Development of half-cycle terahertz and mid-infrared pulses for Lightwave-driven STM

Y. Arashida, N. Umeda, A. Takamatsu, S. Kayano, H. Mogi, S. Yoshida, O. Takeuchi, and H. Shigekawa

Institute of Pure and Applied Sciences, University of Tsukuba, Tsukuba 305-8573, Japan

Recent progress of coherent terahertz (THz) wave has opened to study various exotic fundamental excitations such as excitons, phonons, polarons, charge density waves, superconducting quasi-particles, etc, in ultrafast temporal regime [1,2,3]. Especially, new features induced by electric-field-driven excitation of these states have intensively studied. Microscopic understanding of these phenomena is quite important because electron scattering is influenced by atomic scale fluctuation of potentials. We have developed lightwave-driven scanning tunneling microscopy (STM) with the temporal resolution of 29 fs using mid-infrared pulses [4]. In this time, we succeeded in developing terahertz pulses in the UHV chamber for exciting field-driven quasi particles.

We used light source of a high repetition (4 MHz) optical parametric chirped pulse amplifier (OPCPA) which has two optical outputs. One is called as NIR1 with the wavelength λ range from 680 nm to 940 nm, pulse duration Δt of 8.1 fs, pulse energy P of 1 μJ, which was used for generating half-cycle mid-infrared pulses that is probe pulses [4]. The other is called as NIR2 with the λ of 1032 nm, Δt of 324 fs, and P of 5 μJ, used for generating THz pulses by tilted pulse front method [5]. We combined these two beams with coaxial geometry and focus them into a UHV-STM via a parabolic mirror with 15 mm focal length. We put a photoconductive antenna (PCA) to measure the waveform of the MIR and THz in the vacuum chamber as shown in Fig. 1a. We succeeded in measuring the waveform of the MIR and THz simultaneously as shown in Fig. 1b. Half-cycle MIR appears in the THz oscillation. The delay time between the MIR and THz ($\tau_{\mathrm{MIR\text{-}THz}}$) can be tuned so that we can measure THz-phase-sensitive phenomena. This technique is expected to reveal atomic scale ultrafast phenomena.

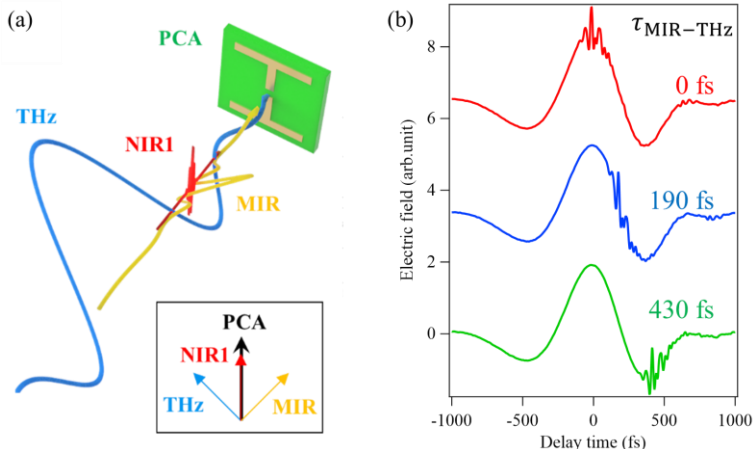

Fig. 1, a, waveform measurements of MIR and THz waves using a PCA. b, waveforms of MIR and THz in an UHV-STM.

References:

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