Coherent control of two-color above-threshold photoemission from tungsten nanotips

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Synopsis We demonstrate coherently controlled two-color above-threshold photoemission from a single crystal tungsten nanotip. With optimized fundamental and second harmonic intensities near perfect phase contrast can be obtained.

The field enhancement at nanotips promises realization of strong-field physics already at moderate laser intensities. Moreover, as the transverse coherence known from dc field emission persists in photoemission from sharp nanotips, they hold the promise to serve as laser-triggered ultrafast electron source with exceptional beam quality.

While most coherent control studies are performed with gaseous systems or macroscopic surfaces we take advantage of the localized emission from nanotips to achieve near perfect control of the electron emission yield. Since the nanotip is much smaller than the focal spot sizes, we can exclude the influence of the inhomogeneous intensity and phase distribution in the laser focus.

Experimental parameters to control electron emission are the mixing ratio and the relative phase of two-color laser fields. Additionally, the dc field present at the tip to extract emitted electrons from the target region can be used to optimize the photoemission.

Without overlap, adding the second harmonic (780 nm, pulse duration 64 fs; 2ω admixture $< 5\%$) to the fundamental (1560 nm, pulse duration 74 fs; both pulses linearly polarized along the tip axis) does not increase the photocurrent noticeably as compared to electron emission in single-color mode. If the pulses overlap, however, a strong increase of electron emission is observed together with a delay-dependent modulation of the measured photocurrent at the frequency of the second harmonic [1, 2]. Optimizing dc field and mixing ratio a modulation depth of 97.5% could be reached.

Based on density-functional theory calculations we have analyzed the density of states (DOS) at the surface of W(310) surfaces, the facet at the tip apex and with the smallest workfunction for tungsten. Close to an energy corresponding to 4ω above the Fermi energy we find a pronounced maximum in the DOS which serves as a doorway state for photoelectron emission. The modulation of the photocurrent can be related to this maximum in the DOS as it can be reached by two equivalent interfering pathways ($4\times\omega$ or $2\times\omega + 1\times 2\omega$).

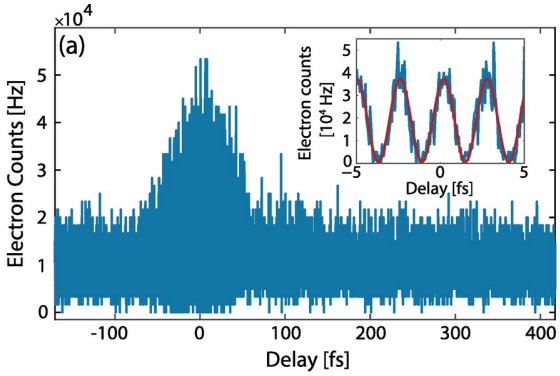

Figure 1. Two-color electron emission from a tungsten nanotip as a function of the delay of fundamental and second harmonic pulses. Depending on the optical phase a dramatic increase or decrease of emission is noticeable in the overlap region (inset).

Coherent control of photoemission from nanotips may in the future allow to use such structures as nanometric probes for light phases. In turn, control of the light phase will pave the way to the generation of femtosecond user-defined electron bunches emitted from nanometric sources.

References

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