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A method for the coherence measurement of the supercontinuum source using Michelson interferometer

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Abstract. Coherent properties of supercontinuum sources are highly significant for various applications, including low-coherence interferometry and optical frequency metrology. We propose a fast method for the spatial and temporal self-coherence of the SC measurement using Michelson interferometer without a mirror movement. Furthermore, we present self-coherence measurements of the supercontinuum, generated in microstructured fiber at 780 nm.

1. Introduction

Supercontinuum (SC) generated in microstructured fiber is a unique source of broadband light, which can span for more than an octave, and now it is an indispensable part of various applications [1]. But not only the SC ultrabroad bandwidth is an important parameter to be considered for any given application, the spectral and temporal coherence characteristics are also of primary interest [2]. Therefore, the coherence properties of SC have been studied intensively for the last decade both theoretically and experimentally [1-5].

All experiments for the coherence properties of SC measurements can be divided into two groups depending on whether the ‘same’ pulse spectral coherence or “pulse-to-pulse” mutual coherence is measured. In the first case the interference is provided with the pair of the same SC pulses, separated into the reference and sample pulses, and it is the self-coherence of the supercontinuum. The resulting interference pattern depends on time-delay interference that is averaged over multiple pairs [1]. The mutual coherence results in interference between independently generated supercontinua pulses.

A number of methods to measure self-coherence properties of the SC have been demonstrated for both spatial and temporal domains [1,5]. Spatial spectral coherence is usually measured with the Young-type double-split experiments [5]. The conventional setup for the spectral-temporal coherence measurement includes diffraction-grating-based interferometer or the Michelson-type interferometer [1]. When the Michelson-type interferometer is used, the reference and object mirrors are set parallel and the delay between pulses is obtained by the object mirror movement. The interference between pulses results in the circular interference pattern on the interferometer exit. An intensity distribution versus path delay is obtained by measuring the intensity in the center of interference pattern at different positions of the object mirror.

This paper presents another method for the temporal self-coherence of supercontinuum measurement using Michelson interferometer. Note that the spectral spatial coherence of the SC can also be measured by this method.
2. Method description
The temporal self-coherence of a femtosecond supercontinuum was measured with a compact Michelson setup. But in contrast there was a small angle \( \alpha \) between object and reference mirrors [6]. The interference between reference and objective pulses results in isoclinic fringes in the image plane. Since the interferometer mirrors are angled, there is a temporal delay between different points of the pulses’ wave fronts. There is a zero delay for the central fringe in the interference pattern and the other fringes’ delay \( \Delta \) is given by
\[
\Delta = \pm \frac{m \lambda}{\alpha},
\]
where \( m \) – diffraction order of the fringe, \( \lambda \) – radiation wavelength. Visibility of fringes decreases from the center to the edges of the interference pattern accordingly to the increase of the delay between the pulses. Visibility of the fringes is given by
\[
V = \frac{I_{\text{max}} - I_{\text{min}}}{I_{\text{max}} + I_{\text{min}}},
\]
where \( I_{\text{max}} \) and \( I_{\text{min}} \) is the maximum and minimal intensity of the fringe, respectively. Thus, one can measure the module of the complex degree of coherence without any mirror movement. Spectral coherence of the SC can also be obtained from the resulting interference pattern.

3. Experimental setup
Figure 1 shows the optical schematic of the experimental system configured in this investigation. A Ti:Sapphire femtosecond laser of a 780 nm center wavelength is used as the light source to generate pulses of \( \sim 80 \) fs duration. After going through the dispersion compensator, duration of the pulses was 10-20 fs. For SC generation through nonlinear processes, a microstructured crystal fiber MS-38 is used. The 30 cm length fiber is consisted of a fused silica core, embedded in a fused silica cladding of air-filled cylinders parallel to the core in a hexagonal pattern. The SC spectrum was measured with ASP100 spectrometer with detection range 190-1100 nm. To measure the coherence properties of the SC, the Michelson interferometer with angled mirrors was used. The intensity distributions on the interferometer exit were registered using digital commercial camera Canon 1000D without an objective. All the photos were taken in RAW format to achieve a linear intensity distribution.

![Figure 1. Experimental setup for spectral-temporal coherence of the supercontinuum generation measurements. PCF – microstructured fiber; SC – supercontinuum pulse; BS – beam splitter.](image-url)
Figure 2 shows a recorded spectrum of the SC on the microstructure fiber exit.

**Figure 2.** A recorded spectrum of the SC at a pump wavelength of 780 nm. The SC spectrum covers the range from 550 to 900 nm, spanning from green to near infrared.

4. Data processing

Solid photosensors in CCD matrix present RGGB-structure of Bayer colored filters array. Thus, the incoming light is divided into three channels: red, green and blue. To extract the linear data from the RAW snapshots, the open-source program converter DCRAW was used. Linear file is a grayscale image, which repeats RGGB-structure of Bayer colored filters array. From the grayscale image data three images were allocated in LabVIEW, corresponding to the different color filters. To minimize the error caused by wavelength dependence of the matrix transmittance, these three images were summarized with calculated weight coefficients. To obtain the module of the complex degree of coherence, the visibility of the fringes across the image were calculated using equation (2). The result is shown in figure 3A.

5. Conclusion

Method of estimation of the spatial and temporal self-coherence of the supercontinuum source is proposed. It utilizes the Michelson interferometer with angled mirrors. The method was used to measure spectral-temporal coherence of the femtosecond supercontinuum source. Estimated temporal coherence length is about 2.3 mkm that is in a good agreement with theoretical value of 2 mkm.

References