system or monitoring system.

CO#3. To provide knowledge about simulation and characterization of different sensors.

CO#4. To provide an understanding on characteristic parameters to evaluate sensor performance

Syllabus

Unit 1. ***Basics of Energy Transformation:*** *Transducers, Sensors and Actuators Understanding of thin film physics: Application in MOSFET and its variants.*

Unit 2. ***Techniques:*** *Chemical Vapor Deposition (any three: APCVD, LPCVD, UHVCVD, PECVD, ALCVD, HPCVD, MOCVD). Physical Vapor Deposition (Thermal Deposition, E-beam Evaporation, Sputtering, Pulsed Laser Deposition)*

Unit 3. ***Photolithography:*** *Etching methods, understanding various gas sensors: Optical gas sensor, Metal oxide semiconductor gas sensor, Field effect transistor gas sensor, Piezoelectric gas sensor, Polymer gas sensor, Nano-structured based gas sensors.*

Unit 4. ***Fabrication of Microsensors:*** *Force Sensors, Pressure Sensors, Strain gauges and practical applications. Working principles of Actuators. Piezoelectric and Piezoresistive actuators, micropumps and micro actuators with practical applications.*

Unit 5. ***Microfluidics:*** *Photomask design using Clewin Software, pattern transfer techniques, PDMS moulding and degassing, device bonding techniques.*

Text Books

1. B. C. Nakra, K.K. Choudhury, Instrumentation, Measurement and Analysis -3rd Edition, Tata McGraw, 2009
2. Jacob Fraden, Hand Book of Modern Sensors: physics, Designs and Applications, 3rd ed., Springer, 2010
3. Edward Sazonov, Michael R Neuman, Wearable Sensors: Fundamentals, Implementation and Applications Elsevier, 2014

Reference Books

1. Stefan Johann Rupitsch: Piezoelectric Sensors and Actuators, Fundamentals and A Microsystem Design, Kluwer Academic Publisher, 2001 J.D. Plummer, M.D. Deal, P.G. Griffin
2. James D. Plummer, M. Deal & Peter D. Griffin: Silicon VLSI technology: fundamentals, practice, and modeling;2000
3. Marc J. Madou: Fundamentals of Microfabrication, The Science of Miniaturization, Second Edition 2002

PH66301 : Quantum Communication Systems (Elective - II)

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

To introduce quantum transmission and detection mechanism along with coherent / incoherent system. To introduce conventional IM/DD optical systems and new optical communication technologies like FSO along with the transmission system design concepts.

Course Outcome

Students will be able to unerstand the concepts of optical communication and system design as well as capable to configuring an optical link along with transmission losses, dispersion and power penalty management.

Syllabus

Unit 1. ***Optical Transmitters :*** *Optical transmitter, intensity modulation, LEDs, Laser diodes fundamentals. Efficiency, characteristics, modulation bandwith emission pattern, source limitations, nnoise in lasers, effect of noise on different modulation schemes, external optical modulators.*

Unit 2. ***Optical Receivers :*** *Devices types, optical detection principle, quantum efficiency, responsivity, semicondcutor photodiodes with and without internal gain, phototransistors, photoconductive detectors, noises encountered in channel as well as in receiver, signal-tonoise ratio (SNR) calculations, receiver strcutures, optical preamplifiers.*

Unit 3. ***Free Space Optics :*** *Introduction to FSO, beam divergence, atmospheric attenuation, weather condition influence, atmospheric turbulence effects viz scientillation, beam wander and beam spreading, Transmission parameters, sources and detectors for FSO terrestrial systej FSO link performance.*

Unit 4. ***Coherenct Optical Communication :*** *Detection principles, practical constraints, modulation formats homodyne and heterodyne detection, phase diversity reception, receiver sensitivities, BER, system performance, multicarrier system and network concepts.*

Unit 5. ***Transmission System Design :*** *Intensity modulation/direct detection, design considerations, Digital systems, regenerative repeatr, bit error rate (BER) eye diagram, link design: power budget, rise time budget, Analog system, dirct intensity modulation, subcarrier intensity modulation, power penalty associated with transmitter, receiver and optical amplifier, Amplifier spacing penalty, Crosstalk, crosstalk reduction, wavelength stabiliztion.*

Text Books

1. H. Kolimbris, Fiber optics communications, Pearson Education, 17e, 2004.
2. J. Gower, Opticl communiation systems, PHI 2/e, 2001.
3. J. M. Senior, Optical fiber communications, Principles and Practice, (PHI), 2/e, 2004.

