Plasma Mirror Frequency-Resolved Optical Gating in Vacuum Ultraviolet Wavelength Region

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Abstracts: *We demonstrate that the methodology of frequency-resolved optical gating (FROG) is applicable to time-resolved reflection spectroscopy of a plasma mirror in the vacuum-ultraviolet (VUV) region. A VUV waveform and a time-dependent reflectivity in the VUV region are simultaneously retrieved from a VUV reflection spectrogram of a plasma mirror formed on a fused silica surface by an intense femtosecond laser pulse. The present method enables us to fully characterize a significantly chirped VUV pulse whose duration is as long as 1 ps.*

Ultrashort light sources in the short wavelength region from vacuum ultraviolet (VUV) to hard X-ray have been rapidly developed based on free-electron laser and high-order harmonic generation (HHG). The characterization of VUV pulses is still difficult owing to the lack of efficient nonlinear optical material. In this study, we utilize a plasma mirror as an ultrafast optical switch in the VUV region ($\lambda \sim$ 160 nm). The plasma mirror is formed on a fused silica surface by an intense fs laser pulse (795 nm, 60 fs, ~ 3.3 J cm^{-2}) and time-resolved VUV reflection spectra of the plasma has been measured [1].

Figure 1(a) shows the time-resolved reflection spectra, which are regarded as a FROG trace. We call the present method plasma-mirror FROG (PM-FROG). Using the least-square generalized projections algorithm [2], the PM-FROG trace can be retrieved as shown in Fig. 1(b). The temporal VUV waveform is obtained as shown in Fig. 1(c). The VUV pulse is found to be significantly chirped, reflecting the group delay dispersion caused by the transmission of a lithium fluoride (LiF) lens. It should be noted that the time-dependent reflectivity caused by the plasma formation can be retrieved simultaneously without any model function.

PM-FROG has advantages that (i) the applicable wavelength is extended to the shorter wavelength region where there are no transmission material, (ii) neither carrier envelope phase stabilization of laser pulses nor sufficient intensity of VUV pulses for a nonlinear process is required, and (iii) the VUV optical measurement is used in place of the photoelectron measurement, which is usually used in other methods.

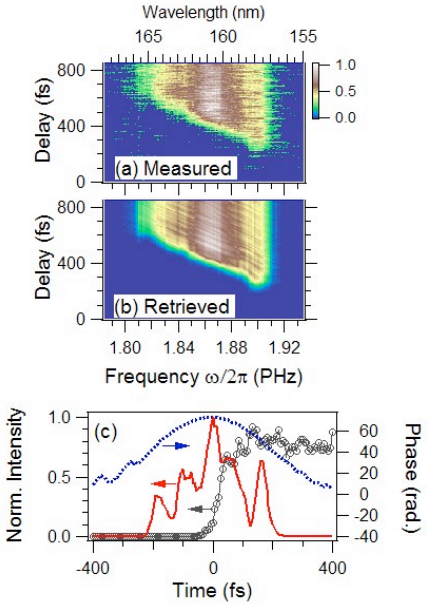

Fig. 1 (a) Measured PM-FROG trace. (b) Retrieved PM-FROG trace. (c) Retrieved temporal intensity (solid) and phase (dotted) of the VUV pulse, and time-dependent reflectivity of the plasma mirror (circle).

[1] R. Itakura, T. Kumada, M. Nakano, and H. Akagi, Opt. Express, **23** (2015) 10914.
[2] J. Gagnon, E. Goulielmakis, and V. S. Yakovlev, Appl. Phys. B **92** (2008) 25.