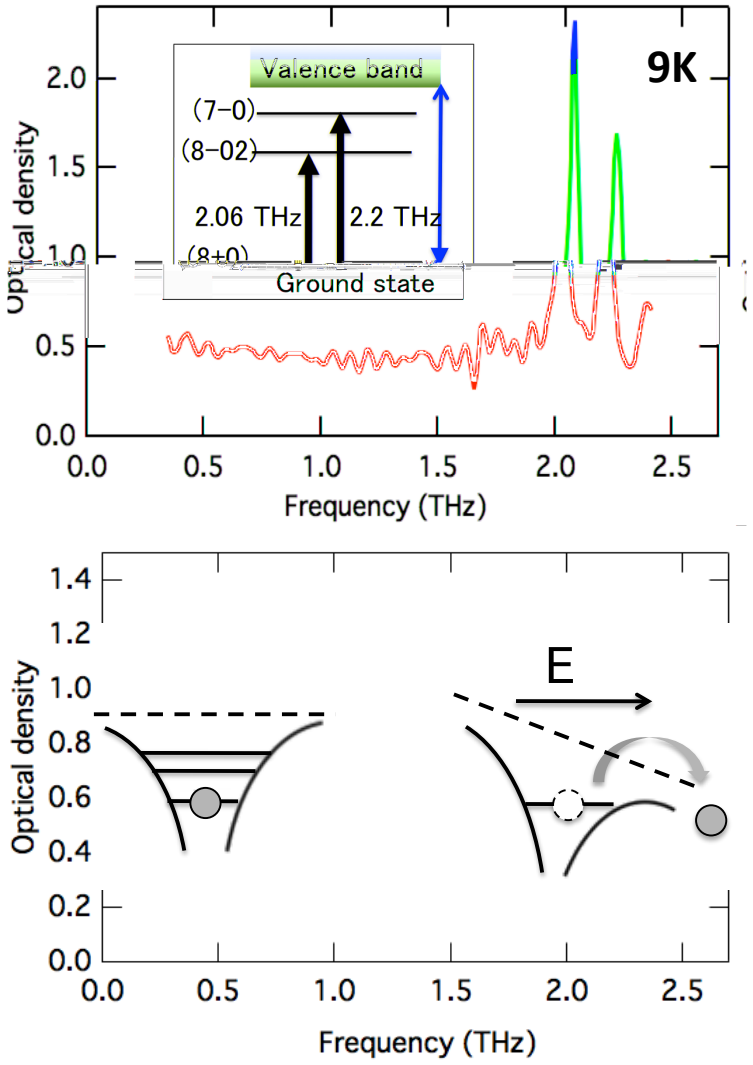
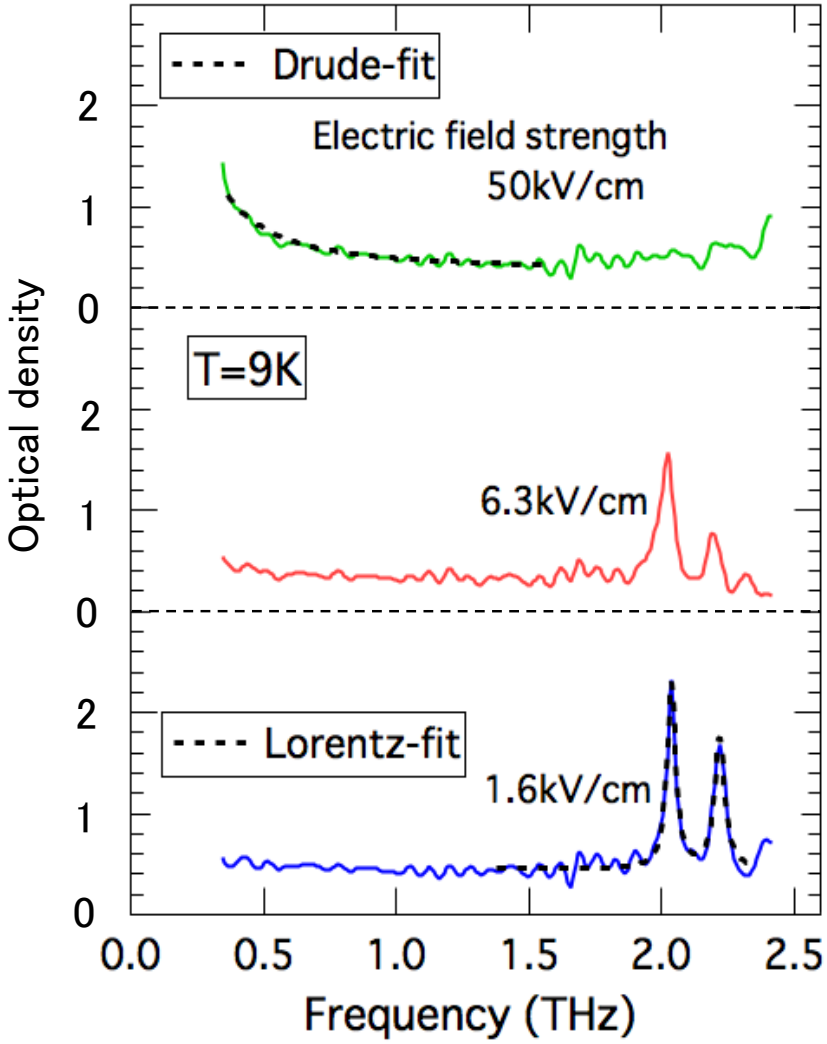
Contents

