ECEN/PHYS 5606 Advanced Optics Lab Organizational Meeting

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Advanced Optics Lab

The optics lab consists of experiments which introduce the techniques and devices essential to experimental work in modern optics from the Physics and Engineering perspectivesi, with an emphasis on Computational Optical Sensing and Imaging (COSI). Labs will be offered in both the ECE optics lab (ECEE105), and Physics Advanced Lab. Lectures will be in ECEE-1B55, Mondays 12:00-1:50 or Fridays 12:00-1:50 in the OCS conference room. Lab sessions will require a full day, T, W, or Th, and conflicts with the scheduled time are OK because labs will literally **require a full day**. Plan on 9AM-9PM, maybe even leaving at midnight (or 2AM). The Optics lab is only offered every 2 years, so you should take it now if you are interested.

The enrollment limit is listed as 18 (3 days with 3 groups of 2 each) but we might be able to accommodate 1 more via setup holes. We could alternatively increase the limit to either 24 or 27 by going to 4 days a week or groups of 3. You will probably find that the Advanced Optics Lab (AOL) is a grueling bootcamp of optics laboratory techniques and will require a substantial commitment. If you are not fully committed to such a possibly grueling lab schedule or do not have the required background of at least one or more graduate optics courses you should probably drop.

Reference Material and Background Reading

- Hobbs, *Building Electro-Optical Systems: Making It All Work*, 2000, Wiley is an additional very practical reference for optics lab work. Amazing tips and hacks.
- Saleh & Teich, *Fundamentals of Photonics* is the primary background reference for many of the more basic experiments and technologies in the lab.
- Additional background references will be available in the lab or on-line
- Documentation for key devices and equipment will be available in the lab and should be read prior to the lab if you are not familiar with the equipment.
- Other useful references
  - Fowles, *Modern Optics*. very accessible, short, cheap Dover book
  - Hecht, *Optics*, awesome photos of optics results, good introductory book
  - Moore,Davis &Copeland, Building Scientific Apparatus, 1989, general lab ref

Labs

0. *Optional Basic Skills Lab* (ECE 105)
1. Fourier Optics (ECE 105)
2. Interferometers (ECE 105)
3. Polarization and Crystal Optics (ECE 105)
4. Spectroscopy (ECE 105)
5. Photorefractive Crystals (ECE 105)
6. Acoustooptic Devices (ECE 105)
7. Optical Coherence Tomography (ECE 105)
8. Wavefront Sensing/Adaptive Optics (ECE 105)
9. Spatial Light Modulators/PSF Engineering (ECE 105)
10. Gaussian beam, resonators, and mode coupling (Phys labs)
11. Ti:Sapphire Laser (JILA Keck Lab)
12. Nonlinear Doppler Free Spectroscopy (Phys labs)

3-3-3-3 scheduling

- The day you actually are registered for is not set in stone!
- To accommodate 12 students we will only have lab 2 days
- To accommodate 18 students we will operate 3 labs on 3 days (T,W,Th) with 2 students each
- We will start with 3 lab rotations in ECE.
- Followed by 3 more lab rotations in ECE.
- Then we will have 3 lab rotations doing COSI experiments
- We will finish with 3 lab rotations in PHYS
- We will assign the groups, and change them each change (3-3-3-3), trying to mix the departments as much as possible.
- Lab setup will be done on the weekends preceding each 3-3-3-3 group. You will sign up to help with the setup of that lab, and devote at least a FULL weekend day (F,S,S) to setup, maybe more. *This is 7.5% of your grade.*

