Integrated LED for Peripheral Illumination of Fiber Optics

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Introduction

Patch-clamp electrophysiology has been adopted as the primary method of producing high resolution recordings of neuronal electrical activity. To overcome the technique's difficulty barrier, the Smith lab at ASU has developed a fluorescence-guided automated system [1]. However, this system still faces limitations. The current optical fiber loading mechanism requires deep concentration and risks damaging the fiber. Additionally, fiber optic systems such as these must contend with noise caused by ambient light, forcing a trade-off between image quality and acquisition time [2]. Finally, the current optical fiber positioning method requires a careful and lengthy setup with less optimal light intensity. This project endeavors to improve on the system in three ways: by designing an optical fiber side loading mechanism, optimizing light proofing properties of the optical fiber casing, and discerning an optimal location to integrate a peripheral light for optical fiber positioning.

Experimental Methods

The side loading instrument was designed to decrease fiber loading fail-rates while retaining light blocking properties. Optimized light-proofing efficacy was additionally sought, defined by the minimization of residual light after light energy (470nm, 100µW) was passed through a 3D-printed disk variation. Each increment was averaged between 300 data points. Intensity of peripherally coupled light was evaluated at different relevant horizontal and vertical distances from the optical fiber.

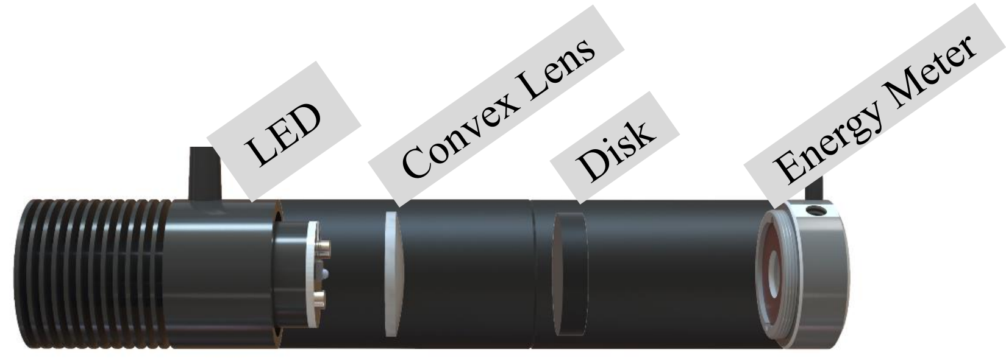

Figure 1. Assembly of experimental setup. Rendered is LED (M470L5, Thorlabs), convex lens (LA1509, Thorlabs), 3D-printed disk, and energy meter (S120VC, Thorlabs).

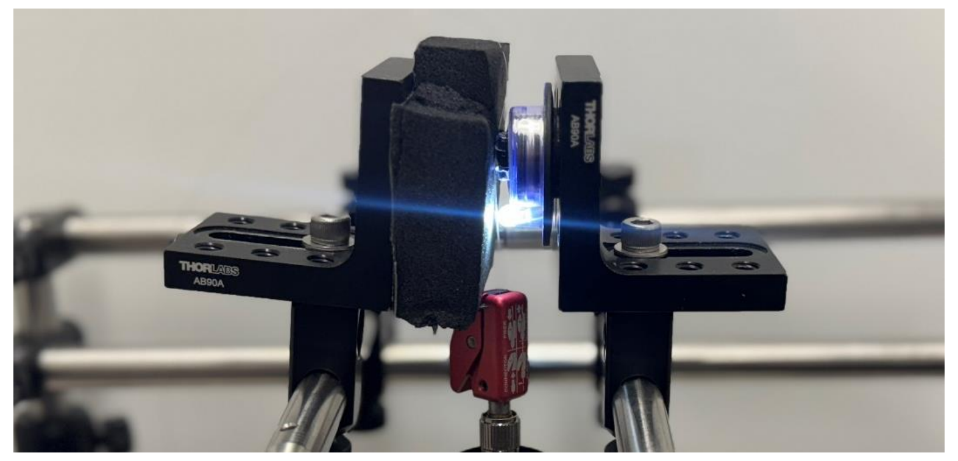

Figure 2. Peripheral optical fiber illumination experimental set-up using a focused fiber.

