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WIDEBAND SPIRIT FOR CHARACTERIZATION OF FEW-CYCLE FEMTOSECOND PULSES

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Abstract–Spectral interferometry resolved in time (SPIRIT) is a passive and self-referencing characterization technique that has shown to be suitable for a variety of pulse conditions. Wideband SPIRIT represents a novel configuration aimed for the measurement of a few optical cycle pulses. We present the experimental scheme of Wideband SPIRIT and report first experimental results of characterization of few-cicle pulses. Experimental results demonstrate the capabilities of the method for the full characterization of 0.25 nJ 8 fs pulses.

Keywords**:** femtosecond phenomena, femtosecond pulses, ultrafast measurements

1. Introduction

Nowadays complete amplitude and phase characterization of ultrashort optical pulses has become an essential tool for many fundamental physics experiments. Several techniques have been proposed for extracting the temporal and spectral features of short pulses [1]. Unlike other schemes involving time-consuming iterative algorithms, spectral shearing interferometry allows immediate measurement. Thus, techniques like SPIDER (Spectral Phase Interferometry for Direct Electric field Reconstruction) [2], SORBETS (Superposition of Optical Radiations and Beatings to Extract the Time Signal) [3] or SPIRIT (SPectral Interferometry Resolved In Time) [4,5] rely on the interference of two spectral sheared pulses.

Different SPIRIT configurations have shown the method to be convenient either for measurement of single pulses or high repetition rate trains. Also, 2D-SPIRIT [6] offers a direct and intuitive characterization of ultra-short pulses. SPIRIT measurement is independent on the input pulse, contrasting to SPIDER, where the frequency conversion stage may depend on the pulse initial features, namely on its chirp. SPIRIT arrangement is avoiding the use of expensive or intricate tools, such as the streak camera required for implementing SORBETS.

In this paper, the principles of SPIRIT and its configuration aiming at the characterization of pulses with just a few femtoseconds duration and a broad bandwidth is described in detail: Wideband SPIRIT. Furthermore, the data processing allowing direct measurement are briefly explained, and first experimental results are presented.

2. Results and Discussion

SPIRIT principle is illustrated in Fig. 1. An input pulse is first split into a temporal gate pulse and a measurement pulse which is further split. These latter replicas are temporally delayed and angularly sheared through a Mach-Zehnder-type interferometer, and then they are imaged into a dispersive element. The inset of Fig. 1 shows the effect of the angular shear at the Fourier plane of the dispersive element, where the angular deviation is transformed into a spatial shear between two spectra. Thus, two spatially shifted spectra of the input pulse are obtained. The interference between these spectra generates spatio-temporal beatings that cannot be discriminated with a slow detector. Instead, the spatio-temporal beatings are sampled thanks to the non-linear mixing of the temporal gate pulse and the interfering spectra. This is possible by placing a non-linear crystal at the Fourier plane of the dispersive element. A line detector captures the stationary interferogram, a second harmonic signal, which is processed in real-time. The complete information about the pulse is retrieved from the interferogram. The method is robust and permits direct and fast pulse characterization.

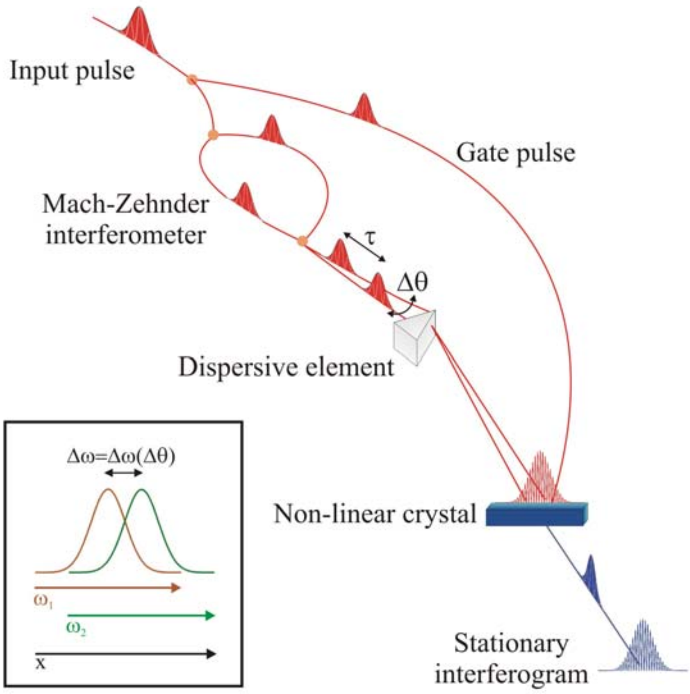

Fig. 1. Principal scheme of SPIRIT.

