

Chromatic dispersion measurement of microstructured optical fibers for nonlinear applications

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We present a frequency domain group velocity dispersion (GVD) measurement setup based on a Mach-Zehnder interferometer. A supercontinuum light source is used to ensure that enough power is transmitted through fibers with very small cores over a wide spectral range. We show GVD measurements of three specialty microstructured optical fibers and verify their zero dispersion wavelength.

1 Introduction

In general, microstructured optical fibers (MOFs) consist of a hexagonal array of air holes running along the fiber axis, exhibiting a hole diameter d and a hole-to-hole distance (pitch) Λ (see figure 1). Since their first presentation in the late 1990's, MOFs have attracted great interest. Depending on their geometry, they have been used as endlessly single mode (ESM) fibers, large mode area (LMA) fibers or highly nonlinear fibers, e. g. for supercontinuum generation. Especially for the latter application, the control of the group velocity dispersion (GVD), especially the zero-dispersion wavelength (ZDW), is crucial. We present our method for the determination of the GVD of the fundamental mode of highly nonlinear MOFs.

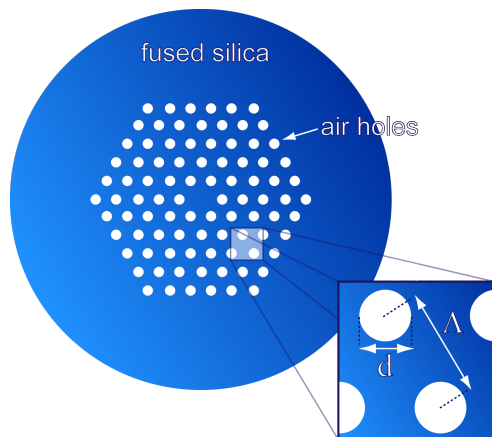


Fig. 1 End face of microstructured optical fiber.

2 Experimental setup

The measurement method is based on an unbalanced white light Mach-Zehnder interferometer (MZI), which we use to determine the differential group delay (DGD) of the fiber under test [1, 2, 3]. Figure 2 shows the schematic experimental setup. We use a commercial fiber-based supercontinuum (SC) source with a maximum optical power of 4 W

as white light source. Before the light enters the interferometer, it is coupled into a pre-fiber (ESM MOF) to match the intensity profiles in both interferometer arms. Afterwards, the beam gets divided by beam splitter 1 (BS1) into the reference arm and the test arm. The reference arm contains a motorized translation stage acting as an adjustable delay line. The light in the test arm is coupled into the fiber sample using an apochromatic microscope objective and it is collimated after leaving the fiber. Both beams interfere collinearly at beam splitter 2 (BS2) and are measured by an optical spectrum analyzer (OSA). The interferometer is adjusted with a laser diode at 655 nm.

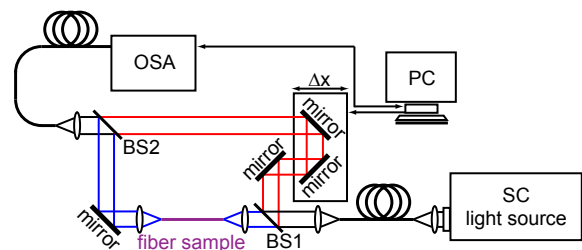


Fig. 2 Experimental Setup.

3 Measurement & data analysis

Several interference patterns (spectra) are recorded for different path delays of the MZI. Figure 3 shows an example of the measured spectra for two different reference path lengths x_1 and $x_2 = x_1 + 800 \mu\text{m}$. The symmetry axis of an interference pattern corresponds to the equalization wavelength of the MZI. To provide a reliable and precise tool for the determination of this symmetry axis, we use an autoconvolution, which actually is an autocorrelation of the spectrum with its mirrored image. The corresponding autoconvolution functions of both measured interference spectra are shown in the bottom inset of figure 3.

