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DEGLI STUDI DI TRIESTE

T-ReX Research Group

Elettra Sincrotrone Trieste

Advances in time domain spectroscopies, a table-top approach complementary to FEL and SR sources

Daniele Fausti,
Elettra-Sincrotrone Trieste S. c. p. a. and University of Trieste

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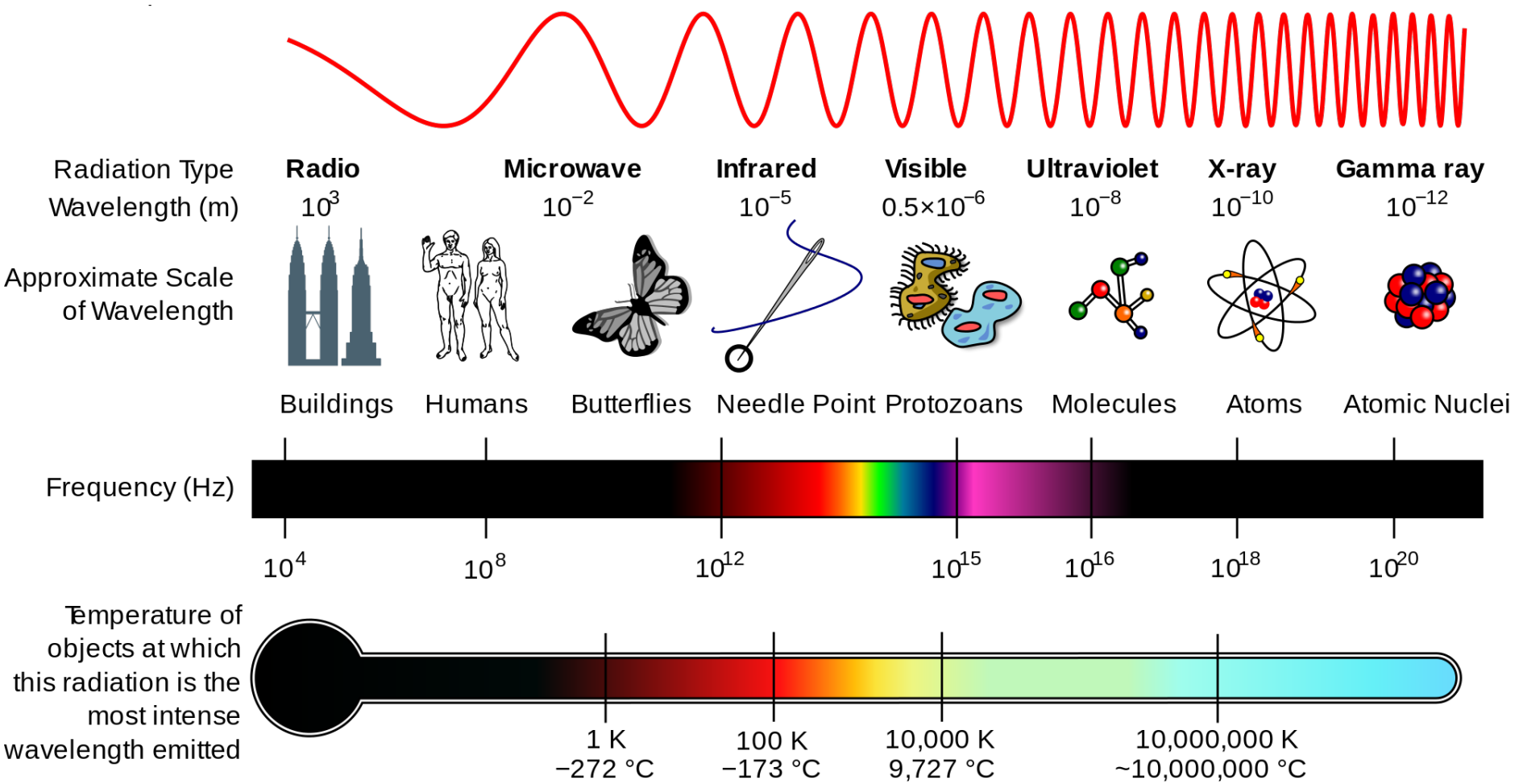
The energy scale of Table top



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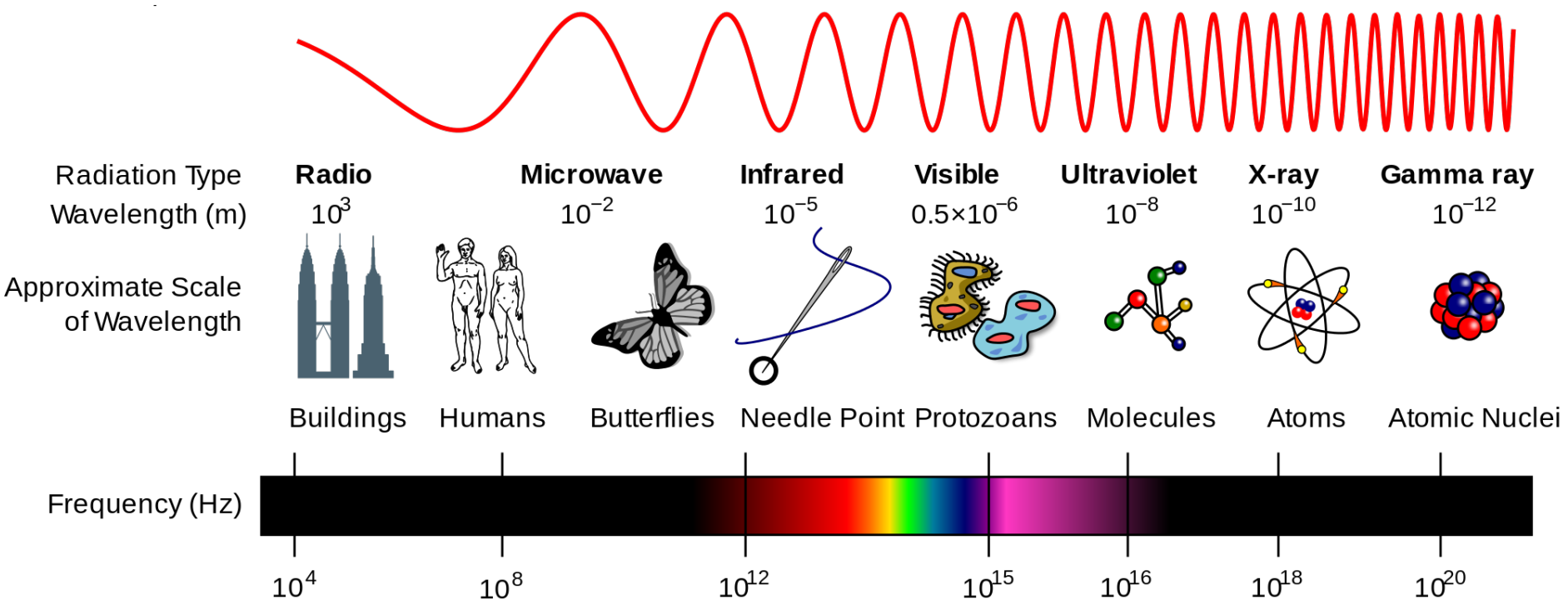

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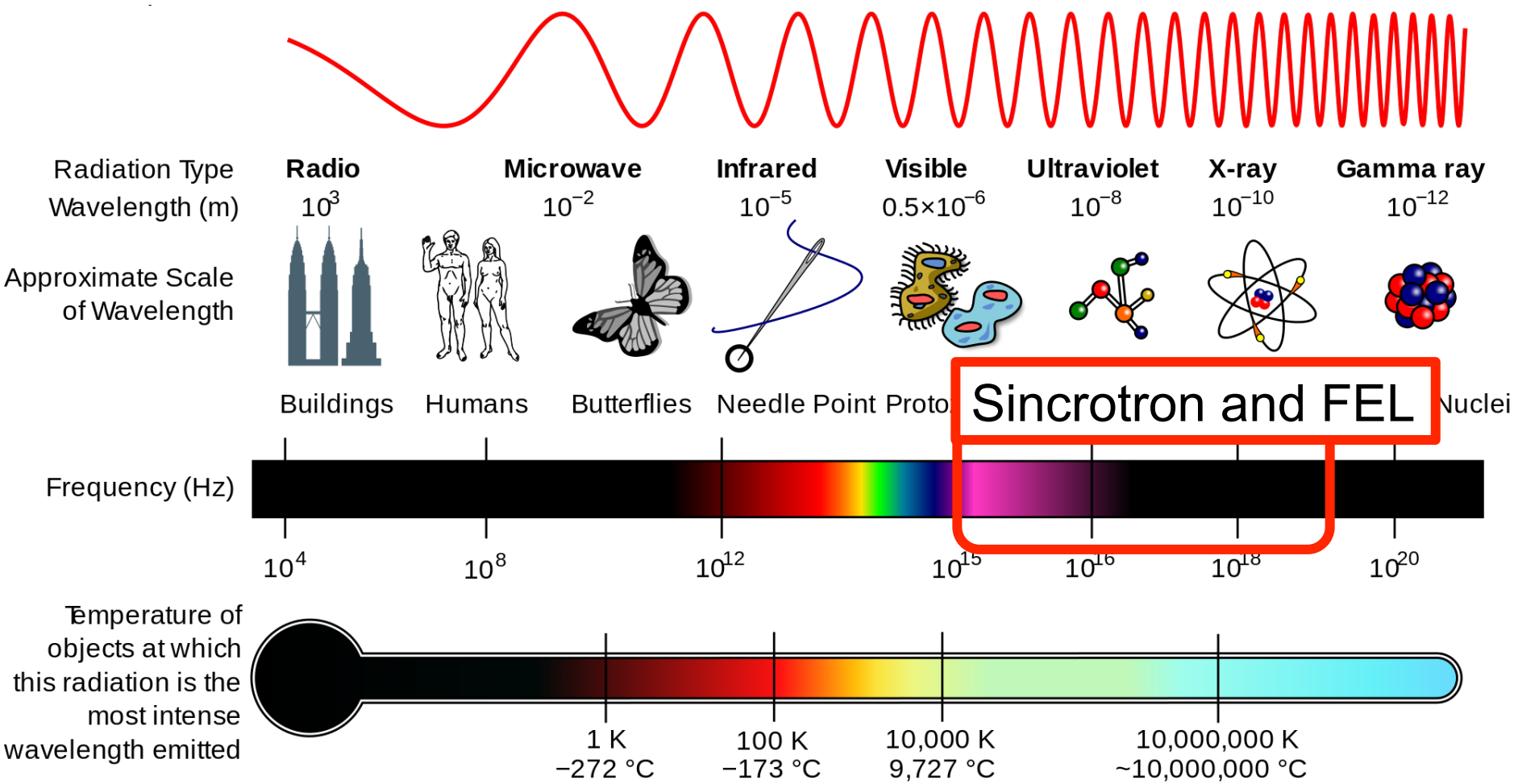

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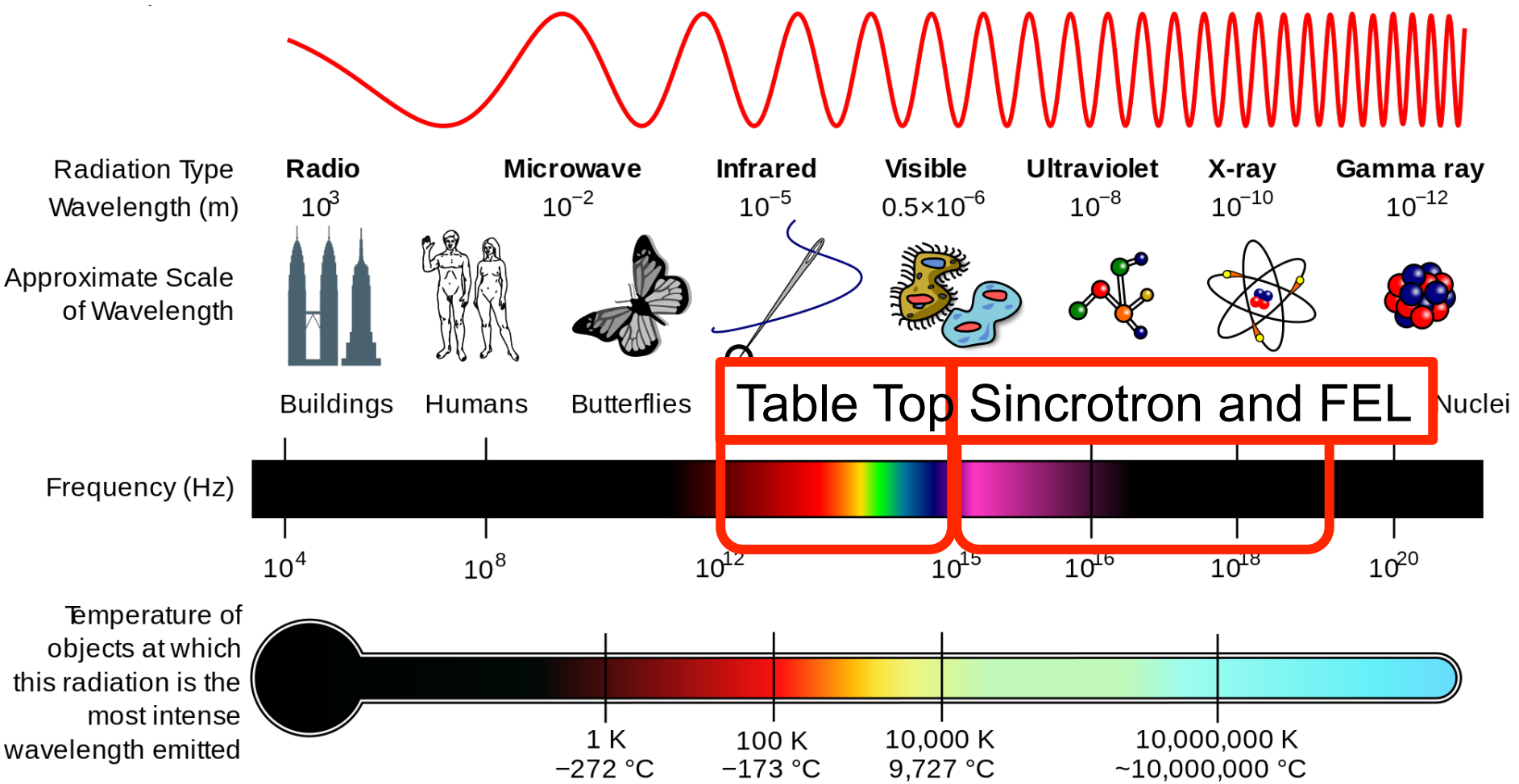

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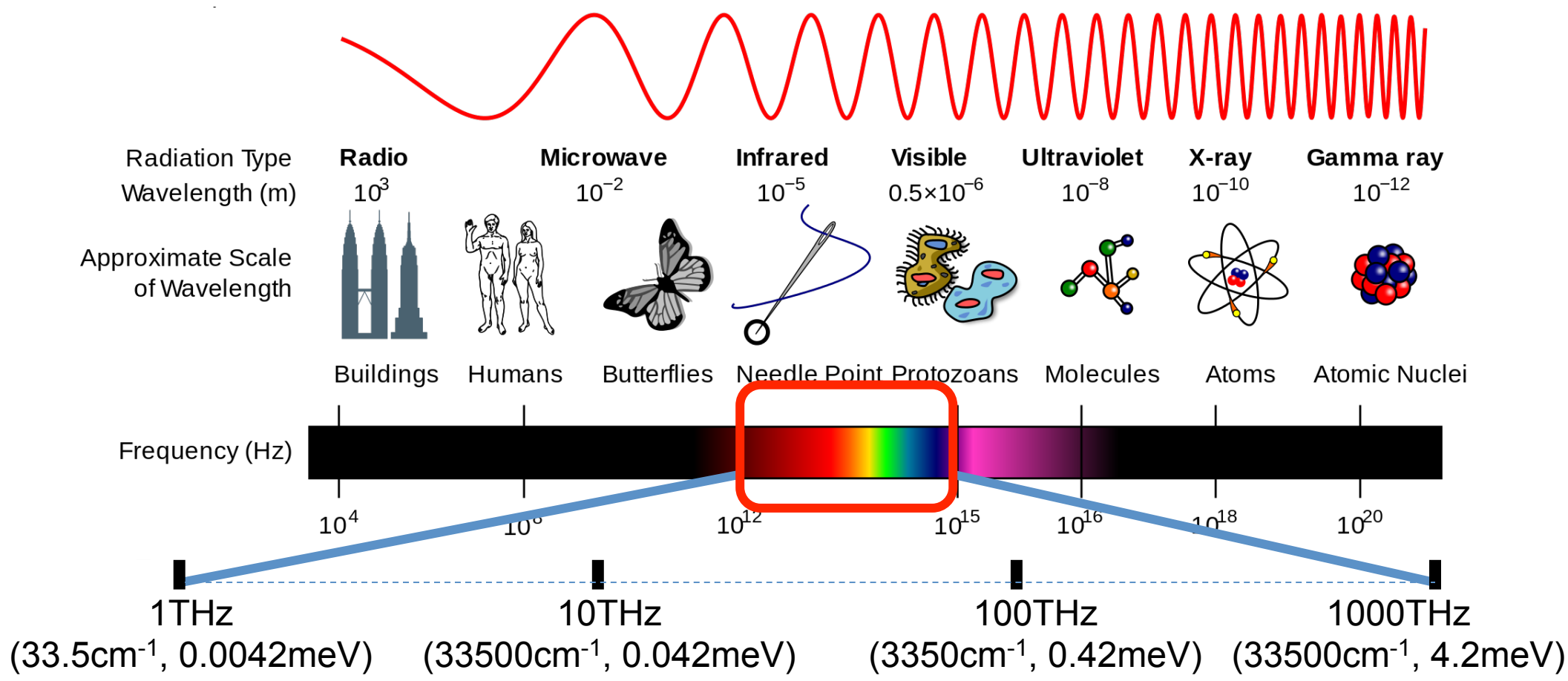

Phonons

Acoustic, librational → Optical, Molecular

Magnetic excitations

Electronic excitation

Free Electron (Drude) → dd-transition, Charge Transfer, Plasma res., etc

Outline

- ✓ **Equilibrium Optical Spectroscopy**
  - -The optical conductivity in the Visible and Near-IR
  - -What do we learn from optical conductivity?
  - -An example, metal insulator transition in complex oxides
- ✓ **Non-equilibrium optical (visible near-IR) spectroscopy**
  - -Pump&probe the main idea
  - -«Single color» Pump and probe
  - -Broadband P&P spectroscopy
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  - -Revealing the excitonic nature of excitation (Hubbard Exciton)
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Equilibrium optical conductivity

Caracterization of the response of the material to a field at a specific frequency

-**Optical conductivity** → $\sigma_1(w)$ and $\sigma_2(\omega)$
Links the current density to the electric field for general frequencies → **$J(\omega)=\sigma(\omega)E(\omega)$**

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$$\widetilde{\epsilon(\omega)} = \epsilon_\infty + \sum_{i=1}^{M} \frac{\omega_{P,i}^2}{(\omega_i^2 - \omega^2) - i\Gamma_i\omega}$$

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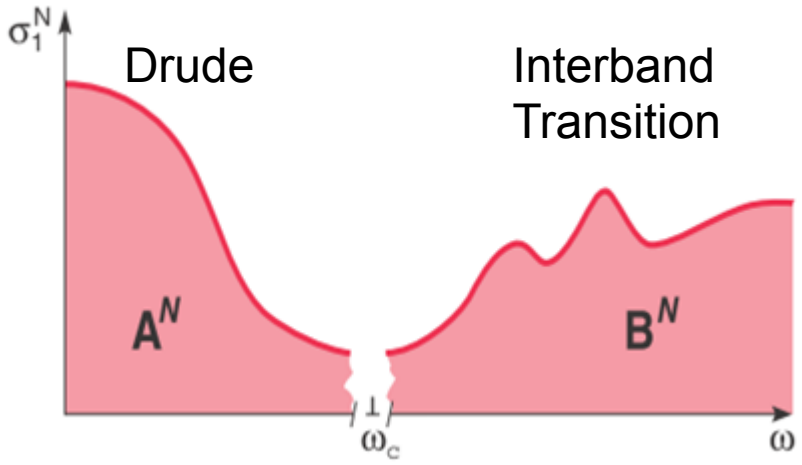
Integral of sigma one is a conserved quantity (sum rule...)

What do we learn from equilibrium optical conductivity?

Optical Conductivity of a **Metal**



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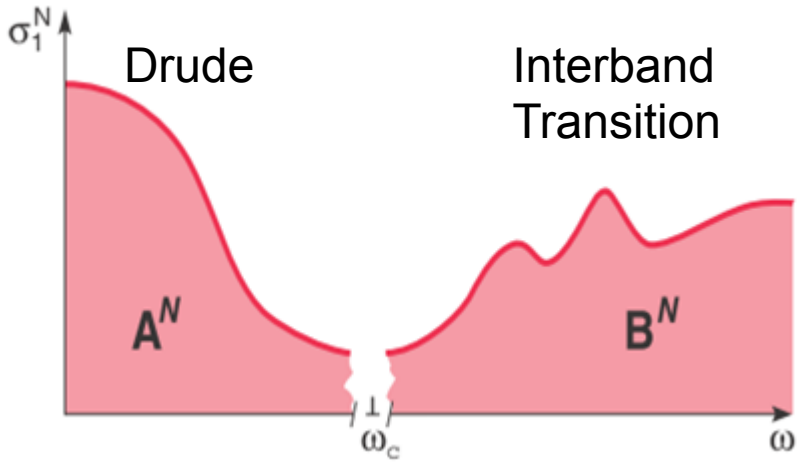

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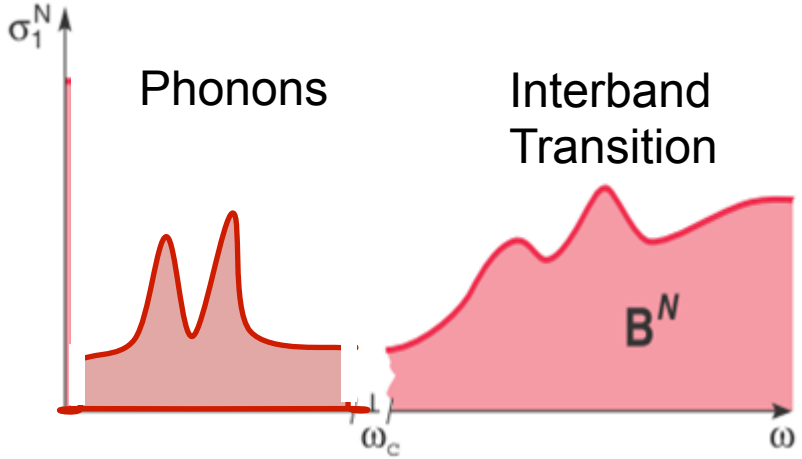

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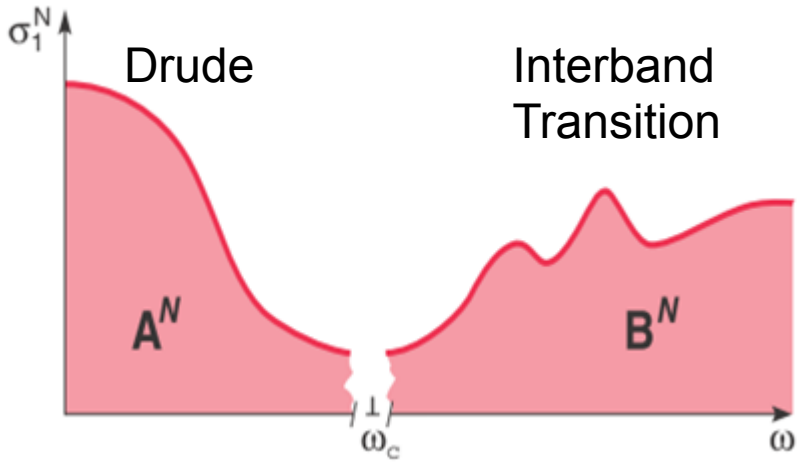
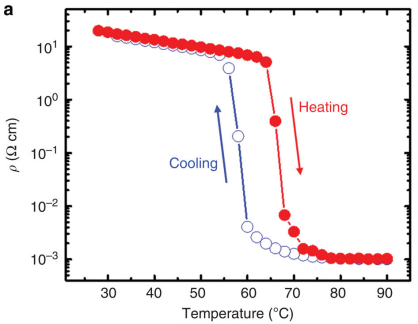


Metal insulator Transition in VO2

Transition to a metallic state at 60 °C



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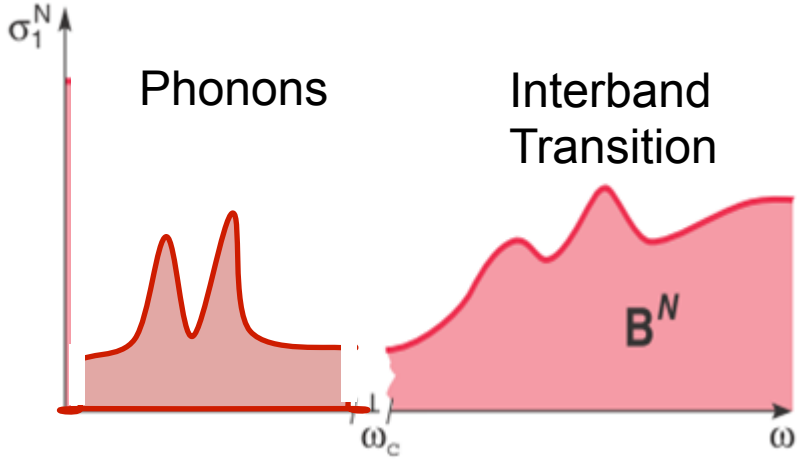

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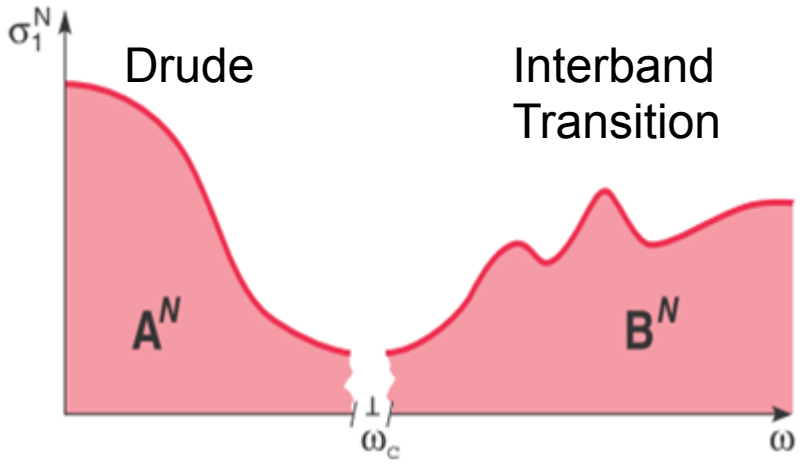

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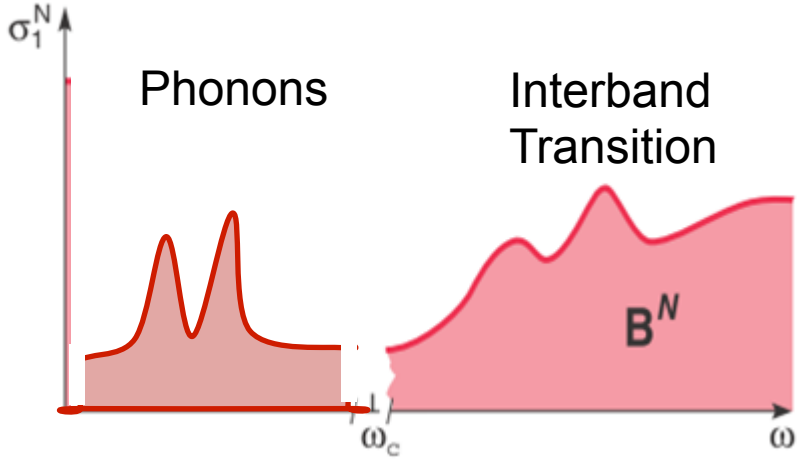

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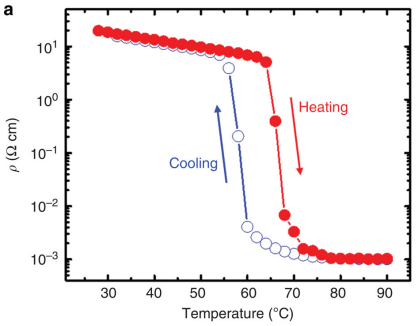

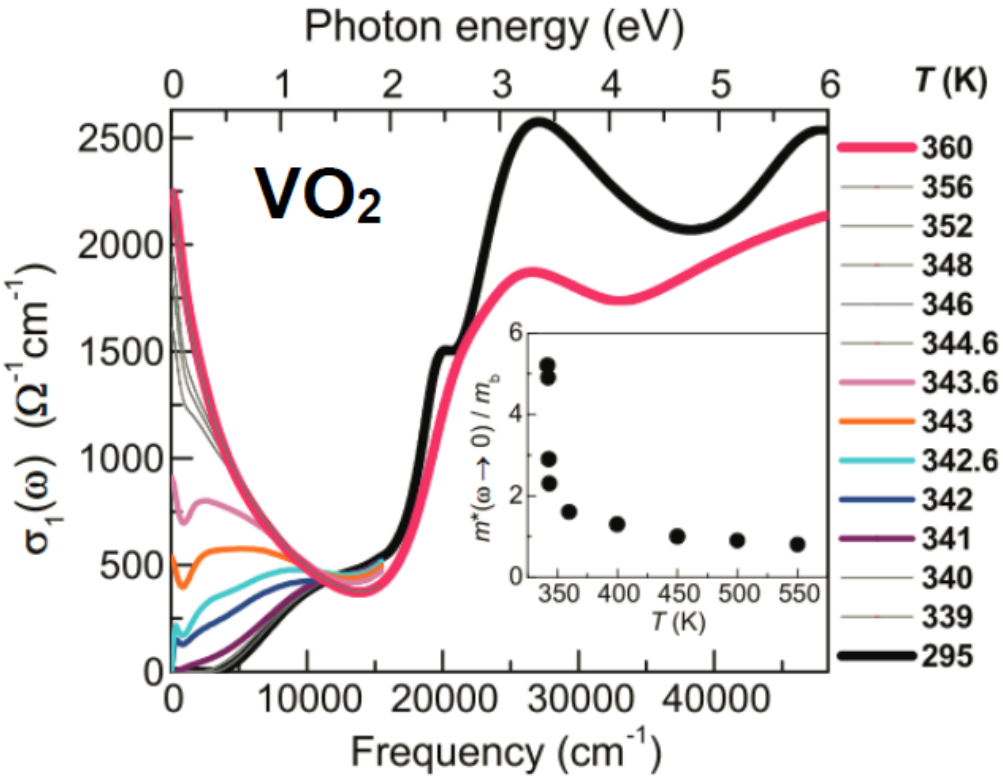

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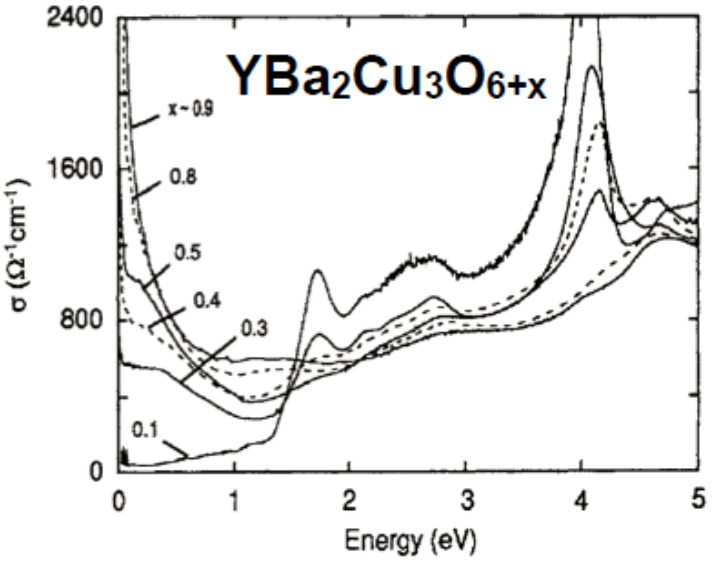
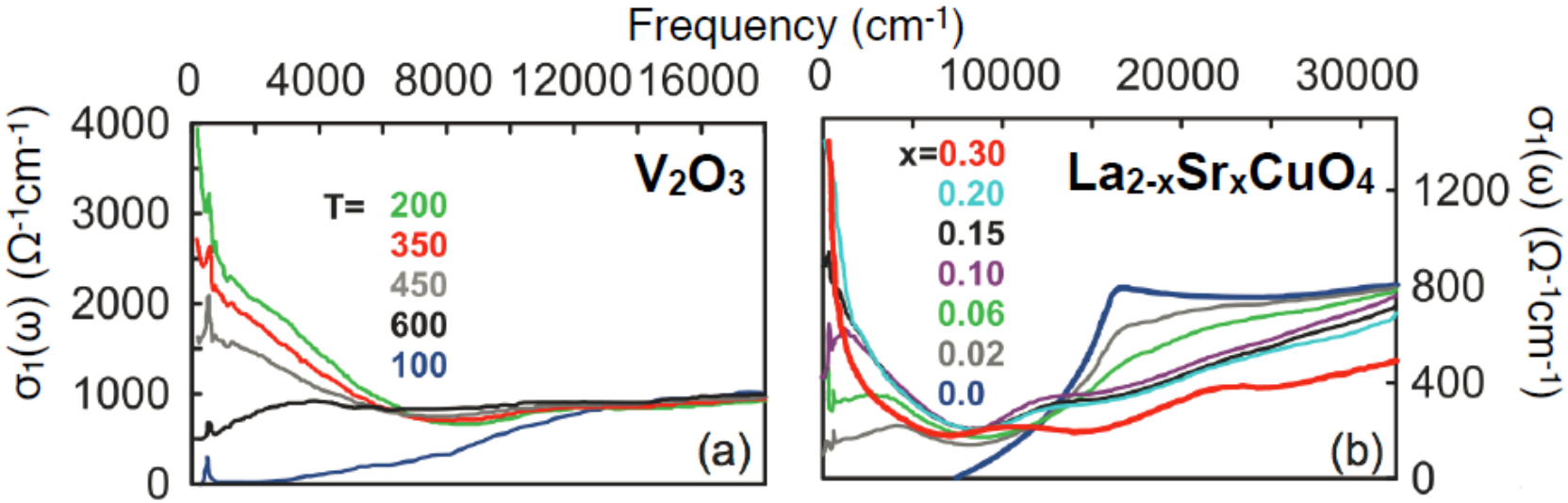
What do we learn from equilibrium optical conductivity?

