Dispersion characterization of microstructured optical fibers

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We report a realized Mach-Zehnder-interferometer based setup for measuring chromatic dispersion of microstuctured optical fibers over a wavelength range from 600 nm to 1700 nm. This is to the best of our knowledge the broadest spectral range observed yet. Furthermore the obtained results are highly accurate with an error of less than 3 ps/km·nm.

1 Introduction

The chromatic dispersion of optical fibers and its management plays an important role for a variety of applications like ultra short pulse fiber lasers, supercontinuum sources and soliton generation. Microstructured optical fibers (MOFs) form a new class of waveguides whose dispersion characteristics can be changed over a wide range [1, 2]. MOFs usually consist of a hexagonal lattice of air holes running along the fiber axis with a core formed by a missing hole in the center (see Fig. 1). By varying the hole diameters and pitches, the optical properties of such fibers can be designed in a quite simple way.

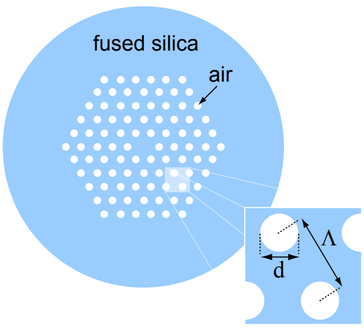

***Fig. 1** cross section of a microstructured optical fiber with hole diameter d and pitch Λ*

Unlike classical fibers, MOFs can exhibit a strongly waveguide dependent dispersion which leads -to zero dispersion wavelengths down to 500 nm [3]. However, these manifold possibilities in dispersion design require a measuring method which is very accurate and not limited to a small optical window but can scan through a large wavelength range of several hundred nanometers.

2 Experimental setup

A halogen lamp is used as white light source, which is sent through a monochromator (see Fig. 2). Subsequently the light is coupled into an endlessly single-mode microstructured pre-fiber which acts as spatial filter [4]. A beamsplitter directs the light into the test-fiber and the variable length reference path of the Mach-Zehnder interferometer.

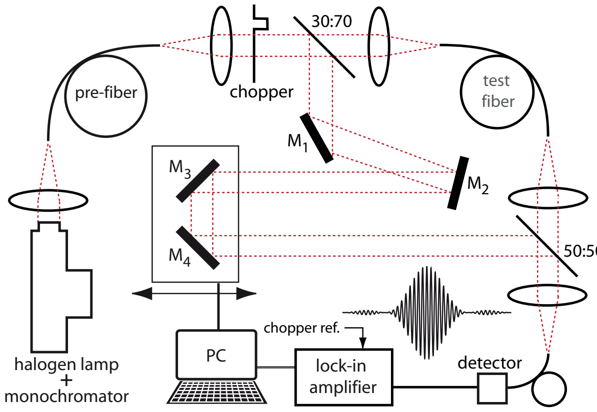

***Fig. 2** schematic setup*

Both beams are combined and interfere at the second beamsplitter. The intensity is detected by a Si/InGaAs sandwich photodiode with a detection range from 300 nm to 1700 nm. The signal is amplified using lock-in technology and analyzed with a computer.

3 Measurement & Data Analysis

The detected intensity is given by

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}|\gamma_{12}|\cos\phi, \tag{1}$$

where I_1 and I_2 are the partial intensities of the beams, γ_{12} is their mutual coherence function and ϕ their relative phase. Since the used light is partial coherent with a spectral width of 7 nm and its spectral density is approximately triangular distributed, it follows that

$$\gamma_{12} = \mathrm{sinc}^2(\pi x/l_c), \tag{2}$$

where $l_c = \lambda^2/\Delta\lambda \approx 50...400$ µm is the coherence length.

Fig. 3 shows three measured interference patterns at different wavelengths and the corresponding fitted sinc^2-envelopes. The equalization position at a specific wavelength can be converted into a differential group delay $\tau = x/c$, where c is the speed of light. Since interferometric measurements are very accurate, a resolution of ± 0.1 ps can be obtained.

