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Learning Microscopy by Designing One in ‘Advanced Optical Microscopy for Biomedical Engineering’

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Abstract:

Optical microscopy has emerged as an indispensable tool for biomedical studies. Recognizing this significance and possessing strong expertise in optical microscopy, the PI, a new faculty member in BME, will create a new course titled "Advanced Optical Microscopy for Biomedical Engineering" to equip graduate students with essential knowledge and skills in optical microscopy. This course aims to introduce fundamental optical concepts, practical basics, commonly used microscopy modalities, and cutting-edge imaging techniques. Moreover, it integrates the application of artificial intelligence (AI) in optical imaging to prepare students for future research endeavors.

Inspired by a similar course, "Modern Microscopy for the Modern Biologists", audited at UC Berkeley, the PI identified a missing link in conventional teaching approaches. While attending lectures and reading textbooks enables students to learn the principles of microscopy techniques, appreciate pretty images, and understand their biological implications, they often lack exposure to the practical transition of these principles into a functioning tool. Addressing this gap, the new course will emphasize understanding the user's needs, determining target specifications, and optimizing a microscope's performance.

To enrich the learning experience and bridge the theoretical-practical divide, an innovative group research project: ‘learning microscopy by designing one’ (Fig. 1) is proposed to be integrated into the course curriculum. Students will collaborate in teams to design an optical microscope, selecting from four commonly used microscopy techniques: structured illumination, 2-photon fluorescence, confocal, and light sheet microscopies. During this project, students will start from considering the intended applications and target specifications of the microscope. They will next conduct optics selection, performance evaluation, and optical design optimization using tools such as Zemax. By the end of the course, they will present to the class, introducing the theory, design, and expected performance of the microscope they designed. Through this hands-on and research-oriented approach, student will gain a deeper understanding of basic optics as well as practical considerations in building a microscope. Furthermore, students will gain insights of optical microscopy from both an engineer's and a user's perspective.

To evaluate the effectiveness of this teaching strategy, a survey will be conducted at the end of the course. Students will assess the project's impact on their understanding of optics, specific imaging

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modalities, crucial imaging performance specifications, and proficiency in optical optimization using Zemax. Upon successful implementation and positive outcomes, the project will be extended to other relevant courses within and outside the Biomedical Engineering department. The PI will also share the experience by giving presentations in teaching and learning conferences/workshops. Additionally, outstanding Master's students may be offered opportunities to advance their studies and research under the guidance of the PI. This approach aims to enhance the educational experience and foster the development of future innovators in the field of optical microscopy for biomedical engineering.