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IPT54100 Spring, 2022

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IPT54100 Laser and Nonlinear Optics Laboratory

雷射與非線性光學實驗

國立清華大學 光電光程研究所/電機工程學系
Institute of Photonics Technologies, National Tsinghua University, Hsinchu 30013, Taiwan

Prof. 黃衍介

Spring, 2022

Location: first time to meet at Delta 212 W9, Wednesday, Feb. 16th, 2022 .

Head Teaching Assistant: 陳文祺

- For the laboratory sessions, the lab is located at 2nd floor of the 光電中心 高能光電實驗室, HOPE Laboratory https://goo.gl/maps/FxstGWowwJGPnkMEA
- Pre-lab meetings (9:30 am ~ noon, every other Tuesday) @ HOPE 406, (a week before each lab session)

一、課程說明

This course is to help students develop laboratory skills on modern photonics with emphasis on laser and nonlinear optics. The course first teaches a student the operation of basic instruments, such as oscilloscope, photodetector, lockin amplifier, monochromator, and spectrophotometer etc. The students then get hand-on experience on characterizing laser beam, laser mode, laser gain, and laser Q-switching. The third part of the laboratory course is about electro-optic modulation and laser wavelength conversion utilizing the 2nd and 3rd order optical nonlinearity in materials. We will have lectures and exams of this laboratory course merge with those for the IPT5110 Nonlinear Optics course.

Students are encouraged to come to the Nonlinear-Optics Course Lectures @ Delta 212, W4R3R4.

二 指定用書

1. Lecture notes + Laboratory handouts (available at the on-campus 利捷影印店 or http://www.hope.nthu.edu.tw after Feb. 22nd, 2021)

三、參考書籍

0. David K. Cheng, Field and Wave Electromagnetics 2nd Ed., Addison Wesley,

1989.

1. 近代實驗光學，東華書局，黃衍介 著。
2. Nonlinear Optics by E.G. Sauter, John Wiley & Sons, 1996.
2. Fundamental of Photonics by Saleh & Teich, John Wiley & Sons, Inc.
3. Optical Waves in Crystals by Yariv and Yeh, John Wiley & Sons, Inc.
4. Quantum Electronics, by Yariv, John Wiley and Sons, Inc.

四、教學方式

- **Laboratories with lectures**

During the semester, students are required to carrying out 8 experiments on the 2nd floor of the HOPE Laboratory (高能光電實驗室), one experiment every other week. Each student is asked to turn in a laboratory report, due in 7 days from the first day working on the experiment. Detailed descriptions for the laboratory sessions are given below.

- **Exams –** midterm and final exam. (coincide with the IPT5110 Nonlinear Optics Course)
- Homework
  1. Slides: preparing at least 5 slides in each pre-lab meeting, containing what to measure and what to observe in the experiment. Don't copy down the full theory from the handout and present it.
  2. QA Sheet: The pre-lab meeting is held at HOPE 404 one week before each lab session. Before the meeting, email Prof. Huang and the teaching assistant a pre-report containing the 5 slides and one page of 5 answers or speculated answers to those questions in the lecture notes + laboratory reader. If you can't find questions in the lab reader, please design the questions by yourself. The filename of the homework should identify yourself, such as your_name_HW-1.pdf for the first submission.
- Presentations: Each student will be called to give a presentation in the pre-lab meeting. Fellow students and the instructor will grade the presentation.

五、教學進度

* The persons listed after an experiment are responsible for collecting the components and set up the experiment with the head TA before the first day of the laboratory session.

Week 0 (Feb. 16th @ W9 17:30~18:20, Delta 212) Introduction

Laboratories (* "reading material" refer to the content in the nonlinear-optics

handout)

Weeks 1, Feb. 21~, pre-lab meeting @ HOPE 404

Reading Material: Electromagnetic Wave

Reading Material: Gaussian Laser Beam

Week 2, Feb. 28th ~ , lab session @ 2nd-floor of HOPE

- **Experiment 1 Photonics measurement** (楊于聖) – photonics instruments, photodetector, pulse, wavelength, absorption, noise

Reading Material: Optical Resonator

Reading Material: Wave Propagation in Aniostropic Material

Week 3, March 7th, pre-lab session @ HOPE 404

Week 4, March 14th ~, lab session

- **Experiment 2 Laser transverse modes** (彭珞豪): Transverse modes generation from externally injected HeNe laser cavity. Gaussian Beam Characterization – M^2 measurement

Reading Material: Acousto-optics

Week 5, March 21st, pre-lab meeting @ HOPE 404

Week 6, March 28th ~, lab session

- **Experiment 3 Acousto-optic modulation** (羅裕傑)

Reading Material: Laser

Week 7, April 4th, pre-lab meeting

Week 8 April 11th ~, lab session

- **Experiment 4 diode pumped Nd:YAG/Nd:YVO_4 laser** (陳傑儒): relaxation oscillation, upper state lifetime, Q-switching, longitudinal mode etc.