Different examples of optical conductivity





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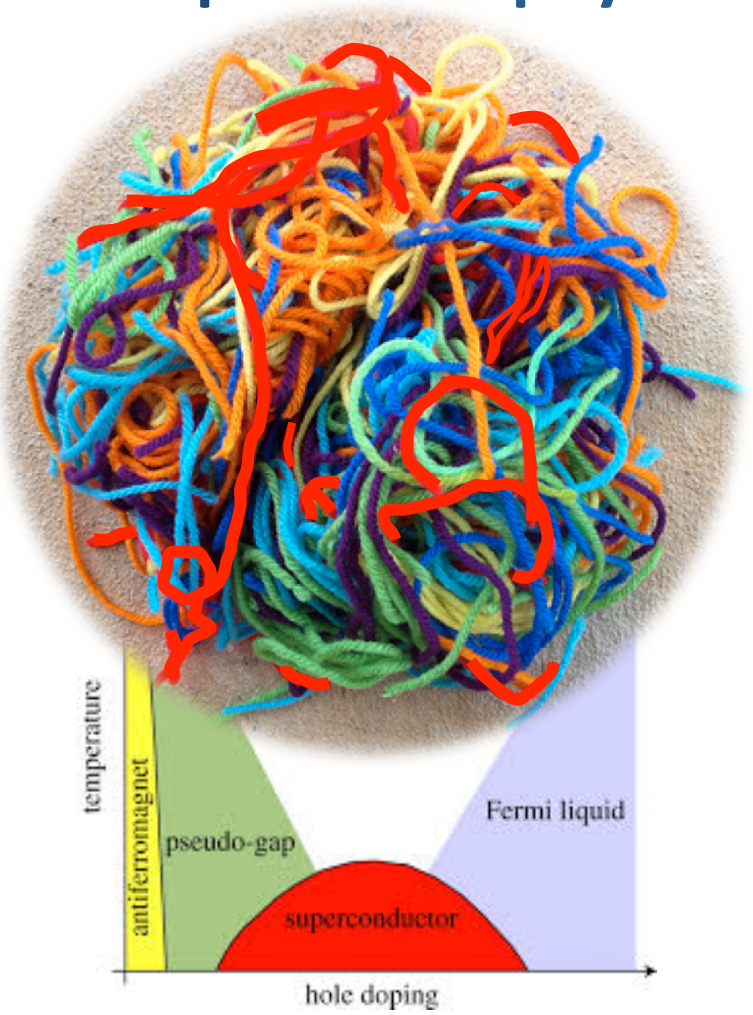
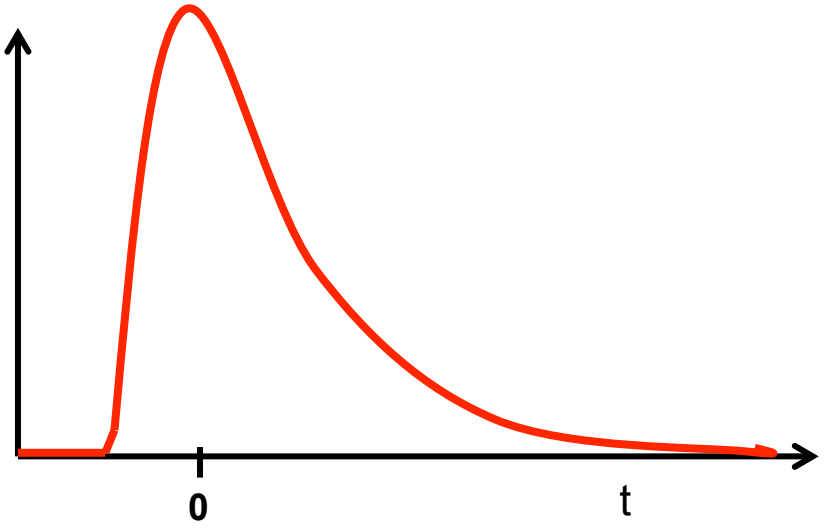
Non-Equilibrium studies

for Equilibrium physics





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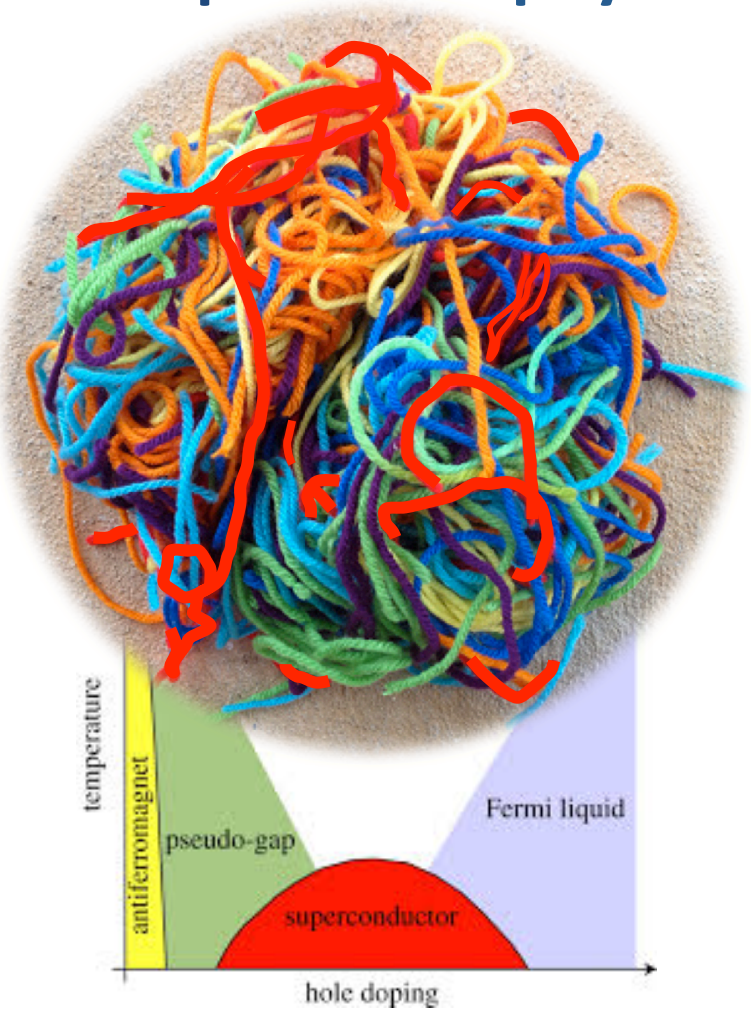
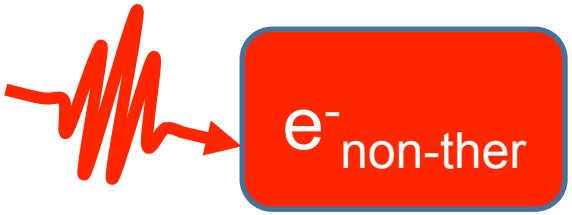
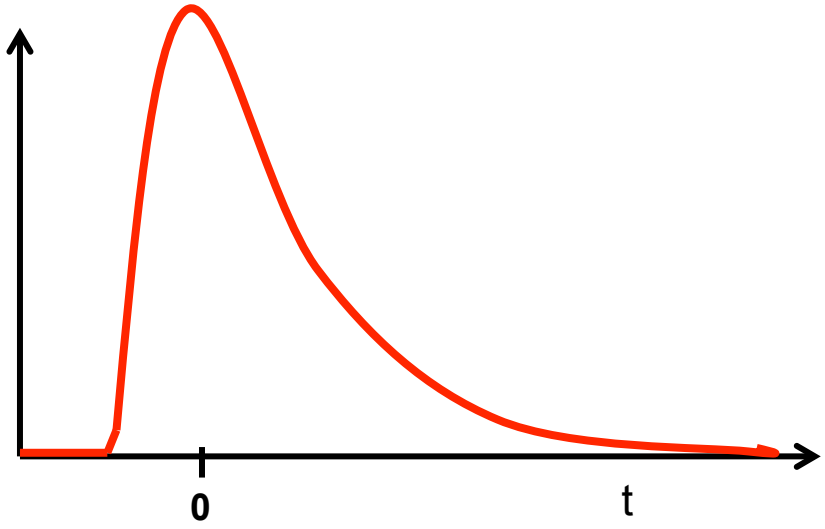


Dynamical response domeinated by a

Higherarchy in the time scales





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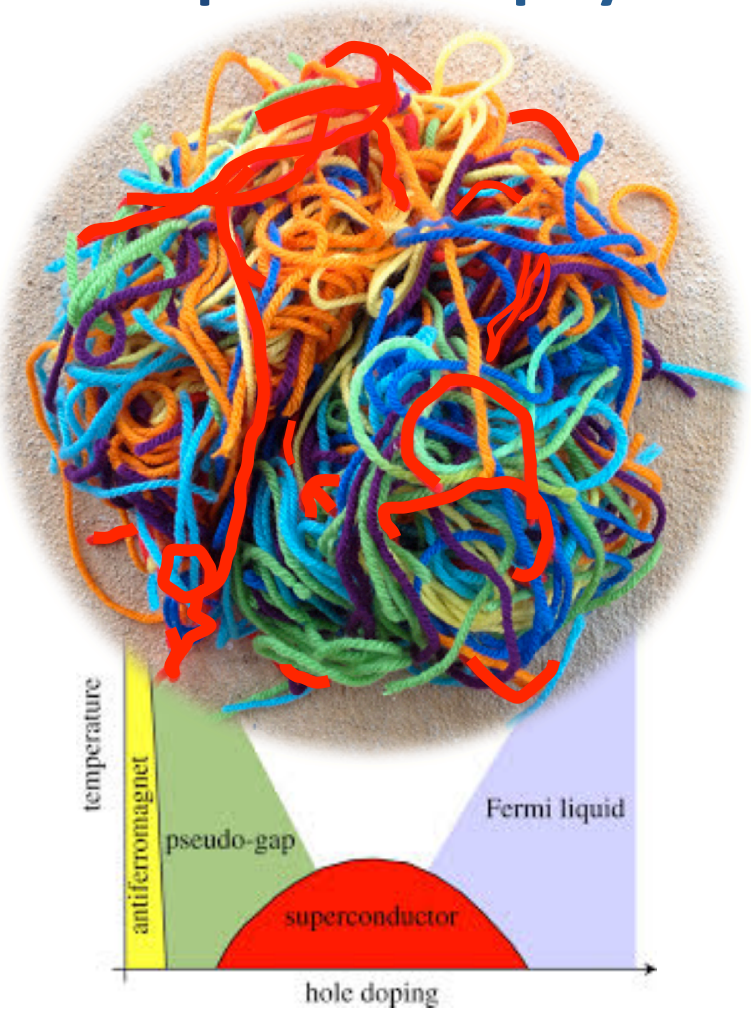

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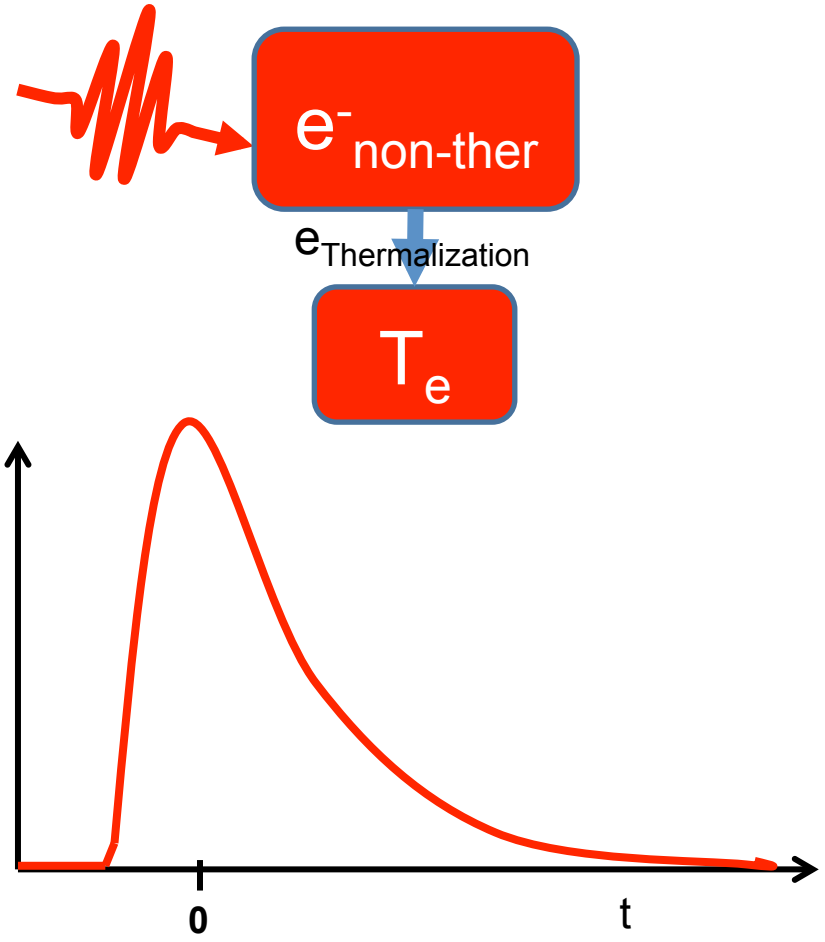

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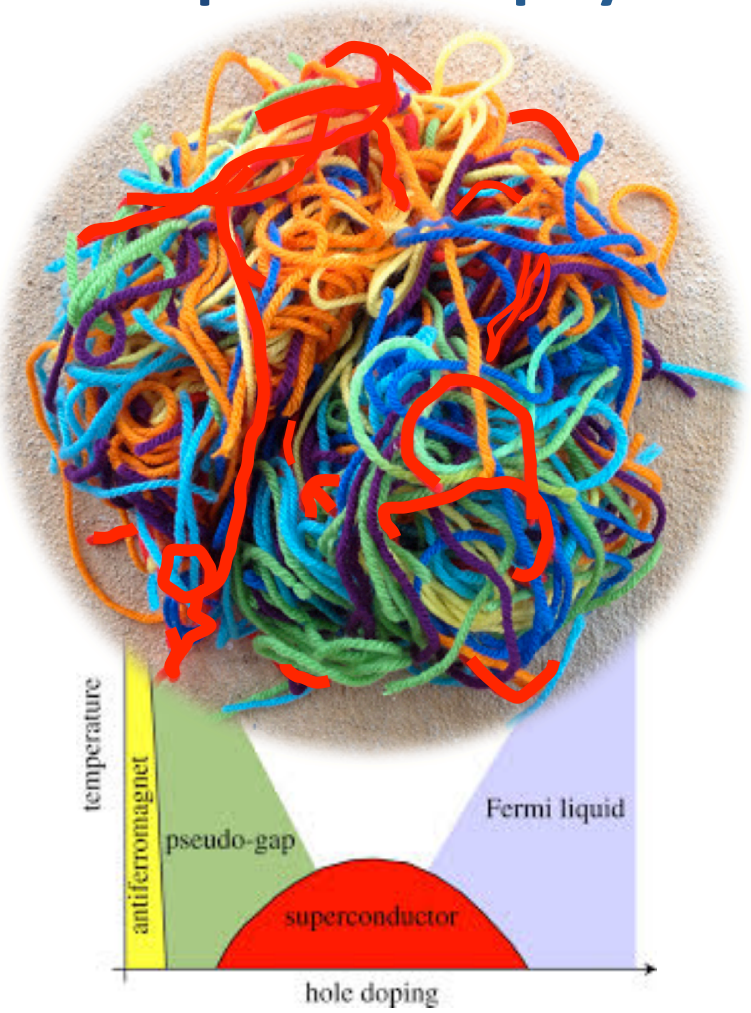

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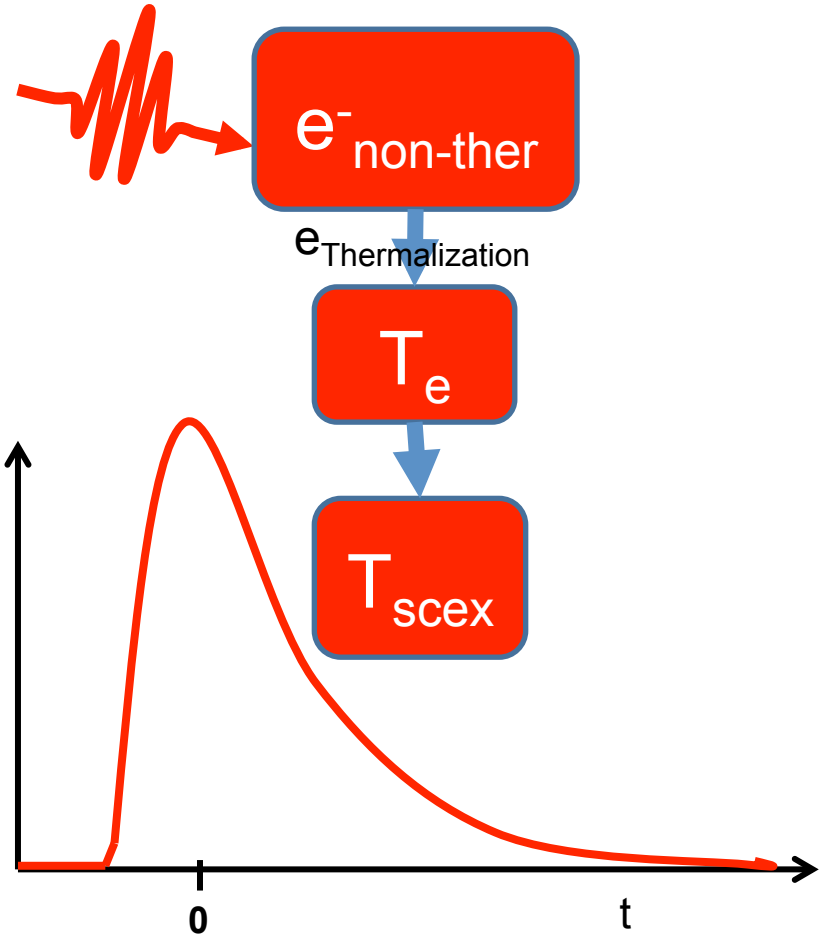

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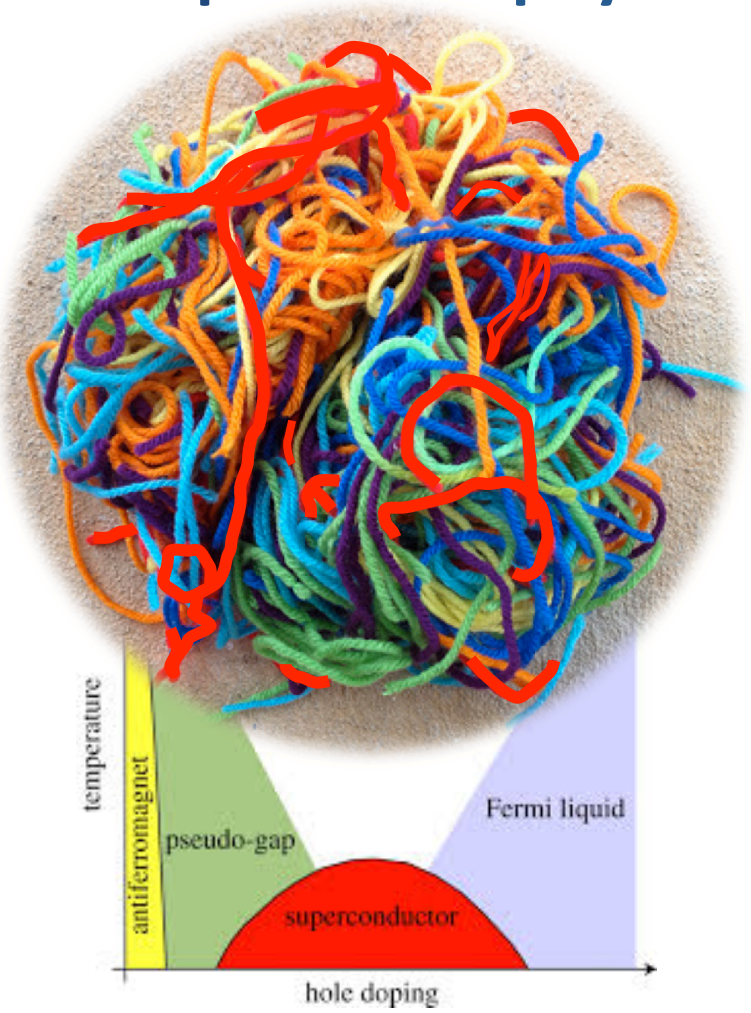

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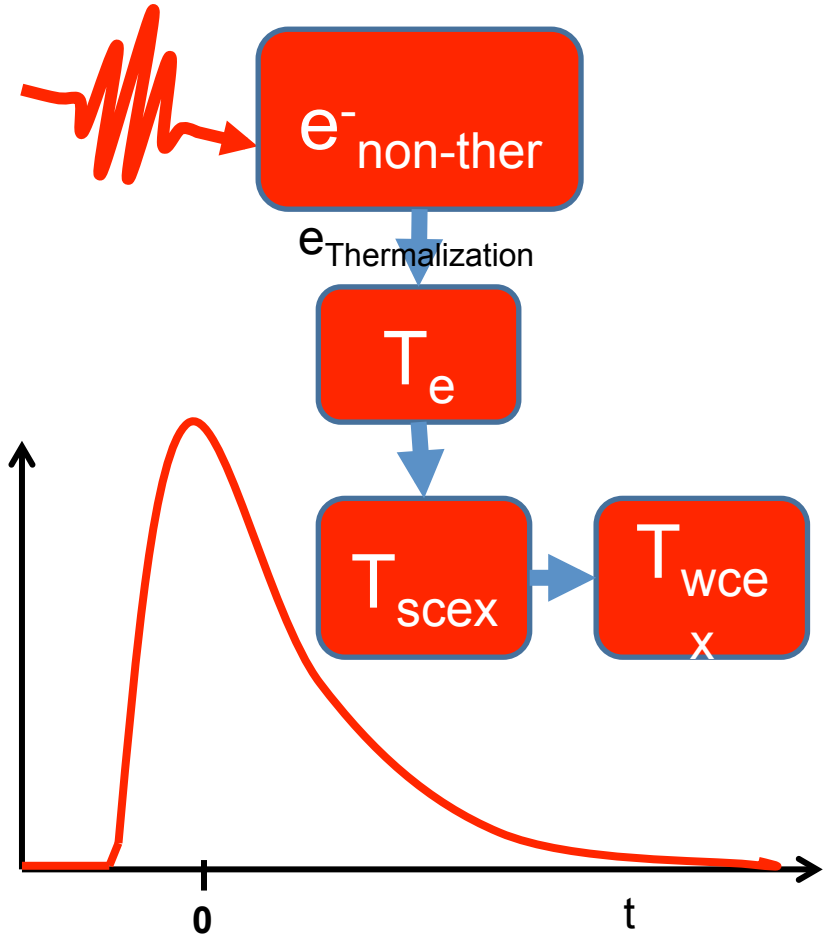

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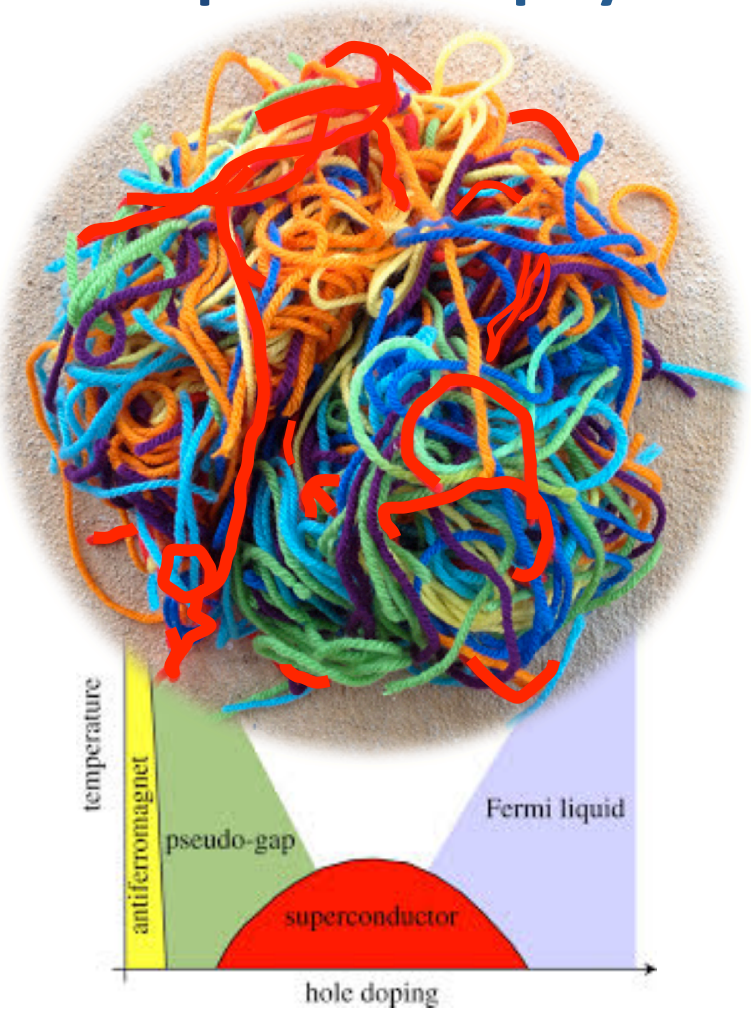

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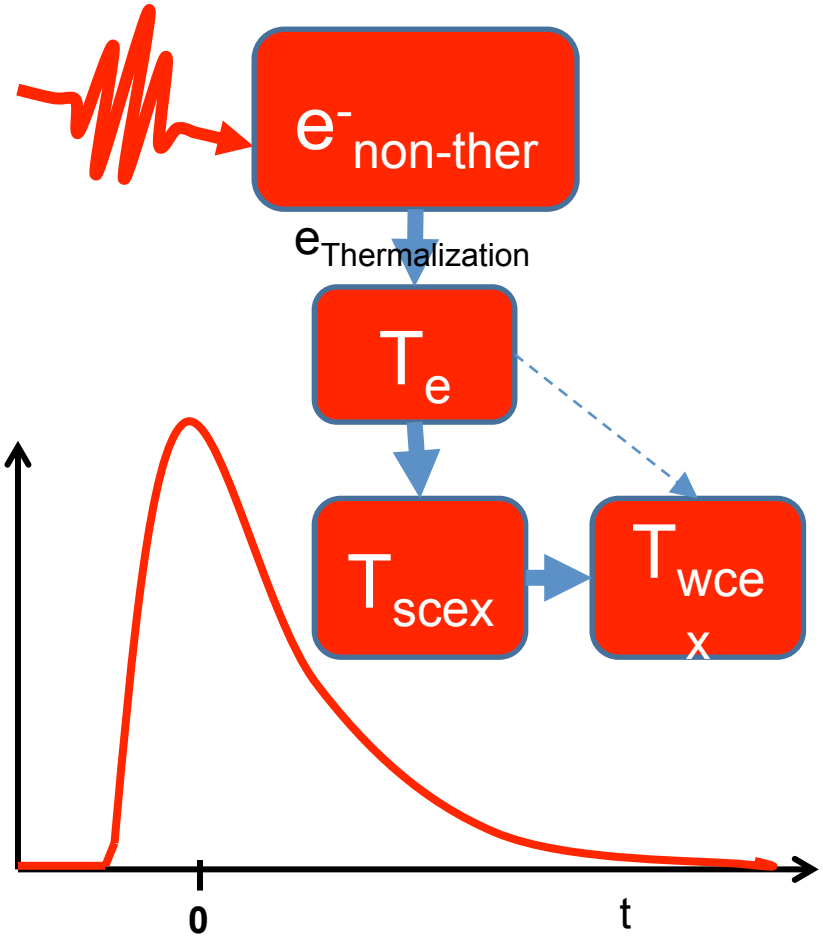

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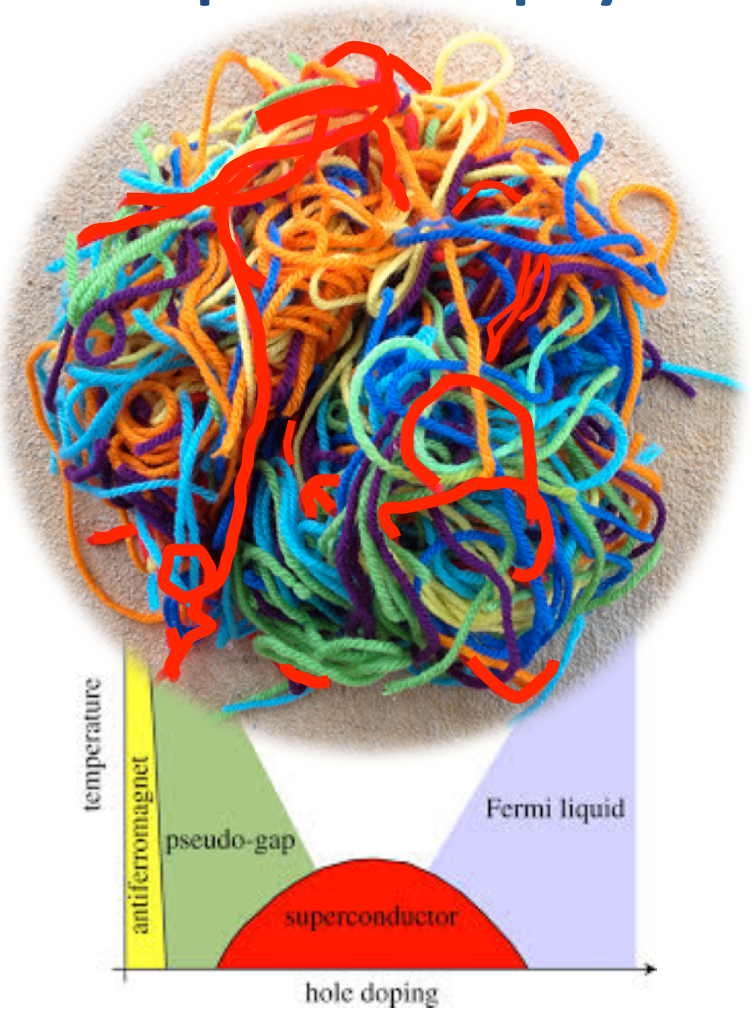

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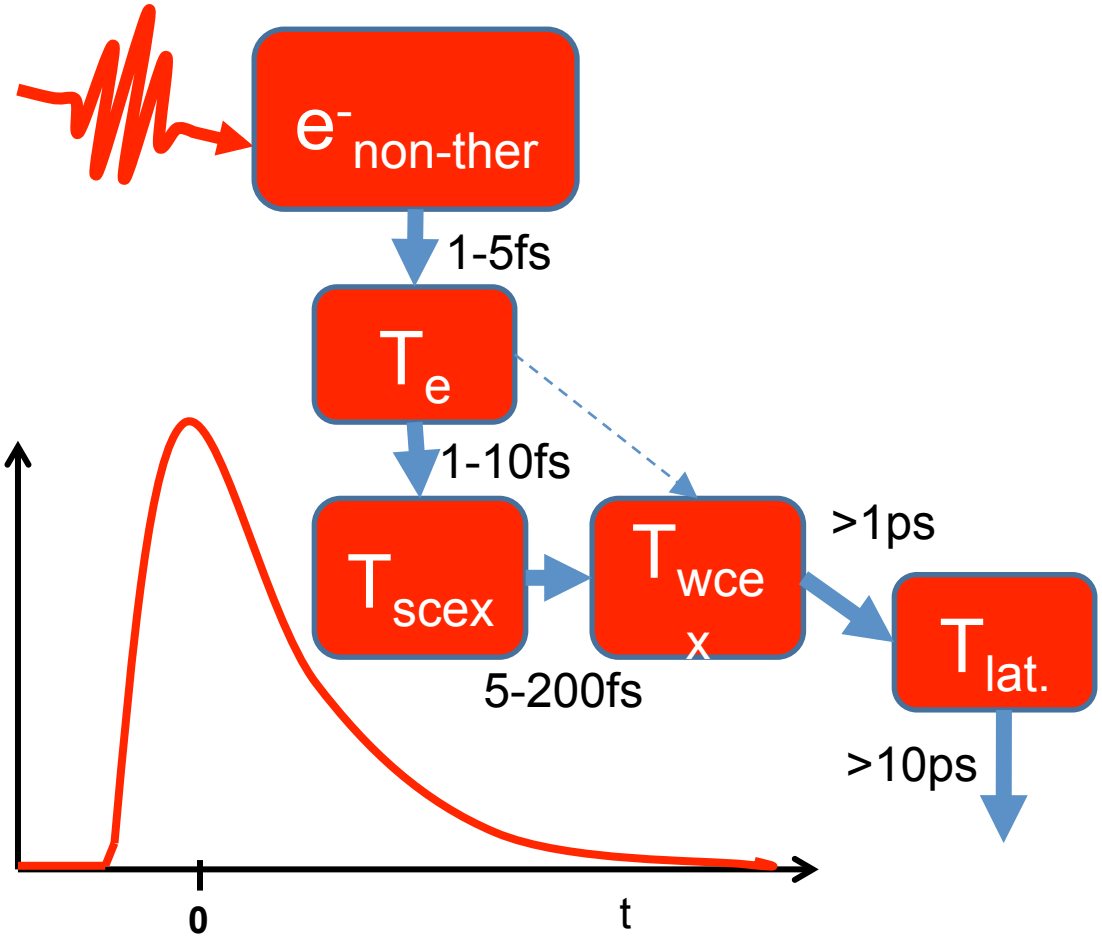

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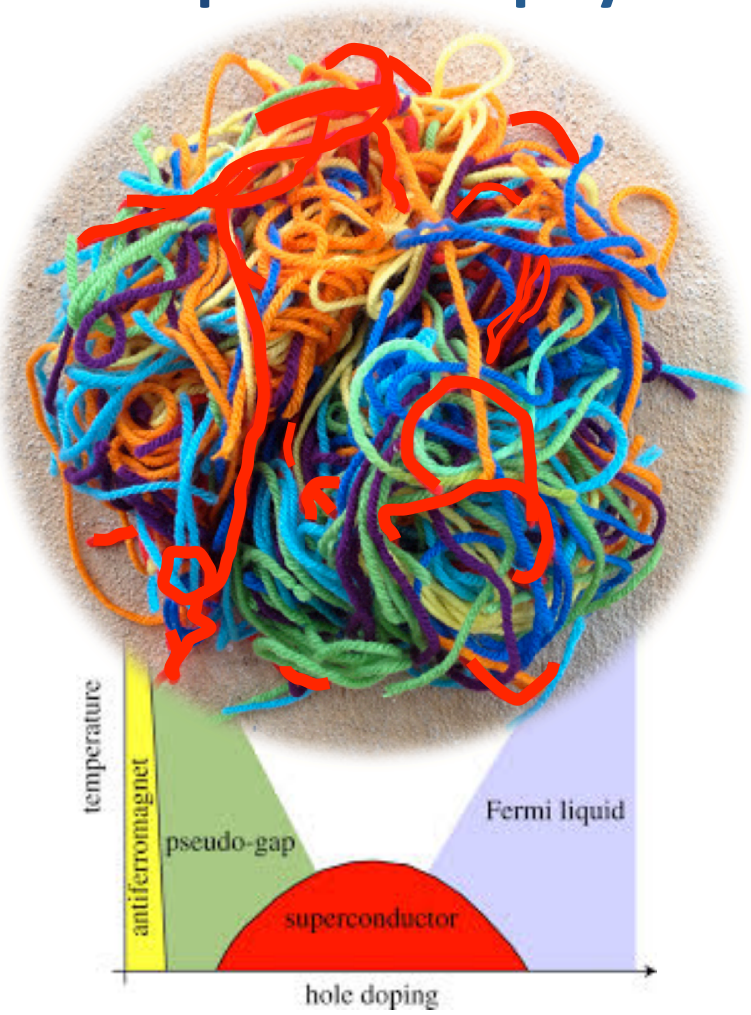

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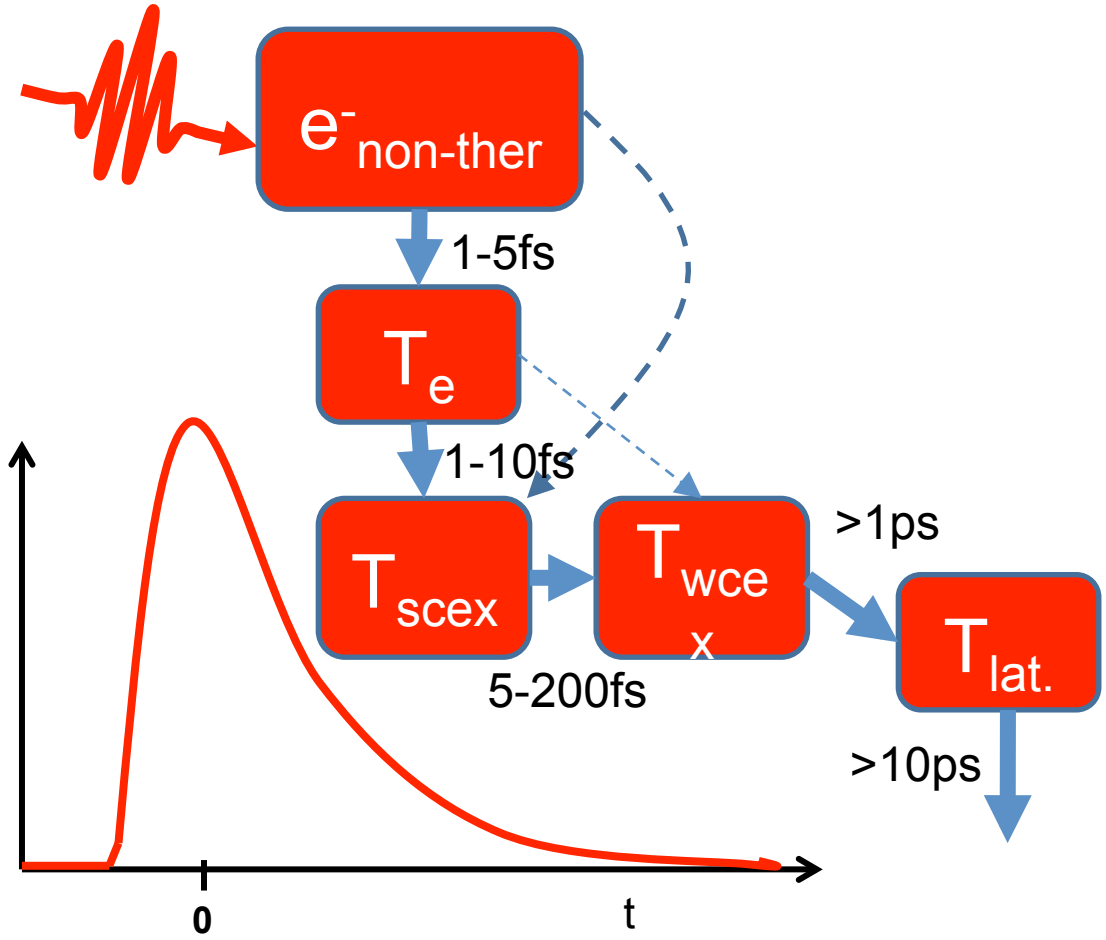

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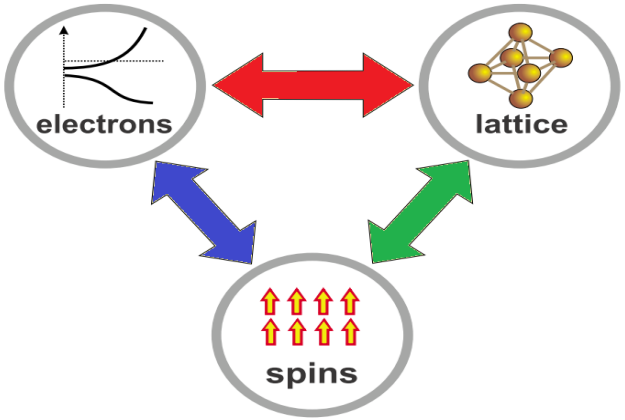
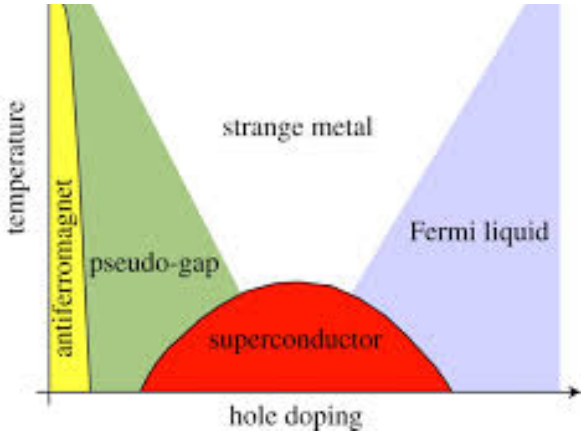
Complexity





Nat. Comm. 5, 5112, 2014

Why non-equilibrium physics?

