

# Exact Theory for Pulsed Laser Induced Photoemission from Biased Surface\*

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Photoelectron emission from nanostructures triggered by ultrafast laser fields enables the spatiotemporal control of electron motion in femtosecond and nanometer scales. It is important to ultrafast electron microscopy, free-electron lasers and novel nano-vacuum devices [1-3]. For ultrashort pulsed laser induced photoemission, numerical simulations are typically implemented to study the emission property. Simplified Fowler-Nordheim based models are widely used to calculate the photoemission rate, but it works only in the strong optical field regime. To clearly reveal the underlying physics in different emission regimes, a general theory under ultrashort pulsed condition is highly desirable.

Here, we construct an exact analytical theory for the photoelectron emission from a dc biased surface illuminated by few-cycle laser pulses, by solving the time-dependent Schrödinger equation [4, 5]. The single formulation is valid from photon-driven electron emission in low intensity optical fields to field-driven emission in high intensity optical fields. Our calculations exhibit the coherent interaction of neighboring laser pulses on the photoelectron emission (Fig. 1) and recover the experimentally measured carrier-envelope-phase sensitivity [6] accompanied by a  $\pi$  phase shift in the optical-field regime (Fig. 2). We also find adding a large dc field to the photoemitter is able to greatly enhance the photoemission current and shorten the electron emission pulse.

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## References

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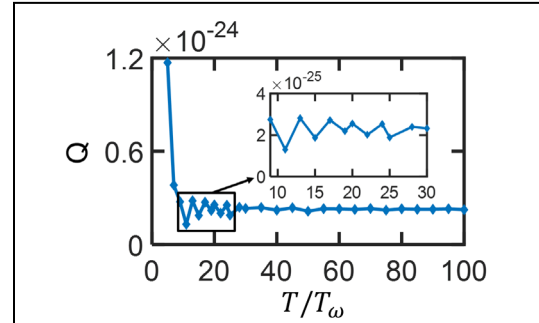


Figure 1 – Total emission charge density  $Q$  per pulse due to a laser pulse train, as a function of the ratio of time separation  $T$  between adjacent laser pulses over the laser period  $T_\omega$ . Here,  $T_\omega$  is fixed as 2.67 fs. The oscillatory behavior of  $Q$  (enlarged in the inset) is due to the coherent interaction between neighboring pulses.

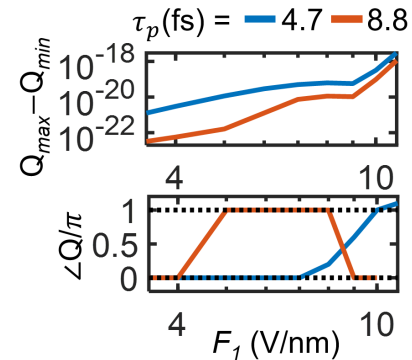


Figure 2 – (a) Magnitude of carrier-envelope phase (CEP) modulation on the total emission charge  $Q_{\max} - Q_{\min}$  as a function of laser field  $F_1$  for different pulse duration  $\tau_p$ ; (b) Phase of CEP modulation on the photoemission charge  $\angle Q$  as a function of  $F_1$  for different  $\tau_p$ .