Lab Schedule

Advanced Optics Lab Schedule Spring 2012

				ECEN105			PHYS/COSI				ECEN105			PHYS/COSI				ECEN105			PHYS/COSI				
		Mon Lectures	**Tue**							**Wed**							**Thur**							**Fri**	Weekend
				A	B	C	D	E	F		A	B	C	D	E	F		A	B	C	D	E	F		
11-Jan -- 15-Jan			**OM**	Lab Basics						**Fourier**	Lab Basics							Lab Basics						**KW Xtal**	
18-Jan -- 22-Jan		**MLK holiday**	**KW int**	Lab Basics							Lab Basics							Lab Basics						***Setup ECE***	***Setup ECE***
				Int	Four	Xtal					Int	Lab	Xtal					Int	Four	Xtal					
25-Jan -- 29-Jan	groups of 3	**KW AO**		1	2	3					4	5	6					7	8	9					
01-Feb -- 05-Feb		**KW PRXtal**		3	1	2					6	4	5					9	7	8					
08-Feb -- 12-Feb		**KW Spect**		2	3	1					5	6	4					8	9	7				***Setup ECE***	***Setup ECE***
				PRXt	AO	Spect					PRXt	AO	Spect					PRXt	AO	Spect					
15-Feb -- 19-Feb	groups of 3	**RP OCT**		1	2	3					4	5	6					7	8	9					
22-Feb -- 26-Feb		**RP WS/AO**		3	1	2					6	4	5					9	7	8					
29-Feb -- 04-Mar		**RP SLM**		2	3	1					5	6	4					8	9	7				***setup COSI***	***setup COSI***
							OCT	SLM	WS/AO					OCT	SLM	WS/AO					OCT	SLM	WS/AO		
07-Mar -- 11-Mar	groups of 3	**SC resonators**					1	2	3					4	5	6					7	8	9		
14-Mar -- 18-Mar		**SC Ti:Sapphire**					3	1	2					6	4	5					9	7	8		
21-Mar -- 25-Mar		!!!SPRING BREAK!!																						***setup PHYS***	***setup PHYS***
28-Mar -- 01-Apr		**JY NL spect**					2	3	1					5	6	4					8	9	7	***setup PHYS***	***setup PHYS***
							Reso	TiSa	Dopfree					Reso	TiSa	Dopfree					Reso	TiSa	Dopfree		
04-Apr -- 08-Apr	groups of 3						1	2	3					4	5	6					7	8	9		
11-Apr -- 15-Apr							3	1	2					6	4	5					9	7	8		
18-Apr -- 22-Apr							2	3	1					5	6	4					8	9	7		
25-Apr -- 29-Apr	NO LABS (possible makeup)																								
Wed May 9	**Final 7:30PM**									**Final 7:30PM**															

11-Jan -- 22-Jan Lab Basics
25-Jan -- 12-Feb *ECE setup Jan 26-29 KW*
A room in ECE105 **Interferometry**
B room in ECE105 **Fourier optics**
C room in ECE105 **Crystal Optics**
15-Feb -- 04-Mar *ECE setup Feb 17-19 KW*
A room in ECE105 **Photorefractive Crystals**
B room in ECE105 **Acoustooptics**
C room in ECE105 **Spectroscopy**

07-Mar -- 01-Apr *COSI lab setup Mar3-7 TB*
B room in ECE105 Optical Coherence Tomography
C room in ECE105 Wavefront Sensing/Adaptive Optics
A room in ECE105 Spatial Light Modulators
04-Apr -- 29-Apr *PHYS setup Spr Brk & Mar 28-Apr 3 JY*
D room in PHYS Rsonators and Mode matching
E Keck Lab Ti:Sapphire laser
F room in PHYS Nonlinear Doppler Free Spectroscopy

Lecture schedule for the next few weeks MWF 2:00-3:45 ECEN 1B28

- Approximately one lecture per lab (12 lectures) in ECEE265
- Need to pack in all lectures before first labs start in week 3
  - Tuesday Jan 12 OM 5:00-6:00 !B28
  - Wed Jan 13 Fourier Optics 12:00-1:45 OCS
  - Fri Jan 15 Crystal optics 12:00-1:45 OCS
  - Tue Jan 19 Interferometry 5:15-6:45
- Then decrease to 1 lecture per week, Mon in ECE or Fri in OCS 12:00-1:45
  - Fri Jan 29 Acousto-optics 12:00-1:45 OCS
  - Fri Feb 5 Photorefractives 12:00-1:45 OCS
  - Fri Feb 12 Spectroscopy 12:00-1:45 OCS
  - Mon Feb 15 OCT (Barsic)
  - Mon Feb 22 Wavefront Sensing/Adaptive optics (Barsic)
  - Mon Feb 29 SLM/PSF Engineering (Barsic)
  - Mon Mar 7 Resonators and Mode Matching (Ye)
  - Mon Mar 14 Ti:Sapphire (Ye)
  - Mon Mar 28 Nonlinear Doppler-Free Spectroscopy (Ye)
- No lectures during last 4 weeks of semester

Lab Organization

- The labs will be held in ECEN105 in weeks 3-11, and in PHYS C235 during weeks 12-14. Three rooms will simultaneously have experiments and each week you will rotate to a new experiment.
- Lectures will be given on Mondays in ECEE or Fridays in OCS at 12:00 while the OM will be Tuesday from 5:15-6:15 in ECEN1B28
- You will be expected to do significant amounts of independent reading out of the suggested references and other sources before each lab.
- Prelab problems must be completed before each lab and handed in by Friday at 5:00 PM the week before the lab or you can not participate!
- Since we have not scheduled makeup sessions, missing a lab will have a detrimental affect on your grade. Some accommodation of conference travel can be made (scheduling or holes) or doing the lab on your own on Friday.
- Grading will be based on prelabs(27.5%), lab books(55%), proficiency in the lab(5%), setup(7.5%), and overall lab book organization and clarity(5%).
- **Expect a significant work load every week.** Weeks 1-2 are just lectures and the optional Basic Skills lab. The last week before finals is off (hopefully).

