Approved in 38th BoA Meeting (22-01-2021)

Course number : **EE551**
Course Name : **Applied Photonics for Scientists and Engineers**
Credit : **2-1-0-3**
Prerequisite : **IC110, IC111, IC221**
Intended for : **UG, PG, M. Tech, M. Sc. Physics, I-PhD, PhD**

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1. Preamble:

Photonics is a powerful enabling technology that offers unique tools and solutions for innovation. But beyond this, photonics can be also viewed as a gateway discipline – as it can be used to bridge the gap between disciplines towards making valuable long-standing contributions.

This course aims to equip the students with the conceptual foundations of the principles of photonics, and requisite skills for enabling them to apply it in their own disciplines. The course topics will include essential principles of photonics, but with a focus on their applications. It is expected that at the end of the module, students will be able use core principles and applied techniques of photonics in their respective disciplines.

Pre-requisites for this course are a working knowledge of calculus, vector and matrix algebra. A basic understanding of vector calculus and Fourier transforms are desirable, though not necessary.

Upon completion of this module, it is expected that students will be able to

- ***describe*** light propagation and its interaction with diverse media using wave and ray models.
- ***use*** basic photonic components and devices in their own disciplinary areas.
- ***analyze and evaluate*** the use of photonic-based technologies in real-world interdisciplinary applications.

2. Course Modules with quantitative lecture hours:

Fundamentals of the Electromagnetic theory of light – complex representation of electromagnetic field disturbances, Maxwell's equations, Fresnel equations, limitations of the electromagnetic description. (2 hours)

Optical systems – Fermat's principle, basic optical elements, matrix methods for optics, thick lens and their systems, determination of cardinal points, basic optical systems. (3 hours)

Polarisation – fundamentals, special devices – crystals, compensators, spatial light modulators, mathematical representations of polarised light. (3 hours)

Gaussian Beam Optics – beam propagation equation, beam properties and their characterization, matrix approach for Gaussian beam optics. (2 hours)

Interferometry – principles and applications – fundamental concepts – conditions for interference, coherence theory elements, Young's double slit experiment, multiple-beam interference. Systems - Michelson, Twyman Green, Fizeau and other select configurations. Selected applications – e.g. metrology, sensors. (4 hours)

Fourier Transforms in Optics – Foundational concepts and theorems, Fourier methods in diffraction theory, Abbe Porter's experiment, applications – e.g. optical waveshapers. (3 hours)

Fibre optic systems – principles of guided wave propagation, basics of single mode and multimode, passive components, active components, fibre-optics based system design considerations, select applications – e.g. Dispersive Fourier Transformer, fibre optic sensors, imaging configurations. (4 hours)

Nonlinear optics - Light-matter interaction and the nonlinear wave equation, second order nonlinearity - second harmonic generation, three-wave mixing, third order nonlinearity - third harmonic generation, four-wave mixing, Kerr nonlinearity and its applications. (4 hours)

Detection of Optical Radiation – Time-domain methods: High speed detectors, Photomultipliers, Time of flight detectors, Cameras, characterization of ultrashort pulses. Spectral-domain methods – Essential components, resolving power of dispersive devices, the optical spectrum analyzer. Basics of quantum light – single photon generation and detection, applications – e.g. qubits. Full-field measurement techniques. (4 hours)

Tutorial sessions – 10.

- *Resource required* for tutorial sessions – Access to computer labs for numerical/computational solving of problems.

3. Text books:

Hecht, E., Optics, 4/e, Pearson.
Ghatak, A. K., & Thyagarajan, K., Optical Electronics, Cambridge University Press 2018.

4. References:

Saleh, B. E. A, & Teich, M. C., Fundamentals of Photonics, 2/e, Wiley Interscience 2007.

5. Similarity Content declaration with existing courses:

S. No.	Course Code	Similarity Content	Approx. % of Content
1.	PH502	Electromagnetic theory; polarization; Detection of light; Guided wave optics.	Less than 40%

6. Justification of new course proposal if cumulative similarity content is >30%:

The discipline of focus of the presently proposed course is photonics, which is the same for the existing course PH502.

However, the emphasis of the presently proposed course is more on the applied nature of the topics discussed. It is designed with the goal that upon completion of the course, the students will be able to use the techniques learnt and apply them practically in their own labs and experiments. To this end, student learning will be supported during tutorial sessions by looking at real-world systems and case studies. In addition, students will be required as part of their summative assessment to present a current topic of their choosing (vetted by the course instructor) as a poster to faculty and other scholars, who would adjudge their understanding of the material at par with working professionals on the field.

The existing similarities between the two courses primarily arise owing to the correspondence to fundamental concepts. Again, as highlighted above, the course content and approach taken will be one tailored towards applying the taught concepts, and transferring them to the student's own field of expertise.

Furthermore, the proposed course ***includes 5 new topics***, viz. optical systems design, Gaussian beam optics, Fourier Transforms in Optics, Optical detection – spectral domain methods, and Nonlinear Optics. **These will serve to complement the existing PH502 course.**

The table below indicates the similarity content in 5 of the 10 topics of the presently proposed course. This table also serves to highlight inclusion of additional content within the similar topics, which underscore the applied ethos of the proposed course.

Similar content are indicated in blue –

PH502	This proposed course
Electromagnetic optics – Electromagnetic theory of light, electromagnetic waves in vacuum & dielectric media, absorption and dispersion, pulse propagation in dispersive media, Metamaterials	**Fundamentals of Electromagnetic theory of light** – complex representation of electromagnetic field disturbances, Maxwell's equations, Fresnel equations, limitations of the electromagnetic description.
Polarization optics – Polarization of light, reflection and refraction, optics of anisotropic media, Optics of liquid crystals, polarization devices.	**Polarisation** – fundamentals, special devices – crystals, compensators, spatial light modulators, mathematical representations of polarised light,
Guided wave optics - electromagnetic waves in dielectric layered media, photonic crystals, waveguides, resonators, plasmonics. & **Fiber Optics**: electromagnetic waves in fiber, Attenuation and dispersion, photonic crystal fibers & **Optical fiber communication**: fiber Optic components, optical fiber communication syatem, modulation and multiplexing, fiber optic networks.	**Fibre optic systems** – principles of guided wave propagation, basics of single mode and multimode, passive components, active components, fibre optics based design considerations, select applications – e.g. Dispersive Fourier Transformer, fibre optic sensors, imaging configurations.
Detection of light - theory of photo detection, photodetectors, photodiodes, avalanche photodiodes, noise in photodetectors.	**Detection of Optical radiation -** Time-domain methods: High speed detectors, Photomultipliers, Time of flight detectors, Cameras, characterization of ultrashort

	pulses. Spectral-domain methods – Essential components, resolving power of dispersive devices, the optical spectrum analyzer. Full-field measurement techniques.