Removal of interference artifact in time-resolved STM by means of precise phase control of laser pulses

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In order to explore the transient dynamics in organized nanostructures, we recently developed shaken-pulse-pair-excited STM (SPPX-STM)[1], in which the tunnel junction is illuminated by a sequence of ultrashort laser pulse pairs; while the delay time between the two pulses in the pairs is periodically modulated, the response in tunnel current is detected by a lock-in amplifier. By SPPX-STM, we have visualized carrier dynamics in semiconductors at 10^{-9}~10^{-12} s time scales [2].

However, the method suffered from large fluctuation of exciting laser intensity when the delay time crosses over zero because of the interference of pump and probe laser pulses. It encompasses expansion and contraction of STM tip, resulting in considerable artifact in time-resolved signals.

To eliminate the interference artifact, we here present a new method which precisely modulates the phase of exciting laser pulses by electro-optic phase modulator (EOM). In this method, pump and probe pulses are aligned on a same axis with having orthogonal polarization to each other. Then, they are introduced into the EOM device, with which the relative phase of the two pulses is periodically shifted exactly by half wavelength at a high frequency ~100 kHz.[Fig.1] This phase sifting causes inversion of the laser interference at so high frequency that the time-averaged laser intensity which the STM tip experiences becomes almost constant [Fig.2].

Adopting this method, we could eliminate the interference artifact on the tunnel current. Consequently, the time-resolved STM measurement became applicable to shorter time scale physics.

[1] O. Takeuchi et al., Appl. Phys. Lett. 85, 3268 (2004).
[2] Y. Terada et al., Nature Photonics, 4, 869 (2010).

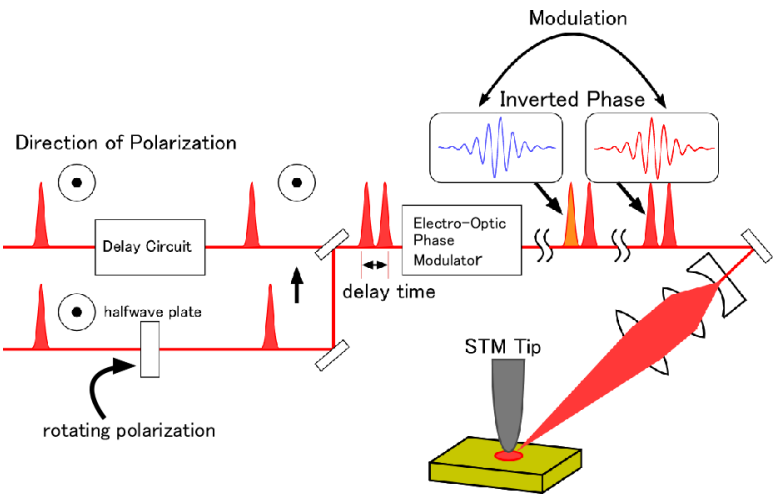

Fig.1 schematic of phase shift system

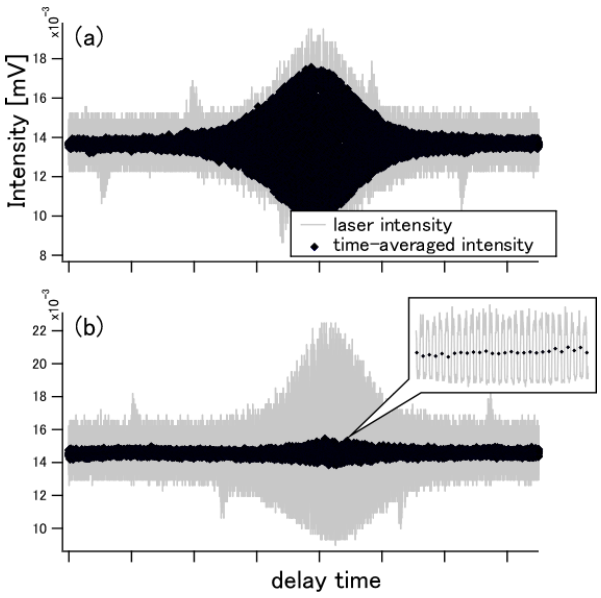

Fig.2 (a)fluctuation of laser intensity(b) with phase modulation by EOM