NEEDLE PROBES FOR OPTICAL COHERENCE TOMOGRAPHY: RECENT ADVANCES IN TECHNOLOGY AND APPLICATIONS

Dirk Lorenser¹, Xiaojie Yang¹, Rodney W. Kirk¹, Bryden C. Quirk¹, Robert A. McLaughlin¹, and David D. Sampson¹,²

¹ Optical + Biomedical Engineering Laboratory, School of Electrical, Electronic and Computer Engineering, The University of Western Australia, Crawley, WA 6009, Australia
² Centre for Microscopy, Characterisation and Analysis, The University of Western Australia, Crawley, WA 6009, Australia
E-mail: dirk.lorenser@uwa.edu.au

KEY WORDS: Needle probe, imaging needle, optical coherence tomography, cancer, lungs, alveoli, phase mask, extended depth of focus

Optical coherence tomography (OCT) is limited to an image penetration depth of 2-3mm in turbid tissue. OCT needle probes provide a new technique to overcome this limitation. The distal focusing optics are miniaturised and encased in a medical needle, which may then be inserted deep within the tissue. We report on a number of advances which we have made both in the design and application of OCT needle probes.

We have recently demonstrated the smallest published needle probe capable of acquiring 3D OCT data volumes [1]. Encased within a 30-gauge needle (outer diameter 310µm), the probe is appropriate for small animal imaging, and it has been used to acquire 3D data volumes of adult rat, fetal lamb and adult pig lungs, resolving alveoli and bronchioles deep within lung tissue, as shown in Figure 1.

We have also developed a novel dynamic OCT needle probe, capable of acquiring multiple images per second over a wide field of view (12mm x 2mm). The probe incorporates a fast-oscillating linear scanning needle encased in a protective outer needle. This probe has been used to track changes in alveoli shape during simulated inflation and deflation of isolated, saline-filled pig lungs.

OCT needle probes have great potential in distinguishing healthy from malignant tissue. We have explored the use of OCT needle probes to assess tumour margins in ex vivo samples from human breast cancer patients [2], and current work is developing techniques for ultrasound-guidance of OCT needle probes.

A topic which remains largely unexplored in needle OCT is the use of beam shaping elements for achieving an enhanced depth of focus (DOF), such as axicons or pupil phase masks. We show initial results obtained using a simple gradient-index fiber pupil phase mask which can enhance the DOF of a lensed fiber probe by up to a factor of 2.