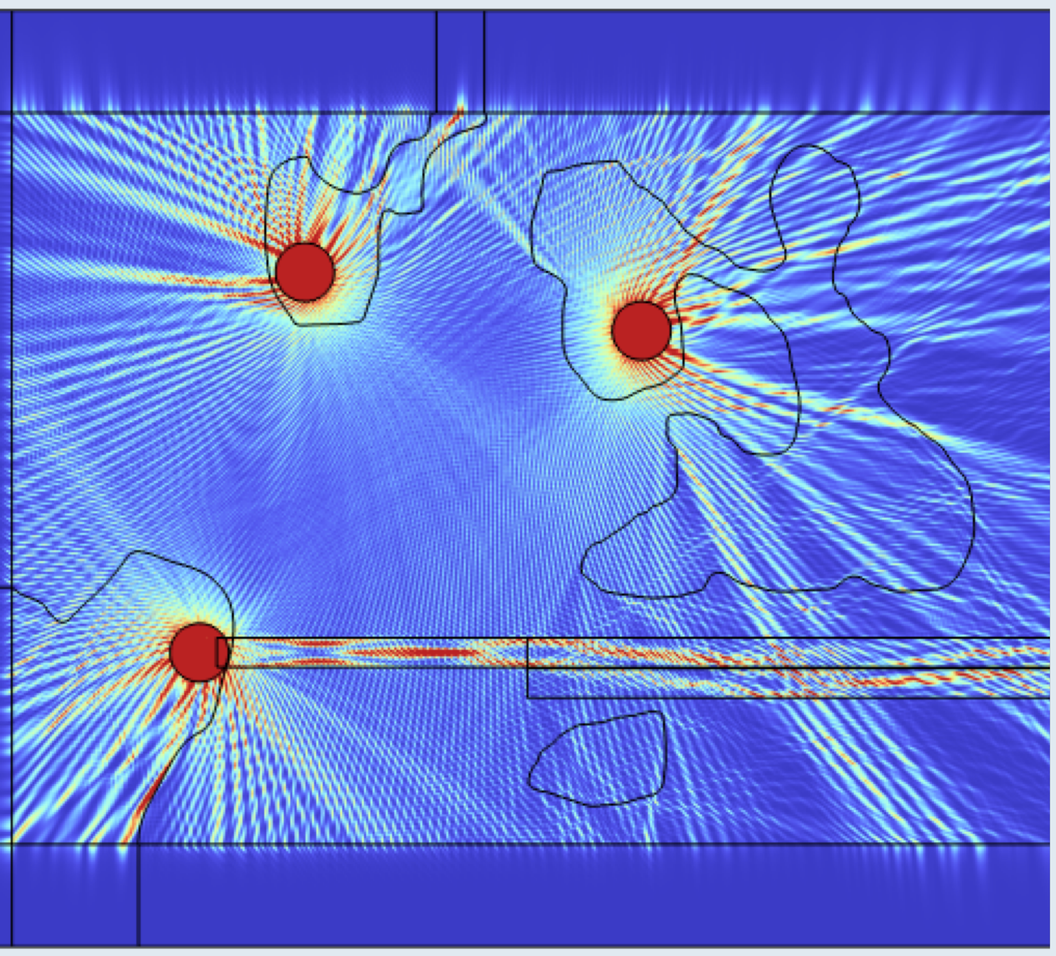


Understanding Light Propagation Characteristics of a Single GFP Transfected Neuron with Simulations

Studying how light could be guided through an axon can lead to a deeper understanding of neuronal communication.

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Introduction & Goals

Biophotons are ultraweak photons emitted by living cells as a byproduct of metabolic activity [1]. Elevated biophoton emission in neurons has led to speculation that photons may play a role in intercellular communication [2]. The biophotons may act as signals guided from neuron to neuron through axons.

To investigate the light-guiding properties of axons, green fluorescent proteins (GFP) were expressed in neuronal nuclei were excited using two photon microscopy. A tapered optical fiber probe was used to measure the optical signals near the axons and detect signatures consistent with evanescent coupling.

Measurements indicated that the surrounding cells may be interfering with the measurements, leading to questions on how neighboring cells can be scattering signals. To better understand axons light-guiding properties and the scattering role of neighboring cells, COMSOL Multiphysics was used to simulate ideal propagation cases and compare them with noisy scenarios.