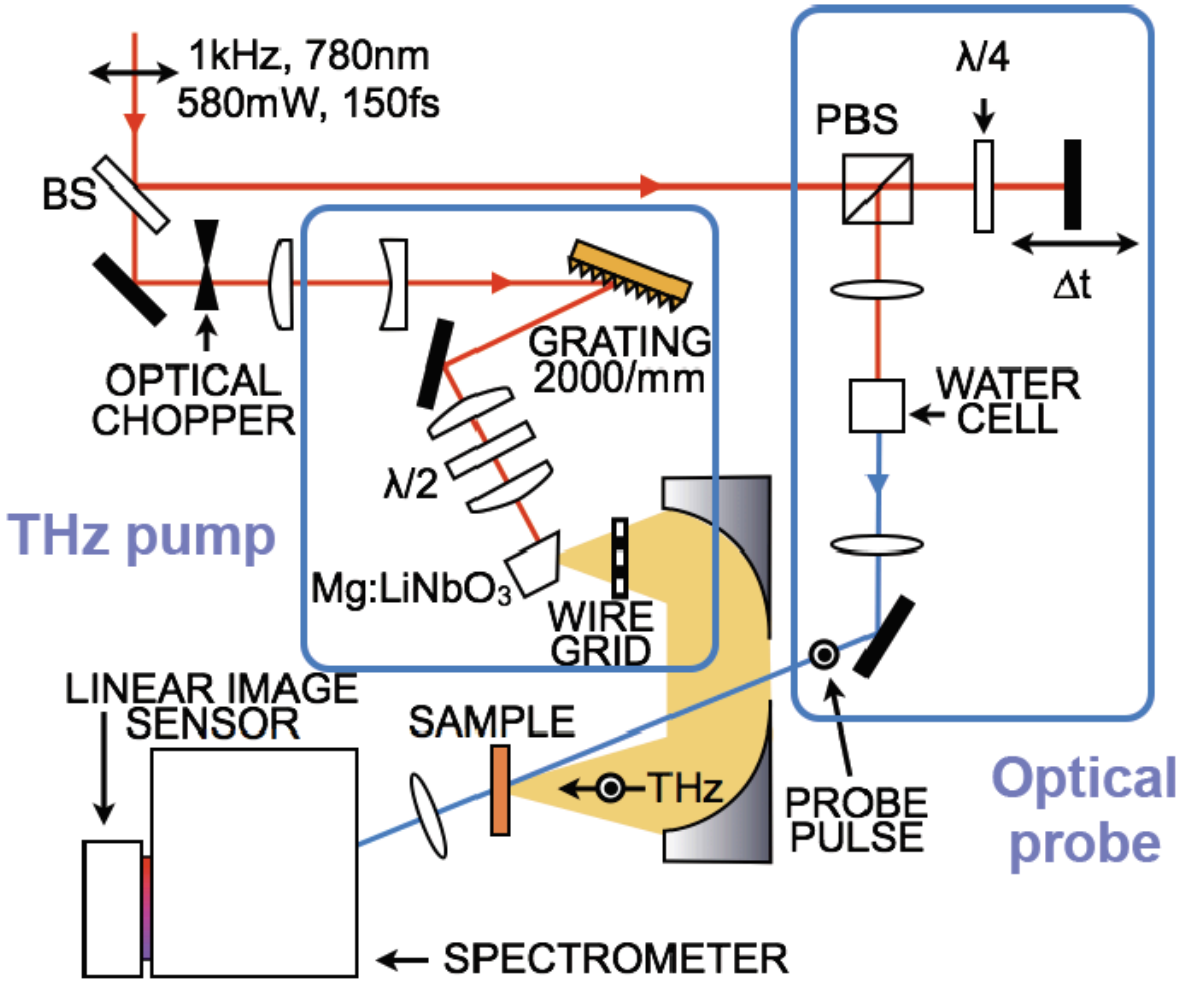
- Background (Extreme nonlinear optics)
- High-power THz-wave generation
- Non-linear THz spectroscopy in solids
- Perspectives

