Technical Advantages of Single Channel for Medical Applications

Briefly, the single channel approach measures the relative changes in the OCT signal (back-reflection intensity) while the reference arm polarization states are changed, which will be clarified below. The fact that it measures relative changes at points within the tissue improves its robustness over certain artifacts (such as fiber bending) and allows for easy implementation and real time assessments [22]. In other words, like ultrasound, radiology, MRI, and CT are measuring relative contrast in images, so is single channel PS-OCT.

Dual channel approaches <u>attempt</u> to measure absolute values of tissue birefringence. Although technically more challenging, these techniques offer the potential for measuring certain parameters such as the numerical optical axis, although their clinical utility is unknown at this time. Nonetheless, there may be uncommon clinical scenarios where this precision may be critical. With dual channel approaches, which will be briefly discussed, the Muller matrix is typically measured, or less importantly, the depth-resolved Stokes vectors of the back-reflections from the tissue are measured [23-30]. Most dual channel approaches generating a Muller's matrix of the tissue require analysis of many-frame measurements, and therefore cannot be interpreted rapidly and explicitly. Furthermore, the Stokes or Jones vectors of incident and reflected light, measured at the detector, do not typically represent tissue birefringence properties. This occurs primarily due to birefringence artifacts introduced as the back-reflected light propagates between the sample and detector through variable fiber distortions. Thus, the polarization altering properties of the system need to be maintained constant to prevent artifacts, which adds significant complexity to the system, may not be possible, and is generally not an issue with single channel systems. As we have previously demonstrated, these artifacts can be seen to result in completely opposite results to the actually situation.

This is distinct from the single channel PS-OCT approach, sometimes referred to as single detector PS-OCT, which measures relative birefringence (similar to other clinical imaging technologies which measure relative contrast) and allows clinicians to directly assess birefringence during imaging from the image itself. It is quiescent to catheter or other fiber optic bends in the system because it is measuring birefringence changes relative to different locations in the sample (and not an absolute number at the output) [22]. Our previous work has demonstrated clinically relevant assessments with single channel PS-OCT in tissue including cartilage, tendons, ligaments, and coronary arteries [15-18]. Imaging has been performed in vivo in humans, and the validity has been confirmed with picrosirius stained histological sections (polarization microscopy) or scanning electron microscopy (SEM). The data can be obtained in real time and interpretations are made directly from the image. In an example study of clinical relevance, we have shown that loss of birefringence, which correlates with collagen disorganization, precedes cartilage thinning in osteoarthritis. Similarly, we have confirmed the efficacy of the single channel approach in vivo in human knees both in open surgical fields and during arthroscopy [18, 32]. We have also modeled in detail the theoretical principles behind the ability of single channel PS-OCT to measure tissue birefringence [20].

However, as will be seen in this work, the single channel PS-OCT technique to date has never been optimized with respect to the reference arm polarization rotation, which could further improve the performance. For birefringent tissue, the back-reflection intensity changes with alterations of the reference arm polarization state. The greater the birefringence, the more rapidly the back-reflection changes with the reference arm polarization alterations. The birefringence can be characterized by inter-frame back-reflection changing in the reference arm, but no study has been systematically conducted on how best to rotate polarization in the reference arm. This modification will appear in the International Journal of Biomedical Optics in late 2011 or early 2012.

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