주파수 간섭계를 이용한 증폭된 1kHz 레이저 펄스의 절대 위상 변화 측정

Measurement of carrier-envelope phase changes of 1 kHz amplified laser pulses by spectral interferometry

Tayyab Imran, Yong Soo Lee, Jae Hee Sung*, Tae Jun Yu*, Kyung-Han Hong* and Chang Hee Nam

Dept. of Physics and Coherent X-ray Research Center, KAIST, Daejeon 305-701

*Advanced Photonics Research Institute, GIST, Gwangju 500-712

Email: tayyabmrai@.kaist.ac.kr

Many high field intensity experiments that use few cycle laser pulses require a stable carrier-envelope phase (CEP). Amplification of the oscillator pulses by chirped pulse amplifier (CPA) is normally used for producing high intensity laser pulses, adds fluctuations and shifts to the CEP even when the CEP of pulses from the oscillator itself is controlled[1,2].

Carrier envelope phase can be explained by considering an example of a beat pattern created by summing of two frequency components[1]:

$$E = E_0 \cos(\omega_1 t + \theta) + E_0 \cos(\omega_2 t + \theta)$$

$$E = 2E_0 \{\cos[(\omega_1 + \omega_2)t/2 + \theta] \cos(\omega_1 - \omega_2)t/2\}$$

Where $\omega_1$and ω_2 are the two frequency components.

The envelope $\cos(\omega_1 - \omega_2)t/2$ is independent of the common phase of the two beams, and rapidly oscillating term $\cos[(\omega_1 + \omega_2)t/2 + \theta]$is phase dependent. In materials, the envelope moves with the group velocity and the carrier moves with the phase velocity, so the phase θ of the oscillation changes with respect to the envelope changes.

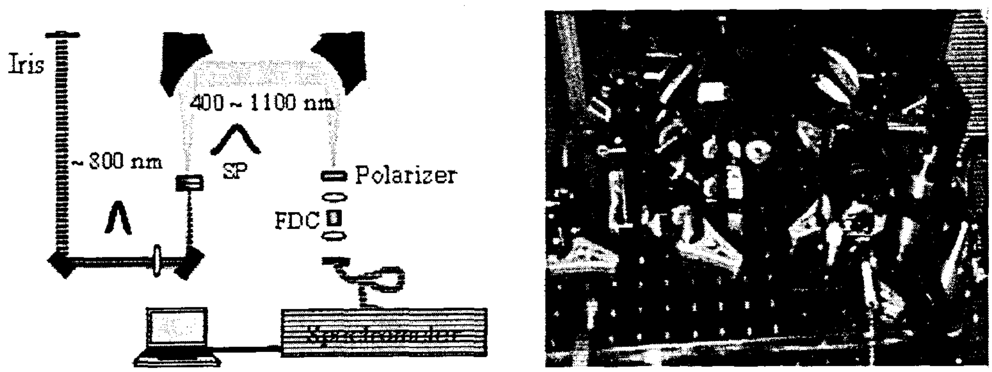

Fig. 1. SI setup for the measurement of single shot CEP shift.

In this work we measured the CEP fluctuations of amplified laser pulses using a technique that measures the Spectral interference between the white light continuum and its second harmonic. The spectral interference fringes contain information on the carrier -envelope phase. The spectral interferometer setup is shown in Figure. 1.

To generate the SH components, spectrally broadened pulses were sent through a 1mm BBO crystal. The fringes were observed only when both components pass through the polarizer. For single shot measurements the spectra were measured using a spectrometer at 60Hz, this rate being limited by the spectrometer characteristics. Figures. 2(a) and (b) show the spectral interference fringes in the wavelength range 520 nm to 550 nm obtained for two successive pulses. The data shown were obtained using our CEP stabilized oscillator, CEP locking was achieved using a direct locking method which operates in time domain and locks the shot-to-shot CEP slip to zero. From this data we calculate the CEP $\Delta\theta$ change between the two successive pulses[2, 3]. The CEP fluctuations introduced during the passage through the amplifiers occur at a much longer time scales and therefore could controlled using feedback signals derived from our Spectral Interferometer setup.

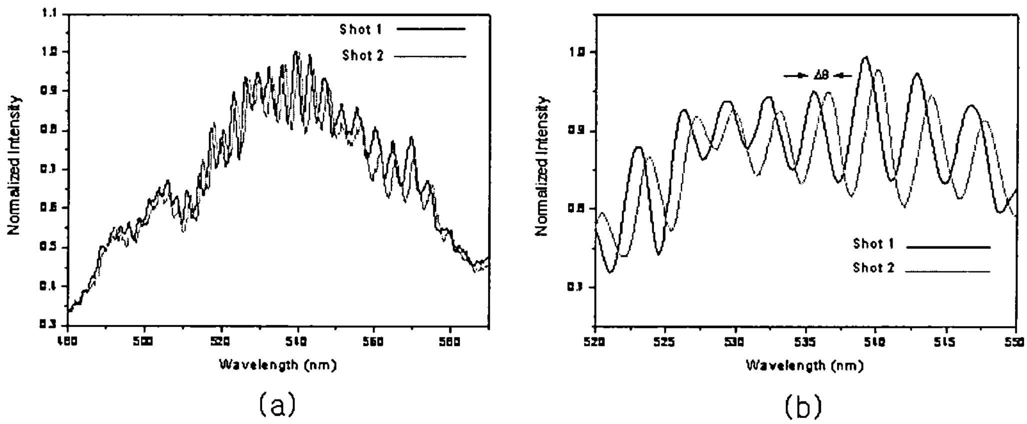

Fig 2. Spectral interferometric signal (a) and central part (b) of the spectral interferometric signal measured for two successive shots.

Reference

[1] M. Mehendale, S. A. Mitchell, J. P. Likforman, D. M. Villeneuve, and P. B. Corkum, Opt. Lett. **25**, 1672 (2000).

[2] M. Kakehata, H. Takada, Y. Kobayashi, K. Torizuka, Y. Fujihara, T. Homma, and H. Takahashi, Opt. Lett. **26**, 436 (2001).

[3] A. Baltuska, Th. Udem, M. Ulberacker, M. Hentschel, E. Goullelmakis, Ch. Gohle, R. Holzwarth, V. S. Yakovlev. A. Scrinzi, T. W. Hansch and F. Krausz, Nature **421**, 611 (2003).