Femtosecond phase spectroscopy for wave packet detection

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Processing the optical phase information is one of the challenging technologies to realize ultrafast massive data transmission in the twenty-first century. We proposed "wave-packet engineering", where optical phase information of femtosecond pulses is transferred to that of electronic wave packets in semiconductor devices, processed by means of nonlinear interference, and converted back to the phase modulated pulses. This paper presents novel ways to measure amplitude and phase change of femtosecond pulses through a device material by means of a Sagnac interferometer (SI) and cross-correlation Frequency Resolved Optical Gating (XFROG).

We adopted a Sagnac interferometer configuration, which is one of the common-path interferometers. Figure 1(a) shows the experimental setup of SI. The time course at the sample of excitation, reference, and probe pulses is also depicted in Fig.1(b). The reference pulse arrives at the sample first, and the excitation pulse causes the refractive index change. The probe pulse propagates through the sample, which detects the refractive index change caused by the excitation pulse. Reference and probe pulses travel in the opposite direction in the SI, and these two pulses get out of SI coincidentally. Hence, spatial fringes can be observed between the probe and reference pulses.

When the excitation induces refractive index change, resultant phase shift in the probe pulse spatially shifts the maximum peak position of the interference fringe. On the other hand, when the absorption changes, the peak intensity becomes reduced. Thus it is possible to deduce the phase-shift and absorption-change from the fringe shift and visibility change, respectively. By scanning the temporal delay between the probe and excitation pulses, time dependence of the nonlinear refractive index change can be measured.

The XFROG is a cross-correlation measurement between test and reference pulses, where the test pulse is transmitted through or reflected on a sample. Figure 2 shows the schematic diagram of the experimental setup of the XFROG. The spectrum and phase dispersion of the reference pulse is characterized beforehand. The spectrum of the sum frequency signal between the test and reference pulses is measured using a spectrometer as a function of the time delay of the one with respect to the other. Even if the test pulse has the reduced amplitude due to the absorption of the sample, the nonlinear signal can be easily detected, because the reference pulse has an intensity large enough for the sum frequency generation.

We measured the phase and amplitude change of femtosecond pulses reflected on a dielectric interference filter by XFROG. The advantage of the method is to obtain the phase and amplitude spectra from one experimental trace. The interference filter is originally designed for band-pass centered at 800 nm. The measured spectrum is in good agreement with that obtained by the ordinary reflectance measurement. The dispersion spectrum is also successfully determined, and the amplitude and phase spectra is found to satisfy the Kramers-Kronig relation.

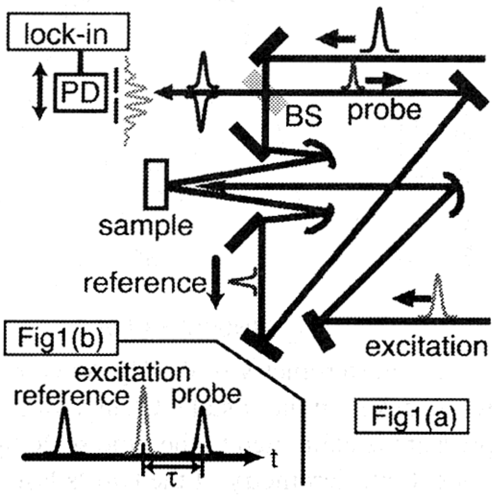

Fig.1: Experimetnal setup of SI

[1] T. Nagana, K. Misawa, and R. Lang, Abstracts of International Workshop on FST 2001, p.184 (2001).
[2] S. Itoh, K. Misawa, and R. Lang, Abstracts of International Workshop on FST 2001, p.185 (2001).

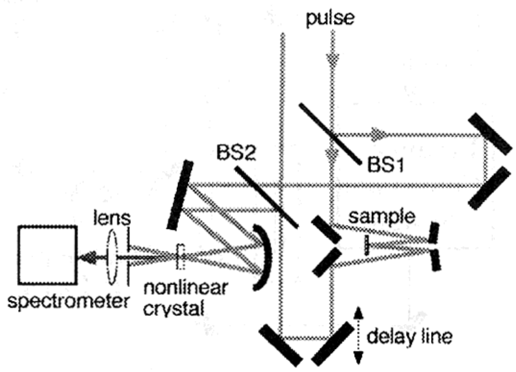

Fig.2: Experimetnal setup of XFROG