

CLIC workshop 15.1.29

Optical control of field emission from a tungsten tip

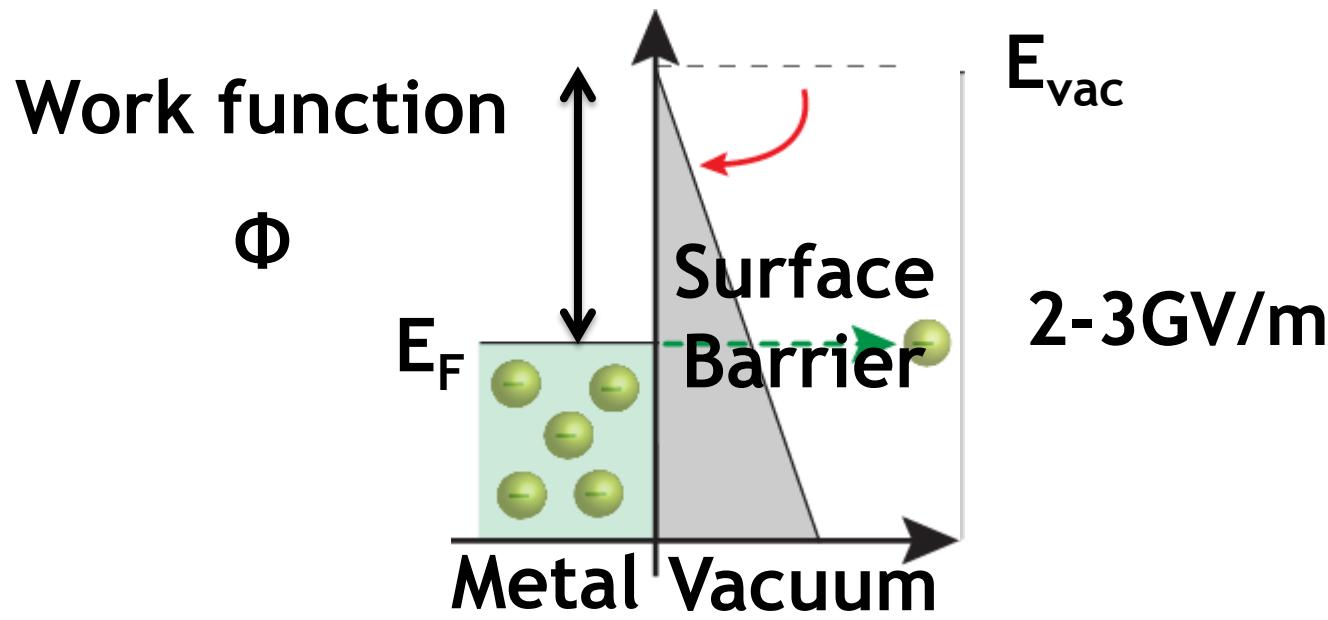
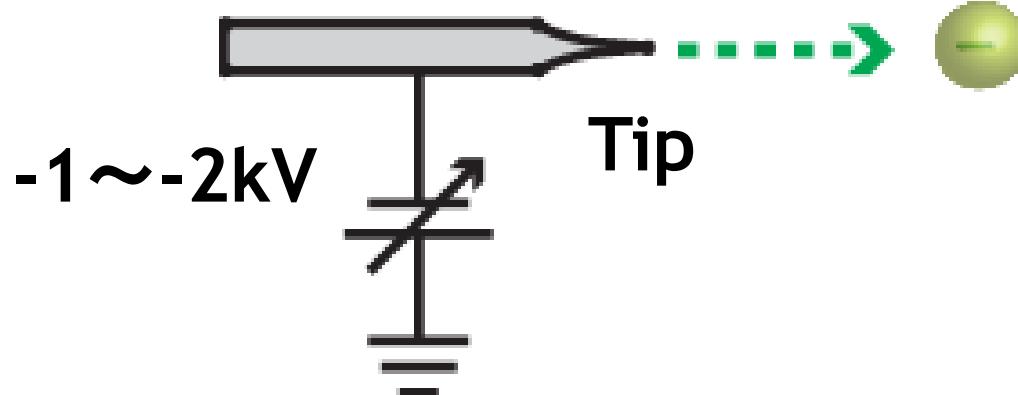
Hirofumi Yanagisawa

