PhD THESIS DEFENSE: Deep-learning enhanced bioluminescence microscopy

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November 21, 2025
10:00
ICFO Auditorium

Bioluminescence microscopy presents a powerful alternative to fluorescence imaging by eliminating the need for external illumination, thereby avoiding issues such as phototoxicity, photobleaching, and background autofluorescence. However, the inherently low photon output of luciferase-based reporters significantly restricts the signal-to-noise ratio (SNR), as well as the achievable spatial and temporal resolution-challenges that are especially pronounced in dynamic or volumetric biological imaging. This thesis addresses these limitations by introducing a deep learning-driven imaging pipeline designed to enhance bioluminescence microscopy at both the data acquisition and image reconstruction stages.?
Our strategy integrates optical system design with advanced neural networks to enabl rapid, high-resolution 3D imaging under extremely low-light conditions. We engineered

custom microscope featuring a highly compact optical axis and paired it with a single-photo sensitive camera, significantly boosting the SNR of bioluminescent images. To achieve fas volumetric imaging, we incorporated light field microscopy (LFM) and Fourier light fiel microscopy (FLFM), enabling single-shot 3D acquisition while improving axial and latera resolution via Fourier-domain filtering. The primary objective of this work is to demonstrat how deep learning can substantially enhance bioluminescence microscopy, pushing th technique beyond its traditional limits in both 2D and 3D imaging

At the core of our approach is a suite of convolutional neural networks specifically trained o bioluminescent data. Using both synthetic and experimental datasets, we designed an trained models capable of extracting meaningful information from low-SNR raw data recovering otherwise lost details and offering deeper insight into the biological sample. Th models developed in this thesis cover key tasks such as denoising and reconstruction o wide-field, light field, and Fourier light field bioluminescent images. Together, they form modular, learnable pipeline that significantly elevates the performance of bioluminescenc microscopy in terms of both quality and speed

We validate our system using live biological samples, including Caenorhabditis elegans mouse stem cells, and zebrafish embryos, capturing neuronal activity and intracellula dynamics at subsecond timescales. By placing deep learning at the heart of the imagin process, this work establishes a new paradigm for bioluminescence microscopy transforming a traditionally low-SNR modality into a robust tool for fast, high-resolution, an label-specific imaging in living organisms

Friday, November 21, 10:00 h. ICFO Auditorium

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Hosted by: Academic Affairs