Real-time multimodal high resolution biomedical imaging instrument using supercontinuum optical sources

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Abstract: We present progress towards developing a multimodality imaging instrument, optical coherence tomography (OCT)/ photo-acoustic microscopy (PAM). By utilizing supercontinuum optical sources, that deliver wide spectral bandwidths and high energy densities, we devised a real-time imaging instrument which can be employed to image biological tissues. The OCT channel was devised to operate around 1300 nm. A custom built spectrometer ensures a constant axial resolution of 6 μm over an axial range of up to 1.5 mm. The PAM operates within the therapeutic window providing an axial resolution of 30 μm. The lateral resolution in both channels is 6 μm.

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1. Introduction

Multi-modality imaging instruments can provide diverse contrast and supplementary, structural and functional information about the biological tissues. Optical coherence tomography (OCT) relies on the scattering properties of the tissues while Photo-acoustic microscopy (PAM) relies on the absorption of the optical energy from specific tissue chromophores, such as haemoglobin, lipids, melanin, water, etc

Optical Coherence Tomography is a high acquisition speed, non invasive, high resolution imaging modality, capable of producing cross-sectional and also volumetric high sensitivity images of biological tissues [1]. Optical Coherence Tomography instruments are capable to deliver axial resolutions down to 2 microns and depth penetration of a few millimeters in the biological tissue. Thus, during the past decade, OCT systems have been employed in various biomedical applications for *in-vivo*, and *ex-vivo* imaging. On the other hand, PAM is an emerging imaging technique able to provide both high resolution, high optical absorption contrast, high depth penetration and functional information such as oxygen saturation, blood flow and melanin concentration [2], vital information for cancer angiogenesis and monitoring cancer treatment response [3]. Here we report the capabilities of an OCT-PAM hybrid multimodal imaging instrument powered by supercontinuum sources.

2. Experimental setup

The dual imaging instrument is presented in Fig.1. In the PAM channel, a commercially available, supercontinuum laser (SuperK Compact, NKT Photonics) delivering pulses of 2 ns bandwidth. To make use of the VIS/NIR channel (400-800 nm) light is coupled into a filter (SuperK VARIA, NKT Photonics) which provide a flexible way to swiftly change the central wavelength and the spectral bandwidth. For the OCT channel, to ensure a better sensitivity of the images, a second supercontinuum laser (SuperK EXTREME EXR9, NKT Photonics), coupled into another tunable filter (SuperK Gauss, NKT Photonics) is employed. This uses the IR channel (1310 nm). The VIS and the IR beam are combined by a dichroic mirror and directed towards the galvanometric scanner head (GXY) (6220H, Cambridge Technology), then conveyed through a custom made objective to the sample. IR light back-scattered by the sample returns into the 50/50 directional coupler DC being directioned towards the spectrometer. The spectrometer consists of a custom made collimator, a transmission diffraction grating (Wasatch Photonics), a doublet pair as a focusing lens and a line camera (LC, Goodrich, model SU1014-LDHI) equipped with 1024 pixels with a 25 μm pitch. Camera is typically operated at 20 kHz but in principle can be operate at reading speeds of up to 47 kHz. Data is digitised using a camera link board (National Instruments, model IMAQ 1429).

The PA waves are detected by a PMN-PT needle transducer (NT) of 60 MHz bandwidth. The electrical signal hence produced is then amplified and digitized. The digitization is performed in sync with the pulse repetition rate of the SuperK Compact which is around 20 kHz by using a fast digitizer (National Instruments, model PCI 5124). The display of B-scan OCT and PAM images is done in real-time. The generation of the PAM A-scans does not involve complex mathematical operations (only a Hilbert transform is applied to each acquired temporal signal) hence the real-time display of the images is straightforward. The OCT channel is powered by the Master-Slave method which allows for fast generation of B-scans without need of calibration and dispersion compensation procedures [4, 5].

3. Results and Discussion

The spectrometer is designed in such a way that a very wide spectral bandwidth of the optical source is employed. In addition, the spectrometer was designed to use the less noisy spectral range so a very high sensitivity was achieved, whilst mitigating the optical aberrations and obtaining a sufficiently small spot size on the linear camera. Thus, a spatially constant, isometric resolution of 6 μm is achieved in the OCT channel over an axial range of 1.5 mm (resolutions measured in air). The acquisition synchronization architecture makes possible for a B-scan of 500 A-scans to be obtained and displayed, in both channels a frame rate of 20 Hz. For both OCT and PAM, both volumetric, cross-sectional and *en-face* images can easily be produced. As an illustration, some images produced by our instrument are presented in Fig. 1(top). Further details and data about the capabilities of the instrument will be presented at the conference.

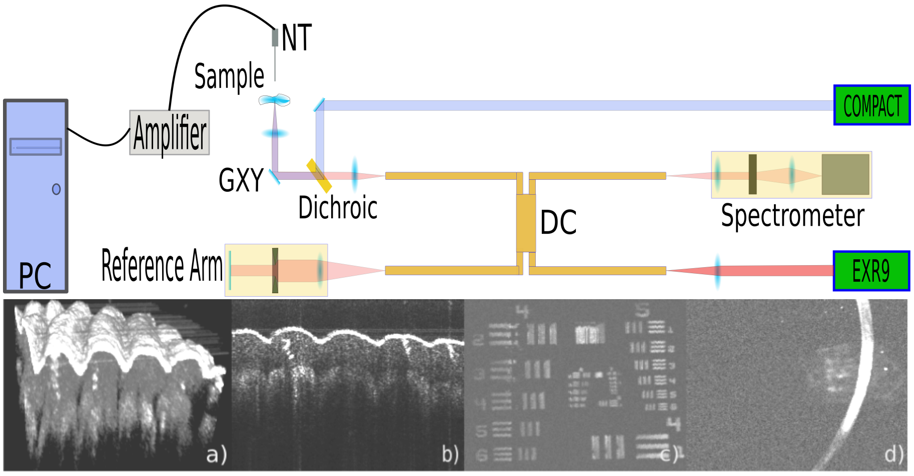

Fig. 1. Schematic of working principle of the OCT/PAM system and images obtained : (a) 3D OCT image of a fingertip. (b) OCT B-scan of the fingertip, (c) *En-face* PAM image of a USAF target, (d) PAM z-projection of a human hair.

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