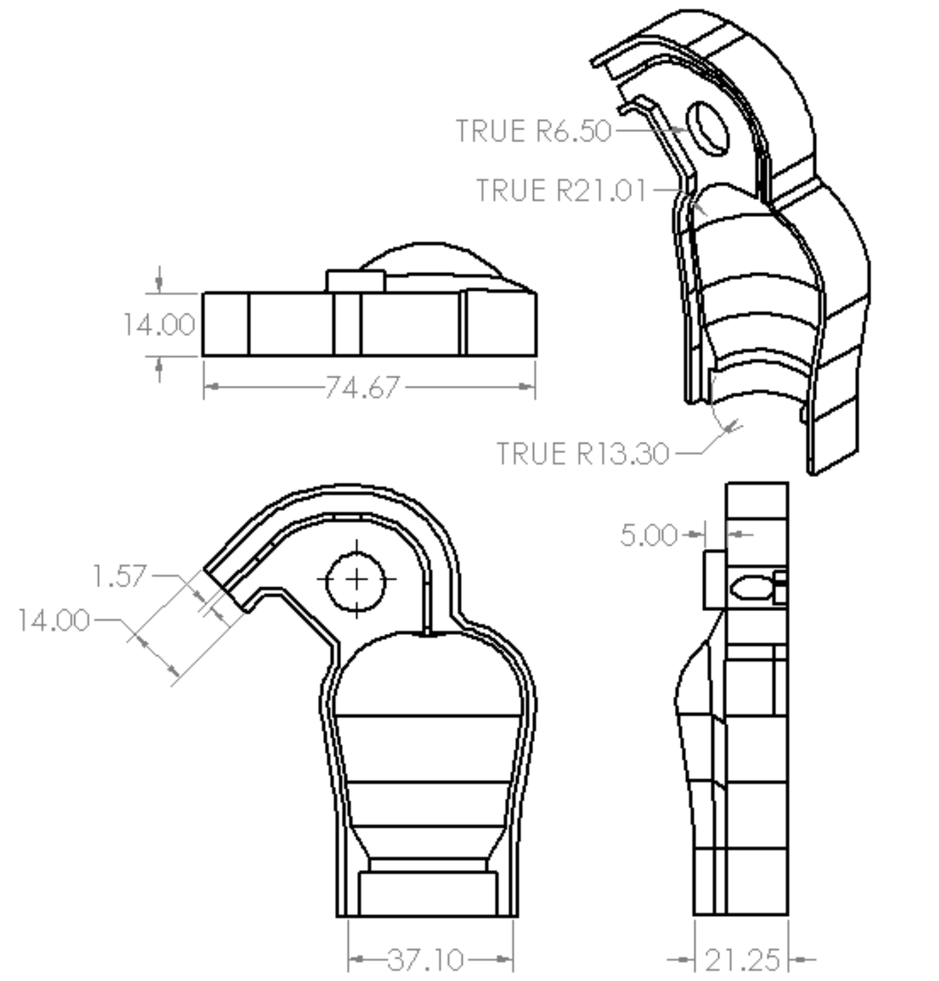

Figure 3. 2D cross-sectional drawings of the improved optical fiber side-loading instrument. Units in mm.