Optional Basic Skills Lab available in week 1-2

Next week the labs will be available for some mostly unsupervised practice lab experience. The ECE labs will be available for sign up for 2 hour mini-labs. Lab notebooks will not be required for these practice sessions, but don't get used to not recording everything in your lab book.

The idea is to practice skills you will need to utilize throughout the labs and need to become facile with in order to finish at a reasonable time.

- Laser alignment
- Spatial filtering
- Collimation and collimation testing
- Use of an oscilloscope
- Use of an optical power meter
- Use of a CCD detector array or knife-edge beam profiler

Lab Notebooks

- Detailed lab notebooks must be kept and turned in to the TA the day of the lab.
- Because they will need time to grade it, you should **buy 2 lab note books**, and use them on alternate weeks.
- I like National 43-648 or equivalent. Numbered pages. Not copying. quadrille ruled.
- Include a Table of Contents on page 1 and maintain it, label prelab and experimental sections for each lab, make it easy to follow and well organized.
- The lab book will be in the style of an industrial notebook or technical journal (although witnessed pages and ink not required). It should be a complete concise narrative account of your work, clearly readable and understandable by people not intimately familiar with your experiments (eg patent attorneys or you in 10 years).
- This is not a formal report, do not be overly wordy, but describe your procedures and observations briefly and clearly. Indicate your motivations, conclusions and speculations, as well as suggestions of improved experimental procedures.
- You may wish to cut out and tape (bring your own tape) in parts of the lab or copies of key parts of reference material, and intersperse your results. However write your own narrative as well, the handouts are incomplete.

Lab Notebooks: cont

- Draw the setup with a good labeled drawing, bring and use a straightedge.
- Box any important results in both lab and prelab.
- Record all data numerically as a table then plot immediately to get a feel for the data, you may wish to do fancy computer data analysis plots later, but do a quick plot by hand in the lab book as you take the data.
- Tape in scope photos and other hard copy data. Don't use lab double stick tape in your notebooks that is only for mounting optics. Bring your own tape and scissors (or precut lab parts).
- Make liberal use of sketches of experimental setups and arrangements, including explanations of the parts (Dick Tracy arrows).

- Use every page in order (both sides), do not leave blank spaces. If you have to add something later, date and initial the addition. If you make a mistake, cross it out, but do not obliterate or erase.
- Hierarchical headings using underlined section titles and color coding help delineate sections. Neatness counts but speed is also important.
- Make conclusions from your data. Note possible sources of error. Estimate and record errors of measurements.

TA advice on Experiment Description

- Please write legibly. Use an ink pen (not a pencil)
- Clearly distinguish different sections and tasks of the description.
- It's better if you cut and paste the instructions of each experimental step into your lab notebook as you proceed. But describe your augnmentation to the procedure.
- Answer the questions in order.
- Describe everything you see in the experiment, accurately and even if it doesn't exactly match the procedure.
- If something is not expected, draw attention to that in the description.
- EXPLAIN why you're seeing those results. The explanation doesn't need to be long, but you must show that you understand what you're doing.
- Document the relevant settings of every piece of equipment.
- Show all of your calculations in your notebook.
- Cross out all errors with a single line (this allows an arbitrator / lawyer to read through them in the event of a discovery or patent dispute).
- Don't "word-wrap" around figures without a clear distinction. It saves space, but is very hard to read (especially if the figure has labels.)
- Re-read and revise your lab notebook, but initial and date any revisions.

TA advice on Data, Tables of Data, and Figures

- Write down all of the data you take.
- Don't forget units and all scalings and settings;
- Offset the data in some way for easy reference. (use a table, draw a box around a single data point, etc),
- Label each column/ row of data.

Figures

- Bring your own tape to tape in procedures or plots or photos
- If you plan to use a printer to plot your data, leave enough space so that the plot is adjacent to the data.
- Draw a picture of your experimental setup, label components and important values like lens focal lengths, RF frequencies you're feeding into the AOs, parameters of the spatial filter, etc;
- When you draw a figure, don't forget to label your axis;
- Although photographs are nice, they do not contain all of the quantitative information. Please accompany all photos with an experimental setup, and label the appropriate dimensions and features within the photograph.
- For sketches of results, place a box around the observation; it is tough to distinguish a few floating spots in space.
- Use a straight edge.