Impurity ionization in Ge:Ga

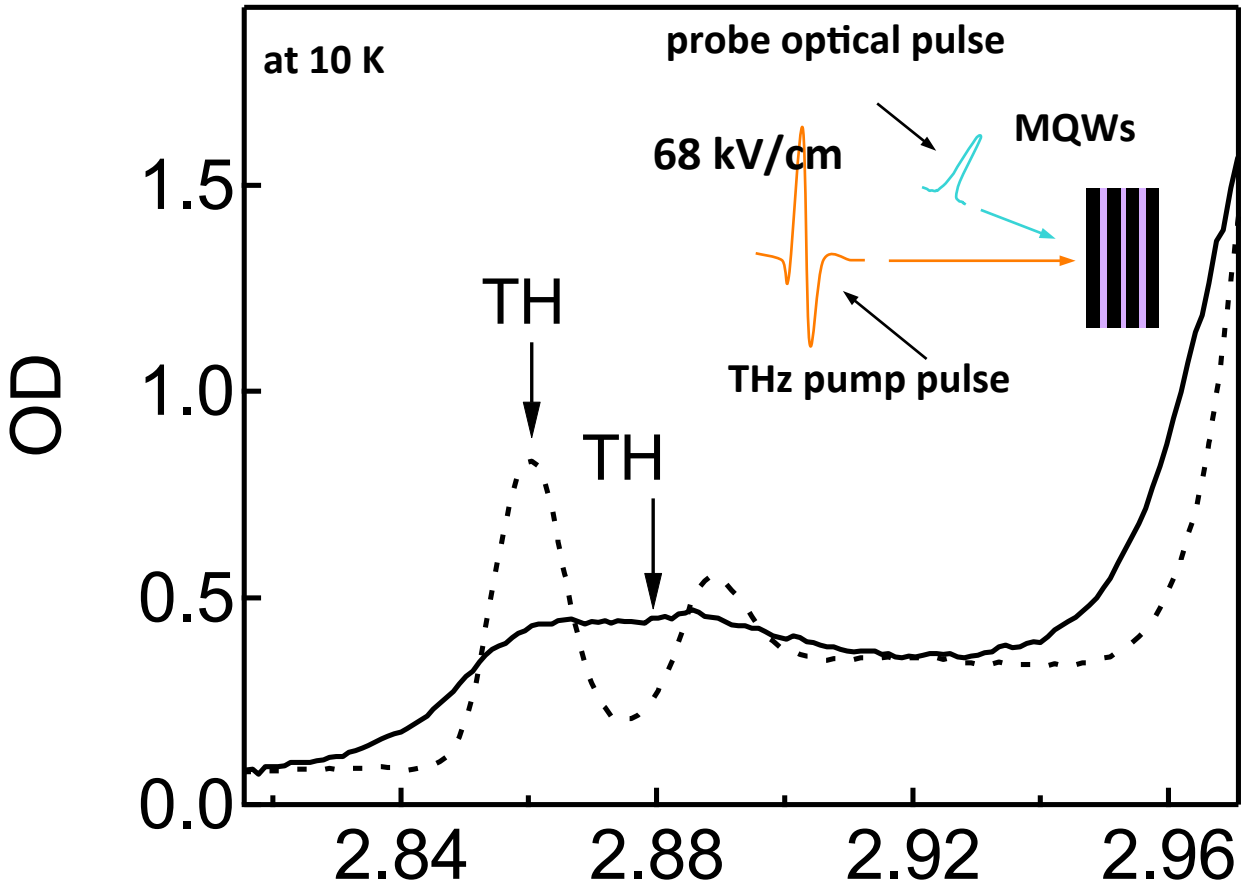


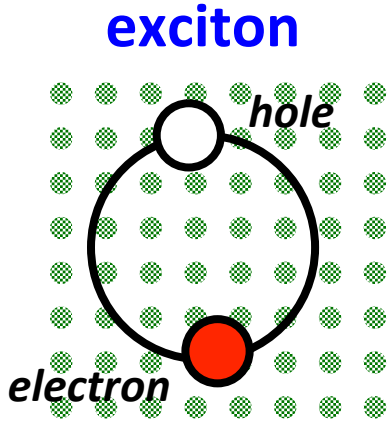


THz-pump and visible-probe system



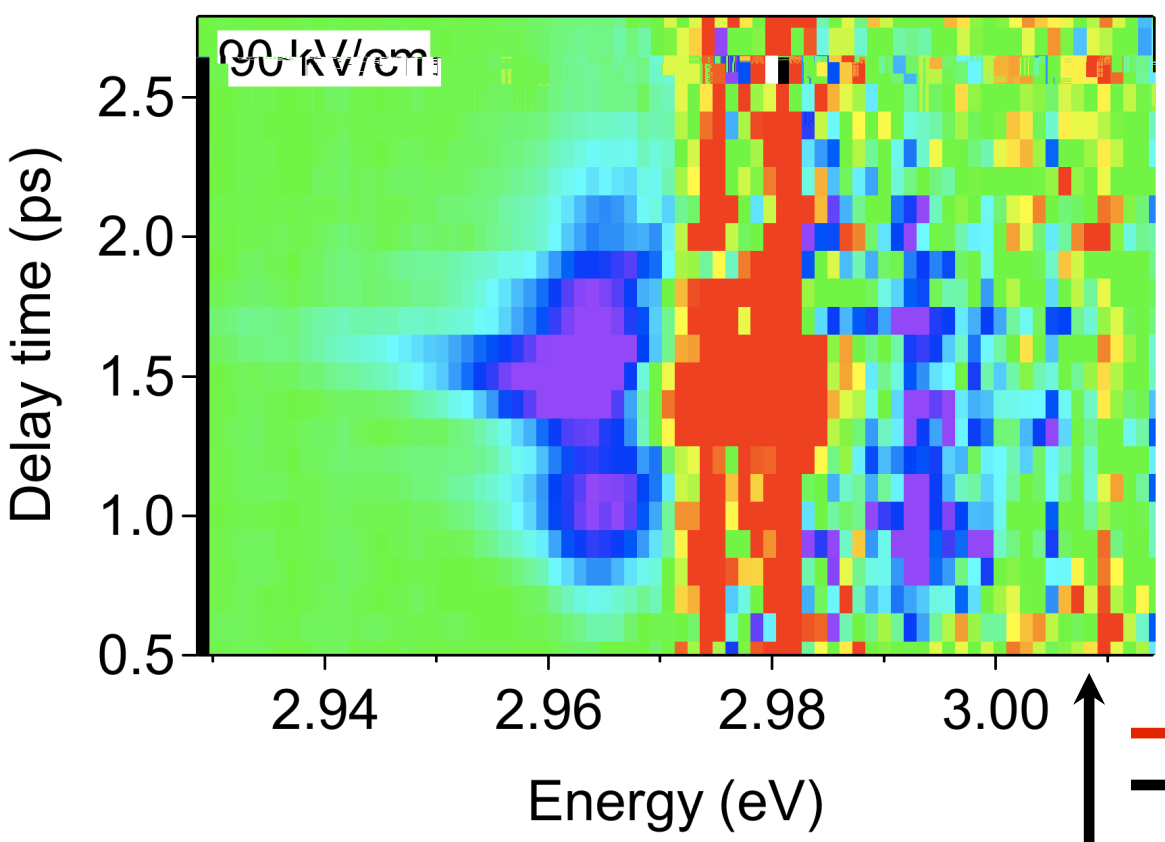
Exciton ionization in ZnSe MQWs

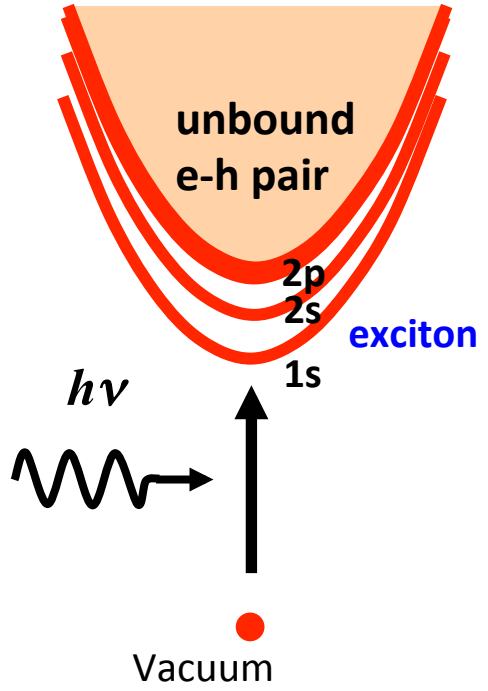


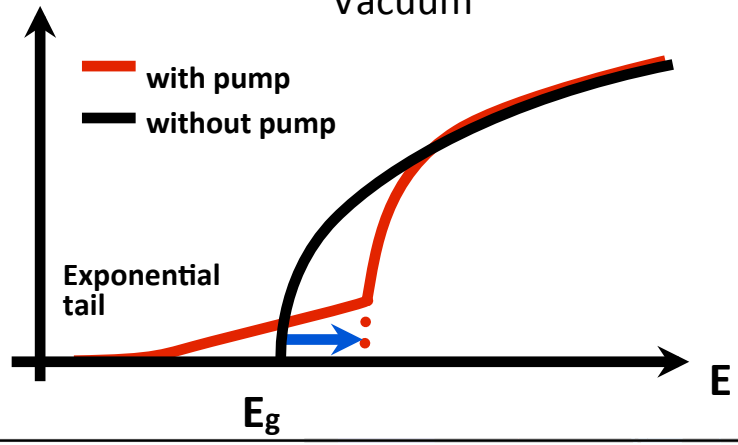


PRB 81, 081305(R) (2010).