ETH Zuerich

Introduction -field emission-

Mesh Grid

Nanometer sharpness



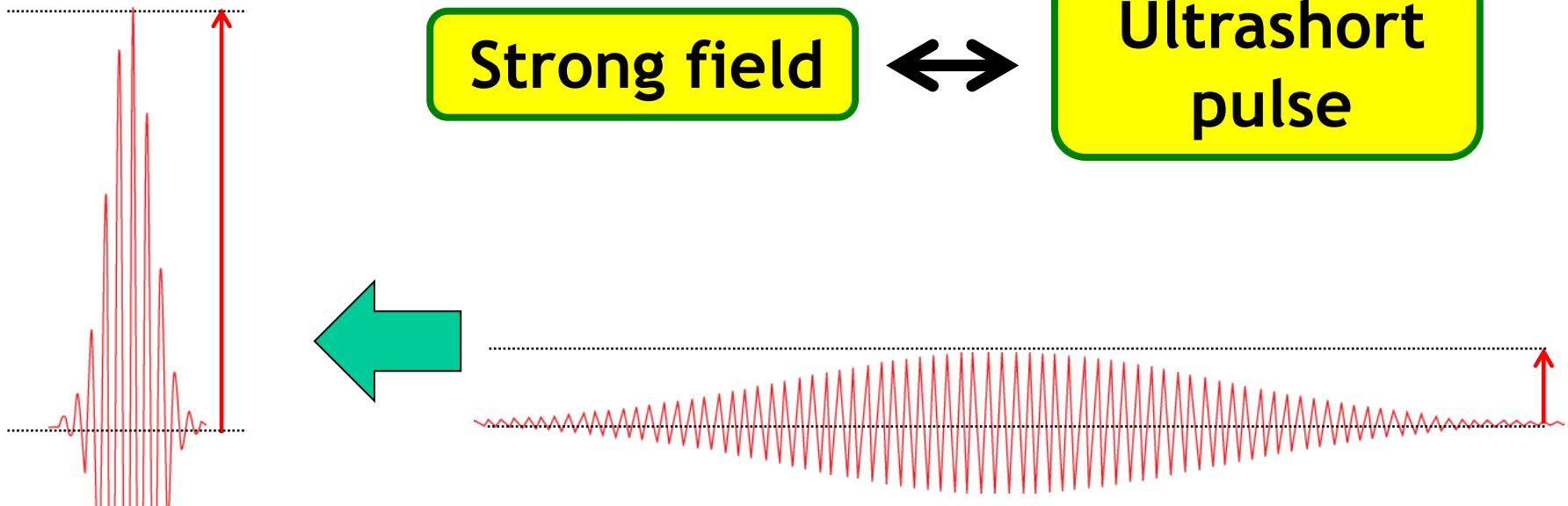
Introduction2 -Ultrafast science-

Sub 10

femtosecond

Strong field

Ultrashort
pulse

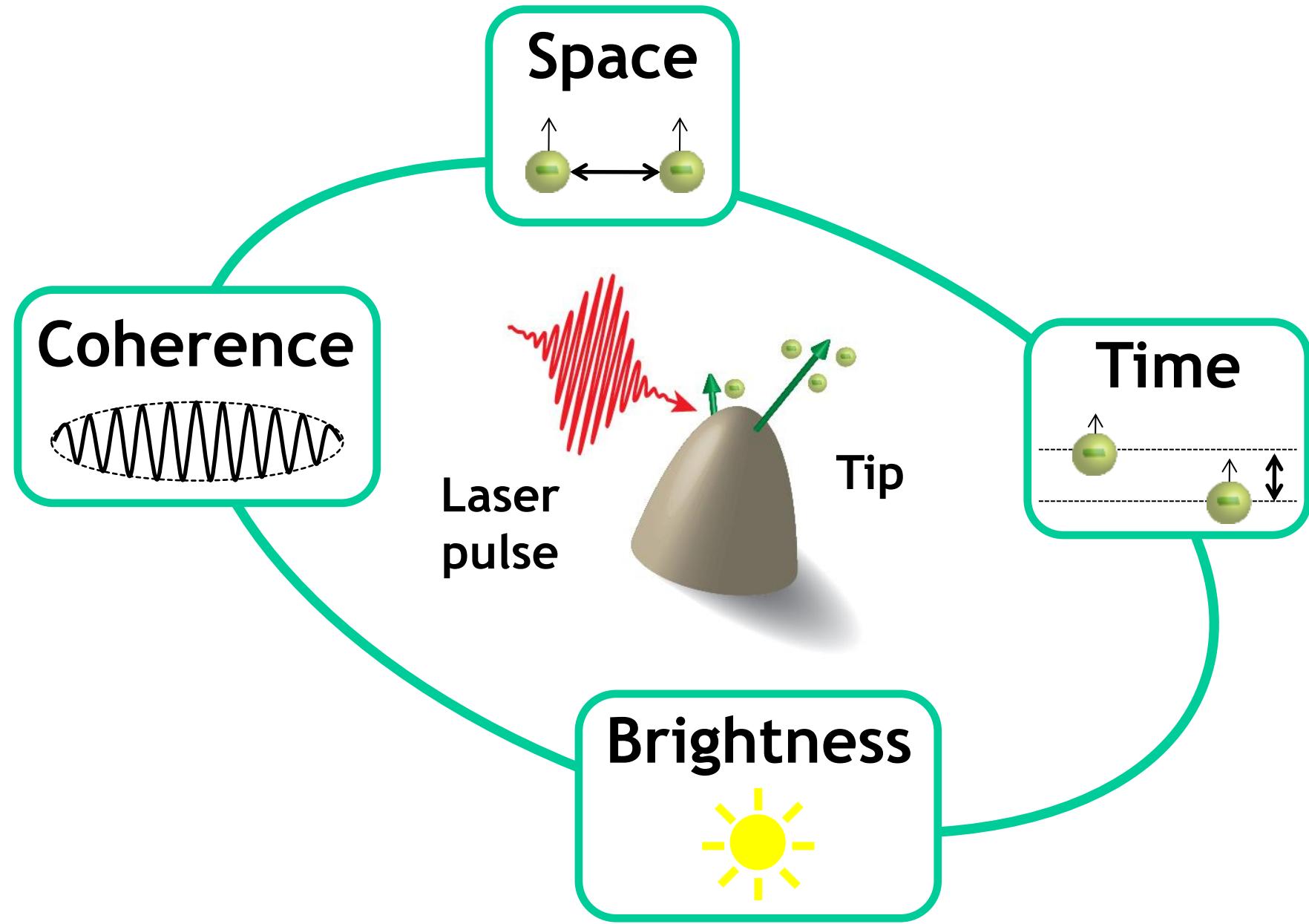


Laser
pulse

Tip

Field enhancement
 $\Rightarrow \sim 10 \text{ GV/m}$

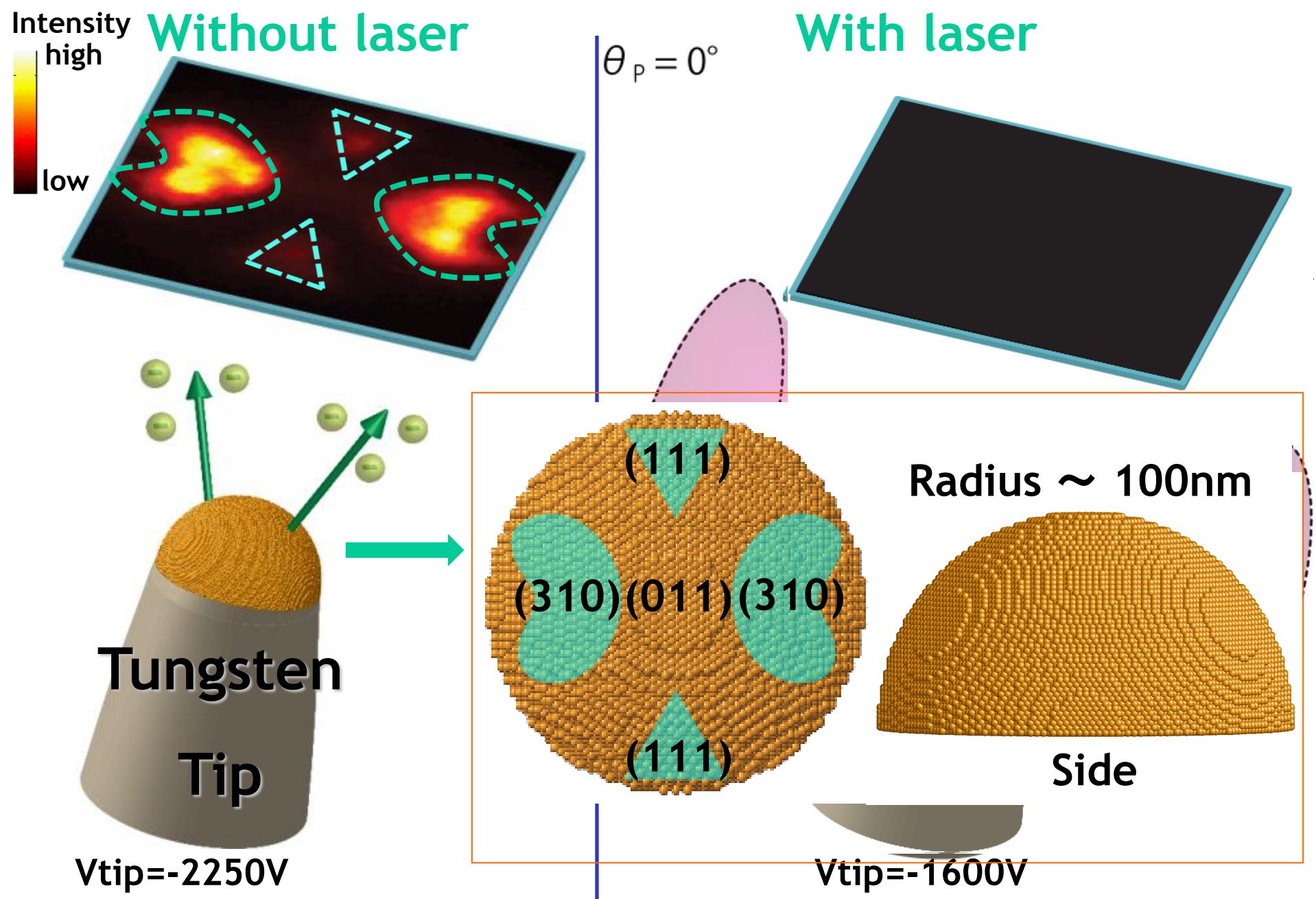
Introduction3 -Electron gun-



Outline

- 1. Optical control of field emission sites**
- 2. Emission mechanism in weak field**
- 3. Emission mechanism in strong field**

Field emission pattern with and without laser



Propagation of surface electromagnetic waves

Propagation of Laser

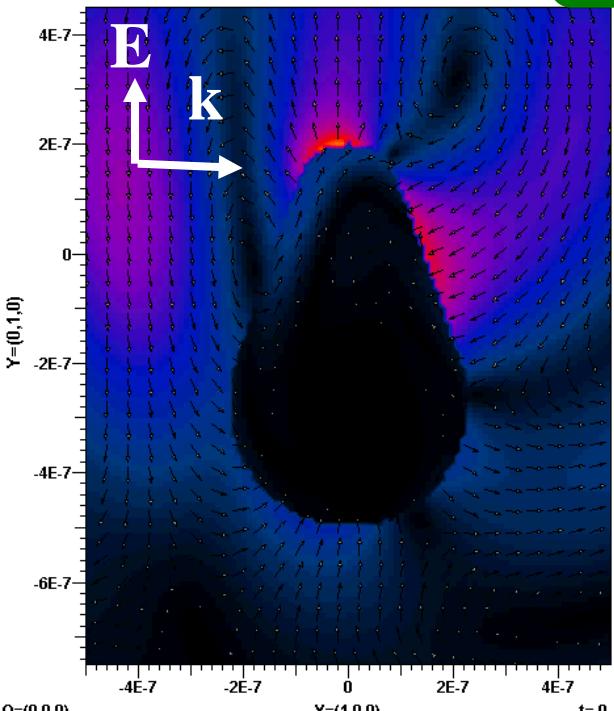
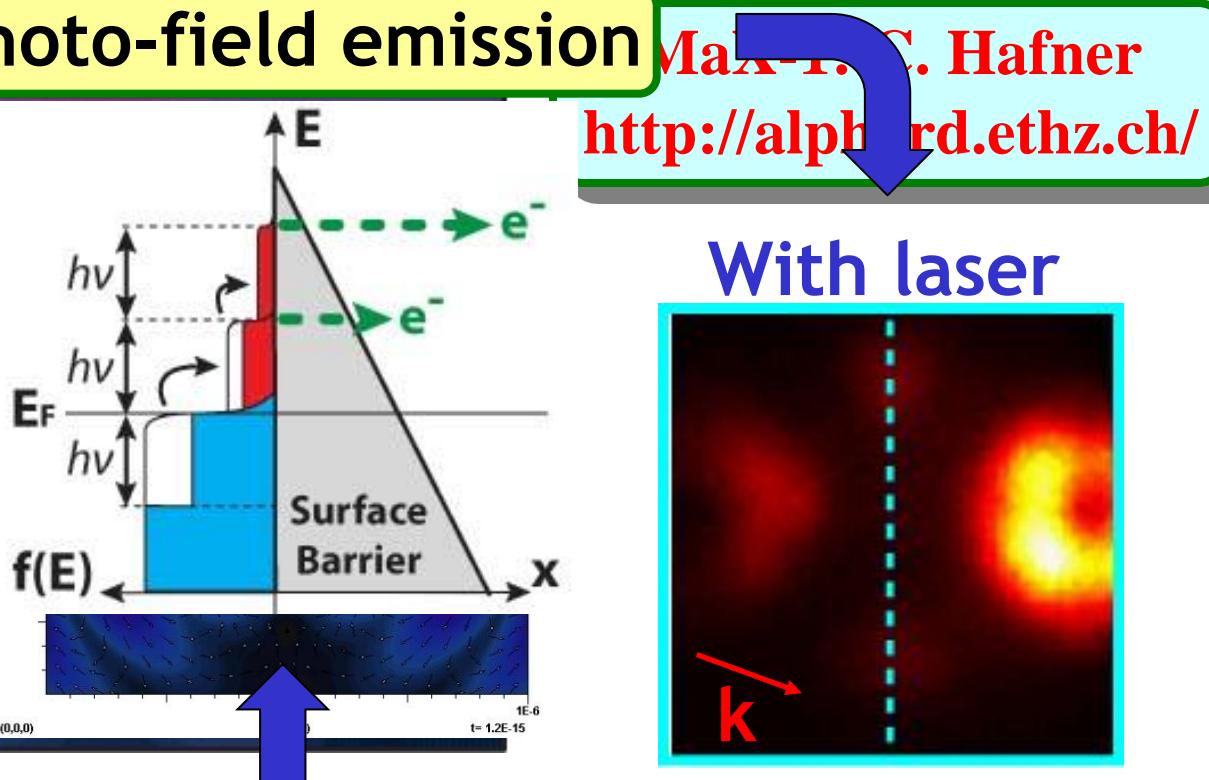