Prelab procedures

- Prelab consists of suggested readings and "homework-like" problems.
  - Read the required references and skim any auxiliary refs that you need to
  - Do the problems in your lab book. Each lab should have prelab and lab subsections.
- You must complete the prelab problems in your lab notebook and turn in on Friday at 5:00 the week before the lab.
- They will be graded over the weekend and returned on Monday.
- If your prelab is unacceptable it will be marked as such, and you **must** rework on the following pages of your lab book. You must get it approved by a TA or Prof before you are allowed to do the lab.
- **You will not be allowed to do the lab without a completed prelab and you will miss that lab and not be allowed to make it up**.

Prelab guidance from the TAs

- Draw a clear distinction between different parts, figures, etc.
- Box your answer;
- Explicitly state any clever identities, transforms, approximations, or other leaps of logic. Reference sources, if used.
- Work out a rough solution on scratch paper before you document it in your lab notebook.
- Understand the pre-lab before you come to the lab.
- Read the experiment before you come to the lab

Lab book flow

- You will need at least 2 lab notebooks, but don't worry you will fill them.
- In and out boxes will be available in both the Physics and ECE labs for turning in and retrieving your lab notebooks.
- Turn in lab notebooks in box in lab when you leave or at the latest noon of the following day.
  - It will be graded and returned by your next lab (1 week).
- Turn in prelab problems in notebooks by Friday at 5:00 PM.
  - They will be graded and returned by class on Monday.
- Note that you may need to begin working on the prelab before getting your lab book back, especially for Thursday labs. 3 lab books might be used.
- We will have to grade 18 prelabs and 18 lab notebooks each week. If your notebook is illegible, you will fail. If it is late you will be penalized.
  - Late labs will be docked 25% per day
  - Late prelabs will be docked 50% if turned in late, and if not done by Monday will prevent you from participating in that lab.

General lab rules and access

- Labs will start at 9AM or so, and often may continue to the wee hours (2AM is not uncommon). If you are the last to leave, be sure the door is locked and pulled shut.
- TAs will open the labs and let you in to ECE, since keys aren't available.
- You will be given a keypad access to the Physics lab.
- Special arrangements are required for off-day make up labs, and little TA support will be available.
- If you borrow references from the lab, copy and return immediately.
- To borrow equipment in off semesters, have a TA or prof sign it out and back in. If you break it you bought it.
- Only once you have completed the lab will you be allowed to borrow equipment for a short period, but you must also have a Prof to guarantee it.

Handling Optics

- Never touch an optical component!!! Finger oils damage optics. Wear optical cotton gloves or finger cots when it is required to handle a component (eg for mounting). (avoid touching anything else - face, oily parts, dirty counters - with gloves) Have your TA demonstrate.
- Never let double stick tape touch the precision optical surfaces of any component.
- Don't clean an optic on your shirt - lenses and mirror require precision delicate cleaning techniques. Never clean an optic without explicit instructions on the proper procedure. If in doubt, ask TA.
- Never set an optic down on the table directly, it will get scratched. If absolutely necessary, use a padded cleaning cloth as an optical surface to set the optics on (eg while mounting component).
- Never precariously balance an optic, always use a firm mounting ring or double stick tape, clamps, etc.
- When mounting a precision optic, first clean your hands. Arrange a clean padded work surface, with the mount and optic in box on surface. put on glove to handle optic.
- **ALWAYS LABEL THE OPTIC** with hard pencil when removing from box and mounting. MFG, part no, λ-range, f-length
- Use gloved hand to hold optic, place in mount, gently tighten down retaining ring or set screw, but not too hard or you will strain it and introduce birefringence.
- When finished for the day BAG YOUR OPTICS - use clean bag. When a bag touches the floor it is history.
- Always magnetically lock down optics in cupboard or on table.
- **If something breaks or gets damaged, tell your TA.**

Use of Optomechanics

- Never force mechanics, if it doesn't move something is wrong. (set-screw tightened or needs grease or ...)
- Use heavy duty mag bases for large items (CCDs, AO, SLM, BS, lenses) and always lock down. Use weak mag bases only for irises or other nonbreakable components.
- When returning components to cabinet, determine which drawer is correct, then put it in the right drawer. Straighten up drawers each time.
- If a post is stuck, don't use pliers or vise grips - this will ruin it. Use Newport SB-SP or wrap with many layers of black tape, then use pliers gently, don't break through tape.
- The mag bases levers are sticky, always hold onto mag base while rotating lever to avoid components being knocked over and chipping.
- never use a conventional 1/4-20 screw in post holder - it scratches posts - use nylon tipped screws only.
- z-translation on 910 spatial filters is typically very hard to turn. Preset the z as close as possible by moving objective back and forth, look at speckle in back reflection - when speckle gets big you are at good z.
- At the end of day, sort your screw kit. Pick up any loose screws. sort your ball drivers, make sure you have a full set. You will appreciate it if others do this.