Dynamical Frantz-Keldish effect in ZnSe MQWs

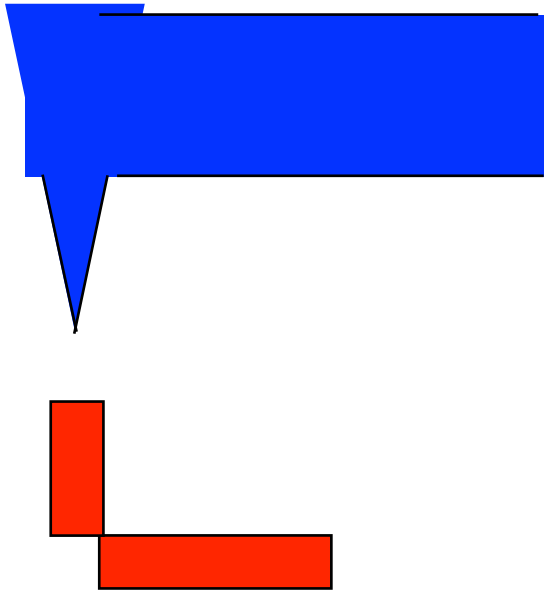




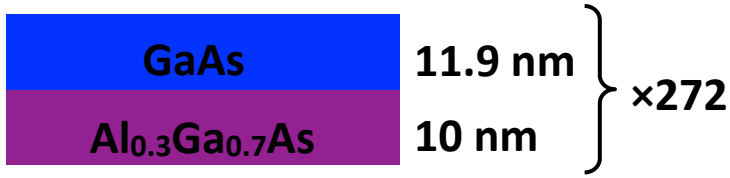


THz induced luminescence

Setup



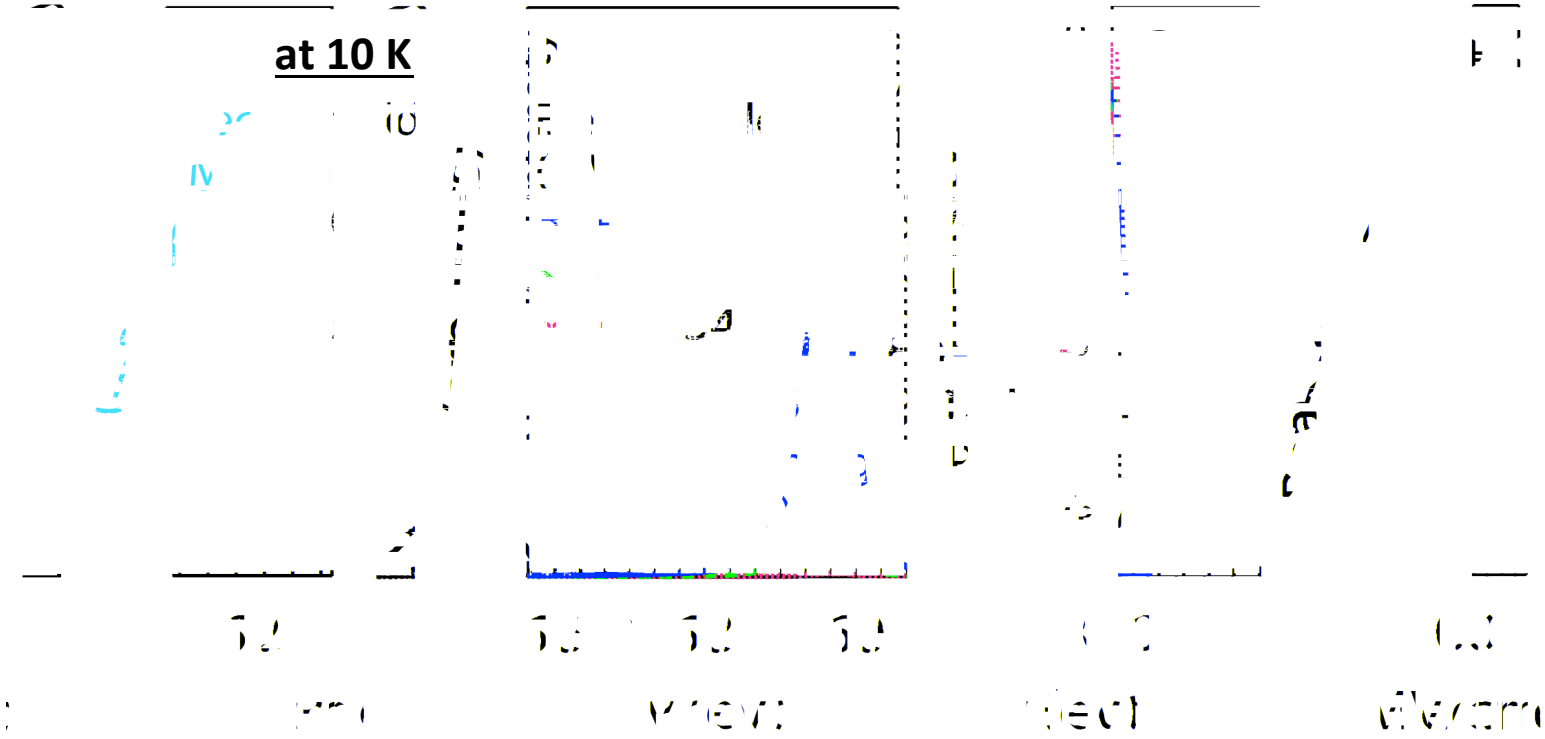
GaAs quantum wells



- Non-doped
- Low temperature measurement (10 -150 K)
- The electric field is perpendicular to the stacking direction and along the (100) direction of the sample

Bright exciton luminescence by THz pulse without photoexcitation

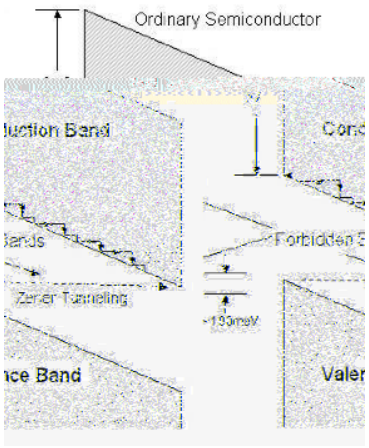
Electric field dependence



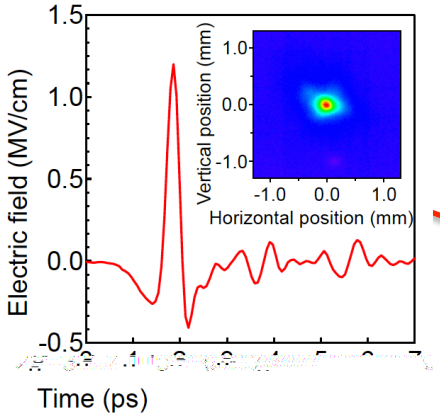
- Luminescence centered around 1.55 eV.
- The number of carriers increases by about three orders of magnitude.

