

OPTI x85: Illumination Engineering

Course Goal

To learn skills and theory in illumination design, especially the use of state-of-the-art optical design and illumination software, to carry out an individual project and present the results.

Pre-requisites

OPTI 485: OPTI 201R or equivalent; OPTI 306 suggested

OPTI 585: OPTI 201R/502 or equivalent or permission; OPTI x06 suggested

Overview

Illumination Engineering (3). Fields: Illumination, Nonimaging, and Concentration; Sources: Incandescent, Fluorescent, LED, HID, Modeling, and Experimental Measurement; Modeling: Ray Tracing, Radiometry and Photometry, Color, Polarization, and Scattering; Theory: Radiometry, Photometry, Étendue, Skew Invariant, and Collection; Design Methods: Edge Ray, Flow Line, Tailored Edge Ray, Non-Edge Ray, and Imaging; Optics: Reflectors, Lightpipes, Couplers, Films, and Hybrids; Applications: Displays, Automotive, Solar, Sources, and Lighting; Special Topics: Software Modeling, Optimization, Tolerancing, and Rendering. Previous requirements: Undergraduate: OPTI 201R or equivalent; Graduate: OPTI 201R/502 or equivalent or permission from the instructor. OPTI x06 is suggested.

Class Schedule

Lecture: MW 3.30 pm – 4.45 pm Meinel 307 – lecture and software demos

You are expected to be in class, using only the videos to supplement the lectures.

Instructor and TA

Instructor: John Koschel, Open, Meinel 403A, jkoschel@optics.arizona.edu, phone 621-6357

TA: Stefan Forschner, Thursday, 2.30 – 3.30 pm, Meinel 554, forschner@arizona.edu

Office Hours

Koschel: Open / by appointment (most individuals in the AP Office can access my schedule)

- Available via Zoom at <https://arizona.zoom.us/my/koschel>
- I get an email when you enter – wait a couple minutes to see if I can get into Zoom
- If not, I will email you back about availability (you must have your name / recognizing ID within Zoom)

Distance Learning

OPTI 585 is available via the College's DL program. You are to hand in materials by the specified dates and times. You may request an extension beforehand. There are no exams in this course.

Primary Learning Outcomes (both 485 and 585)

- How to conduct independent research from the proposal through critical design review (Student Outcomes 2, 5);

- Explain components of an illumination system: source, optics, and target (Student Outcome 3);
- How to apply fundamental optics principles (e.g., radiance, étendue, skewness, ...) to calculate baseline performance, initialize the design, and provide paths for improvement (Student Outcome 1);
- How to design and model illumination systems using state-of-the-art software optical design and analysis software (Student Outcome 3); and
- How to present technical papers in both written and oral formats (Student Outcome 6).

Secondary Learning Outcomes (585)

- Apply the limits of optics, étendue, radiance, skewness, etc. (Student Outcome 1);
- Apply the limits of ray sampling in nonimaging systems (Student Outcome 2);
- Explain illumination applications: lighting, automotive, displays, etc. (Student Outcome 2);
- Explain developing areas within illumination: optimization, tolerancing, and rendering (Student Outcome 5); and
- Present and/or publish (potentially!) your work at an optics conference or in a journal (Student Outcome 6).

THE GRADING

Without written/email approval, there will be a score reduction of 10% per day (or portion thereof) late for any submission. The due date is till end of the given day (Tucson time); therefore, for example, one day late will begin at midnight and last till the end of the day following the due date. All submissions will be reviewed for originality.

Undergraduate (OPTI 485) – all dates tentative:

- **Project Proposal:**
 - 7.5%, due Friday, 2 February 2024 (end of day)
 - Paper (3+ pages, with references and pictures)
- **Preliminary Design Review (PDR):**
 - 15%, written due Friday, 1 March 2024 (end of day)
 - Paper (7+ pages text with references and graphics)
- **Preliminary Video Presentation (PVR):**
 - 15%, video presentation, Friday, 22 March 2024 (end of day)
 - 7.5%, team video review, Friday, 5 April 2024 (end of day)
- **Critical Design Review (CDR):**
 - 30%, due last couple weeks of semester
 - Poster/Oral presentation (15%)
 - On campus: Poster, Wednesday, 1 May 2024 (Wednesday class session, submit to D2L by end of day)
 - Paper (15%)
 - 12+ page report, with references and pictures
 - Due Wednesday, 8 May 2024 (end of day)

