백색광 간섭계를 이용한 광학소자의 군지연분산 측정
Measurement of the group-delay dispersion of optical elements using white-light interferometry

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The characterization of laser mirrors is important for obtaining proper performance of femtosecond lasers. Characteristics of laser mirrors are usually described in terms of their reflectivity at a certain wavelength. In femtosecond laser applications, however, the dispersion property of the mirror should be considered because the temporal shape of a femtosecond light pulse changes during the reflection at the mirrors. To analyze and balance the dispersive effects of the optical elements on the intra/extra-cavity of laser oscillators, an accurate measurement system is first of all required. Most approaches for the measurement of the group-delay dispersion (GDD) of optical elements have been based on a white-light interferometer that contains the dispersive element in one arm, keeping the other are as a reference. The cross-correlation pattern reveals the wavelength-dependent optical path difference between the two arm.(1, 2) In this presentation, we measured the dispersion characteristics of various optical elements using a compact white-light interferometer. We enhanced the performance in terms signal to noise ratio and discussed the detector dependence of the measured GDD.

If $E_i(t)$ is the electric field of incident light, the electric field of the transmitted (through the test arm containing a sample) light $E_i(t)$ becomes(2)

$$E_i(t) = \int_{-\infty}^{\infty} dt' h(t-t') E_i(t'), \tag{1}$$

where $h(t)$ is the response function of the sample. Fourier transform of the above function is

$$\tilde{h}(w) = \tilde{E_t}(w)/\tilde{E_i}(w). \tag{2}$$

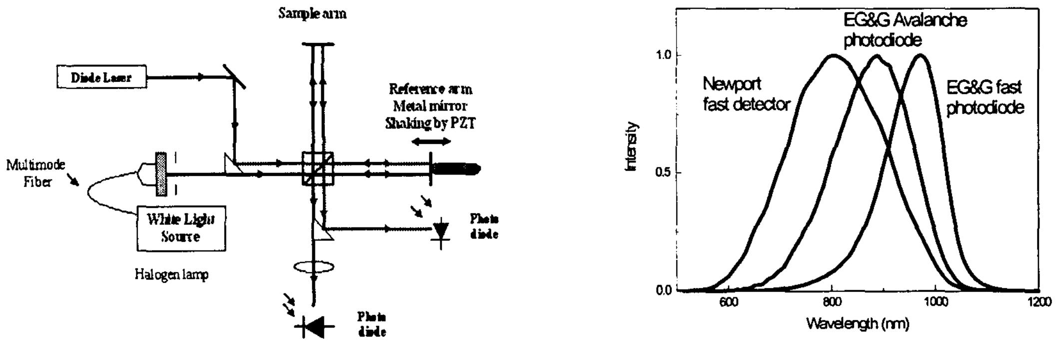
We measured two kinds of interferograms: one is the autocorrelation $C_A(\tau)$ of the input light and the other is cross-correlation $C_C(\tau)$ between the lights from the reference and the sample mirrors, i.e.,

$$C_C(\tau) = \int_{-\infty}^{\infty} d\tau' h(\tau-\tau') C_A(\tau') \tag{3}$$

$$\tilde{h}(w) = \tilde{C_C}(w)/\tilde{C_A}(w) \tag{4}$$

The phase difference between $C_C(\tau)$ and $C_A(\tau)$ corresponds to the phase of $\tilde{h}(w)$, allowing the measurement of the group delay (GD) and the group-delay dispersion (GDD) of the sample. A noise-free experiment is important because a small noise can be magnified during this process.

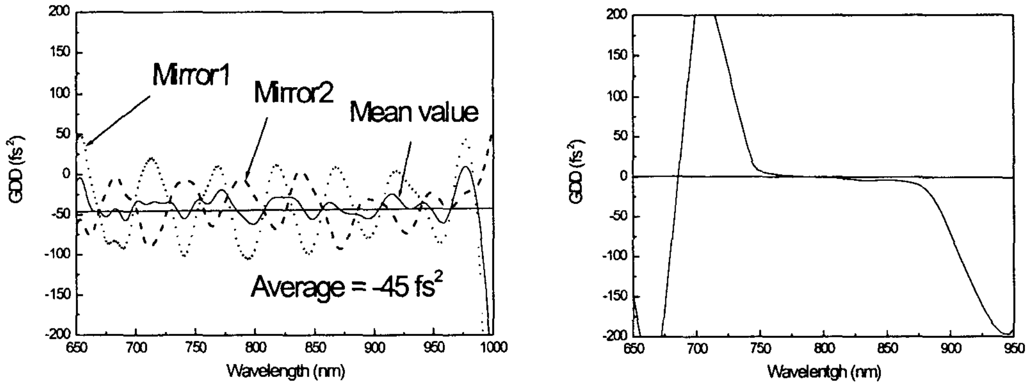
We set up a typical Michelson-type white-light interferometer as illustrated in Fig. 1. One mirror was driven on a piezo-translator (PZT) and a diode-laser (wavelength=651nm)-based distance calibration was used. We tested different silicon detectors (EG&G fast photodiode, Newport fast photodetector, EG&G Avalanche photodiode) to find out the detector dependence of our measurement. To reduce the experimental noise induced by detectors, we used an averaging method by synchronizing the interferometric signal to the PZT-driving voltage signal. This method significantly enhanced the fringe visibility especially in the low-intensity region. The autocorrelation signal without the test optical elements was first obtained to calculate the phase distortion by the reference metal mirror, and then the cross-correlation trace was measured. The GDD was explicitly calculated from the phase of the measured cross-correlation trace.



(a) (b)

Fig. 1 (a) Optical setup (b) Comparison of optical spectra for all theof three detectors.

We characterized a pair of chirped mirrors, which are the most important dispersion-compensating elements for the generation of sub-10-fs pulses due to the negative dispersion characteristics in broad band.[3] The measured GDD, shown in Fig. 2(a), was in good agreement to the data offered by the manufacturer (Layertec, Inc.). We also characterized the broadband femtosecond laser mirrors, manufactured by Newport and by CVI, and a thin glass block. The measured GDD of a TLM2 mirror (CVI) is shown in Fig. 2(b). The zero dispersion around 800 nm is consistent to the characteristics of the femtosecond broadband mirror. The other results also have a good match to the prediction. The dependence of detector has been observed as shown in Fig. 1(b), wherein the used white-light source covers the spectrum from 500 nm to 1200 nm and is centered at 900 nm. The Newport fast photodetector whose spectral sensitivity was maximum at 800 nm was the most suitable for the characterization of femtosecond optics based on Ti:sapphire lasers. The GDD measurements of the chirped mirrors also showed that the result using Newport fast photodetector had minimal noises.



(a) (b)

Fig. 2 Group delay dispersion curves of chirp mirrors (a) and a CVI TLM2 mirror (b).

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