Non-Equilibrium studies

for Equilibrium physics

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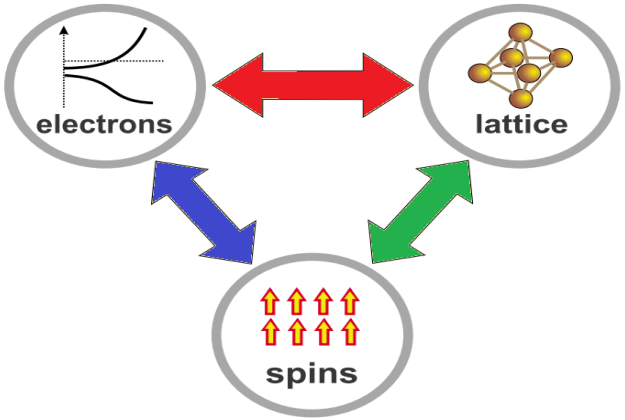
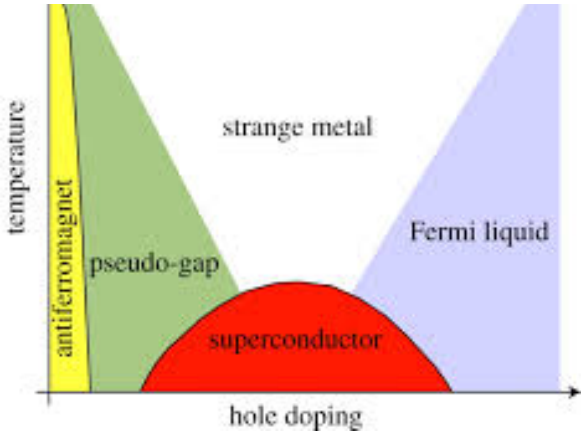
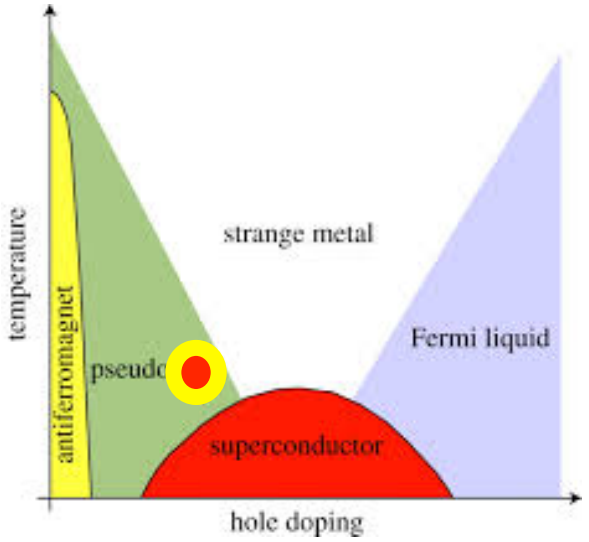




Nat. Comm. 5, 5112, 2014

Non-Equilibrium physics

for optical control



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for Equilibrium physics

Non-Equilibrium physics

for optical control

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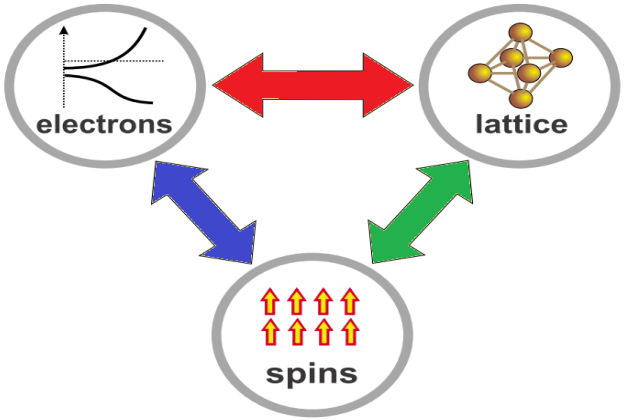

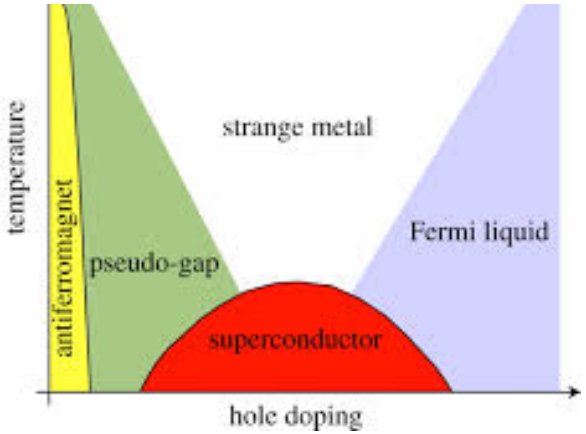

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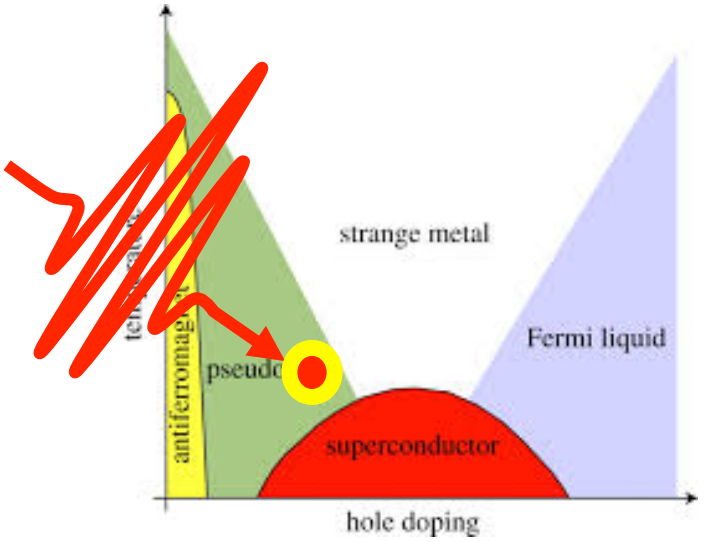

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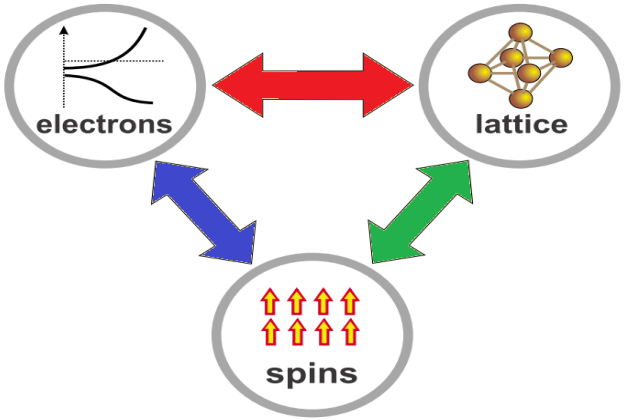

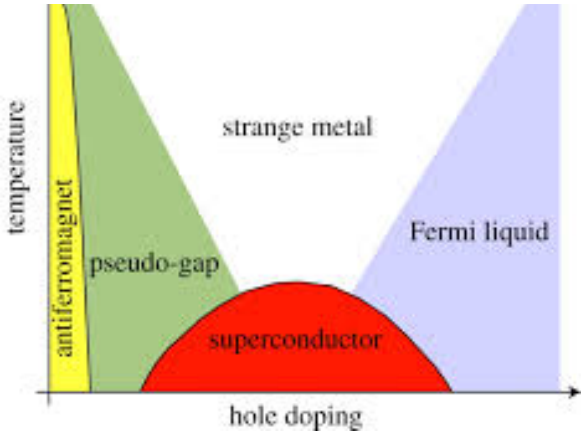

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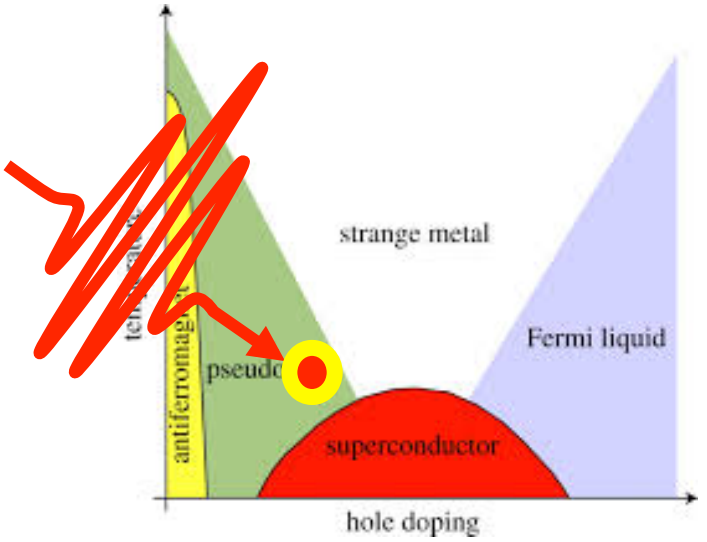

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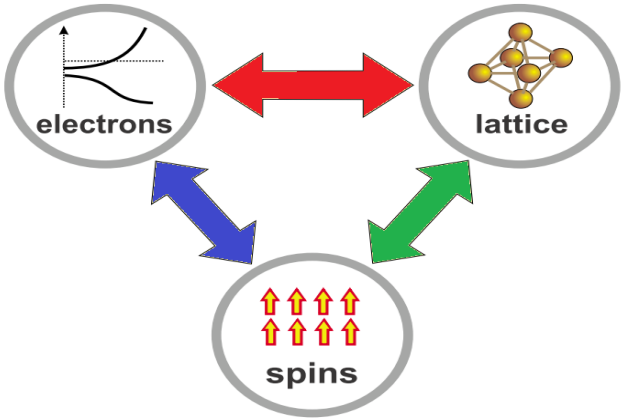

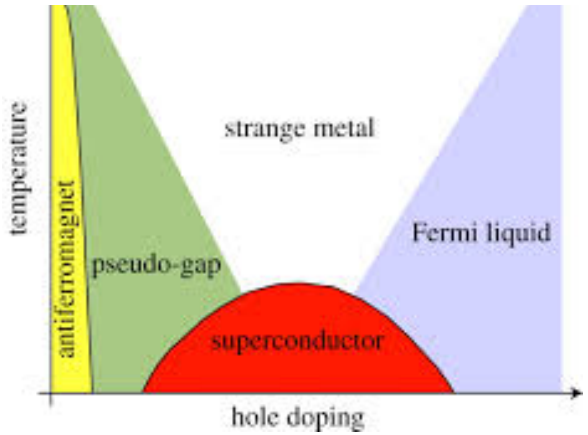

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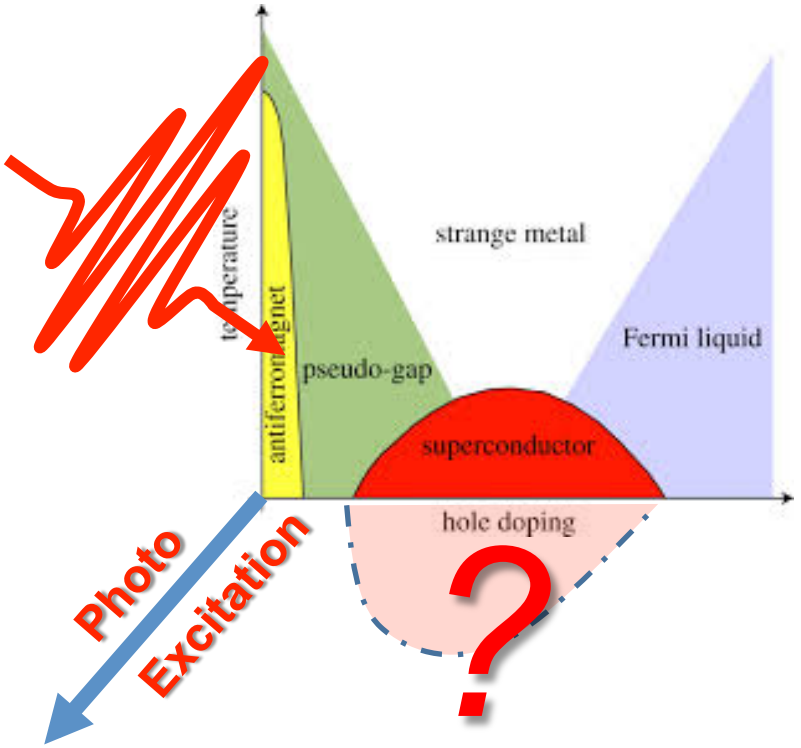

T-ReX Research Group

Elettra Sincrotrone Trieste

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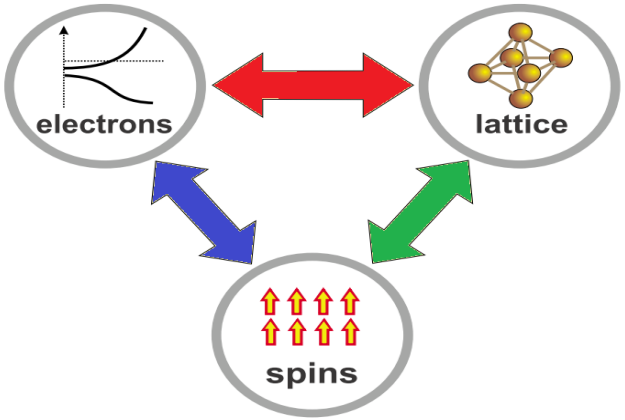
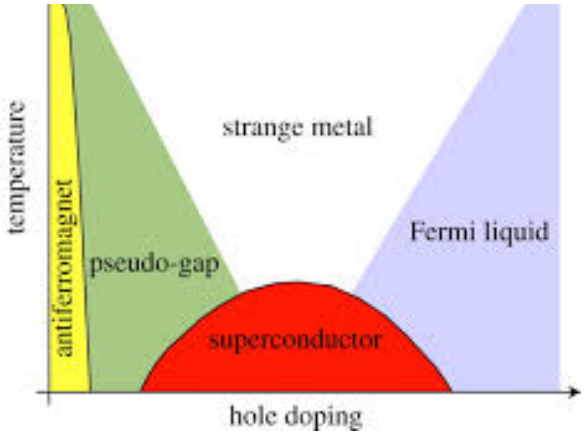


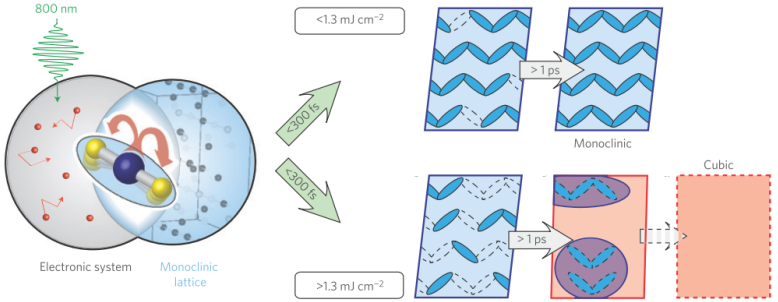


Nat. Comm. 5, 5112, 2014

Non-Equilibrium physics

for optical control

Insulator-to-metal transition



Nature Material 12, 882 (2013)
Phys. Rev. B 93, 054305 (2016)

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Non-Equilibrium studies

for Equilibrium physics

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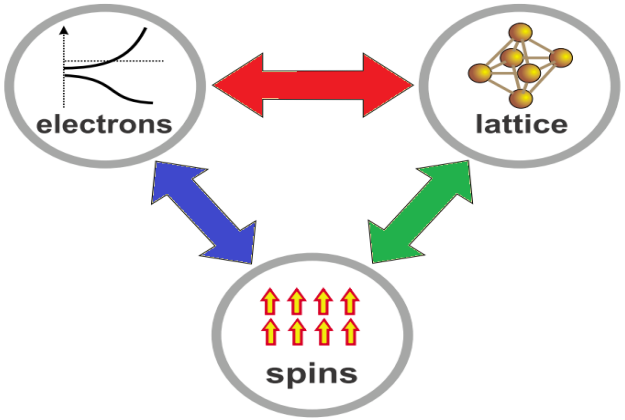

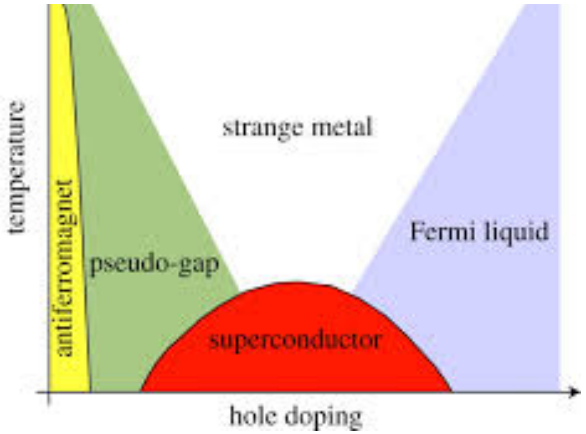

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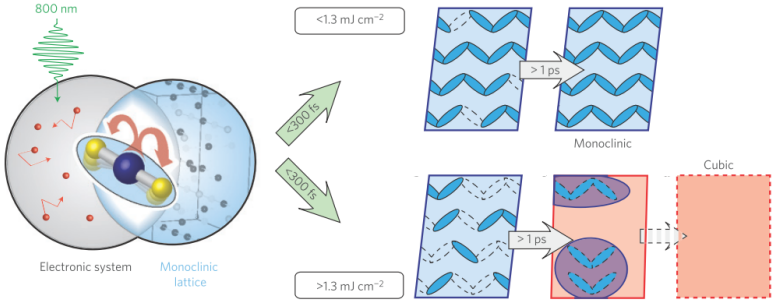

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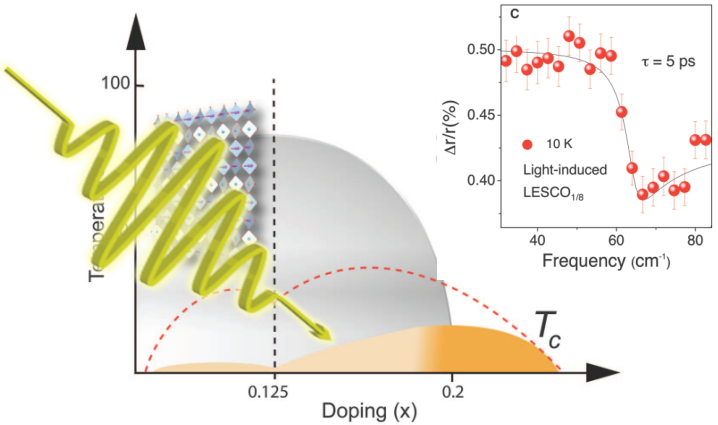
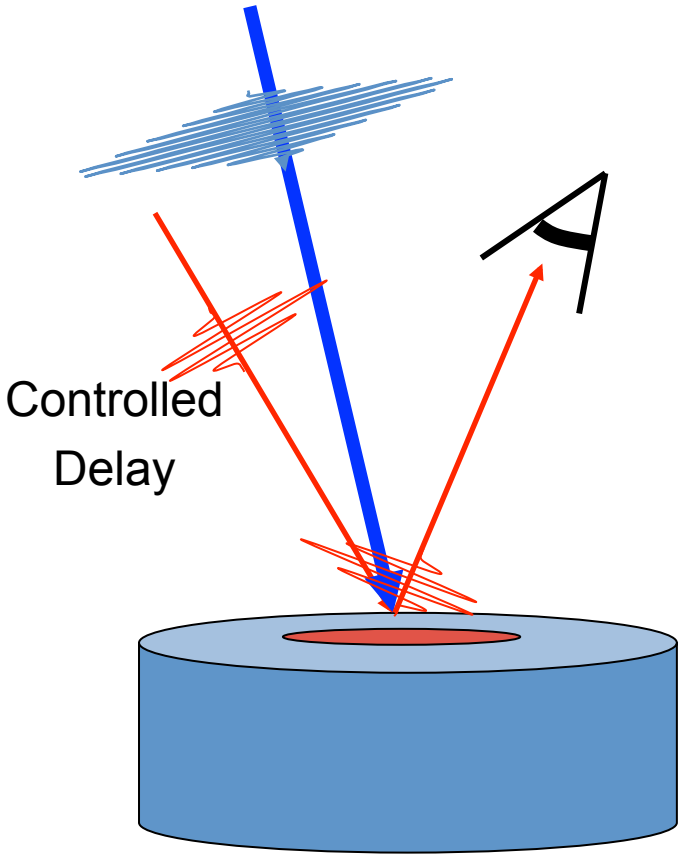
Photo-induced Superconductivity



Science 331, 189 (2011)

The prime tool for non-equilibrium physics: Pump and probe



-«All Optical» pump and probe spectrocsopy

-Reflectivity, Transmission, Kerr, Moke...

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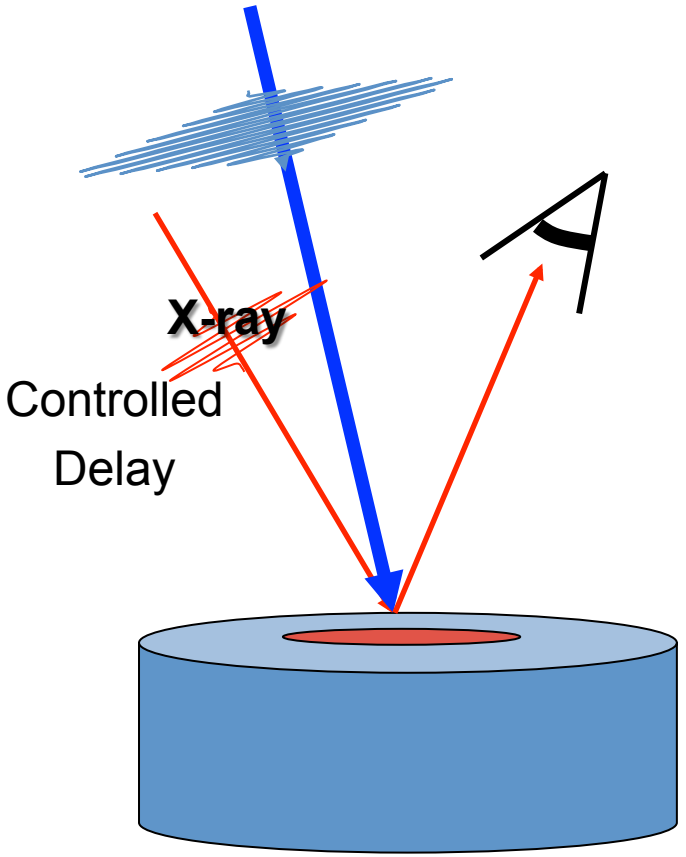

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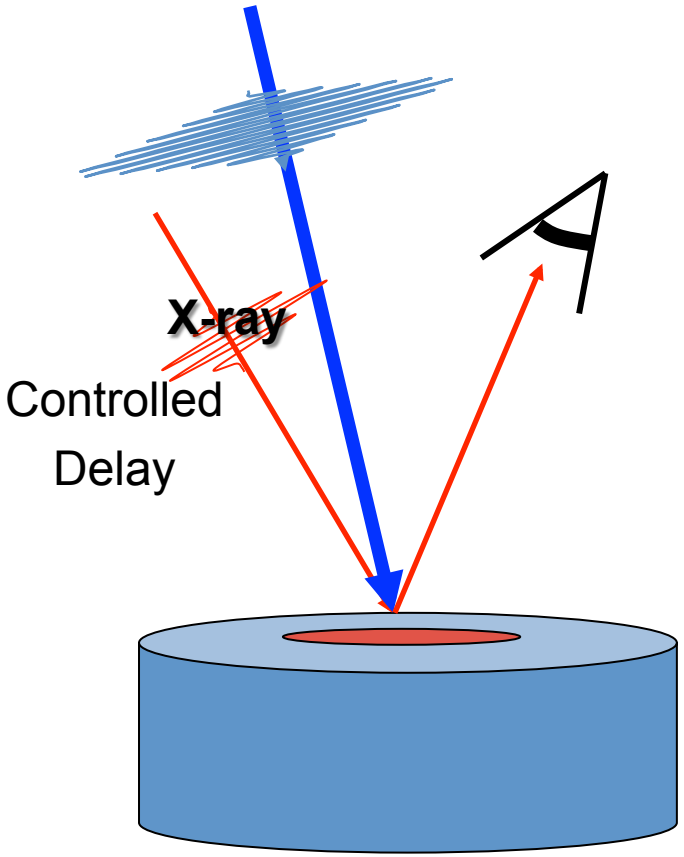

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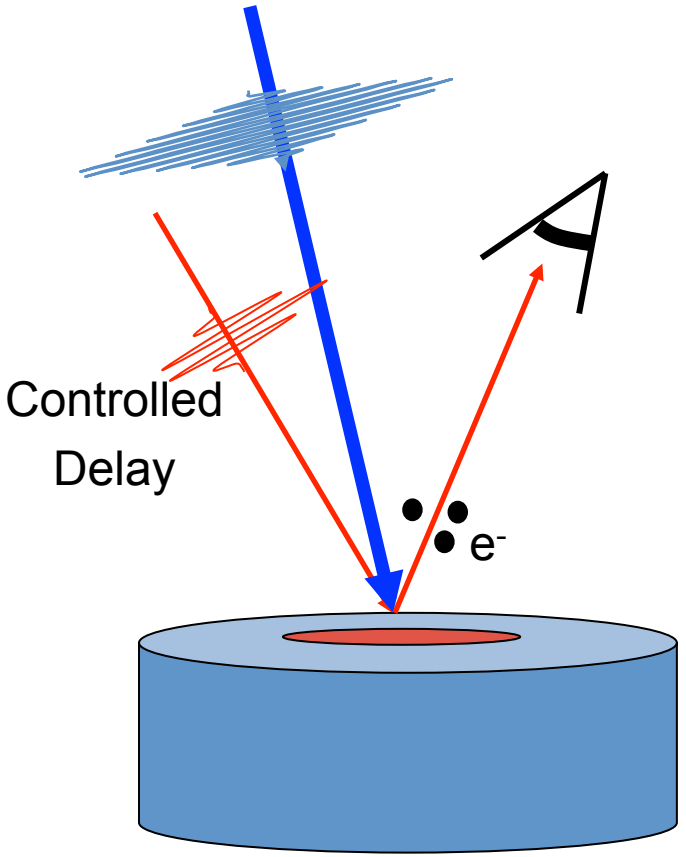

-«All Optical» pump and probe spectrocsopy

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-Photon-in/electron-out pump and probe

-Time and Angle Resolved Photoelectron Spectroscopy

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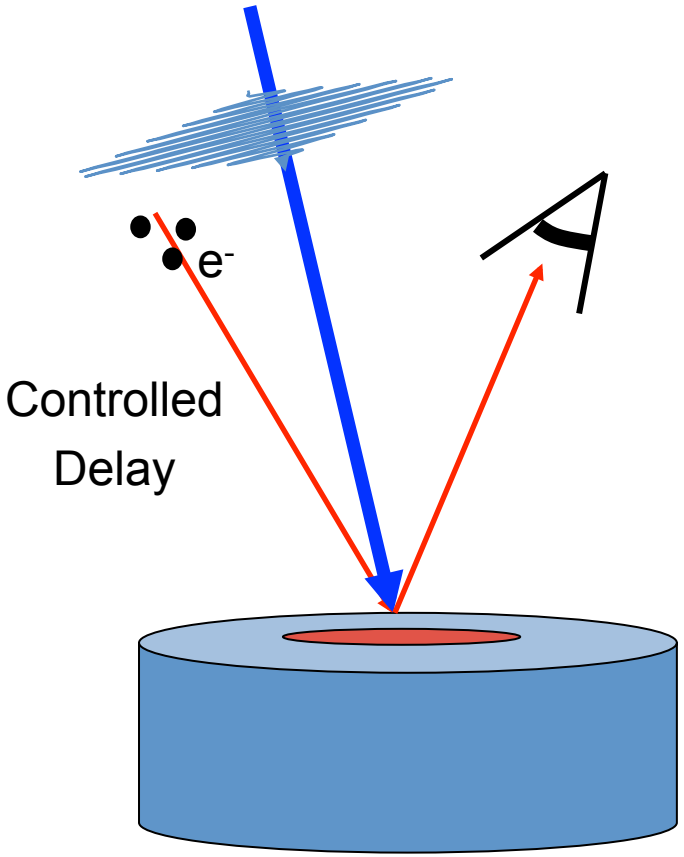

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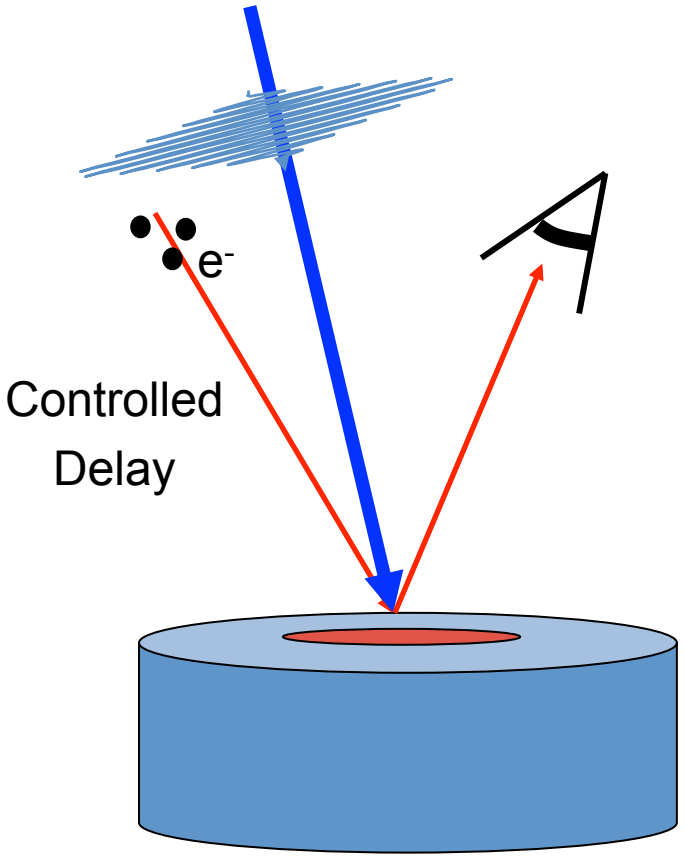

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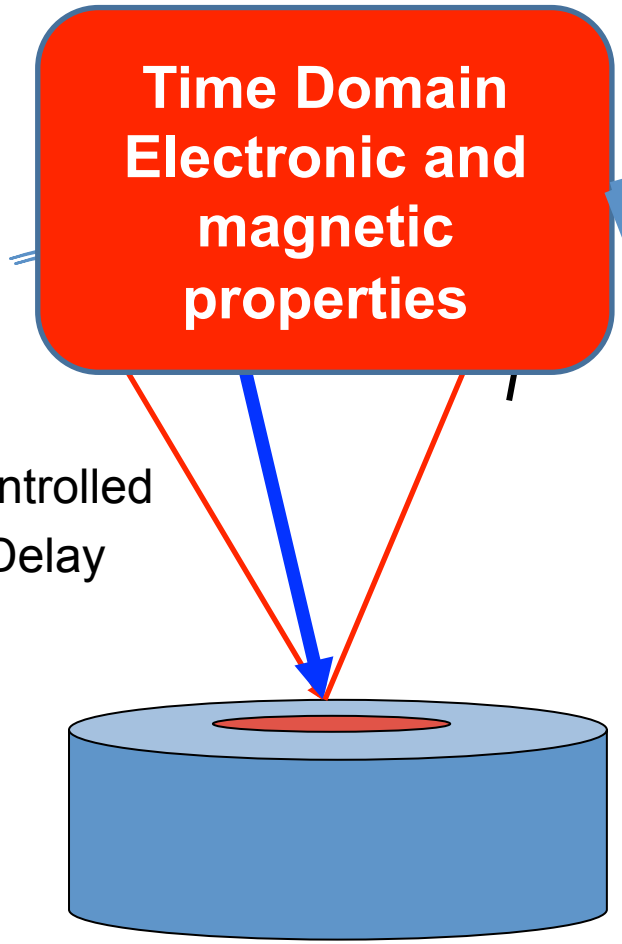

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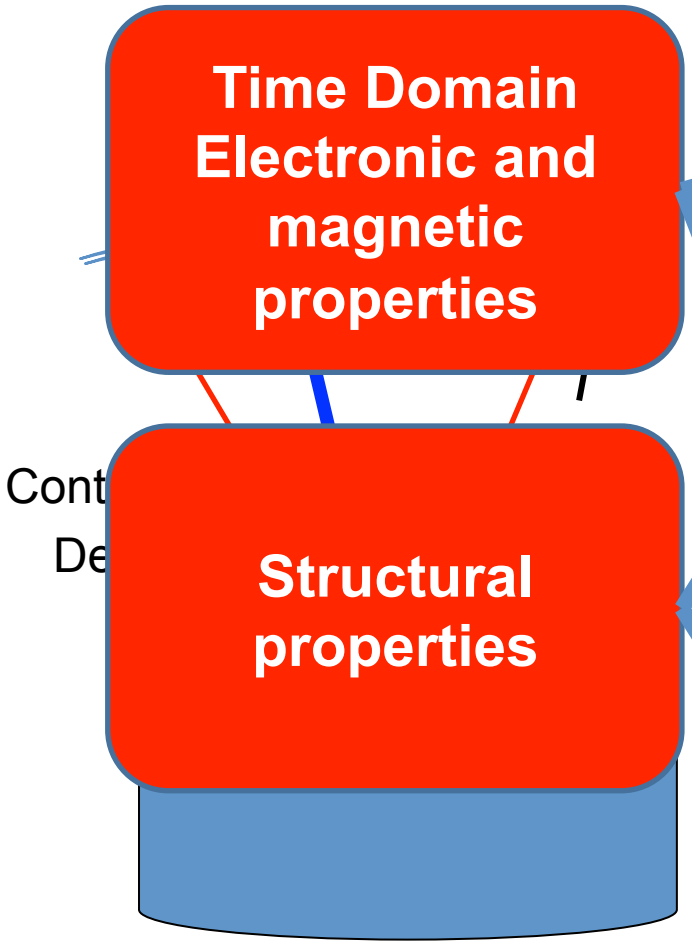

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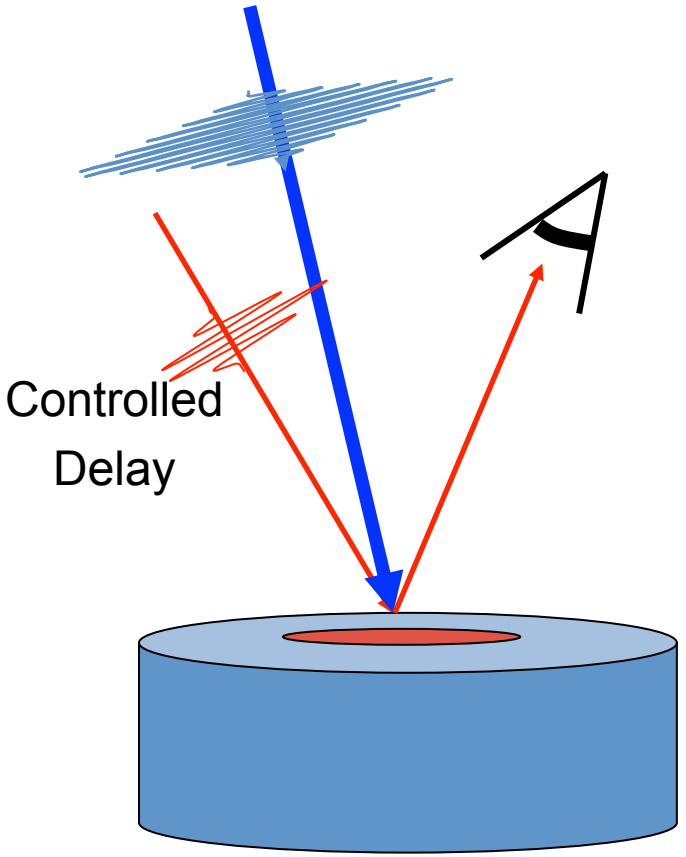
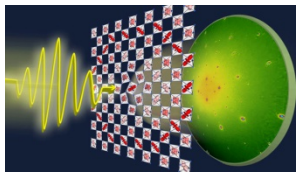
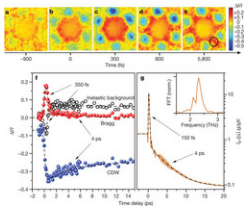


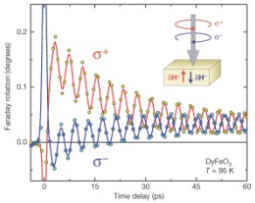
-What do i measure?