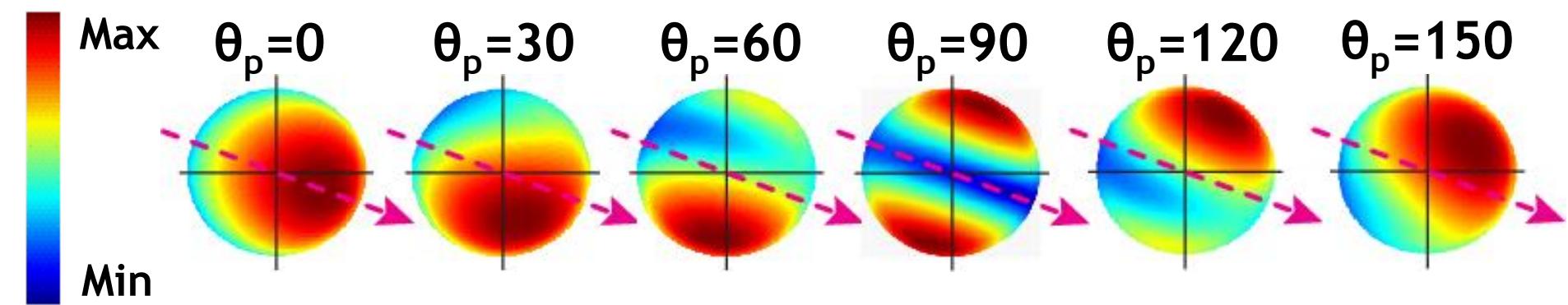
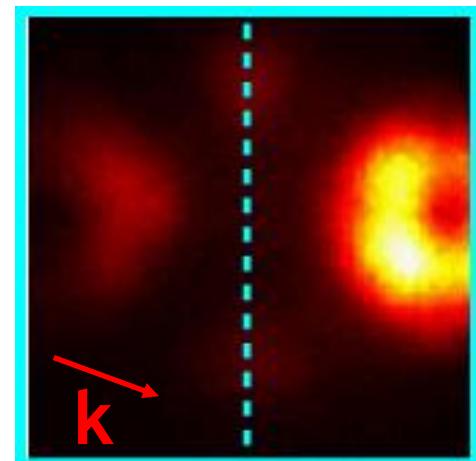
Photo-field emission



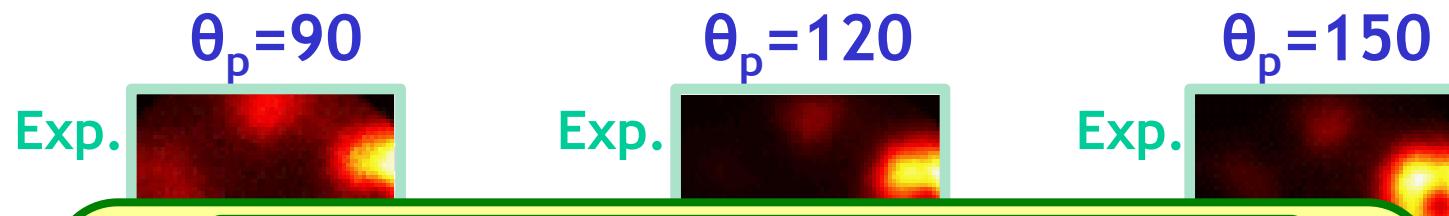
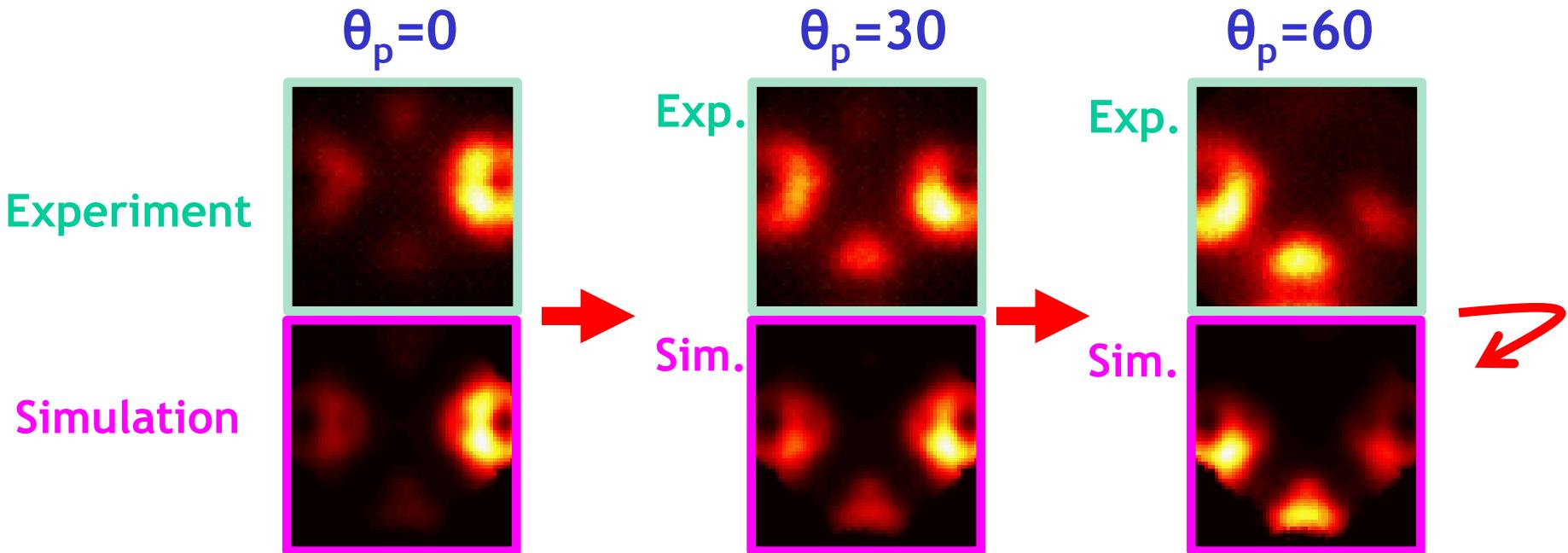
Max T. C. Hafner

