Boston University Department of Biomedical Engineering

44 Cummington Mall
Boston, Massachusetts 02215
T 617-353-2805 F 617-353-6766

www.bu.edu/bme

BE518 Modern Optical Microscopy for Biomedical Imaging

1. Introduction

Optical microscopy has become a ubiquitous tool in a variety of disciplines. The goal of this course is to provide you a comprehensive overview of modern optical microscopy techniques, with applications in biological imaging. The first half of the course will cover foundations, including basic principles of Fourier optics, image formation, intensity versus phase contrast, and fluorescence imaging. The second half of the course will examine state-of-the-art microscope techniques designed to address different challenges, including imaging in thick media, high-speed imaging, volumetric imaging, super-resolution imaging, etc.. You will be assigned weekly exercises related to image processing. There will be a mid-term exam. Finally, you will be required to present an oral report on a current research topic of their choice involving optical microscopy.

2. Instructor and Office Hours

Jerome Mertz:	Friday 2:00 pm – 3:00 pm	LSEB 202

3. Course Hours

Lectures:	Monday and Wednesday 12:20-2:05 pm	TBA

Lecture attendance is mandatory.

4. Expectations and Grading Breakdown

Class participation (10%):

Lecture handouts will be posted on Blackboard. You are required to read the handouts prior to start of lectures. This way you will be able to constructively participate in class discussions. Your active participation will help us assess your understanding of the class material.

Homework (35%):

Homeworks are due in class one week after they are assigned. Any late homeworks will suffer a 20% grade reduction per day.

Homeworks will involve image processing. You can use any software you are comfortable with (Matlab, Python, ImageJ, etc.). Homeworks should be as concise as possible. Written responses should be short and to the point. Label your plot axes!! I am not looking for style here. I am looking for evidence that you understand the concepts. You are allowed to work with classmates, however you must submit your own homeworks, **written in your own words**.

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Midterm Exam (25%):
There will be only one exam administered during the course. Please refer to the course calendar for the scheduled date.

Final Project (30%):
Students are required to identify a paper specifically involving optical microscopy and present a 20-minute presentation on this paper. Your powerpoint presentation is required. Please refer to the syllabus for scheduling details. *Extensions will not be granted unless you can prove illness or other emergency.*

Final grades will be curved.

5. Resources

Course documents:
http://learn.bu.edu

Microscopes – Basics and Beyond:
https://micro.magnet.fsu.edu/primer/pdfs/basicsandbeyond.pdf

Youtube online iBiology Microscopy Course:
https://www.youtube.com/playlist?list=PLQFc-Dxlf4pSHREZvz41xHFSEp65iNkBL

Classic book on Fourier Optics:
Joseph W. Goodman, Introduction to Fourier Optics, 4th Ed., W.H. Freeman, 2017

A bit more involved:
Jerome Mertz, Introduction to Optical Microscopy, 2nd Ed., Cambridge University Press, 2019

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6. Syllabus

- **Week 1**
  Basics of microscopy: lenses, NA, FOV, field and aperture stops, Kohler illumination
  Detectors and noise: cameras, shot noise, dark noise, readout noise
  - Homework: simulation and characterization of noise
- **Week 2**
  Fourier optics: field propagation, imaging, coherence
  Fourier optics: PSF, OTF, deconvolution
  - Homework: simulation of coherent vs incoherent imaging
- **Week 3**
  Phase contrast: oblique field, Zernike, quantitative Zernike
  Phase contrast: DIC, oblique back-illumination
  - Homework: simulation of phase contrast
- **Week 4**
  Fluorescence: rate eqtns, photobleaching, lifetime
  Fluorescence: filter cubes, spectral unmixing, FRET
  - Homework: simulation of spectral unmixing
- **Week 5**
  Fluorescence: optical sectioning, TIRF, light sheet, oblique light sheet
  Scanning microscopes: confocal, line-scan, spinning disk
  - Homework: simulation of scanning confocal
- **Week 6**
  Scanning microscopes: multiphoton (2P, 3P), SHG/THG
  Non fluorescence techniques: OCT, reflection vs transmission
  - Homework: simulation of frequency-domain OCT
- **Week 7**
  Non fluorescence techniques: Raman, CARS, SRS, Brillouin
  Non fluorescence techniques: speckle imaging (time/space domains)
  - Homework: simulation of speckle imaging
- **Week 8**
  Neurosci applications: calcium imaging, voltage imaging
  Review session
- **Week 9**
  In-class midterm exam
  Ultrafast imaging: spatiotemporal multiplexing, spectral coding, compressive imaging
- **Week 10**
  Volumetric imaging: EDOF (Bessel), multiplane, light-field
  Superresolution: SIM, ISM, Pixel reassignment
  - Homework: prepare student presentations
- **Week 11**
  Superresolution: PALM/STORM, SOFI
  Superresolution: STED, RESOLFT, MinFLUX
  - Homework: prepare student presentations