Course Requisites (if applicable)

Pre-requisites	Nil
Co-requisites	Nil
Pre-requisite to	Nil
Mutually exclusive to	Nil
Replacement course to	Nil
Remarks (if any)	

Course Aims

This course intends to equip you with the fundamental knowledge and methodologies on nanophotonics, nanophotonic structured light, nanophotonic materials and devices, by focusing on several frontier subfields including plasmonics, metamaterials, subwavelength gratings, and near-field optics. The emphases of the course are on the fundamental principles, applications, and recent developments of the nanophotonic devices. The related numerical modeling methods, nanofabrication techniques, and characterization methods of the nanostructures and fields will also be introduced. By learning the course, the students' problem-solving skills will be sharpened. Besides, students are expected to grasp the fundamental knowledge and methodologies that can be applied in their research work with topics related to nanophotonics.

Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	Identify the relevant features of nanophotonics
ILO 2	Derive the wave equation of wave solution from Maxwell's equations
ILO 3	Explain the dispersion of materials
ILO 4	Master numerical methods for nanophotonics including finite difference time domain (FDTD) method and finite element method (FEM)
ILO 5	Master FDTD Solutions workshop
ILO 6	Explain the basics of radiation in free space
ILO 7	Explain the Berry phase principle and generalized snell's law
ILO 8	Apply the concept of light matter coupling in photon-electron systems and derive formulas for the dispersion of surface plasmon polaritons (SPPs)
ILO 9	Master the methods of the excitation and characterization of SPPs
ILO 10	Explain the difference of localized surface plasmons (LSPs) on metal nanoparticles with SPPs
ILO 11	Apply the coupling effects of LSPs between nanoparticles to realize nanoparticle chain used as SPP waveguide
ILO 12	Build the plasmonic circuit, including the components of SPP waveguides, mirrors, routing of SPPs, multiplexers & demultiplexers, couplers, filters, SPP sources and launchers, amplifiers and detectors of SPP
ILO 13	Use physical optics concepts (such as Fresnel's equation, group velocity) to analyse and solve problems for practical applications (such as beam splitters, optical fibres, TIR microscopy and photonic crystals)
ILO 14	Grasp the utilization of the scanning near-field optical microscopy in collection and illumination operation mode
ILO 15	Apply the Scanning Probe Microscopy (SPM) to measure many optical field parameters in near-field, including topography, intensity, phase & amplitude, polarization & vector, magnetic field, dynamics

ILO 16	Explain the need for a completely new set of material system by discussing the limitations in the naturally occurring materials and the fundamental electric and magnetic property of existing natural materials
ILO 17	Apply the Maxwell's equations to a new form of electromagnetic materials known as negative-index metamaterials (NIMs) and predict their unique properties such as negative refraction and backward wave propagation
ILO 18	Cite examples of the applications of metamaterials in perfect lens (superlens), superlens and cloaking
ILO 19	Explain light-matter interaction in planar chiral metamaterials (PCMs)
ILO 20	Design metasurface-based devices such as vortex beam generation, switchable unidirectional SPP excitation, dual-polarity metalens and meta-holograms

Course Content

Note: This course includes partial content similar to PH4608 Plasmonics and Metamaterials, but focuses on more general and cutting-edged nanophotonic subjects, advanced nanophotonic technologies and calculation methods, such as nanoscale structured light, topological light shaping, spin-orbit conversion, FDTD method, and so on.

Light propagation

Electromagnetic wave description of Maxwell Equations, boundary conditions, constitutive equations, wave equation, time- and spatial-harmonic field;

Phase velocity and group velocity in Fresnel's equations;

k-ω dispersion relation;

nanophogonics;

Numerical modeling methods

Finite difference time domain (FDTD) method

Finite element method (FEM)

Numerical workshop FDTD Solutions

COMSOL Multiphysics Simulation Software

Plasmonics

Surface plasmon polaritons (SPPs)

SPPs in multilayer systems

Excitation of SPPs

Characterization of SPPs

Localized surface plasmons of metallic nanoparticles

Resonance and coupling condition of LSPs

LSPs of complex nanostructures

Plasmonic circuitry

Near-field optics

Fundamentals of near-field optics and

Near-field optical imaging,

Scanning probe microscopy (SPM) family

Nano-optical detection based on near-field optics

Subwavelength resonance gratings: optical anomalies, guided-mode resonance (GMR) gratings and surface plasmon resonance (SPR) gratings

Metamaterials & metasurfaces

Definition and characteristics of metamaterials

Negative-index metamaterials (NIMs)

Light-matter interaction in chiral metamaterials

Metasurfaces and meta-devices

Nanoscale structured light

Vortex beams

Vector beams

Orbital angular momentum of light

Spin angular momentum of light

Spin-orbit conversion of light

Topologically structured light

Reading and References (if applicable)