Carrier multiplificion

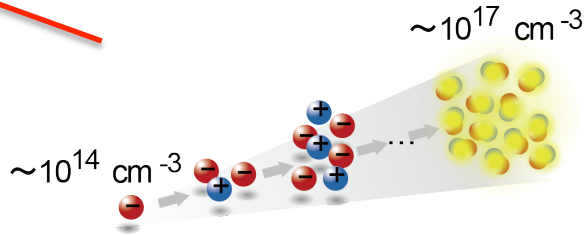
E = 1 MV/cm =0. 1 V / nm



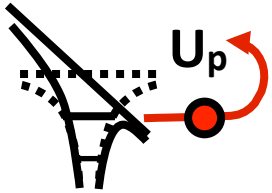
Zener Tunneling



Multiple process within THz half cycle 0.5 ps



Linear Acceleration



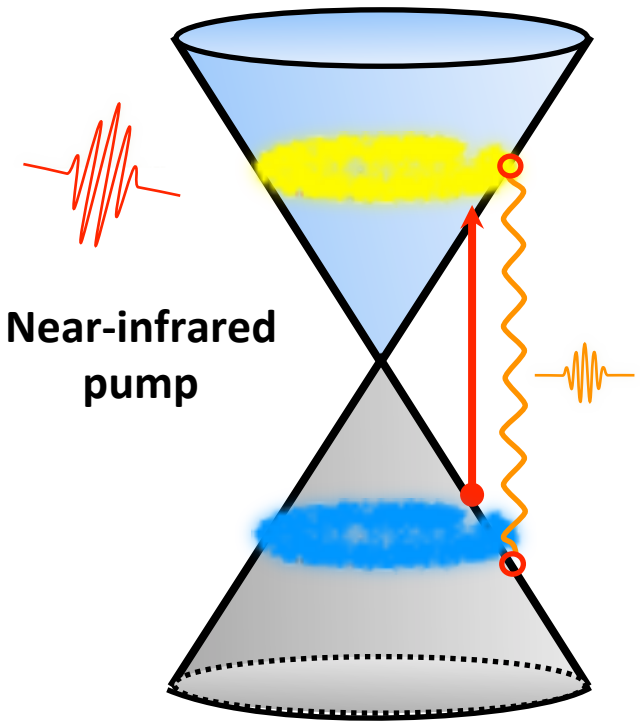
Tunneling ionization

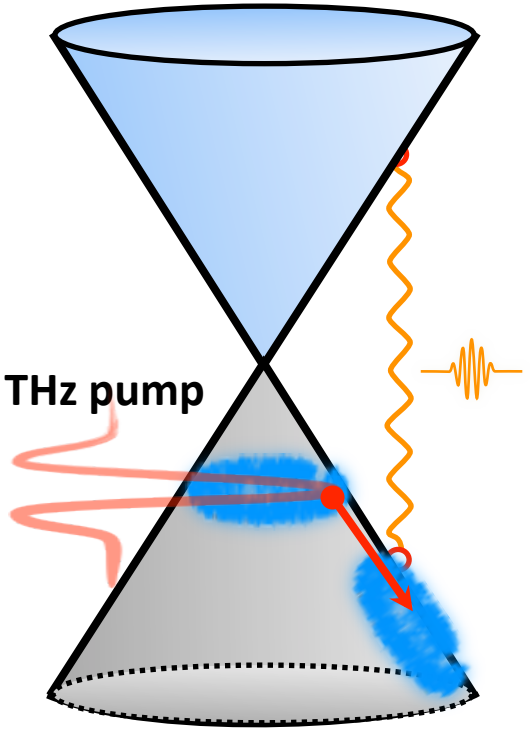
Impact ionization

Avalanche effect

10^3 multiplications!!

Extreme Hot Carrier Dynamics in Graphene



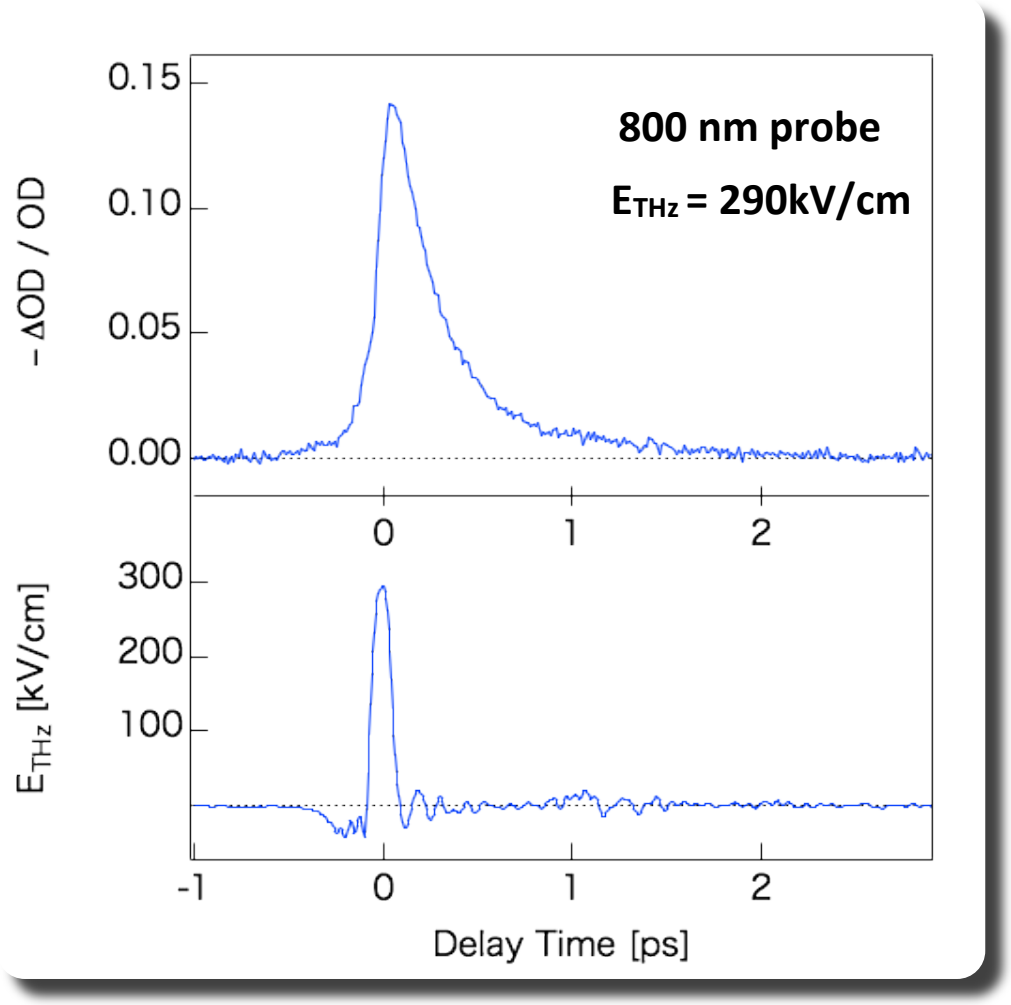


According to optical-pump optical-probe measurement

- Carrier-carrier scattering：2 ～ 10 fs
- Optical phonon emission：100 ～ 400 fs

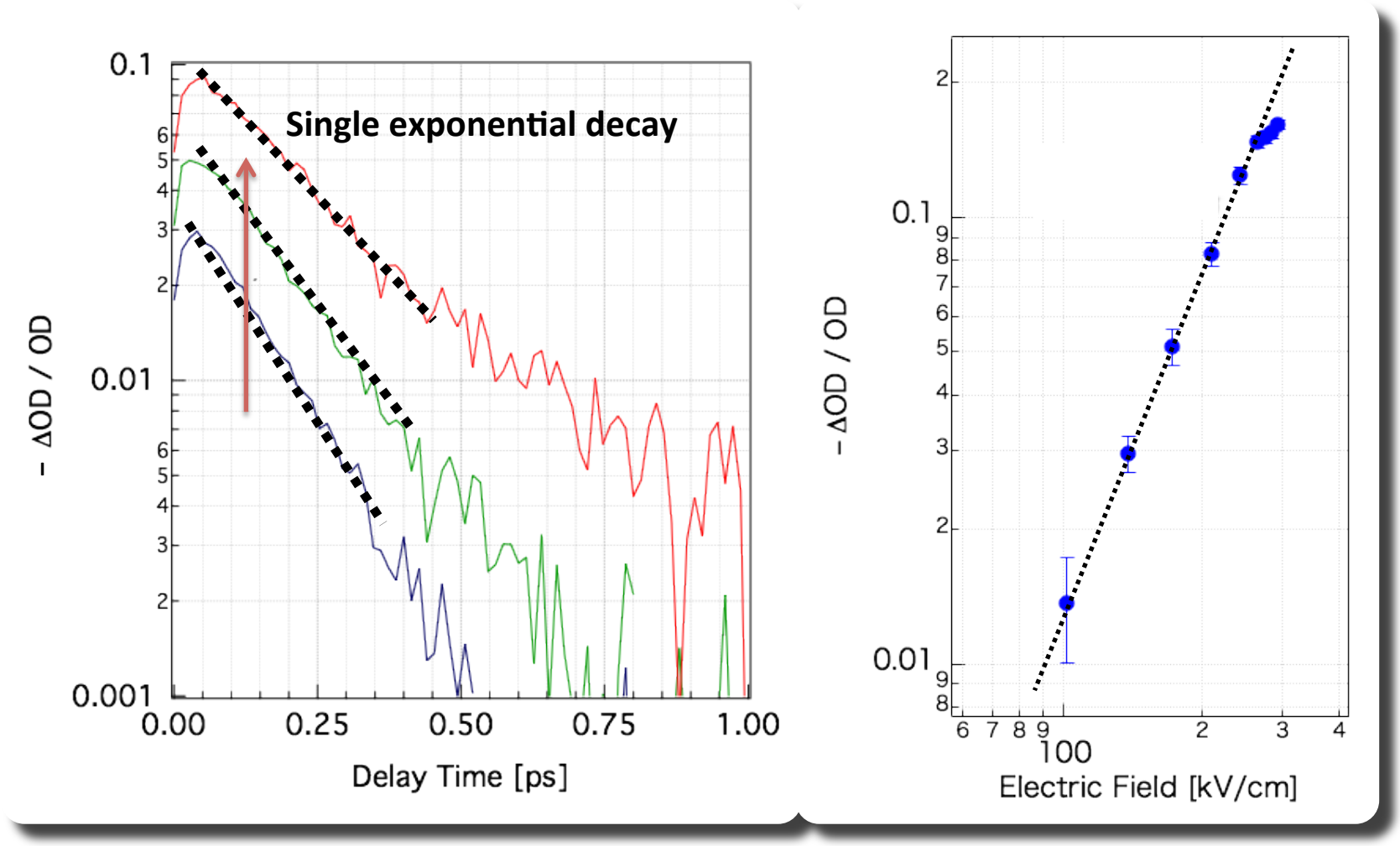
Near-infrared transient absorption measurement with single cycle THz pulse excitation