- **Assignments & Weekly Reports:**
 - 25%, various due dates
 - Lecture quizzes: assigned at end of each Wednesday lecture, due end of day following Wednesday
 - Weekly report: due end of day each Monday
 - Three lowest of combined quizzes and reports dropped

Graduate (OPTI 585) – all dates tentative:

- **Project Proposal:**
 - 7.5%, due Friday, 2 February 2024 (end of day)
 - Paper (4+ pages, with references and pictures)
- **Preliminary Design Review (PDR):**
 - 15%, written due Friday, 1 March 2024 (end of day)
 - Paper (9+ pages text with references and graphics)
- **Preliminary Video Presentation (PVR):**
 - 15%, video presentation, Friday, 22 March 2024 (end of day)
 - 7.5%, team video review, Friday, 5 April 2024 (end of day)
- **Critical Design Review (CDR):**
 - 30%, due last couple weeks of semester
 - Poster/Oral presentation (15%)
 - On-campus: Poster, Wednesday, 1 May 2024 (Wednesday class session, submit to D2L by end of day)
 - Distance: come to poster session (as on-campus), virtual meeting presentation (tbd), or recorded video (Wednesday, 1 May 2024, end of day)
 - Paper (15%)
 - 15+ page report, with references and pictures
 - Due Wednesday, 8 May 2024 (end of day)
- **Homework/Lecture Quizzes:**
 - 25%, various due dates
 - Lecture quizzes: assigned at end of each Wednesday lecture, due end of day following Wednesday
 - Weekly report: due end of day each Monday
 - Three lowest of combined quizzes and reports dropped

D2L is used throughout the class for providing the lectures, assignments, and so forth. You can hand in assignments in hardcopy format, but it is preferred if you use D2L

If for some reason you need an extension on an assignment, you must request it ahead of time

THE TEXTS

Required Textbook:

- 2019 – 2023 Lectures provided on D2L.

Suggested Textbooks:

- R. J. Koschel, Ed., *Illumination Engineering: Design with Nonimaging Optics*, Wiley (2013). (This is an “**awesome**” book that can be found online via UA Libraries)
- R. Winston, J. C. Miñano, P. Benitez, *Nonimaging Optics*, Elsevier Academic Press (2004). (Nice theoretical book that can be found online via UA Libraries)
- J. Chaves, *Introduction to Nonimaging Optics*, CRC Press (2008). (Great book with different notation than I use. It can be found online via UA Libraries)
- V. Arecchi, T. Messadi, and R. J. Koschel, *Field Guide to Illumination Optics*, SPIE Press (2007). (Short book that can be found online via UA Libraries or directly via SPIE from UA computer)

I will be bringing many other books to class to show to you. These other books tend to be in specific areas of illumination. Please talk to me about which books are good for your interests.

THE SCHEDULE

Course Outline: Two 1-hour lectures once per week, 1-hour “lab” to discuss software and projects

- Week 1: Introduction: course discussion, course survey, course project; types of optics, software modeling, radiometry, photometry, étendue, skew invariant, introduction to design methods and sources
- Week 2: Sampling: ray trace sampling, Rose Model, appearance modeling.
- Week 3: Sources: LEDs, incandescent, high-intensity discharge, daylight, Fluorescent, source measurement, source modeling, luminaires, lighting.
- Week 4: Étendue I: definition, conservation of étendue, examples.
- Week 5: Étendue II: concentration, skewness, examples
- Week 6: Nonimaging optics I: edge ray principle, compound parabolic concentrator, edge-ray concentrator, truncated CPC, tailored edge ray design, non-edge-ray design,
- Week 7: Nonimaging Optics II: flow line method, dielectric design, simultaneous multiple surfaces, hybrid optics.
- Week 8: Lightpipes: straight sections, bent sections, principal sections, parameterization, lightguides.
- Week 9: Displays I: backlit displays, wedged lightguide, microstructure, back reflector, diffusers, polarizers, source coupler, color modeling.
- Week 10: Displays II: polarization, microstructure design, brightness enhancement film, diffuser design, system modeling.
- Week 11: Short Oral Presentations/Displays III: projector displays, mixing rods, fly’s eye integrators, system modeling.
- Week 12: Optimization: methods, merit function, parameterization, non-uniform rational b-splines, fractional optimization, constraints, reflectors, hybrid optics, lightpipes.

