Welcome to Fundamentals and Applications of Modern Optical Imaging. This class provides an opportunity for graduate students in sciences and engineering to learn about modern light-based imaging systems. The overarching goal is to apply models of light propagation and light-matter interaction to analyze and design imaging systems. General topics include: Ray optics, wave optics, beam optics, Fourier optics, holography, lenses for photography, biological imaging, light field imaging, adaptive optics, imaging through complex media, Fourier ptychography, point spread function engineering, and super-resolution microscopy.

Course learning objectives. Some of the benefits you will derive from active engagement and completion of the course assignments are:

1. You will learn to apply models of imaging systems to design them and analyze their performance.
2. You will become familiar with current research and gain perspective on future research directions in modern optical imaging.
3. You will practice oral communication and critiquing literature by reviewing the content of a recent peer-reviewed journal article in the field for the class.

Course design. This course is split into two content threads. The first portion of the course focuses on fundamentals of imaging systems: that is, models of how light travels and interacts with matter. You will learn models of light propagation from simple to complex (e.g. rays to waves). You will practice using these models during various in-class and homework exercises, as well as observe these phenomena in action through in-class demos and MATLAB exercises. With these fundamentals in hand, the second portion of the course focuses on applications of imaging systems, both commercial and research. Design considerations governing “everyday” imaging systems like camera lenses and microscopes will be discussed. The course will conclude with “split” lectures: I will review select literature in the field, and you and your classmates will select, review, and critique recent peer-reviewed journal articles of interest to you!

Prerequisites. ESE 318/319 or their equivalent course on vector calculus and Fourier transforms; ESE 330 or PHY 421/422 or equivalent course on electrostatics and electrodynamics.

Credit and deliverables. Most students should take ESE 582 with grades for 3 credit units; please see me if you wish to take the course pass/fail or audit the course. Enrollment is capped to allow enough lecture
In-class participation consists of in-class exercises, discussions during student presentations, and providing feedback to students on their presentations. You are asked to give feedback on at least 5 of your classmates’ presentations.

Homework will be assigned at least one week before it is due, generally on Wednesdays. Homework is to be submitted electronically as a PDF via the course website. (If you hand-write your homework, please scan and submit as a PDF. The Adobe Scan and Microsoft Office Lens apps work well for this.) Late homework will receive half credit if it is handed in within 48 hours of the due date; no credit will be given otherwise. Your lowest homework grade will be dropped at the end of the semester.

The midterm exam will be given in class (see schedule below). You may use your course notes, homeworks, solutions, and official course textbooks during this exam, but any other materials are strictly forbidden (including internet resources). In lieu of an in-class midterm exam, you will instead complete two mini-projects in the form of longer homework assignments.

**Grading and late work policy.** Course grades will be computed as follows: homework 40%, midterm exam 25%, mini-projects 25%, final presentation (no final exam) 25%, in-class participation 10%. Final course grades may be curved after all assignments have been graded. If a curve is applied, it will only increase students’ final letter grades, i.e., the cutoff for an A- will not be higher than 90%; the cutoff for a B- will not be higher than 80%; etc.

**P/F Policy.** For each McKelvey course offering a letter grade option, students can choose the pass/fail option or letter grade option. Students may change grade options up until the last day of classes, April 24, at 9 PM. **Students must earn a C- or better to earn a passing grade in ESE582.** Due to the COVID-19 crisis, SP2020 courses completed with the pass/fail grade option will count toward all McKelvey degree and program requirements (both undergraduate and graduate) if the courses are passed. In SP2020 undergraduate students may exceed the cap of 6 units pass/fail, and SP2020 courses will not count against the maximum 18 units pass/fail attempted.
Readings. Readings are outlined in the topic summary below. Homeworks will be assigned from the primary textbook for the course. The textbooks below are on reserve on the first floor of Olin Library.


Primary literature to be discussed during second half of the course:


Additional weekly readings will be posted to the course website as needed.
Course feedback. You can help make the course more effective for you and your classmates by filling out the anonymous survey on Canvas anytime during the semester.

Academic integrity. You are encouraged to work together and collaborate on homework and mini projects. However, the work that you turn in must be your own; plagiarism will not be tolerated. Collaboration is not allowed on the midterm exam.

Students are expected to abide by the McKelvey School Academic Integrity Policy.

Students with disabilities. At Washington University we strive to make the academic experience accessible and inclusive. If you anticipate or experience barriers based on disability, please contact Disability Resources at 314.935.5970, disabilityresources@wustl.edu, or visit our website for information about requesting academic accommodations. See: https://students.wustl.edu/disability-resources/

Sexual assault reporting and accommodations. If a student discusses or discloses an instance of sexual assault, sex discrimination, sexual harassment, dating violence, domestic violence or stalking, or if a faculty member otherwise observes or becomes aware of such an allegation, they will keep the information as private as possible, but as a faculty member of Washington University, we are required to immediately report it to the Department Chair or Dean or directly to Ms. Jessica Kennedy, the University’s Title IX Director, at (314) 935-3118, jwkennedy@wustl.edu. Additionally, you can report incidents or complaints to the Office of Student Conduct and Community Standards or by contacting WUPD at (314) 935-5555 or your local law enforcement agency. See: Title IX

