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White light probe system of solid state irradiated by EUV free electron laser

EUV自由電子レーザー照射固体状態の白色光観測システム

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Recent development of X-ray and EUV free electron laser makes it possible to achieve high density inner shell excitation in the condensed matter. Some nonlinear optical phenomena is observed in Japan and Europe facilities. However, these experiments use only single EUV or X-ray laser pulse so that it is very difficult to understand the detail dynamics. For this purpose femtosecond white light probe system is prepared and EUV-pump and white-light-probe experiments are done in SCSS EUV line. The preliminary results denote that atomic polarizability dominates electron one just after the illumination of EUV light.

1. Introduction

Extreme Ultraviolet (EUV) interacts with inner shell electron, because frequency of EUV is higher than resonant frequency of free electron in the metal. Recently high intensity EUV generated from free electron laser (FEL) induces some nonlinear optical phenomena [1]. It is considered that high energy shift of the absorption edge with change of electron energy level is induced because most of atomic inner shell electrons are excited keeping solid density. However detailed physics is not to understand.

2. System

We prepare EUV-pump white-light-probe system with the use of ultra-wideband white light pulse (Fig.1) synchronized with EUV-Free electron laser. As shown Fig.2: white light generated from 800nm femtosecond laser and sapphire crystal irradiate thin film target evaporated on fused silica at an incidence angle of 60 degrees. White pulse is reflected on the target surface. Finally probe light is observed with a polarization and vertical resolved spectrometer. Jitter of the probe pulse is about

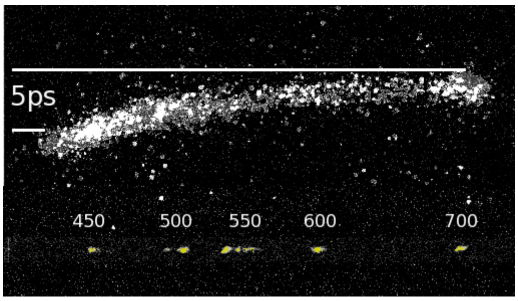

Fig.1 White pulse profile by streak camera

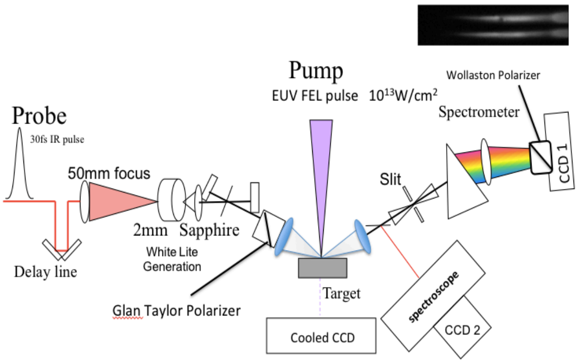

Fig. 2 Experimental system

200fs because of electrical synchronization. Generated white pulse has group delay of 5ps between 450nm and 700nm as shown in Fig.1.

The chirped probe pulse is overlapped a 100fs-EUV pulse.

3. Result and discussion

One of the typical observation data is shown in Fig.3 We find to change reflection intensity from result. Looking after the EUV shot on Fig.3, p polarization reflectivity decrease and s polarization reflectivity increase. we observed reflection intensity decrease longer than 550nm, on the other hand increase shorter less than 550nm. This phenomenon cannot explain carrier increasing with inner shell electron excitation and rise of temperature to be explained by the Drude model written

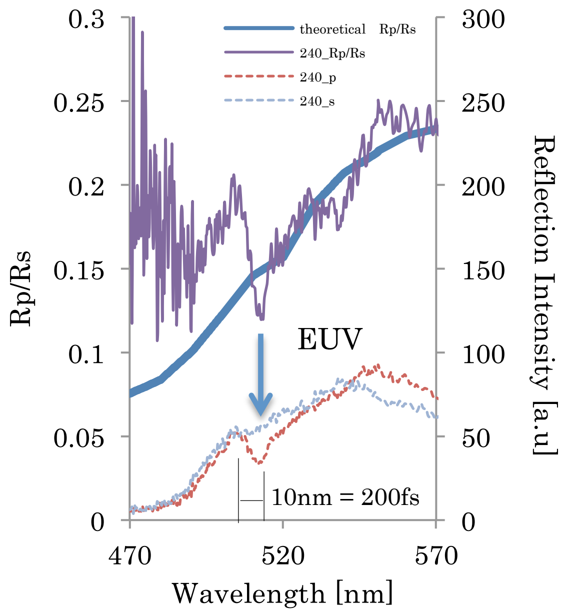

Fig. 3 Au 10.2 nm film target reflection intensity changed by EUV-FEL. Blue line is Calculate Rp/Rs. Purple line is actual measured Rs/Rp. Red dashed line is reflection intensity of p polarization. Red dashed line is reflection intensity of p polarization.

Table.1 Comparison Drude model at λ =510nm

	n	k	Rp/Rs	Rp	Rs
Cold	0.706	2.031	0.139	0.052	0.370
γ +20%	0.873	1.936	0.114	0.042	0.367
ω_c^2+20%	0.644	2.264	0.161	0.064	0.399
ω_c^2, γ +20%	0.803	2.161	0.135	0.053	0.392

	ε_{re}	ε_{im}	$\omega_c^2/(\omega^2+\gamma^2)$	γ/ω
Cold	-3.625	2.868	4.625	0.620
γ +20%	-2.986	3.381	3.986	0.848
ω_c^2+20%	-4.713	2.915	5.713	0.510
ω_c^2, γ +20%	-4.026	3.472	5.026	0.691

in Formula (1) to be indicative Table.1

$$\hat{n} = n - ik$$

$$\mathrm{Re}\cdot \hat{\varepsilon}(\omega) \equiv n^2 - k^2$$

$$\mathrm{Im}\cdot \hat{\varepsilon}(\omega) \equiv 2nk$$

$$\hat{\varepsilon} = \hat{n}^2 = 1 + \frac{i\sigma}{\varepsilon_0 \omega} = 1 - \frac{Ne^2}{m\varepsilon_0}\frac{1}{\omega(\omega + i\gamma)}$$

$$= 1 - \frac{\omega_c^2}{(\omega^2+\gamma^2)} + i\frac{\omega_c^2}{(\omega^2+\gamma^2)}\frac{\gamma}{\omega} \quad (1)$$

4. Conclusion

We are assuming that Reflection intensity change effect atomic susceptibility instead of increase free electrons.

[1] H. Yoneda Optics Express. Vol. 17 Issue 26, pp.23443-23448 (2009)