Rules for use of lasers

- Never look into the bore of a laser with remaining good eye!!!
- When in room with high power laser: Always wear laser safety goggles - this is mandatory.
- When bending down or standing up, close eyes as you pass through laser height.
- Argon laser turn on: First turn on water, then laser power, then both keys to on position (no 17 error), be sure beam is safely blocked, press on switch, go to constant power mode, after turn on delay adjust power to 100mW minimum, use attenuator wheel to attenuate to 5mW for alignment.
- Never align spatial filter at high power, it will burn up. First align at low power, get it centered and perfect, then turn up power.
- When using laser diodes driven by pulse generator, double check all pulse parameters and polarity conventions before applying to laser.
  - Use static protection techniques. Avoid chairs, sweaters. Use ground strap.
- Always check laser polarization. Vertical or Horizontal only!!!

Tips for use of Electronic Test & Measurement Equipment

- Usually keep electronics equipment on rack, avoid fan vibrations on optical table
  - Heavy items (RFSA) can stand on floor. Avoid bending power cables on back.
- Separate equipment to allow fans to give sufficient airflow and avoid overheating
- For RF use 50 Ohm cable (RG58) with proper 50 Ohm termination on scope and other equipment.
- 75 Ohm cable is slightly thicker, and is only to be used for video (CCD to monitor).
- Video triggering and line and frame triggering on CCDs is very useful, but much easier on back-porch DC clamped video. Otherwise need to shade CCD from room light level fluctuations (use narrow-band filter and tubes).
- When using electronics on optical table, pay attention to shorting out connections on all the metal of the table and components.
- Good idea to ground table through current limiting resistor to water pipe.
- Use ground straps for handling static sensitive components (laser diodes)
- High voltage Burleigh piezo-driver connections and adjustment knobs flaky. Learn which is flaky, and adjust the others.

Lab Setup over 4-day weekends 7.5% of your grade

Each student will help setup one experiment over the weekend on a 3-3-3-3 week schedule. This will give you a very different and valuable perspective on these experiments. After doing the setup and verifying each step, with the TA and Prof assisting, you will not be required to attend lab the corresponding week, meaning your partner will perform that experiment on his own or with a floating partner filling the hole (you may assist if you wish). But if the lab writeup needs clarification you will assist in that process before Monday.

We will have a setup sign-up sheet. Choose a lab you know something about. 2 students per lab (3 for excessively difficult labs). Check your scheduled availability.

- ECEN 105 Jan 22-24,
- ECEN 105 Feb 12-14,
- ECEN 105 Mar 4-6
- PHYS Mar 19 -Apr 3 imncluding Spring Break

Lab Setup

- Cleanup from the previous set of experiments
- Locate all required equipment and assemble required mounts w/DOF
- Layout experiment on table. Choose rails, post & forks, or mag bases.
- Carefully consider required alignment DOF and provide critical adjustments.
- Lock down kinematic alignments for removable components.
- Make sure laser is parallel to table.
- Set up proper height irises, lock one at end of beam path for reference - never move.
- Align mirrors in vertical plane at start by back reflecting.
- Always align components using back reflections and forward non deviation.
- Check laser polarization! Rotated polarization bouncing off tilted mirror can yield arbitrary polarization state and bizarre results.
- Use wedge to test beam collimation.
- Make the experiments convenient for your colleagues and make sure it can be readily returned to the starting state

At the end of the lab

- Turn off lasers. Let Ar laser cool for 10 minutes before turning off water.
  - Leave etalon oven and vacuum on.
- Turn off all electronics.
- Turn off photodiode switch (battery will drain).
- Turn off IR viewer.
- Bag optics, always use clean bags.
- Make sure all mag bases are locked down!!!
- Replace ball drivers in proper order in kit.
- Sort and arrange your screw kit. (Fight the entropy)
- Return extra components to cabinet.
- Turn in lab books - late lab books are not accepted.
- In ECE pull the lab door shut so that it locks - it sticks if you don't.