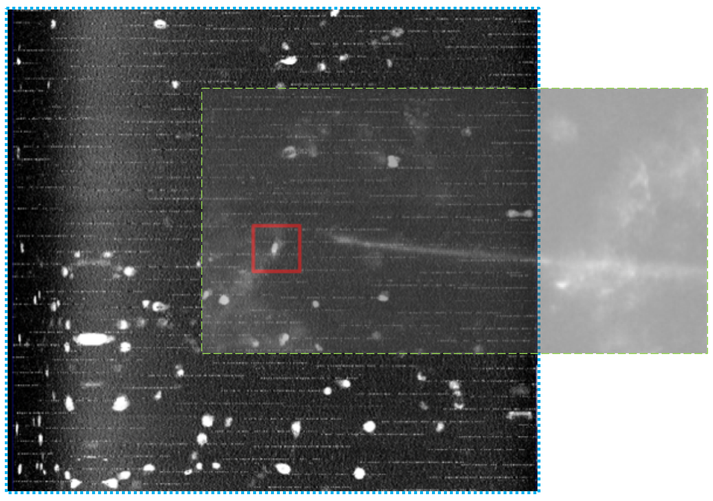


FIGURE 1. Brightfield image of the experimental domain (dashed green outline) overlaid with the two-photon image (blue outline), revealing neurons with active GFP (cell of interest highlighted in red)

Methodology

GFP was transfected into the cell nuclei to generate photons from within the cell. Optical signals were measured using a tapered optical fiber scanned along the axon. Evanescent coupling from axon to fiber was expected to produce oscillations and decreasing intensity with increasing distance from the emitter. Instead, an increase in signal with slight oscillations was detected.

The experiment was modeled in 2D using COMSOL. The brightfield image was used to derive the cell geometries. A circular domain with an external current density represented the GFP-containing nucleus. The probe was swept along the axon while fiber-coupled power was monitored. Additional light sources were added representing surrounding cells, and perfectly matched layers were used to avoid back reflections at the border.

Results

The general trend from the simulations follows the axon surrogate measurements on an integrated waveguide (coupled power decreasing over distance). However, when comparing the ideal case of a single emitter with no surroundings (Case 1) to the case of a single emitter with neighboring cells (Case 2), an increasing trend in coupled power as the probe moves further from the main emitter is revealed. Adding neighboring emitters (Case 3), produces a similar increase with an overall power offset.

In conclusion, as Case 2 and Case 3 show the same trend, secondary emitters are unlikely to be the primary cause. Instead, nearby cells appear to scatter light from the main emitter into the fiber probe.

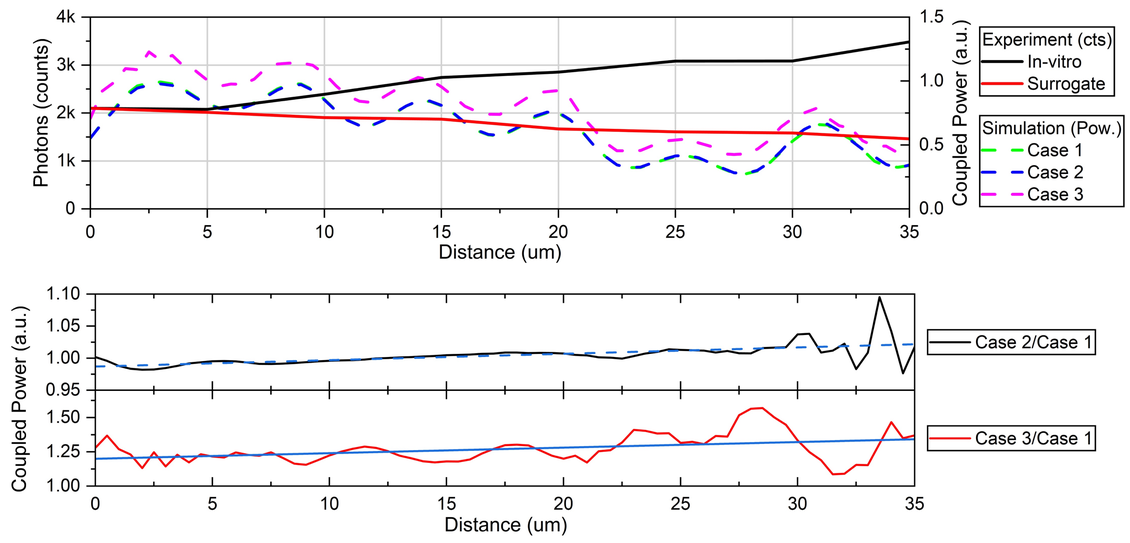


FIGURE 2. (Top) In-Vitro and surrogate measurement photon counts compared with the three simulation cases (Bottom) Cases normalized to the ideal case of single emitter with no cells present

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