Wideband SPIRIT introduces several modifications comparing with previous SPIRIT versions, in order to deal with pulses of just a few femtoseconds duration and a broad bandwidth. The experimental set-up is shown in Fig. 2. The pulse under test was first split in two beams. One was sent to cylindrical mirror (Melles Griot PS-RCC-40.0-25.4-254.3-C, f=127.15 mm) and served later for time gating. The gate beam is spatially broadened for overlapping the two sheared spectral signals upon the non-linear crystal (type I Eksma Optics BBO 5×5×0.01, θ=30º, φ=90º). The other beam entered a Mach-Zehnder-type interferometer. The two sub-pulses that came out of the Mach–Zehnder interferometer are temporally delayed and angularly sheared (see point A in Fig. 2) and next they are imaged into a dispersive element (see point B in Fig. 2). The angular shear was equal to $\Delta\theta$=0.5º. The spherical mirrors which were located in this path had a focal length equal to f=150 mm (Thorlabs CM508-150-P01). Slit of 2 mm wide, was used to filter the light coming directly from gate or from Mach-Zehnder interferometer, and leaving only the SPIRIT signal (second harmonic signal). The interferogram was recorded by a standard linear CCD array.

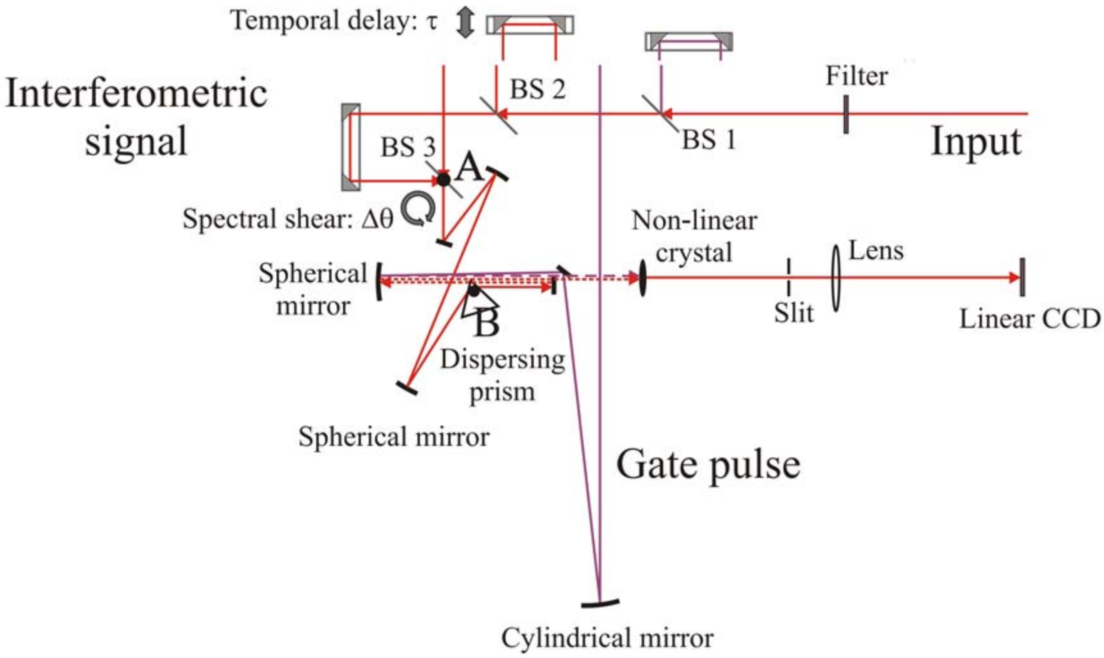

Fig. 2. Wideband SPIRIT set-up. A and B are conjugated by two spherical mirrors. BS: very thin pellicular beam splitter, with very low dispersion.

In SPIRIT, the derivative of the input pulse phase is encoded in the recorded interferogram, as a function of the relative positions of the fringes. The gate pulse has just an intensity effect in the second-order mixing, but it does not affect the phase information. An inversion algorithm [7] reconstructs the pulse information from the experimental data. Through few and direct calculation steps the spectral and temporal pulse profile and the spectral phase information are obtained. The method is passive and self-referenced. The time delay between the two pulse replicas and the angular shear are required parameters in order to reconstruct the pulse.

Preliminary experimental results have shown the capability of Wideband SPIRIT for the measurement of ultra-short pulses, like the pulses below 10 fs that have been characterized with our scheme. Low energy (0.25 nJ) pulses below 10 fs directly coming from a Rainbow oscillator (FEMTOLASERS GmbH, 200 nm bandwidth, 75 MHz, 300 mW mean power, 810 nm as a central wavelength) have been measured by means of Wideband SPIRIT. An example of the full characterization of an 8 fs pulse is shown in Fig. 3.

