ECE 442: Silicon Photonics

Silicon photonics is a rapidly growing multi-$B industry as well as an active area of advanced research. This course will focus on practical applications of Electro-Magnetic concepts to photonic integrated circuits.

1. **Passive** devices: filters, converters, polarizers.
2. **Active** devices: modulators, switches, photodetectors.
3. **Optical communications** using silicon photonics.
4. **Applications** in biosensing, quantum, and neuromorphic computing.

Optional 4 credit hours: independent project on design, testing, and analysis of your own silicon circuit.

[https://courses.engr.illinois.edu/ece442/sp2021/](https://courses.engr.illinois.edu/ece442/sp2021/)
Catalog description: Electromagnetic waves, optical waveguides, waveguide couplers, waveguide filters, electro-optical devices, modulators, photodetectors, optical communications.

Information for undergraduate students:
I taught this class ECE498YV for several years now and it can be either taken in a sequence to ECE452 or as a stand alone class. The only pre-requisite is ECE350 or analogous class on basic EM concepts. Over last several years that I taught it about third of each class were undergraduates that perform as good, or in a number of cases even better, than many graduates.
Credit hours: 3 (undergraduate students)

Information for both undergraduate and graduate students:
There is an add-on advantage for both undergrads and graduate students to receive up to 4 credits.
Optional credit hours: 4
This additional credit hour is given to students who choose to participate in design and testing of your own photonic integrated circuits. Report is required at the end of the course.
Fantastic course! Enjoyable class. Learned a lot
Learning physical theory behind device operation is very very useful
Interesting mix of qualitative and physics description w practical apps
Unique perspective. Provides great insight to industry “why tech matters”
Very passionate, knowledgeable, caring, and helpful. Fair grading
Topics are well presented and relevant
Really helpful homework's add a lot to understanding
Course topics


3. **Communications systems**: Attenuation and dispersion. Signal distortion in optical waveguides, group delay. Optical data communications basics: modulation formats, optical link budget, BER and penalties.

4. **TX active devices**: Si modulators. Electro-optical effects in silicon, amplitude and phase modulators. Traveling wave modulator in reverse-biased electro-optic

5. **RX active devices**: Ge photodetector. Shottky and PIN diodes. Fabrication approaches. RX figures of merit.

6. **Emerging applications** of Si photonics in quantum computing, neuromorphic computing, and biological sensing.
Course Timeline and Structure

- **Part 1**: Waveguide optics
- **Part 2**: Passive wg devices
- **Part 3**: System
- **Parts 4&5**: Active devices

**Timeline**

- **Jan**: Midterm 1 (2/25)
- **Feb**
- **Mar**
- **Apr**: Midterm 2 (4/07)
- **May**: Final (5/12)
Optional independent design project
For up to 4 credit points total

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This additional credit hour is given to students who choose to participate in design and testing of your own photonic integrated circuits. Report is required at the end of the course.
Optional independent design project
For up to 4 credit points total

Taking this option, you will:

- **Model** the optical waveguide using a mode solver to determine the wavelength-dependent effective index and propagation constant. Model a silicon photonic optical circuit using a compact model approach.
- **Design** photonic components and circuits, e.g., interferometer. Identify design parameter variations.
- **Create and submit a layout** for fabrication. Learn the fabrication design rules, automated testing constraints, and design submission details.
- **Receive measurement** data from fabricated devices. Analyze the data to extract parameters from the measurements and compare with models.
- **Report** on your design results.
Jan 21-Jan 29

Modelling & Design

Mar 11- May 01

Data Analysis

Jan 29-Feb 18

Mask Layout

Feb 18-Mar 11

Automated Test

Feb 18-Mar 11

Fabrication
As a **first-time designer**, you will design an Mach-Zehnder Interferometer, consisting of fiber grating couplers, two splitters, and optical waveguides.
Textbook:

- UIUC have a subscription to this book, offering free PDF downloads.
- https://www.cambridge.org/core/books/silicon-photonics-design/BF3CF13E8542BCE67FD2BBC7104ECEAB
For **advanced designers**, this course is an opportunity to design many other devices, such as: directional couplers; rings, racetrack and disk resonators; Bragg gratings, photonic crystals; multi-mode interference (MMI) couplers; arrayed waveguide gratings (AWG); polarization diversity components; etc.
Jan 21  software licenses & intro videos available
Jan 29  starting with photonic component modelling
Feb 21  **Tape-out**
March 11 Chips & Measurements done
May 01  **Report due**