Zero-dispersion wavelength measurement of fiber polarization modes using a supercontinuum source

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Introduction

In this paper we present two spectral interferometric methods which allow us to determine the chromatic dispersion of the investigated pure silica birefringent holey fiber [1], including the zero-dispersion wavelength [2]. Both of these techniques are based on processing of either a set of interferograms in a wide spectral range [3, 4] or a single one in a narrower spectral range [5]. All interferograms are recorded in an experimetal setup utilizing a supercontinuum source in combination with a Mach-Zehnder interferometer. To verify the experimental results the dispersion characteristics obtained by both techniques are compared each other.

Experimental methods

Measurement of the chromatic dispersion in a wide spectral range

To measure the chromatic dispersion of polarization modes guided by a tested fiber we employ a spectral interferometric technique, utilizing a dispersion balanced Mach-Zehnder interferometer. The experimental arrangement is shown in Fig. 1. A key part of this setup is the Mach-Zehnder interferometer with the fiber under test (FUT) of length z placed in the test arm. The reference arm with an adjustable air delay line is configured so as to compensate dispersion of the optical components placed in the test arm. Orientation of both the polarizer and the analyzer is adjusted parallel to the shorter polarization axis of the fiber, i.e., only the y-polarization mode is excited.

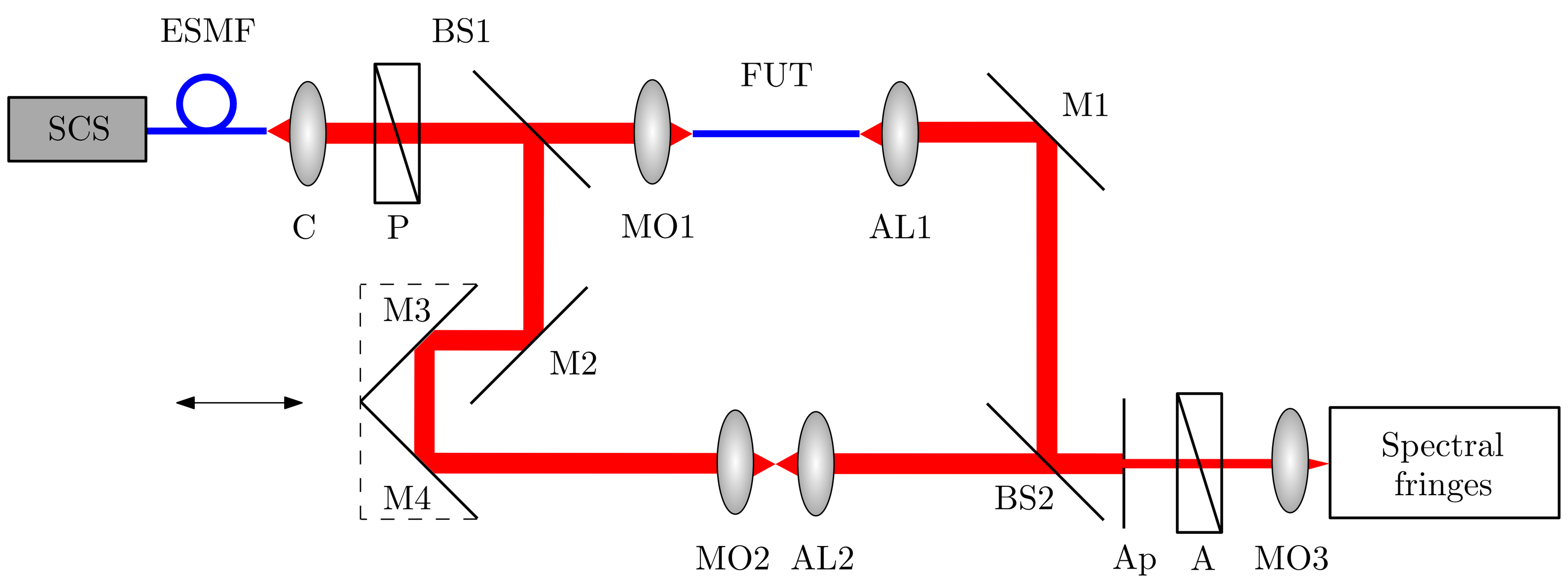


Figure 1: *Experimental setup with a dispersion balanced Mach-Zehnder interferometer for the differential group index dispersion measurement.*