Non-equilibrium "Parameters Space"

-Pump & Probe → Time resolved spectroscopies







- ✓Time Resolved x-rays and electron diffraction
- ✓TR Kerr, moke and X-MCD, Arpes
- ✓TR Spectroscopy, TRRaman

Phys. Rev. Lett., 106, 217401 (2011), Nature 468, 799–802, Nature 435, 655 (2005)

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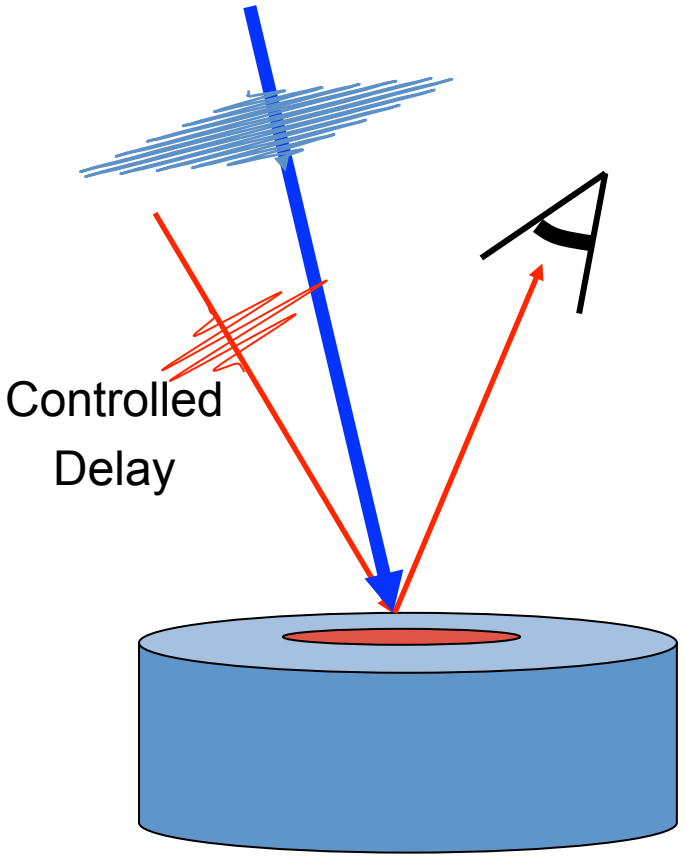

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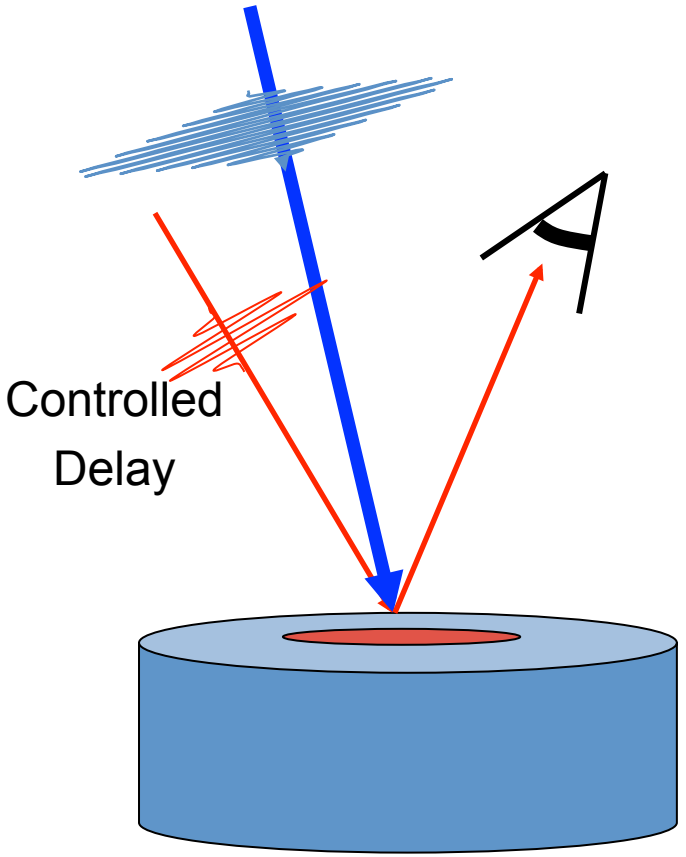

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Non-equilibrium "Parameters Space"

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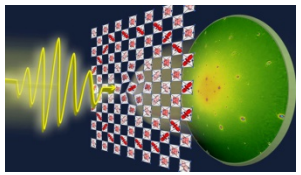
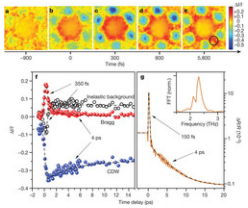
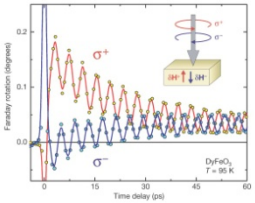
Time resolved spectroscopies







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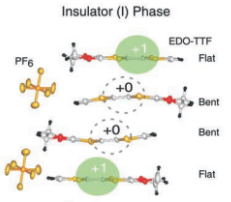
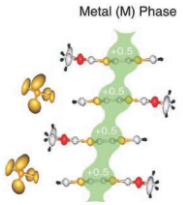
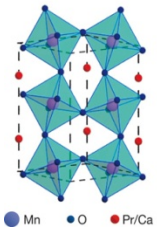
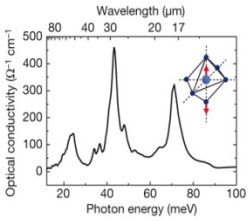
-Pump & Probe

Optical Control of Material

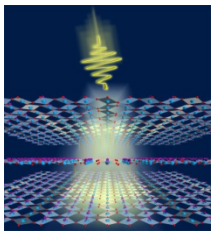








- ✓Photo-Induced phase transitions
- ✓Coherent control (IR and THz)
- ✓Light control of quantum coherent phases

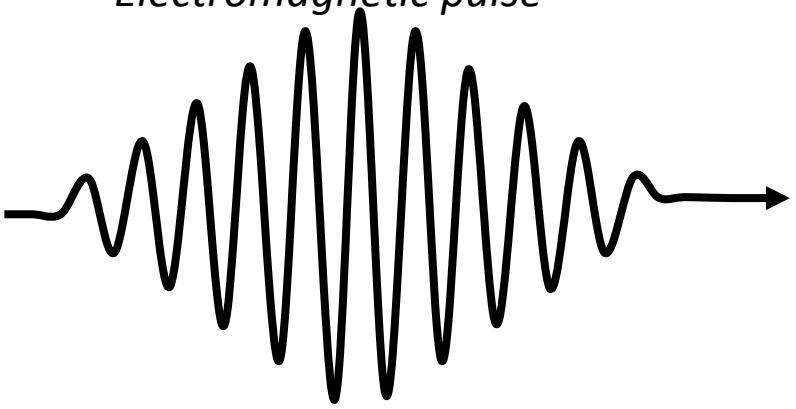


Science 307, 2005, Nature 449(2007)

Science 331, 2011

Non-equilibrium "Parameters Space"

Electromagnetic pulse



Non-equilibrium "Parameters Space"

Pump & Probe

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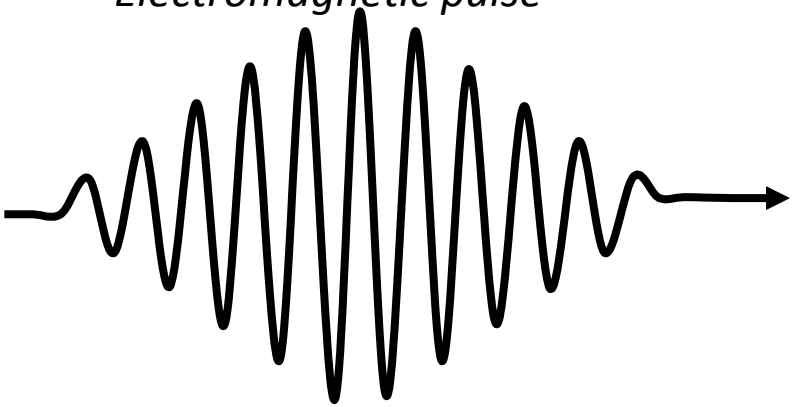
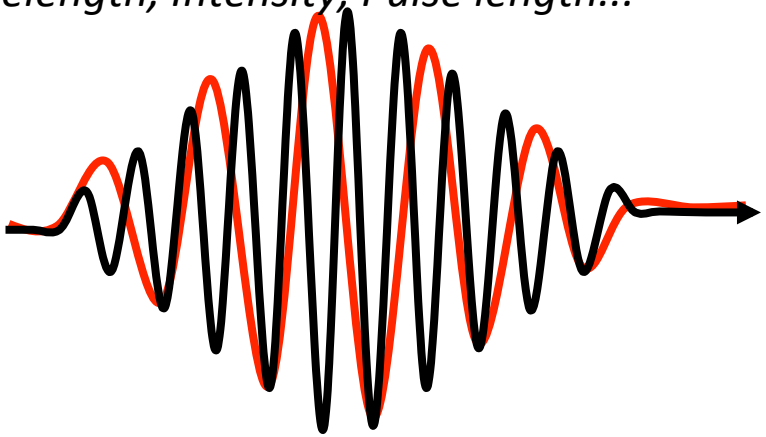


Wavelength, Intensity, Pulse length...



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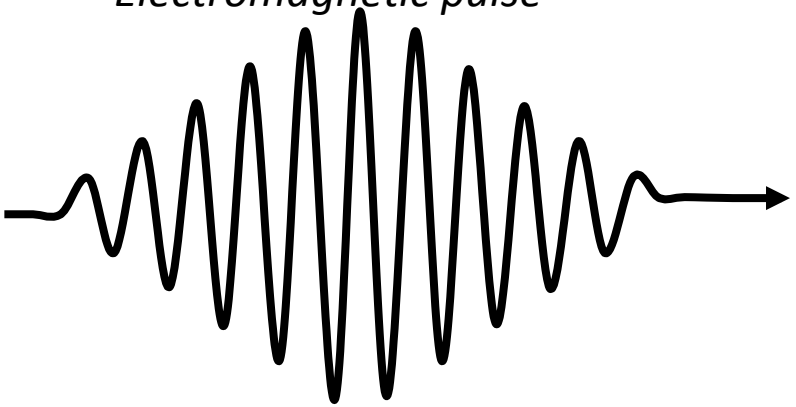

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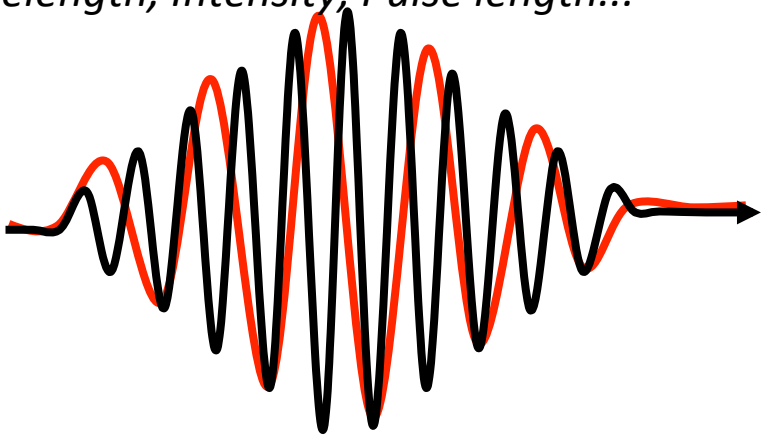
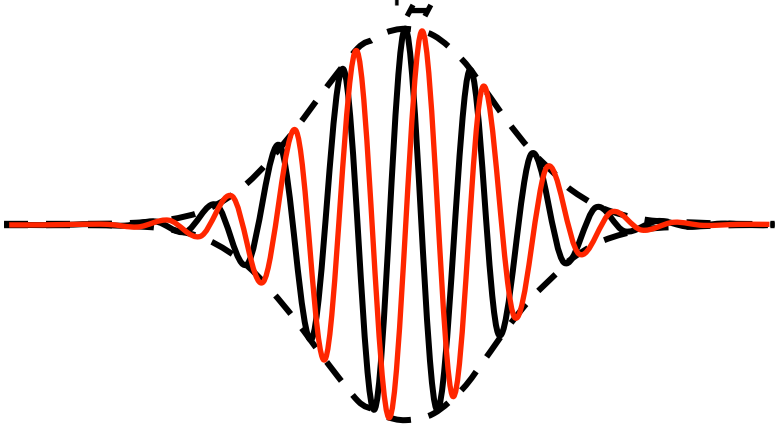


Carrier Envelope Phase

$\Delta\phi=\pi/2$



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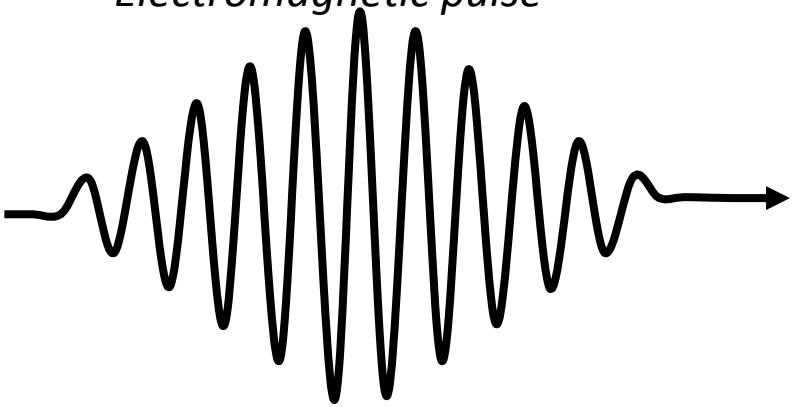

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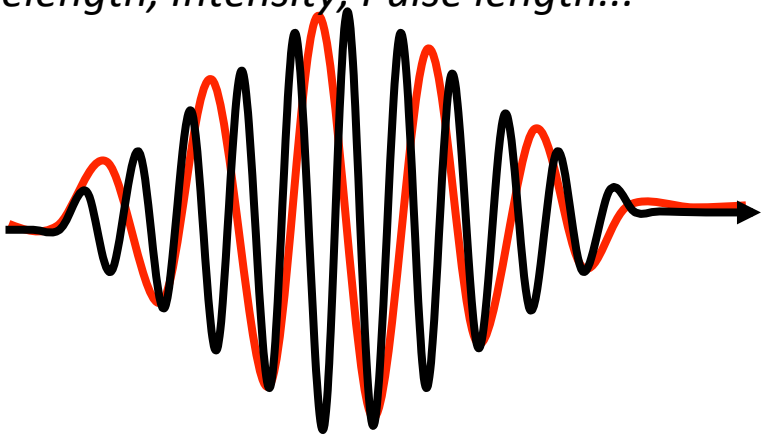

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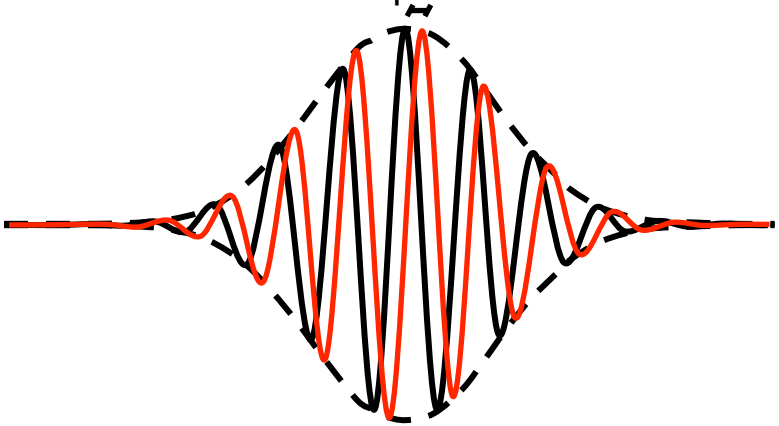
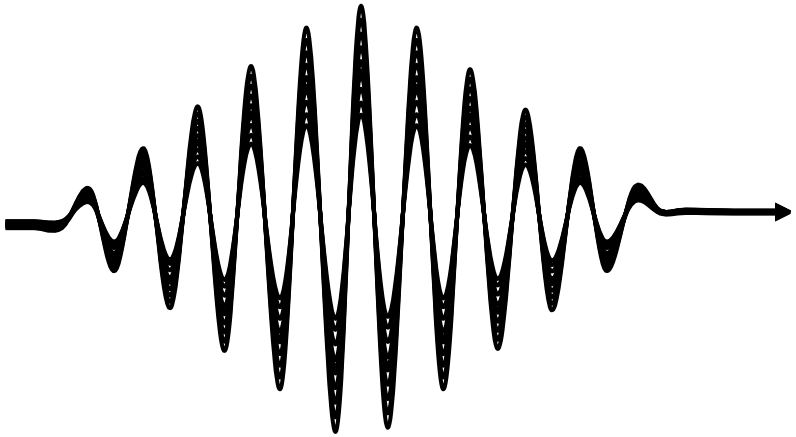


Quantum State of the e.m. Field



Outline

- ✓ **Equilibrium Optical Spectroscopy**
  - -The optical conductivity in the Visible and Near-IR
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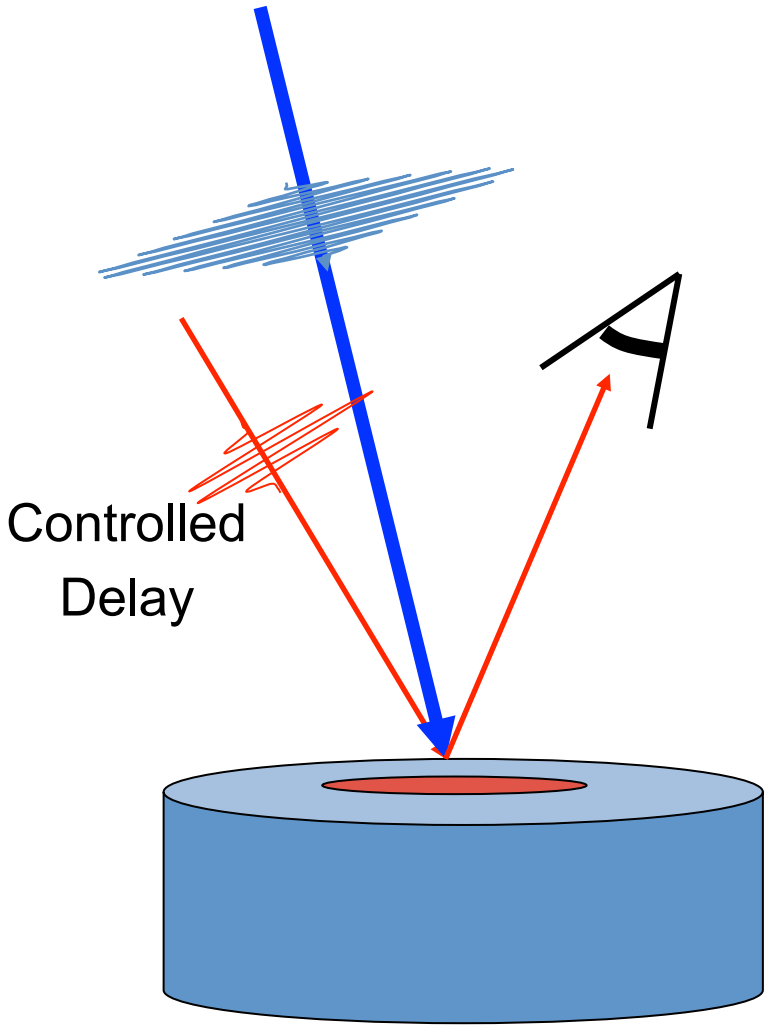

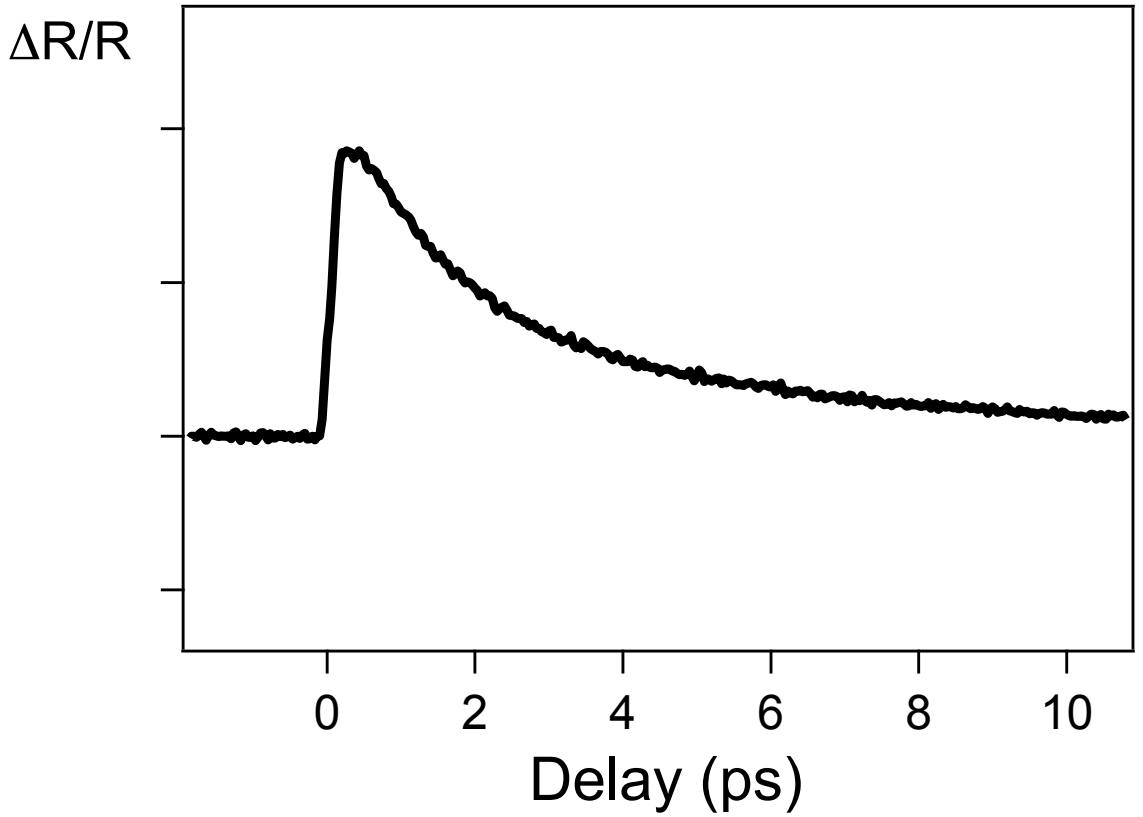

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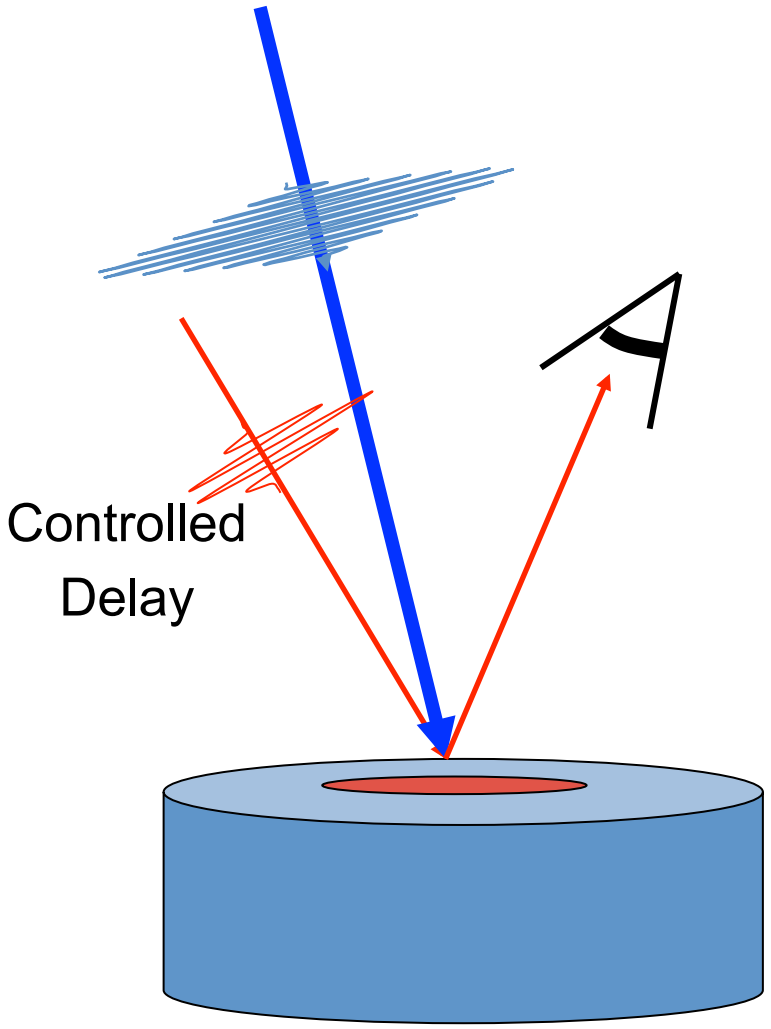
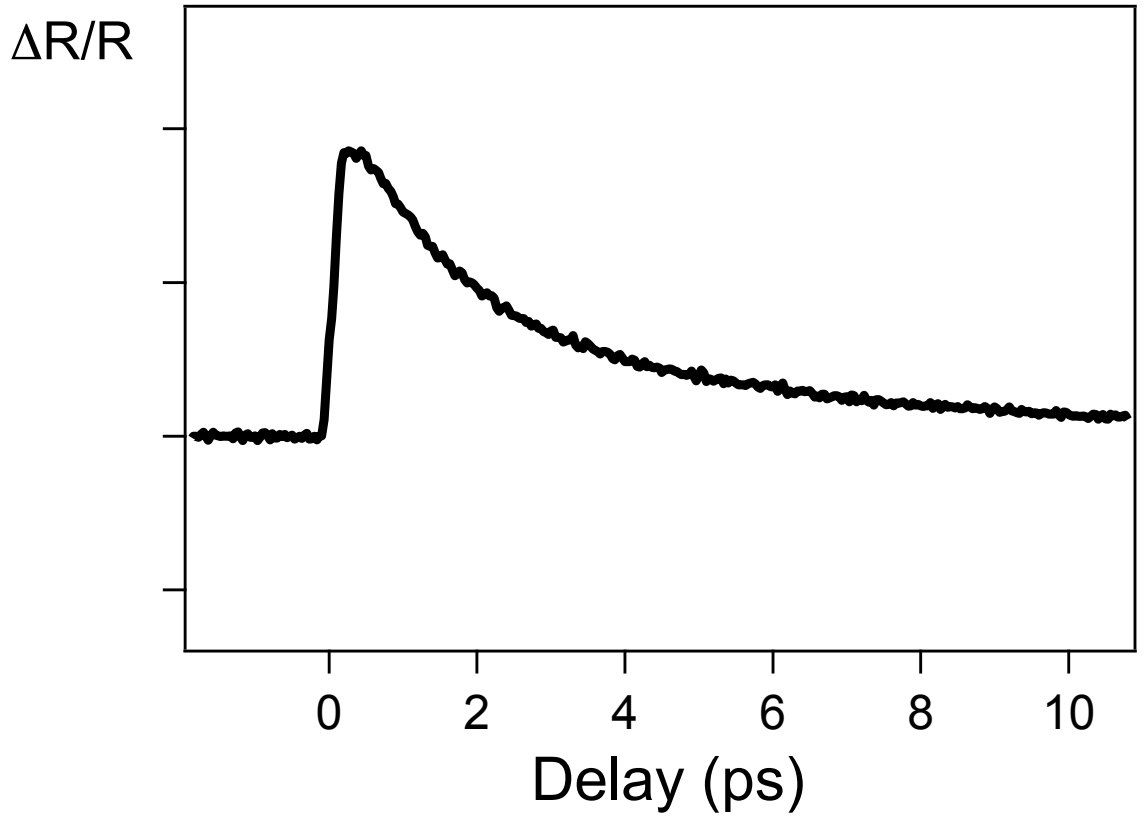
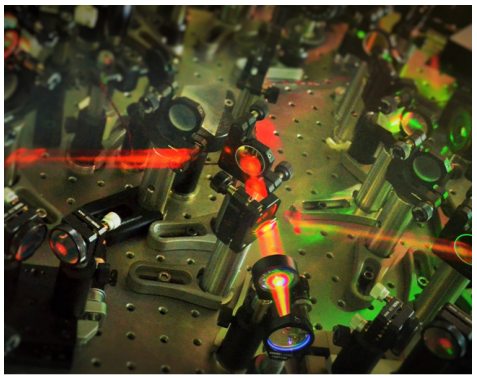
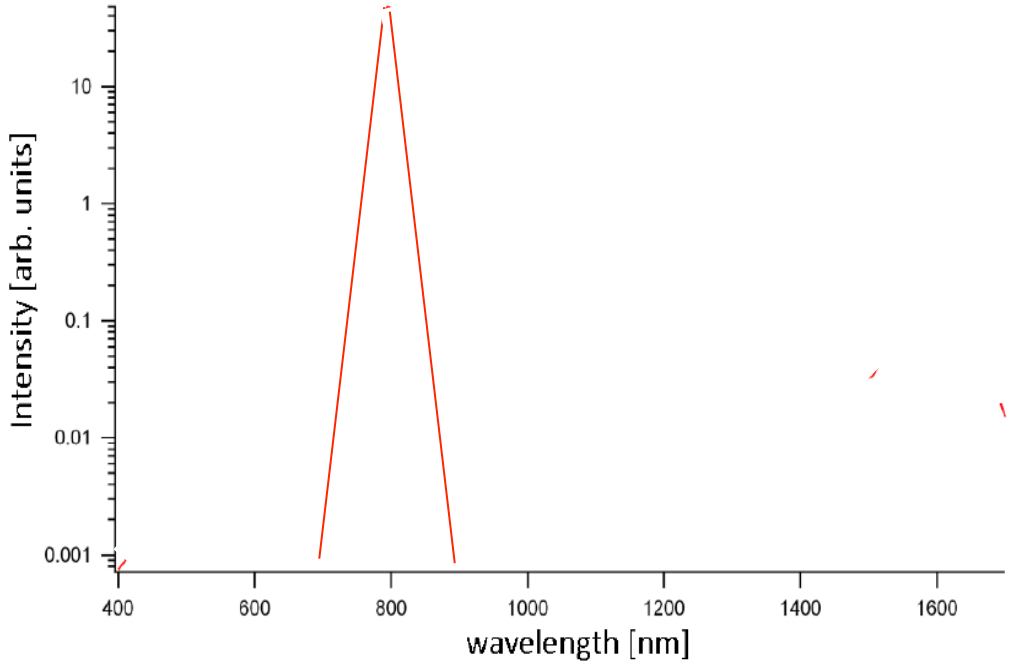






Non-Linear Optical Processe: White light generation



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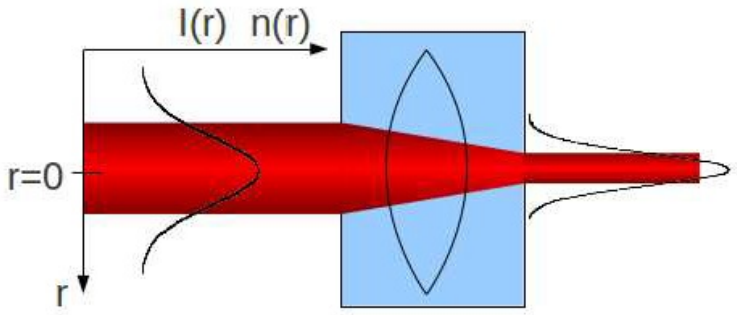
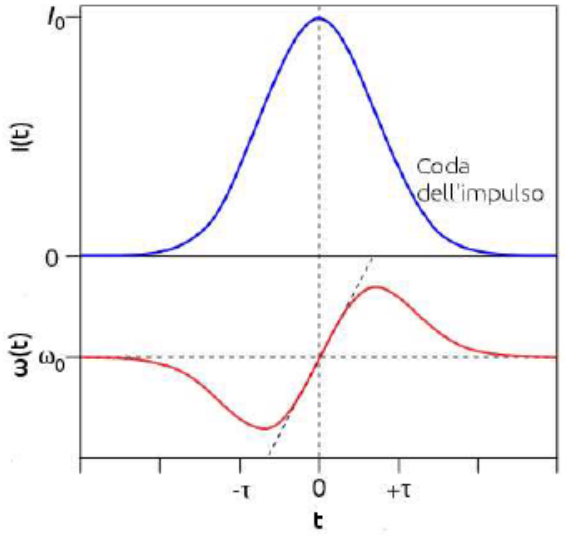
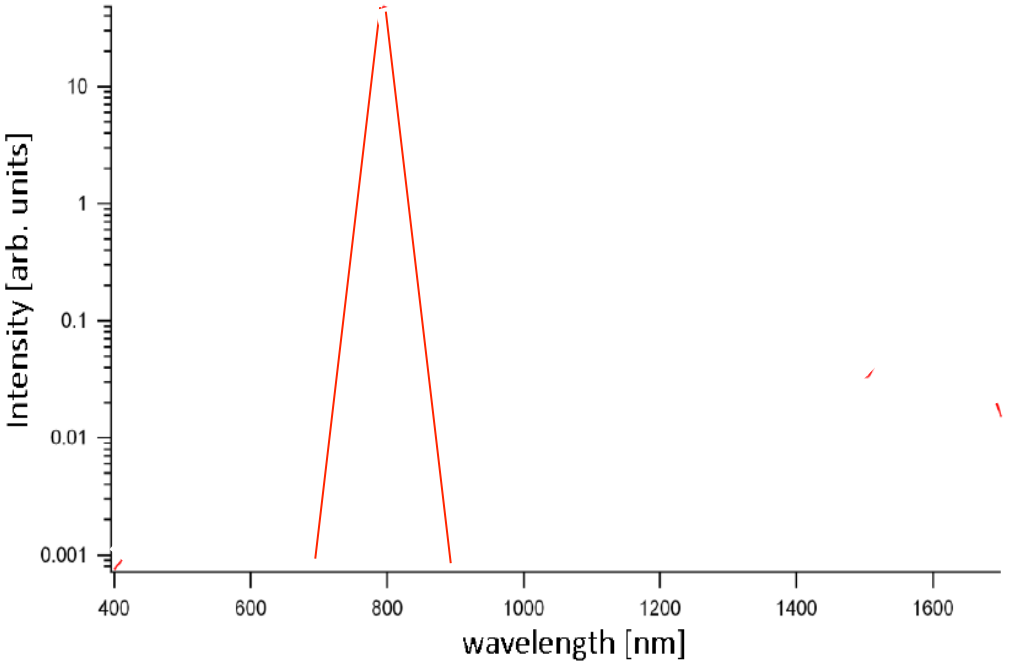
Self Focusing