<http://alphaard.ethz.ch/>

With laser



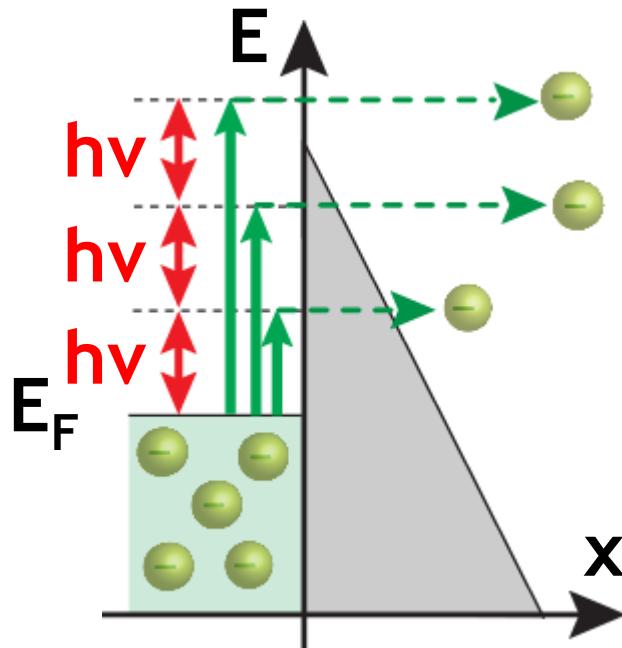
Simulations : Photo-field emission model



Si

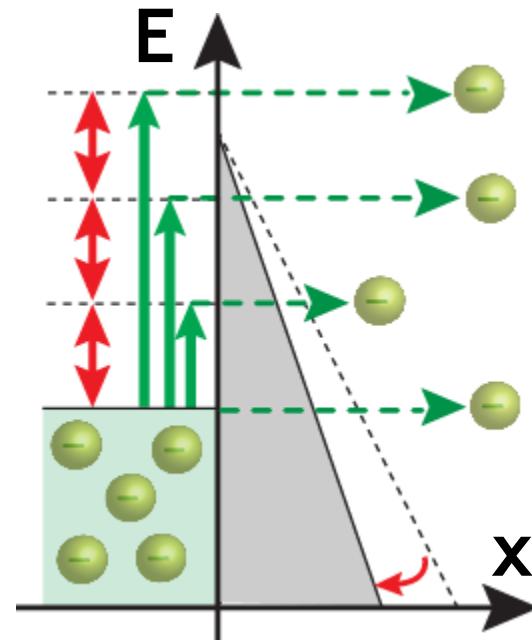
Laser induced electron emission from tip

Photo-field emission
photoemission



Weak field

optical fieldemission

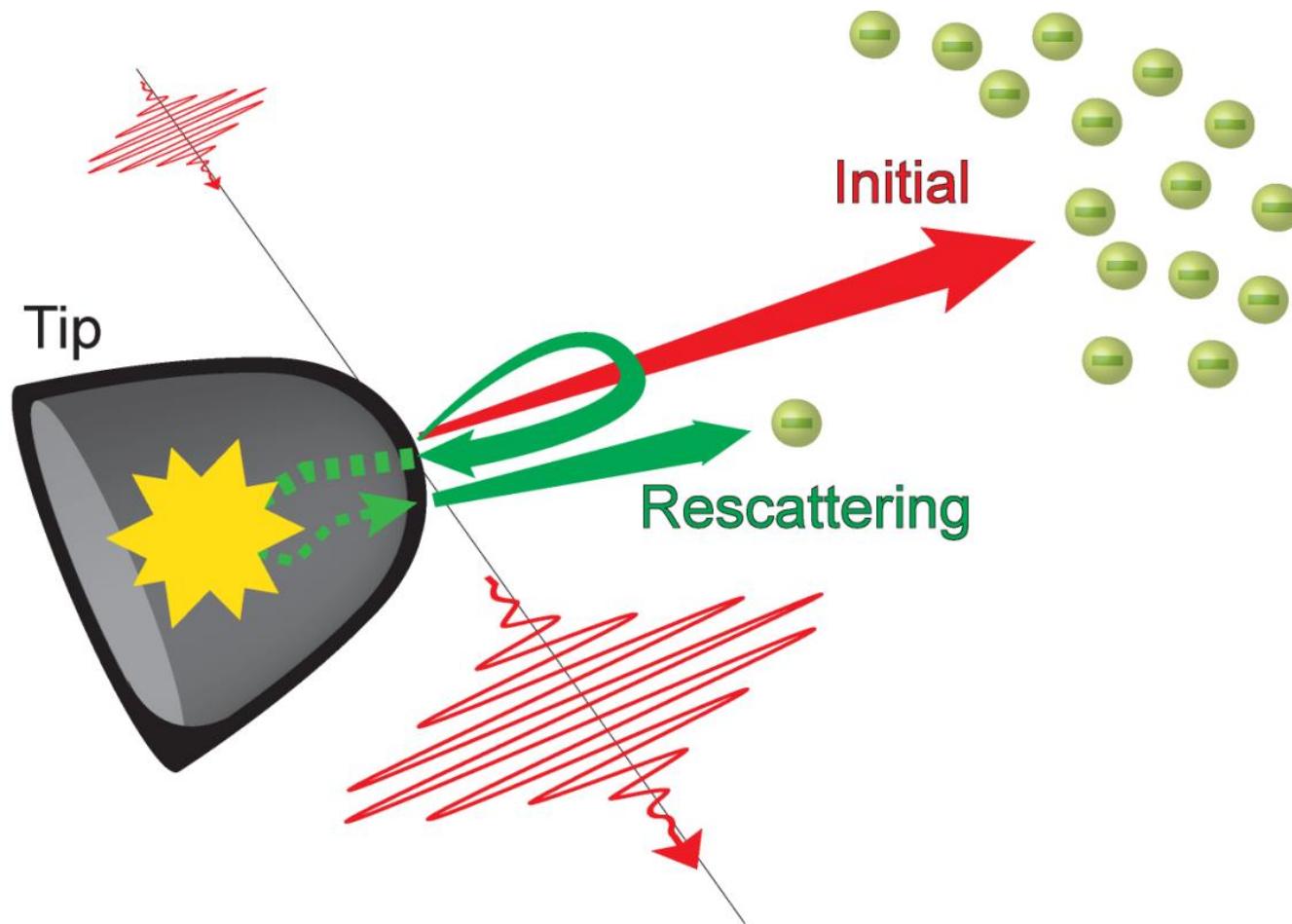


Strong field

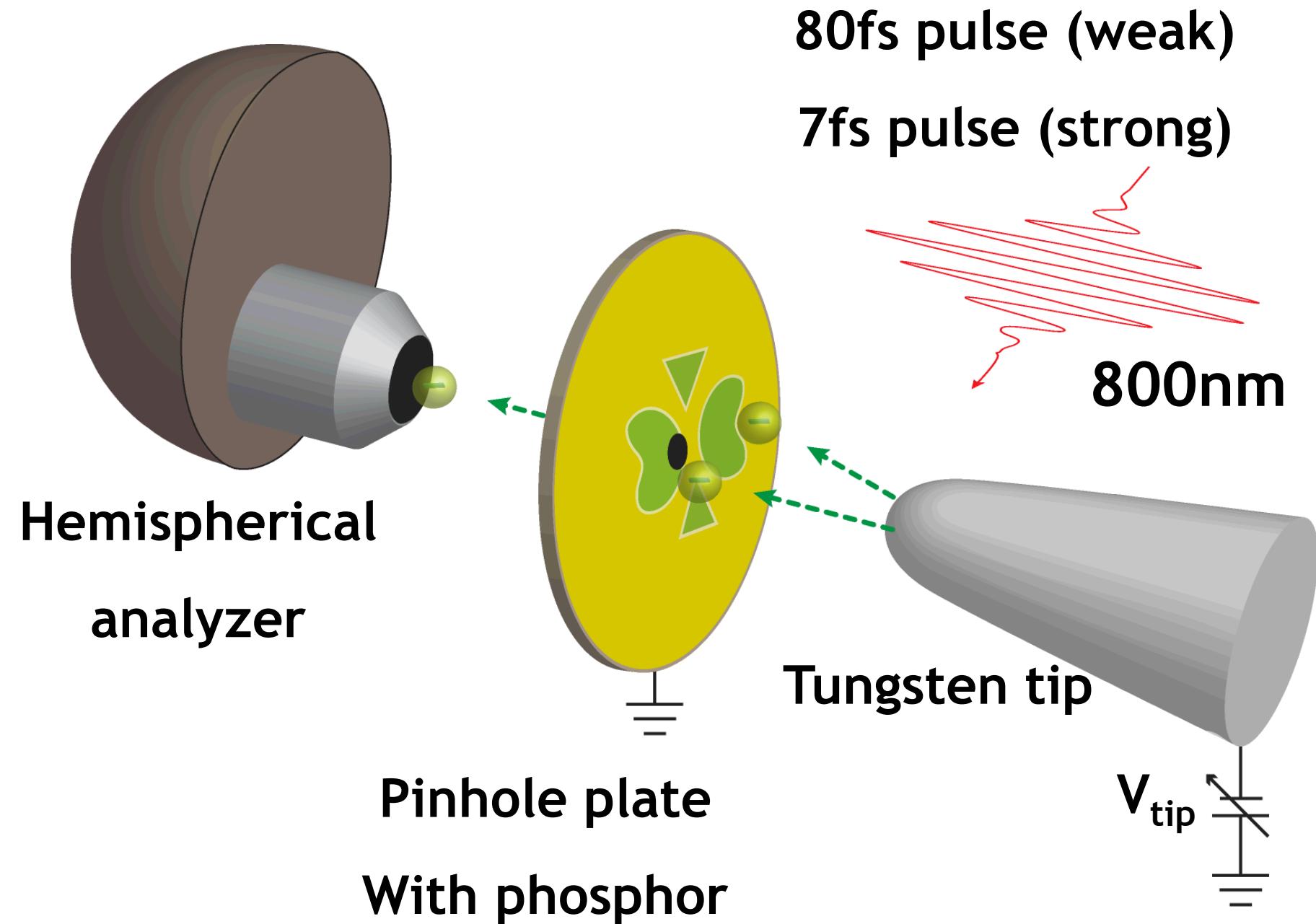
Electron dynamics in strong field regime

