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Monitoring the dominance of higher-order chromatic dispersion with spectral interferometry using the stationary phase point method

Tímea Grósz [a,*], Attila P. Kovács [a], Katalin Mecseki [a,b], Lénárd Gulyás [a], Róbert Szipőcs [c]

[a] Department of Optics and Quantum Electronics, University of Szeged, Dóm tér 9, H-6720 Szeged, Hungary
[b] Blackett Laboratory, Imperial College London, Prince Consort Road, SW7 2BW London, United Kingdom
[c] Institute for Solid State Physics and Optics, Wigner RCP, Konkoly Thege út 29-33, H-1121 Budapest, Hungary

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ABSTRACT

Simulations were performed in order to investigate whether the stationary phase point method can be used to estimate the dominance of higher-order dispersion of the optical element under study. It was shown that different higher-order dispersion terms may result in the appearance of more than one stationary phase point on the interferogram in contrast to common glasses having group-delay dispersion as the highest decisive term in their spectral phase. The results obtained by simulations were demonstrated experimentally with spectral interferometric measurements conducted on a photonic bandgap fiber sample and a prism pair. We concluded that from the shape, movement and number of the stationary phase points it is generally possible to predict which dispersion terms are the most significant, however, in some cases the retrieval of the coefficients is also necessary in order to rule out any ambiguity. The method can offer a dispersion monitoring possibility which is useful in quality testing of specialty fibers and when adjusting stretcher-compressor systems, for example.

1. Introduction

Nowadays there are countless applications relying on optical fibers which require precise control of certain characteristics, such as dispersion, birefringence or nonlinear behavior. Bragg-type [1] and photonic crystal fibers [2–5] have received considerable attention owing to their unique attributes, which can be tailored by the proper design of their geometrical structure. To date, a considerable amount of effort has been devoted to decrease the second-order, so-called group-delay dispersion (GDD) and the third-order dispersion (TOD) of the fibers, which are responsible for pulse broadening and post- or pre-pulses, respectively. Doing so, the fourth- (FOD) and higher-order dispersion become significant unlike in common materials which do not exhibit such dispersion characteristics.

A similar effect is observable in high power laser systems relying on chirped pulse amplification (CPA) [6]. Numerous solutions have been proposed to eliminate the GDD and the higher-order dispersion terms of the stretcher and the amplifier stage with the compressor in order to obtain nearly transform-limited pulses at the output of a CPA laser [7–14]. Nonetheless, reducing the GDD and the TOD generates uncompensated FOD in the system [13,14] which might be of concern in applications requiring pulses with ultrahigh contrast. All in all, it can be concluded that reduction of the lower-order dispersion results in pronounced contribution of the higher-order dispersion which limits the performance of the fiber in pulse propagation or the achievable peak power in a CPA laser.

Retrieval of the pulse duration is of great prominence, however, when optimizing laser systems retrieval of the spectral phase is even more important as it shows the residual dispersion of the pulse. As certain pulse distortions can be associated with given dispersion terms, monitoring and precise measurement of the higher-order dispersion is essential. Numerous pulse diagnostic schemes have been invented, which can be divided into self-referencing and non-referencing schemes. The oldest self-referencing method the interferometric autocorrelation (IAC) accompanied by the pulse spectrum can be used to retrieve the pulse shape and the spectral phase, as various chirps produce distinctive patterns. Despite its benefits, the method contains an ambiguity in the sign of the chirp and moreover the accuracy of the chirp measurement is not very high [15]. Frequency-resolved optical gating (FROG) is another autocorrelation-type measurement possibility which has several implementations, such as polarization gate (PG), self-diffraction (SD), transient grating (TG), second- (SHG) or third-harmonic generation (THG) FROG [16]. PG FROG is a complete and unambiguous pulse characterization technique although requires high-quality polarizers thus it is very expensive.

* Corresponding author. Fax: +36 62 54 46 58.
E-mail address: tgrosz@titan.physx.u-szeged.hu (T. Grósz).

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