Results

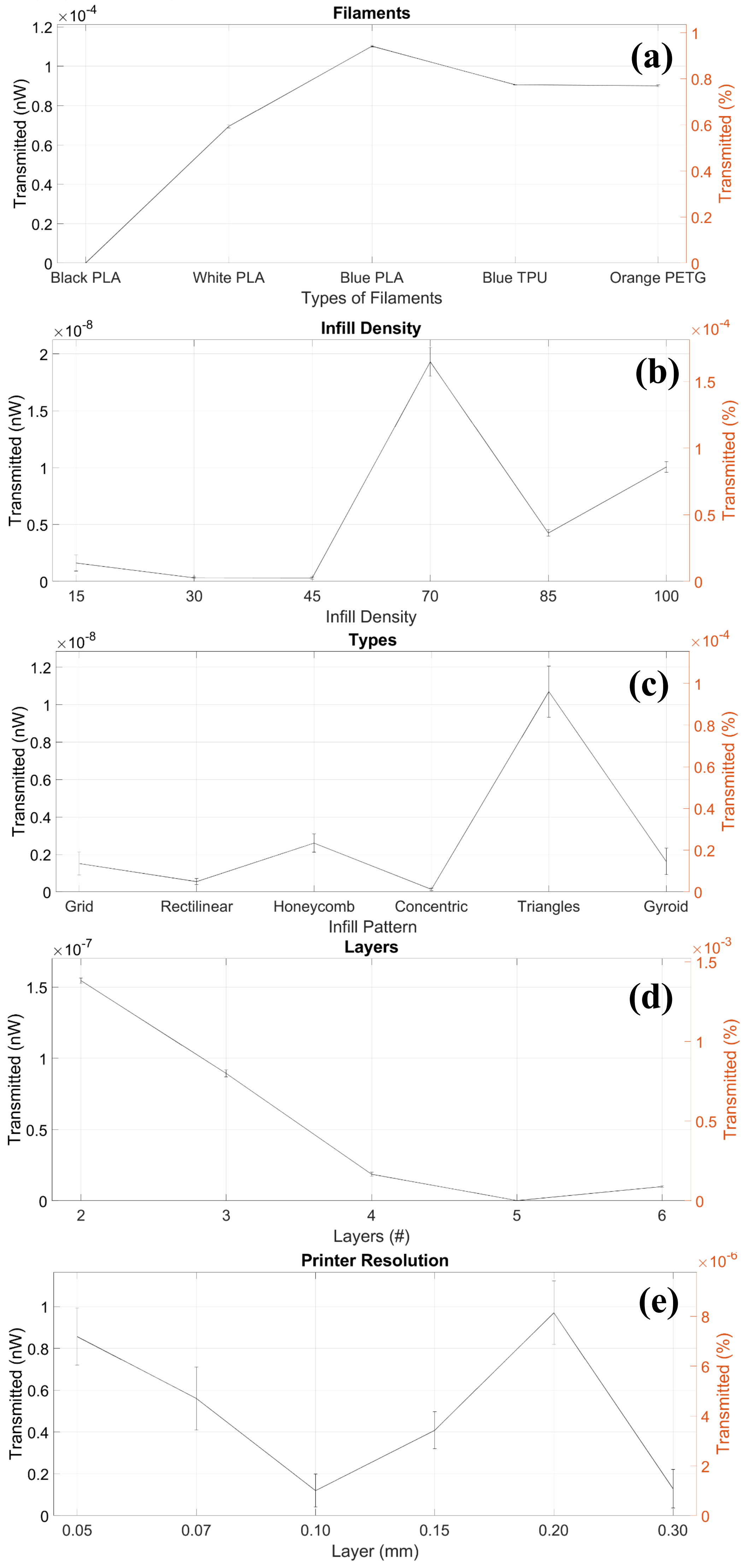

Figure 4. Comparison of light transmission (nW) through each 3D printing parameter. Parameters tested were (a) filament type, (b) infill density, (c) infill pattern, (d) horizontal layer number, and (e) printer resolution.