Rescattering process

⇒ Delayed emission



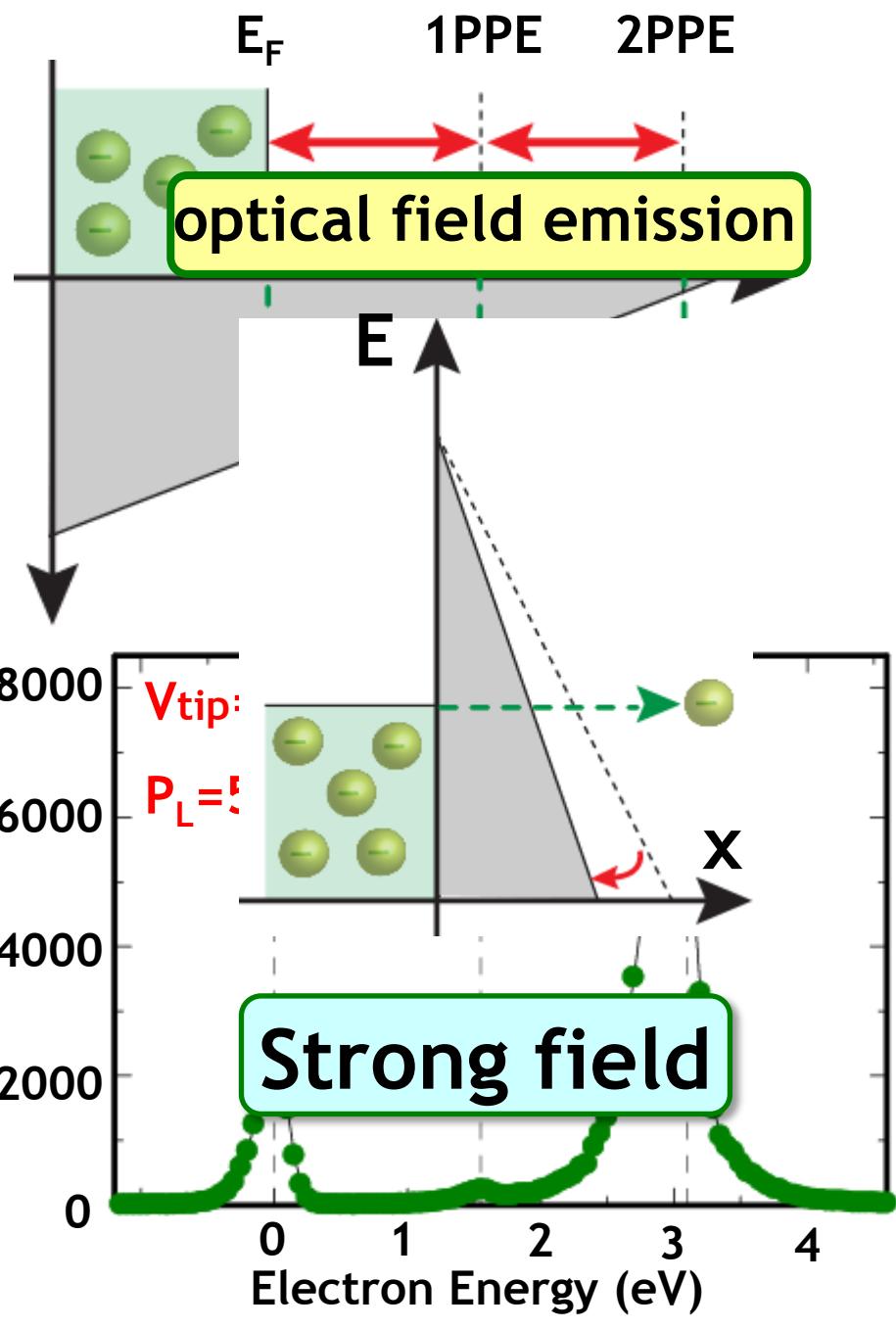
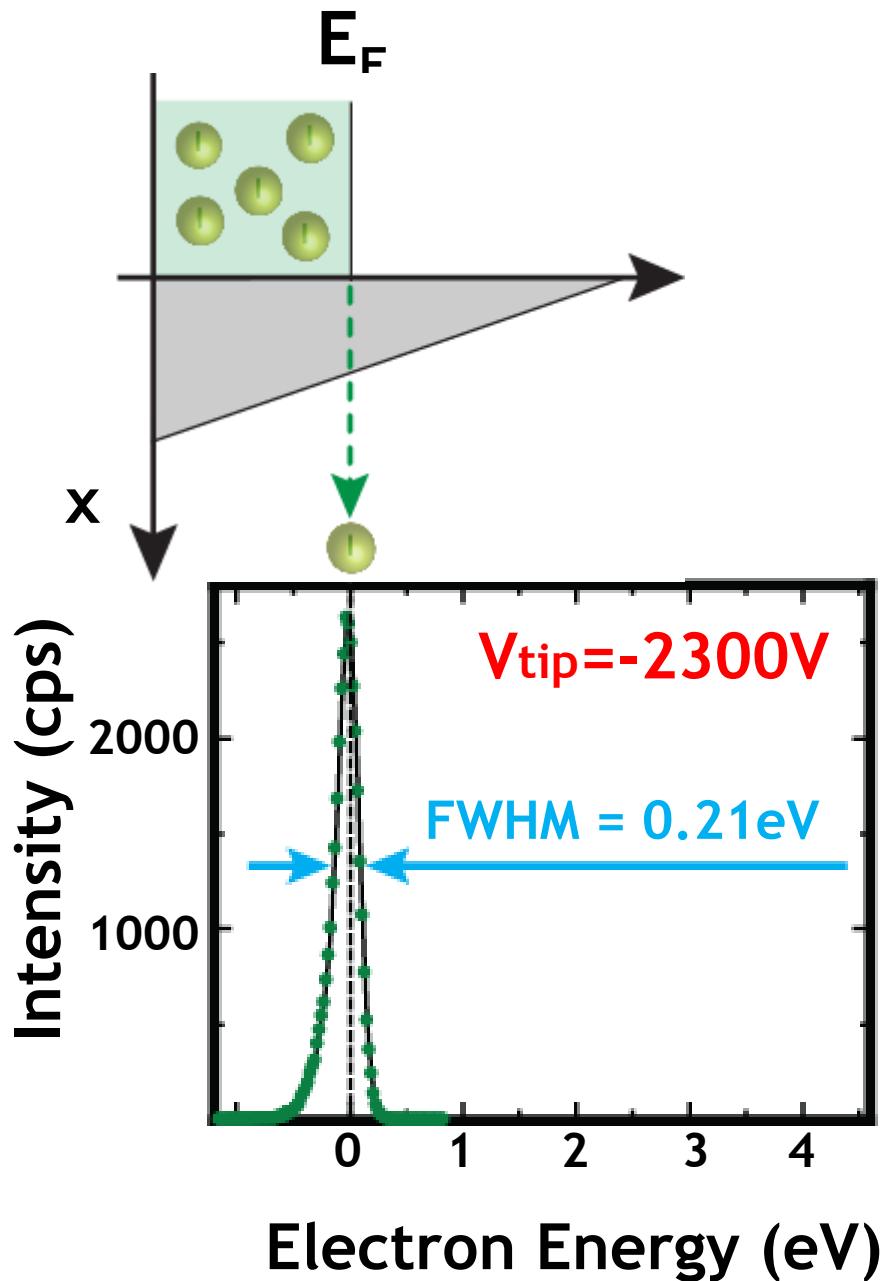
Experimental Setup for Electron Energy Analyzer



