Spectral measurements of polarimetric sensitivity of holey fiber to strain, temperature and hydrostatic pressure

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1. Abstract

Polarimetric sensitivity of a birefringent holey fiber to strain, temperature and hydrostatic pressure is measured in the spectral domain. In an experimental setup comprising a broadband source, a polarizer, a birefringent holey fiber under a variable physical parameter, a birefringent delay line, an analyzer and a compact spectrometer, the spectral interferograms are resolved. These are characterized by the equalization wavelength at which spectral interference fringes have the largest period due to the zero overall group modal birefringence. The spectral interferograms are processed to retrieve the phase as a function of the wavelength. From the retrieved phase functions corresponding to different values of the physical parameter, the polarimetric sensitivity as a function of wavelength is obtained. Using this approach, the polarimetric sensitivity to strain, temperature and hydrostatic pressure is measured.

2. Measurement method

If the resolving power of a spectrometer in Fig. 1 is insufficient to resolve spectral interference fringes at the output of the fiber alone, the fiber of length z in tandem with a birefringent crystal of thickness d and the phase and group irefringences, $B_c(\lambda)$ and $G_c(\lambda)$, can be used [1].

The spectral intensity at the output of the tandem configuration with a polarizer and an analyzer oriented 45° with respect to the fiber eigenaxes is [1]:

$$I(z;\lambda) = I_0(\lambda)\left\{1+\exp\{-(\pi^2/2)\left\{[G_c(\lambda)d - G(\lambda)z]\Delta\lambda_R/\lambda^2\right\}^2\}\cos\{(2\pi/\lambda)[B_c(\lambda)d - B(\lambda)z]\}\right\}, \quad (1)$$

where $I_0(\lambda)$ is the reference spectral intensity and $\Delta\lambda_R$ is the response function of the spectrometer.

The period of the spectral modulation $\Lambda(\lambda)$ is given by

$$\Lambda(\lambda) = \frac{\lambda^2}{|\,G_c(\lambda)d - G(\lambda)z\,|}, \quad (2)$$

The equalization wavelength λ_0 is resolved in the recorded spectrum when the relation $G_c(\lambda_0)d = G(\lambda_0)z$ is fulfilled.