Self Phase modulation





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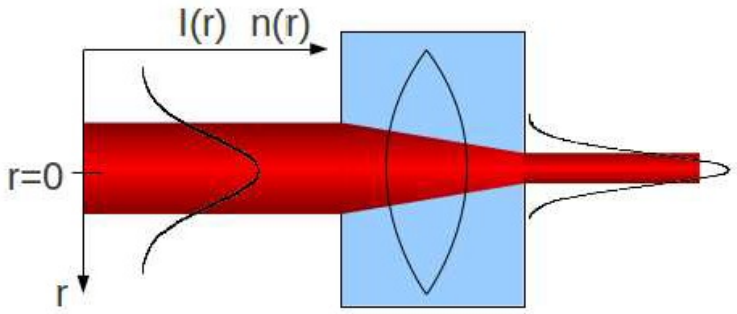

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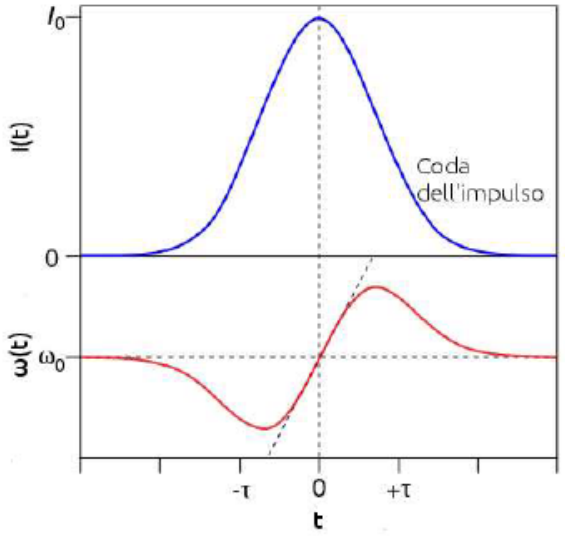

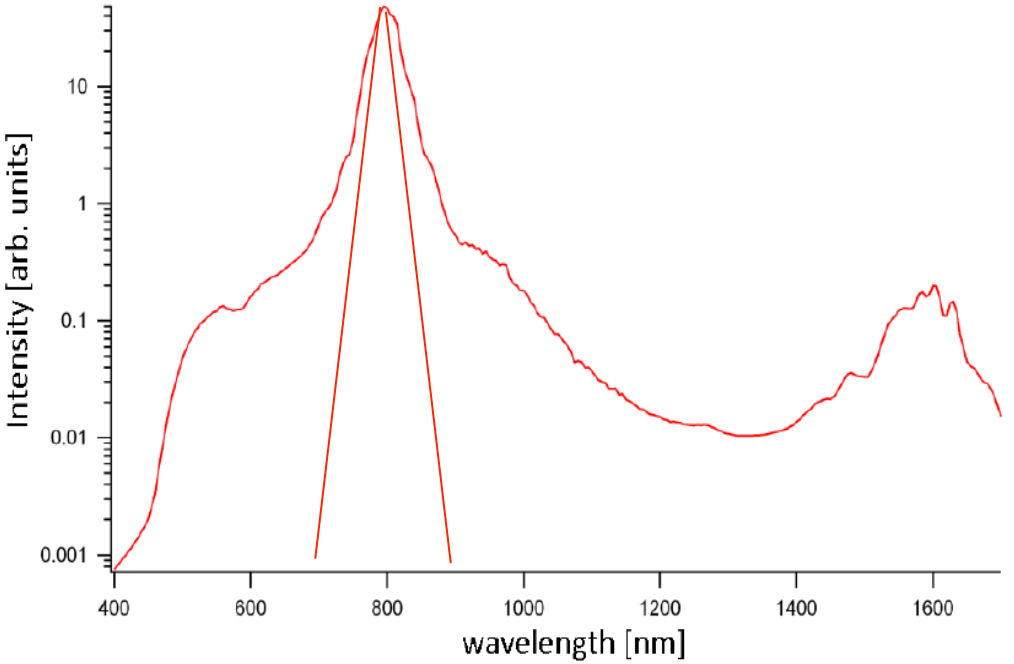

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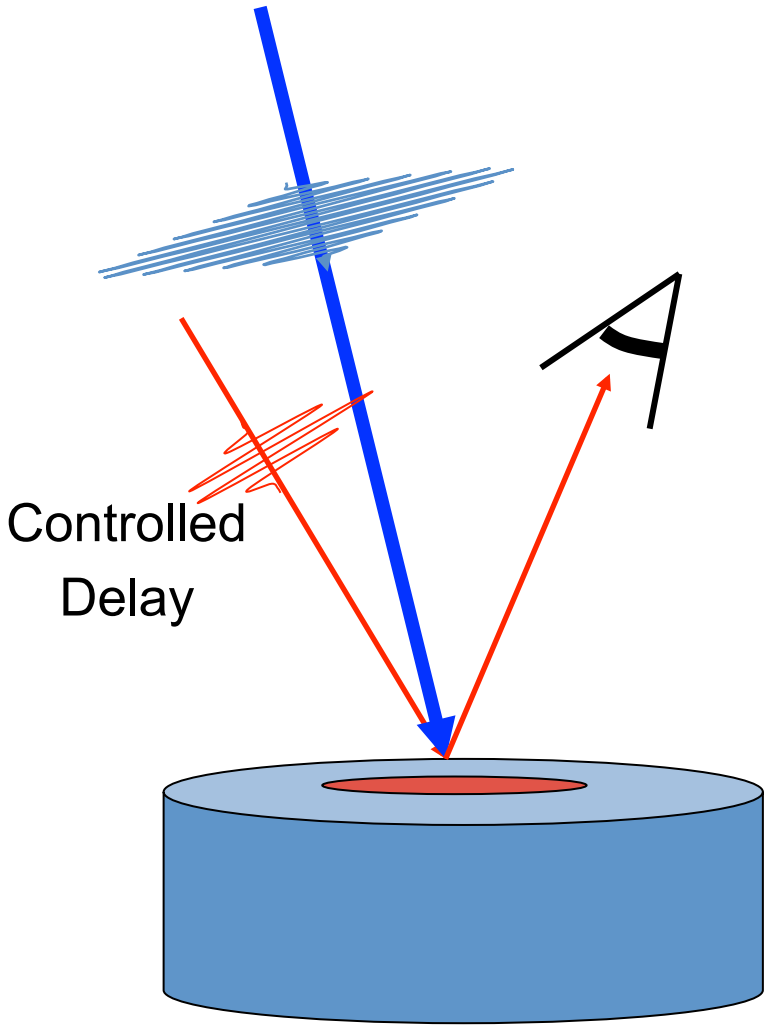

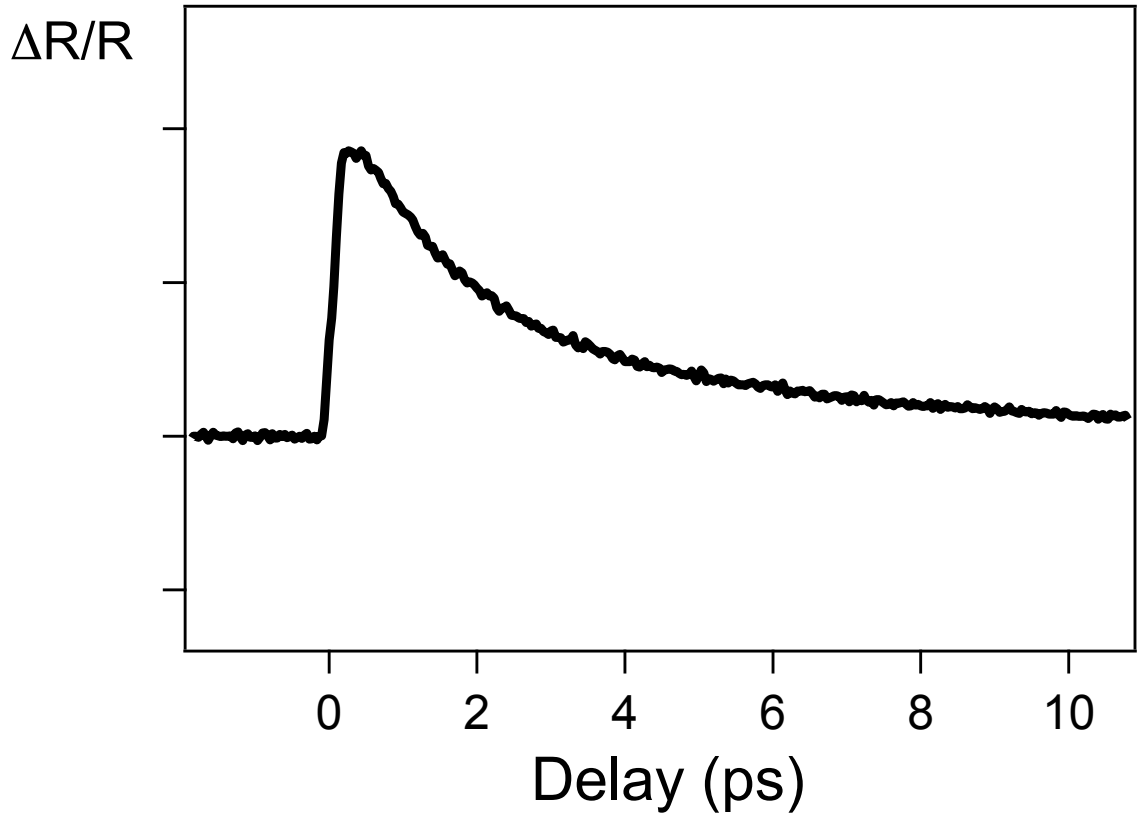

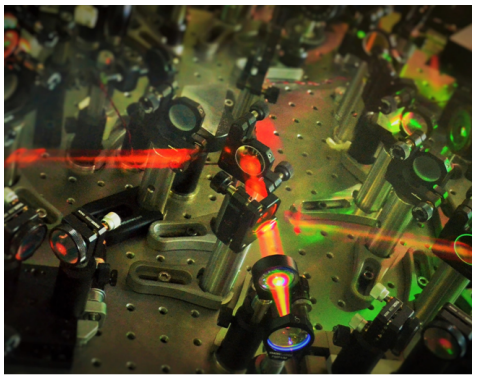

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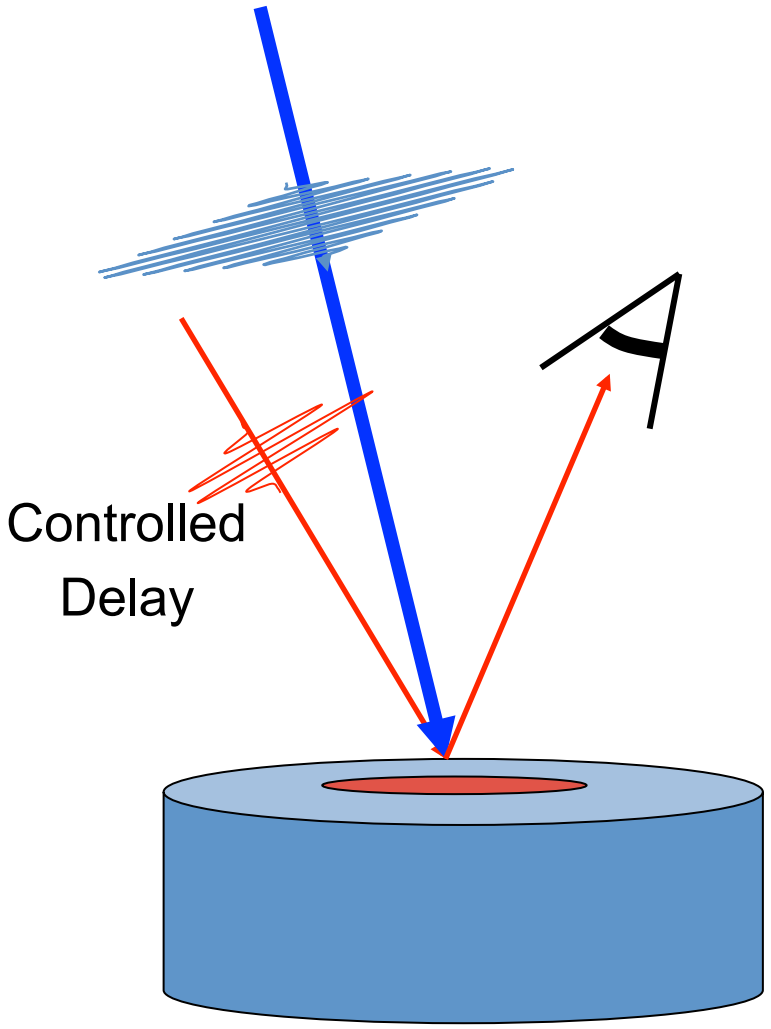

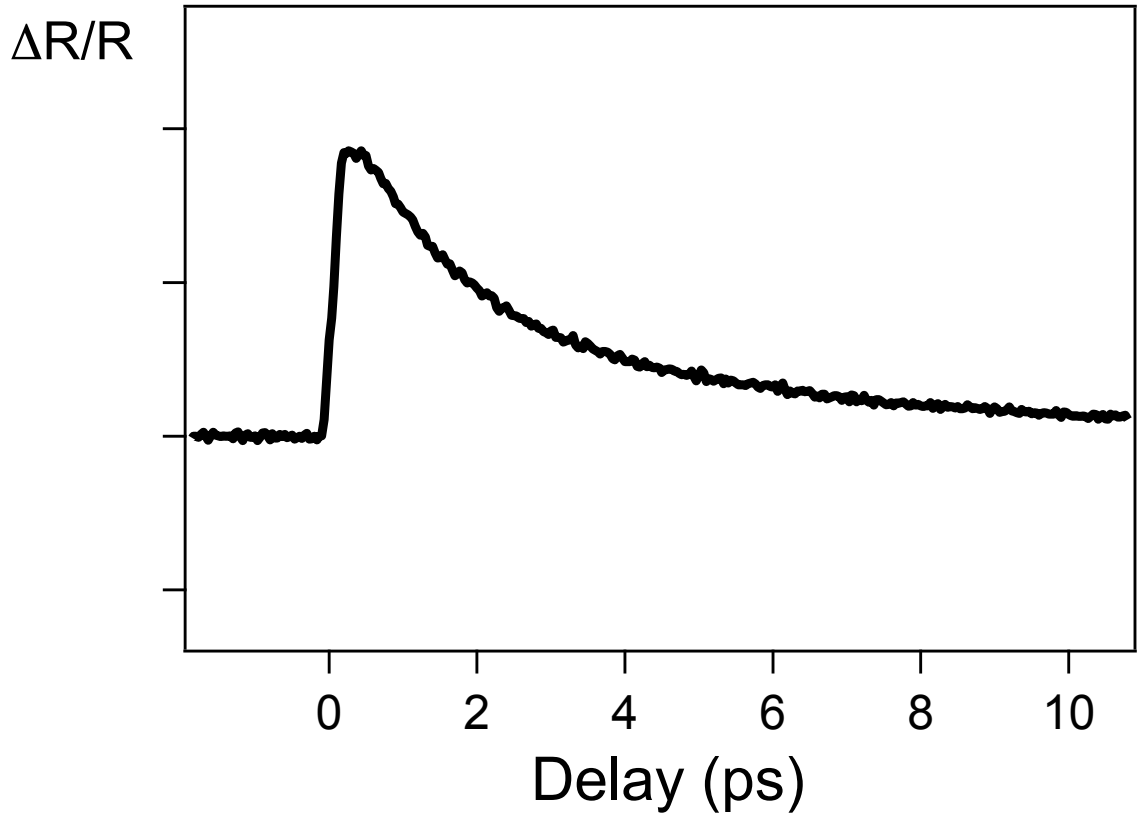

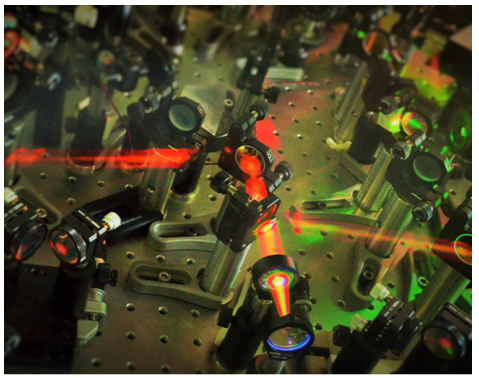

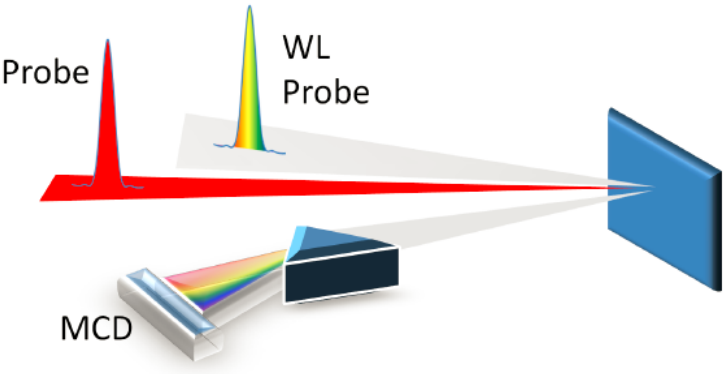

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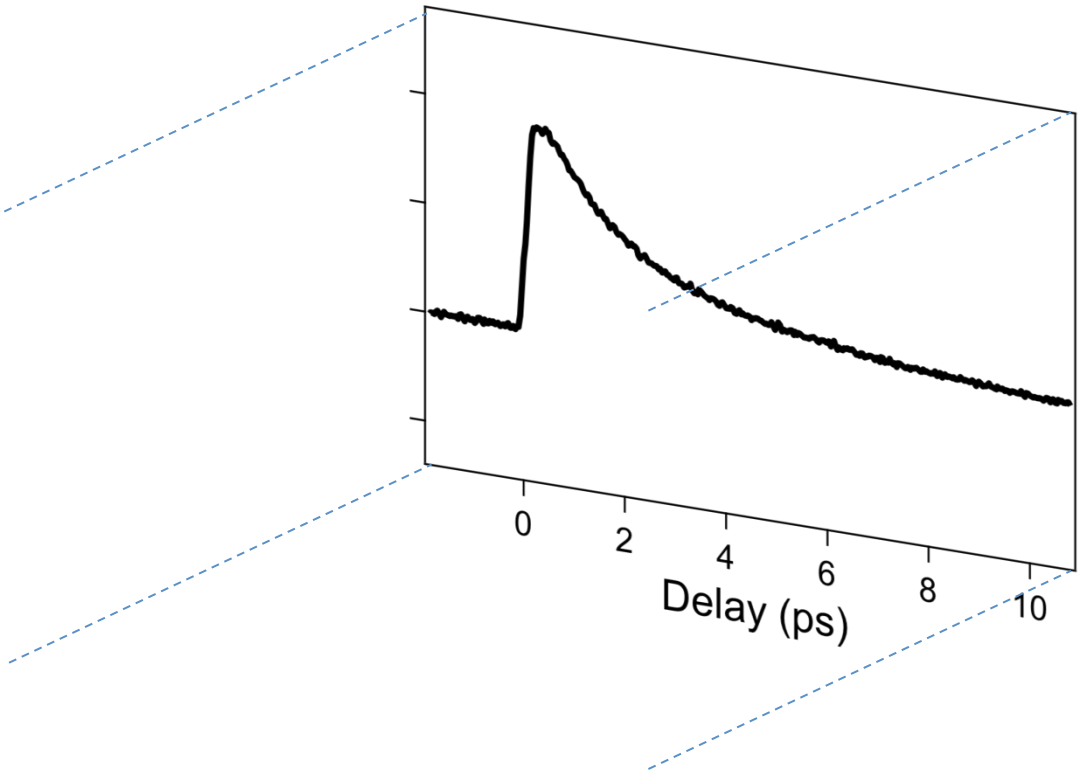

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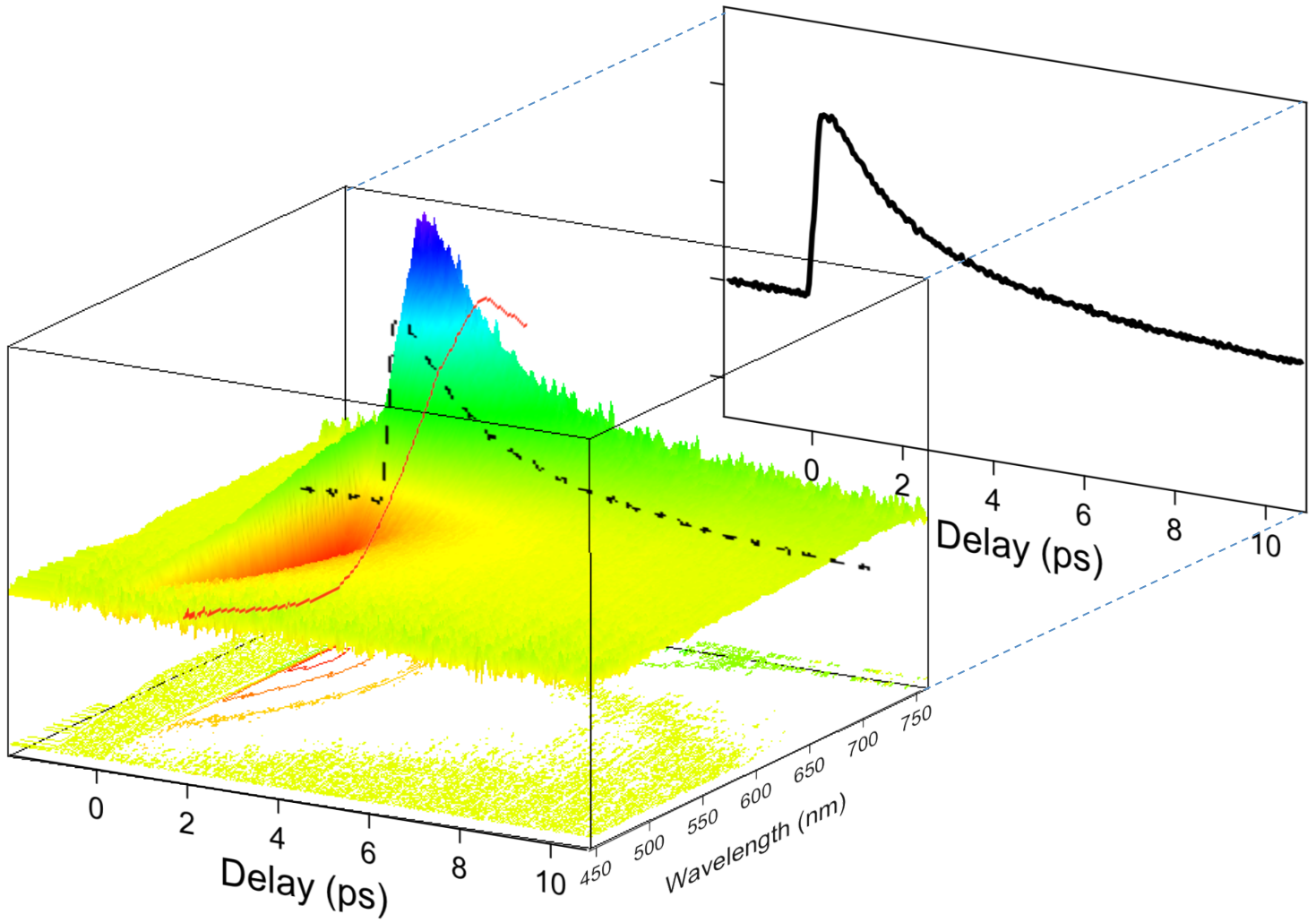

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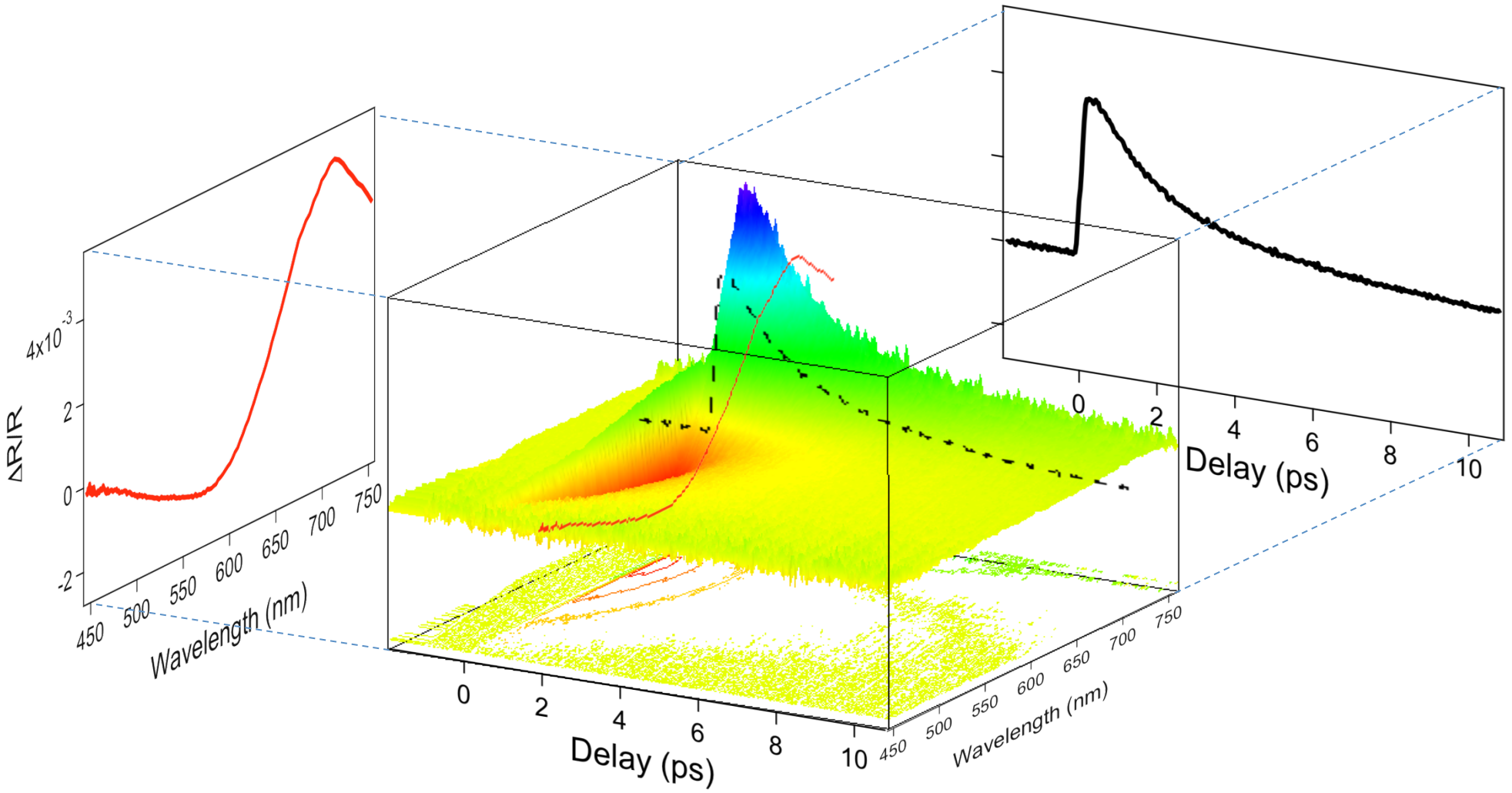

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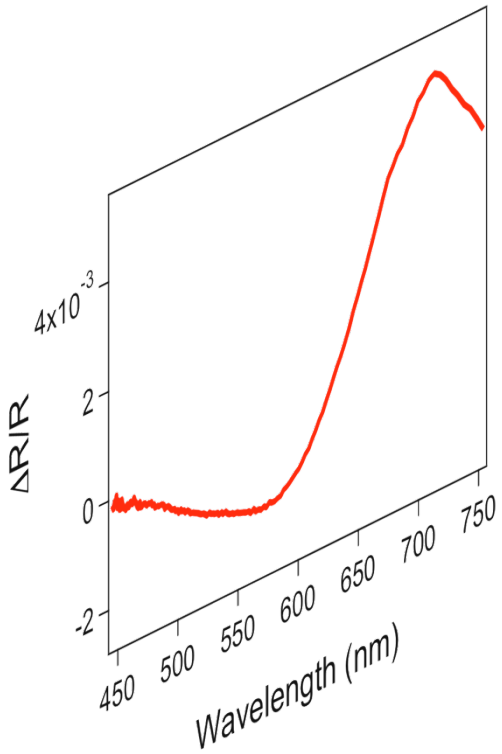

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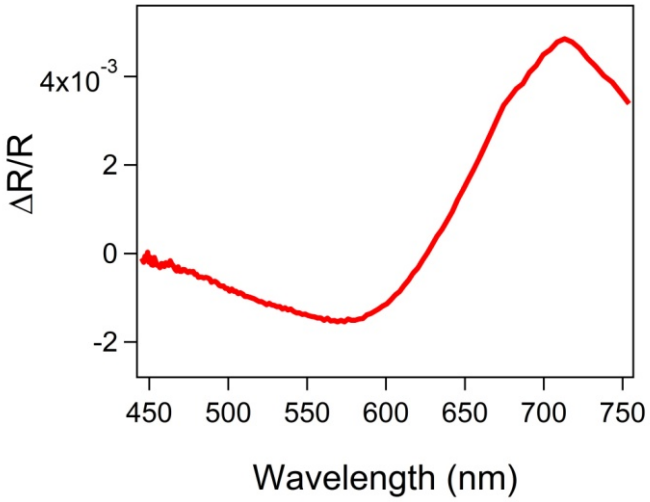

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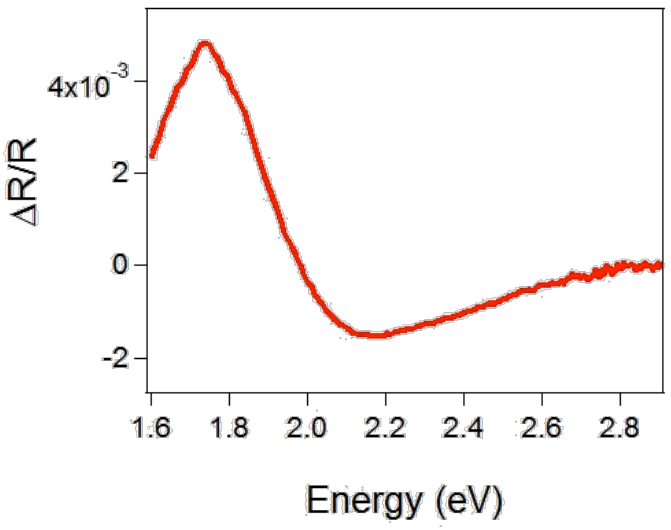

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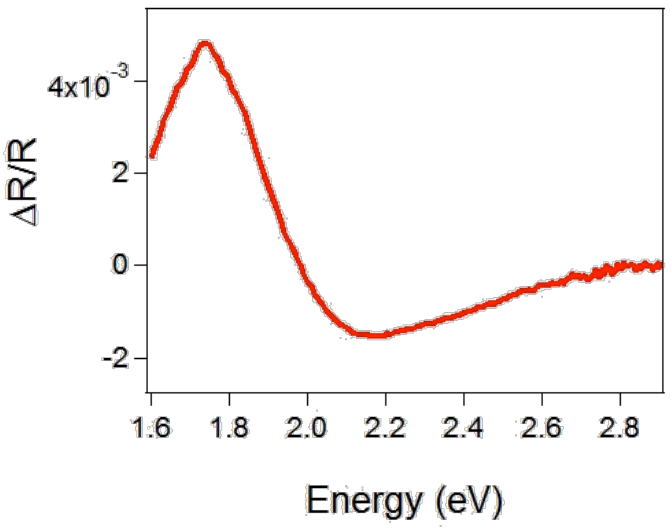
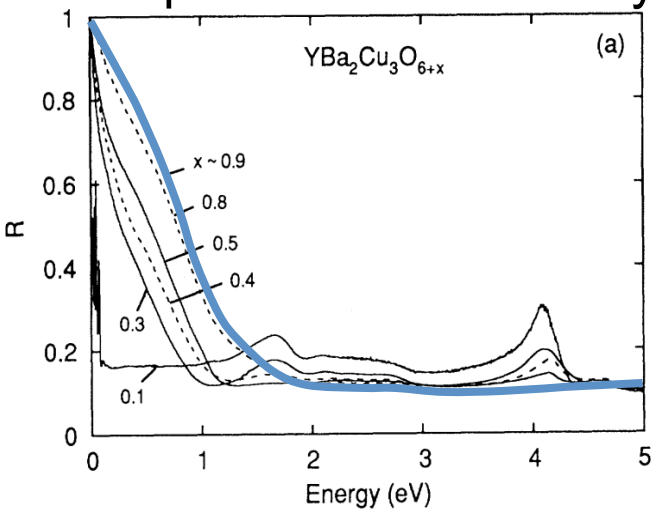
$\Delta R(\omega)t_0$



Equilibrium Reflectivity



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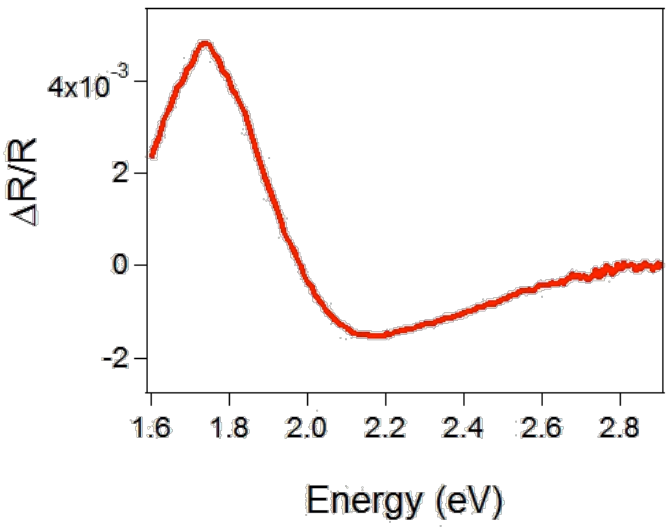

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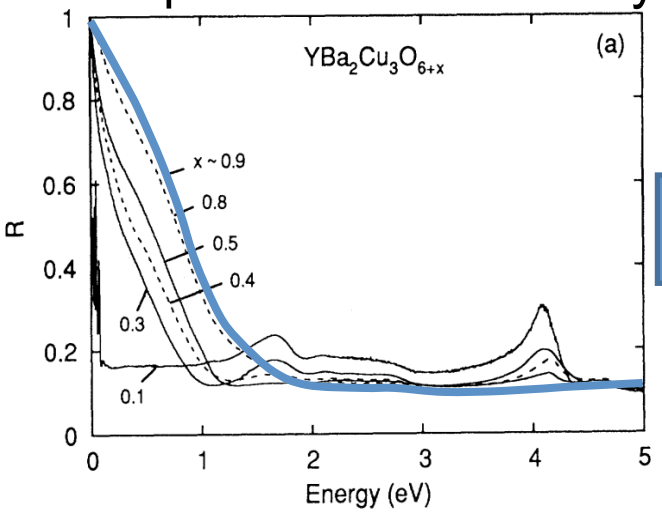