THz-induced Transparency

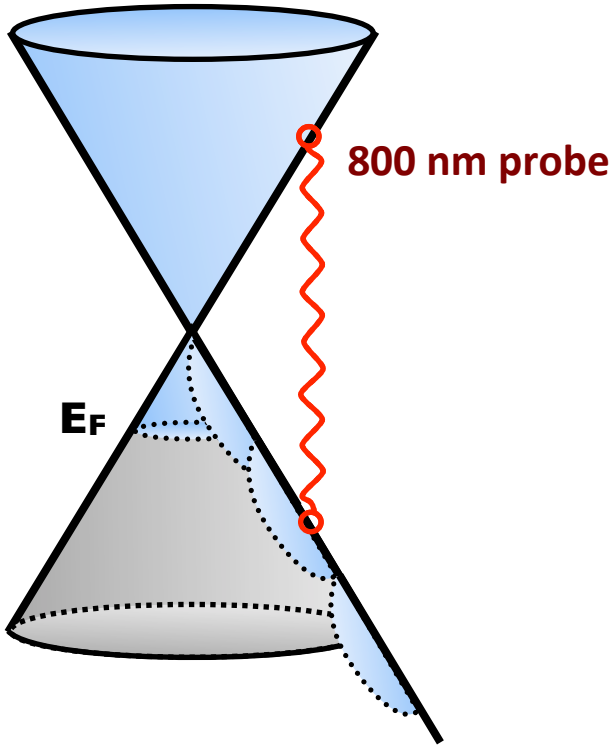


THz induced transparency over 14% at 800 nm

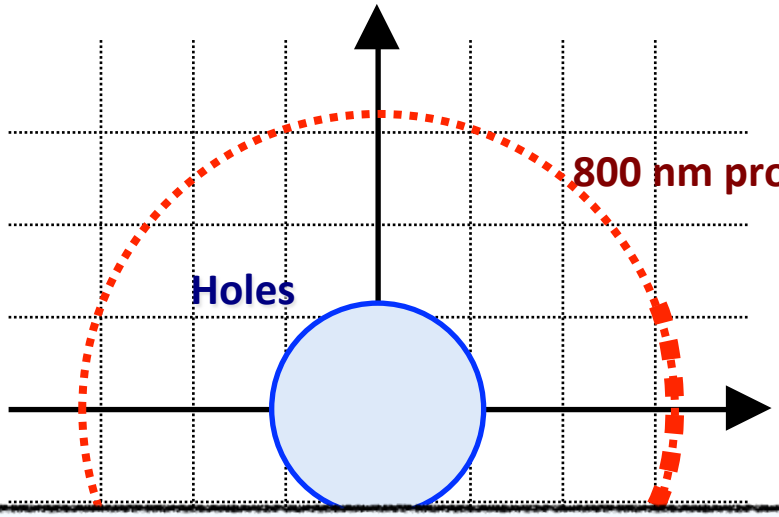
THz-induced Transparency



Boltzmann equation



Hole distribution in the momentum space



Boltzmann equation for $f(\vec{k},t)$

$$\frac{\partial f}{\partial t}+\frac{e\vec{E}}{\hbar}\cdot\frac{\partial f}{\partial \vec{k}}=\left.\frac{\partial f}{\partial t}\right|_{col}$$

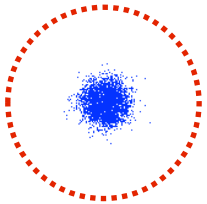
$$=\left.\frac{\partial f}{\partial t}\right|_{e-e}+\left.\frac{\partial f}{\partial t}\right|_{h-h}+\left.\frac{\partial f}{\partial t}\right|_{OPE}$$