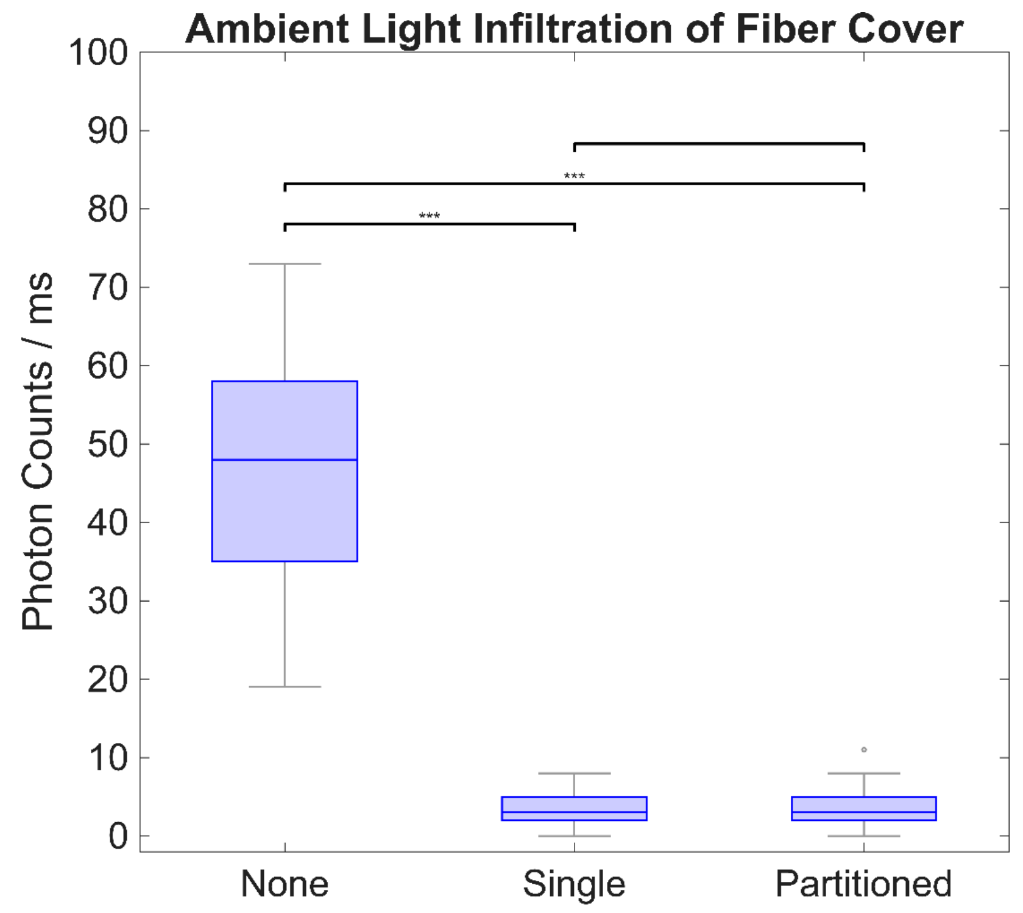

Figure 5. Comparison of ambient light blocking properties of the original optical fiber loading mechanism and the new side-loading mechanism using infiltrating photon counts per millisecond as recorded by an avalanche photodiode.

