

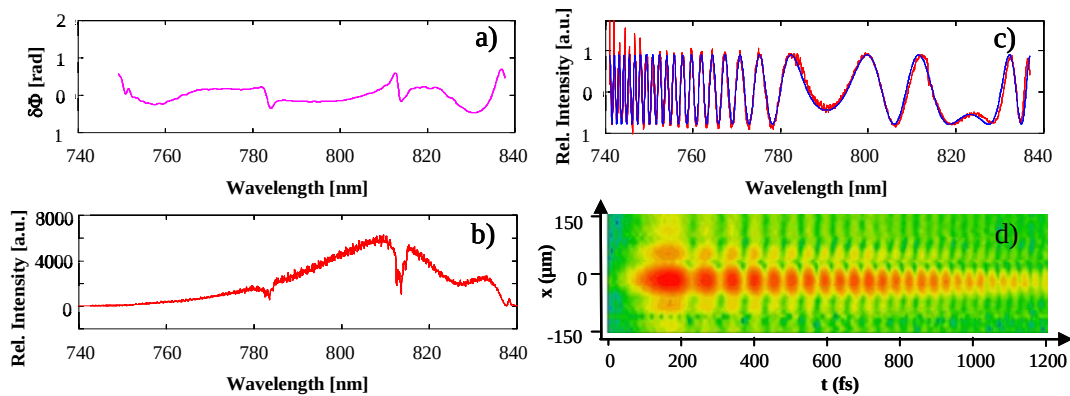
# Dispersion Measurement of Photonic Crystal Fibers up to Fifth Order Using Spectral Interferometry

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The dispersion properties of photonic crystal fibers (PCF) can be tailored in a wide range by the proper design of their geometrical structure. Spectral interferometry has proved to be an effective tool for the dispersion measurement of fibers. To retrieve the spectral phase from the interferograms, generally the stationary phase point (SPP) [1], the minima-maxima [2], the cosine function fit (CFF) [3] and the Fourier-transform (FT) [4] methods are used. With careful fabrication of dispersion free fibers the second order dispersion can be minimized, which makes higher order terms more significant than in commercial fibers. Therefore it is important to know which evaluation method can measure the third and the higher order dispersion coefficients with the highest precision. Here we present a comparative study considering the precision of the methods mentioned above by measuring the dispersion coefficients of a 37 cm long PCF up to the fifth order. There are some applications where ultrashort laser pulses are transmitted through a fiber and focused on a sample. In such cases a simple dispersion measurement is not enough because if lens aberrations and higher order transversal modes are present, they can modify the spatial-temporal profile of the pulse, so the spatial profile of the pulse is also necessary to know in the vicinity of the focal point.

The experimental setup consisted of a combination of a Mach-Zehnder interferometer and an Ocean Optics spectrometer. The interferometer was illuminated by a Ti:sapphire oscillator (20 fs@800 nm), and the PCF under test was inserted in one arm. The spectrally resolved interferograms were recorded at different delays. We found that the FT method provided the dispersion coefficients with the highest precision. The precision of the third, fourth and fifth order dispersion terms were 0.4%, 2% and 4 %, respectively. A further advantage of the FT method is that it can detect phase jumps in the vicinity of the absorption valleys seen in the spectrum of the fiber (Fig. 1a,b), and if higher order transversal modes are present, their dispersion coefficients can also be determined using the same interferogram. Although the precision of the CFF method proved to be smaller than that of the FT method, its sensitivity to higher order dispersion coefficients increases particularly at the delays where two stationary phase points appear on the interferogram. We showed that two SPPs can be seen when the dominant dispersion term is the third order term (Fig. 1c). In order to determine the spatial and temporal shape of the focused pulse we developed a simplified algorithm based on the Fourier-transform, which provides the spatial and temporal shape of the ultrashort laser pulse with higher precision and more quickly than the usual FT method.



**Fig. 1** a: The difference between the measured and the fitted spectral phase of the PCF. b: The spectrum of the laser pulse after the PCF. c: The measured spectrally resolved interferogram (red) with the two stationary phase points and the fitted curve (blue). d: The measured spatial and temporal profile of the focused ultrashort laser pulse after transmission through the PCF. It can be seen that the main pulse is followed by a long pulse train caused by the large third order dispersion ( $1.2 \cdot 10^5$  fs<sup>3</sup>) and side pulses are present.

## References

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