Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	2017/2018	**Semester**	1
Course Coordinator	Ranjan Singh		
Course Code	PH4608		
Course Title	Plasmonics and Metamaterials		
Pre-requisites	PH2102 Electromagnetism		
No of AUs	3		
Contact Hours	26 hours - Lecture 13 hours - Tutorial		
Proposal Date	11/03/2017		

Course Aims

The course will be interdisciplinary in nature where the students would expand their knowledge base in the areas of nanophotonics, solid state physics, and spectroscopy. The aim would be focused at delivering the current state of the art research topic in the field of plasmonics and metamaterials. This course would encourage undergraduate students to apply their fundamental knowledge of optics and solid state physics into new area of nanophotonics.

Intended Learning Outcomes (ILO)

By the end of this course, you (as a student) would be able to:

Fundamentals (FUNDA)

1. explain the common terms used in the discussion of light-matter interaction;
2. cite examples of the applications of photons at micro-nanoscale in Science and conversely identify the appropriate phenomena and experiments;
3. apply the basic concept of photon coupled with electron resulting in the concept of plasmonics based applications and devices;
4. apply metamaterial concepts to manipulate light in different novel material systems at extremely small scale with ultrafast, and ultra-low power functionalities;
5. apply basic concepts of micro-nanophotonics to solve practical technological problems such as designing ultrasensitive sensor systems;

Plasmonics (PLASMON)

6. apply the concept of light matter coupling in photon-electron systems and derive formulas for the dispersion of surface plasmon polaritons;
7. apply the plasmonics dispersion relationship to to solve the problem of diffraction leading to super focusing enabled by plasmonics;
8. provide a graphical interpretation of coupling schemes and apply the appropriate techniques for momentum matching between free space photons and the surface plasmon polaritons;
9. apply the boundary conditions in Maxwell's equation to solve the exact conditions for the excitation of surface plasmon polaritons;
10. cite examples of the applications of plasmons in Science (such as beyond diffraction limit imaging) and conversely discuss the relevant scientific phenomena and experiments;

Metamaterials (META)

11. 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;
12. apply the Maxwell's equations to a new form of electromagnetic materials known as metamaterials and predict their unique properties such as negative refraction and backward wave propagation;
13. cite examples of the applications of metamaterials in Science and engineering and the methods to design application specific metamaterial devices;
14. apply nearest neighbor coupling to illustrate the effective properties of metamaterial resonators in different lattices;

Novel Material Systems in Micro-Nanophotonics (NMS)

15. apply different exotic material systems to design active metamaterial photonic devices for different functionalities;
16. select the appropriate material systems that empower the performance of metamaterials including superconductors, semiconductors and low dimensional material systems; and
17. discuss the physics of novel material system and illustrate its impact on the manipulation of light at micro-nanoscale, specifically in the metamaterial and the plasmonic system.

Course Content

The course would mainly consist of the following topics:

1. Fundamentals of Surface Plasmon Polaritons
2. Dispersion relation and coupling mechanisms
3. Fundamentals of metamaterials: The material that exists beyond the nature.
4. Active Metamaterials
5. Bright and dark mode resonances in metamaterials
6. Near field coupling phenomena: Slow light in metamaterials
7. Superconductor metamaterials
8. Fano resonant high quality factor metamaterials
9. Toroidal dipole: A new class of exotic excitations in metamaterials
10. Microelctromechanical Systems (MEMS) for Active Metamaterials

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team/Individual	Assessment Rubrics
1. Final Examination	ALL	Competence, written communication	60	Individual	2 hour examination with limited open book. They have an A4 sized cheat sheet

					consisting of formulas Appendix 1
2. Mid-term Test	FUNDA / PLASMON LO 1-10	Competence, written communication	15	Individual	1 hour mid-term test with limited open book. A4 sized cheat sheet with formulas. Appendix 1
3. CA: Research Project Assignment	ALL	Competence, Communication, Creativity	25	Individual	Research topic study and a class presentation of 20 minutes See Appendix 2
Total			100%		

Formative feedback

This course would be an interactive course where the inputs of each students would be taken for some of the open questions asked during the class and the tutorial session. The two assignments would be another indicator of how each student is progressing through the course. The research study and presentation would also allow me to provide feedbacks to the students.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Lectures	The interactive lecture session where there is 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.

