Near-Infrared Optical Tomography in Endoscopy-Geometry

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Near-infrared (NIR) optical tomography is a non-invasive diagnostic imaging technique that has the potential of acquiring unique tissue-specific contrast. The high contrast of NIR optical tomography originates from the stronger light attenuation by hemoglobin relative to water in parenchymal tissue, as well as the distinct spectral differences of hemoglobin between the oxygenated and deoxygenated states. Contrast as high as 300 percent has been demonstrated in NIR tomography for vascular densities of 2 percent, due to increased vascularity in malignant tissues.[1] Such high blood-based contrast means that pathognomic diagnosis for cancer detection and hemodynamic imaging are quite feasible.

Over the past two decades, NIR optical tomography has advanced steadily by finding key applications in the characterization of breast cancer,[2] the assessment of brain functionality[3] and the evaluation of extremity abnormality.[4] All these applications have focused on using external applicator arrays. However, this approach can also be extended to endoscopy geometries for imaging internal organs such as the prostate, colon and rectum. The key factor in attempting NIR tomography of internal organs has been the development of appropriate applicator arrays.

Recently, we constructed a novel applicator array and demonstrated an NIR optical tomography system that allows two-dimensional NIR contrast mapping of internal organs via endoscopic interrogation.[5] The technique, illustrated in the figure, incorporates a broadband light source with spectrometer-based detection. The broadband light that disperses with a grating and passes a collimating lens forms a one-dimensional linear distribution of the source spectrum, which is coupled to the tissue by linearly aligned fibers.

We rearranged the fibers into a circular geometry inside the endoscope probe, where a coated cone-prism was used for circumferential light deflection. The wavelength separation coupled to each fiber generates spectral-encoding of the illumination over to the tissue, which accommodates concurrent sampling of all source-detector pairs when using a spectrometer and CCD in the detection. This design enables both the probing in endoscopy-geometry and the rapid sampling for NIR optical tomography.

The inset image in the figure shows an example of this endoscopy-geometry NIR tomography imaging, obtained from inside avian rectal tissue ex vivo, sampled at an 8Hz frame rate. The walls of the rectal tissue were quite uniform in terms of light absorption; therefore, we injected a tiny amount of exogenous absorption agent made by diluted India ink into the rectal wall to demonstrate the principle. The endoscope NIR probe was then inserted into the rectum and the NIR imaging plane was placed at the region of extraneous absorption agent. The reconstructed image reveals excellent contrast of the occlusion over the ex vivo background tissue.

In summary, we demonstrated the first implementation of NIR optical tomography in endoscopy imaging geometry. This innovative technique presents a new paradigm for non-invasive tissue-specific cancer detection in internal organs, including the prostate, colo-rectum and cervix.

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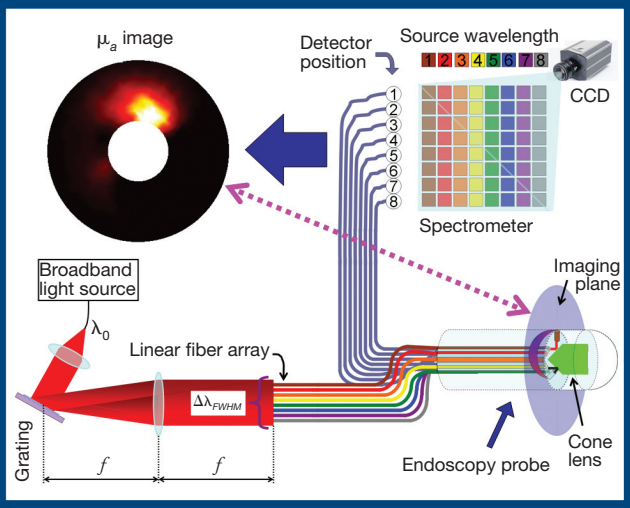

The schematic setup of the endoscopy-geometry NIR optical tomography technique is illustrated. The endoscopy NIR probe consists of fibers in circular geometry for circumferential illumination and detection via a coated cone lens. The spectral-encoding of the broadband light through grating dispersion is delivered to the probe for parallel source illumination, and a spectrometer/CCD configuration is used for concurrent separation and sampling of all source-detector signals. The inset image is an example of one static tomographic image obtained using rectal tissue ex vivo with exogenous absorption contrast.

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