Ultrafast laser-induced electron emission from field emission tips

A sub-10 fs optical pulse triggers ultrafast electron emission from a field emission tip.

Waveform sampling concept

(a) Apply RF bias voltage to tip (in addition to DC bias)
(b) Measure energy of the emitted electrons
(c) Reconstruct RF signal

Experimental setup

Titanium Sapphire laser
780 nm, <10 fs pulses
<100 mW to trigger electrons

Energy analysis:
Retarding grid in front of MCP (electron detector)
The electron beam is collimated

For proof-of-principle, RF signal derived from the laser pulse train

Waveform. RF automatically synchronized to laser repetition rate

Fundamental resolution limits

• Voltage resolution
  • Energy spread in emission process ~0.5 - 2.5 eV
  • Demonstrated count rates up to ~103 electrons/pulse

• Time resolution
  • Depending on emission process
    • Multiphoton emission: ~5 - 10 fs
    • Optical field emission: <1 fs
  • Frequency response of the tip

Sampling of a periodic waveform

9.28 GHz sine wave
Derived from 62nd harmonic of frep.
Red points: time step = 22.4 fs
(0.075 degrees)

Arbitrary waveform

A non-linear transmission line (NLTL) is used to generate a complex waveform.
Fundamental: 750 MHz = 5 frep.
The NLTL generates a comb-like spectrum of harmonics of the fundamental.

Future work:

Direct measurement of electron emission profile

Streaking in energy domain could provide a means of characterizing the emitted electron pulses.

Illustration of the concept:
• Two laser pulses trigger electron emission separated by ~ 5 ps
• 9.28 GHz, 6.8 V amplitude sine wave
• "Streaking" at zero crossings: 0.40 V/ps

Ultrafast e-source in a microwave cavity

• Need larger slope at the zero crossing:
  • Larger amplitude (and/or larger frequency)
  • With 20 W amplifier and microwave cavity Q~2500
  • 750 V amplitude signals at ~9.28 GHz
  • 45 mV/fs streaking

• Two pulses
  • 40 mV (<10 fs)
  • Systematic shift of peak position due to line pulling from background
  • "Streaking" at zero crossings: 0.40 V/ps

Two red curves superposed

Positive zero crossing: 4.85 ps
Negative zero crossing: 4.75 ps

Two pulses

Two red curves superposed

Grid potential (V)
Grid potential (V)

Two pulses

Two red curves superposed

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