Ultrafast Dynamics of Coherent Phonon Probed by Optical Pump-probe Scanning Tunneling Microscopy

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The optically excited coherent phonon dynamics on semiconductor materials, has been studied both experimentally and theoretically in past decades, exploring the quantum mechanical behaviors of the collective atomic motions as well as the possible applications to emitter or detector of terahertz waves. In this study, We applied an Optical Pump-probe Scanning Tunneling Microscopy (OPP-STM) to the investigation of coherent phonon dynamics, with ultimate temporal (~50fs) and spatial(<100nm) resolution.

It has been known that, optical reflectivity of a semiconductor changes with the oscillation of some modes of coherent phonons. Consequently, measurement of optical reflectivity or absorbance of the semiconductor with ultrafast time resolution reveals the real-time evolution of the amplitudes and phases of coherent phonons. Meanwhile, we have shown that the ultrafast time evolution of optical absorbance of a semiconductor can be investigated by an OPP-STM with nanometer spatial resolution via the change in the density of optically-excited carriers that affects the tunneling current. We had to have, however, improve the temporal resolution and sensitivity, as well as the signal to noise ratio, of the system in order to probe the coherent phonon dynamics in this study.

The sample was GaAs(110). The ultrafast femtosecond laser pulse trains (center wavelength at 800nm, repetition rate at 80MHz, average power 4.5mW) were divided into two different 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 in an ultra-high-vacuum chamber, 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, with carefully designed optical system, the pulse width was kept as short as ~35fs, which is enough to probe the phonons in GaAs. Basic experimental setting and part of the obtained results are shown in figure 1 below, more details will be given in the presentation.

a **b**

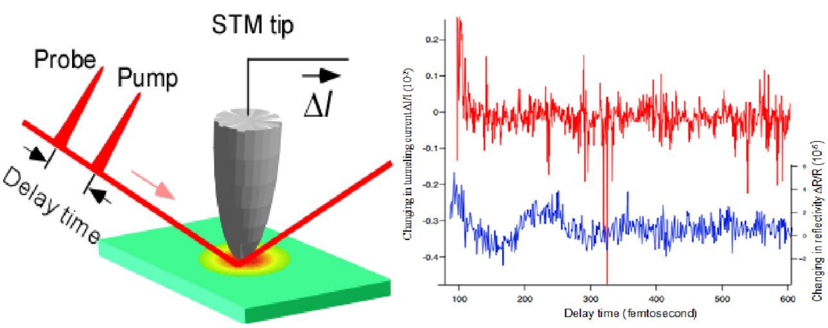

Figure 1 **(a)** The basic schematic of OPP-STM experimental setup. **(b)** Sample: GaAs (110), red curve: the OPP-STM spectra of coherent phonon signal with sample bias voltage V_b=1.0V, tunneling current I_t=100pA; blue curve: the optical pump-probe reflectivity spectra of coherent phonon signal.