Weak field

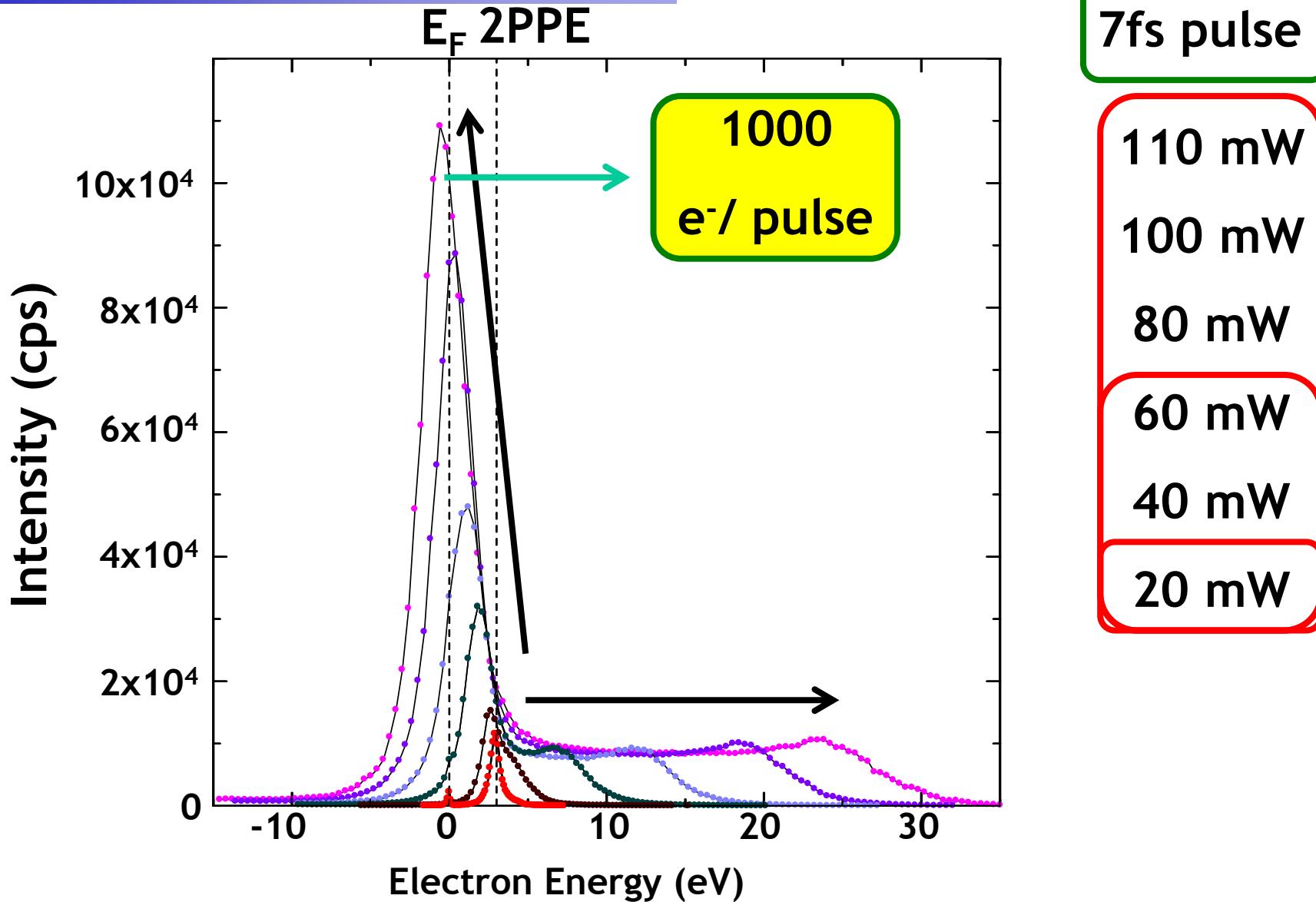
Results with 80fs laser pulse

H. Yanagisawa, et. al. PRL 107, 087601 (2011)



Strong field

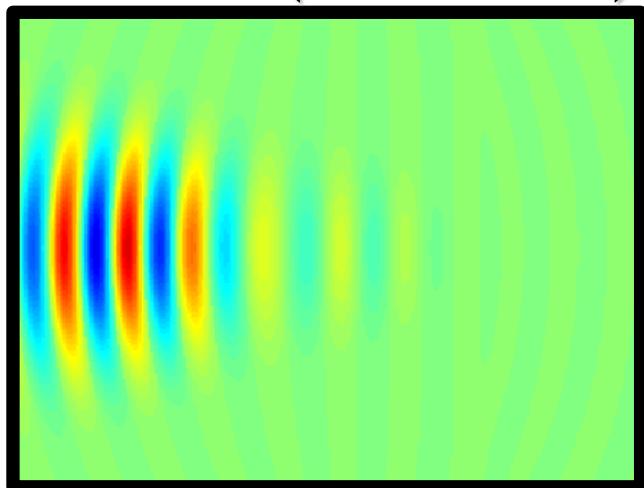
Results with 7 fs laser pulses



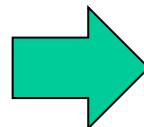
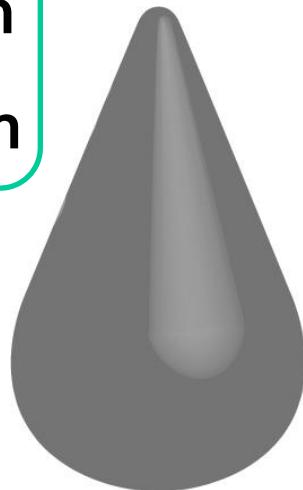
Simulation with space charge effects !!

Step 1: Plasmonic simulation

7f Pulse (1um waist)

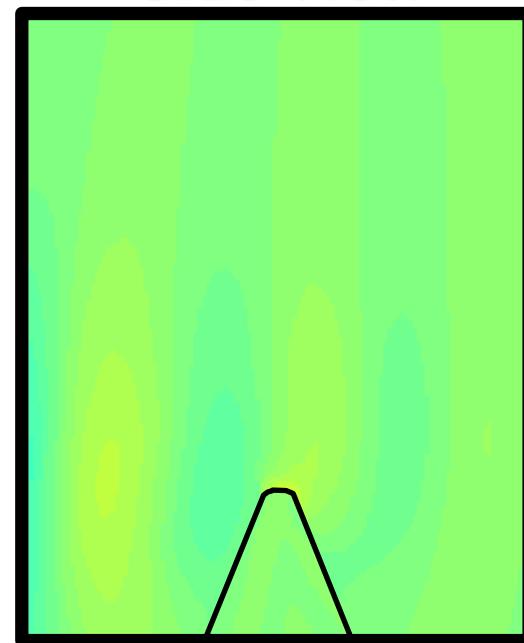


Tungsten
 $R=100\text{nm}$

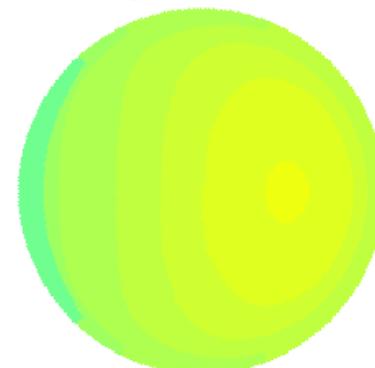


MaX-1: C. Hafner
<http://alphard.ethz.ch/>

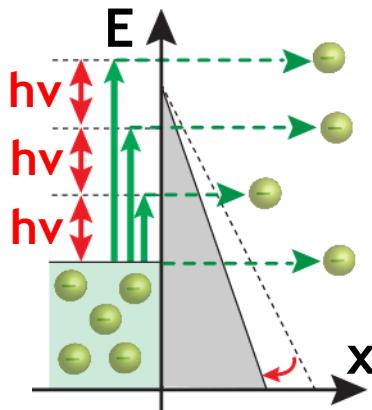
Side view



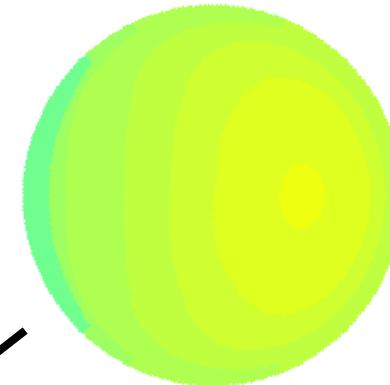
Top view



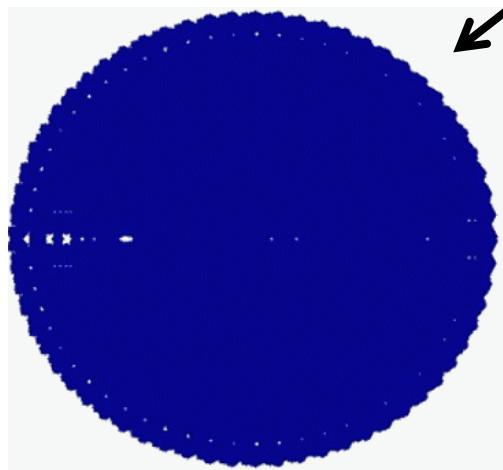
Step 2: Emission Current Simulation in Space and Time



Top view



Each point
(~2000 points)



How many?

