Course Proposal

Department of Electrical Engineering

Indian Institute of Technology Kanpur

1. **Course Number:** EE798I (Old Course No.), (Old course name: Nanophotonics)
2. **Course Title:** Integrated Nanophotonics: From Maxwell to Photonic Circuits
3. **Prerequisite:** Basic familiarity with electromagnetism/Maxwell's equations.
4. **Course Credits:** (3-0-0-0) [9]
5. **Course Duration:** Full Semester
6. **Proposing Department:** EE
7. **Proposing Instructor:** Rituraj, email: rituraj@iitk.ac.in

   Other faculty members who may be interested in teaching the course:

   Prof. Shilpi Gupta, Prof. Debdatta Ray
8. **Other departments who may be interested in the proposed course:** Physics, MSE, SEE.
9. **Course Type:** PG, 3rd & 4th year UG, Open Elective
10. **Course Description:** Photonic devices and systems play a crucial role in diverse areas ranging from modern communication, information processing, display, imaging, and energy harvesting. To meet the current technological demands in these areas, photonic systems have increasingly grown in complexity and functionality. Some of the notable developments in recent years include Photonic integrated circuits (or Silicon photonics), photonic accelerators for AI, AR/VR displays, and quantum communication networks.

    This course aims to bridge the gap between the "abstract" Maxwell's equations and the building blocks of a photonic integrated circuit. The course starts with a discussion of different formulations of the Maxwell's equations, the general properties of its solutions, and the commonly used techniques to determine these solutions. Building on these, the course introduces the standard photonic structures such as dielectric waveguides, cavities, and photonic crystals. Numerical simulation and visualization tools are frequently used to better illustrate the concepts. The course concludes with a discussion of designing photonic systems using these standard building blocks for a certain application.

11. Course Contents:

Content Outline of Lectures	**Lect.**
Introduction: Importance, applications, and scope of the course	1
Maxwell's equations in time-domain: Differential & Integral forms, Constitutive relations, Free and bound sources, Analogy with Linear and Time Invariant (LTI) systems, Continuity equation, Energy conservation, Poynting vector, Wave equation, Plane wave solution, Polarization, Pulses of finite duration	6

Maxwell's equations in frequency-domain: Fourier transform, Phasors, Drude model, Lossy and dispersive media, Time-reversal symmetry, Scaling invariance, Gaussian beam	4
Inhomogeneous media: Field continuity conditions & Solution methodology, Step discontinuity, Reflection, Refraction, Total Internal Reflection, Dispersion plots, Brewster angle, Multi-layer dielectric stacks, Transfer Matrix Method, Wave impedance formulation, Dielectric mirror and Anti-reflection coating	8
Dielectric waveguide: Divergence of Gaussian beam, Guided modes of a dielectric slab, Group velocity and dispersion, Different waveguide geometries, Excitation of waveguide modes	6
Photonic crystals: Unit cell and Reciprocal lattice, Bloch's theorem, Eigenvalue formulation of Maxwell's equations & Band structure, 1D photonic crystal, Origin of bandgap, Omni-directional dielectric mirror, Fabry-Perot cavity, Bragg fiber, Grating coupler, Perturbation theory, 2D and 3D photonic crystals	7
Photonic Integrated Circuits: Different material platforms, Coupled-mode theory, Scattering matrix, Directional coupler, Y Splitter, Mach-Zehnder Modulator, Ring-resonator, Waveguide filter design, LIDAR and/or AR/VR displays	7
Total no. of lectures	**39**

9. References:

1. *"Waves and Fields in Optoelectronics",* Hermann A. Haus.
2. *"Photonic Crystals: Molding the Flow of Light",* Joannopoulos, Johnson, Winn and Meade.
3. *"Fundamentals of Photonics"*, Saleh and Teich
4. Journal papers