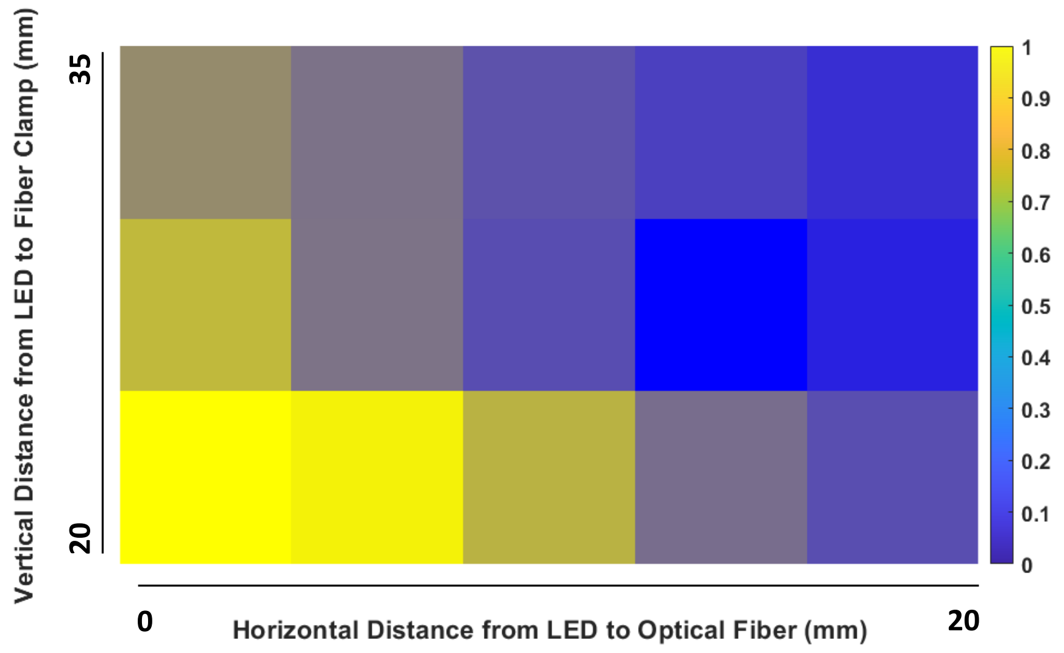

Figure 6. Comparison of collected light intensity of peripheral light coupled into the optical fiber at different horizonal and vertical positionings.

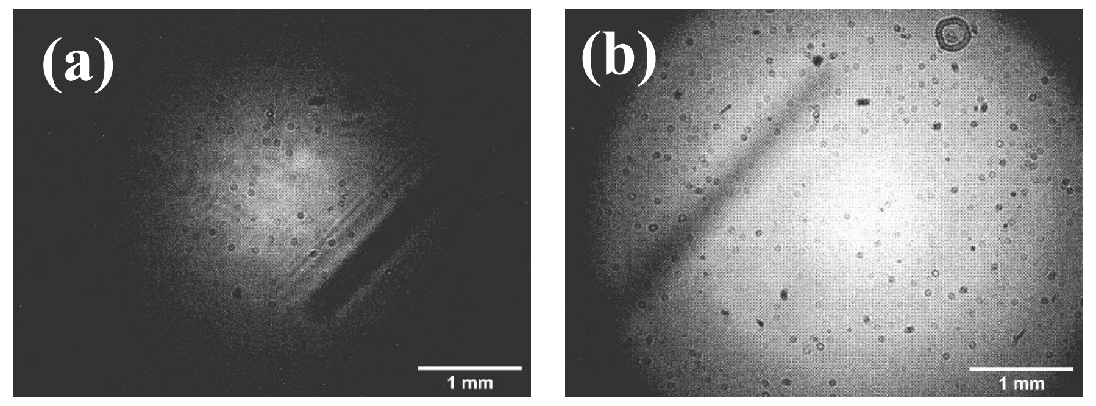

Figure 7. Comparison of light coupling techniques using models of (a) core-only illumination versus (b) peripheral illumination on beam profile for optical fiber positioning. Core-only illumination spans ~1mm while peripheral illumination of the fiber spans ~3.5mm of light. Peripheral illumination was recorded at 0mm x-positioning and 21.14mm y-positioning.

Conclusion

This study seeks to improve research prototype fabrication techniques by developing an optimized fiber optic loading, positioning, and signal recording instrument for use in decreasing fiber loading fail rates, decreasing noise in signal recording, and increasing visibility and ease of optical fiber positioning. This will contribute to the improvement of housings used in biomedical imaging and optics systems. We've applied the findings of this work in the optical fiber instrument used in our own lab. These findings will be applied to an integrated LED for peripheral illumination and positioning of the system.

Figure 8. Final optical fiber loading instrument. Fiber is loaded through opening on left partition and tip is secured with a bare fiber optic terminator clip (Thorlabs, BFT1). Ambient light is blocked by attaching the two partitions using magnets around the fiber. The other tip of the fiber is loaded into the patch-clamp electrophysiology system.

Future Work

The next phase of this research involves integrating a peripheral LED into the 3D-printed instrument for a seamless optical fiber loading and positioning process. From our research, it is implied the optimal position for an integrated peripheral light for maximum light intensity without overloading the avalanche photodiode would be (0mm, 21.14mm).

References

[1] Miranda, Christopher, et al. "Automated microscope-independent fluorescence-guided micropipette." Biomedical Optics Express 12.8 (2021): 4689-4699.

[2] G. Keiser, F. Xiong, Y. Cui, P.P. Shum, "Review of diverse optical fibers used in biomedical research and clinical practice," in *Journal of Biomedical Optics, Vol. 19, Issue 8*, Aug. 2014.

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