The University is committed to offering reasonable academic accommodations (e.g., no contact order, course changes) to students who are victims of relationship or sexual violence, regardless of whether they seek criminal or disciplinary action. If you need to request such accommodations, please contact the Relationship and Sexual Violence Prevention Center (RSVP) at rsvpcenter@wustl.edu or 314-935-3445 to schedule an appointment with an RSVP confidential, licensed counselor. Information shared with counselors is confidential. However, requests for accommodations will be coordinated with the appropriate University administrators and faculty. See: RSVP Center

Bias reporting. The University has a process through which students, faculty, staff and community members who have experienced or witnessed incidents of bias, prejudice or discrimination against a student can report their experiences to the University’s Bias Report and Support System (BRSS) team. See: brss.wustl.edu

Mental health. Mental Health Services’ professional staff members work with students to resolve personal and interpersonal difficulties, many of which can affect the academic experience. These include
conflicts with or worry about friends or family, concerns about eating or drinking patterns, and feelings of anxiety and depression. See: https://students.wustl.edu/mental-health-services/

**Center for Diversity and Inclusion.** The Center for Diversity and Inclusion (CDI) supports and advocates for undergraduate, graduate, and professional school students from underrepresented and/or marginalized populations, collaborates with campus and community partners, and promotes dialogue and social change to cultivate and foster a supportive campus climate for students of all backgrounds, cultures and identities. See: https://diversityinclusion.wustl.edu/

**Preferred name and gender inclusive pronouns.** In order to affirm each person’s gender identity and lived experiences, it is important that we ask and check in with others about pronouns. This simple effort can make a profound difference in a person’s experience of safety, respect, and support. See: https://students.wustl.edu/gender-pronouns-information/, https://registrar.wustl.edu/student-records/ssn-name-changes/preferred-name/
**Topic summary and schedule.** Topics are in regular font. *Readings are in italics. Assignment due dates are in bold italics.*

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<th>WEEK</th>
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<tr>
<td>1: 1/13</td>
<td>Course overview. Describe material properties that govern light-matter interaction. Illustrate phenomena that occur as light travels from one medium to another. <em>Saleh &amp; Teich Sec. 1.1.</em></td>
<td>List and explain various optical elements used to manipulate light. Describe imaging and light guiding phenomenon. <em>Saleh &amp; Teich Sec. 1.2.</em></td>
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| 2: 1/20 | **MLK Jr. Day: No lecture.** | Employ a ray-transfer matrix model to analyze light propagation through various optical elements and optical systems. *S&T Sec. 1.4.*

**Homework 1 due.** |
| 3: 1/27 | Geometric ray tracing: thick lenses and two-element systems. | Describe fundamental observable properties of waves. *S&T Sec. 2.1.*

**Homework 2 due.** |
| 4: 2/3 | Explain complex quantities of waves and their propagation behavior. *S&T Sec. 2.2.*
Analyze wave models of light-matter interaction and optical elements. *S&T Sec. 2.4.* | Discuss and demonstrate wave interference phenomena. Analyze interferometer designs. *S&T Sec. 2.5.*

**Homework 3 due.** |
| 5: 2/10 | Interference phenomena (cont.). | Describe wave propagation in free space. *S&T Sec. 4.1.*

**Homework 4 due.** |
| 6: 2/17 | Compare spatial vs. angular spectrum domains, transfer function vs. impulse response of free space. Explain model and implications of Huygens-Fresnel Principle. *S&T Sec. 4.1.* | Explain how optical Fourier transformations result from free-space propagation and propagation through a lens. *S&T Sec. 4.2.*

**Homework 5 due.** |
| 7: 2/24 | Employ Fraunhofer approximation to model diffraction of various apertures. *S&T Sec. 4.3.* | Diffraction (cont.)

**Homework 6 due.** |
| 8: 3/2 | Compare image formation models: ray optics vs. wave optics. *S&T Sec. 4.4.* | More Fourier Optics: examples of imaging systems and Fourier plane filtering.

**Homework 7 and final presentation topic due.** |
<p>| 3/9 | <strong>Spring Break: No lectures.</strong> |</p>
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<tr>
<td>9: 3/16</td>
<td><strong>Extended Spring Break: No lectures.</strong></td>
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<td>10: 3/23</td>
<td>Fourier optics (cont.)</td>
<td>Discuss fundamentals and applications of holography: recording and reconstruction. S&amp;T Sec. 4.5.</td>
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<td><em>Homework 8 due and final presentation paper choice due.</em></td>
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<td><strong>Mini-project 1 due.</strong></td>
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<td>13: 4/13</td>
<td>Describe fundamentals of and recent developments in super-resolution microscopy. <em>Ref. [8–12]</em></td>
<td><strong>Student presentations (2 groups)</strong></td>
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<td>14: 4/20</td>
<td><strong>Student presentations (2 groups)</strong></td>
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<td><strong>Mini-project 2 due.</strong></td>
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**NOTE:** 5/4, 3:30-5:30 PM: Special class session for student presentations (2 groups)  
No final exam.