K
K

$\sigma_1(\omega)_{eq}$, $\sigma_2(\omega)_{eq}$

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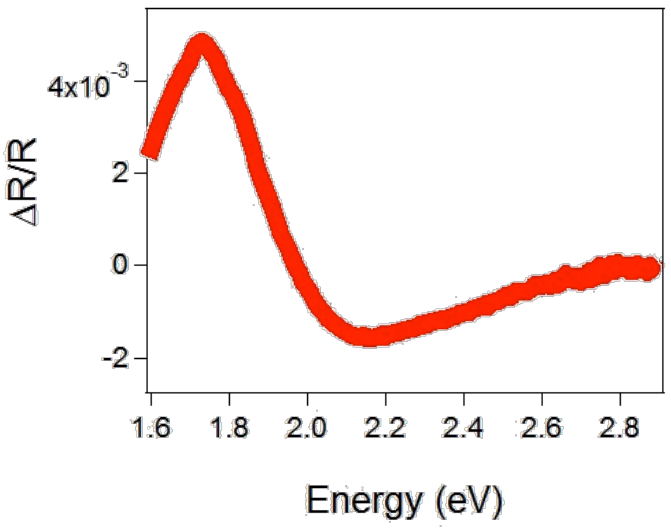

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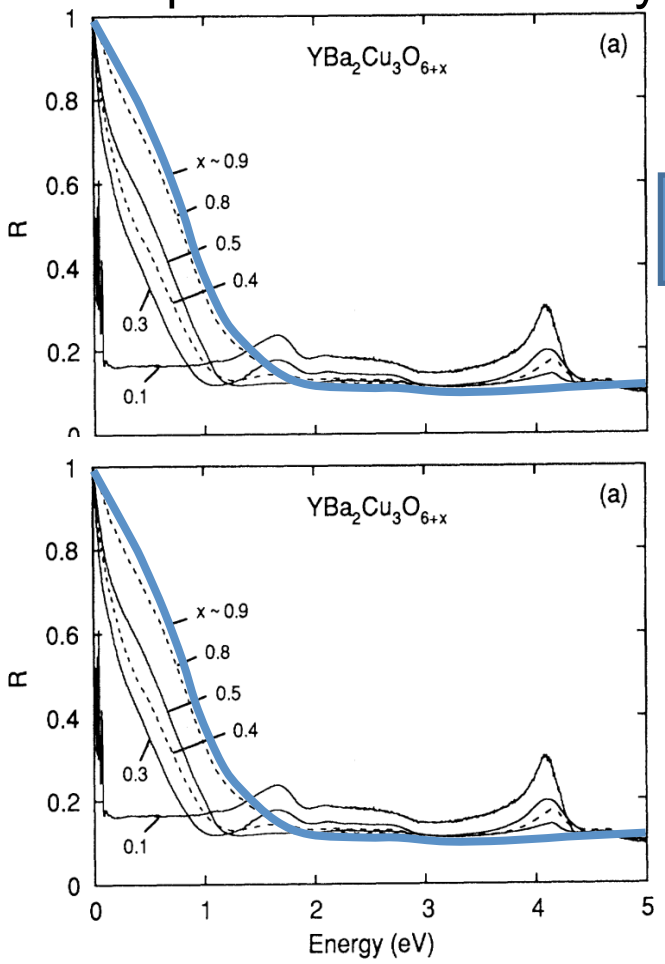

Non-eq. Reflectivity

K
K

$\sigma_1(\omega)_{eq}$, $\sigma_2(\omega)_{eq}$

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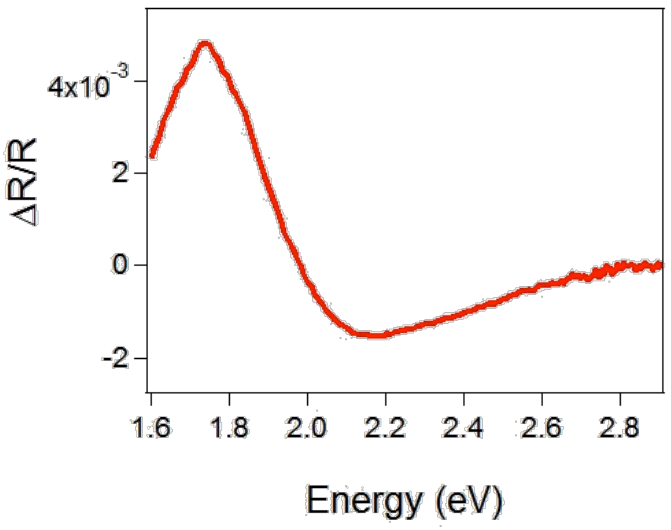

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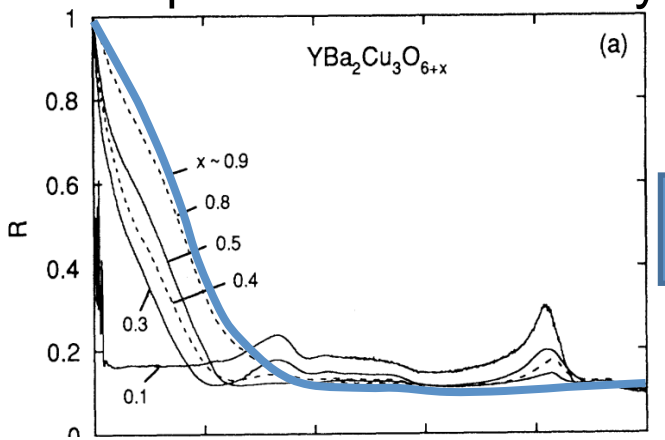

K K

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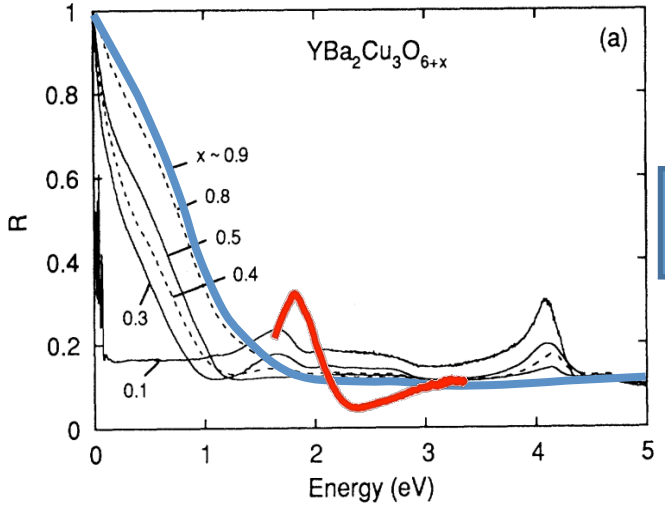

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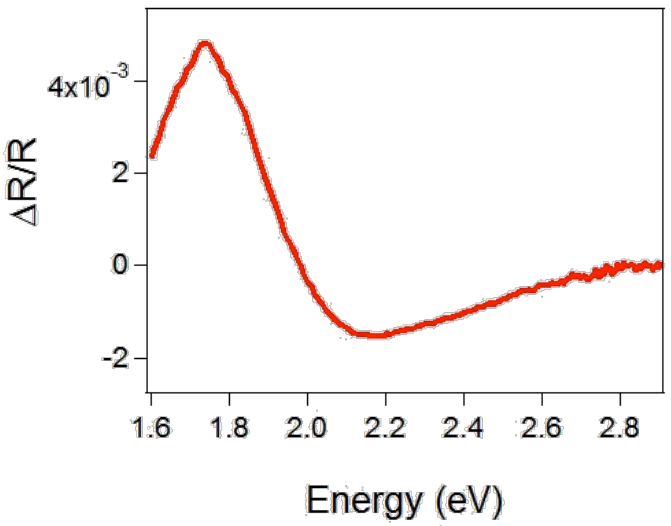

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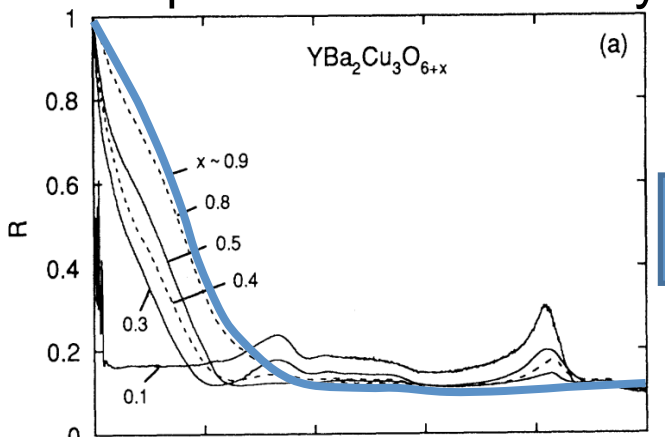

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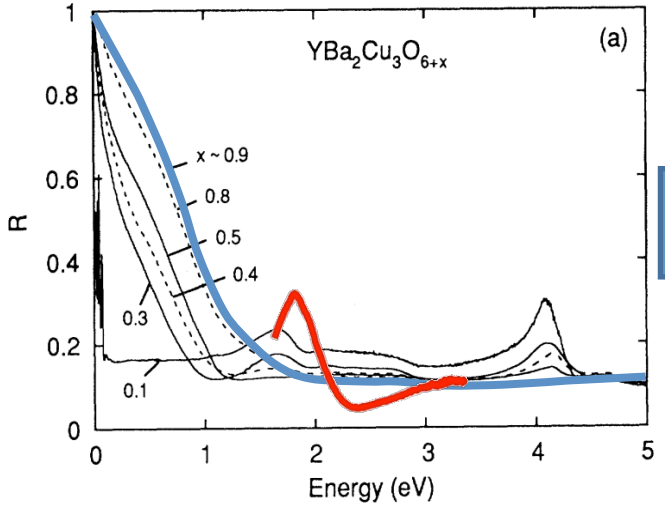

K K

$\sigma_1(\omega)_t$, $\sigma_1(\omega)_t$

Non-eq. Reflectivity

$\Delta\sigma_1(\omega)_t$, $\Delta\sigma_2(\omega)_t$

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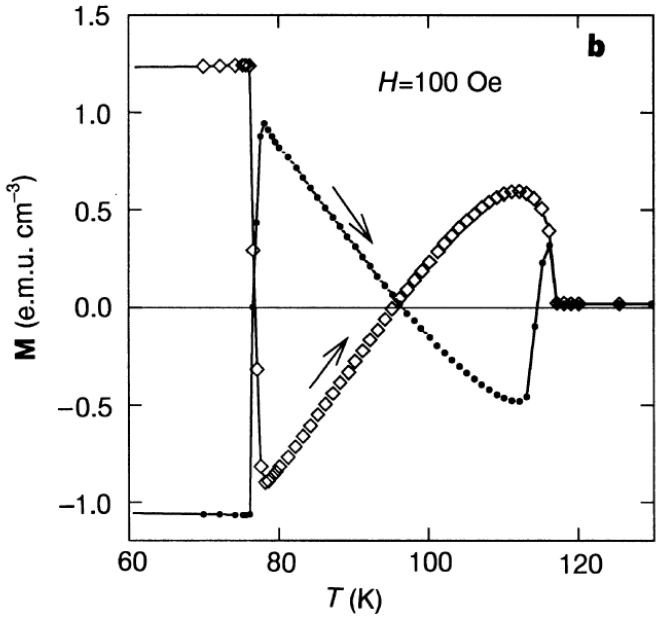
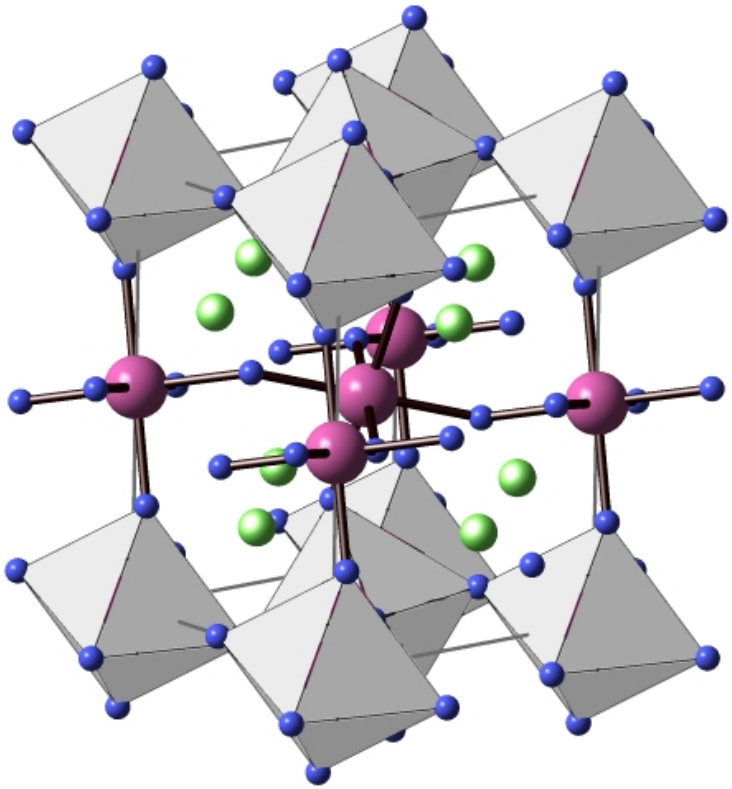
YVO_3: Properties

- ✓ Layer compound of BaTiO3-like distorted/tilted octahedra (Pbnm)
- ✓ $V^{3+} \rightarrow 3d_2$
- ✓ Mott insulator
- ✓ Magnetization reversal
- ✓ Orbital/Spin orderings

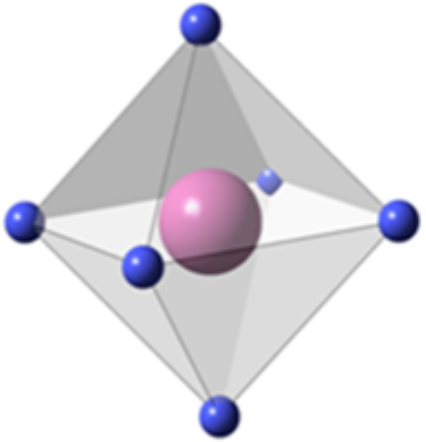


Y. Ren, Nature 396, 401,1998



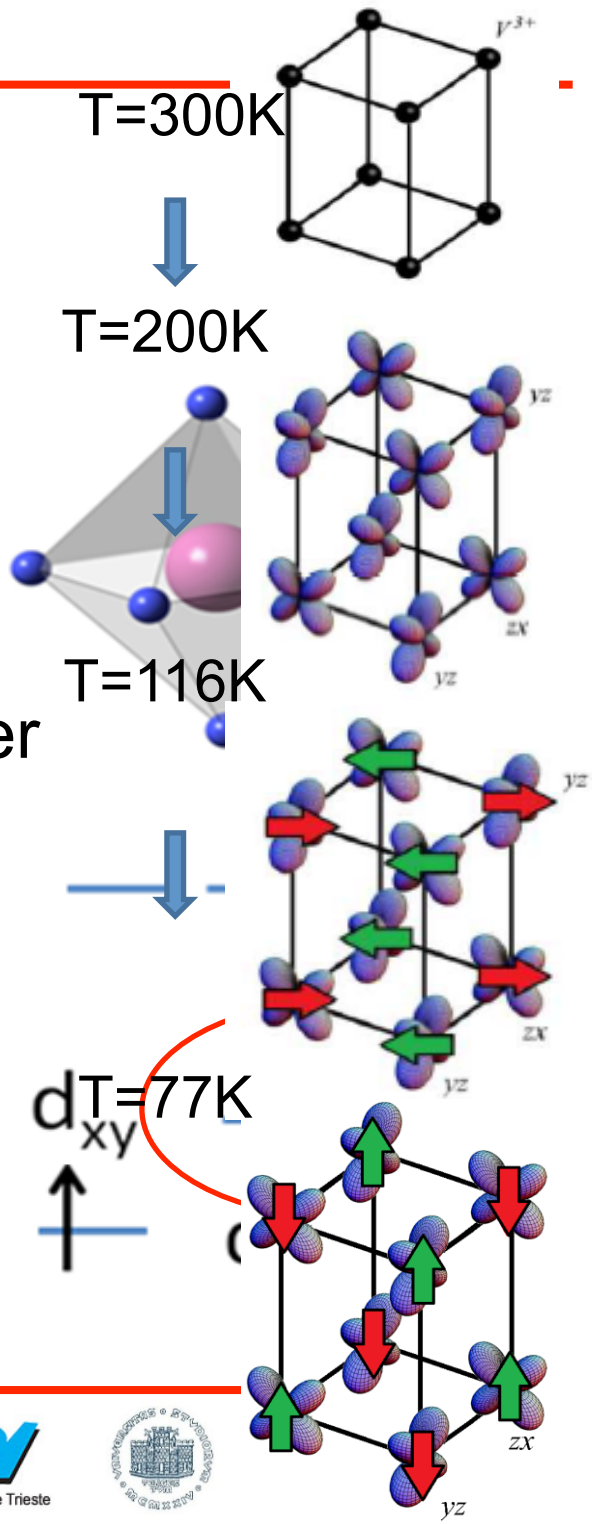
YVO_3: Properties

Orbital Physics in V^{3+} ($3d_2$)



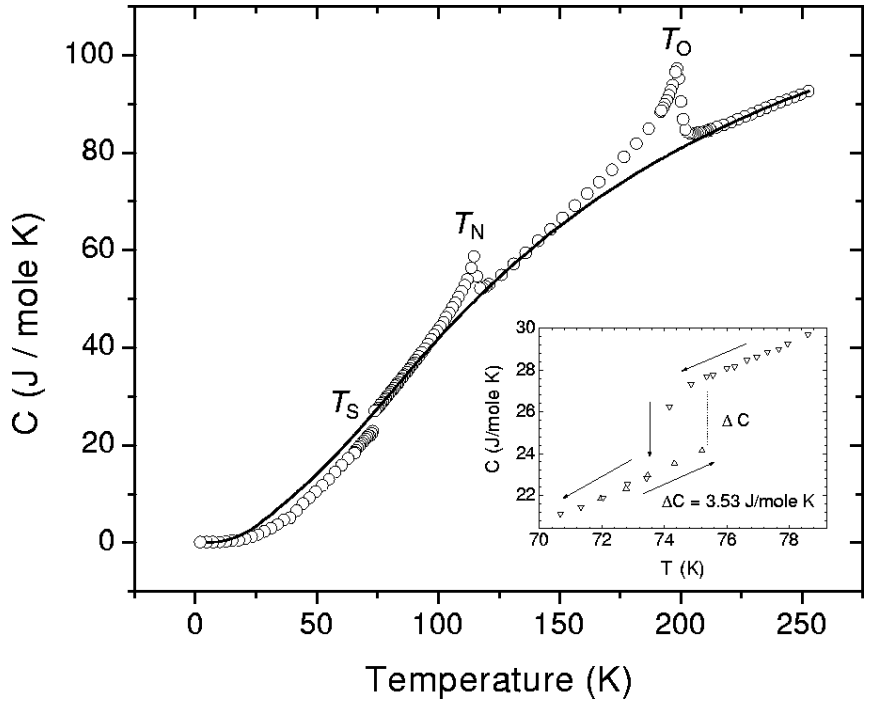
Oxygen octahetron

Jahn-Teller distortion



YVO_3: Properties

- ✓ Mott insulator
  Mott gap ~1.2eV
- ✓ Crystal field determined "mainly" by JT
- ✓ No Quantum fluctuation

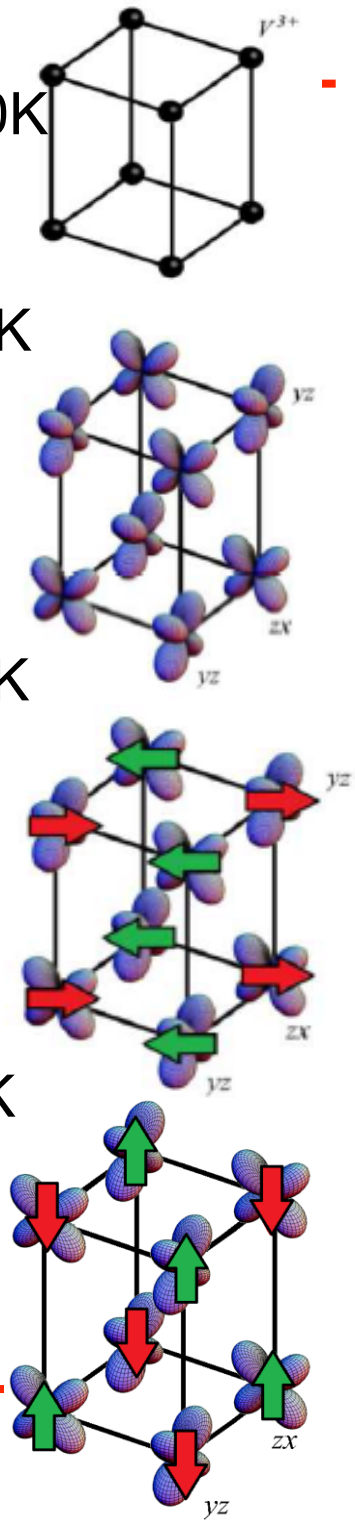


T=300K

T=200K

T=116K

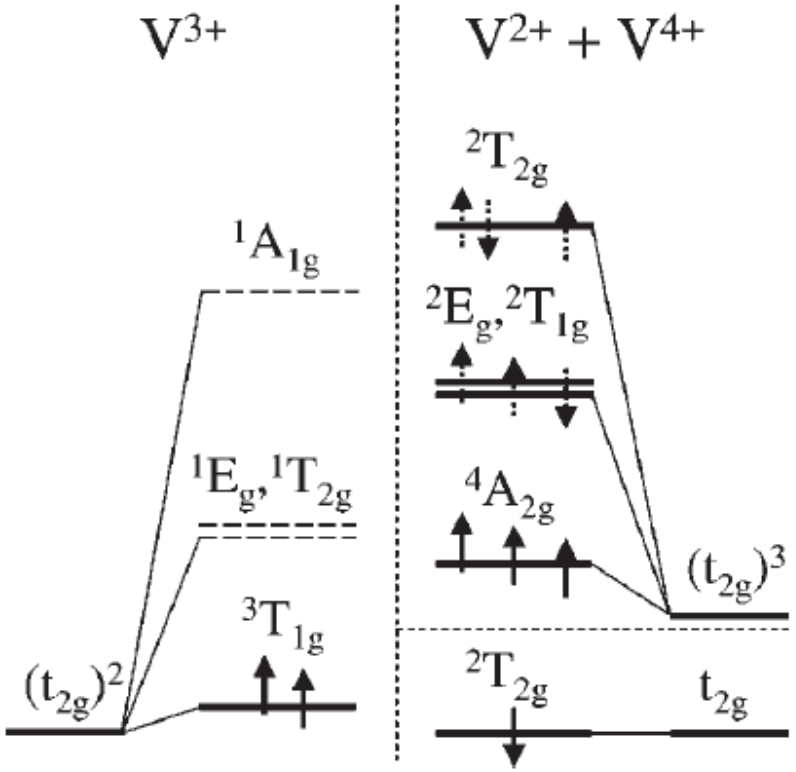
T=77K



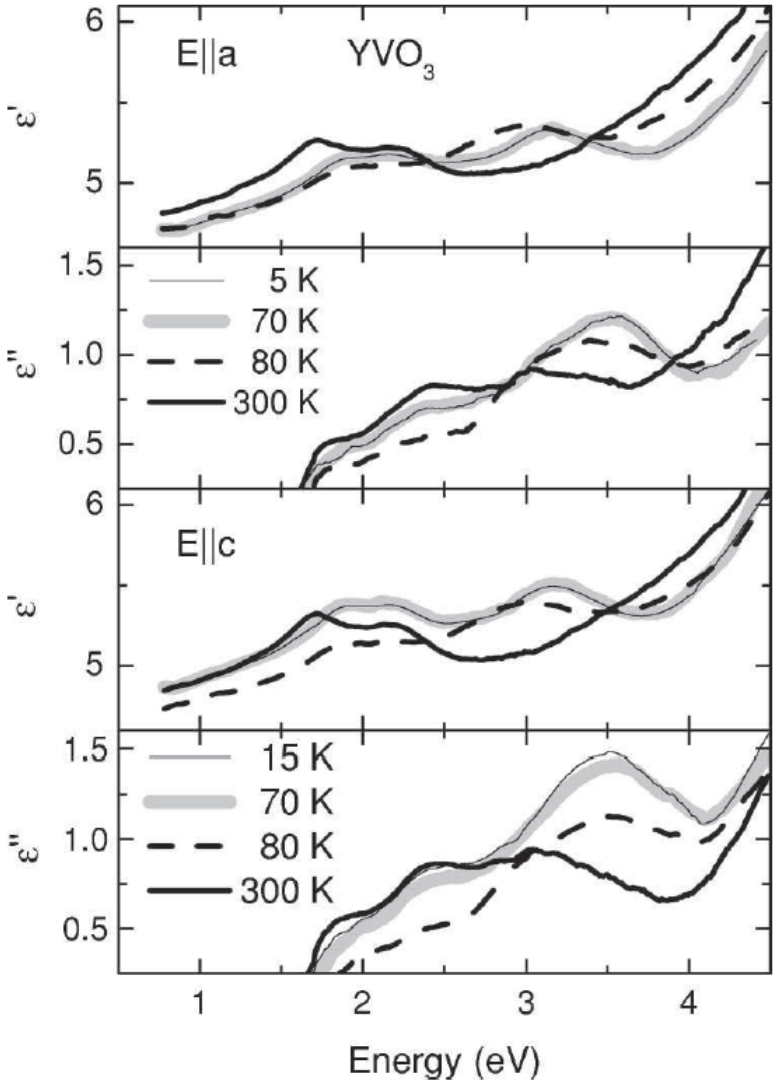
PRB, 65, 174112 (2002); PRL 91, 257202 (2003); PRL 99, 126402 (2007)

YVO_3: Optical Properties

- ✓ $d_2d_2 \rightarrow d_1d_3$
  $V^{3+}V^{3+} \rightarrow V^{2+}V^{4+}$
- ✓ Multiplet Calculations

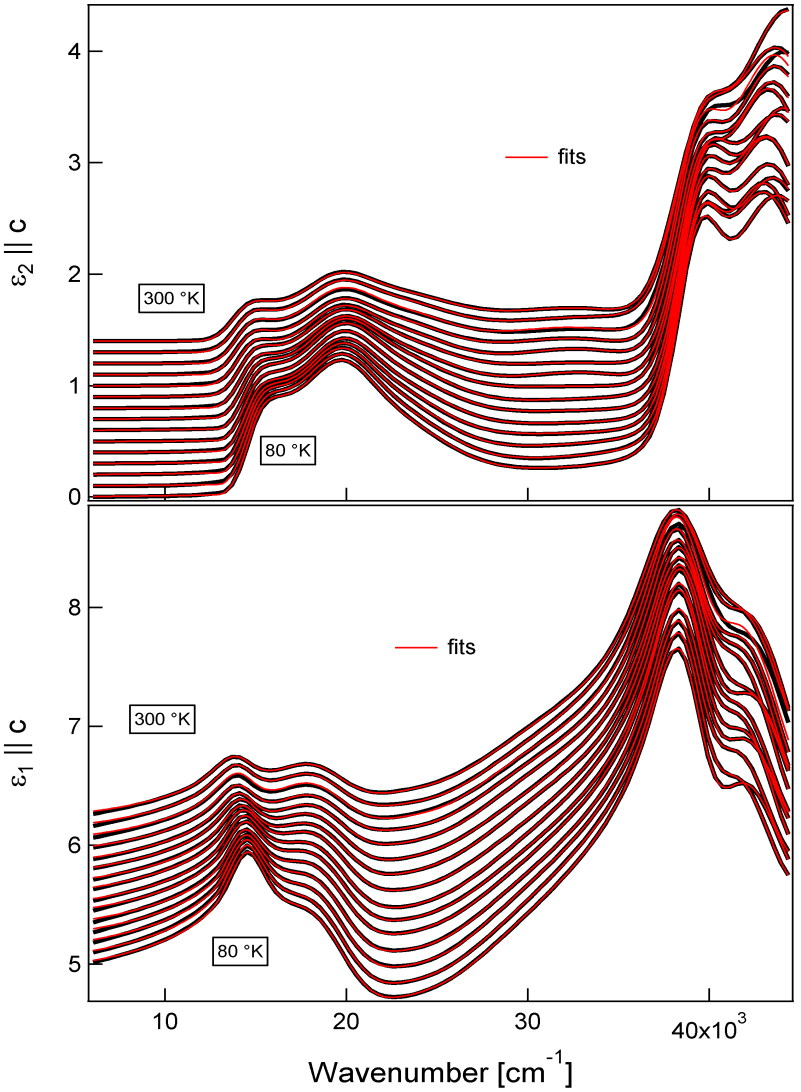


Tzvetkov A. & al. PRB, 69, 075110



YVO_3: Optical Properties

- ✓ 6 Gaussian and 1 Tauc-Lorentz oscillators



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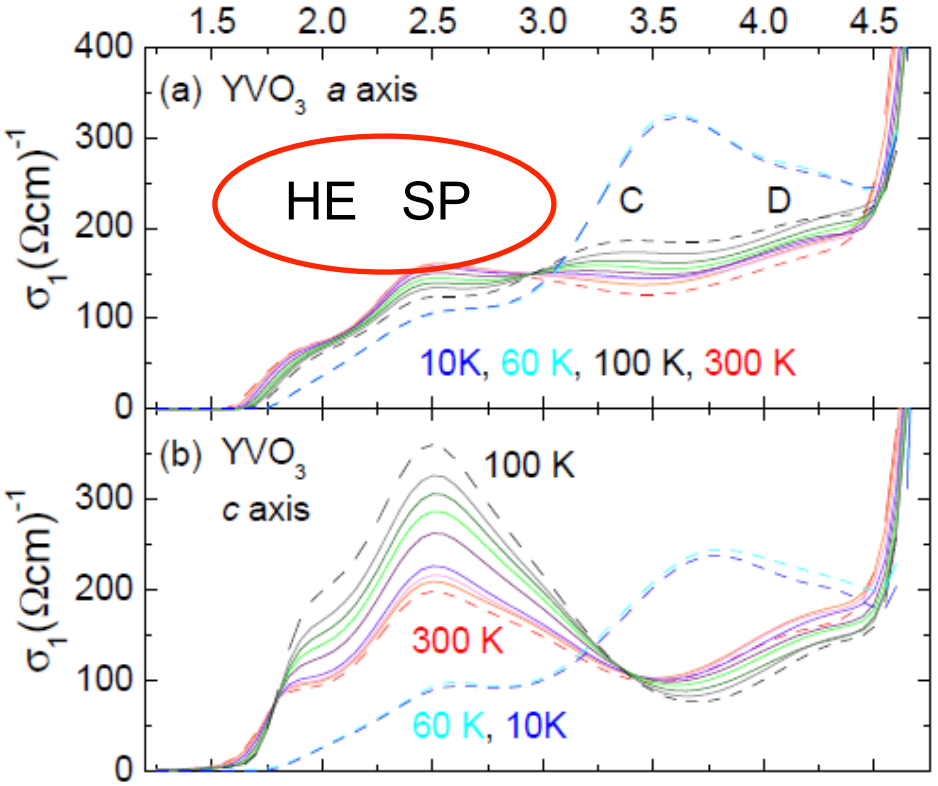
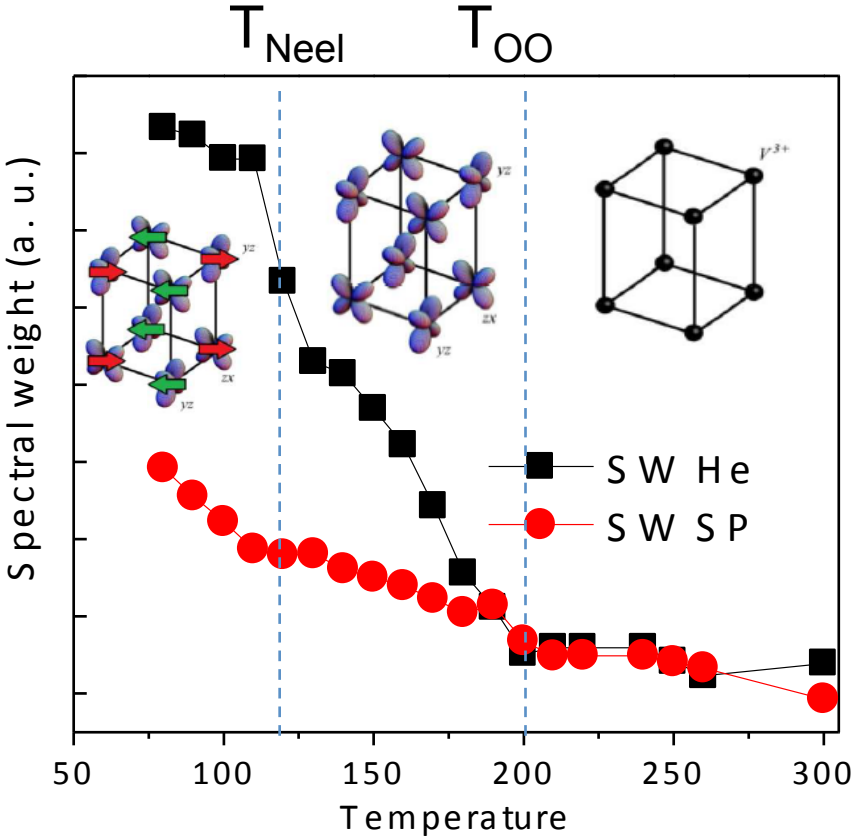
- ✓ Anomalous behavior of SW in the Spin and OO phases?!





Reul. J, Gruninger M. & PRB

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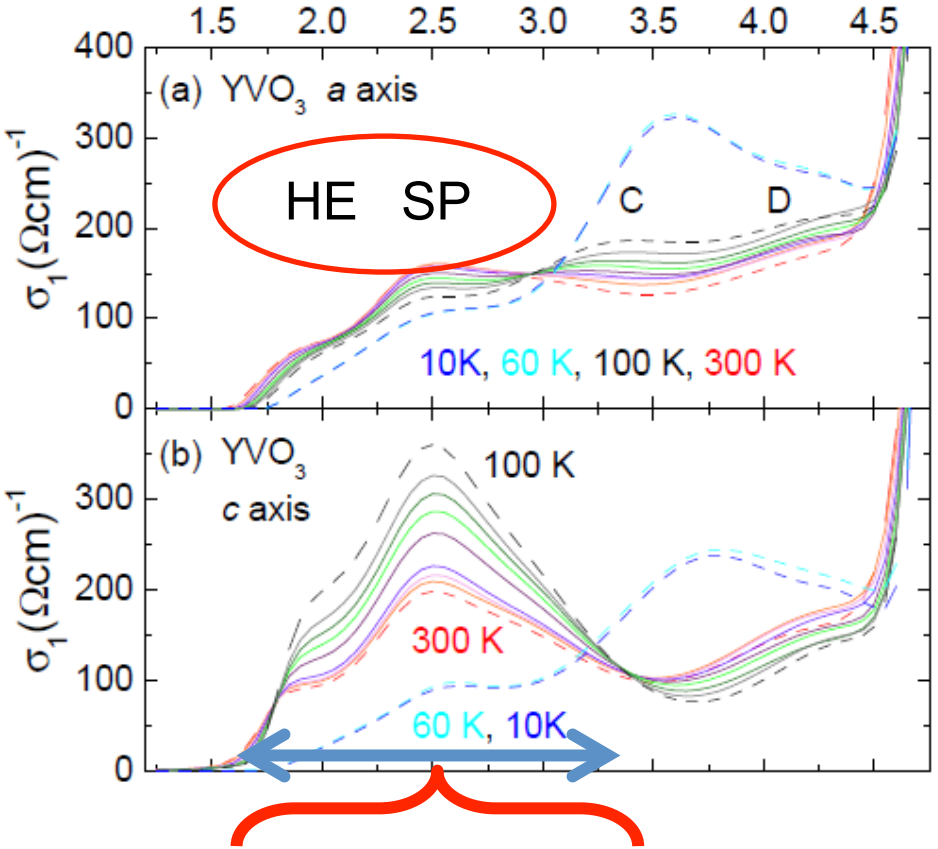
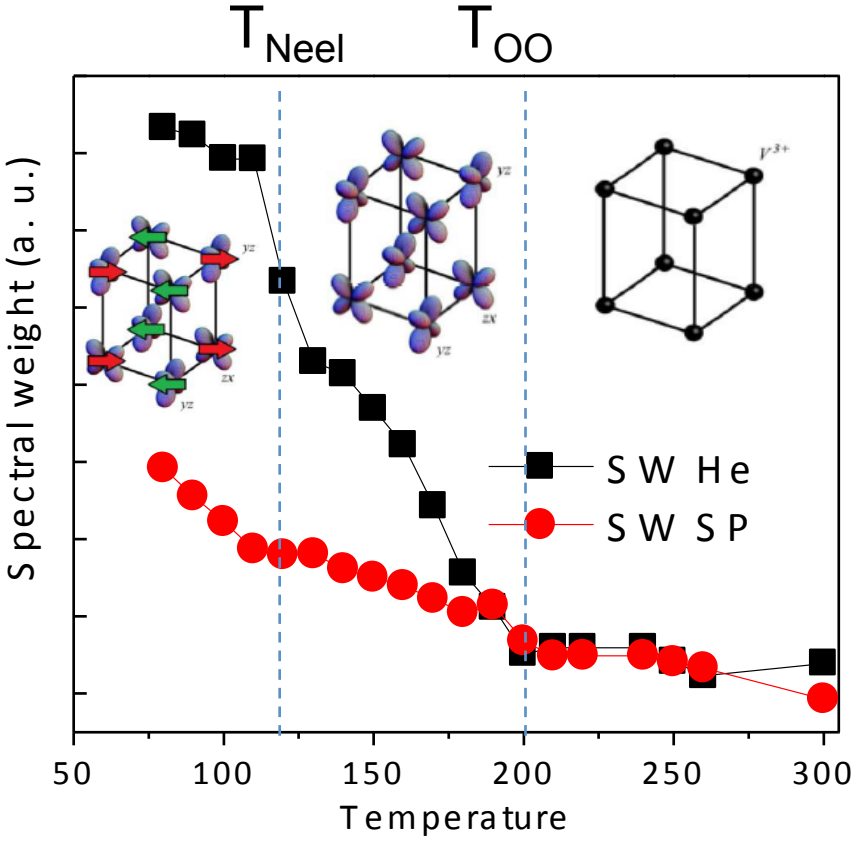
- ✓ 6 Gaussian and 1 Tauc-Lorentz oscillators
- ✓ Anomalous behavior of SW in the Spin and OO phases?!





