Measurement of Polarization-dependent Chromatic Dispersion in a Birefringent Hollow-core Photonic Crystal Fiber Using Spectral Interferometry

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Abstract: Three evaluation techniques of spectral interferograms were compared in order to find the most precise method which is sensitive to higher order dispersion of a slightly birefringent hollow-core photonic crystal fiber. We showed that the two fundamental modes have considerably different dispersive properties and concluded that the Fourier-method is the most accurate.
OCIS codes: (060.2300) Fiber measurements; (060.5295) Photonic crystal fibers; (120.3180) Interferometry.

1. Introduction

In most of the applications, such as nonlinear microendoscopy, it is important to preserve the linear polarization state of the laser light coupled into the fiber which requires a certain degree of birefringence of the design. Photonic crystal fibers (PCF) have recently received considerable attention since their properties, such as controllable dispersion [1], birefringence and single-modal guidance can be adjusted by the proper design of their geometrical structure. Due to the uncertainties in modeling and manufacturing, it is necessary to measure the polarization-dependent chromatic dispersion of these fibers as accurately as possible [2]. It would be of great advantage to find a method sensitive to higher order dispersion which may be significant in tailored PCFs with reduced second order dispersion.

Spectral interferometry is a widely used technique for dispersion measurement. To retrieve the spectral phase of the fibers from the spectral interferograms numerous evaluation techniques, such as the cosine function fit [3], the Fourier-transform method [4] and the stationary phase point method [5] are used. So far, a comparative study has been missing to find the most precise one for fibers with a bandwidth smaller than 200 nm.

In this work we present the results of measuring chromatic dispersion of the two fundamental, orthogonal polarization modes in a commercial, slightly birefringent hollow-core PCF fiber (HC-800, NKT Photonics).

2. Experimental Setup

The 33 cm length fiber under study was placed in the sample arm of a Mach-Zehnder interferometer illuminated by a Ti:sapphire oscillator (20 fs@800 nm) (Fig. 1). The interference fringes were observed by a high resolution spectrometer (Ocean Optics, HR4000). In order to excite only one polarization mode of the fiber a half-wave plate was placed in front of the fiber.

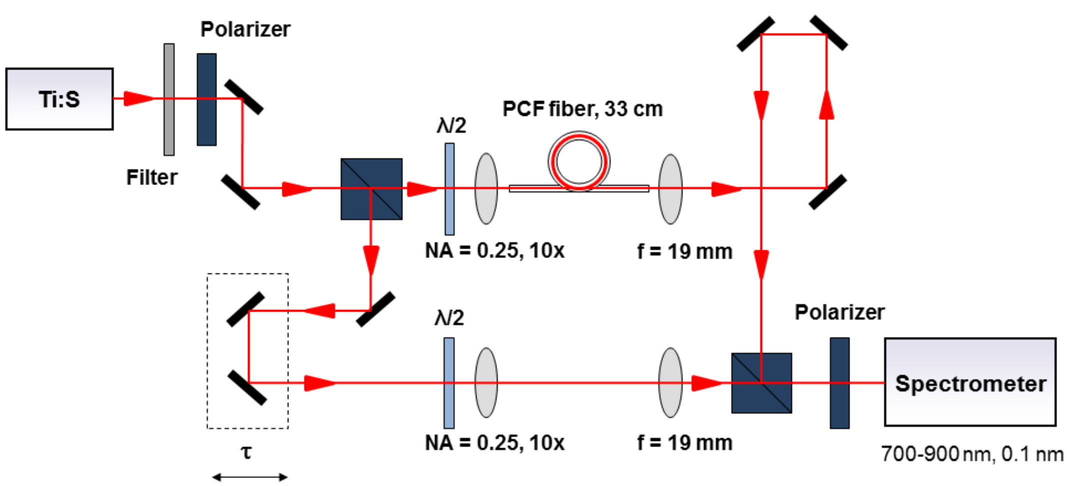

Fig. 1. Experimental setup.

3. Results

The dispersion for both the x- and the y-polarization modes of the fiber was determined with the cosine function fit (CFF), the Fourier-transform (FT) and the stationary phase point method (SPP), and 40 interferograms corresponding to various reference arm length were evaluated. The dispersion coefficients resulting from the Taylor expansion of the spectral phase in the x- and y-polarization modes were determined up to the fifth and fourth order, respectively (Table 1.). In the y-mode it was enough to use a fourth order polynomial to obtain perfect fit.

Table 1. Dispersion coefficients of a 33 cm long PCF at 800 nm obtained by the three evaluation methods.

	GDD [10^3 fs^2]		**TOD [10^5 fs^3]**		**FOD [10^6 fs^4]**		**QOD [10^7 fs^5]**
	x	y	x	y	x	y	x
CFF	2.92±0.20	-3.75±0.051	3.84±0.085	1.10±0.014	5.45±0.17	-0.62±0.016	5.86±0.18
FT	3.21±0.051	-3.75±0.037	3.97±0.036	1.10±0.011	5.71±0.11	-0.63±0.012	6.11±0.14
SPP	2.98±0.13	-2.59±0.47	4.06±0.14	1.37±0.091	6.37±0.37	-0.34±0.071	7.18±0.35

It can be seen in the insets that the dispersion curves for a given polarization mode are almost completely identical in the case of the cosine fit and the Fourier-transform methods, and it is slightly different in the case of the stationary phase point method (Fig. 2).

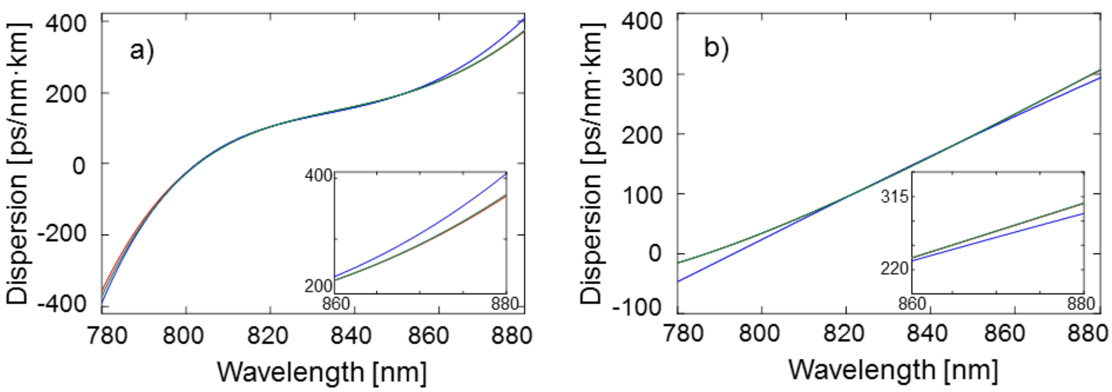

Fig. 2. Chromatic dispersion curves in (a) the x and (b) the y direction determined with the stationary phase point (blue), the cosine function fit (red), and the Fourier-transform methods (green). Insets: zoomed curves.

4. Summary

The polarization dependent chromatic dispersion of the orthogonal polarization modes of a slightly birefringent hollow-core PCF fiber (HC-800, NKT Photonics) was measured by spectral interferometry up to the fifth order. From the utilized spectral interferogram evaluation methods the Fourier-transform method provided the dispersion coefficients with the highest accuracy. As it was demonstrated, in the case of hollow core PCFs, both of the two fundamental modes of orthogonal polarization states can be efficiently excited, which may exhibit considerably different dispersive properties as well as confinement losses. Accordingly, precise polarization control is required when such fibers are used.

5. References

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