E35 ESE 582/E62 BME 5820: Fundamentals and Applications of Modern Optical Imaging  
Spring 2019  
Mondays and Wednesdays, 10:00-11:30 AM, Cupples II 200  
wustl.instructure.com/courses/11605

Instructor  
Prof. Matthew D. Lew, mdlew@wustl.edu  
Office: Green Hall 2160D, 314-935-6790  
Office hours: Tuesdays and Thursdays 2-3 PM (except 3/7 and 4/14 4-5 PM), others available by appointment

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 time for student presentations. Coursework will include nine weekly homework assignments, a midterm exam, and a final presentation.
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).

**Grading and late work policy.** Course grades will be computed as follows: homework 40%, midterm exam 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.
Readings. Readings are outlined in the topic summary below. Homeworks will be assigned from the primary textbook for the course. The textbooks below are available for purchase in the Campus Bookstore and are on reserve in the campus libraries.


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

Additional weekly readings will be posted to the course website as needed.
**Topic summary and schedule.** Topics are in regular font. *Readings are in italics. Assignment due dates are in bold italics.*

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<tr>
<th>WEEK</th>
<th>MONDAY</th>
<th>WEDNESDAY</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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<td>2: 1/20</td>
<td><strong>MLK Jr. Day: No lecture.</strong></td>
<td>Employ a ray-transfer matrix model to analyze light propagation through various optical elements and optical systems. <em>S&amp;T Sec. 1.4.</em></td>
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<td>3: 1/27</td>
<td>Geometric ray tracing: thick lenses and two-element systems.</td>
<td>Describe fundamental observable properties of waves. <em>S&amp;T Sec. 2.1.</em></td>
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<td>4: 2/3</td>
<td>Explain complex quantities of waves and their propagation behavior. <em>S&amp;T Sec. 2.2.</em> Analyze wave models of light-matter interaction and optical elements. <em>S&amp;T Sec. 2.4.</em></td>
<td>Discuss and demonstrate wave interference phenomena. Analyze interferometer designs. <em>S&amp;T Sec. 2.5.</em></td>
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<td>5: 2/10</td>
<td>Interference phenomena (cont.).</td>
<td>Describe wave propagation in free space. <em>S&amp;T Sec. 4.1.</em></td>
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<td>6: 2/17</td>
<td>Compare spatial vs. angular spectrum domains, transfer function vs. impulse response of free space. Explain model and implications of Huygens-Fresnel Principle. <em>S&amp;T Sec. 4.1.</em></td>
<td>Explain how optical Fourier transformations result from free-space propagation and propagation through a lens. <em>S&amp;T Sec. 4.2.</em></td>
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<td>7: 2/24</td>
<td>Employ Fraunhofer approximation to model diffraction of various apertures. <em>S&amp;T Sec. 4.3.</em></td>
<td>Diffraction (cont.)</td>
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<td>8: 3/3</td>
<td>Compare image formation models: ray optics vs. wave optics. <em>S&amp;T Sec. 4.4.</em></td>
<td>More Fourier Optics: examples of imaging systems and Fourier plane filtering.</td>
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<td>3/10</td>
<td><strong>Spring Break: No lectures.</strong></td>
<td><strong>Homework 7 and final presentation topic due.</strong></td>
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| 9: 3/17 | Fourier optics (cont.) | Discuss fundamentals and applications of holography: recording and reconstruction. *S&T Sec. 4.5.*  
**Homework 8 due and final presentation paper choice due.** |
| 10: 3/24 | **Midterm exam.** | Holography (cont.) |
**Describe Fourier modulation of detection optics for 3D, multicolor imaging: point spread function engineering. *Ref. [6, 7]***  
**Homework 9 due.** |
| 14: 4/21 | **Student presentations (2 groups)** | **Student presentations (2 groups)** |

**NOTE:**  
5/6, 10:30 AM-12:30 PM: Special class session for student presentations (2 groups)  
Note special location: Cupples II 230  
No final exam.

**Course feedback.** You can help make the course more effective for you and your classmates by filling out the anonymous survey on the course website anytime.

**Academic integrity.** You may discuss homework questions with one another, but all written work must be your own. No collaboration is allowed on the midterm exam. Students are expected to abide by the statement on student academic integrity at [engineering.wustl.edu/current-students/student-services/Pages/academic-integrity-policy.aspx](http://engineering.wustl.edu/current-students/student-services/Pages/academic-integrity-policy.aspx)

**Students with disabilities.** Washington University is committed to providing accommodations and/or services to students with documented disabilities. Students who are seeking support for a disability or a suspected disability should contact Disability Resources at 935-4153. Disability Resources is responsible for approving all disability-related accommodations for WU students, and students are responsible for providing faculty members with formal documentation of their approved accommodations at least two weeks prior to using those accommodations. I will accept Disability Resources Verification of Individual Student Accommodation (VISA) forms by email and personal delivery. If you have already been approved for accommodations, I request that you provide me with a copy of your VISA within the first two weeks of the semester.
Accommodations based upon sexual assault. The University is committed to offering reasonable academic accommodations to students who are victims of sexual assault. Students are eligible for accommodation regardless of whether they seek criminal or disciplinary action. Depending on the specific nature of the allegation, such measures may include but are not limited to: implementation of a no-contact order, course/classroom assignment changes, and other academic support services and accommodations. If you need to request such accommodations, please direct your request to Kim Webb (kim_webb@wustl.edu), Director of the Relationship and Sexual Violence Prevention Center. Ms. Webb is a confidential resource; however, requests for accommodations will be shared with the appropriate University administration and faculty. The University will maintain as confidential any accommodations or protective measures provided to an individual student so long as it does not impair the ability to provide such measures.

If a student comes to me to discuss or disclose an instance of sexual assault, sex discrimination, sexual harassment, dating violence, domestic violence or stalking, or if I otherwise observe or become aware of such an allegation, I will keep the information as private as I can, but as a faculty member of Washington University, I am required to immediately report it to my Department Chair or Dean or directly to Ms. Jessica Kennedy, the University’s Title IX Director. If you would like to speak with directly Ms. Kennedy directly, she can be reached at (314) 935-3118, jwkennedy@wustl.edu, or by visiting the Title IX office in Umrath Hall. 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

You can also speak confidentially and learn more about available resources at the Relationship and Sexual Violence Prevention Center by calling (314) 935-8761 or visiting the 4th floor of Seigle Hall. 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: shs.wustl.edu/MentalHealth