Reference Books

1. G.P. Agrawal, Fiber optica communication systems, John Wiley & Sons, Inc, 3/e 2002.
2. R. Ramaswami and K. N. Sivarajan, Optical Networks, Morgan Kaufmann Publishers, 2/e, 2002.

PH66305 : Optical Networks

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

CO#1. To provide knowledge about evolution of Optical networks,

CO#2. Deep understanding of Transmission standards, routing and switching.

CO#3. To infix concepts of network components in WDM/DWDM, ATM, SONET and SDH networks.

Course Outcome

CO#1. Understand the basic concepts involved in current technologies e.g., FTTH, FDDI, SONET etc.

CO#2. Will be capable of analysing, designing and configure typical optical communication networks.

Syllabus

Unit 1. ***Introduction to Optical Networks:*** *First and second generation optical networks, network topologies and protocols, circuit and packet switching. OSI model, multiplexing techniques, transparency of regenerators, Broadcast and Select Networks: MAC protocols, throughput calculation, aloha and slotted aloha.*

Unit 2. ***WDM networks and components :*** *WDM networks, DWDM, CWDM, WDM multiplexers and demultiplexers, Arrayed waveguide grating, optical add/drop multiplexers, fiber Bragg gratings as add/drop multiplexers, WDM Filters, Fabry Perot filters, acousto-optic tunable filters, switching technologies, characterization of switches.*

Unit 3. ***Client Layers & Storage Area Networks:*** *SONET/SDH, ATM: Functions, Adaptation Layers, Flow Control, IP: Routing & Forwarding, QoS, ESCON, Fiber Channel, HIPPI, Gigabit & 10-Gigabit Ethernet.*

Unit 4. ***Wavelength Routing Networks:*** *Classification of light paths, The Optical layer, Wavelength Cross Connects (WXC) wavelength reuse, node design, degree of wavelength conversion, Static and reconfigurable network, N/W design considerations.*

Unit 5. ***Photonic Packet Switching:****Optical time domain multiplexing (OTDM), methods of multiplexing and demultiplexing, broadcast OTDM networks, bit interleaving and packet interleaving, optical AND gates, nonlinear optical loop mirrors, switch based networks, deflection routing.*

Text Books

1. R. Ramaswami and K. N. Sivarajan, Optical Networks : A Practical Perspective, Harcourt Asia P. Ltd. 1999.
2. C. S. R. Murthy and M. Gurusamy, WDM Optical Networks, Prentice Hall, 2002.
3. A.S. Tanenbaum, Computer Networks, Prentice Hall of India Pvt. Ltd., 2002.

Reference Books

1. J.E. Midwinter, Photonics in Switching, Academic Press, 1993.
2. U. Black, Optical Networks, Prentice Hall, 2002.

PH66512 : Optoelectronic Integrated Circuits

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

CO#1. To develop a familiarity with the characterization tools and basic functioning of nano fabrication techniques.

CO#2. To cultivate the fundamental understanding of micro and nano elector mechanical systems.

CO#3. To deliver the knowledge about optical waveguide and TE, TM mode propagation.

CO#4. To develop elementary problem-solving capability of EM propagation in waveguide and anisotropic medium.

CO#5. To comprehend the basic concepts of integrated optics for directional coupler and coupled wave theory

Course Outcome

CO#1. Will have deep understanding of EM wave propagation in symmetric and asymmetric optical wave guide.

CO#2. Able to demonstrate various fabrication and cabling techniques of optical fiber and its application.

CO#3. Have knowledge to solve the problems attributed mode propagation attenuation and dispersion of optically bounded EM wave.

CO#4. Trained with knowledge about the type of optical waveguide and anisotropic crystals.

