TO: The Faculty of the College of Engineering

FROM: The Faculty of the School of Biomedical Engineering

RE: New Undergraduate Course, BME 43300, Biomedical Optical Microscopy

The faculty of the School of Biomedical Engineering have approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

BME 43300 Biomedical Optical Microscopy
Term offered: Spring or Fall, Lecture 3, Cr. 3
Prerequisites: PHYS 24100 or PHYS 27200

Description: The course focuses on the fundamental physics and engineering principles of the newest instruments for medical and biological optical imaging including modalities such as Phase Contrast, Differential Interference Contrast, Total Internal Reflection Fluorescence (TIRF) Microscopy, Fluorescence Correlation Spectroscopy (FCS), Förster resonance energy transfer (FRET), confocal microscopy, multi-photon microscopy and super-resolution techniques such as Structured Illumination Microscopy (SIM), Stimulated emission depletion (STED) microscopy and Single Molecule Switching Nanoscopy (SMSN, also known as PALM/STORM). Through demonstrations and lectures you will learn optics instrumentation principles, contrast generation (including genetically encoded probes and physiological indicators), image formation, detection, and analysis. The course will also explain specific discoveries and biomedical applications such as brain imaging using these innovative biomedical microscopy techniques.

Reason: This course teaches physics principle, engineering considerations and applications of the newest optical imaging methods and instruments within the context of current biomedical research. These emerging technologies are revolutionizing the field of imaging in biomedical applications. We felt that this course addresses a current weakness within the approved BME curriculum in imaging area and this course will serve as a cornerstone on biomedical imaging focusing on optical imaging supporting our overall biomedical engineering curriculum. Other imaging modalities such as X-ray, CT, PET, SPECT and MRI are taught in BME 595, Medical and Diagnostic Techniques. Currently there are no existing competing courses at Purdue that address this topic.

This course has been offered twice as a 400-level experimental course with the following enrollment history in Spring 2016 (12), and Spring 18 (7), and very positive course evaluations for both offerings.

George R. Wodicka

George R. Wodicka,
Dane A. Miller Head and Professor
Weldon School of Biomedical Engineering

BME 43300 Biomedical Microscopy
(Introduction to Optical Microscopy, From Principles to Applications)

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Course Information
Spring, 2019
TBD
MJIS 1083

Course Description
Introduction to Optical Microscopy, From Principles to Applications. The goal is to have the students master the universal principles and ideas rather than a smattering of individual techniques.

The course covers principles of optics, contrast generation (including genetically encoded probes and physiological indicators), image formation, detection, and analysis. The course will also discuss specific biomedical applications and discoveries using specific microscopy techniques. The course will also cover modern microscopy modalities such as TIRF, FCS, FRET and super-resolution techniques such as SIM, STED and PALM/STORM.

In addition, through demos and guest lectures (**GL**), we will cover, quantitative fluorescence microscopy, EM, functional MRI, in vivo brain imaging (AO+two photon microscopy), OCT and CARS with their biomedical applications.

Demos: confocal microscopy, two photon microscopy and adaptive optics, 4Pi microscopy, super-resolution microscopy.

Guest Lectures (GL): These lectures cover aspects that are not covered during normal lectures of the course from leading labs in various field at Purdue which include: Microscopy application in Neuron biology (Suter), EM and applications (Wen), Adaptive optics for *in vivo* brain imaging (Cui), OCT and applications (Goergen), live animal imaging (Andy Schaber)

Prerequisites (if needed)
None

Course Goals,
Upon completion of the course each student will be able to
- Explain the universal principles and ideas behind various microscopy techniques and its development.
- Explain the principle of image formation, digitization and processing techniques.