Monte Carlo

When?

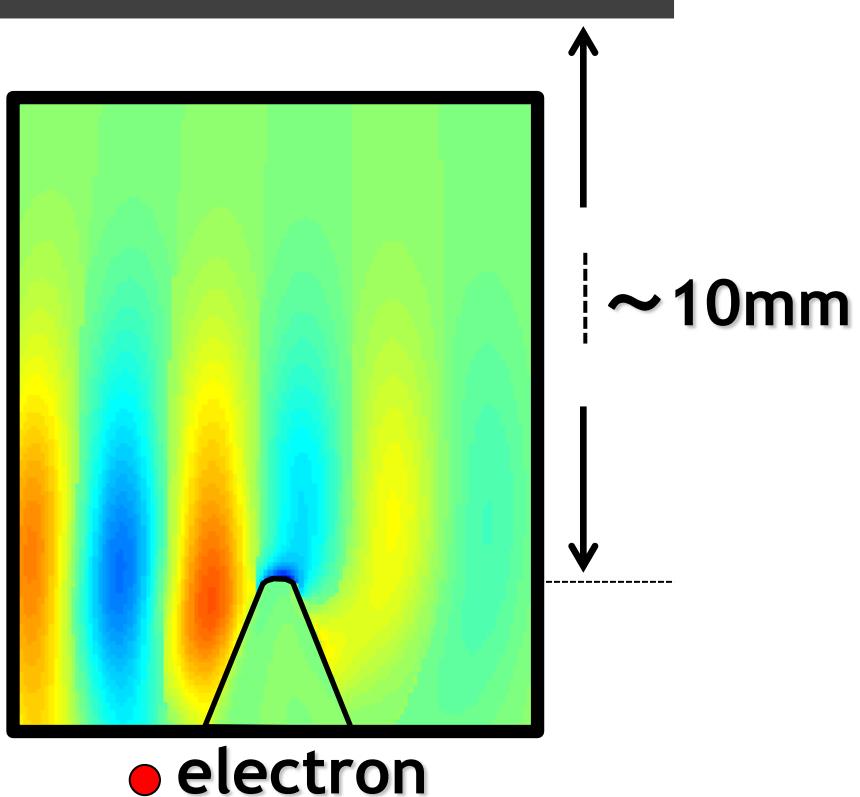
Where?

Which energy?

Which direction?

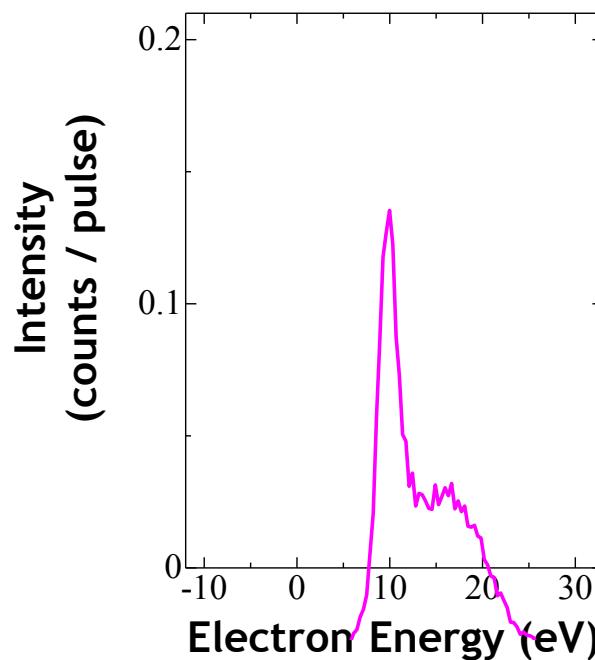
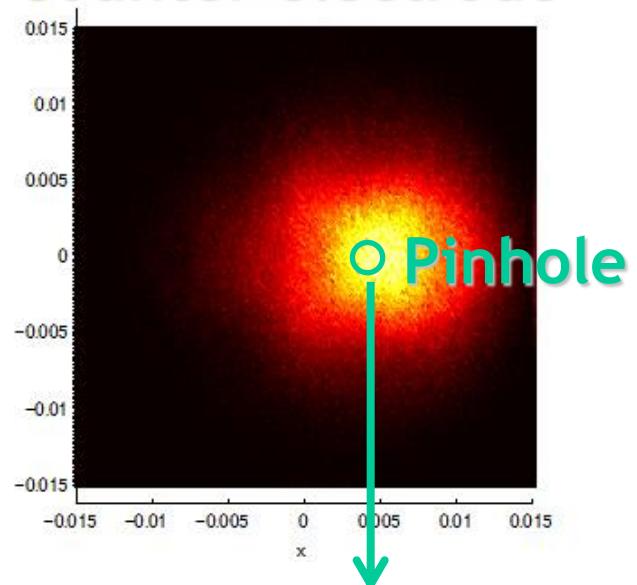
Step3: Electron Trajectory Simulation with DC and AC Fields