Syllabus

Unit 1. *Integrated Optics: Modes in an asymmetric planar waveguide, strip waveguides, the optical directional coupler and coupled mode theory, some guided wave devices, periodic waveguides, fabrication of optical waveguide.*

Unit 2. *EM Wave Propagation in Anisotropic Crystals: index ellipsoid index ellipsoid in presence of external electric field. Electrooptic (EO) effect in KDP crystals, EO devices. Acoustooptic (AO) effects. Raman-Nath and Bragg AO effect. AO devices.*

Unit 3. *MEMS & NEMS: Sensing and actuation, pressure-, flow-, acceleration-sensors, imaging and display, DMD, laser tuning, wavelength locker, M x N optical switch, microfluidics, mixing microfluids, Applications to RF system*

Unit 4. *Fabrication Techniques: Top-down and bottom-up methods, molecular beam epitaxy, atomic layer deposition, pulsed laser deposition, chemical vapor deposition, spin coating, thermal and magnetron sputtering, UV optical lithography*

Unit 5. *Characterization-Tools: Scanning electron microscopy and energy dispersive x-ray, tunnelling electron microscopy, atomic force microscopy, UV-VIS spectroscopy, ellipsometry, fluorescence spectroscopy, x-ray diffraction, I-V, C-V and Q-V measurements.*

Text Books

1. S. Lindsay, Introduction to Nanoscience, (Oxford university Press,) 2014.
2. N. Maluf,and K. Williams, An Introduction to Microelectromechanical Systems Engineering, 2nd Ed., (Artech House Boston) 2004
3. J. H. Davies, The Physics of Low-dimensional semiconductors (Cambridge, Cambridge, 1998).

Reference Books

1. J. Piprek, Semiconductor optoelectronic Devices, Introduction to physics and simulation, Academic Press, London, 2003.
2. A. Ghatak & K. Thyagarajan, Optical electronics, (Cambridge Univ. Press, Cambridge) 1989.
3. Robert G. Hunsperger, Integrated Optics: Theory & Technology (Springer, New Delhi) 6th Ed., 2009.

PH66513 : Classical and Quantum Information Theory

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

CO#1. To provide the students an introduction to Classical & Quantum Information theory.

CO#2. To gain insight of the basic concepts and mathematical techniques of classical Information and entropy.

CO#3. Have knowledge of the basic concepts and techniques of quantum Information and entropy

CO#4. Develop understanding of quantum states and accessible states, Entanglement and quantum error.

Course Outcome

CO#1. Learn the history and emergence of Classical & Quantum Shannon Theory.

CO#2. Understand the basic concepts and techniques of Classical Information and entropy.

CO#3. Distinguish between Classical & Quantum Information and entropy.

CO#4. Establish the principle behind quantum accessible states, Entanglement and quantum error.

Syllabus

Unit 1. *Introduction: Classical Shannon theory, brief history of quantum theory, emergence of quantum Shannon theory, The Noiseless quantum theory, The Noisy quantum theory.*

Unit 2. *Classical Information & Entropy: Entropy of a random variable, Conditional entropy, Joint entropy, Relative entropy, mutual information, Entropy inequalities, Classical information from quantum systems.*

Unit 3. *Quantum Information & Entropy: Quantum entropy, Joint quantum entropy, Conditional quantum entropy, Coherent information, conditional quantum mutual information, Quantum Relative entropy, Quantum Entropy inequalities.*

Unit 4. *Quantum information Theory-I Distinguishing quantum states and the accessible information: The Holevo bound, Example applications of the Holevo bound, Classical information over noisy quantum channels: Communication over noisy classical & quantum noisy channels.*

Unit 5. *Quantum information Theory-II Quantum information over noisy quantum channels: Entropy exchange, Quantum Singleton bound, Quantum error-correction, Entanglement as a physical resource: Entanglement distillation and dilution, Entanglement distillation and quantum error-correction.*

Text Books

1. M. A. Nielsen and I. L. Chuang, "Quantum Computation and Quantum Information";Cambridge University
2. M. M. Wilde, "From Classical to Quantum Shannon Theory", Cambridge University Press, 2019. CUP.
3. J. Preskill Lecture notes on Quantum Information (http://www.theory.caltech.edu/p̃reskill/ph229/#lecture)

Reference Books

1. The mathematical language of quantum theory: from uncertainty to entanglement, T. Hienosaari & M.Ziman, Cambridge University Press (2011).
2. Quantum systems, channels, information, A.S. Holevo, de Gruyter Studies in Mathematical Physics(2012)

PH66514 : QUANTUM COMPUTING - II

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

CO#1. To learn the modern quantum computing tools.

CO#2. The understand examples cases and train solutions for them

CO#3. To learn quantum computing with industry level cases.

