Pressure Contrast Imaging: A New Approach to the Acousto-optic Detection of Optical Scattering Inhomogeneities at Depth in Diffuse Media

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Abstract: Acousto-optic imaging (AOI) is a dual-wave modality that combines ultrasound with diffuse light to achieve deep-tissue imaging of optical properties with the spatial resolution of ultrasound. Progress has been made in the detection of optically absorbing inhomogeneities, yet it remains a challenge for AOI to detect targets possessing low scattering contrast and to obtain quantitative measurements of optical properties at depth with high resolution. A new photonic-crystal fiber (PCF) based AOI system operating in the near-infrared wavelength region can be used to detect low scattering contrast targets. This system can be used to quantitatively map the scattering contrast at depth; the one-to-one mapping of signal ratio and the reduced scattering coefficient allows for accurate and quantitative characterization of the local optical properties at depth within the diffuse media. Moreover, it provides the opportunity to image and quantify the low contrast inhomogeneities (which still remains challenging with direct AOI), as long as the inhomogeneity is less than the acoustic pulses. (The experiments are under exploration these days and will be concluded soon).

Background

Motivation of Acousto-optic Imaging (AOI):
- Acoustic/optic high resolution, depending on acoustic properties - Invasive in diagnosing cancers
- Optical imaging: functional imaging, relying on optical properties - Trade-off between imaging depth and resolution
- Acoustic/optic imaging (AOI): A dual-wave sensing technique using ultrasound-modulated diffuse light
  - Optically relevant physiological information - Ultrasound spatial resolution
  - Fusion of AOI and diagnostic ultrasound: Simultaneously obtain both acoustic and optical information

State of the Art:
- Ultrasound and OCT have become the primary techniques for imaging deep tissue.
- Other techniques include Diffuse Optical Tomography (DOT), Optical Coherence Tomography (OCT), Photoacoustic Tomography (PAT), and Magnetic Resonance Imaging (MRI), which are all limited by spatial resolution, penetration depth, and cost.

Project Motivation
- Direct AO signals are relatively unreliable in diagnosing cancers
- Motivation of Acousto-optic Imaging (AOI): A case intended to demonstrate the utility of AOI technique

Acoustic Axial Distance (cm)

A new mechanism, pressure contrast imaging (PCI), is proposed and demonstrated experimentally that the pressure ratio at the focus is independent of the background light distribution and optical collection system, allowing for accurate and quantitative characterization of the tissue’s optical properties.

System Setup and Theoretical Considerations

We developed a near-infrared wavelength system potentially suitable for in-vivo measurements.

A case intended to demonstrate the utility of AOI technique

Summary and Future Plan
- A novel detection mechanism, pressure contrast imaging (PCI), is proposed and demonstrated experimentally that the pressure ratio at the focus is independent of the background light distribution and optical collection system, allowing for accurate and quantitative characterization of the tissue’s optical properties.
- Thermal lesions formed in chicken breast under HIFU field are successfully imaged using AOI, opening up the possibility of using AOI system to assess the progress of HIFU therapy.
- Future experiments: quantitatively low contrast imaging optical scattering inhomogeneities at depth in diffuse media; monitoring the ongoing changes in optical properties during the formation of HIFU thermal lesion.

Technology Transfer
This technology can have a broad impact in the detection of tissue abnormalities and diseases states, can be readily combined with diagnostic ultrasound systems to provide enhanced diagnostic capabilities and can be used for quality control monitor and assess of HIFU therapy. Companies that could potentially benefit from this technology include: Analogic Corp., Intuitive, China Medical Technologies, and Philips Medical Systems, etc.

References

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