Reading Material: Nonlinear susceptibility

Reading Material: Electro-optics

Week 9, April 18th, pre-lab meeting @ HOPE 404

Week 10, April 25th ~ , lab session

- **Experiment 5: Electro-optic Modulation** (楊于聖)

1. Measurement: Measure the half-wave voltage of an electrode-coated lithium niobate and observe 1-f & 2-f modulation
2. Instruments & Components: HeNe laser or a frequency-doubled Nd laser, function generator, voltage amplifier (transformer) with DC voltage offset, polarizer, silicon detector

Reading Material: $\chi^{(2)}$ optical frequency up-conversion

Week 11, May 2nd, pre-lab meeting @ HOPE404

Week 12, May 9th ~, lab session

- **Experiment 6 Second harmonic generation** (彭珞豪)

1. Measurement: Identify the crystal axis, Sinc curve (temperature bandwidth for various crystal lengths), conversion efficiency (nonlinear coefficient), angular bandwidth for critically and non-critically phase matched SHG
2. Instruments & Components: Diffuser, HeNe laser, 1064 nm CW laser, prism or filter, oven+controller, crystals, silicon detector, oscilloscope, printer, rotation stage

Reading Material: $\chi^{(2)}$ optical frequency down-conversion

Week 13, May 16th, pre-lab meeting @ HOPE404

Week 14, May 23rd ~, lab session

- **Experiment 7 Optical Parametric Generation (OPG)** (羅裕傑)

1. Measurement: Measure the wavelength tuning curves as a function of the temperature, output signal + idler power vs. pump power, OPG spectral width vs pump energy.
2. Instruments & Components: 1064-nm passively Q-switched laser, monochrometer, oven+controller, crystals, silicon detector, oscilloscope, waveplate etc.

Reading Material: Third-order Nonlinear Frequency Mixing

Week 15, May 30th, pre-lab session @ HOPE404

Week 16 June 6th ~, lab session

- **Experiment 8 Stimulated Raman Scattering (SRS)** (陳傑儒)

1. Measurement: Measure the Stokes shift of a silica fiber, determine the Raman gain, and observe multiple Stokes generation.

2. Instruments & Components: 1064-nm passively Q-switched laser, monochrometer, optical fiber, silicon detector etc.

六 、成績考核

Homework (slides + QA sheet, TRY to answer all the questions and generate your questions/answers from the lab handout prior to a lab)	15%
Pre-lab presentation	10%
Laboratory report (due 7 days after a lab session)	45%
Midterm exam (same as the IPT5110 NLO course)	15%
Final exam (same as the IPT5110 NLO course)	15%

七、講義位址 available at http://www.hope.nthu.edu.tw (passcode to access: TBA) and bound copies available at on-campus 利捷影印店 after Feb. 22nd.

Arrangement of the Lab Experiment

1. Each lab group consists of 2-3 students at most, supervised by 1-2 TAs. We will draw lottery in each pre-lab session to decide the next lab-session groups.
2. Each group takes one day from the 5 weekdays for doing the experiments. For example, Group 1 takes each Monday for doing the experiments and Group 2 takes each Tuesday for doing the experiment.
3. All the equipment and parts are VERY EXPENSIVE. If failure of any instrument and component is due to **apparent carelessness or lack of common sense** in experiments, 5% of the final grade is deducted from the very student who causes the failure and 2% of the final grade is deducted from each of the other group members.
4. All the experiments have to be completed in one week for each assignment. The lab report has to be turned in 7 days from the day you do the experiment.

Requirements on Lab Reports

1. The report has to be written in **good** English.
   The lab report has to include the following sections
   i. Purpose of the experiment
   ii. Principle of the experiment
   iii. Comparison between experimental data with theoretical curves/prediction. (Offer reasonable explanations to any discrepancy. If necessary, re-do the

experiment to verify your argument.)

iv. Conclusions of the experiment

2. All laboratory reports have to be written in the two-column 4-page format of *Optics Letters*. See http://www.osa.org for the official format. Usually there are 4 graphs in each letter paper.
3. The grading policy is as follows
   a. Format 20%
   b. English 40%
   c. Content 40%
4. Pass-deadline reports are not accepted. Please observe the deadline for each report.
5. Email an electronic copy of your report in the WORD format to Prof. Huang at ychuang@ee.nthu.edu.tw by the deadline. Use your_name_Exp_1.doc as your file name for your first experiment report. The file size can't exceed 2 Mb. Reduce the size of the photos in the lab report.

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Presentation Grading Sheet

Grader's name: _____ Grader's ID #: _____

Date (mm/dd/yyyy): _____

1st presenter's name:

A+ (90-100)	A (85-89)	A- (80-84)	B+ (77-79)	B (73-76)	B- (70-72)	C (60-69)	D (1-59)	X (0)

2nd presenter's name:

A+ (90-100)	A (85-89)	A- (80-84)	B+ (77-79)	B (73-76)	B- (70-72)	C (60-69)	D (1-59)	X (0)

3rd presenter's name:

A+ (90-100)	A (85-89)	A- (80-84)	B+ (77-79)	B (73-76)	B- (70-72)	C (60-69)	D (1-59)	X (0)

4th presenter's name:

A+ (90-100)	A (85-89)	A- (80-84)	B+ (77-79)	B (73-76)	B- (70-72)	C (60-69)	D (1-59)	X (0)

5th presenter's name:

A+ (90-100)	A (85-89)	A- (80-84)	B+ (77-79)	B (73-76)	B- (70-72)	C (60-69)	D (1-59)	X (0)