Course Outcome

CO#1. Trainied to find solutions for problems at various levels

CO#2. Will have the ability to resolve and use modern tools for current problems

CO#3. Able to independently understand and find solutions in quantum computing.

Syllabus

Unit 1. *Quantum Cryptography: Polarization, RSA encryption, examples and solutions. Controlled NOT attack. B91 Protocol, B92 protocol*

Unit 2. *Quantum Noise and Error correction, examples and solutions. Quantum operations, Krauss operators, depolarizing channel, Bit flpo and phase flop channel operation, amplitude and phase damping, error corrections.*

Unit 3. *Tools: No cloning theorem, examples and solutions for trace distance, fidelity, concurrence, information content and entrophy.*

Unit 4. *Adiabatic quantum computation, adiabtic process, cases and solutions. Cluster state of computing.*

Unit 5. *Quantum Technology: Heteropolymer based QC, Ion-trap based QC, Cavity-QED based QC, NMR based QC, Quantum dots based QC.*

Text Books

1. D. McMohan, Quantum Computing Explained, Wiley-Interscience, Ney Jersy, 2008.
2. W.-H. Steeb, Y. Hardy, Problems and Solutions in Quantum Computing and Quantum Information, World Scientific, Singapore 2004.
3. C. P. Williams and S. H. Clearwater, Explorations in Quantum Computing, Springer, New York, 2018.

Reference Books

1. M. A. Nielsen and I. L. Chuang, "Quantum Computation and Quantum Information";Cambridge University

PH66707 : Nanophotonics and Technology (Elective-III)

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

CO#1. To understand the semiconductor device fabrication technology.

CO#2. To learn the use of appropriate semiconductor nanostrucutre for quantum operations

CO#3. To visuvalize the modern semiconductors and technology for new devices.

Course Outcome

CO#1. Will able to select and use appropriate semiconductor for applications.

CO#2. Will able to interpret the outcome of the product fabricated from various modern semiconductor grow techniques.

CO#3. Will able to adopt correct nano-optical techniques for diagnostics in semiconductor device, post fabrication.

Syllabus

Unit 1. *Introduction: Nanomaterials, smart materials, new materials. Maxwell's equations, light-matter interaction, dispersion, em properties of nanostructures*

Unit 2. *Optoelectronics materials : Electrical, Optical and Thermal properties of III-V and II-VI semiconductors required for optoelectronics devices for visible and IR range, Growth techniques: Czochralski method, bridgman method, Flote zone method, Lely growth method, MBE, CVD, RF sputtering, PLD, Characterization techniques: FTIR, Ellipsometry, XRD, SEM & EDAX, AFM, PL, Lithography (top down and bottom up), Contact preparation of thin films for device fabrication*

Unit 3. *Semiconductor quantum well structures: Quantum well, quantum wire and quantum dot, super lattices, quantum well and quantum dot lasers, distributed feedback laser, vertical cavity-surface emitting lasers.*

Unit 4. *Nano-optics: Photonic nanocircuits, nano and micro fluidics, Surface plasmon resonance, Metal optics, Manipulating light with plasmonic nanostructures, Plasmonic nano-sensors.*

Unit 5. *Metamaterials: negative refractive index and super-resolution, the concept and modeling of metamaterials, dispersive model for dielectric permitivity, phase and group velocity, photonic band gap materials, plasmonics. Super-lens, electromagnetic invisibility.*

Text Books

1. P. N. Prasad, Nanophotonics, John-Wiley, New Jersey, 2004.
2. D. Minoli, Nanotechnology Applications to Telecommunications, John Wiley, new Jersy, 2006.
3. J-M. Lourtioz, C. Delalande, A. Levenson, Nanophotonics, ISTE, London, 2006.

Reference Books

1. H. Baltes, O. Brand, Enabling Technology for MEMS and Nanodevices, Wiley, New York, 2004.
2. "S. A. Ramakrishna and T. M. Grzegorczyk, Physics and Applications of Negative Refractive Index Materials, CRC Press, New York, 2009."
3. H. Ukita, Micromechanical Photonics, Springer, Berlin, 2007

PH66708 : OPTICAL AND QUANTUM COMMUNICATION (ELECTIVE-III)

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

CO#1. To introduce optical trasnmission and detection mechanism along with coherent/noncoherent systems and the corresponding transmission system parameters

CO#2. To introduce fundamentals of Quantum systems and Quantum Cryptography.