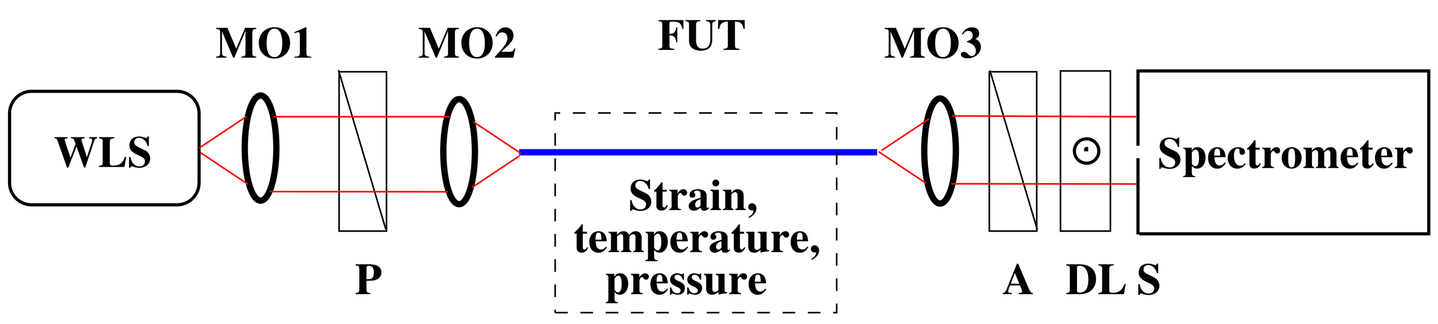
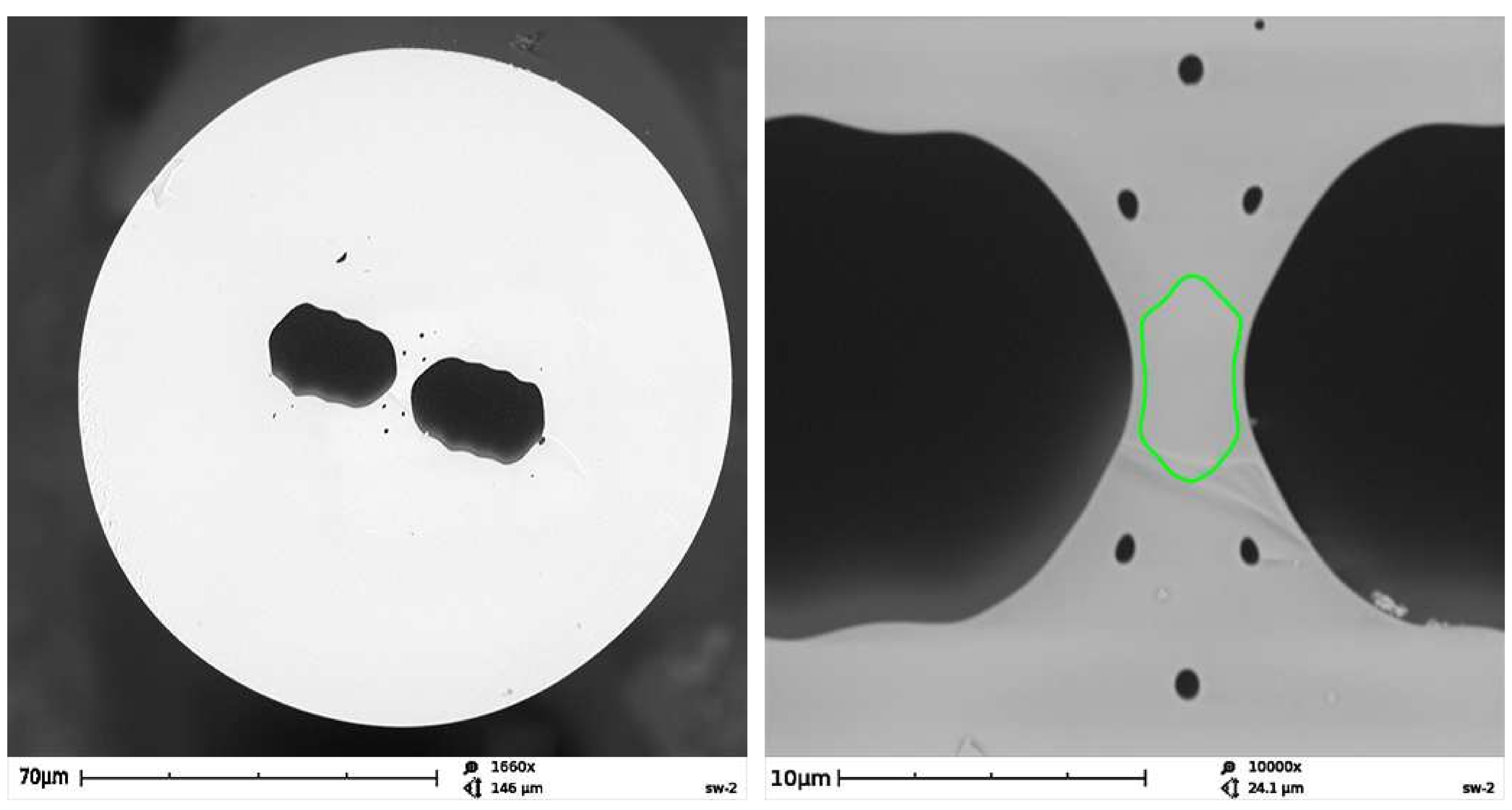


Figure 1: *Experimental setup with a fiber under test (FUT) to measure the polarimetric sensitivity to a given physical parameter.*

3. Experimental setup

The experimental setup we used to record the spectral intensity $I(z;\lambda)$ is shown in Fig. 1. It consists of white-light source WLS: a supecontinuum source (NKT Photonics), the first microscope objective MO1 (10×/0.30), polarizer P (LPVIS050, Thorlabs), the second microscope objective MO2 (10×/0.30), fiber under test FUT, the third microscope objective MO3 (10×/0.30), analyzer A (LPVIS050, Thorlabs), birefringent delay line DL, a spectrometer (USB4000, Ocean Optics) with 25 μm wide slit S and a personal computer. The FUT is a birefringent side-hole fiber shown in Fig. 2 with nearly elliptical core of dimensions 6.5 μm × 2.8 μm, and a cladding diameter of 129 μm [2].



