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Comment on "Optical-fiber-based Mueller optical coherence tomography"

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We comment on the recent Letter by Jiao *et al.* [Opt. Lett. **28,** 1206 (2003)] in which a polarization-sensitive optical coherence tomography system was presented. Interrogating a sample with two orthogonal incident polarization states cannot always recover birefringence correctly. A previously presented fiber-based polarization-sensitive system was inaccurately characterized, and its method of eliminating the polarization distortion caused by single-mode optical fiber was presented earlier by Saxer *et al.* [Opt. Lett. **25,** 1355 (2000)].

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In a recent paper paper by Jiao *et al.*[1] a polarization-sensitive fiber-based optical coherence tomography system was presented.[1] The method of determining polarization properties described in that Letter is unable to correctly recover tissue birefringence under all circumstances. In their experiment a tissue sample was interrogated by two orthogonal but unknown polarization states. If these polarization states are linear and are parallel and orthogonal to the optic axis of the tissue, then the two polarization states will be unchanged, regardless of the magnitude of tissue birefringence. As a consequence, tissue birefringence cannot always be recovered accurately. Since birefringence in the sample-arm fiber changes the polarization state in an uncontrolled manner, linear states that are incident upon the tissue cannot be ruled out in the previously presented experimental configuration. To address this problem, we have used incident polarization states that are perpendicular in a Poincaré sphere representation (e.g., a circular and a linear state) since 2000, when we first demonstrated a fiber-based polarization-sensitive optical coherence tomography (PS-OCT) system.[2] Such a choice of incident states makes possible the correct recovery of tissue birefringence under all circumstances, regardless of the sample-arm birefringence or the orientation of the sample's optic axis, and thus it represents a superior choice of incident polarization states.

In the paper by Jiao *et al.*,[1] the characterization of our aforementioned earlier work,[2] i.e., that it did not reflect the correct physical process and is unable to correctly recover the orientation of the birefringence, is incorrect. Our algorithm is not equivalent to using $\mathbf{J}_{f2}{}^{-1}$ directly to treat $\mathbf{J}_{sf2}$, and whether or not $\mathbf{J}_{s2}$ and $\mathbf{J}_{f1}$ are permutable is irrelevant to our method, which instead analyzes birefringent properties in terms of rotations in the Poincaré sphere representation. Our earlier work treated the sample as a pure retarder and neglected diattenuation. This is a reasonable assumption, though [see, e.g., Fig. 3(c) in Ref. 3], as the angular displacements of Stokes vectors in the Poincaré sphere as a result of diattenuation are at least an order of magnitude smaller than those due to birefringence in biological tissues.[4] Under this assumption samples act as pure retarders, and the transformations in the Poincaré sphere are correctly described by rotations. With the additional constraint that the fibers and fiber-optic components have no polarization-dependent loss,[2] our analysis is valid and the correct orientation of the birefringence is recovered as an integral part of the phase-retardation calculation presented in our earlier work,[2,5] up to the same unknown offset γ described by Jiao *et al.*[1]

In their abstract Jiao *et al.*[1] claimed that, "... for the first time to our knowledge, fiber-based polarization-sensitive OCT system was dynamically calibrated to eliminate the polarization distortion caused by the single-mode optical fiber in the sample arm, thereby overcoming a key impediment to the application of optical fibers in this technology." In fact, our earlier Letter (Saxer *et al.*[2]) described the first fiber-based PS-OCT system that dynamically compensated on the same time scale (2 s) for the polarization distortion caused by the single-mode fiber in the sample arm, by using the polarization state reflected from the sample surface as a reference.[2,5] Although it is more an issue of implementation rather than methodology, a key impediment to the application of a system in a clinical environment as described by Jiao *et al.* is an acquisition time of ~10 min per image.[1,6] With their system, acquisition of a single A-line takes approximately 2 s, which is a factor of 600 to 2000 times slower than our previously reported systems.[2,7] In addition, our group was the first to describe a PS-OCT system that detected the amplitude and the relative phase between interference fringes in orthogonal polarization channels to efficiently and completely characterize the polarization state of coherent light reflected from a sample in a single depth measurement,[3] which has formed the basis of nearly all advanced PS-OCT methodologies since 1999, including the work by Jiao *et al.*[1]

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