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Ultrafast field-driven transport excited by high-repetition, quasi-single cycle light pulses with electrooptic timing modulation

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Field-induced electronic transport in solids driven by phase locked laser pulses allows the investigation of spatiotemporal properties in condensed matter system at ultrafast timescales in the femto- to even attosecond ranges. It thus started to attract great attention in recent years, especially from the context of realizing nanoscale imaging of the electronic wavepackets by combining scanning microscopy with ultrafast light pulses [1]. In such experiments, MHz repetition rate is preferred to avoid special charge and saturation effects, in contrast to the traditional high-field experiments such as high-harmonics generation wherein kHz laser repetition rates are typically used. Under such high repetition rates, how to modulate the pump pulse becomes critically important. The intensity modulation, as conventionally used for the optical pump-probe experiments, lacks sensitivity because e.g. thermal offset signals lasting beyond the intrapulse distance contaminate the relevant ultrafast dynamics occurring at much shorter time scales.

To overcome this problem, we introduced a technique called timing modulation scheme [2] and incorporated it into a 40 MHz EDF-based, phase-stable single-cycle light source [3]. In this scheme, the arrival timing of the pump pulse is electrooptically switched either before or after the probe pulse and the difference signal between them is extracted. In parallel, the system delivers passively carrier-envelope-phase locked pulses, with octave-spanning spectrum and pulse duration compressed down to 4.2 fs. As a benchmark demonstration of the system, we show that the developed system is capable of inducing field-induced transport in InGaAs by means of quantum interference current (QIUC), and to record its transient changes induced by the timing-modulated optical pumping. As a result, the decay dynamics of the photoexcited carriers has been successfully resolved, opening route to the possible attosecond transport experiment using near-infrared pulses in future.

References

[1] T. L. Cocker, et *al.*, Nature 539, 263–267 (2016).
[2] C. Traum et *al.*, Rev. Sci. Instrum. 90, 123003 (2019)
[3] C. Schoenfeld, T.K. et *al.*, Opt. Lett., OL 47, 3552–3555 (2022)