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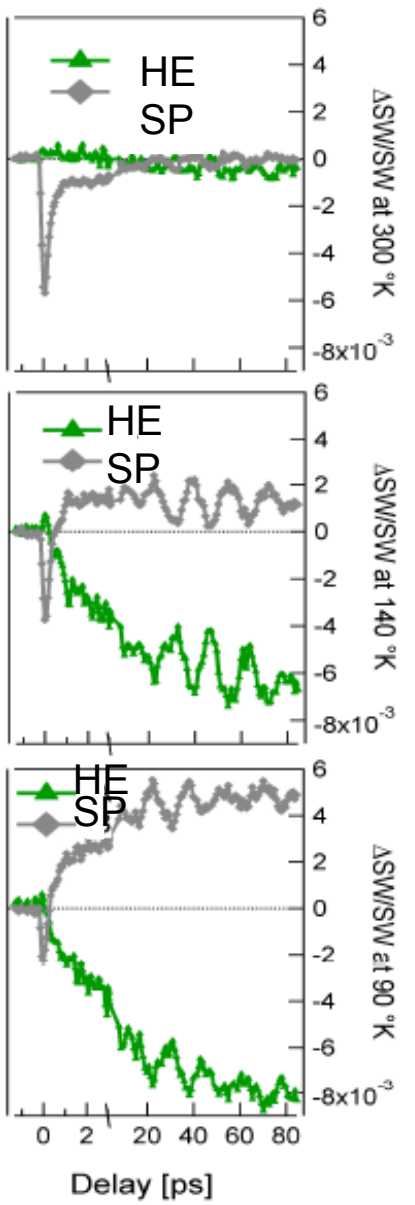
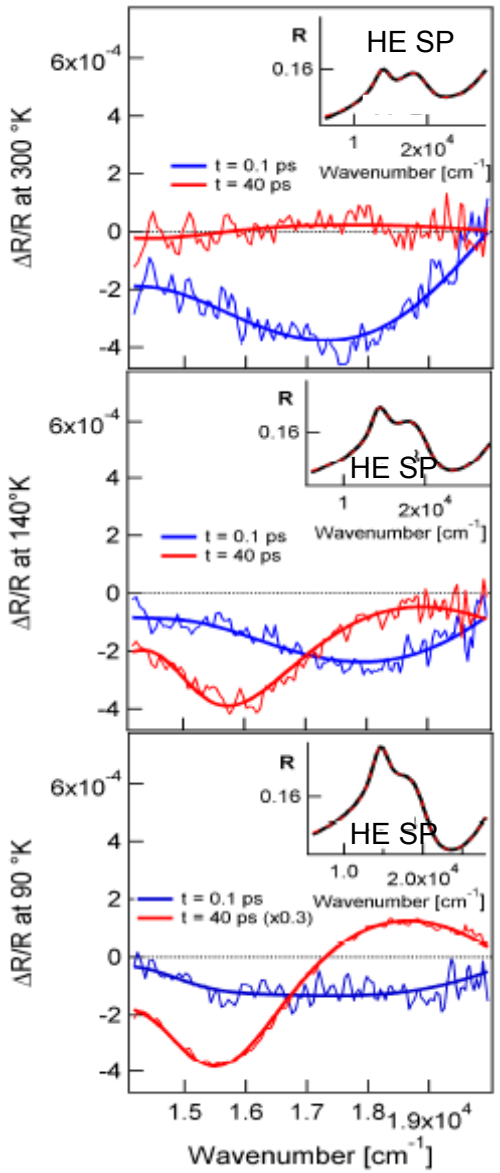
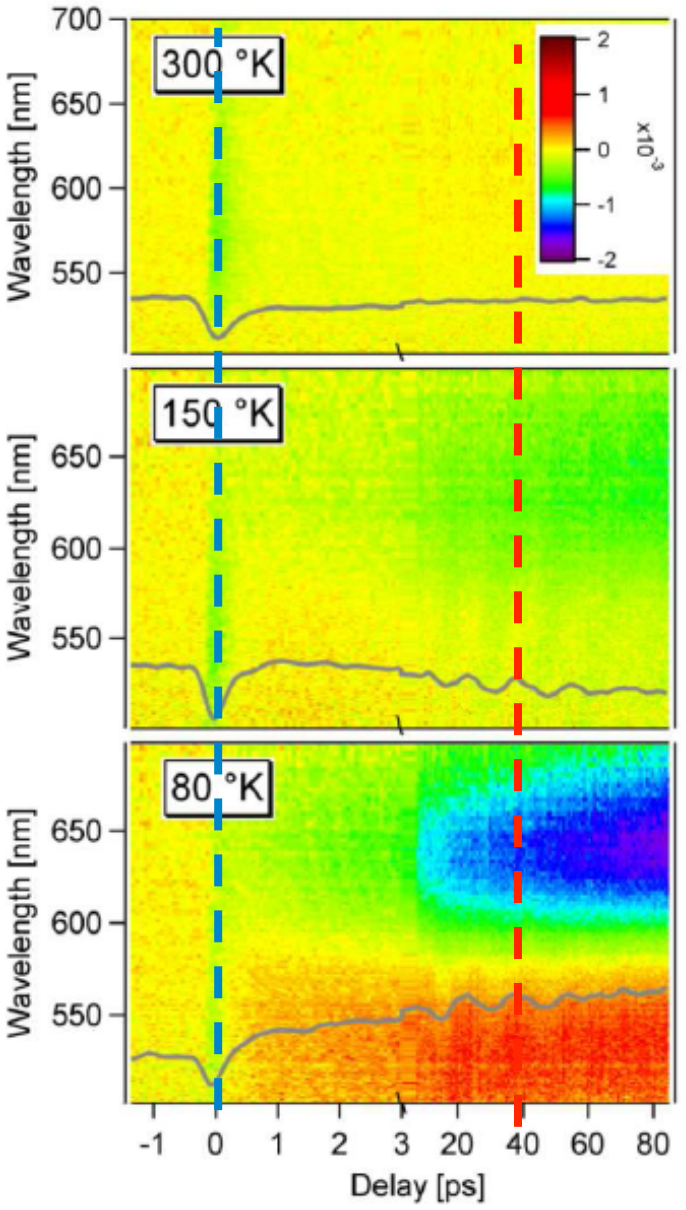
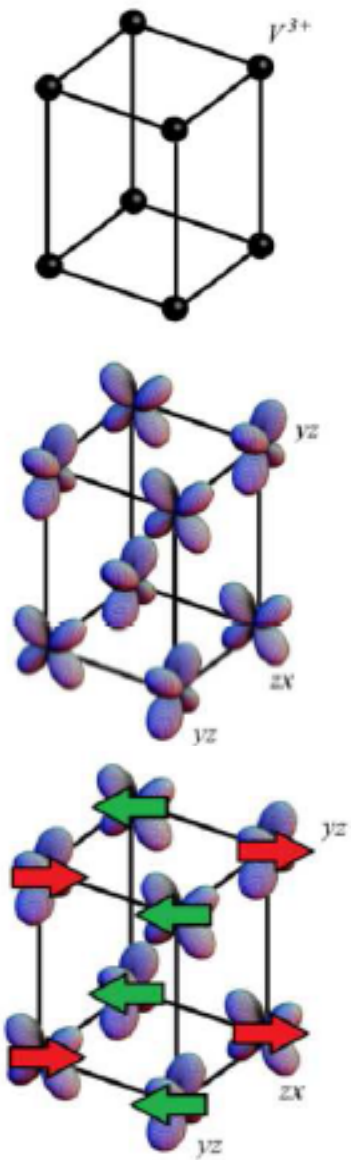
YVO_3: Transient Optical Properties

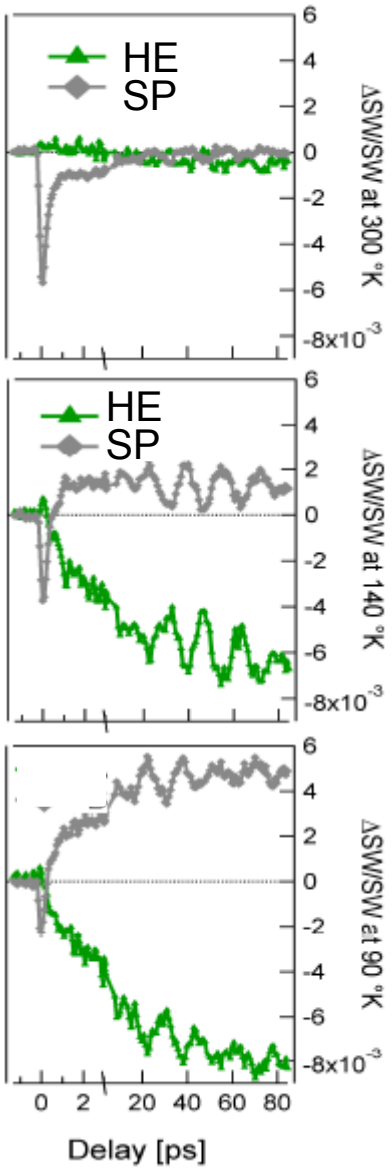






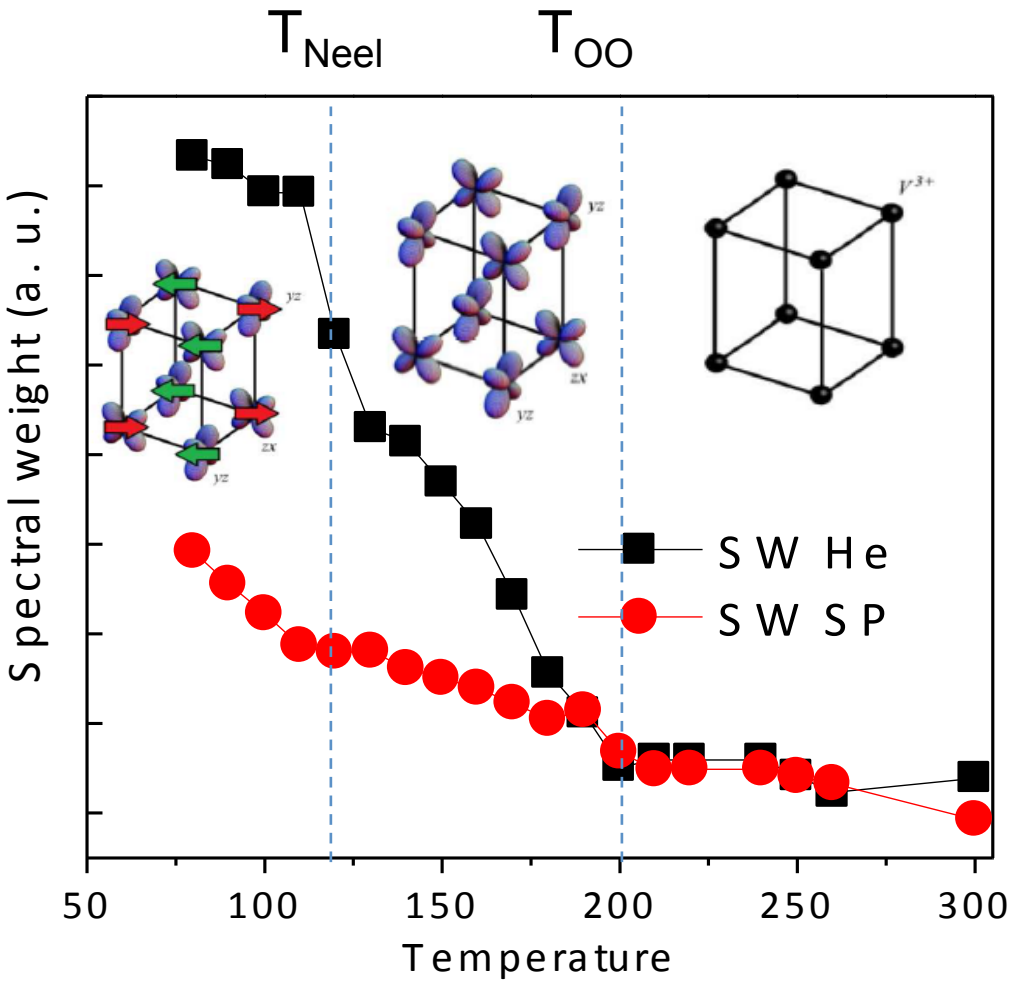


Thermal Vs. Non-thermal SW



✓Thermal benchmark

✓Non-Thermal Thermal contribution



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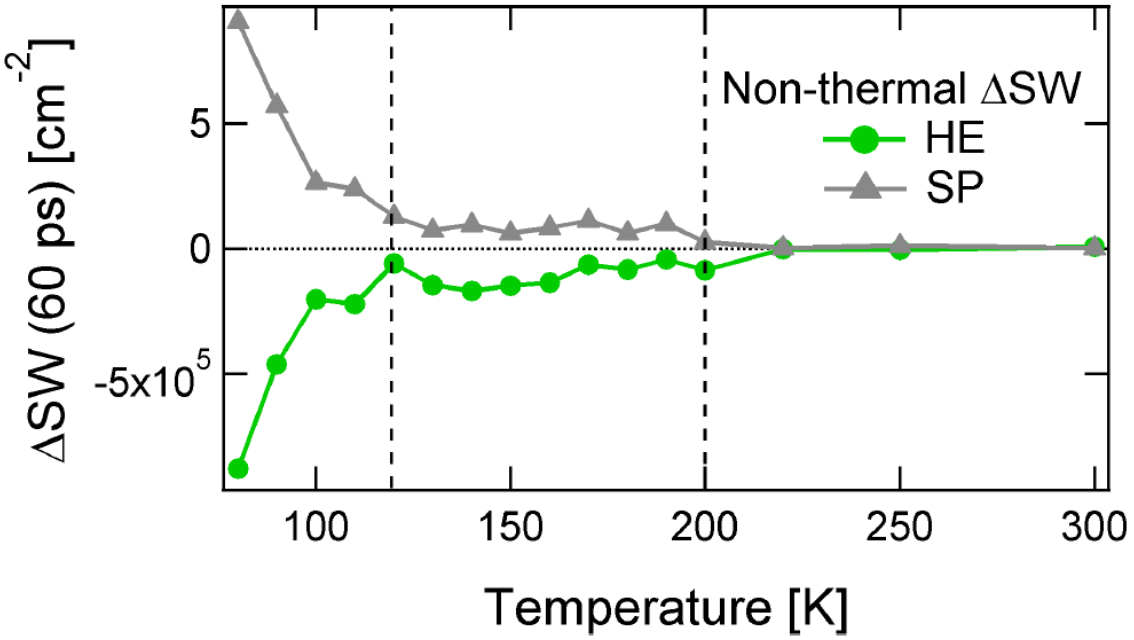
Thermal Vs. Non-thermal SW

✓Thermodyn. estimate of the T variation in the photo-excited state(ΔT)

✓Extrapolation of static optical properties (T_x+ΔT)

$$\Delta T[K] = \frac{Q_{abs} \cdot N_A \cdot V}{S \cdot d \cdot u \cdot C_{mol}}$$



✓Direct Exchange of SW between the two bands

i.e. It is the same band!

Hubbard Exciton?!

Phys. Rev. B **86**, 165135 (2012)

Outline

- ✓ **Equilibrium Optical Spectroscopy**
  - -The optical conductivity in the Visible and Near-IR
  - -What do we learn from optical conductivity?
  - -An example, metal insulator transition in complex oxides
- ✓ **Non-equilibrium optical (visible near-IR) spectroscopy**
  - -Pump&probe the main idea
  - -«Single color» Pump and probe
  - -Broadband P&P spectroscopy
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  - -The electron-phonon (EP) interaction in with strong electronic correlation
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  - -Table top Vs. FEL and sincrotrons

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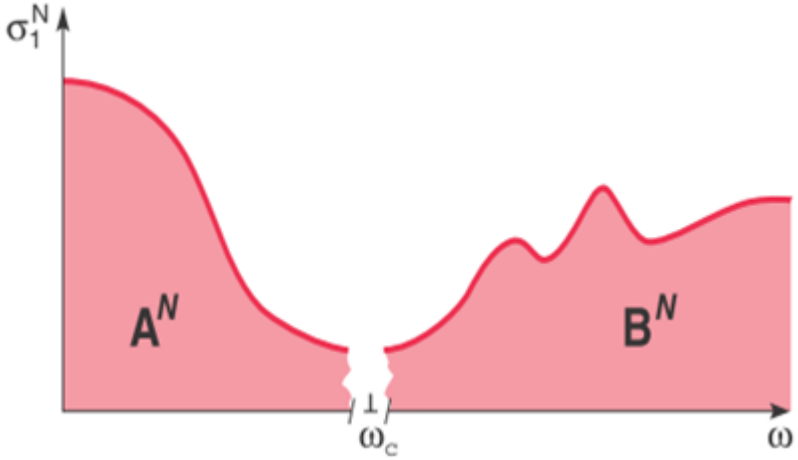
Open problem in the cuprates



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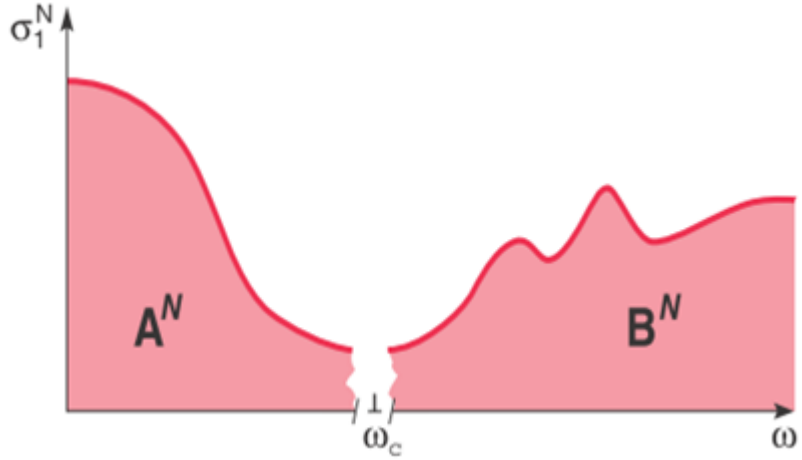
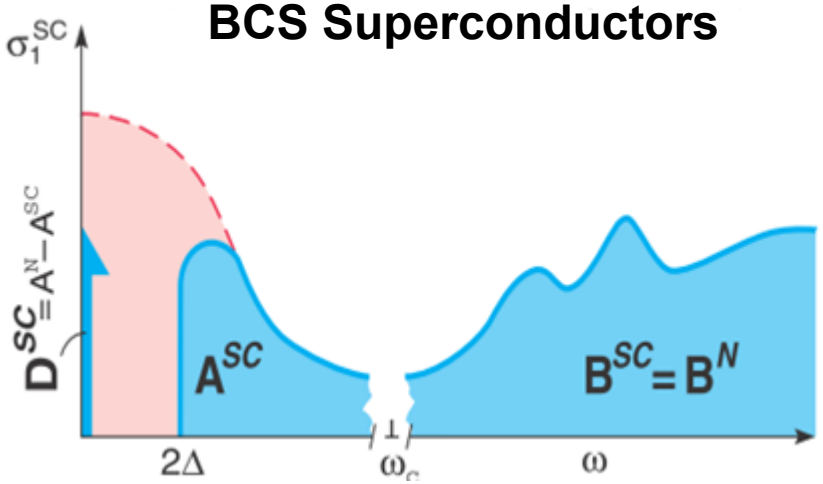


BCS Superconductors



$T < T_c$

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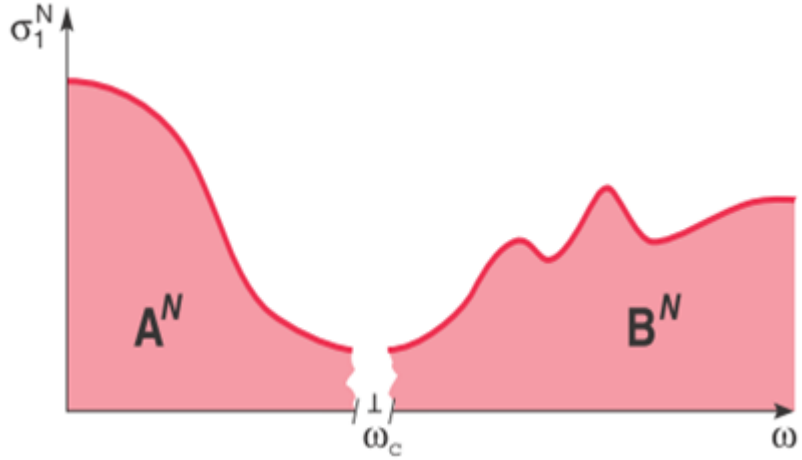

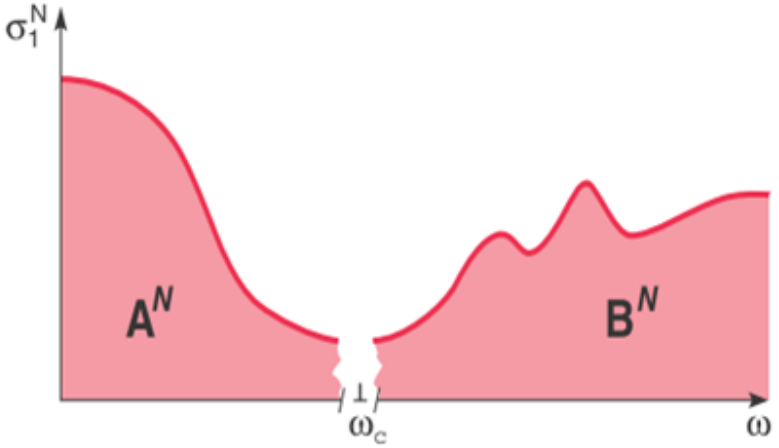

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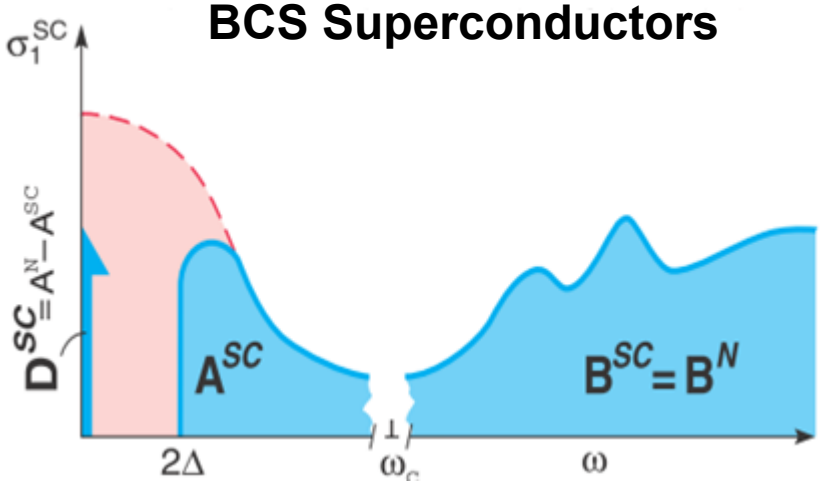

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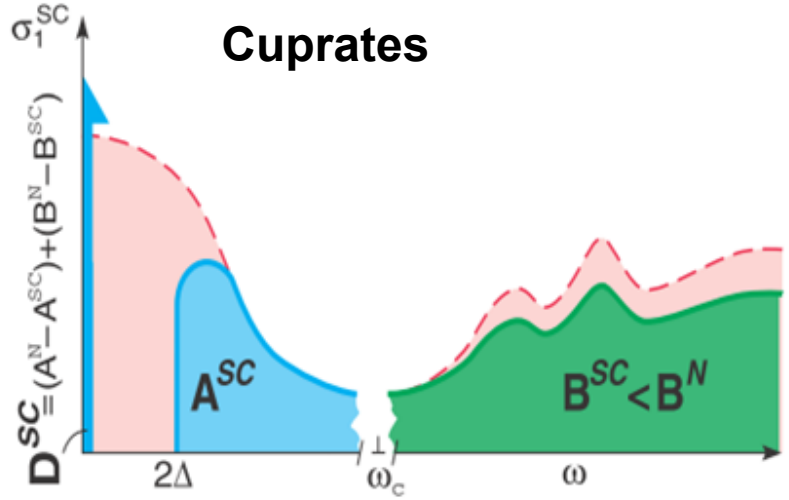

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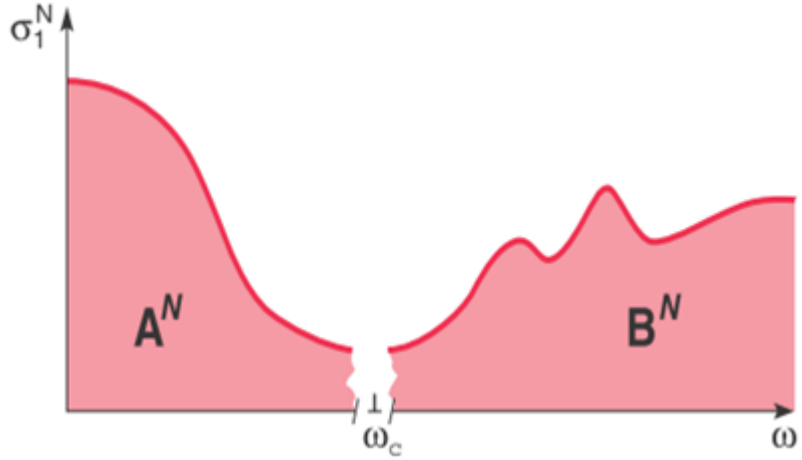

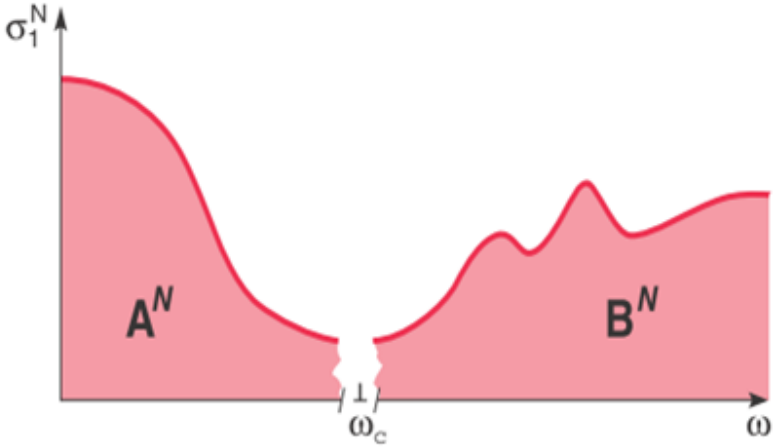

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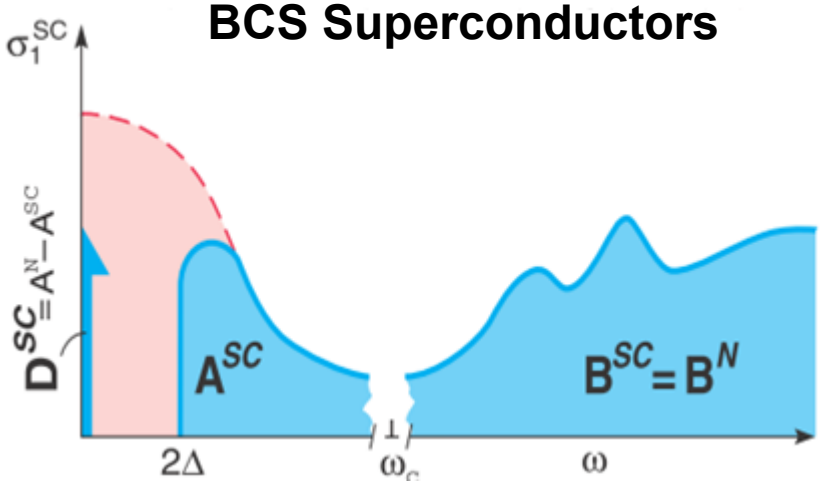

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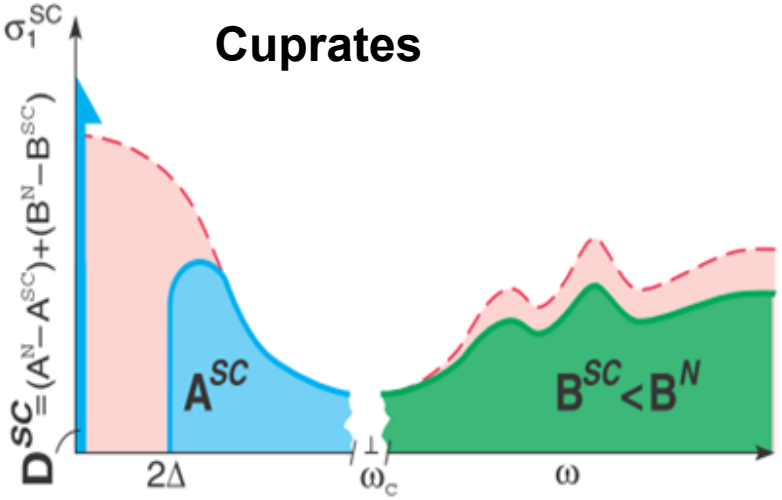

What links the low energy physics of superconductivity to high energy?

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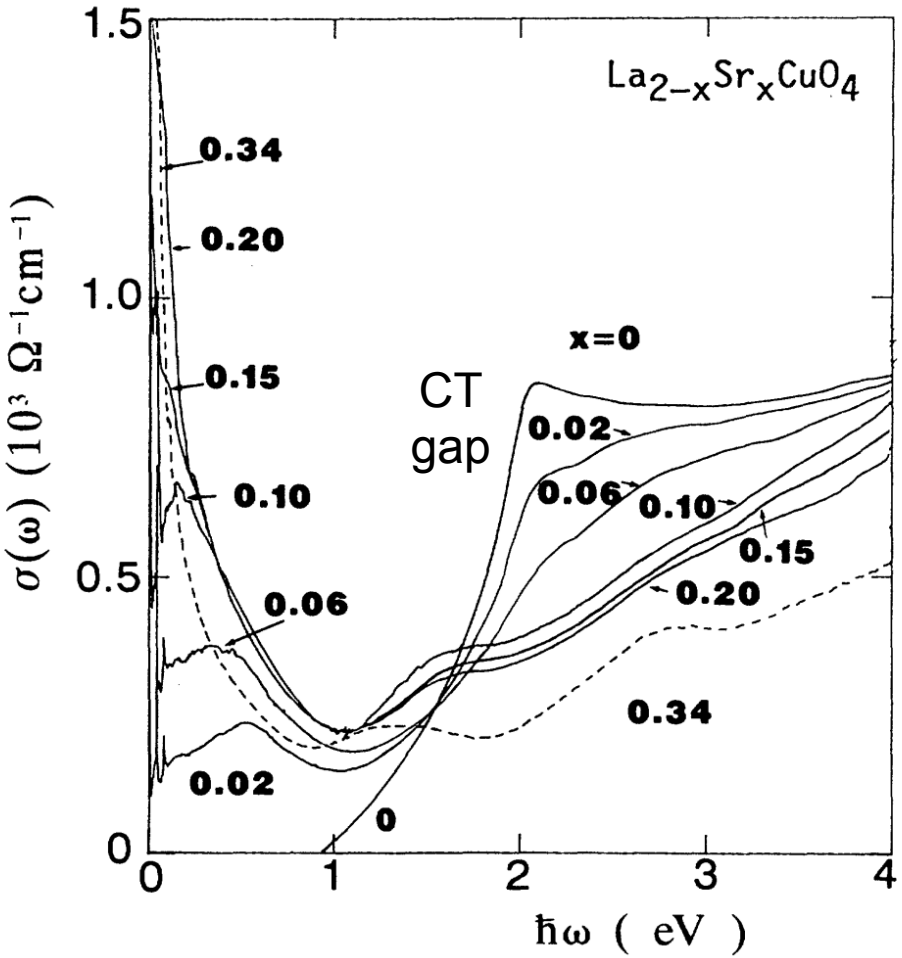
Optical properties of $La_{2-x}Sr_xCuO_4$



PRB 43 7942 1991

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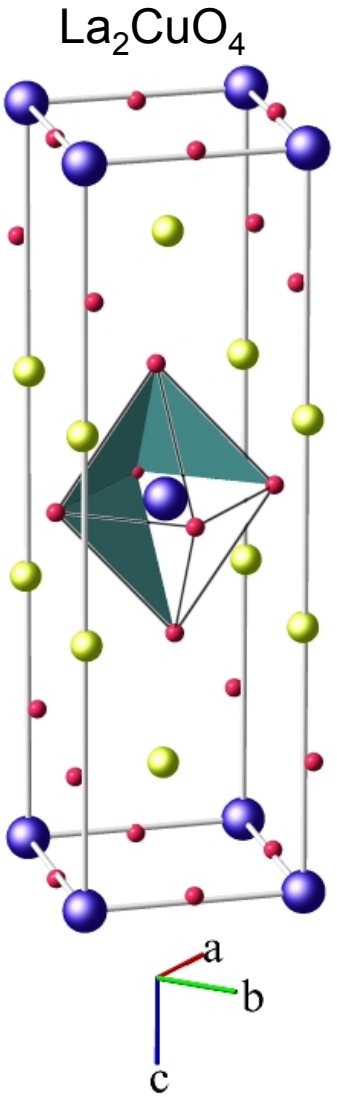

