Optimization of plasma-blue-shift spectral shear interferometry for characterization of few-cycle pulses

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Measurement of ultrashort ultraweak laser pulses with over-an-octave wide spectra poses a well-known challenge because of the spectral overlap of harmonic orders. The problem of the interference between the nonlinear signal and the fundamental spectrum can be mitigated in both frequency-resolved optical gating (FROG) and spectral shearing interferometry (SPIDER) [1] techniques by using non-collinear sum-frequency generation in very thin crystals. However, the suitable phase-matching bandwidth for frequency conversion is ensured as a rule by using low conversion efficiency several-μm-thick nonlinear crystals. Additional issues that become increasingly important as the pulse duration shrinks are the minimum added dispersion of the pulse characterization apparatus [2] and the time delay accuracy/jitter between the interfering pulse replicas in SPIDER [3]. These issues were addressed in newly developed technique based on ionization induced blueshifting called iSPIDER [4]. Here we investigate optimal parameters for the use of this technique.

In a pump-probe experiment we compare spectral shifting of a weak probe pulse in a plasma created by focusing pump pulses with different wavelengths into a krypton jet. In the first case there is spectral overlap between the pump and the probe pulse which leads to distortion of the spectrum of the probe pulse when they coincide in time (see Fig. 1a). No distortion of the probe pulse spectrum is observed in the second case in which there is no overlap between the spectra of the pump and the probe pulse (see Fig. 1b). The second harmonic of the pump pulse used in the first case was utilized as a pump pulse in the second case. Since the regime of ionization was set to be multiphoton in both cases, the delay window in which the blue shift of the probe pulse could be observed was the same. It is important to note, that for the iSPIDER technique it is necessary that the regime of ionization is multiphoton.

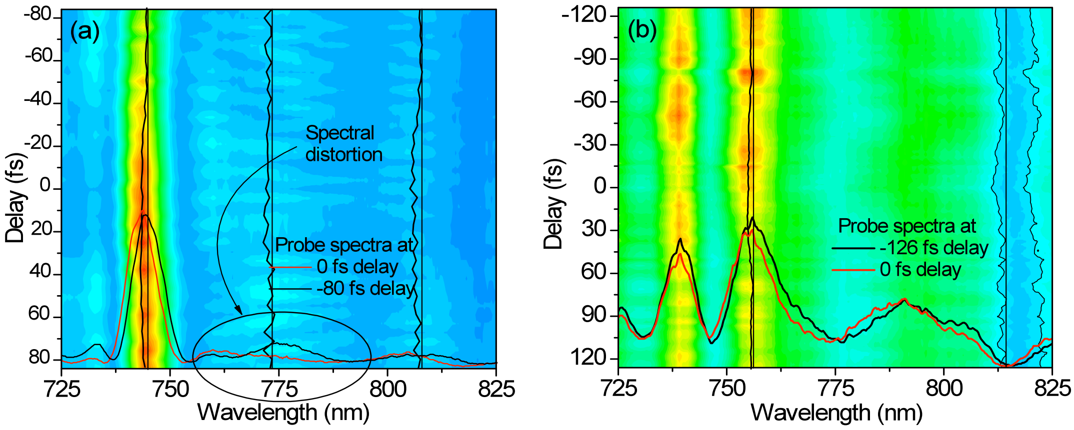

Fig. 1. Probe spectra as a function of pump-probe delay, for a 780-nm pump pulse (a) and a 390-nm pump pulse (b). The probe spectral intensity is encoded in colors, for comparison spectra of the probe pulse at zero fs delay and at no temporal overlap between pump and probe are collapsed on the wavelength axis. The vertical black lines emphasize the observed spectral shift. The pressure of krypton was set to 360 mbar and 2 bar in (a) and (b) cases respectively.

Although the power of the second harmonic is much lower than the power of the fundamental – which needs to be compensated by using a higher pressure in the gas jet – for the iSPIDER technique it is necessary to use a pump pulse with no spectral overlap with the probe to avoid spectral distortions. However, the pressure should be kept low enough to avoid exsessive frequency shifting due to cross phase modulation [5]. For our conditions the frequency shift due to cross phase modulation was limited to a few percent of the shift caused by the time-varying electron density.

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