- No screening
- ω_{TO} = 160 meV

Monte Carlo Simulration

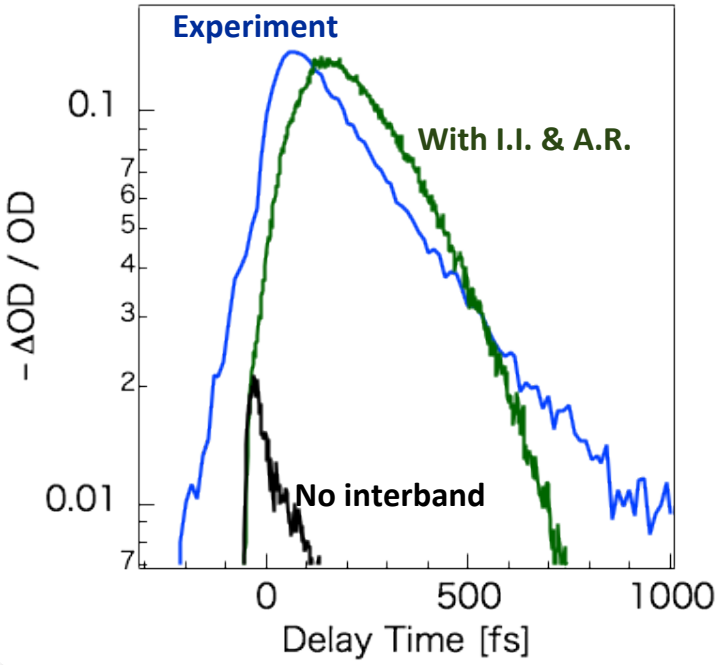
E_{THz} = 300 kV/cm
E_F = - 200 meV

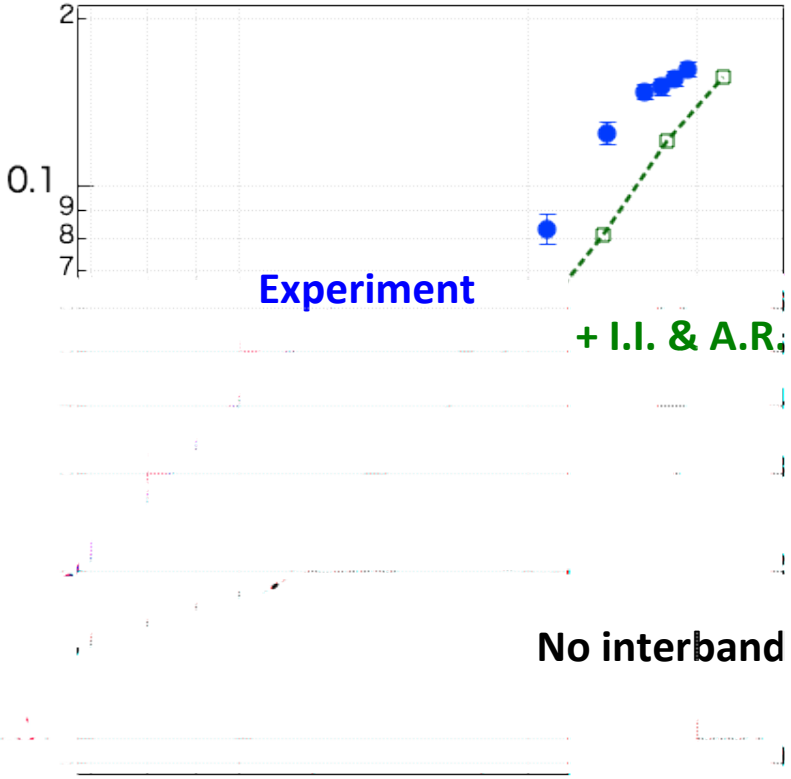
-100 fs



— New hole
— Initial hole

at 800 nm





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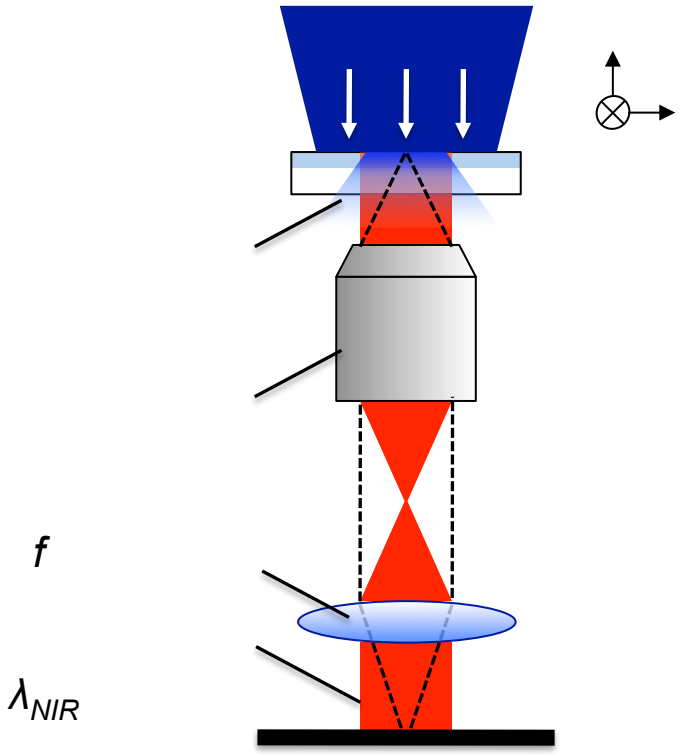
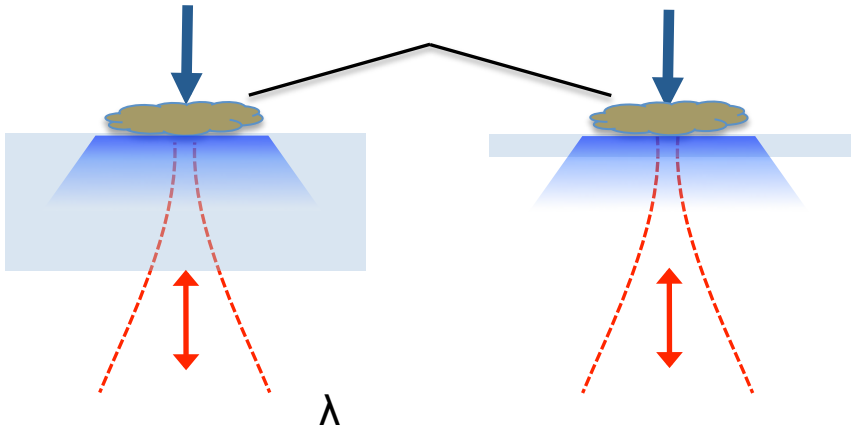
Near-field detection



