SPIDER diagnostic for short pulse characterization at PHELIX

S. Kunzer[1], E. W. Gaul[2], W. Heddrich[1], Th. Kühl[2], P. Neumayer[2], C. Spielmann[3], P. Wiewior[2,3]

[1]FH Darmstadt, Schöfferstr. 3, 64295 Darmstadt, Germany; [2]Gesellschaft für Schwerionenforschung mbH, Planckstr.1, 64291 Darmstadt, Germany; [3]Julius Maximilian Universität, Würzburg, Am Hubland, 97074 Würzburg, Germany

To reach laser powers at the Petawatt level at PHELIX the technique of chirped pulse amplification (CPA) is used, where an originally short laser pulse is stretched in time by over several orders of magnitude and is recompressed close to its original duration after amplification. This requires a reliable diagnostics of the recompressed ultra-short pulse.

The SPIDER (Spectral Phase Interferometry for Direct Electric field Reconstuction) [1] is one of the techniques capable to provide the full information on an ultra-short laser pulse. In contrast, standard autocorrelation techniques can give the temporal pulse duration only, and under the assumption of the temporal pulse shape.

SPIDER is a self referencing variant of spectral interferometry, where the ultra-short pulse interferes spectrally with its own, delayed in time replica. The resulting interference pattern is measured by a spectrometer. By shifting the center frequency ω_0 of one of the two pulses by an amount $\delta\Omega$, information of the spectral phase is encoded in fringe shifts and can be recovered by a direct non-iterative (inversion) numerical algorithm. Shifting the center frequency is achieved by frequency mixing with a third pulse which is linearly chirped in time. This way the two pulses are up-converted with two different frequencies. The chirped pulse can be obtained by sending a portion of the original pulse through a compact stretcher.

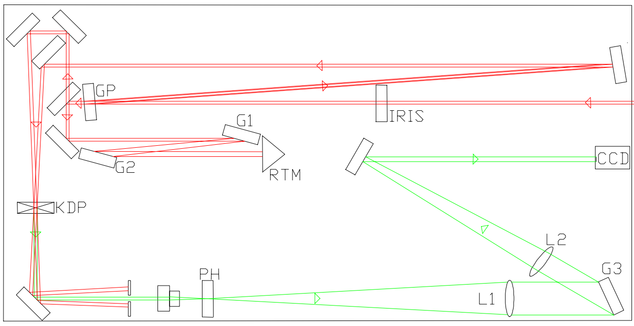

Figure 1: Setup of the SPIDER apparatus at GSI. GP: Etalon, G1,2: stretcher gratings, RTM: roof top mirror, G3: spectrometer grating, KDP: non-linear crystal, PH: pinhole,L1,L2: lenses, CCD: camera

The CPA pulses from the PHELIX laser ($\lambda = 1054$ nm) exhibit a bandwidth $\Delta\lambda$ between 4 nm and 7 nm, depending on the pulse energy. Upon recompression this corresponds to pulse durations of 400 fs to 300 fs. For these kind of pulses the parameters for the SPIDER were chosen to $\tau = 20$ ps and $\delta\Omega = 9\times10^{-4}$ fs^{-1}.

The PHELIX SPIDER set-up is shown in Fig. 1. Two pulses are generated by reflection off the two sides of an uncoated glass plate (BK7, 2 mm thickness). The time delay τ between the two interfering pulses is 20 ps. It has to be large enough to obtain a reasonable number of interference fringes within the pulses' spectrum. On the other hand the sampling rate of the interferogram must fulfil the Nyquist criterion.

The transmitted portion of the pulse is used to generate the chirped pulse. The frequency shift $\delta\Omega$ has to be small enough to provide multiple sampling of the spectral phase (Whittaker-Shannon theorem), while with too small a frequency shift a noise problem arises. The two quantities are related by $\delta\Omega = \tau/\Phi_2$ where Φ_2 is the group velocity dispersion (the second derivative of the spectral phase of the chirped pulse at the central frequency). The required $\Phi_2 = 2\times10^7$ fs^2 is reached in a standard double-pass grating stretcher consisting of two parallel gratings (1800 lines/mm, incidence angle 75°) with a separation of 200 mm. The pulses are overlapped in a 2 mm thick type-I KDP crystal.

The polarization of the up-converted signal is rotated by a periscope and the beam is focused by a 4x microscope objective through a 10 micron pinhole. The pinhole constitutes the entrance aperture for the spectrometer. It uses a 2400 lines/mm holographic grating (25×25mm^2) under 25° angle of incidence. The beam from the pinhole is expanded to >5 cm diameter to overfill the spectrometer grating. A 600 mm focal length lens images the pinhole onto the CCD camera chip (760x580 pixel). The camera is synchronized to the laser pulses.

Fig. 2 shows a typical interferogram obtained from the device in a single shot. For reconstruction of the spectral phase from a SPIDER interferogram a software developed at the University of Würzburg was adapted to read the interferograms provided from the SPIDER at GSI. The software is written in LabView, performs the complete SPIDER algorithm and provides a user-friendly graphical interface.

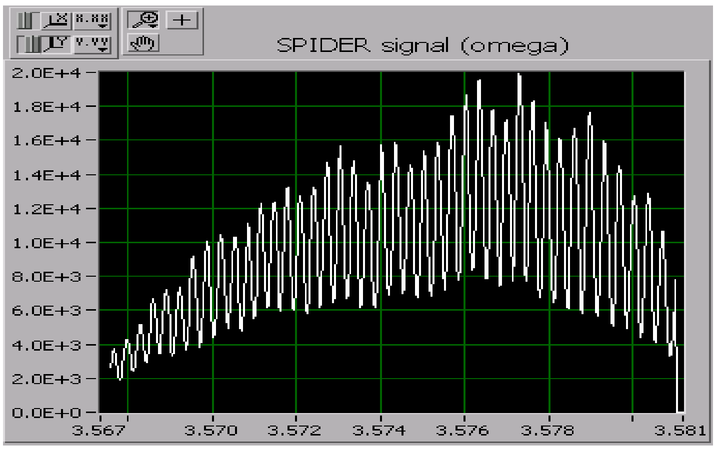

Figure 2: Interferogram from the SPIDER apparatus analysed by the SPIDER software from Univ. of Würzburg.

References

[1] C. Iaconis, I.A. Walmsley, Optics Letters **23**, 792 (1998)