Also, third-order dispersion (TOD) introduced by a piece of glass has been effectively measured. We have performed an experiment with pulses from a COHERENT Micra laser, with a bandwidth of 95 nm, in which TOD is introduced by 16 cm of SF11 glass, and second-order dispersion has been compensated through a GRISM line. In this communication, we present the characterization of those pulses mostly influenced by TOD. Fig. 4 shows the spectral phase, spectrum of the pulses and the reconstructed pulse temporal profile, which is compared in the inset with an additional interferometric autocorrelation trace registered with an independent system.

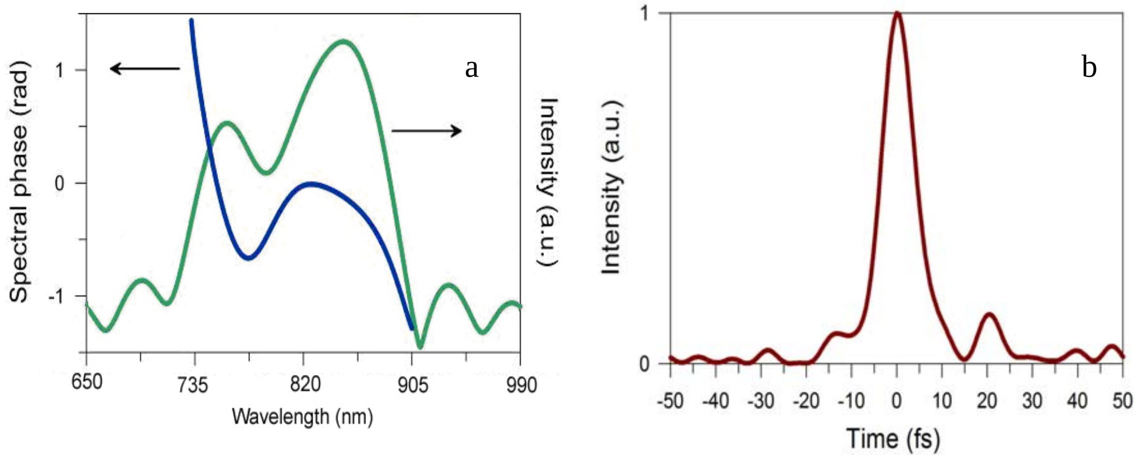

Fig. 3. 8fs 0.25 nJ pulse characterization: (a) spectral phase and spectrum of pulses, (b) reconstructed pulse temporal profile.

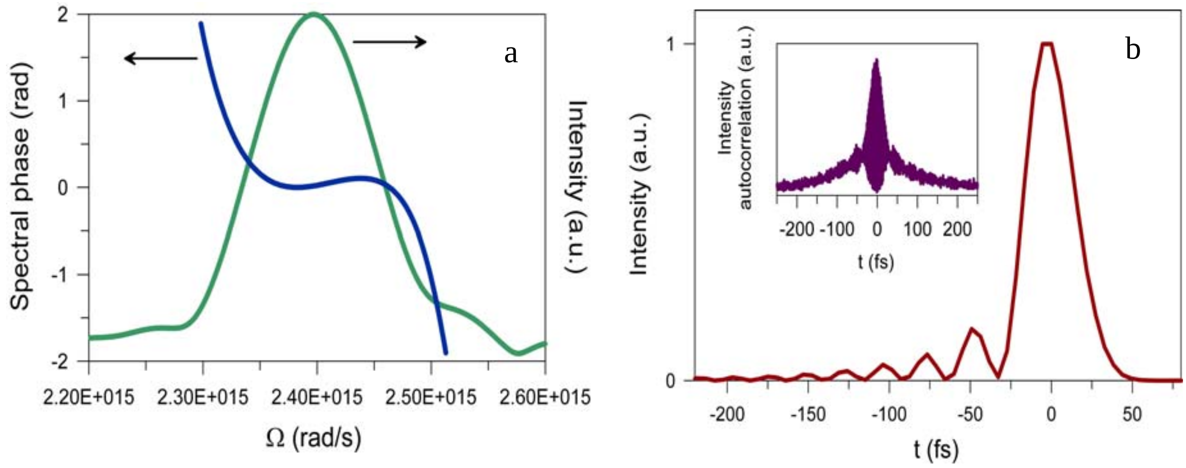

Fig. 4. Characterization of pulses with TOD: (a) spectral phase and spectrum of pulses, (b) reconstructed temporal profile of pulse. The inset shows the interferometric autocorrelation trace of the same pulse.

Conclusion

Wideband SPIRIT, a method for the measurement of ultra-short and wideband pulses based on Spectral Interferometry has been reported. The measurements of broadband pulses are possible thanks to a thorough optical design. A compact and moveable set-up has been prepared. The experimental results demonstrate the capabilities of the method for the characterization of a few femtosecond pulses. Furthermore, third-order dispersion measurement has been possible with Wideband SPIRIT.

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