Reading and References

Text Book

Plasmonics: Fundamental and Applications, First Edition, Stefan Alexander Maier, Springer, 978-0387331508, 2007

Course Policies and Student Responsibilities

(1) General

Students are expected to complete all assigned pre-class readings and activities, attend all seminar classes punctually and take all scheduled assignments and tests by due dates. Students are expected to take responsibility to follow up with course notes, assignments and course related announcements for seminar sessions they have missed. Students are expected to participate in all seminar discussions and activities.

(2) Absenteeism

An important component of the course is the research project presentation where students learn from each other. Both the presenter and the audience contribute to the discussion and learning. Therefore, both research presentation and contribution to class discussion will be assessed [See Appendix 2]. Absence from class without a valid reason will affect your overall course 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.

If you miss a research project presentation, you must inform me via email prior to the start of the class.

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. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Ranjan Singh	SPMS-PAP-03-13	63162965	ranjans@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Introduction to plasmonics	FUNDA 1-5 PLASMON 6	Text book: Chapter 1
2	Coupling mechanisms in plasmonics	PLASMON 6-10	Text book: Chapter 2
3	Maxwell's equations: A review; Introduction to metamaterials	META 11-14	Problem solving in class on the concept of displacement current from Maxwell's equations.
4	Passive and Active Metamaterials	META 11-14	Read lectures/ publications on active metamaterials
5	Bright and dark mode resonances in metamaterials	META 12	Reads journals on bright and dark mode resonances in metamaterials and plasmonics
6	Near field coupling in metamaterials	META 13	Lecture notes/ Journal publication
7	Fano resonances in metamaterials	META 12-14	Lecture notes
8	Superconductor Metamaterials	NMS 15-17	Lecture notes/ Journal publications
9	Toroidal Metamaterials	META 14 NMS 15-17	Lecture notes/ Journal Publication
10	MEMS Metamaterials	NMS 16	Lecture notes/ Journal Publications
11	Review of plasmonic metamaterials	FUNDA 1-5 PLASMON 6-8	Text book/ Lecture notes
12	Review of metamaterials	META 11-17	Lecture Notes
13	Review of plasmonics systems	PLASMON 6-10	Text book

Appendix 1: Assessment Criteria for Final examination, mid-term test, and the research project

Marks	Criteria
> 90%	Demonstrates Excellent understanding of the concepts of plasmonics and metamaterials
75% to 89%	Demonstrates good understanding of the course content taught and discussed in the class
65% to 74%	Demonstrate average understanding of the content
50% to 64%	Demonstrates below average grasp of the concepts taught in the class
< 50%	Has no idea of the concepts taught in the class.

Appendix 2: Rubrics for Research Project Presentation

Source: hplengr.engr.wisc.edu/Rubric_Presentation.doc

Category	Scoring Criteria	
Organization (15 points)	The type of presentation is appropriate for the topic and audience.	
	Information is presented in a logical sequence.	
	Presentation appropriately cites requisite number of references.	
Content (35 points)	Introduction is attention-getting, lays out the problem well, and establishes a framework for the rest of the presentation.	
	Technical terms are well-defined in language appropriate for the target audience.	
	Presentation contains accurate information.	
	Material included is relevant to the overall message/purpose.	
	Appropriate amount of material is prepared, and points made reflect well their relative importance.	
	There is an obvious conclusion summarizing the presentation.	
	Ability to handle questions	
Presentation (30 points)	Speaker maintains good eye contact with the audience and is appropriately animated (e.g., gestures, moving around, etc.).	
	Speaker uses a clear, audible voice.	
	Delivery is poised, controlled, and smooth.	
	Good language skills and pronunciation are used.	
	Visual aids are well prepared, informative, effective, and not distracting.	
	Length of presentation is within the assigned time limits.	
	Information was well communicated.	
Score	**Total Points**	
Participation in past class discussion (20 points)	Ask questions and contribute to discussion in other research project presentation	