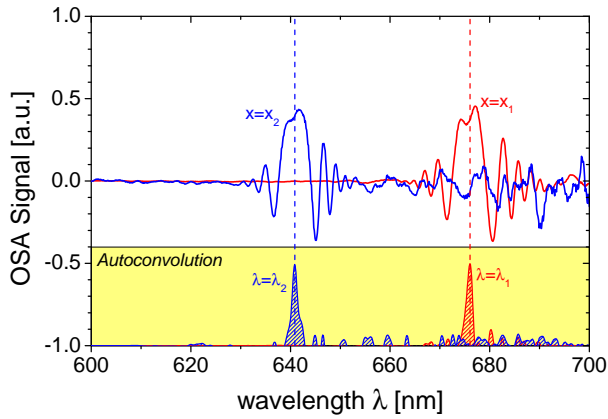


Fig. 3 Example of two measured interference patterns at two different delays.

The maximum of the autoconvolution provides the equalization wavelength for each reference path length. A 3-term Sellmeier function

$$x(\lambda) = \frac{A_1}{\lambda^2} + A_2 + A_3 \cdot \lambda^2, \quad (1)$$

is fitted to the resulting set of group delays and equalization wavelengths $\{\lambda_i^{\text{EQ}}, x_i\}$, where A_1 , A_2 and A_3 are the fit-parameters. Differentiating equation (1) yields the group velocity dispersion (GVD) in form of the dispersion parameter

$$D(\lambda) = \frac{1}{L \cdot c} \cdot \frac{dx}{d\lambda}, \quad (2)$$

which is commonly used in fiber optics and expressed in the units ps/km*nm.

4 Results

We investigated three different MOFs, which have been manufactured at the IPHT Jena and are shown in figure 4. Their geometry parameters are listed in table 1, where D is the core diameter.

MOF A	$\Lambda = 8.4 \mu\text{m}$	$d = 3.5 \mu\text{m}$	$D = 13.4 \mu\text{m}$
MOF B	$\Lambda = 3.1 \mu\text{m}$	$d = 2.8 \mu\text{m}$	$D = 2.9 \mu\text{m}$
MOF C	$\Lambda = 2.2 \mu\text{m}$	$d = 2.0 \mu\text{m}$	$D = 2.2 \mu\text{m}$

Tab. 1 Geometry parameters of the measured MOFs.

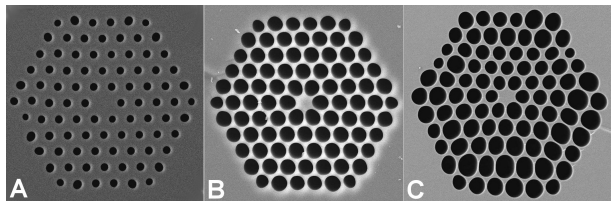


Fig. 4 Examples of PCF fibers.

The measured DGD and calculated GVD of the fibers are shown in figure 5. Due to the variation of fiber geometries and the resulting increase of waveguide dispersion from fiber A to C, the ZDW gets shifted to smaller wavelengths. The measured ZDWs are found to be $\lambda_0^A = 1217 \text{ nm}$, $\lambda_0^B = 909 \text{ nm}$ and $\lambda_0^C = 827 \text{ nm}$.

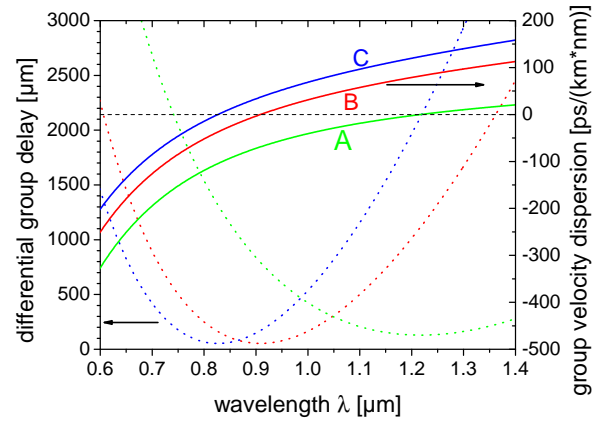


Fig. 5 Differential group delay (DGD) and group velocity dispersion (GVD) of the investigated fibers.

5 Conclusions

We presented an experimental setup for the measurement of the group velocity dispersion of optical fibers, using a supercontinuum light source and a Mach-Zehnder interferometer. By means of an autoconvolution function we were able to determine the equalization wavelengths of the interferometer for each delay line position, and therefore the group velocity dispersion and zero dispersion wavelength. Three different types of fibers were presented, exhibiting zero dispersion wavelengths of down to 827 nm.

References

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