The measured wavelength dependence of the differential group index $\Delta N_y(\lambda_0)$ is fitted to a function $\Delta N_y(\lambda)$, which allows us to determine the chromatic dispersion $D_y(\lambda)$, using the relation

$$D_y(\lambda) = \frac{1}{c}\frac{\mathrm{d}[\Delta N_y(\lambda)]}{\mathrm{d}\lambda}, \qquad (1)$$

where c is the free-space velocity of light.

The group modal birefringence $G(\lambda) = N_x(\lambda) - N_y(\lambda)$ of the polarization modes supported by the fiber was measured by a method of spectral-domain tandem interferometry [3] in the setup illustrated in Fig. 2.

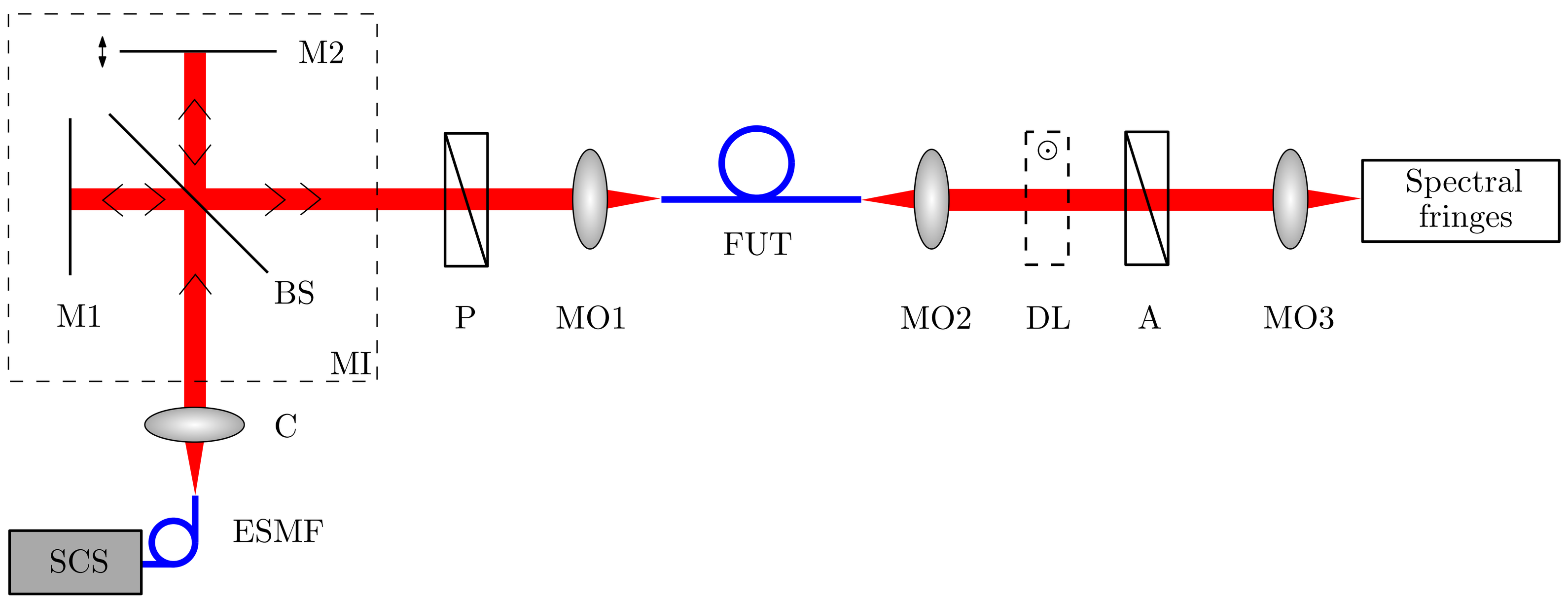


Figure 2: *Experimental setup with a Michelson interferometer for the group modal birefringence measurement.*

