A novel scheme for tissue birefringence assessment with Polarization Sensitive OCT

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Nowadays, Optical Coherence Tomography (OCT) is a noninvasive technique, which permits high-resolution cross-sectional imaging of superficial layers in biological tissues without the use of ionizing radiation. In fact, the precursor to OCT was based on sectioning of light-scattering media with low-coherence interferometry (1). A promising diversity of OCT is Polarization-Sensitive OCT (PS-OCT) (2). PS-OCT could assist the early diagnosis of malignant skin cancer – melanoma, inasmuch as fibrillar collagen, an abundant constituent of living tissues, loses its signature polarization properties, i.e. birefringence, when melanoma cells proliferate to cutaneous layers (3). Often melanoma-type cancers are not diagnosed until they are in the later stage of development. The fatality rate of melanoma in comparison to other types of malignant superficial lesions is quite high. Conventional biopsy requires the surgical removal of the skin tissue for a microscopic histological examination that is subjective, invasive, expensive, and a time consuming process. Noninvasive methods to identify skin abnormalities in their early stages would be beneficial.

A challenge to clinical applications of PS-OCT is birefringence measurement artifacts caused by inherent change in ambient conditions (4). A solution is, e.g. to embody Wollaston prism as receiving interferometer and sensing interferometer of Michelson type combined with polarization maintaining (PM) fibers (5). The system is devoid of mechanical scanning within submillimetric depth. Such a thickness of the primary melanoma is the approved indicator for better predicting overall survival and selecting patients for treatment.

In this work, we introduce a new hybrid configuration comprising Babinet Compensator (BC) as receiving interferometer and sensing Mach-Zehnder Interferometer (MZI) based on free-space nonpolarizing beam-splitter and polarizing beam-combiner (see Fig.1). Obviously, polarizer's 1-3, $\lambda/4$ retarder, $\lambda/2$-bistable-switch, focusing lens with B-scanning subunit (not shown) and beam-splitter can be combined into a patient-friendly handheld probe connected through PM fibers to the whole system. The well known flexibility in fringe localization gives the MZI important advantage over many other interferometers, and the BC-interferometer is much more insensitive to misalignment than the Michelson interferometer used in spectral domain PS-OCT (6, 7). Alternate snapshot-like detection of intensities for vertical V(z) and horizontal H(z) polarization components within the depth of focus $\Delta z \geq 0.5$ mm is feasible with only one linear CCD array and by means of sufficiently achromatic $\lambda/2$-bistable-switches based on ferroelectric-liquid-crystal fast devices. The proposed hybrid configuration ensures fringe pattern to be spatially evolved by the BC without any autocorrelation artifacts inherent to Fourier domain OCT. Signal-to-noise evaluations were made by analogy with those from optical communication technology and resulted in the system sensitivity sufficient for the intensity-based assessment of skin birefringence [3, 4]. Exposure limits for the skin were taken into consideration [8]. Birefringence Δn may be assessed from the average period $\delta z = \lambda/2\Delta n$ of the banded pattern plotted using the sign(V-H)10log|V+H| of the data [9]. Regions of collagen depletion would manifest through disruption of the banded pattern.

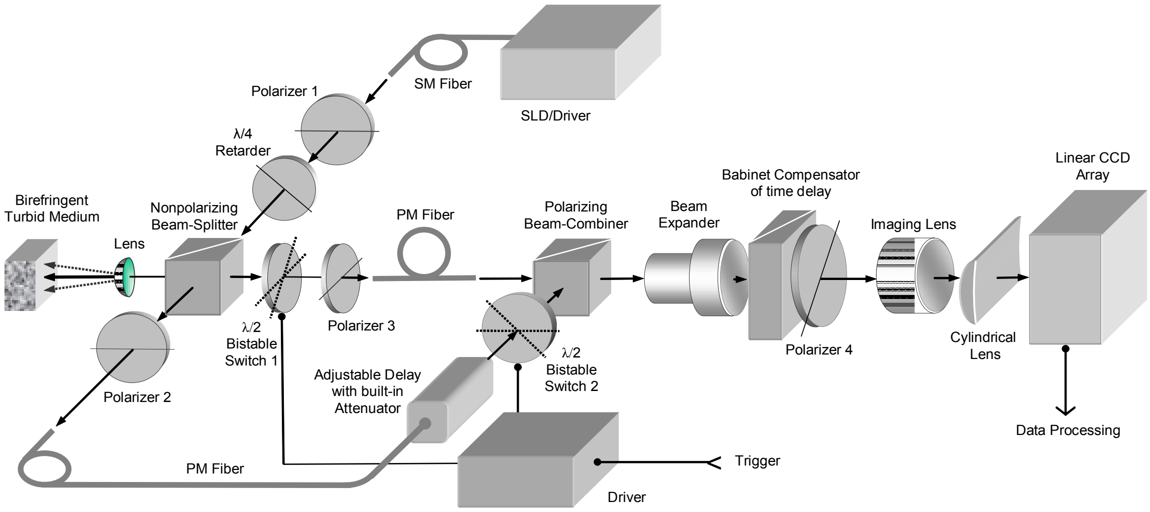

Fig. 1. System schematic

Future improvements are anticipated in adopting a concept of all-fiber interferometers [10] as well as a fiber analog of quarter-wave plates [11]. Moreover, interdisciplinary cooperation between researchers in photonics and signal processing will be crucial for PS-OCT.

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