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Multi-channel cross-correlator for single-shot laser time contrast measurement
マルチチャンネルのクロスコリレータを用いたシングルショット
時間コントラスト計測

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Temporal contrast of an ultrahigh-intensity laser is a crucial parameter for laser plasma interaction experiments. We have developed a multi-channel cross-correlator (MCCC) for single-shot measurement of temporal contrast of Petawatt class laser pulse. The MCCC is based on a third order cross-correlatior, and has a four independent optical delay. We have experimentally demonstrated that the MCCC system achieves the high dynamic range of ~10^9 and large temporal window of >100.

1. Introduction

Developments in laser technology have recently allowed to examine the fundamental physics of ultra-relativistic regime (peak intensity >10^{20} W/cm^{-2}) [1, 2]. However, ultrahigh intensity lasers contain typically a pre-pulse and/or pedestal with >10^{10} W/cm^2 before main pulse. The pre-pulse/pedestal is mainly due to amplified spontaneous emission (ASE). The pre-pulses, for instance, are due to the imperfect matching of some optical components inside the laser chain. These pulses interact with a target and produce pre-formed plasma in front of the target before the arrival of the main pulse. As a consequence, the main pulse interacts with an expanded preformed plasma, which prevents, for example, the efficient generation of high energy proton beams from the thin foil target [3]. Therefore, the temporal intensity of the pulse must be measure and monitored over a wide temporal range (>100 ps) with high dynamic rang (ex: ~10^{10} at peak intensity 10^{20} W/cm^2) for each laser shot. It is essential to measure shot-to-shot fluctuation of the contrast of the laser pulses, in particular, for the large high-power laser system in low repetition-rate operation. We developed a multi-channel cross-correlator (MCCC) for laser pulse contrast measurement. The MCCC is based on third order cross correlation which is typically used in a delay-scanning mode (ex. Sequoia (Amplitude Technologies)). The MCCC has a four independent delay and channels, can measure temporal contrast in single shot mode.

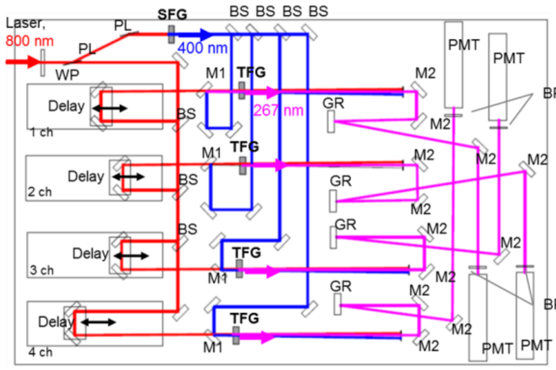

Fig.1. optical layout of a Multi-channel cross-correlator (MCCC) based on third order cross-correlation technique. **M1**: dielectric mirrors for second-order harmonics, **M2**: dielectric mirror for third-order harmonics, **BS**: beam splitter, **SFG**: second-frequency generation crystal, **TFG**: third-frequency generation crystal, **GR**: grating, **PMT**: Photomultiplier tube, **PL**; polarizer, **WP**: half-wave plate, **BPF**: third order band pass filter, No symbol optics are aluminum mirrors.

2. Experimental setup of MCCC

Third order cross-correlation techniques are widely used for temporal contrast measurement. Figure. 1 shows optical layout of the MCCC. The input laser from JLITE-X laser system [4, 5] with a pulse fluence of 3 mJ/cm^2, duration of 40 fs, and wavelength of 800 nm is split by a half-wave plate and two polarizers. The *s*-polarized pules is frequency doubled in a 0.5 mm thick type I BBO crystal, and separated into each channel. The *p*-polarized 800 nm laser pulse is separated into each channel. Where each channel has an optical delay of (-150ps~ +100ps). The pulse passes through a 0.2mm thick type I BBO crystal for the third harmonics generation with the frequency doubled pulse in a non-collinear configuration. A intensity of the third-order frequency pulse generated in the crystal is measured by the photomultiplier tube (R759, Hamamatsu Inc.) after passing through the 3 dichroic mirrors, a grating (1200 /mm) and band a pass filter whose center wavelength of266 nm. Finally, the PMT signals is displayed and analyzed with a 2 GHz oscilloscope and personal computer.

3. Experimental results

Figure 2 (solid line) shows measured temporal contrast of JLITE-X with 4 ch line with the dynamic range of ~10^{-9}. The contrast ratio ASE level at 100 ps before the main pulse is 10^{7}~10^{8}. Some spikes at 5 ps and 10 ps are identified as the artifacts caused by beam splitters of 1 mmt in the optical pass of MCCC.

Figure 2 shows temporal contrast measured in a single shot mode. Each delay setting is attributed to Shot 1: $t_{1ch\sim4ch}$ =0 ps, -5.5 ps, -11 ps, -100 ps, Shot 2: $t_{1ch\sim4ch}$ =0 ps, -1 ps, -2 ps, -3 ps. The measured contrast by the single shot mode is consistent with that measured by the scanning mode.

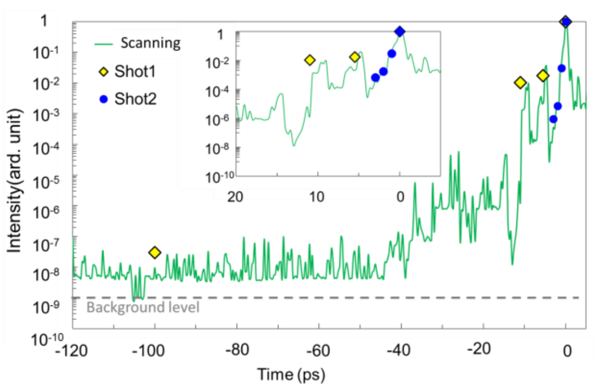

Fig.2. Temporal contrast measurement of J-LITE X laser with MCCC. Shot 1: $t_{1ch\sim4ch}$ =0, -5.5, -11, -100 ps, Shot 2: $t_{1ch\sim4ch}$ =0, -1, -2, -3 ps.

4. Conclusion

The temporal contrast measurement is very important because the generated pre-plasma by the pre-pulses or pedestals have strong influence on the laser-plasma interaction. To measure the temporal contrast of the laser pulses in a single shot mode, we firstly, demonstrated the multi-channel cross-corelator (MCCC) for temporal contrast ratio in single shot measurement. With the 4 channels and independent delay lines. We can measure the intensity of the pre-pulses, which most probably produce pre-formed plasma before the arrival of the main pulse. Moreover, by using the information of pre-pulse, hydrodynamic simulations enables to characterize a profile of density [6] of the pre-plasma. Currently, the continuous efforts to reduce the optical noise and to increase input laser fluence would bring us the successful measurement of the laser contrast of >10^{12} level for the high intensity laser pulses of >10^{21} W/cm^2 [7].

Acknowledgments

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