The path length difference Δ_M adjusted in the interferometer and measured as a function of the equalization wavelength λ_0 gives directly the wavelength dependence of the group modal birefringence $G(\lambda_0) = \Delta_\mathrm{M}/z$ in the tested fiber. In this case, treating a pure silica birefringent holey fiber, the experimental values of $G(\lambda_0)$ are approximated as [4]

$$G(\lambda) = (1-m)\xi\lambda^m. \qquad (2)$$

The known values of m and ξ enable us to determine the chromatic dispersion difference $D_p(\lambda)$, represented by the expression [4]

$$D_p(\lambda) = \frac{1}{c}\frac{\mathrm{d}[G(\lambda)]}{\mathrm{d}\lambda} = (1-m)m\xi\lambda^{m-1}/c. \qquad (3)$$

Finally, the chromatic dispersion $D_x(\lambda)$ of the x-polarization mode is deduced from the measured group modal bifringence $G(\lambda)$ via the known chromatic dispersion $D_y(\lambda)$ of the y-polarization mode, using definition

$$D_x(\lambda) = D_p(\lambda) + D_y(\lambda). \qquad (4)$$

Measurement of the chromatic dispersion in a narrower range

The chromatic dispersions $D_x(\lambda)$ and $D_y(\lambda)$ of the fiber x- and y-polarization modes, respectively, were also determined in a narrower spectral range (in the vicinity of the zero-dispersion wavelength) by processing a single interferogram. This technique is based on the least-squares fitting of the recorded spectral interferogram for each of the polarization modes.

In this case, the y-polarization mode effective phase index $n_y(\lambda)$ is approximated by a Laurent polynomial [5]

$$n_y(\lambda) = \frac{A_1}{\lambda^4} + \frac{A_2}{\lambda^2} + A_3 + A_4\lambda^2 + A_5\lambda^4, \qquad (5)$$

where A_i are coefficients.

The fitting procedure is carried out in two steps. In the first step, it is essential to make a good estimation of the fitted parameters. In the second step, the estimated values are utilized for the direct interferogram fitting procedure. The obtained coefficients A_i enable us to determine both the effective phase index $n_y(\lambda)$, given by Eq. (5), and the group effective index $N_y(\lambda)$, which is defined as

$$N_y(\lambda) = n_y(\lambda) - \lambda\frac{\mathrm{d}n_y(\lambda)}{\mathrm{d}\lambda}. \qquad (6)$$

