

Syllabus, Physics 6770 and Physics 6775,
University of Utah, Spring Semester 2009,
Version: June 16, 2008

Optical Measurement Techniques and Instrumentation

Physics 6770 is a three credit hour class consisting of a lecture.

Physics 6775 is a two credit hour class consisting of student laboratory exercises.

PLEASE NOTE:

In order to register for PHYS6775 you MUST also be registered for PHYS 6770 during the same semester. PHYS6770 and PHYS6775 are closely connected which means the laboratory experiments performed in PHYS 6775 are discussed and prepared in PHYS 6770. The lecture and the laboratory part are in two different courses in order to allow students only to take the lecture section but not the laboratory part. Note that it will not be possible to take the lab part without the lecture part though.

The course instructor of PHYS 6770 is

Christoph Boehme, JFB 310,

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Web: <http://www.physics.utah.edu/~boehme/>

The course instructor of PHYS 6775 is

John Viner,

South Physics 307,

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The TA for both classes is

to be determined

Coursewebpage for both 6770 and 6775 will be: <http://www.physics.utah.edu/~boehme/6770>

Christoph Boehme's office hours:

Tue, Wed: 2pm – 4:00pm – you can also contact me outside of these hours of course

When and where is class? M +W 4:35 to 5:55 pm, JFB 209

(optics laboratory of the physics department)

When and where is lab ?

Only two students can work on one experiment at a time. Because of this, a lab occupation plan will have to be worked out when the class meets for the first time. The lab location (PHYS6775) is the same location as the class location (PHYS6770) in JFB 209, the student optics laboratory of the physics department.

Description of the Course:

The purpose of the class is to enable the students to handle optical equipment as it is used for various physics research and technological applications. The student will get to know the instrumentation and technologies for the detection, the qualitative and quantitative analysis of light (light here means electromagnetic radiation with wavelength from far infrared to far ultraviolet which are wavelengths between 30nm - 300 μ m) as well as the knowledge of how to design and implement the setups necessary to do this. The class will have its greatest benefit for students who are about to start their own research in an experimental field involving the presented methods and techniques.

Among the topics covered are:

Physical principles and practical use of optical measurement techniques and instrumentation: Photodetectors, lasers, optical ranging interferometry, acousto-optic modulation, ellipsometry, optical spectroscopy, optical fibers. Fundamental sensing limits, noise sources, system characterization, error analysis, signal averaging/filtering, impedance loading, and frequency/time analysis. Laboratory provides hands on experience with these optical techniques and measurement systems.”

Course Mechanics:

Prerequisite: **Recommended:** Optics (PHYS 3410 or 6750)

Mandatory: Engineering physics sequence PHYS 2210, 2220.

Read more about this below. Note this class is a graduate physics class and while students of other fields (chemistry, biology and engineering) are explicitly encouraged to take this class, they must be aware that knowledge gaps in PHYS 2210 and 2220 and their prerequisites can be covered by PHYS6770 only to a limited extent.

If you have any doubts about whether PHYS6770 and/or PHYS 6775 are appropriate for you or not, please try the self assessment exams on the class webpage or contact the course instructors.

Lectures: The lectures will cover the background required to do the lab work..

Laboratory: A total of seven lab experiments will be performed. The experiments are performed in student groups of two. There are 2 one week experiments and 5 two week experiments, a total of eleven laboratory sessions at four hours per session. The lab work will be graded based on a written report about the experiments performed.

Homework: Some homework assignments will be given in preparation for the lab experiments. Homework will be assigned only during weeks when no lab reports are due.

Exams: There will be a midterm exam and a final exam.

Amount of time that you should expect to invest in this class:

As for most laboratory classes, the amount of time necessary for the PHYS6770+PHYS6775 class combination will exceed that of lectures without laboratory sections that would be awarded with 5 credit points. Being aware that this should nevertheless been kept within a reasonable range and based on the experience of past PHYS6770 courses the course load has been adjusted in the way so that you should expect to spend the following amount of time per week:

PHYS 6770

2 lectures per week with two lecture hours each:	160min
Homework, review of course content, exam preparation:	380min

PHYS 6775

One lab section per week:	240min
Preparation of lab, preparation of lab reports:	300min

So this makes a total of 18 hours per week, almost 7 hours at school and another 11 hours of homework. This is a lot of work, but again, the class combination is awarded now with 5 credit points and if you completely fulfill the prerequisites, you may even be able to manage the workload in less than this time. From our experience, many of the students who take this class need to work during the week while they take this class. In order to accommodate these constraints, the lectures are given late in the afternoon on Monday and Wednesday while there is the possibility to have some of the lab appointments on Saturdays.

