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절대위상 안정화된 고대비율의 상대론적 kHz 레이저 광원

High-contrast relativistic kHz laser source with carrier-envelope phase stabilization

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A typical sub-TW kHz chirped-pulse-amplification (CPA) laser has become capable of delivering a relativistic intensity (>$2\text{x}10^{18}$ W/cm^2 in case of 800 nm wavelength) with the help of a laser focusing technique using high-numerical-aperture optics and a wave-front correction method⁽¹⁾. We have called this type of laser as "relativistic wavelength-cubed (λ^3)" laser because of several-cycle (or few-cycle) pulse duration and wavelength-limited spot size. The relativistic λ^3 regime defined by such a laser is technically important for the study on relativistic light-matter interactions and other high-field sciences because it can be cost-effectively achieved by the modification of various sub-TW CPA lasers having a repetition rate from 10 Hz to kHz which are already developed at many laboratories and now are commercially available. Relativistic λ^3 studies also offer very high gradients and the possibility of generating isolated attosecond phenomena.

We have to consider two important factors in the development of a kHz relativistic laser for experimental studies in λ^3 regime: intensity contrast ratio (ICR) and CEP. First, the ICR between main pulse and prepulses is generally important forthe application of a high-intensity laser to solid-target experiments because prepulses can generate unwanted plasmas before the main pulse arrives on the target. ASE is a fundamental limiting factor of the contrast ratio has an ICR of 10^4-10^6 in typical CPA lasers, which is not sufficiently high at relativistic intensity of >10^{18} W/cm^2. The ASE contrast in kHz CPA lasers has received little attention so far because of their relatively low peak powers. However, the λ^3 concept operating at low-peak-power in kHz CPA lasers necessitates the measurement and enhancement of the ASE contrast ratio. Second, Naumova *et al.*⁽²⁾ has recent shown that the CEP of laser pulses is one of the critical factors of generating isolated attosecond pulses in λ^3 regime. As the pulse duration decreases, the CEP effect on relativistic attosecond phenomena gets important. Thus, the CEP stabilization of relativistic-intensity pulses is another requirement for the experimental studies in λ^3 regime. The CEP stabilization of amplified pulses has been demonstrated for several kHz lasers⁽³˒⁴⁾, but it is still challenging to generate CEP-stabilized laser pulses with a relativistic intensity from a grating-based CPA laser with 3 multipass amplifiers.

In this talk, we report on the demonstration of a high-contrast relativistic kHz laser source with carrier-envelope phase stabilization. We have enhanced the intensity contrast ratio between ASE and main pulse of our kHz CPA laser with a relativistic intensity as much as 400 times by employing a high-energy clean-pulse injection method⁽⁵⁾, resulting in the ASE contrast ratio of 10^8 as shown in Fig. 1. Estimated ICR in Fig. 1(a) is $4\text{x}10^8$ considering the peak attenuation factor, 4, in the cross-correlator, which is the best contrast ratio ever measured in a relativistic intensity at a kHz repetition rate. A third-order cross-correlator with a dynamic range of >10^9 and a scanning range of up to 4 ns has been developed for the contrast measurement. Analysis of a common phase-related pedestal structure will be presented.

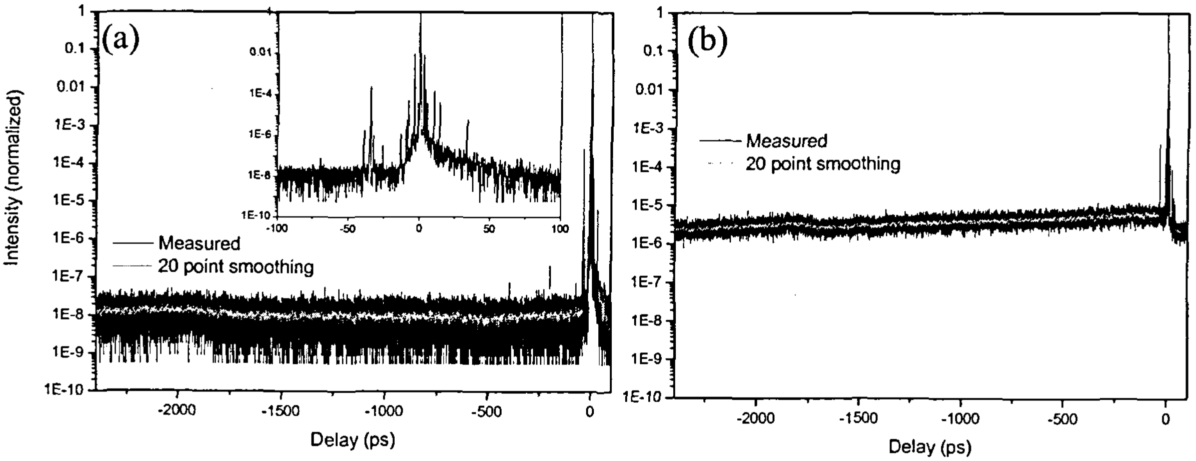

Fig. 1 Measured third-order cross-correlation traces for μJ-injection system (a) and nJ-injection system (b).

We have also stabilized the carrier-envelope phase of the laser pulses generated in our front-end oscillator and measured the phase stability of amplified pulses using a nonlinear spectral interferometer as illustrated in Fig. 2(a). We have observed the phase stabilization of amplified pulses with a jitter of <1 rad for 3 seconds as shown in Fig. 2(b). Detailed analysis of the phase jitter will be discussed.

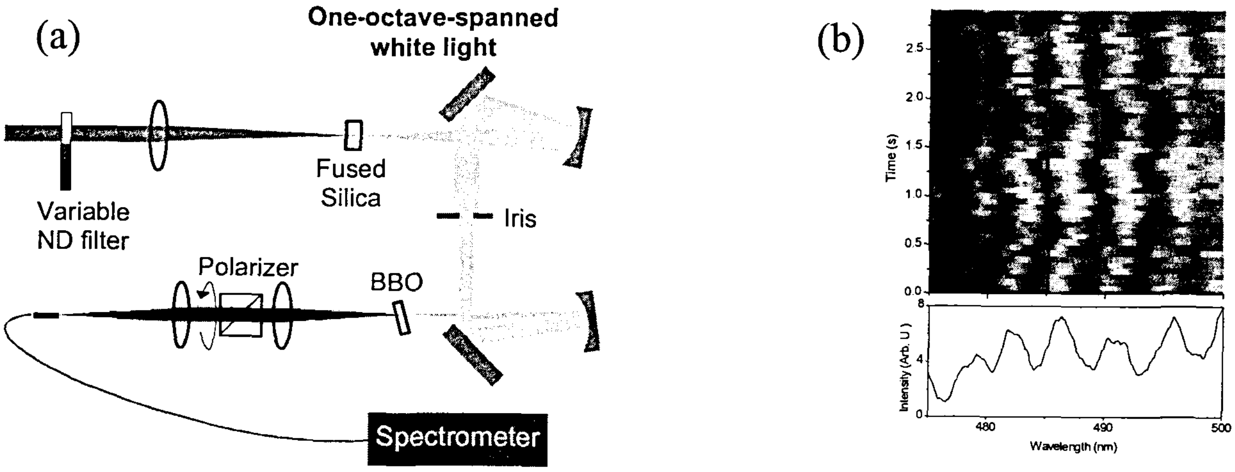

Fig. 2 Nonlinear spectral interferometer (a) and temporal evolution of measured spectrograms (b).

참고문헌

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