Prof. Yen-Chieh Huang
Dept of Electrical Engineering
National Tsing-Hua University
Hsinchu, Taiwan 300

ext. 62340
office: HOPE Lab 301/Delta 856
email: ychuang@ee.nthu.edu.tw
IPT54100 fall, 2023

Last update Sep. 13th, 2023

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

Fall, 2023.

Class time: M7~ every other week for pre-lab meetings

Location: first class to meet at Delta 211, M7, Monday, Sep. 11, 2023. The 2nd class will meet at HOPE 406 at M7 every other week for pre-lab meetings, starting Sep. 18.

Head Teaching Assistant: 吳柏勳 j77859693@gmail.com

- For the laboratory sessions, the lab is located on the 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 every other week @ 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 an 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. IPT5110 Nonlinear Optics is the prerequisite of this laboratory class.

二 指定用書 teaching material

1. Lecture notes + Laboratory handouts (available after Sep. 14, 2023. Check with the head TA)

三、參考書籍 references

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 method

- **Laboratories with lectures**

During the semester, students are required to carry 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.

- 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 406 one week before each lab session. Before the meeting, email Prof. Huang and the head 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 course schedule

* 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 (Sep. 11th @ W7 15:30, Delta 211) Introduction

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

Weeks 1, Sep. 18~, pre-lab meeting @ HOPE 406

Reading Material: Electromagnetic Wave

Reading Material: Gaussian Laser Beam

Week 2, Sep. 25th ~ , lab session @ 2nd-floor of HOPE

- **Experiment 1 Photonics measurement (張恆嘉 Josef Chang, Debby Lien)** – photonics instruments, photodetector, pulse, wavelength, absorption, noise

Reading Material: Optical Resonator

Reading Material: Wave Propagation in Anisotropic Material

Week 3, Oct. 2nd, pre-lab session @ HOPE 406

Week 4, Oct. 9th ~, lab session

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

Reading Material: Acousto-optics

Week 5, Oct. 16th, pre-lab meeting @ HOPE 406

Week 6, Oct. 23th ~, lab session

- **Experiment 3 Acousto-optic modulation (Dr. 胡春龍 Xuan-Long Hu)**

Reading Material: Laser

Week 7, Oct. 30st, pre-lab meeting

Week 8 Nov. 6th ~, lab session

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

Reading Material: Nonlinear susceptibility

Reading Material: Electro-optics

Week 9, Nov. 13th, pre-lab meeting @ HOPE 406

Week 10, Nov. 20th ~ , lab session

- **Experiment 5: Electro-optic Modulation (高偉倫 Alan Kao)**

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, Nov. 27th, pre-lab meeting @ HOPE406

Week 12, Dec. 4th ~, lab session

- **Experiment 6 Second harmonic generation (郭昌禾 Canghe Kuo)**

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, Dec. 11th, pre-lab meeting @ HOPE406

Week 14, Dec. 18th ~, lab session

- **Experiment 7 Optical Parametric Generation (OPG) (溫宥翰 Johnson Wen)**

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, Dec. 25th, pre-lab session @ HOPE406

Week 16 June 1th ~, lab session

- **Experiment 8 Stimulated Raman Scattering (SRS) (唐俊強 Junqiang Tang)**

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)	20%
Pre-lab presentation	20%
Laboratory report (due 7 days after a lab session)	60%

七、講義.pdf is available at EEclass and bound copies are available for a fee from the head TA.

Arrangement of the Lab Experiment

1. Each lab group consists of 2-3 students at most. 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, supported by Huang Group but not by IPT. 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 30%
   c. Content 50%
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.

Prof. Yen-Chieh Huang *ext. 62340*
Dept of Electrical Engineering *office: HOPE Lab 301/Delta 856*
National Tsing-Hua University *email: ychuang@ee.nthu.edu.tw*
Hsinchu, Taiwan 300 *IPT54100 fall, 2023*

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)