- Explain the reasoning behind each contrast generation techniques and its appropriate biological target.
- Explain the construction principle of building systems such as confocal, widefield microscopes (TIRF/non-TIRF), phase contrast and DIC.
- Learn how to incorporate modern modalities such as fluorescence correlation spectroscopy (FCS), fluorescence Resonance Energy Transfer (FRET), Fluorescence Recovery after Photobleach (FRAP), etc.
- Explain the reasoning behind modern cellular dynamic imaging tools and their impact in biological research.
- Explain the concept, construction and data analysis of modern super-resolution microscopy systems such as 4Pi, I^5M, SIM, RESOLFT, STED, PALM/STORM.
- Bridge the biomedical applications with the large variety of modern microscopy methods based on a solid grasp of the advantage and disadvantage of each specific technique.

Learning Objectives

Upon completion students are expected to

- Describe fundamental principle, such as Huygen's principle, refraction, interference, diffraction and abbe's fundamental resolution limit.
- Describe basic components of microscopy components, light sources, cameras, objectives, basic illumination schemes such as critical illumination, Köhler illumination and epi illumination.
- Describe the different between different mirror types such as Metallic mirror, dielectric mirror, different basic lenses such as spherical lens, apochromatic lens, and achromat lens, and basic objective types such as Plan, Plan-Neofluar, Plan-Apochromat and Alpha Plan-Apochromat.
- Design and draw basic optical sketches for a simplified imaging system in either wide-field, or focused optical geometry. These imaging systems includes: Widefield, Phase Contrast, DIC, Confocal, Two photon, Adaptive optics (AO) two photon, 4Pi, I^5M, SIM, RESOLFT, STED and PALM/STORM microscopy techniques.
- Describe the general concept of fluorescence detection, principles of detectors, noise sources and leading development trend of detectors such as APD, PMT, CCD, CMOS, EMCCD and sCMOS.
- Describe the general principle of microscopy image processing, including but not limited to, denoise, deconvolution, sharpening, single molecule localization, noise treatment based on camera type.
- Describe and present the general scheme of imaging protocol and data analysis on imaging data especially on systems such as DIC, SIM, 4Pi, PALM/STORM systems taught during demo sessions.
- Describe advantages and disadvantages of microscopy techniques and their suitability for various biological model systems and biomedical research fields.
- Discuss about concurrent major microscopy innovations and their technical advantages, disadvantages and prospective impact on biomedical fields.

Course Requirements

Quizzes: Weekly quizzes will be given at the start of lectures throughout the semester. The quizzes will be held on Wednesday session during the class prior to the lecture in which the quiz is administered and the topic to be quizzed will be related to what has been taught during the last 4 lectures. They will also be used to assess the retention, and the understanding and integration of the course material from the previous lecture(s). A total of 13 quizzes will be taken. Part of the final grade of an individual student will be based on his/her best 8 scores out of the 13 quizzes.

Final project: A final project will require the student to apply knowledges and skills obtained throughout the course to investigate an area of optical microscopy and/or their applications in biomedical field in the form of a literature analysis. These projects will be completed in self-selected teams of 2 to 3 students over the last month of the course. A formal presentation of the findings will be presented to the class during the final week(s) of lectures. The final project reports and presentations will be evaluated the instructor for clarity, logical progression, in-depth understanding, correctness and significance of findings, in such order.

Required Texts

None

Recommended (but not required) Material

1. "**Fluorescence Microscopy: From Principles to Biological Applications, 1st Edition**" edited by Ulrich Kubitscheck, Wiley-Blackwell 2013
2. "**Imaging: A Laboratory Manual, 1st Edition**" edited by Rafael Yuste; Cold Spring Harbor Laboratory Press 2011
3. "**Fundamentals of Light Microscopy and Electronic Imaging, 2nd Edition**" by Douglas B. Murphy and Michael W. Davidson, Wiley-Blackwell 2013

Important sections of book chapters will be posted on Blackboard for further reading.

Students are expected to learn from courseware including handouts, online java applet (http://micro.magnet.fsu.edu/) and demo session.

Policies

General Course Policies

Questions from Students should be directed to the instructor. Due to the nature of the short quizzes given in the beginning of each lecture, no makeup quizzes will be provided. Cell phones and computers should be put in silence mode during the instruction. This course expects students to fully engage with questions and discussions during and after the class with the instructor.