Textbook:

1. Nanophotonics, by Paras N. Prasad (Wiley-Interscience, 2004).

Reference books:

• Fundamentals

2. Plasmonics: Fundamentals and Applications, by Stefan A. Maier (Springer, 2007).

3. Principles of Nano-Optics, by Lukas Novotny and Bert Hecht (Cambridge University Press, 2006).

• Near-field optics

4. Near Field Optics, by Dieter W. Pohl and Daniel Corjon (Kluwer Academic, 1993).

5. Near-field Microscopy and Near-field Optics, by Daniel Courjon (Inperial College Press, 2003).

• Plasmonics

6. Surface Plasmons on Smooth and Rough Surfaces and on Gratings, by Heinz Raether (Springer, 1988).

• Structured light

7. The angular momentum of light[M]. Cambridge University Press, 2012.

Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	Introduction to Nanophotonics	1	Lectures	In-person	Tutorials
2	Light-matter interaction	2，3	Lectures	In-person	Tutorials
3	Numerical modeling methods	4	Lectures	In-person	Tutorials
4	FDTD Solutions workshop	5	Lectures	In-person	Tutorials
5	Surface plasmon polaritons	8	Lectures	In-person	Tutorials
6	Excitation & characterization of SPPs	9	Lectures	In-person	Tutorials
7	Localized surface plasmons	10, 11	Lectures	In-person	Tutorials
8	Plasmonic circuitry	12	Lectures	In-person	Tutorials
9	Near-field optics (I)	6，13，14	Lectures	In-person	Tutorials
10	Near-field optics (I)	15	Lectures	In-person	Tutorials
11	Metamaterials	16，17，18	Lectures	In-person	Tutorials
12	Chiral metamaterials	19	Lectures	In-person	Tutorials
13	Metasurface	7，20	Lectures	In-person	Tutorials

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Lectures	The interactive lecture session where there are ample opportunities for open discussion on the conceptual questions raised in the class allows the student to think critical and share their ideas and concept with the class. This also allows me to get the concepts clearly through the entire class by involving each student there and ensure that the targeted learning outcomes are being achieved
Tutorials	This would allow the students to crack some intriguing problems and thus help me achieve the learning outcome.
Homework	The homework comprises standard textbook practice questions that are covered during tutorial.
Technology Enhanced Learning (TEL)	Through blending and integration of technology into teaching practices, such as online discussion with other professors, online videos, recorded lectures, etc., TEL affords an enriching learning experience that facilitates learners' learning, knowledge building and achieving the overall learning outcomes.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Team/Individual	Rubrics	Level of Understanding
1	Continuous Assessment (CA): Presentation(CA1: Paper Review)	1, 2, 3, 4, 5	Competency (1, 4, 5), Communication (1, 2)	30	Individual	Holistic	Multistructural
2	Continuous Assessment (CA): Presentation(CA2: Research Project)	8, 9, 10, 11, 12, 14, 15	Communication (1, 2, 3) Creativity (1, 2) Character (1, 2, 3)	30	Team	Holistic	Relational
3	Continuous Assessment (CA): Report/Case study(CA3: Homework Assessment)	6, 7, 13, 16, 17, 18, 19, 20	Competency (1, 3, 4, 5, 6), Creativity, Communication (1, 2)	40	Individual	Holistic	Relational

Description of Assessment Components (if applicable)

CA1: You are required to search for and intensively read 1-2 classic or recent journal paper on Nanophotonics. The selection method of article themes will be presented in class. You will conclude with a slide presentation of your content as a report.

CA2: You are required to form a team with few classmates. You will select a specific cutting-edge molecule in Nanophotonics, and specifically explore the developments and problems in that branch, discuss possible solutions and future applications. The results of the team will be presented in the form of slides.

CA3: You are required to understand the basic principles of spatial light interference, to design and generate spatially structured light based on that principle. Then you implement that design in code. The results will be submitted in the form of an essay.

Formative Feedback

Formative feedback is given through discussion within tutorial lessons.
Feedback is always provided for your response to each question.
Feedback is also given after each midterm on the common mistakes and level of difficulty of the problems.
Feedback is also given during consultant discussion.

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Collaboration	Basic
Communication	Basic
Creative Thinking	Advanced
Information Literacy	Basic
Systems Thinking	Basic

Course Policy

Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values. As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

You are expected to complete all assigned readings, activities, assignments, attend all classes punctually and complete all scheduled assignments by due dates. You are expected to take responsibility to follow up with assignments and course related announcements. You are expected to participate in all project critiques, class discussions and activities.

Policy (Absenteeism)

In-class activities make up a significant portion of your course grade. Absence from class without a valid reason will affect your participation grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU's approved activities supported by an excuse letter from the relevant bodies. There will be no make-up opportunities for in-class activities.

Policy (Others, if applicable)

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