Probing Ultrafast Coherent Phonon Dynamics with Optical Pump-probe Scanning Tunneling Microscopy

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The optically excited coherent phonon dynamics on semiconductor materials, has always been an hot issue both experimentally and theoretically. On the other hand, coherent phonon dynamics in GaAs with specific nanostructures can be very useful for the applications to emitter or detector of terahertz waves. In this study, we developed an Optical Pump-probe Scanning Tunneling Microscopy (OPP-STM) for investigation of coherent phonon dynamics, with ultimate temporal (50 fs) and spatial (<100 nm) resolution.

As is known, coherent phonons in semiconductor with some specific oscillation modes change the refractive index of the material and, as a result, its optical reflectivity. Consequently, measurement of the optical reflectivity or absorbance of the semiconductor with time-resolved techniques reveals the real-time evolution of the amplitudes, as well as the phases of coherent phonons. On top of that, we have also shown that the ultrafast time evolution of optical absorbance of a semiconductor can be investigated by our OPP-STM with nanometer spatial resolution due to the change in the density of optically-excited carriers that affects the tunneling current.

The sample was GaAs (110). The femtosecond laser pulse trains were divided into two different optical paths, to be the pump pulses and probe pulses, respectively, with a novel delay time modulation method. Then, pulses were tightly focused on the sample under STM, the pump pulse generated the coherent phonons, and the amount of photo-carriers generated by the second pulse (probe pulse) was measured by the STM with varying the delay time between the two pulses. Basic experimental setting and part of the obtained results are shown in figure 1, more details will be given in the presentation.

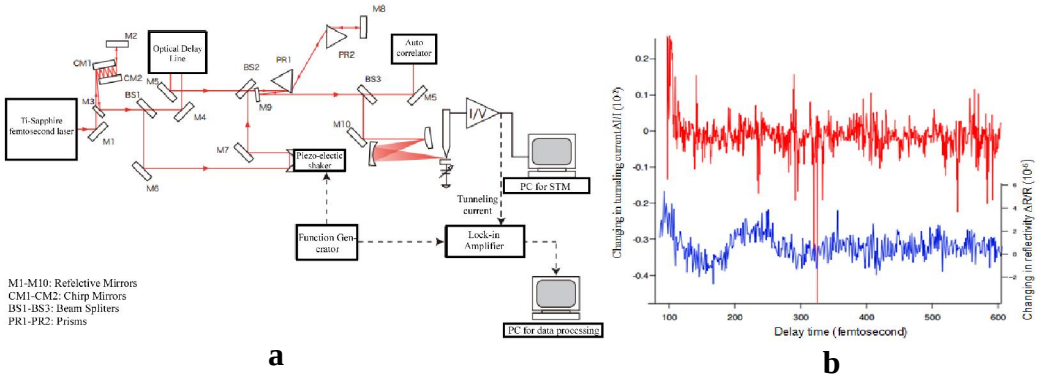

Fig. 1 (a) The basic schematic of OPP-STM experimental setup. (b) Sample: GaAs (110), red curve: the OPP-STM spectra of coherent phonon signal with sample bias voltage V_b =1.0V, tunneling current I_t = 100pA; blue curve: the optical pump-probe reflectivity spectra of coherent phonon signal.

Reference:

1. O. Takeuchi et al., Probing subpicosecond dynamics using pulsed laser combined scanning tunneling microscopy, *Appl. Phys. Lett.* **Vol. 85(15),** 3268-3270, 2004