Tilted fiber Bragg grating spectrometer for Optical Coherence Tomography

Subject: Optics and Photonics
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Optical Coherence tomography (OCT) is a non-invasive high resolution imaging technology capable to detect structural changes in tissue and material. Although, OCT is well established in medical applications as ophthalmology, the cost-intensive and bulky setups of common OCT systems diminish their attractivity for portable and industrial applications. In this work a new concept for potentially miniaturized and low-cost OCT spectrometer is developed and evaluated.

Motivation

Spectrometers, used to measure the wavelengths of light with a high resolution and high optical throughput, are commonly built with diffraction gratings. These devices have high performances, but suffer from cost-intensive and bulky setups. A tilted fiber Bragg grating (TFBG) is an UV-inscribed structure within an optical fiber with a facet angle around 45° causing a diffracted light emission through the fiber cladding. By integrating the diffractive element into a fiber with similar performance to common diffraction grating, the TFBG is appealing for low cost, high resolution and high throughput spectral imaging techniques like OCT. By miniaturization and simplification of spectrometers for OCT, the system costs and form factors can be reduced. This expands the field of OCT in medical applications such as portable and low cost OCT devices for flexible long term monitoring of disease, and opens new fields in industrial applications such as non-destructive testing and fabrication process monitoring.

TFBG spectrometer

The TFBG structure causes partial light decoupling off the fiber-axis by reflection. The angle of the out-coupled light depends on the wavelength. The reflection in the fiber-axial direction leads to a divergent light decoupling in fiber-radial direction. This asymmetric light emission of the TFBG leads to an astigmatic optical design to map the spectrum of the light onto a detector array. In a design study a final mixed reflective and refractive optical design is evaluated. Figure 1. a) shows this design consisting of a cylindrical lens, directly bonded onto the fiber, an aspheric-astigmatic gold coated mirror and a spherical field flattener lens placed onto the detector array. In collaboration with the University of Aston a TFBG is fabricated supporting an angular dispersion of 1.76 radiant/µm.

Results

A customized TFBG spectrometer design optimized to maximize throughput and minimize aberrations with a central wavelength of 830 nm and a broadband of 75 nm is developed. The arrangement of the optical elements is realized in a mechanical setup supporting all necessary degrees of freedom to align the spectrometer shown in Figure 1. b). First OCT measurements (Figure 2.) indicate the functionality of the spectrometer setup. However more time for a proper alignment is used to achieve similar imaging performance to common OCT system.

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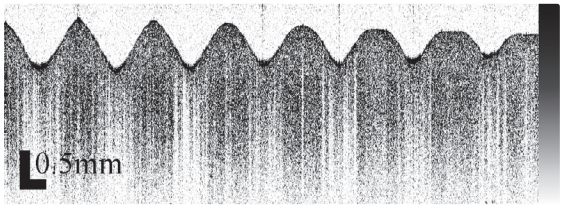

Figure 2. OCT image of a rapid prototyped structure.

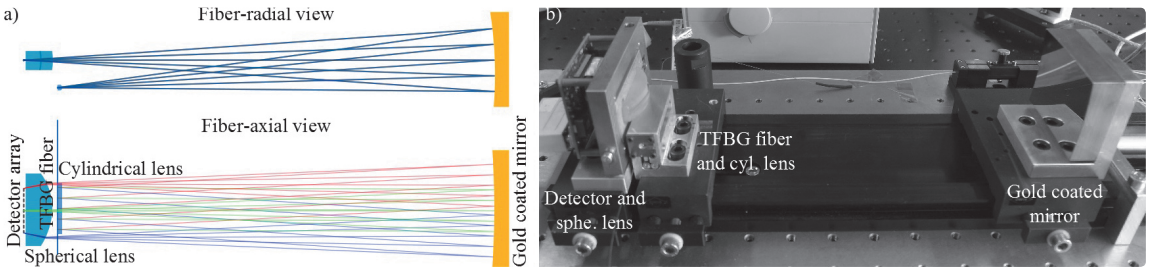

Figure 1. a) Schematic overview of the final spectrometer design. b) Picture of the opto-mechanical setup.