(a) (b)

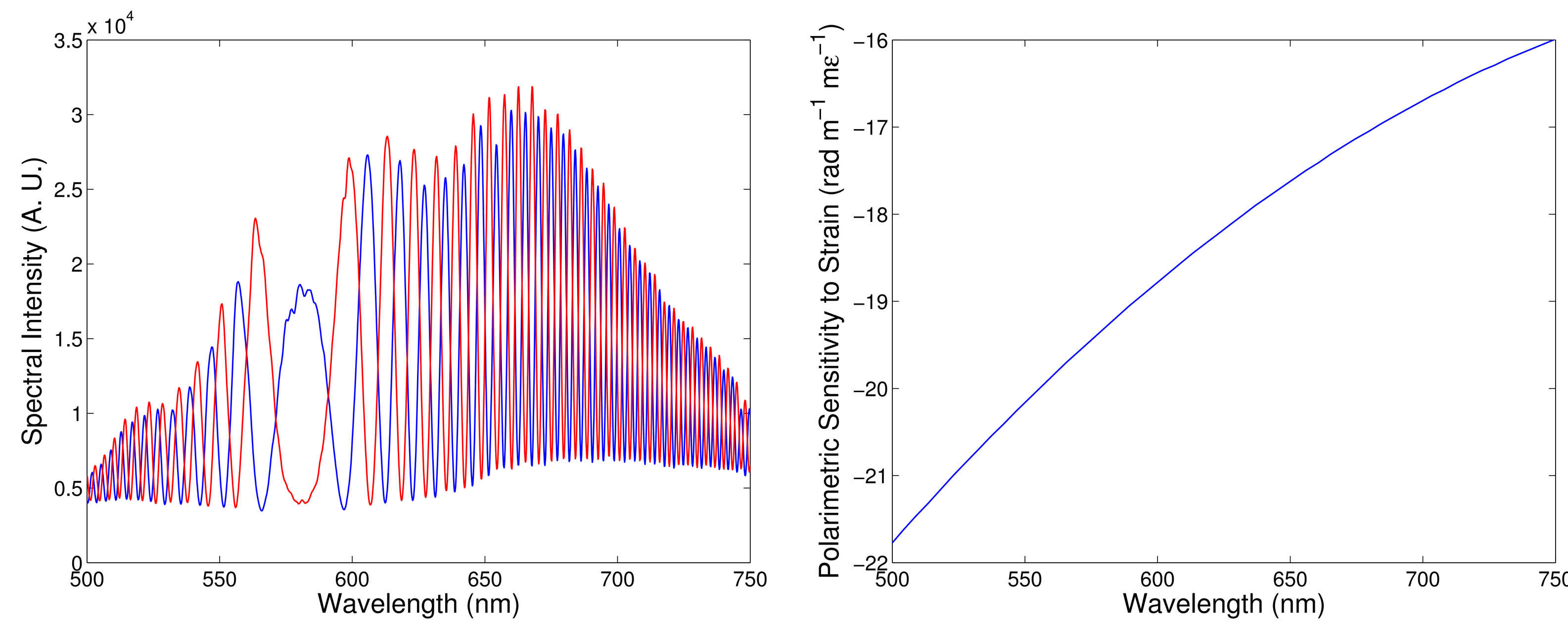
Figure 2: *(a) Structure of the fiber under test: general view of the fiber cross-section. (b) Enlarged image of the central region with green line showing core boundary.*

4. Experimental results and discussion

Using the experimental setup shown in Fig. 1, we measured the spectral dependence of the polarimetric sensitivity $K_X(\lambda)$ of the investigated fiber to a specific physical parameter X. The polarimetric sensitivity $K_X(\lambda)$ is defined by the following relation

$$K_X(\lambda) = \frac{1}{L}\frac{\mathrm{d}[\phi_x(\lambda) - \phi_y(\lambda)]}{\mathrm{d}X}, \quad (3)$$

