

Congratulations to New ICFO PhD Graduate

Dr. Luis Felipe Morales Curiel graduated with a thesis entitled "Deep-learning enhanced bioluminescence microscopy"

November 21, 2025

We congratulate Dr. Luis Felipe Morales Curiel who defended his thesis this morning in ICFO's Auditorium.
Dr. Morales Curiel obtained his MSc in Multidisciplinary Research in Experimental Sciences from the Universitat Pompeu Fabra (UPF), before joining the Neurophotonics and Mechanical Systems Biology research group led by professor Dr. Michael Krieg. His thesis titled Deep-learning enhanced bioluminescence microscopy " was supervised by Prof. Dr. Michae Krieg

ABSTRACT:
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 enable rapid, high-resolution 3D imaging under extremely low-light conditions. We engineered a custom microscope featuring a highly compact optical axis and paired it with a single-photon sensitive camera, significantly boosting the SNR of bioluminescent images. To achieve fast volumetric imaging, we incorporated light field microscopy (LFM) and Fourier light field microscopy (FLFM), enabling single-shot 3D acquisition while improving axial and lateral resolution via Fourier-domain filtering. The primary objective of this work is to demonstrate how deep learning can substantially enhance bioluminescence microscopy, pushing the 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 on bioluminescent data. Using both synthetic and experimental datasets, we designed and trained models capable of extracting meaningful information from low-SNR raw data, recovering otherwise lost details and offering deeper insight into the biological sample. The models developed in this thesis cover key tasks such as denoising and reconstruction of wide-field, light field, and Fourier light field bioluminescent images. Together, they form a modular, learnable pipeline that significantly elevates the performance of bioluminescence 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 intracellular dynamics at subsecond timescales. By placing deep learning at the heart of the imaging process, this work establishes a new paradigm for bioluminescence microscopy, transforming a traditionally low-SNR modality into a robust tool for fast, high-resolution, and label-specific imaging in living organisms.

Thesis Committee:

Prof. Dr. Ricardo Jose Dos Santos Duarte Vieira Henriques, Instituto Gulbenkian de Ciencia

Prof. Dr. Turgut Durduran, ICFO

Dr. Niccolo Accanto, IBEC



Thesis Committee