



ELECTRICAL & COMPUTER ENGINEERING

UNIVERSITY of HAWAI'I at MĀNOA™

ECE 470 / PHYS 460 Physical optics

Syllabus

Time and location: MWF 1:30 PM – 2:20 PM in Watanabe Hall 113

Prerequisites: ECE 372 (Engineering Electromagnetics) or PHYS 450 (Electromagnetic Waves)

Instructor: Bo-Han Wu, bohanwu@hawaii.edu

Office hour: Scheduling appointment by email for in-person and [here](#) for zoom meetings.

Textbook: Fundamentals of Photonics (B. E.A. Saleh, M. C. Teich), Optics (E. Hecht), The Quantum Theory of Light (R. Loudon), Nonlinear optics (R. Boyd)

Course description: This course provides a rigorous treatment of physical optics and photonics, emphasizing the wave, electromagnetic, statistical, quantum, and nonlinear properties of light. The course develops theoretical foundations from Maxwell's equations and applies them to modern photonic systems and devices, preparing students for advanced study and research in optics, photonics, and quantum technologies.

Course objectives: By the end of this course, students will be able to:

- *Derive and analyze* the propagation of electromagnetic waves in free space, dispersive media, and optical systems using Maxwell's equations and wave optics formalisms.
- *Apply physical optics tools*, including Fourier optics, diffraction theory, polarization analysis, and mode theory, to model and interpret modern optical systems.
- *Quantify optical coherence*, employing statistical optics and photon statistics to describe coherent light fields.
- *Synthesize physical insight and mathematical analysis* to evaluate and communicate the performance limits of contemporary photonic and quantum-optical systems.

Major deliverables and assessments:

5 × problem sets (40%), 2 × midterms (30%), final exam (30%)

Grading Standard

Scores: A: >80, B: 70, C: 60, D: 50, F: <49

Problem sets and examinations: Problem sets and exams are graded on correctness and clear reasoning: a fully correct, well-explained solution earns full points; a thorough but not entirely correct solution earns partial points (depending on correctness); submissions that show minimal original work will receive zero point.

*** AI tools warning:** AI tools, such as ChatGPT, are double-edged swords. While they can generate answers quickly and efficiently, their outputs are not guaranteed to be correct and may contain inaccuracies (“hallucinations”). You are expected to learn the material yourself and can use AI tools only to aid your understanding of the context.

For problem sets, all solutions must show clear, logical, and step-by-step derivations or calculations. If the work appears to rely on AI-generated content or copied material rather than your own reasoning, grading will be significantly penalized.

Course Policies

Lamaku: All slides, problems sets and reference papers will be uploaded to Lamaku.

Late Work: Problem sets must be submitted on time. If you have a valid reason for a late submission, you must inform the instructor in and wait for the permission.

NO-CHEATING: Zero tolerance on problem sets and examinations cheating. The students, who violate the rule, will fail the course **WITHOUT ANY EXCEPTION**.

Email: I will use email to communicate with you. You can contact me by email or using the website to book my time in zoom. Please be sure to state your question or concerns clearly and respectfully. I check my email regularly and do my best to respond within 24 hours.

Tentative Course Schedule

| | Topics and contents | Deliverables | References |
|---|--|---------------------------------------|--|
| Week 1 (1/12, 14, 16) <u>Martin Luther</u> <u>Day (1/19)</u> Week 2 (1/21, 23) | Ray optics Key points: History of optics development, Fermat's principle, Ekional equation, reflection, refraction, geometric optics in thin and thick mirrors and lenses formula, aberration, Ray equation, ABCD matrix | HW1 released (1/21) | Fundamentals of Photonics, Ch. 1 Optics, Ch 5, 6 |
| Week 3 (1/26, 28, 30) Week 4 (2/2, 4, 6) | Wave optics Key points: Linear superposition of light, phaser, interference, interferometers (e.g., Mach-Zehnder interferometer), Helmholtz equation, paraxial approximation, Fresnel number, chromatic light, Huygen's principle, Kirchhof diffraction theory, grating, scattering (e.g., Rayleigh, Mie) | | Fundamentals of Photonics, Ch. 2 Optics, Ch4 |
| Week 5 (2/9, 11) | Beam optics Key points: Basic theory of laser, Gaussian beam, beam waist, Rayleigh range, Gaussian beam in optical system, Hermite and Laguerre Gaussian beams | HW1 due (2/9) | Fundamentals of Photonics, Ch. 3 |
| Week 5 (2/13) <u>President's</u> <u>Day (2/16)</u> Week 6 (2/18, 20) | Fourier optics Key points: Basic theory of Fourier transformation, transfer function of free propagation, Fresnel and Fraunhofer approximation, diffraction, diffraction limit, imaging formation in different optical systems (e.g., filter), impulse response function, Holography | HW2 released (2/16) | Fundamentals of Photonics, Ch. 4 Optics, Ch 11 |
| Week 7 (2/23, 25, 27) Week 8 (3/2) | Electromagnetic optics Key points: Wave equation in inhomogeneous media, media absorption, material dispersion (e.g., normal and anomalous dispersion), group velocity dispersion, Sellmeier equation. | | Fundamentals of Photonics, Ch. 5 Optics, Ch4 |
| Week 8 (3/4, 6) Week 9 (3/9, 11, 13) Week 10 <u>Spring recess</u> <u>(3/16, 18, 20)</u> | Polarization optics Key points: Linearly, circularly, and elliptically polarized light, Jones vector, polarization beamsplitter, Brewster angle, total reflection, ordinary wave, extraordinary wave, double refraction effect, liquid crystal, Faraday rotator | HW2 due (3/4) Midterm 1 | Fundamentals of Photonics, Ch. 6 Optics, Ch8 |