Prerequisite of PHYS6770 in detail:

PHYS2220+PHYS2221 (Physics for Scientists and Engineers) are mandatory unless the students have passed classes which go beyond. This means knowledge of the foundations of light and electromagnetic radiation is imperative for the understanding of the topics discussed in this class. This includes the following aspects:

Geometrical optics, electromagnetic waves, wave equations / dispersion, electric and magnetic fields in EM radiation, impedance of free space, photons, intensity / poynting vector, power, the photons momentum, the speed of light and the index of refraction, reflection and refraction laws, lenses, diffraction, polarization.

Note that the backgrounds of the students will probably be quite diverse. Depending on these different backgrounds (as well as the students own assessment of how well they can handle these fields) some of these aspects may be discussed in the class again with regard to the topics for which they will become important. If many students in the class need to review a certain topic, it will be discussed in class. If single or only a small number of students require more information I will always be happy to discuss this during my office hours. It shall be stressed however, the ability of the course instructors to bridge such gaps is finite – students who lack the most fundamental prerequisites (e.g. prerequisites for the PHYS2210+2220 e.g. elementary algebra, simple calculus, elementary vector algebra) should review their decision to join this class. Also, since a good portion of PHYS6770 deals with optoelectronics, students are expected to know the basics of electromagnetism, ohms law, elementary circuit analysis (e.g. Kirchhoff's rules) etc. Please take advantage of the prerequisite tests on the PHYS6770 website (<http://www.physics.utah.edu/%7Eboehme/6770/rightclass/index.html>) which are supposed to help you to make a decision on whether the class is appropriate for you or not.

What will be the topics of this class?

- 1) General measurement analysis
- 2) Time and frequency domain analysis
- 3) Gaussian beam optics
- 4) Lasers
- 5) Photo detectors and noise
- 6) Polarization
- 7) Ellipsometry
- 8) Interferometry
- 9) Optical grating spectroscopy
- 10) Acousto-optic modulators
- 11) Fibers
- 12) Optical components

Textbook for this class

For the given contents and the aims of the class there is no particular textbook which would cover all the topics. Since general optics is of course a necessary prerequisite you should get

Grant R. Fowles, *Introduction to Modern Optics*, **2nd Ed.**, Dover Publishers, NY (1989),

so that you'll have some sort of reference for the topics which are discussed. However, note that this book will provide only supporting knowledge, it does not actually cover many of the topics which are subject of the class in depth. To give you a detailed text about the topics of this class, I can only refer to a whole series of books. I want to stress though that I do not recommend buying all these books for the class since only single or few chapters of each of them are subject of the class.

Amnon Yariv, Pochi Yeh, *Photonics*, **6th Ed.**, Oxford University Press (2007). This book about optoelectronics is probably the closest book to the topics of this class. It shall be emphasized though that even this book does not cover all topics (e.g. interferometry, ellipsometry) and those topics covered are presented on a very advanced level.

J. Bentley, *Principles of Measurement Systems*, **3rd Ed.**, Longman Publishers, Singapore (1995). This book will provide the basis for the lectures about the foundations of physical measurement systems.

Max Born and Emil Wolf, *Principles of Optics* **7th Ed.**, Cambridge University Press, Cambridge, UK (2001). This is a profound treatment of the foundations of optics.

A. E. Siegman, *Lasers*, University Science Books, Sausalito, CA (1986).

This book will cover the few things we discuss with regard to lasers and again, many many topics which can not be covered by PHYS6770.

In spite of this literature list, many non-textbook sources will also have to be used for the class such as technical manuals and data sheets provided by the manufacturers of optical and electronics equipment.

Laboratory experiments:

1. Optical beam / 1st & 2nd order systems / angular measurement (2 weeks)
2. Fabry-Perot interferometry / capacitance / displacement measurement (1 week)
3. Lasers / acousto-optic modulators / optical ranging / distance measurement (2 weeks)
4. Photo detectors / low light level detection / noise / frequency response (2 weeks)
5. Heterodyne interferometry / displacement measurement (1 week)
6. Polarization / ellispometry / compensators / polarization analysis (2 weeks)
7. Optical spectrometer / fibers / luminescence / materials characterization (2 weeks)

The subject and the descriptions of the lab experiments will be discussed in class and will be posted on the course website. The students are expected to prepare the lab work by reading the descriptions and, if necessary review all the course materials necessary for the experiments. The lab work is supposed to follow similar procedures as experimental work in a research environment which means that

(i) Work independently! The course will be most successful, if you organize your work, your literature sources for the preparation as well as the documentation by yourself. The instructors will help you as much as they can when necessary, but try to work independently as much as you can since this will amplify the learning effect.