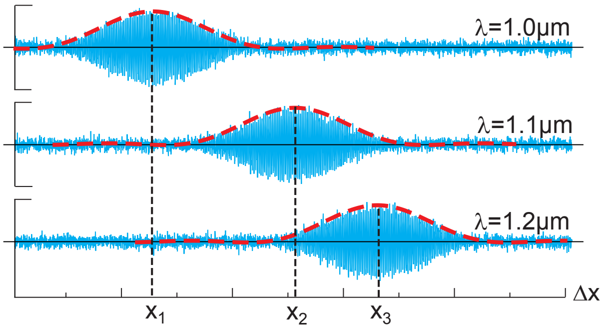

Fig. 3 *interference patterns: variation of equalization position for different wavelengths*

For smoothing purposes the data are fitted to a three-term sellmeier equation

$$\tau(\lambda) = \frac{A_1}{\lambda^2} + A_2 + A_3\lambda^2 \quad (3)$$

and afterwards differentiated for obtaining the dispersion parameter

$$D(\lambda) = \frac{1}{L}\frac{d\tau(\lambda)}{d\lambda}. \quad (4)$$

4 Results & Discussion

We investigated the chromatic dispersion of an LMA-10 MOF by Crystal Fibre. Fig. 4 shows the cross section of this fiber, which has an average hole diameter of $\bar{d} = 2.89$ µm and a pitch of $\bar{\Lambda} = 6.26$ µm.

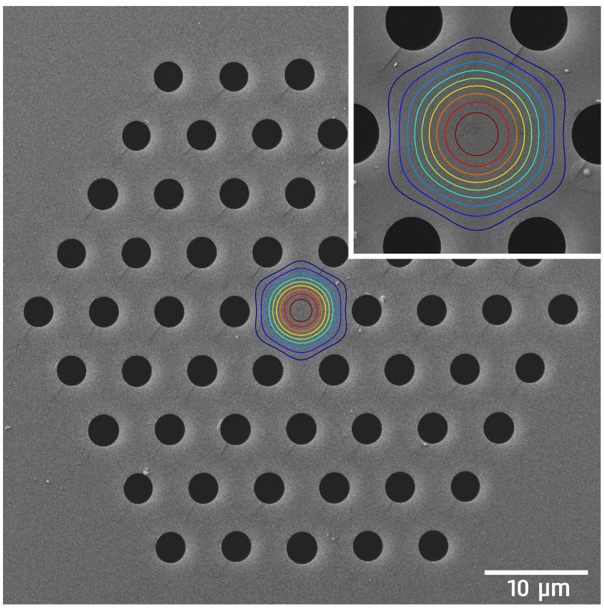

Fig. 4 *cross section of the LMA-10 and its calculated fundamental mode at $\lambda = 1.55$ µm*

Numerical calculations of the mode field and the dispersion properties were made using a full-vectorial finite-difference frequency-domain (FDFD) method [5].

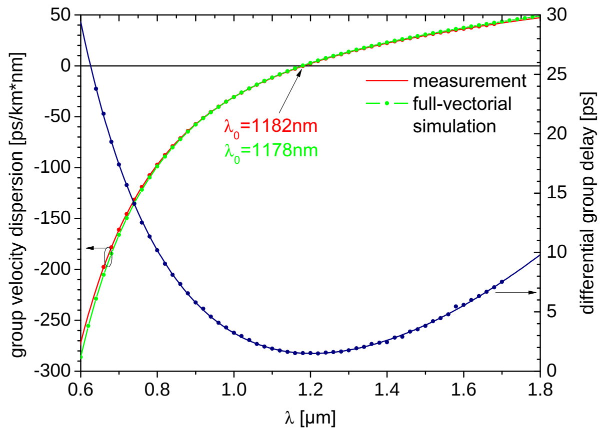

Fig. 5 *measured group delay and group velocity dispersion*

The measured differential group delay and the calculated dispersion parameter are shown in Fig. 5 and compared with the simulations in the wavelength range from 600 nm to 1800 nm.

We determined the dispersion parameter with an error of less than 3 ps/km·nm. The zero-dispersion wavelength was found to be at $\lambda_0 = (1182 \pm 4)$ nm, what is in very good agreement with our numerical calculations.

These results prove the very high accuracy of this measurement method.

References

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