- Week 13: Tolerancing: process error, system error, gross error, roughness error, BSDF/BRDF/BTDF, experimental measurement, source binning.
- Week 14: Applications/Introduction to stray light: solar energy, concentrators, photovoltaics, automotive, lightpipes, lightboxes, OLEDs; scatter, Fresnel reflections, total integrated scatter
- Week 15: Presentations

Lectures for a given week will be posted on D2L. Note that a given lecture for a week may be shorter or longer than the given week.

THE COURSE GRADE

Components: as per previous section

- Project proposal: 7.5%
- PDR: 15%
- PPR: 15%
- Video review: 7.5%
- CDR presentation: 15%
- CDR report: 15%
- Assignments/Reports: 25%

Without written approval, there will be a score reduction of 10% per day late for any submission. The due date is till the end of any delineated day.

Final Grade:

- A 90% - 100%
- B 80% - 90%
- C 70% - 80%
- D 60% - 70%
- E < 60%

For Undergraduates (485):

- A: Excellent – has demonstrated a more than acceptable understanding of the material; exceptional performance; greatly exceeds expectations
- B: Good – has demonstrated an acceptable understanding of the material; good performance; meets or exceeds expectations
- C: Average – has demonstrated a barely acceptable understanding of the material; adequate performance; meets minimum expectations
- D: Poor – has not demonstrated an acceptable understanding of the material; inadequate performance; does not meet expectations
- E: Failure – little to no demonstrated understanding of the material; exceptionally weak performance

For Graduates (585):

- A: Excellent – has demonstrated a more than acceptable understanding of the material; exceptional performance; exceeds expectations
- B: Good – has demonstrated an acceptable understanding of the material; adequate performance; meets expectations
- C: Average – has not demonstrated an acceptable understanding of the material; inadequate performance; does not meet expectations
- D: Poor – little to no demonstrated understanding of the material; exceptionally weak performance
- E: Failure – usually reserved for non-attendance

THE DETAILS

Code of Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: <http://deanofstudents.arizona.edu/codeofacademicintegrity>
<http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity>

According to the Arizona Code of Academic Integrity, "Integrity is expected of every student in all academic work. The guiding principle of academic integrity is that a student's submitted work must be the student's own." Unless otherwise noted by the instructor, work for all assignments in this course must be conducted independently by each student. Co-authored work of any kind is unacceptable. Misappropriation of exams before or after they are given will be considered academic misconduct. Misconduct of any kind will be prosecuted and may result in any or all of the following:

- Reduction of grade
- Failing grade
- Referral to the Dean of Students for consideration of additional penalty, i.e. notation on a student's transcript re. academic integrity violation, etc.

Attendance Policy

It is important to attend all classes, as what is discussed in class is pertinent to adequate performance on assignments and exams. If you must be absent, it is your responsibility to obtain and review the information you missed. This is especially important in this course where a substantial amount of course material will emerge through class discussion.

"All holidays or special events observed by organized religions will be honored for those students who show affiliation with that particular religion. Absences pre-approved by the UA Dean of Students (or Dean's designee) will be honored."

Classroom Behavior Policy

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

Threatening Behavior Policy

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See <http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students>.

Accessibility and Accommodations

Our goal in this classroom is that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please let me know immediately so that

we can discuss options. You are also welcome to contact the Disability Resource Center (520-621-3268) to establish reasonable accommodations. For additional information on the Disability Resource Center and reasonable accommodations, please visit <http://drc.arizona.edu>.

If you have reasonable accommodations, please plan to meet with me by appointment or during office hours to discuss accommodations and how my course requirements and activities may impact your ability to fully participate.

Please be aware that the accessible table and chairs in this room should remain available for students who find that standard classroom seating is not usable.

Subject to Change Statement

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.