(ii) Before you do your experiments, bring yourself into the position that you know what you are doing – reading the lab descriptions is only one part of this. Read about the background or the history of the experiments and understand the context of the respective experiment.

(iii) Collaborate with your group partner - this is a crucial part of the lab exercises to understand how one can work and solve problems as a team.

(iv) Document your experiment. Write down as much as needed in order to make everything that you are doing reproducible. Write down all relevant experimental observations but do not write down unnecessary things. It is part of the learning experience to develop the ability to judge what's important. Keep in mind that all that remains of your experimental work is your lab protocol. If this is not kept in order and complete, your work will be useless.

Grading:

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Student performance will be evaluated based on the homework results (40%), the midterm exam (20%) and the final exam (40%). The final score will range between 0 and 100. It will translate into the university grade point system linearly **with an offset of 20 points**. This leads to the following table

	Grade points = (class score / 20) – 1											
Grade points:	4.0≥ >3.7	3.7≥ >3.3	3.3≥ >3.0	3.0≥ >2.7	2.7≥ >2.3	2.3≥ >2.0	2.0≥ >1.7	1.7≥ >1.3	1.3≥ >1.0	1.0≥ >0.7	0.7≥ >0.0	0.0
Grade:	A	A-	B+	B	B-	C+	C	C-	D+	D	D-	E

PHYS 6775

The lab contribution to the overall grade consists of the grade of the reports of the one week labs which count half as much as the grades of the reports of the two week labs. The final class score will range between 0 and 100. It will translate into the university grade point system linearly **without an offset**. This leads to the following table

	Grade points = laboratory score / 25											
Grade points:	4.0≥ >3.7	3.7≥ >3.3	3.3≥ >3.0	3.0≥ >2.7	2.7≥ >2.3	2.3≥ >2.0	2.0≥ >1.7	1.7≥ >1.3	1.3≥ >1.0	1.0≥ >0.7	0.7≥ >0.0	0.0
Grade:	A	A-	B+	B	B-	C+	C	C-	D+	D	D-	E

Lab reports or homework turned in late will receive no credit unless good reasons exist for the delayed return. Note that both PHYS 6770 and PHYS 6775 can be taken as a pass/fail class. In order to pass, a student has to achieve at least 50% of the score. It is the responsibility of the student to register the class a pass/fail at the beginning of the semester.

University Accommodation Policies

The University of Utah seeks to provide equal access to its programs, services and activities for people with disabilities. If you will need accommodations in the class, reasonable prior notice needs to be given to the Center for Disability Services, 162 Olpin Union Building, 581-5020 (V/TDD). CDS will work with you and the instructor to make arrangements for accommodations. All written information in this course can be made available in alternative format with prior notification to the Center for Disability Services. The web site for the Center for Disability Services is at: <http://disability.utah.edu/>

Policy of academic honesty, class and lab attendance

It shall be pointed out that for all evaluated materials (homework and exams), rules of academic honesty apply as outlined in the University of Utah student handbook and the University of Utah code of student rights and responsibilities (<http://www.admin.utah.edu/ppmanual/8/8-10.html>). Academic misconduct such as use of cheating, plagiarism or fabrication will be sanctioned as outlined therein. The University policies also describe consequences of absence of students from the lectures, as well as the rules for other student rights and responsibilities.