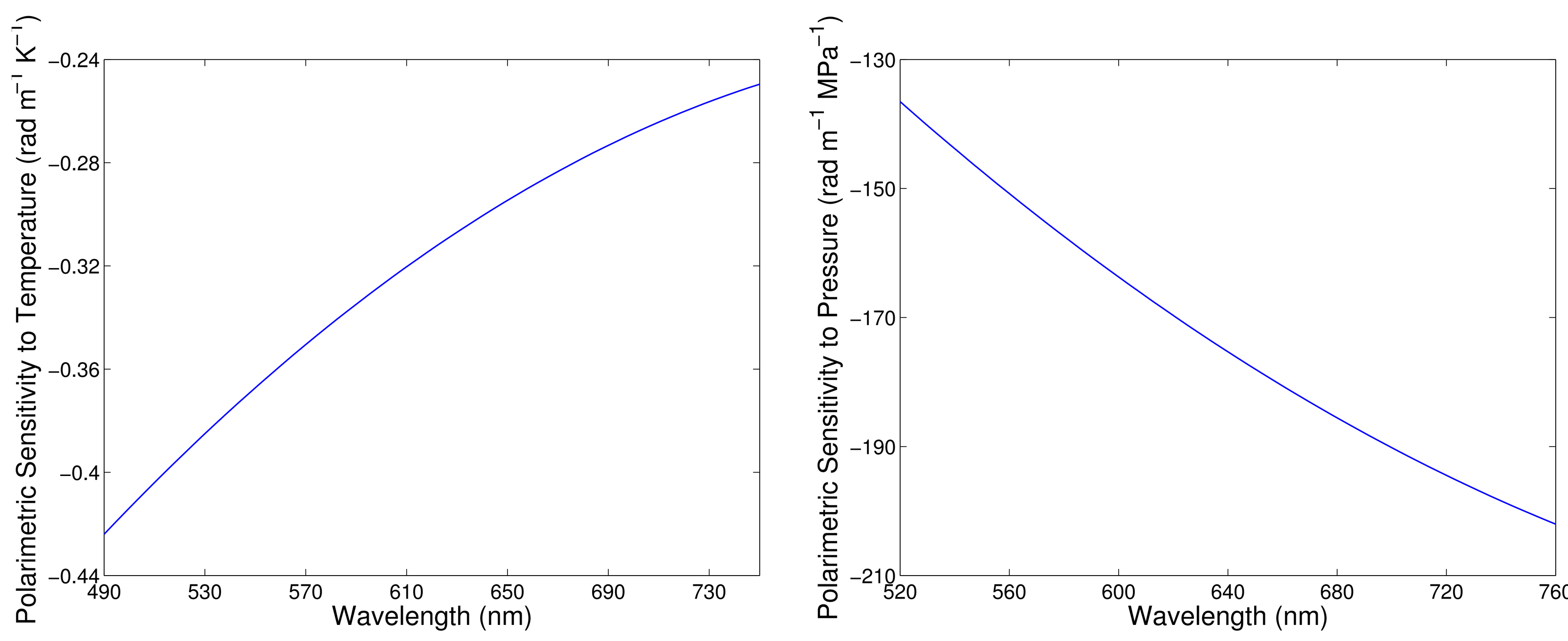
and represents an increase in the phase shift between the polarization modes induced by the unit change of the physical parameter X acting on unit fiber length [3]. As an example, to determine the polarimetric sensitivity to strain $K_\epsilon(\lambda)$, we recorded a sequence of spectral interferograms for increasing strain ϵ with a step small enough to assure unambiguity in retrieving the strain-induced phase changes $\Delta[\phi_x(\lambda) - \phi_y(\lambda)]$. To measure $K_\epsilon(\lambda)$, the fiber of length $L = 0.895$ m was attached with epoxy glue to two translation stages and elongated up to 800 μm (stretched up to 894 μstrain).



(a) (b)

Figure 3: *(a) Two examples of the recorded spectra corresponding to two elongations $\Delta L_1 = 100$ μm (blue) and $\Delta L_2 = 300$ μm (red) of the fiber, (b) The spectral dependence of the polarimetric sensitivity to strain.*

Figure 3(a) shows two examples of the recorded spectra when the overall length of the fiber was $z = 2.295$ m. Using a new procedure [4] we retrieved from the two spectral interferograms the strain-induced phase changes $\Delta[\phi_x(\lambda) - \phi_y(\lambda)]$. The spectral dependence of $K_\epsilon(\lambda)$ obtained from several measurements is shown in Fig. 3(b). Figure 4(a) shows the spectral dependence of the polarimetric sensitivity to temperature $K_T(\lambda)$ obtained from several measurements. Similarly, Fig. 4(b) shows the spectral dependence of the polarimetric sensitivity to pressure $K_p(\lambda)$ obtained from several measurements.



(a) (b)

Figure 4: *(a) The spectral dependence of the polarimetric sensitivity to temperature. (b) The spectral dependence of the polarimetric sensitivity to hydrostatic pressure.*

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