3차 교차상관신호의 역상관을 통한 펨토초 및 처프된 피코초 펄스의 정확한 선행펄스 대비율 측정

Accurate Contrast-ratio Measurement of Femtosecond and Chirped Picosecond Pulses from the Decorrelation of Third-order Correlation Trace

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The intensity contrast ratio between a laser pulse and prepulses is one of the important parameters in the application of a high-intensity laser to solid-target experiments. Two kinds of prepulse are main concern in chirped-pulse amplification (CPA) femtosecond lasers: fs-duration prepulses and amplified spontaneous emission (ASE). The fs-duration prepulses originate from the imperfect isolation of amplified pulse from neighboring pulses, whereas ASE is a general feature found in all the laser amplification systems. The ASE of typical CPA lasers has a duration of a few nanoseconds and a contrast ratio of 10^{-7}-10^{-5}. The ASE contrast-ratio enhancement techniques have been intensively investigated, but well-controlled or intentionally added prepulses are also useful to many physical processes. Recently, a Ni-like silver X-ray lasing, pumped by a single-profiled chirped picosecond pulse in a grazing-incidence pumping (GRIP) scheme, was greatly enhanced by controlling the prepulses(1).

Conventional technique of the contrast-ratio measurement is the third-order cross-correlation(2) allowing the dynamic range of $>10^9$. However, the ASE contrast-ratio estimation from the third-order cross-correlation traces is exposed to an error due to pulse broadening(3). Recently, the correction factor for this error was quantitatively discussed in terms of the decorrelation of the third-order cross-correlation trace(4). It is even more important with sub-10-fs high-intensity optical pulses(5) because the pulse broadening in the cross-correlator can be much higher. Since the high-power sub-10-fs pulse generation based on OPCPA is one of the major strategies for petawatt laser projects, more generalized treatment of the correction factor for the improved contrast-ratio measurement is necessary.

In this presentation, we report on the accurate characterization method of the ASE contrast ratio using the decorrelation of high-dynamic-range third-order cross-correlation traces. Experimental third-order cross-correlation measurements on femtosecond and chirped picosecond pulses show that the correction factor in the contrast-ratio estimation from the cross-correlator should be carefully considered. We will analyze the effect of pulse broadening and shortening of the third-order cross-correlation measurement on the contrast ratio. The origin of pulse duration change with chirp-free femtosecond pulses and chirped picosecond pulses, such as phase mismatch and group velocity mismatch (GVM), will be quantitatively studied for the reliable decorrelation process

We performed the high-dynamic-range third-order cross-correlation measurement of strongly chirped picosecond pulses generated from a 100-TW CPA Ti:sapphire laser at APRI. To check the reliability of the contrast-ratio measurement of these chirped pulses, we scanned the compressor grating separation and generated negatively and positively chirped pulses and a chirp-free pulse. Measured third-order cross-correlation traces with grating detuning from the chirp-free condition (positive direction) are shown in Fig. 1(a). The typical contrast ratio of the chirp-free pulse (bottom) is $2x10^{-7}$, whereas it is as high as $2x10^{-6}$ in the case of a negatively chirped 3 ps pulse (top). The relative ASE contrast ratios at 50 ps ahead of the main pulse, versus the grating detuning, are shown as the lined squares in Fig. 1(b). However, the relative peak intensities calculated from the dispersion formula in the compressor grating, shown as the dotted line in Fig. 1(b), have a different feature. The peak intensity is linear to the contrast ratio because the ASE level is not affected by the grating condition.

The discrepancy in Fig. 1(b) indicates that the correction factor related to the pulse duration is necessary for more accurate contrast-ratio estimation. Even though the chirp-free pulse duration was 40 fs, measured by SPIDER technique, the pulse duration at the third-order cross-correlator was as large as 220 fs. Interestingly, the chirped picosecond pulses had shorter pulse durations at the cross-correlator than calculated ones, where the picosecond pulse durations were not covered by our SPIDER measurement. Note that the relative contrast ratio follows the calculated curve very well, as shown as the lined circles in Fig. 1(b) if the pulse broadening or shortening factor is simply corrected. However, more rigorous analysis is attempt for reliable contrast-ratio characterization. For this purpose, we carefully consider the phase mismatching bandwidth and GVM bandwidth in the decorrelation process of the third-order cross-correlation trace, which allows more accurate estimation of the contrast ratio between main pulse and the ASE.

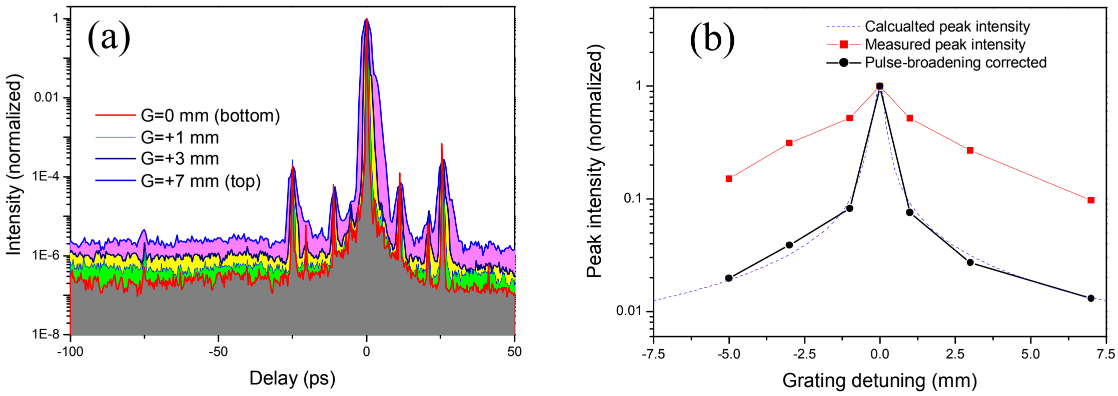

Fig. 1 Intensity contrast ratio of femtosecond and chirped picosecond laser pulses. High-dynamic-range third-order cross-correlation measurements (a) and comparison of contrast ratios with calculation (b).

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