| | Topics and contents | Deliverables | References |
|---|--|---|--|
| Week 11 (3/23) | Metal optics Key points: Free electrons, Drude model, microscopic Ohm's law, conductivity, plasma | HW3 released (3/23) | Fundamentals of Photonics, Ch. 8 Solid State Physics: Ashcroft, Mermin, Ch1 |
| Week 11 (3/25, 27) Week 12 (3/30, 4/1) <u>Good Friday (4/3)</u> | Waveguide optics Key points: Optical modes (e.g., TE, TM), one-dimensional waveguide (e.g., planar waveguide), two-dimensional waveguide (e.g., rectangular mirror waveguide), coupled mode equations | | Fundamentals of Photonics, Ch. 9 |
| Week 13 (4/6, 8) | Fiber optics Key points: LP mode, characteristic equation, V number, fiber dispersion (e.g., modal dispersion) | HW3 due (4/6) HW 4 released (4/6) | Fundamentals of Photonics, Ch. 10 |
| Week 14 (4/13, 15, 17) Week 15 (4/20) | Statistical optics Key points: Coherence time and length, power spectral density, spectral width, cross-spectral density, coherent light, partially coherent light, chaotic light, spatial coherence, visibility, coherence in optical system | Midterm 2 | Fundamentals of Photonics, Ch. 12 The Quantum Theory of Light: Rodney Loudon, Ch. 3 |
| Week 15 (4/22, 24) Week 16 (4/27) | Photon optics Key points: Second-order coherence, single photon, vacuum fluctuation, photon's momentum and spin, photon detection theory, Poisson and Bose-einstein statistics, shot noise, standard quantum limit, Mandel's formula, photon flux | HW4 due (4/20) | Fundamentals of Photonics, Ch. 13 The Quantum Theory of Light: Rodney Loudon, Ch. 4 |
| Week 16 (4/29, 5/1) Week 17 (5/4, 6) | Nonlinear optics Key points: Nonlinear dipole radiation, $\chi^{(2)}$ - nonlinearity: SHG, SPDC, TWM, SFG, DFG, $\chi^{(3)}$ - nonlinearity: degenerate and non-degenerate FWM, OPA, OPO (i.e., single resonance oscillation or double resonance oscillation) | HW 5 released (4/20) HW5 due (5/6) | Fundamentals of Photonics, Ch. 22 Nonlinear optics: Robert Boyd, Ch. 1, 2 |
| Week 18 (5/11) | | Final (5/11) | |

Campus Resources & Services

Statement on Disability: KOKUA Program: If you have a disability and related access needs, please contact the KOKUA Program (Office for Students with Disabilities) at 956-7511,

KOKUA@hawaii.edu, or go to Room 013 in the Queen Lili‘uokalani Center for Student Services. Please know that I will work with you and KOKUA to meet your access needs based on disability documentation. Kokua’s services are confidential and offered free of charge.

Academic Integrity and Ethical Behavior: Office of Student Conduct: Cheating, plagiarism, or other forms of academic dishonesty are not permitted within this course and are prohibited within the System-wide Student Conduct Code (EP 7.208). Examples include: fabrication, falsification, cheating, plagiarism, and use of improper materials. Any incident of suspected academic dishonesty will be reported to the Office of Student Conduct for review and possible adjudication. Additionally, the instructor may take action in regards to the grade for the deliverable or course as they see fit.

Department of Public Safety: (808)956-6911 (Emergency) / (808)956-8211 (Non-Emergency)
<http://manoa.hawaii.edu/dps/>

UH System Basic Needs (text to be used) include food and housing, childcare, mental health, financial resources and transportation, among others. Student basic needs security is critical for ensuring strong academic performance, persistence and graduation and overall student well being. If you or someone you know are experiencing basic needs insecurity, please see the following resources: UH System Basic Needs

Student Success Resources: The Division of Student Success (DSS) houses student support services to build success inside and outside the classroom. If you want learning assistance, academic advising, career resources and guidance, counseling, family and relationship support, identity-based support, services for underrepresented groups, health and wellness services, opportunities for leadership growth, and community engagement, you will find this and more in DSS, (808) 956-3290, <https://manoa.hawaii.edu/studentssuccess/departments/>

University of Hawai‘i at Mānoa (UHM) TITLE IX SYLLABUS INFORMATION: As a member of the University faculty, I am required to immediately report any incident of sex discrimination or gender-based violence to the campus Title IX Coordinator. Although the Title IX Coordinator and I cannot guarantee confidentiality, you will still have options about how your case will be handled. My goal is to make sure you are aware of the range of options available to you and have access to the resources and support you need. For more information regarding sex discrimination and gender-based violence, the University’s Title IX resources and the University’s Policy, EP 1.204, go to: <http://www.manoa.hawaii.edu/titleix/>

UHM is committed to providing a learning, working and living environment that promotes personal integrity, civility, and mutual respect and is free of all forms of sex discrimination and gender-based violence, including sexual assault, sexual harassment, gender-based harassment, domestic violence, dating violence, and stalking. If you or someone you know experiences any of these, UHM has staff and resources on campus to support and assist you. Staff also can direct you to resources in the community. Here are some: If you wish to remain ANONYMOUS, speak with someone CONFIDENTIALLY, or would like to receive information and support in a CONFIDENTIAL setting, contact: (* Confidential Resource).