Development of time resolved THz-STM

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Recently, THz-STM [1-4] has attracted much attention as a novel technique to probe ultrafast dynamics of photo-induced phenomena with atomic scale spatial resolution. Carrier relaxation dynamics of single InAs quantum dot[1] and vibrational motion of single pentacene molecule[2] have been measured by the technique. In this study, we have developed time resolved THz-STM by combining low temperature UHV-STM system with THz optical system. We employed industrial fs pulse laser (Monaco, Coherent Inc, f_{rep} < 1MHz E_{max} < 40uJ) to obtain intense THz pulse train with high repetition rate. Intense THz pulses were generated via optical rectification in $LiNbO_3$ crystal. Fig.2 shows electric fields of THz pulse obtained in our system measured by electro optic sampling. A peak electric field of THz pulse was ~10kV/cm, which is sufficient for THz-STM experiments. In THz-STM, THz pulse induces transient voltage across STM tunneling junction (V_{THz}) which drives ultrafast tunnel current (I_{THz}), we can use I_{THz} to probe ultrafast dynamics of the sample with the ps time resolution. Fig.3 shows THz driven STM image of graphite surface under zero DC bias voltage. Since only the time averaged I_{THz} (= 3pA) was used to image the topographic image, atomically resolved image demonstrates the high spatial resolution of THz-STM. In addition, ps time resolution was confirmed in optical pump THz probe spectroscopy of 1T-TaS_2 and GaAs(110) surface.

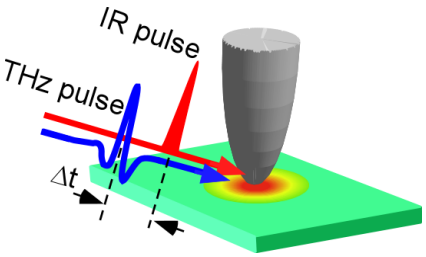

Fig. 1. schematics of THz-STM

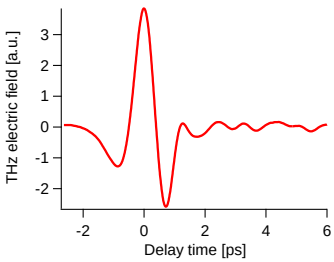

Fig. 2. THz electric field waveform

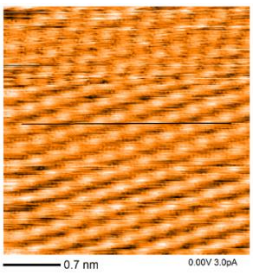

Fig 3. THz-driven STM image of graphite surface (V_{DC} : 0V, I_{THz} : 3pA)

[1] Tyler L. Cocker, et al: Nature photonics7, 620–625 (2013) [2] Tyler L. Cocker,et al: Nature 539, 263–267 (2016)

[3] Katumasa Yoshioka, et al: Nature Photonics 10, 762-765 (2016)

[4] Vedran Jelic, et al: Nature Physics 13, 591–598 (2017)