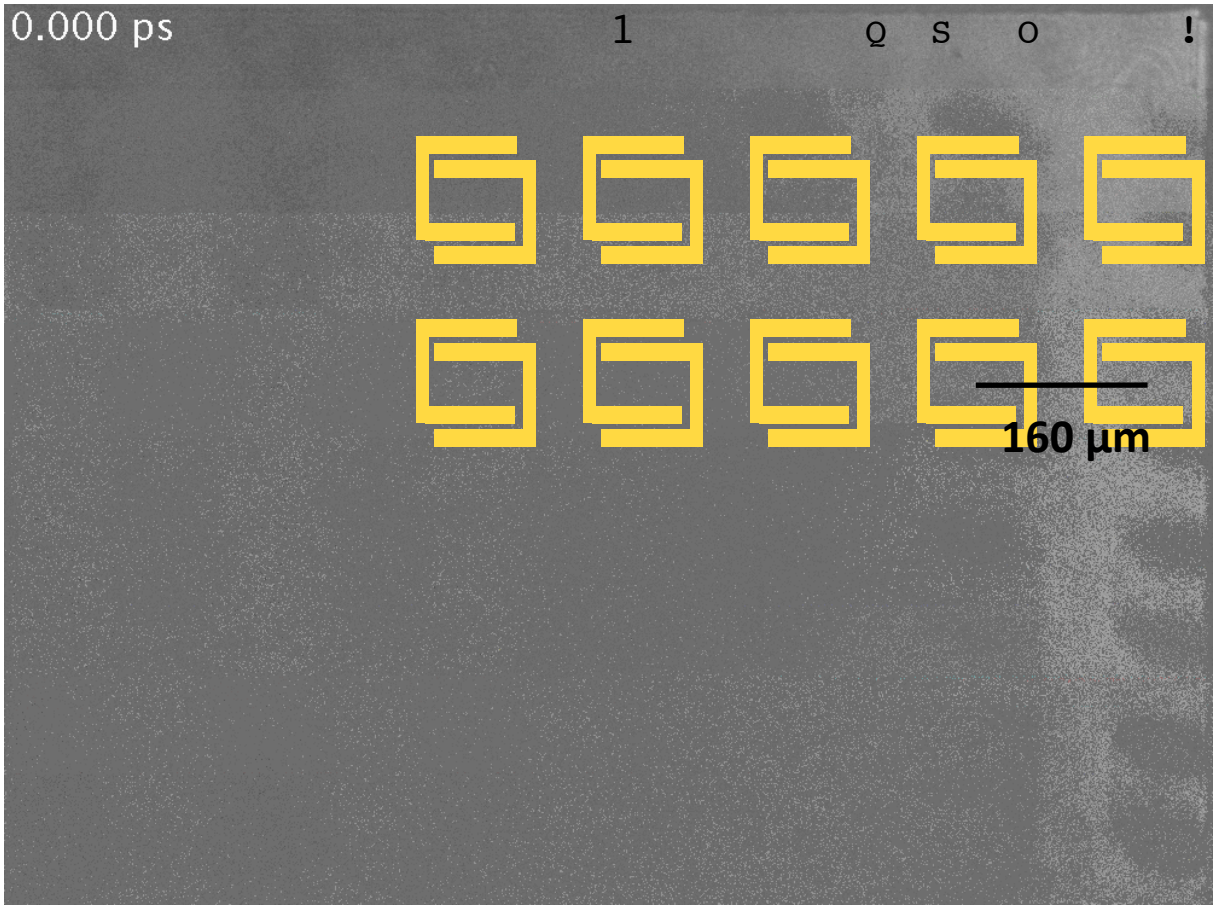
The sample is illuminated at once



$$\frac{i_S - i_P}{i_S + i_P} = \sin\theta \approx \theta = \frac{2\pi}{\lambda} n_0^3 r_{41} EL$$

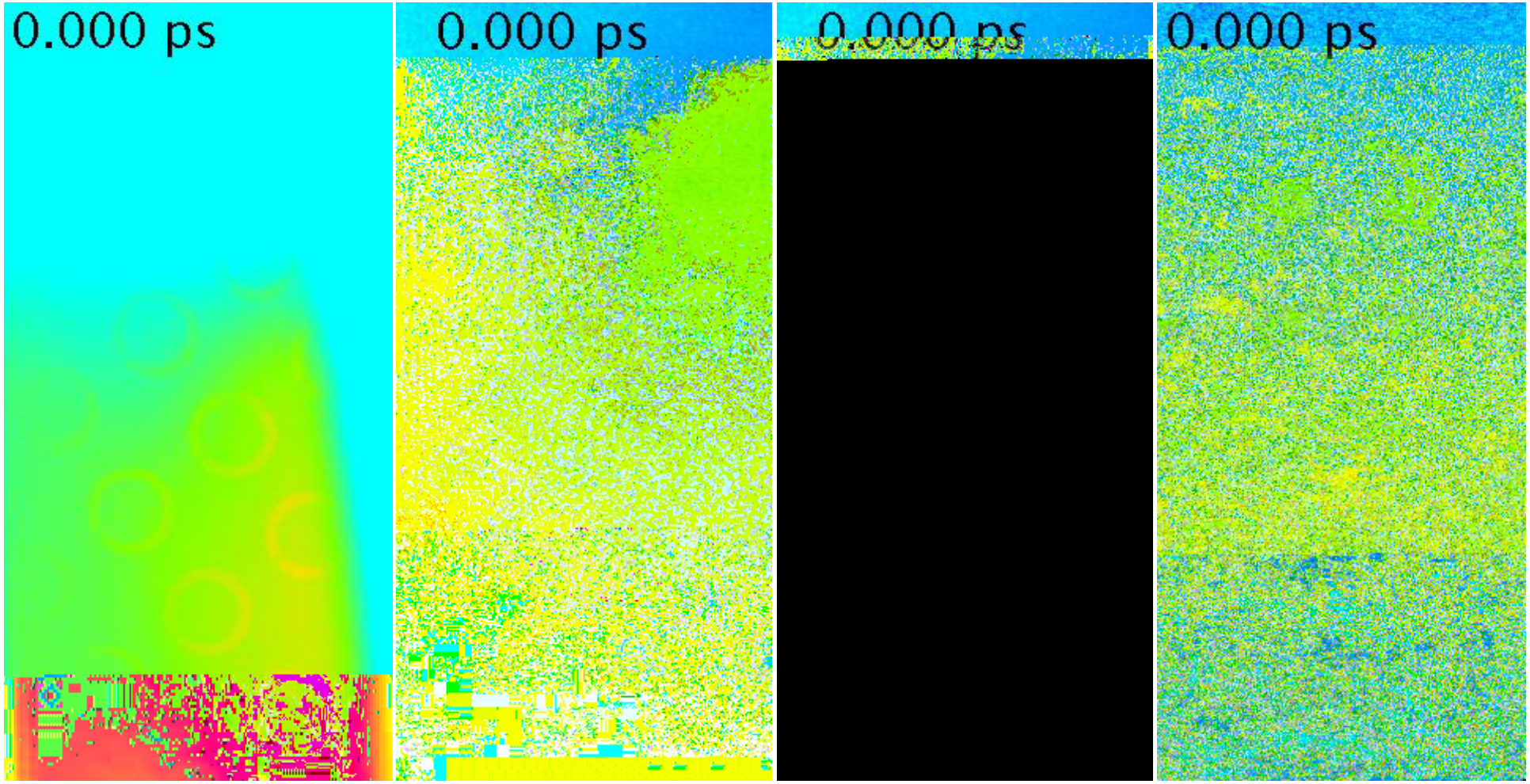
A high intensity THz source is required

Near-field image of metamaterial

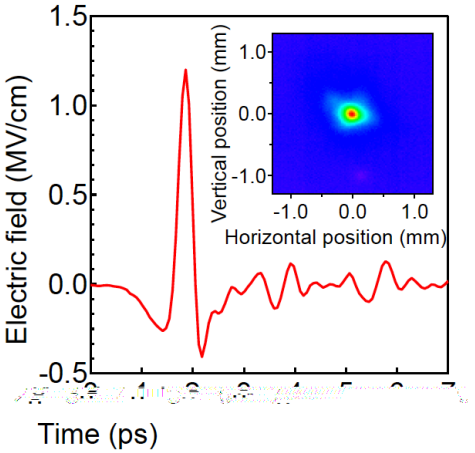


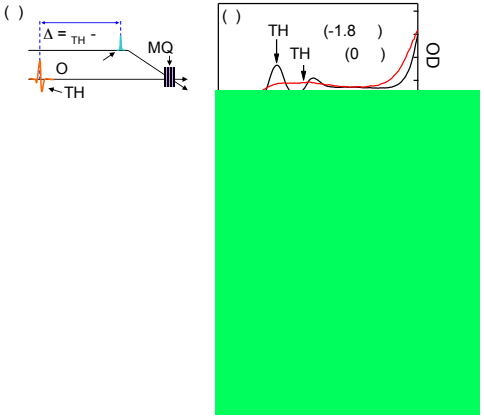
E_{THz} 200 kV/cm
Photron 12 bits/ 500 FPS
34 averaged images
800 x 1000 pixels

Interesting movies of SRR



Conclusion





Thank you for your attention !

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Acknoledgements

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