Counter electrode



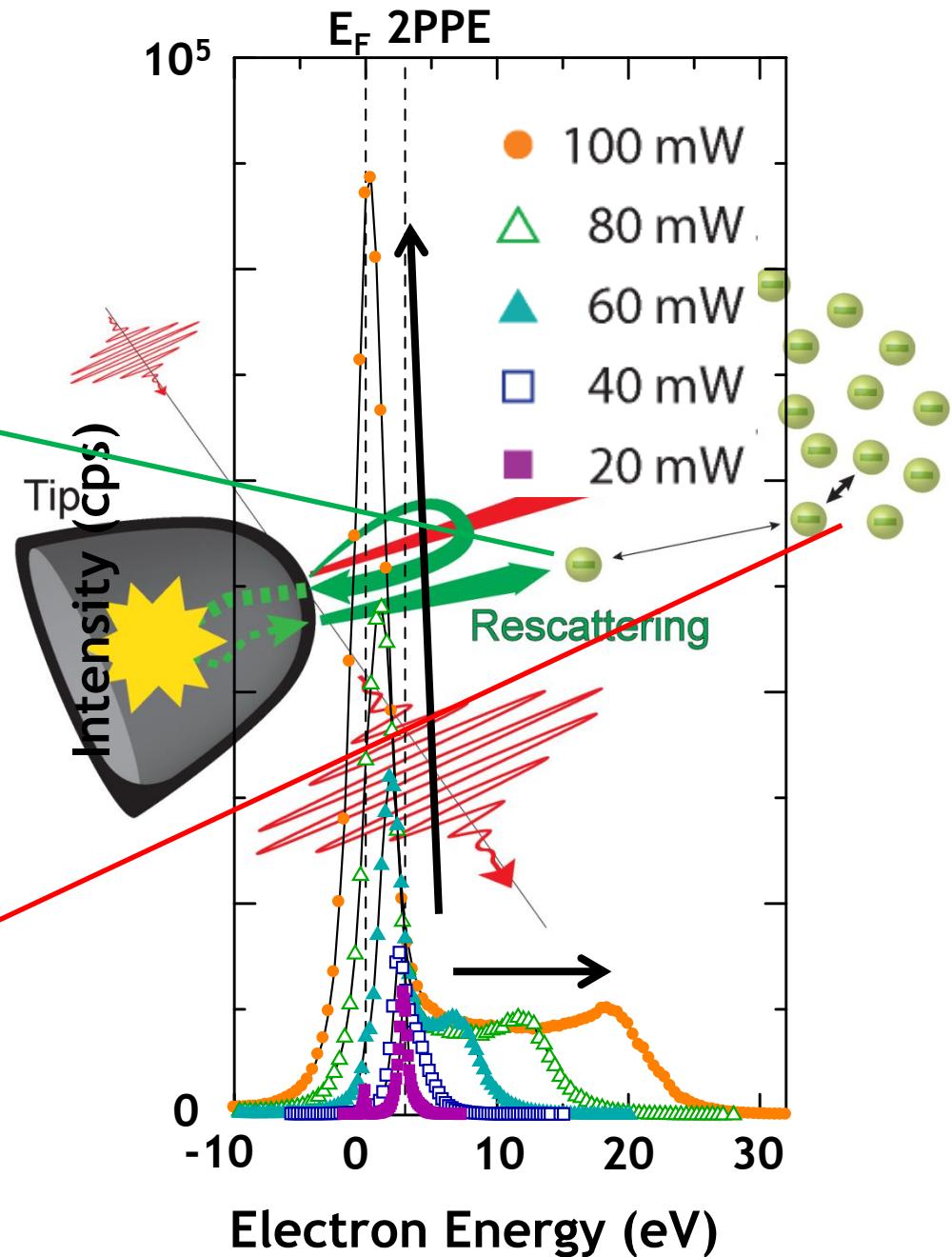
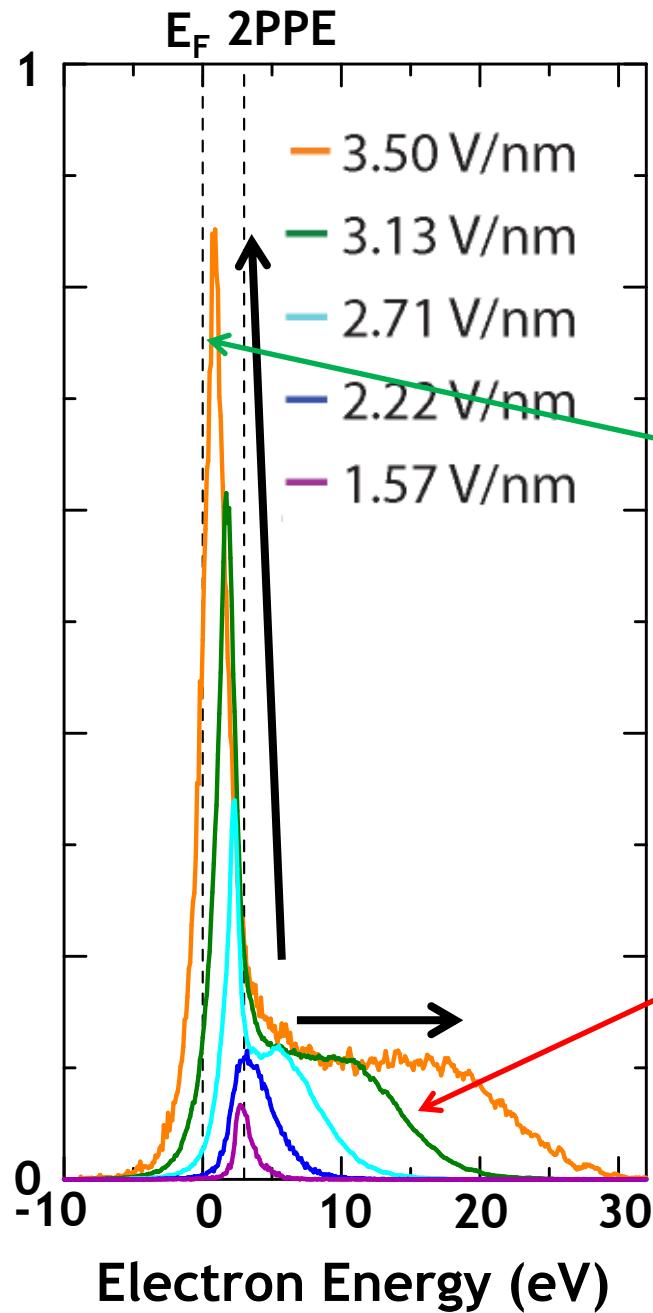
1. AC field $\sim 3\text{V/nm}$
2. DC field $\sim 2\text{V/nm}$
3. Space charge effects
4. Classical image potential

Counter electrode



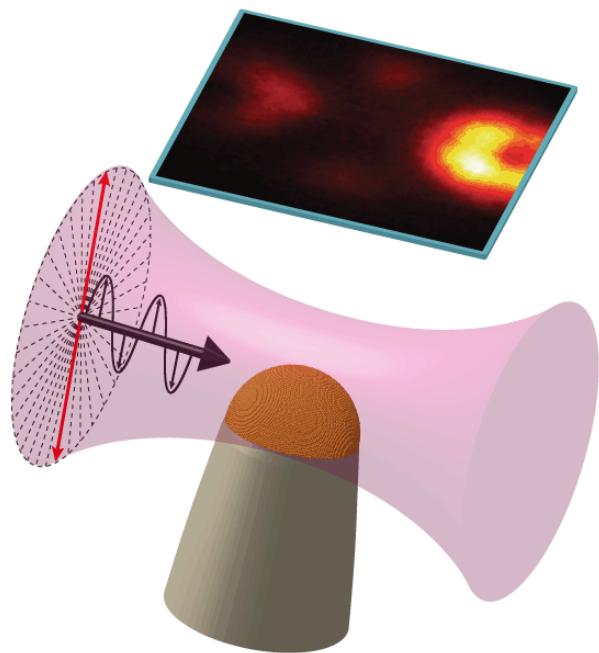
Simulation results 3

Intensity (counts / pulse)

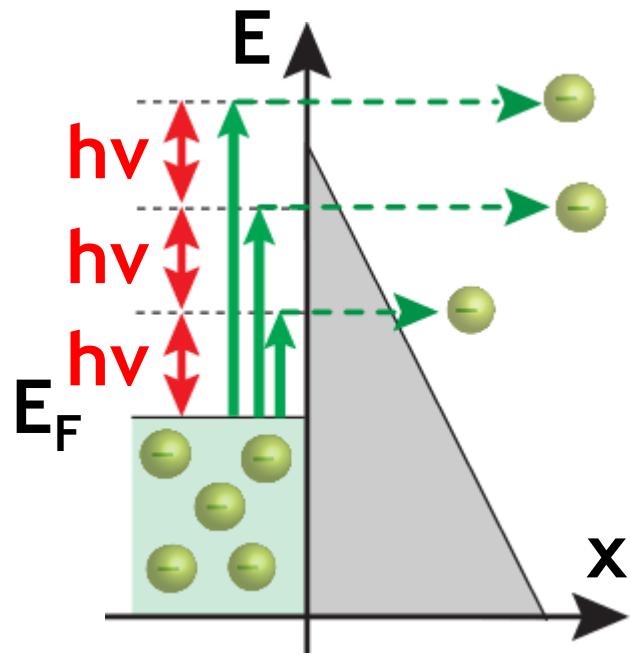


Summary

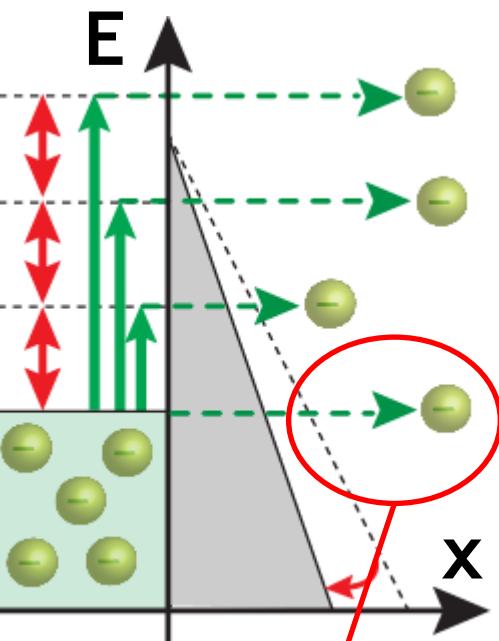
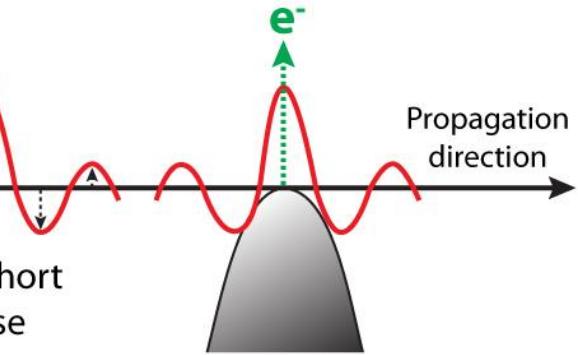
$$\theta_p = 0^\circ$$



Emission site control



Weak field



Strong field

Coherent atto-second electron wave

Acknowledgement

Jürg Osterwalder

Matthias Hengsberger

Thomas Greber

Patrick Donà

Dominik Leuenberger

(Universität Zürich)

Finance

-SNSF : Ambizione

-Kazato foundation

-JSPS

-Nishina Memorial Foundation

-SNSF : NCCR MUST

Alexandra Landsman

Lukas Gallmann

Ursula Keller

(ETH Zürich)

Simulation: Max-1

Christian Hafner

Sascha Schnepp

(ETH Zürich)

Tip fabrication

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Conrad Escher

(Universität Zürich)