Course Outcome

CO#1. Students will be able to understand the concepts of Optical communication and System design as well as capable of configuring an Optical link.

CO#2. They will be capable of analysing Quantum systems and learn about cryptography in quantum communication.

Syllabus

Unit 1. ***Optical Transmitters & Receivers:*** *Optical transmitter, Intensity modulation, LEDs, Laser diodes fundamentals: Efficiency, characteristics, modulation bandwidth, Optical detection principle, quantum efficiency, responsivity, semiconductor photodiodes with and without internal gain, noise, signal-to-noise ratio calculations, receiver structures.*

Unit 2. ***Coherent Optical Communication:*** *Detection principles, practical constraints, homodyne and heterodyne detection, receiver sensitivities, BER, system performance, multicarrier system and network concepts.*

Unit 3. ***Transmission System Design:*** *Intensity modulation/ direct detection, design considerations, Digital systems, regenerative repeater, bit error rate (BER), link design: power budget, rise time budget, Analog systems, direct intensity modulation, subcarrier intensity modulation.*

Unit 4. ***Quantum Systems:*** *History of quantum information, Quantum bits, Multiple qubits, Single-Mode and Two-Mode Quantum systems, linear propagation loss, phase insensitive and phase sensitive amplifiers.*

Unit 5. ***Quantum Cryptography:*** *Public and private key cryptography; Quantum key distribution; Quantum cryptography; Experimental implementation of quantum cryptography protocols.*

Text Books

1. J. Gower, Optical communication systems, PHI, 2/e, 2001.
2. G. P. Agrawal, Fiber-optic communication systems, John Wiley & sons, Inc., 3/e, 2002.
3. Nielsen M.A. and Chuang I.L., Quantum Computation and Quantum Information, Cambridge University Press, 2000

Reference Books

1. Preskill J., Lecture Notes for the Course on Quantum Computation, http://www.theory.caltech.edu/people/preskill/ph229
2. H. Kolimbris, Fiber optics communications, Pearson Education, 1/e, 2004.

PH66754 : QUANTUM ALGORITHMS WITH PYTHON AND QISKIT (ELECTIVE-IV)

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

CO#1. To get acquainted with basic Quantum Computing circults

CO#2. To learn quantum computing concepts practically

CO#3. Learn to write codes using Python and to verify the same with IBM Qiskit

CO#4. To learn the cutting edge practical scenarios in real-time

Course Outcome

CO#1. Mastered the use of IBM Qiskit to real-time problems

CO#2. Apply appropriate coding skills to complicated QC problems

CO#3. Explore the use of coding with Qiskit to low temperature QC problems

CO#4. Create own quantum computer circuit and logics

Syllabus

Unit 1. *Quantum states and cubits, mutiple qubits and entanglement, phase kickback (CNOT and Hadamard),*

Unit 2. *Quantum speedup, hidden subgroup and application to cryptography, search and optimization, applying Grover's algorithm for simiplification, random walk, quantum walks.*

Unit 3. *Quantum protocols and quantum algorithms: Deutsch-Jozsa, Bernstein-Vazirani, Simon's, Quantum Fourier transform, Shor's and Grover's algorithms.*

Unit 4. *Applications: Solving linear system of equations, Solving combinatorial optimization problems using QAOA, Solving Satisfiability Problems using Grover's Algorithm, Quantum Image Processing - FRQI and NEQR Image Representations*

Unit 5. *Quantum Hardware: Calibrating Qubits, introduction to transmon physics, circuit QED, applications of Jayens-Cummings Hamitonion, measuring ac-Stark effect, Hamiltonian tomography.*

Text Books

1. H. Norlan, Quantum Computing in Practice with Qiskit and IBM Quantum Experience, Packt Publishing, Birmingham, 2020.
2. J. L. Weaver and F. J. Harkins, Qiskit Pocket Guide, O'Reily Media, California, 2022.
3. Quantum Computing Labs (qiskit.org) (https://qiskit.org/)

Reference Books

1. Swayam Portal
2. C. C. Moran, Mastering Quantum Computing with IBM QX, Packt, Birmingham, 2020.
3. A. Monta naro, Quantum Algorithms: An Overview (arXiv: 1511.04206v2)

PH66755 : Quantum Networks (Elective - IV)

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

To provide knowledge about evolution of optical networks transmission stantards, routing and switching. To infix concepts of network components in WDM/DWDM ATM, SONET and SDH networks.