Grading:

	Quizzes*:	60%
	Final project (presentation):	20%
	Final project (report):	20%
Total		**100%**

Grade Scale: The following grading scale is just for your reference. Based upon ensemble class performance, final grades will be curved up by the instructor *if appropriate*. The instructor will update on how to curve up the grades after each exam. Students are welcome to discuss his/her progress with the instructor throughout the semester.

>95%	A+
90-94.9%	A
87-89.9%	A-
85-86.9%	B+
80-84.9%	B
78-79.9%	B-
75-77.9%	C+
70-74.9%	C
65-69.9%	C-
60-64.9%	D
<60	F

*To calculate the grade for quizzes, the best 8 scores out of a total 13 quizzes for each student will be used.

Academic Dishonesty

Purdue prohibits "dishonesty in connection with any University activity. Cheating, plagiarism, or knowingly furnishing false information to the University are examples of dishonesty." [Part 5, Section III-B-2-a, University Regulations] Furthermore, the University Senate has stipulated that "the commitment of acts of cheating, lying, and deceit in any of their diverse forms (such as the use of substitutes for taking examinations, the use of illegal cribs, plagiarism, and copying during examinations) is dishonest and must not be tolerated. Moreover, knowingly to aid and abet, directly or indirectly, other parties in committing dishonest acts is in itself dishonest." [University Senate Document 72-18, December 15, 1972]

Use of Copyrighted Materials

Among the materials that may be protected by copyright law are the lectures, notes, and other material presented in class or as part of the course. Always assume the materials presented by an instructor are protected by copyright unless the instructor has stated otherwise. Students enrolled in, and authorized visitors to, Purdue University courses are permitted to take notes, which they may use for individual/group study or for other non-commercial purposes reasonably arising from enrollment in the course or the University generally.

Notes taken in class are, however, generally considered to be "derivative works" of the instructor's presentations and materials, and they are thus subject to the instructor's copyright in such presentations and materials. No individual is permitted to sell or otherwise barter notes, either to other students or to any commercial concern, for a course without the express written permission of the course instructor. To obtain permission to sell or barter notes, the individual wishing to sell or barter the notes must be registered in the course or must be an approved visitor to the class. Course instructors may choose to grant or not grant such permission at their own discretion, and may require a review of the notes prior to their being sold or bartered. If they do grant such permission, they may revoke it at any time, if they so choose.

Attendance

Students are expected to be present for every meeting of the classes in which they are enrolled. Only the instructor can excuse a student from a course requirement or responsibility. When conflicts or absences can be anticipated, such as for many University sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible...For unanticipated or emergency absences when advance notification to an instructor is not possible, the student should contact the instructor as soon as possible by email, or by contacting the main office that offers the course. When the student is unable to make direct contact with the instructor and is unable to leave word with the instructor's department because of circumstances beyond the student's control, and in cases of bereavement, the student or the student's representative should contact the Office of the Dean of Students,

The link to the complete policy and implications can be found at http://www.purdue.edu/odos/services/classabsence.php

Grief Absence Policy for Students

Purdue University recognizes that a time of bereavement is very difficult for a student. The University therefore provides the following rights to students facing the loss of a family member through the Grief Absence Policy for Students (GAPS). GAPS Policy: Students will be excused for funeral leave and given the opportunity to earn equivalent credit and to demonstrate evidence of meeting the learning outcomes for misses assignments or assessments in the event of the death of a member of the student's family.

Missed or Late Work

No make-up quizzes will be accepted unless specific arrangements are made.

Regrade Policy: Students have the right to contest any grades throughout the semester. In the event that a student feels a quiz has been inappropriately graded, the student must provide a clear explanation for the regrading submission along with the original quiz. Students have **1 week** after the return of a graded work to protest a grade; after this time grade disputes will not be accepted.

Violent Behavior Policy

Purdue University is committed to providing a safe and secure campus environment for members of the university community. Purdue strives to create an educational environment for students and a work environment for employees that promote educational and career goals. Violent Behavior impedes such goals. Therefore, Violent Behavior is prohibited in or on any University Facility or while participating in any university activity.