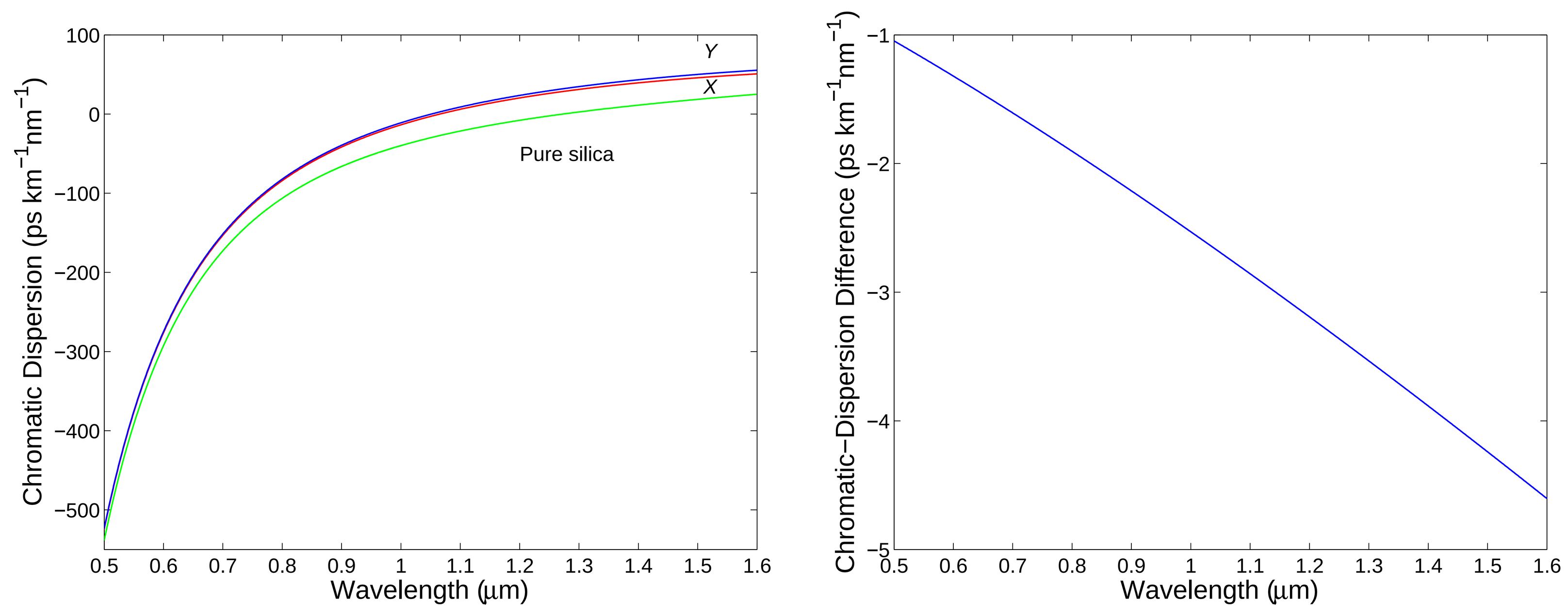
The chromatic dispersion $D_y(\lambda)$ is now given by

$$D_y(\lambda) = \frac{1}{c}\frac{\mathrm{d}N_y(\lambda)}{\mathrm{d}\lambda}. \qquad (7)$$

The spectral signals recorded in the experimental setup after a 90° rotation of both the polarizer and the analyzer, so that their transmision azimuths are adjusted parallel to the longer polarization axis of the fiber, are used to obtain the dispersion characteristics of the other, i.e. x-polarization mode.

