Sub-nanojoule pulse compression in small core area photonic crystal fibers below the zero dispersion wavelength

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Abstract: Compression of sub-nanojoule laser pulses using a commercially available photonic crystal fiber with zero dispersion wavelength of 860 nm is discussed. Theory shows that by the optimization of input and output chirp parameters up to the third-order, high quality, sub-6 fs pulses can be generated from a cost efficient experimental setup. As a verification of our theoretical results, two-fold pulse compression starting from 24 fs transform limited seed pulses is experimentally demonstrated.
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Introduction

Pulse compression of optical pulses down to 5 fs were demonstrated in a wide variety of experimental arrangements using standard single mode optical fiber (SMF) [1] or gas filled hollow core fiber as a nonlinear medium [2]. The common feature of previous studies in this time domain is that they require laser pulses at energy levels well above 10 nJ, i.e., pulse energies that are difficult to obtain directly from a femtosecond pulse laser oscillator. As a result of recent development of small effective core area, single mode photonic crystal fibers (PCF), tenfold pulse compressions were demonstrated in a few experiments [3,4] at nJ or sub-nJ optical pulse energies, which resulted in typical compressed pulse durations of 20 to 35 fs. In our previous studies [3], we found that the compressed pulse duration was primarily limited by the wavelength difference between the laser central wavelength (750 nm) and the zero dispersion wavelength (767 nm) of our PCF sample.

In this paper, we show that it is possible to obtain compressed sub-6 fs pulses using nanojoule or sub-nanojoule seed pulses and novel commercial PCF-s with red-shifted zero dispersion wavelengths by properly choosing the input and output chirp parameters up to the third-order. It is worth pointing out that such input pulse energies with the required pulse durations can be easily obtained from low pump threshold, mode-locked Ti:sapphire laser oscillators pumped by only 1.2 W [5]. As an experimental proof of our calculations, we describe our corresponding experiment with similar experimental conditions. We extend our studies by the investigation of the effect of different dispersion slopes on the quality of compressed pulses.

We calculate the pulse propagation through PCF as a nonlinear Schrödinger type system [6]. The input pulses we used in the simulation have a sech^2 temporal intensity envelope function that is typical for femtosecond pulse solid state laser oscillators. We used dispersion data provided by the manufacturer (type "2.2 Nonlinear PCF" fiber, Crystal Fibre, Denmark [7]) in our calculations. Since the dispersion