Spatial Angle Filtering (SAF) Imaging Device for Deep Interrogation of Scattering Media

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Abstract

Introduction:

Imaging deep tissue structures, such as blood vessels, in scattering media like skin is challenging for optical techniques. This study enhances Spatio-Angular Filtering (SAF), a lens-free fiber optic imaging system, to improve optical imaging depth while maintaining resolution. SAF utilizes a Fiber Optic Plate (FOP), a bundle of micron-sized fibers that minimize resolution loss and improve tissue penetration.

Materials and Methods:

SAF imaging replaces traditional lenses with a FOP, enabling the capture of ballistic light while minimizing scattered light, allowing for high-resolution imaging at greater depths. A spatially resolved diffuse reflectance imaging platform was developed to visualize intrapapillary capillary loops (IPCLs) in skin. The system was optimized using various numerical apertures and near-infrared wavelengths to improve depth and contrast. Skin-mimicking phantoms were fabricated using polydimethylsiloxane (PDMS) incorporated with titanium dioxide and India ink, tuning the optical properties to simulate the dermal and mucosal layers of human skin. The phantoms feature horizontal vascular structures mounted at an angle, allowing for progressively increasing imaging depth as the phantom is scanned.

Results:

Incorporating a low numerical aperture (NA) FOP into the SAF system improved imaging depth, allowing deeper tissue penetration while maintaining resolution. The optimized system, using near-infrared light, enhanced both depth and contrast. The phantoms offer a controlled environment for evaluating the SAF imaging system's performance. Although imaging with the phantoms is ongoing, their design, which allows for progressively increasing imaging depths up to 6.5mm, ensures that the SAF system's capabilities for deep tissue penetration are effectively tested.

Conclusion:

This research demonstrates that SAF imaging, combined with biologically relevant phantoms, is a promising method for deep tissue imaging, offering significant potential for applications in early cancer detection, microcirculation imaging, and other medical diagnostics.