Experimental results and discussion

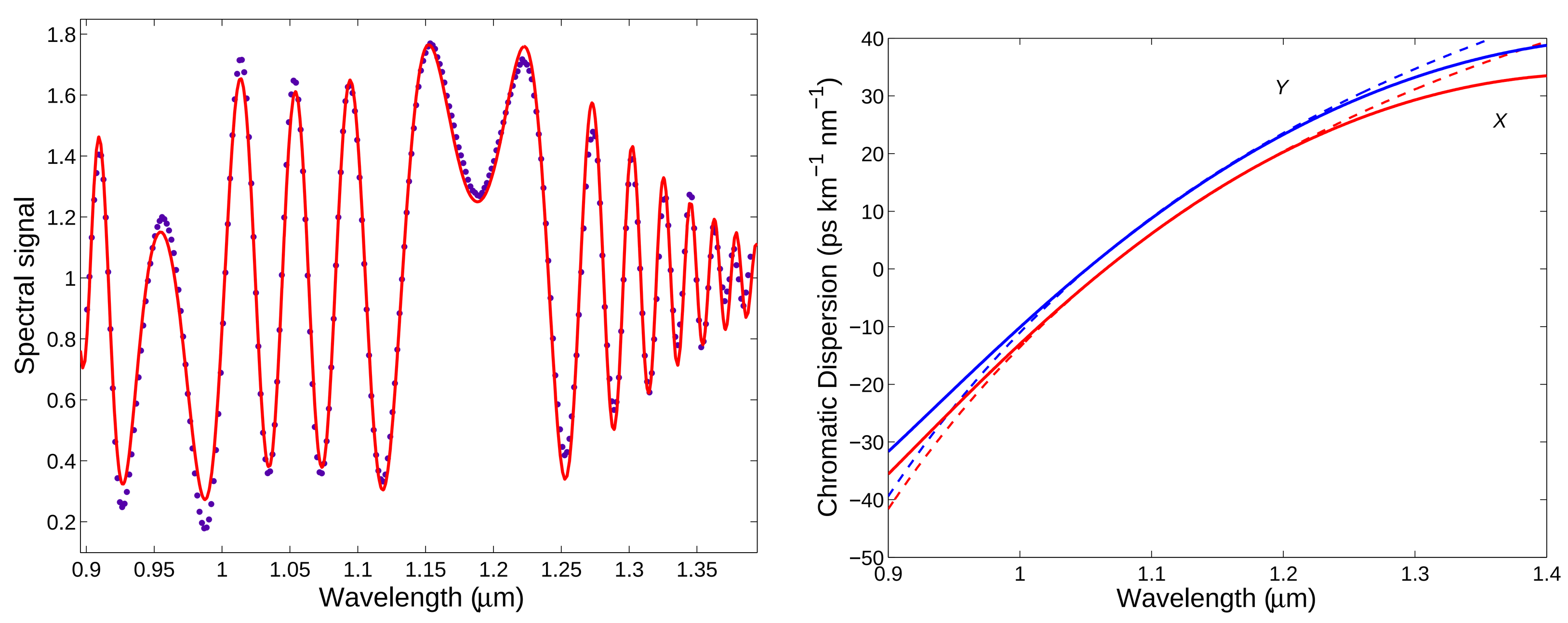
The chromatic dispersion $D_y(\lambda)$, calculated from the measured differential group index dispersion $\Delta N_y(\lambda)$ in a wide spectral range, is represented by the blue line in Fig. 3(a). The chromatic dispersion difference $D_p(\lambda)$, determined from the known group modal birefringence $G(\lambda)$, is shown in Fig. 3(b). Moreover, figure 3(a) shows the chromatic dispersion $D_x(\lambda)$ (red line) together with the material dispersion of pure silica (green line).



(a) (b)

Figure 3: *(a) Chromatic dispersions of the polarization modes in the tested fiber and in pure silica determined in a wide spectral range. (b) Chromatic dispersion difference.*

The chromatic dispersions $D_x(\lambda)$ and $D_y(\lambda)$ were also determined in a narrow spectral range by processing a single spectral interferogram for each of the polarization modes. An example of the processed interferogram for the x-polarization mode is shown in Fig. 4(a) (dotted line) together with the final approximation (solid line). The coefficients a_i and A_i, obtained from the fitting procedure, enabled us to determine the resulting chromatic dispersions $D_x(\lambda)$ and $D_y(\lambda)$, as represented in Fig. 4(b) (solid lines). The corresponding dispersion characteristics obtained in a wide spectral range are shown in the same figure (dashed lines). Finally, the zero-dispersion wavelengths λ_x and λ_y for both polarization modes are summarized in Table 1 (WSRM - a wide spectral range measurement, NSRM - a narrow spectral range measurement).



(a) (b)

Figure 4: *(a) Spectral interferogram recorded for the x-polarization mode (dots) with corresponding fit (solid line). (b) Chromatic dispersions $D_x(\lambda)$ and $D_y(\lambda)$ determined in a narrower spectral range (solid lines) and in a wide spectral range (dashed lines).*

	WSRM	NSRM
λ_x (nm)	1065.5	1065.3
λ_y (nm)	1051.3	1050.9

Table 1: *Zero-dispersion wavelengths λ_x and λ_y of the x- and y-polarized modes.*

Acknowledgments

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