Course Outcome

Students will understand the basic concepts involved in current technologies e.g. FITH FDDI. SONET etc. and will be capable of analyzing designing and configures typical optical communication networks.

Syllabus

Unit 1. *Introduction to Optical Networks : First and second generation otptical network, network topolgies and protocols, circuit and packet switching. OSI model, multiplexing techniques, victural circuit services and data grams, transparency of regererators, Broadcast and Select Netrowks : MAC protocols, throughput calculation, synchronization, aloha and slotted aloha.*

Unit 2. *WDM networks and components : WDM networks, DWDM, CDEM, WDM multiplexers and demultiplexers, attayed wageguide gratting, optical add/drop multiplexers, fiber Bragg gratings as add/drop multiplexers. WDM Filters, Fabry Perot filters, acousto-opti tunalbe filters, switchig technologies and architctures, characterization of switches.*

Unit 3. *First Generation Optical Networks : SONET/SDH, Goals of SONET design, SONET frame structure, overhead channels, payload pointer, virtual tributaris, multiplexing hierarchy, elements of SONET/SDH infrastrucure, SONET physical layer, computer interconnets, ESCON, fiber channel, FDDI, ATM, IP, layered architecture : IP over AMT and SONET.*

Unit 4. *Wavelength Routing Networks: Classification of light paths, The Optical layer, Wavelength Cross Connects (WXC) wavelength reuse, node design, degree of wavelength conversion, Static and reconfigurable network, N/W design considerations; fiber cost trade-off.*

Unit 5. *Photonic Packet Switching: Optical time domain multiplexing (OTDM), methods of multiplexing and demultiplexing, broadcast OTDM networks, bit interleaving and packet interleaving, optical AND gates, nonlinear optical loop mirrors, terahertz optical asymmetric demultiplexer, switch based networks, deflection routing.*

Text Books

1. R. Ramaswami and K. N. Sivarajan, Optical Networks : A Practical Perspective, Harcourt Asia P. Ltd. 1999.
2. C. S. R. Murthy and M. Gurusamy, WDM Optical Networks, Prentice Hall, 2002.
3. A.S. Tanenbaum, Computer Networks, Prentice Hall of India Pvt. Ltd., 2002.

Reference Books

1. J.E. Midwinter, Photonics in Switching, Academic Press, 1993.
2. U. Black, Optical Networks, Prentice Hall, 2002.

PH66756 : Quantum Artificial Intelligence and Machine Learning (Elective-IV)

(Credits: L-3,P-0,T-0. Marks: CW+TH=30+70)

Course Objectives

CO#1. To introduce machine learning concepts and applications

CO#2. To learn and use quantum concepts to solve machine learning process

CO#3. To understand appropriate places where QC could be used.

Course Outcome

CO#1. Able to solve machine learning problems using quantum computations

CO#2. Knows the use of quantum logics for data mining and applications

CO#3. Independtly understand and solve multilevel problems in machine learning

Syllabus

Unit 1. *Introduction: Learning theory and data mining, quantum like classical computers.*

Unit 2. *Data driven models, supervised and unsupervised learning, generalization performance, ensembles, data dependencies and examples*

Unit 3. *Pattern Recognition and Neural Networks, perception, Hopfield Networks, Feedforward networks, Deep learning, computational complexity.*

Unit 4. *Supervised Learning and Support Vector Machines, Optimal Margin Classifiers, Soft Margins, Nonlinearity and Kernel Functions, Least-Squares Formulation, Multiclass Problems, Loss Functions.*

Unit 5. *Quantum Pattern Recognition, Quantum Associative Memory, Quantum Perceptron, Quantum Neural Networks, Physical Realizations*

Text Books

1. P. Wittek, Quantum Machine Learning, Elesevier, Amsterdam 2014.
2. Articles in https://arxiv.org/qu-comp
3. S. Bhattacharyya, I. Pan, A. Mani, S. De, E. Behrman, S. Chakraborti (Eds.), Quantum Machine Learning, Walter de Gruyter, Berlin, 2020.