Students with Disabilities

Purdue University is required to respond to the needs of the students with disabilities as outlined in both the Rehabilitation Act of 1973 and the Americans with Disabilities Act of 1990 through the provision of auxiliary aids and services that allow a student with a disability to fully access and participate in the programs, services, and activities at Purdue University.

If you have a disability that requires special academic accommodation, please make an appointment to speak with me within the first three (3) weeks of the semester in order to discuss any adjustments. It is important that we talk about this at the beginning of the semester. It is the student's responsibility to notify the Disability Resource Center (http://www.purdue.edu/drc) of an impairment/condition that may require accommodations and/or classroom modifications.

Emergencies

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.

Nondiscrimination

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life.

Purdue University prohibits discrimination against any member of the University community on the basis of race, religion, color, sex, age, national origin or ancestry, genetic information, marital status, parental status, sexual orientation, gender identity and expression, disability, or status as a veteran. The University will conduct its programs, services and activities consistent with applicable federal, state and local laws, regulations and orders and in conformance with the procedures and limitations as set forth in Executive Memorandum No. D-1, which provides specific contractual rights and remedies. Any student who believes they have been discriminated against may visit www.purdue.edu/report-hate to submit a complaint to the Office of Institutional Equity. Information may be reported anonymously.

TENTATIVE CLASS OUTLINE AND SCHEDULE

WEEK OF	TOPICS	QUIZZES AND FINAL	ADDITIONAL LEARNING MATERIAL (Bb)
1	Overview of Optics and Photo physics		Handout, web-based Java applets
2	Principles of Light Microscopy	Quiz 1	Handout
3	Construction and Components of Light microscopes	Quiz 2	Handout, web-based Java applets
4	Fluorescence	Quiz 3	Handout
5	Confocal and Wide Field Microscopy. **GL**: Suter, biological applications in primary neurons	Quiz 4	Handout, web-based Java applets
6	Detectors in microscopy **GL**: Jiang, EM and applications	Quiz 5	Handout, web-based Java applets
7	Biological dynamics imaging techniques **GL**: Goergen, OCT and applications	Quiz 6	Handout
8	Principles of Microscopy Image Processing	Quiz 7	Handout
9	Two photon microscopy and deep tissue imaging	Quiz 8	Handout, videos
10	Adaptive optics in microscopy, **GL**: Cui, AO+Two photon	Quiz 9	Handout, demo
11	Single molecule microscopy	Quiz 10	Handout
12	Super-resolution Microscopy I **GL**: Liu/Tong, functional MRI	Quiz 11	Handout, demo

13	Super-resolution Microscopy II	Quiz 12	Handout, videos
14	Biomedical applications of microscopy developments	Quiz 13	
15	Final project presentations (I)	Final project slide due	
Finals	Final project presentations (II)	Final project report due	

1. Readings are done based on materials that will be summarized and send out every class. Extended reading will be on web page and in the form of Java web applet.
2. Books are recommended for extended reading of student's own interest and selected sections of book chapters will be posted on blackboard.
3. Students are required to complete the Quizzes independently. During final project, team members are considered entity for the grade and will be given the same grade based on their work as a whole and should receive help only from the instructor. The final project reports and presentations will be evaluated by the instructor for clarity, logical progression, in-depth understanding, correctness and significance of findings, in such order.
4. Each student will have one opportunity to improve their final grades by taking an oral exam after the within 5 days of the final report (may also lower their grades).

Learning Outcomes

Upon completion students are expected to

- Describe fundamental principle, such as Huygen's principle, refraction, interference, diffraction and abbe's fundamental resolution limit.
- Describe basic components of microscopy components, light sources, cameras, objectives, basic illumination schemes such as critical illumination, Köhler illumination and epi illumination.
- Describe the different between different mirror types such as Metallic mirror, dielectric mirror, different basic lenses such as spherical lens, apochromatic lens, and achromat lens, and basic objective types such as Plan, Plan-Neofluar, Plan-Apochromat and Alpha Plan-Apochromat.
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