Information about other University Policies can be found at

<http://www.admin.utah.edu/facdev/accommodations-policy-background.pdf>

<http://www.admin.utah.edu/facdev/accommodations-policy.pdf>

<http://www.admin.utah.edu/facdev/accommodations-policy.ppt>

Lecture dates, begin of lab session cycles and envisaged topics:

	Dates	Lecture contents	PHYS6770	PHYS6775
1.	M 01/12/09	- Introduction, Laser safety lecture		
2.	W 01/14/09	- General measurement system analysis	HW1 assigned	
3.	W 01/21/09	- Statistical Aspects of Measurements - Introduction to Lab 1, part 1	HW2 assigned	
4.	M 01/26/09	- Time and frequency domain analysis		1 st cycle lab 1: Thermopile, RC circuit
5.	W 01/28/09	- Time and frequency domain analysis - Some facts about light	HW1 due HW3 assigned	
6.	M 02/02/09	- Some facts about light - Introduction to Lab 1, part 2		2 nd cycle lab 1: Optical beam deflection
7.	W 02/04/09	- Lasers I, Overview - Lasers II, Fabry Perot interferometer	HW2 due HW4 assigned	
8.	M 02/09/09	- Lasers II, Fabry Perot interferometer - Lasers III, Gaussian Beam optics - Introduction to Lab 2		Cycle for lab 2: Fabry Perot interferometer
9.	W 02/11/09	- Lasers III, Gaussian Beam optics - Introduction to Lab 3, part 1	HW3 due HW5 assigned	Lab 1, part 1 report due;
10.	W 02/18/09	- Lasers III, Gaussian Beam optics - Lasers IV, Laser equations	HW4 due HW6 assigned	1 st cycle lab 3: Lasers Lab 1, part 2 report due;
11.	M 02/23/09	- Lasers IV, Laser equations, Laser implementations - Acousto-optic modulators - Introduction to Lab 3, part 2		2 nd cycle lab 3: acousto-optical modulators
12.	W 02/25/09	- Lasers V, Laser implementations - Semiconductors I: Bandstructure, doping	HW5 due HW7 assigned	Lab 2 report due;
13.	M 03/02/09	- Semiconductors II: optical properties, pn-junction - Photodetectors I, solid state detectors - Introduction to Lab 4, part 1		1 st cycle lab 4: Photo-detectors / noise
14.	W 03/04/09	- Photodetectors II, circuit analysis - Noise I, statistical noise theory, noise measurement	HW6 due HW8 assigned	Lab 3, part 1 report due;
15.	M 03/09/09	- Noise II, thermal noise, shot noise, optical noise - Introduction to Lab 4, part 2		2 nd cycle lab 4: Photo-detectors / noise
16.	W 03/11/09	- Interferometry I, interference, interferometers - Midterm exam question and answer session	HW7 due HW9 assigned	Lab 3, part 2 report due;
17.	M 03/23/09	- Interferometry II, Mach-Zender interferometer - Polarization I, optical fields - Introduction to Lab 5		Cycle lab 5: Heterodyne interferometry
18.	W 03/25/09	- MIDTERM EXAM, covers lectures topics 01/12/09 - 03/09/09		Lab 4, part 1 report due;
19.	M 03/30/09	- Polarization II, Jones vectors & matrices, polarizers - Introduction to Lab 6, part 1 (polarization)		1 st cycle lab 6: Polarization / ellispometry
20.	W 04/01/09	- Polarization III, birefringence, Fresnel equations	HW8 due HW10 assigned	Lab 4, part 2 report due;
21.	M 04/06/09	- Polarization IV, Ellipsometry - Introduction to Lab 6, part 2 (ellipsometry) - Diffraction I		2 nd cycle lab 6: Polarization / ellispometry
22.	W 04/08/09	- Diffraction II	HW9 due HW11 assigned	Lab 5 report due
23.	M 04/13/09	- Diffraction III, Optical grating spectroscopy - Introduction to Lab 7, part 1 (diffraction)		1 st cycle lab 7: Diffraction, Spectrometry
24.	W 04/15/09	- Diffraction IV, Applications - Lasers VI, semiconductor lasers - Photoluminescence	HW10 due HW12 assigned	Lab 6, part 1 report due
25.	M 04/20/09	- Photoluminescence - Introduction to Lab 7, part 2 (spectroscopy) - Optical fibers I		2 nd cycle lab 7: Spectrometry, luminescence
26.	W 04/22/09	- Optical fibers I - Michelson interferometer	HW11 due	Lab 6, part 2 report due
27.	M 04/27/09	- Separate path heterodyne interferometer	HW12 due	
28.	W 04/29/09	- Final exam question and answer session		Lab 7, part 1 and part 2 report due
	To be det.	FINAL EXAM		

Note: Monday, 01/19/09 is Martin Luther King Jr. Day; Monday, 02/16/09 is Presidents' day and between 03/16 and 03/21 is Spring break

Note: The syllabus is not a binding legal contract. It may be modified by the instructor when the student is given reasonable notice of the modification.