# Generation of high-repetition sub-cycle mid-infrared pulses for ultrafast time-resolved STM

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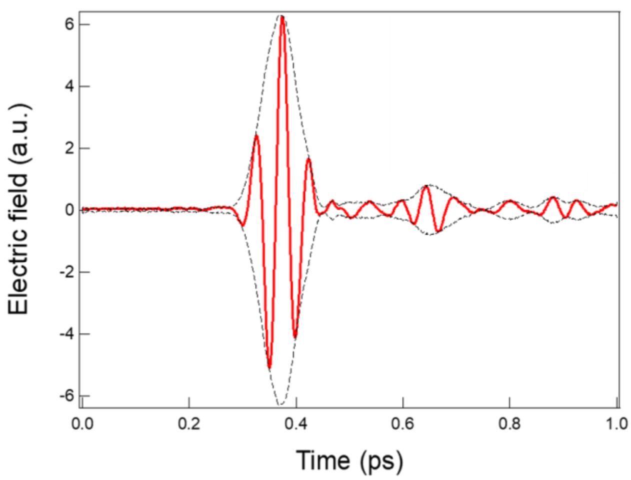
Combination of phase-controlled sub-cycle terahertz (THz) pulses and scanning tunneling microscopy, called as THz-STM [1-3], have enabled to study exotic surface phenomena with sub-picosecond (ps) temporal resolution and atomic resolution. Recent development of femtosecond (fs) laser technology has reported generation of intense mid-infrared (MIR) pulses. One can achieve dramatically improvement of the time-resolution of STM, reaching to several ten fs, by using MIR pulses than THz pulses. For example, it becomes possible to observe and manipulate intramolecular vibration, lattice vibration, and charge transfer by the MIR-STM. To do so, there are several technical requirements on MIR pulses listed below. (a) broadband sub-cycle pulses with stable carrier-envelop phase. (b) High peak electric field which can induce tunneling for electrons at tunnel junctions. (c) High repetition frequency to achieve sufficient signal-to-noise ratio (SN). In this study, we succeeded in generating intense and high repetition sub-cycle MIR pulses, which satisfy the all requirement above, using an optical parametric chirped pulse amplifier (OPCPA) as fundamental light. The OPCPA has 8.2 fs of the pulse duration, 4 MHz of the repetition frequency, 4.3 W of the average power, 660nm to 940 nm of the wavelength range. To generate MIR, we utilized optical rectification of type I phase matching by using a GaSe crystal with the thickness of 20 μm. Figure 1 shows the waveform of the MIR pulses measured by electro-optic sampling using a GaSe crystal. The pulse duration of the envelop of the electric field is 31 fs. We can confirm 0.85 cycle MIR pulses because the bandwidth is 27 THz. The peak field is 190 kV/cm which is sufficient to drive electron tunneling. In addition, the CEP is very stable so that the fluctuation was 48 mrad for 5.6 hours. These features are ideal for lightwave-driven STM. [5]




References:
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