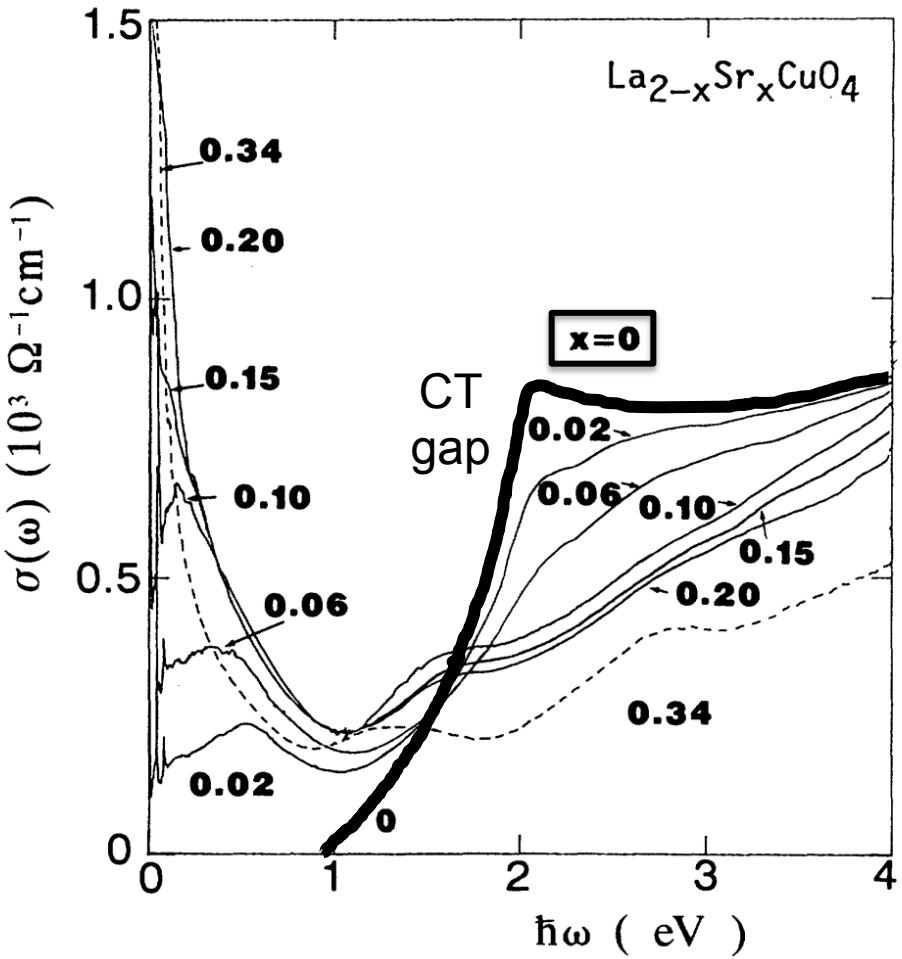

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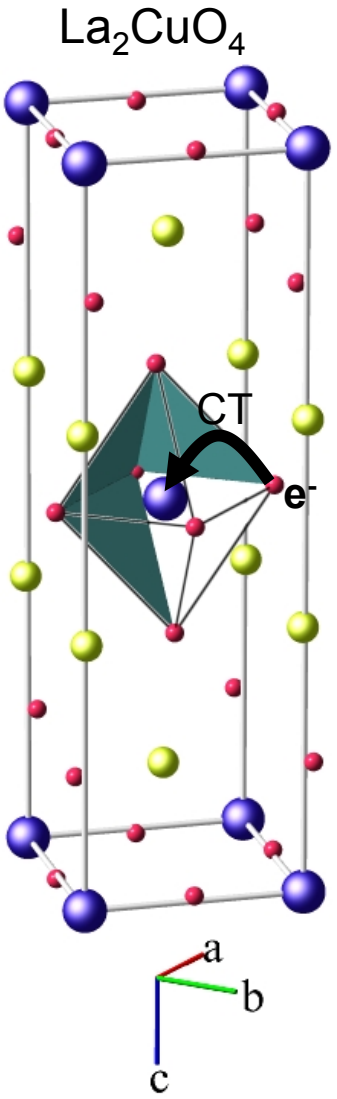

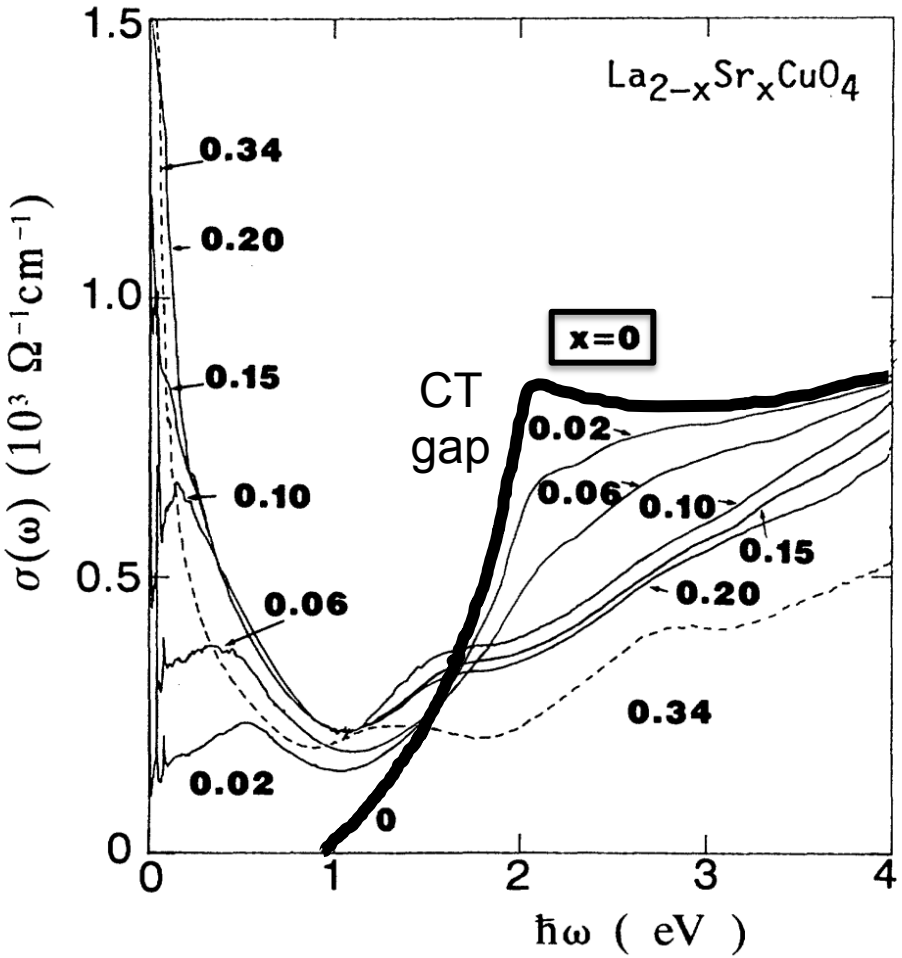

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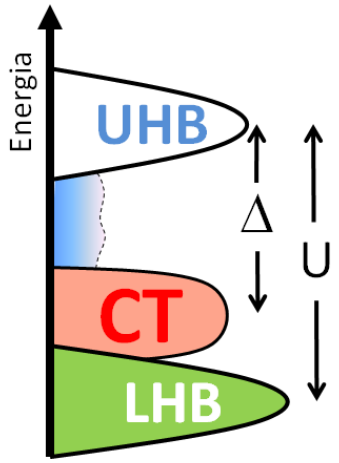

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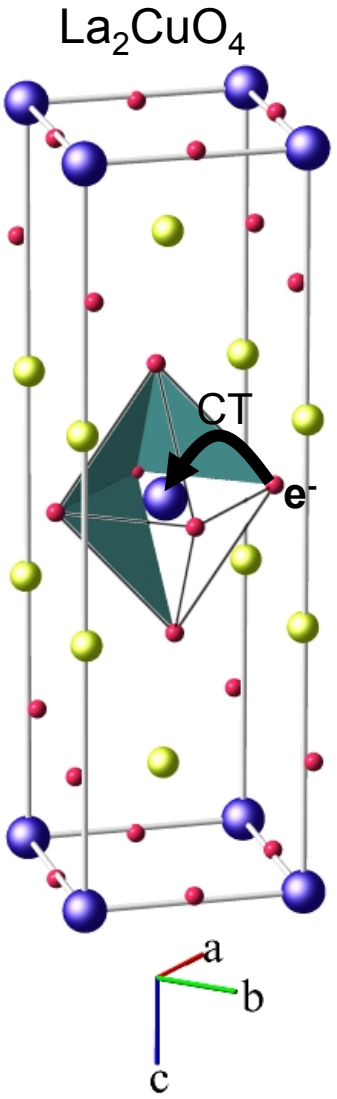

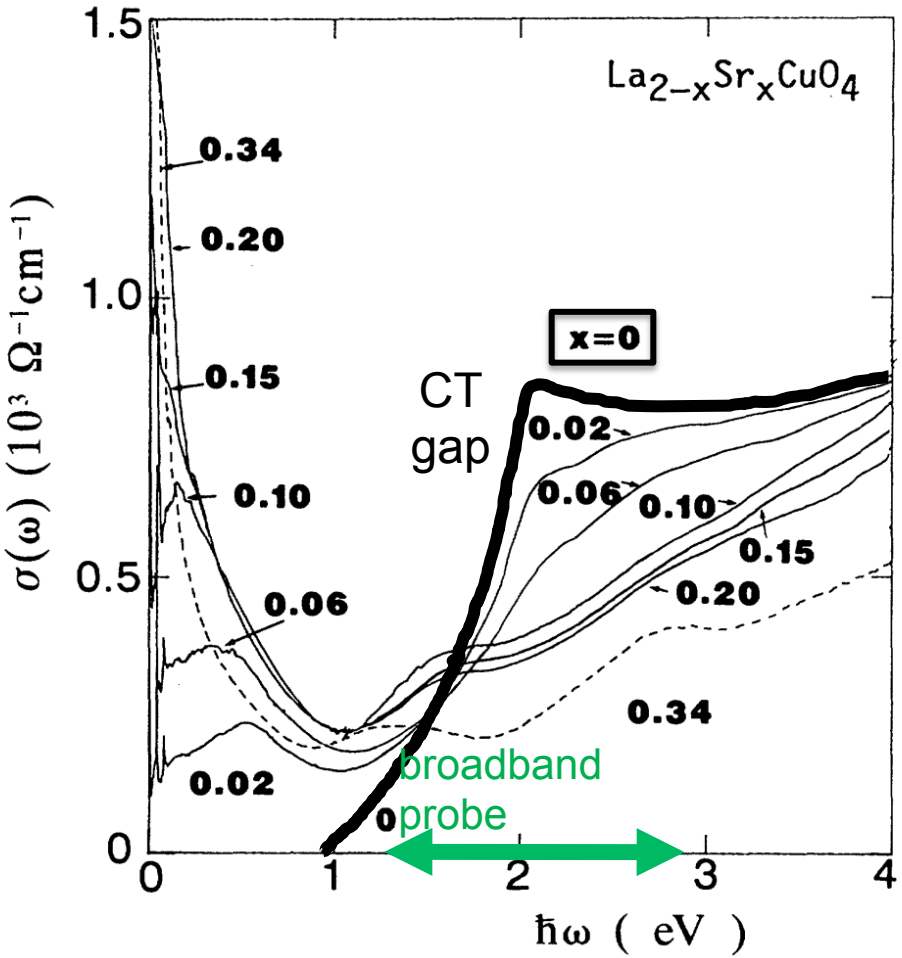

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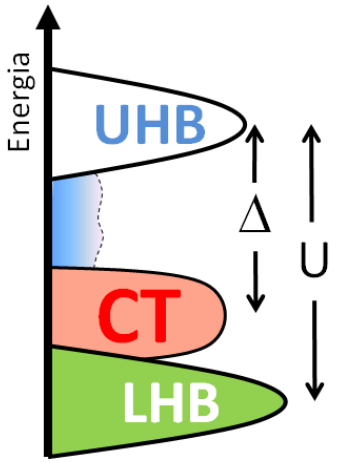

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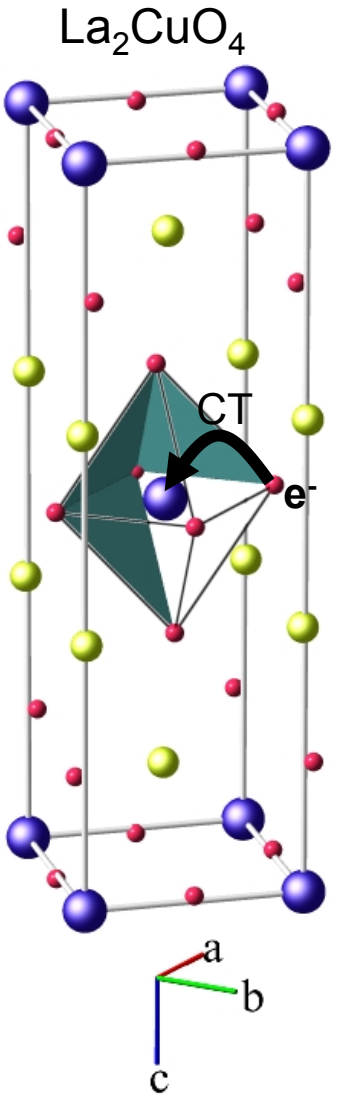

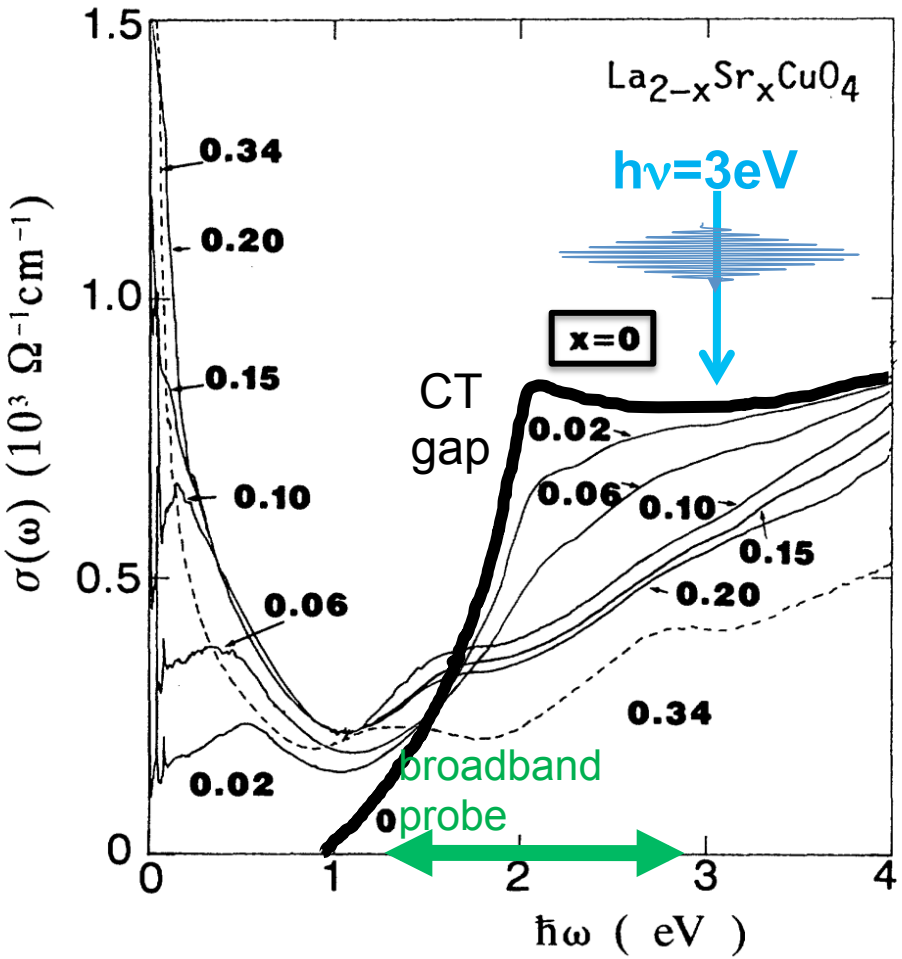

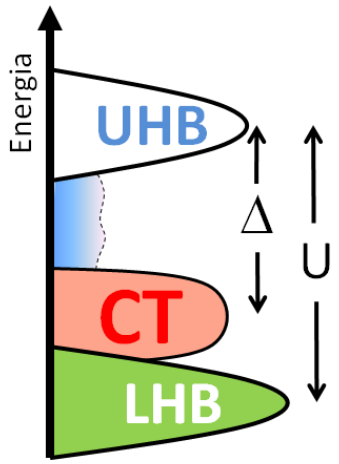

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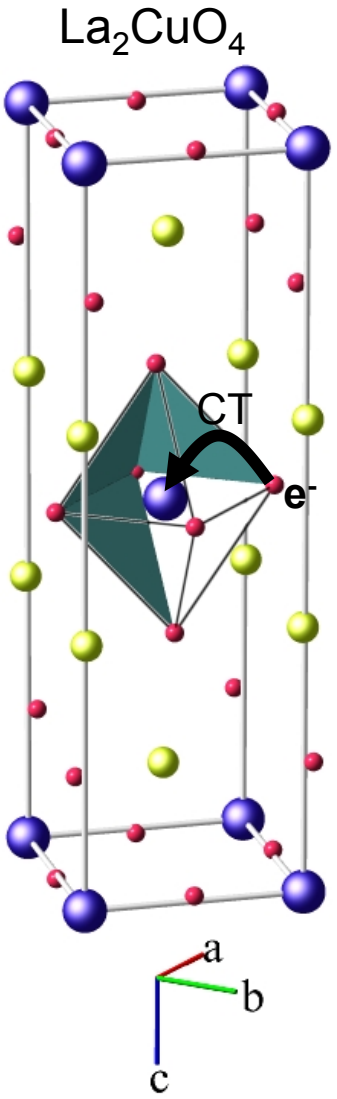

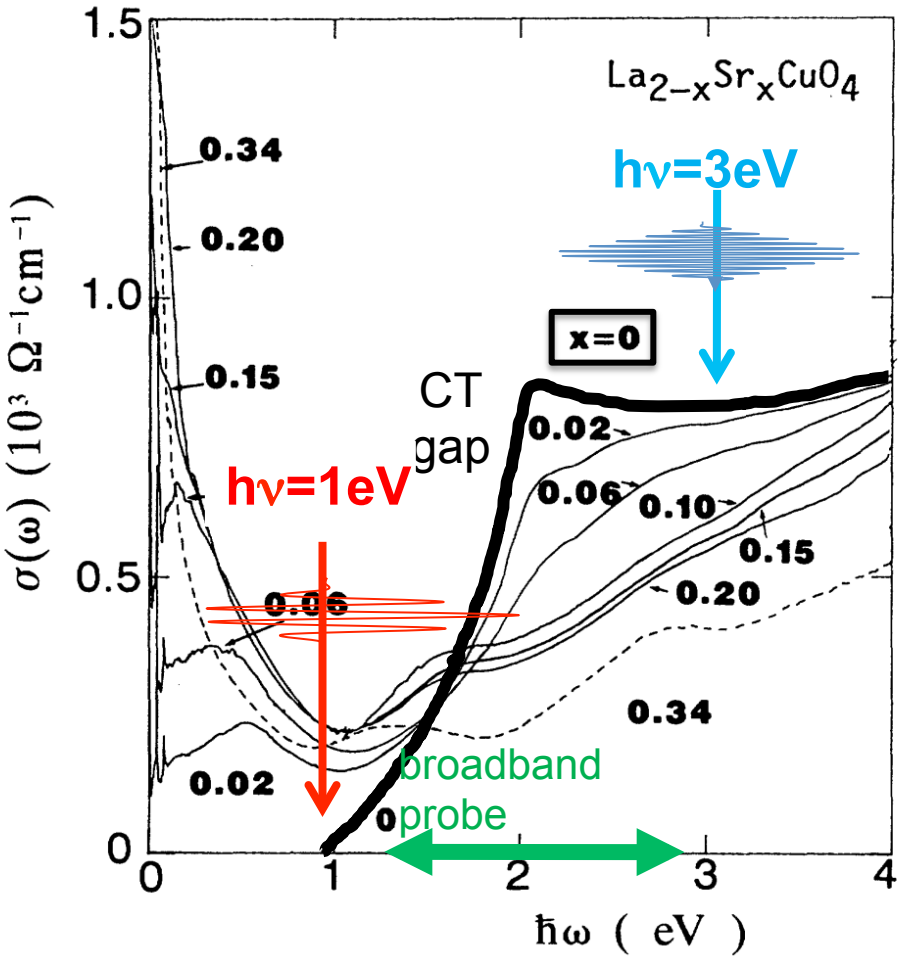

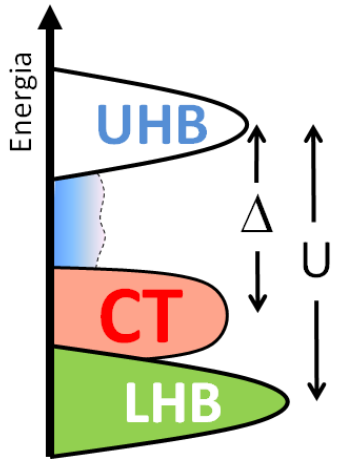

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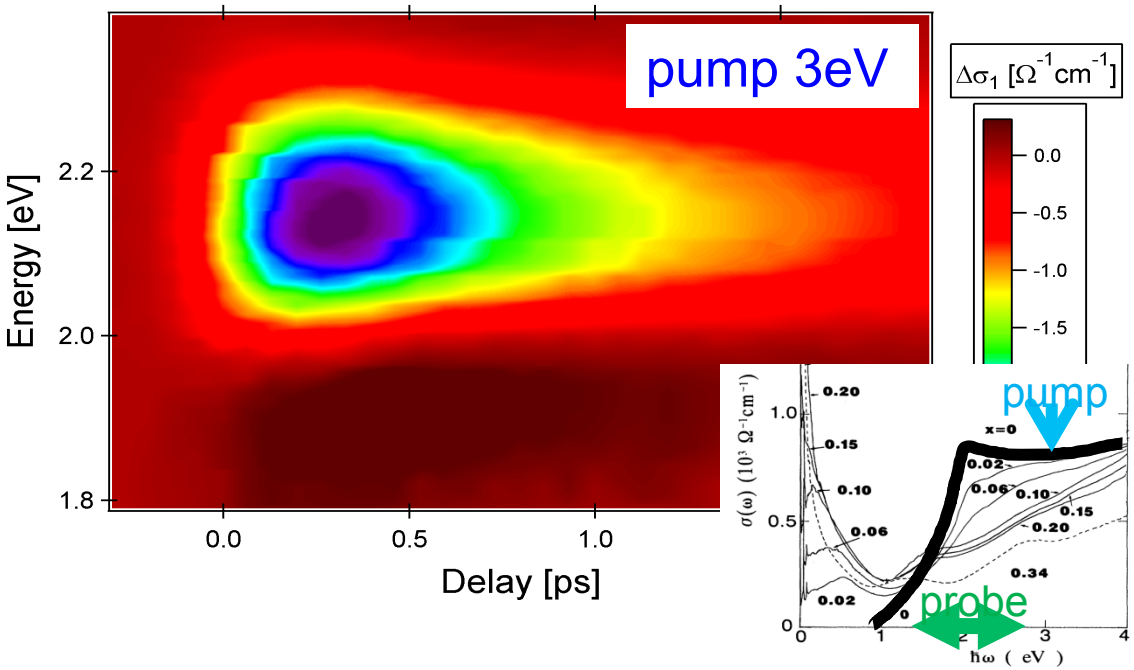
Selectivity of the excitation process



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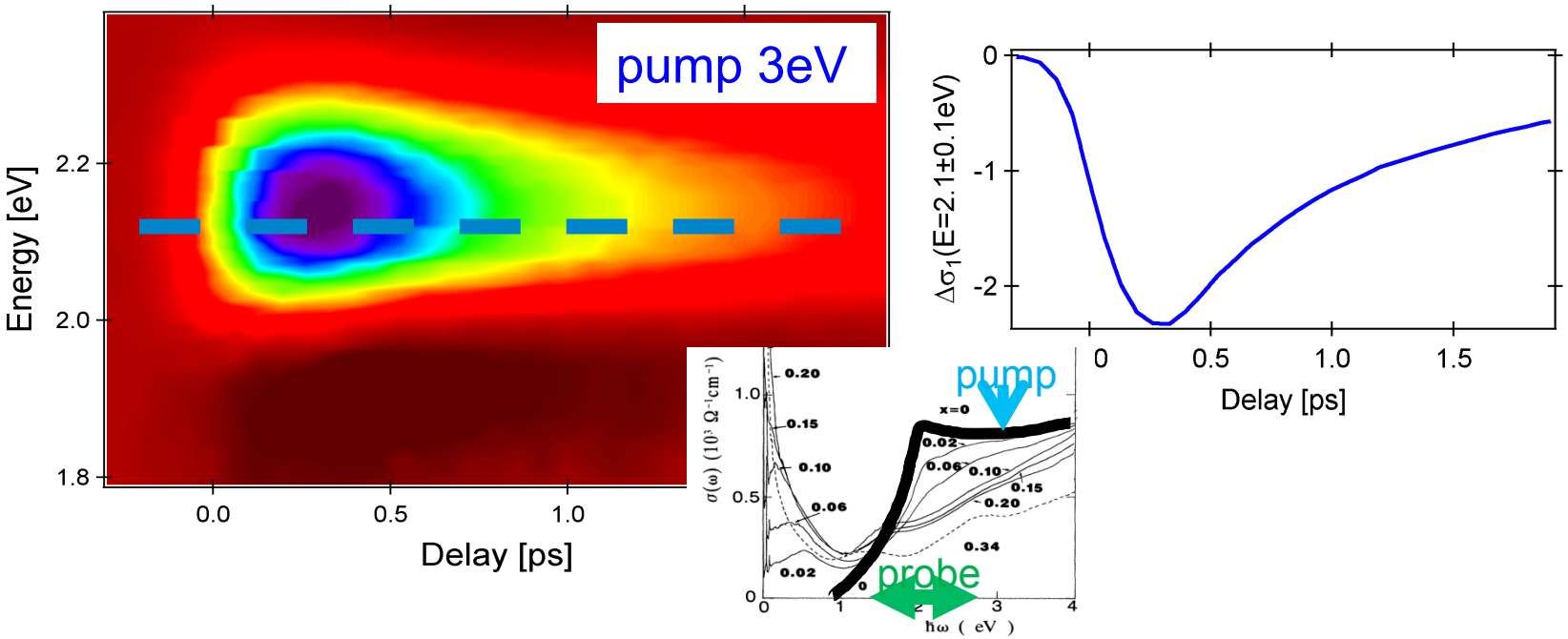

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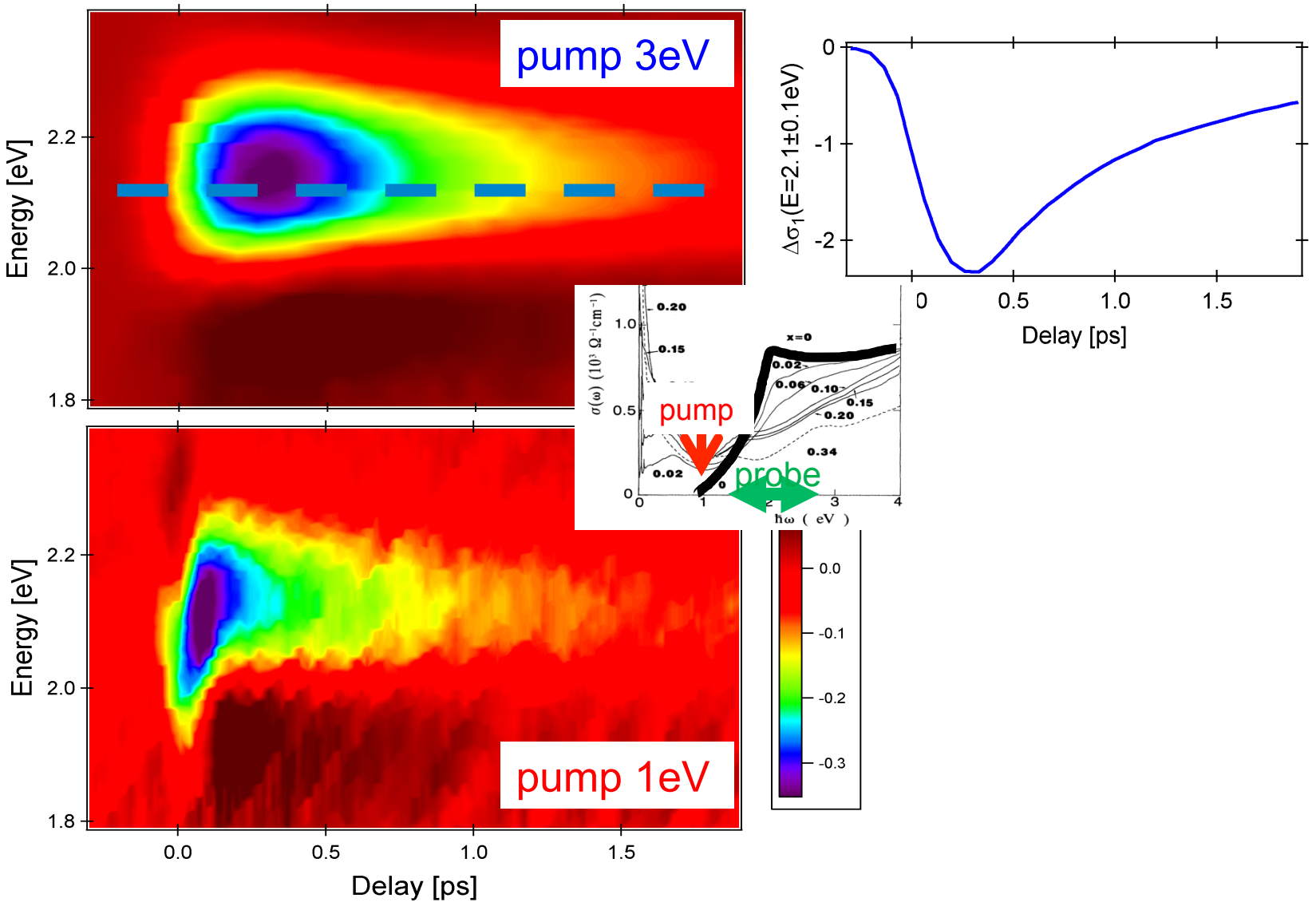

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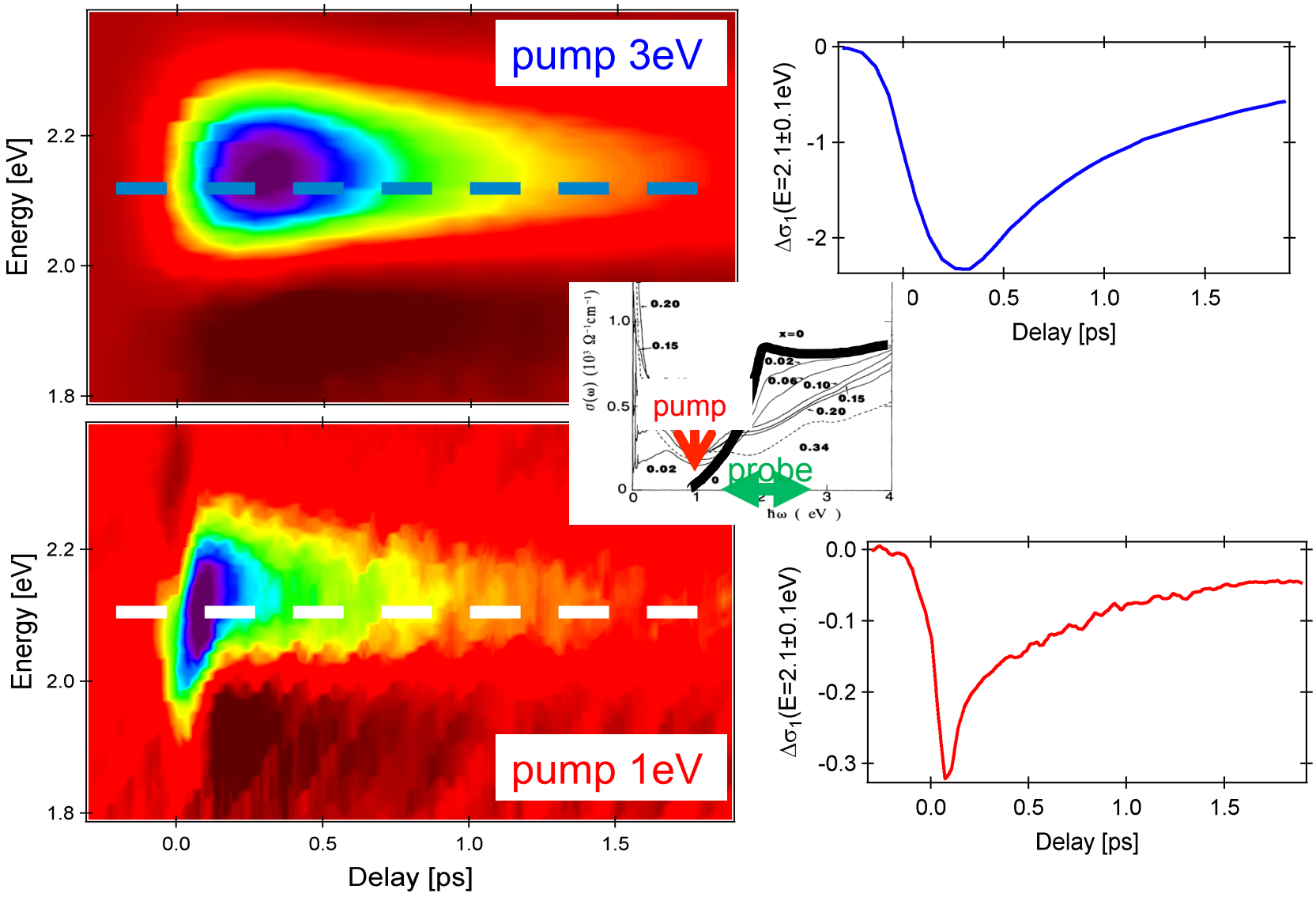

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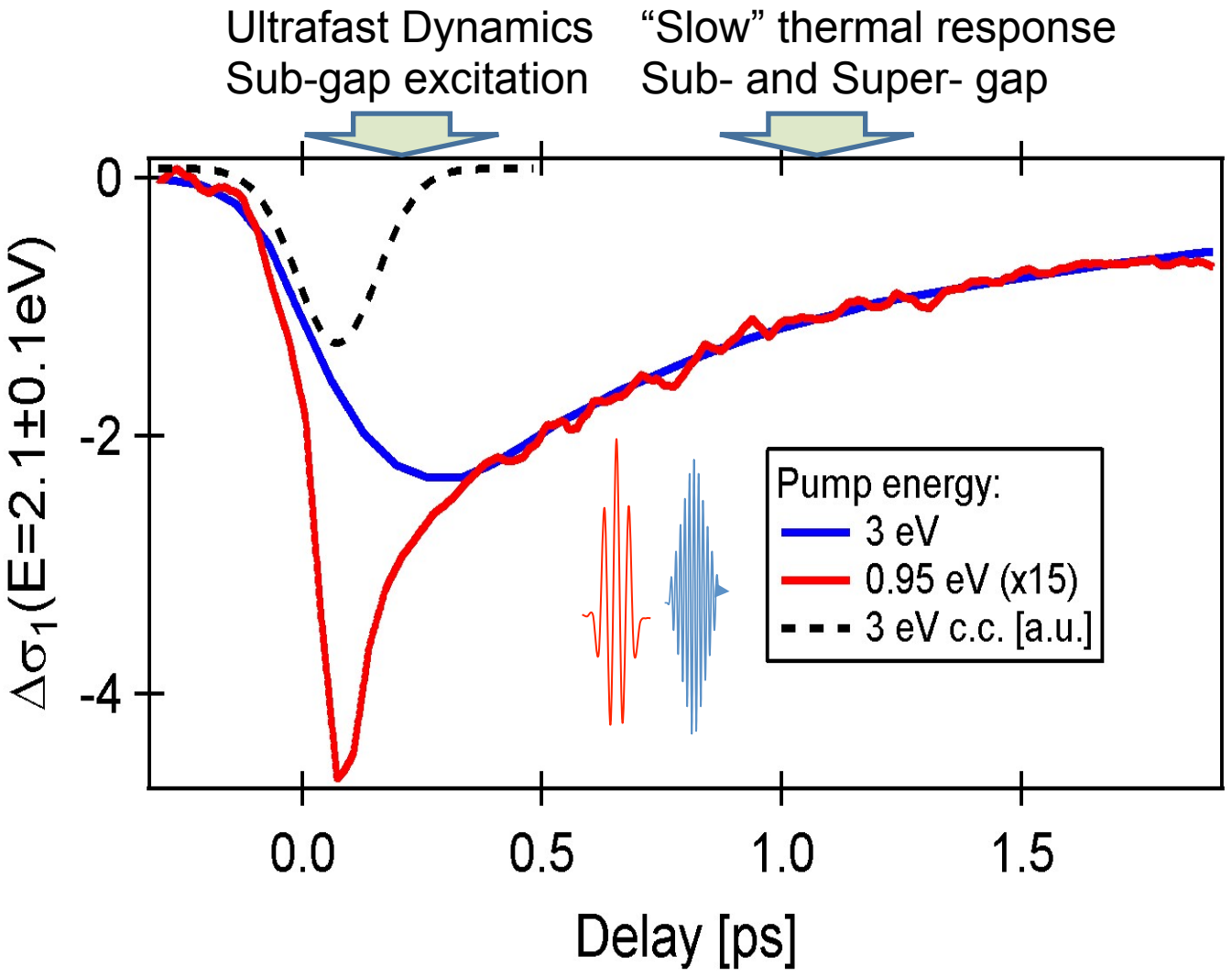

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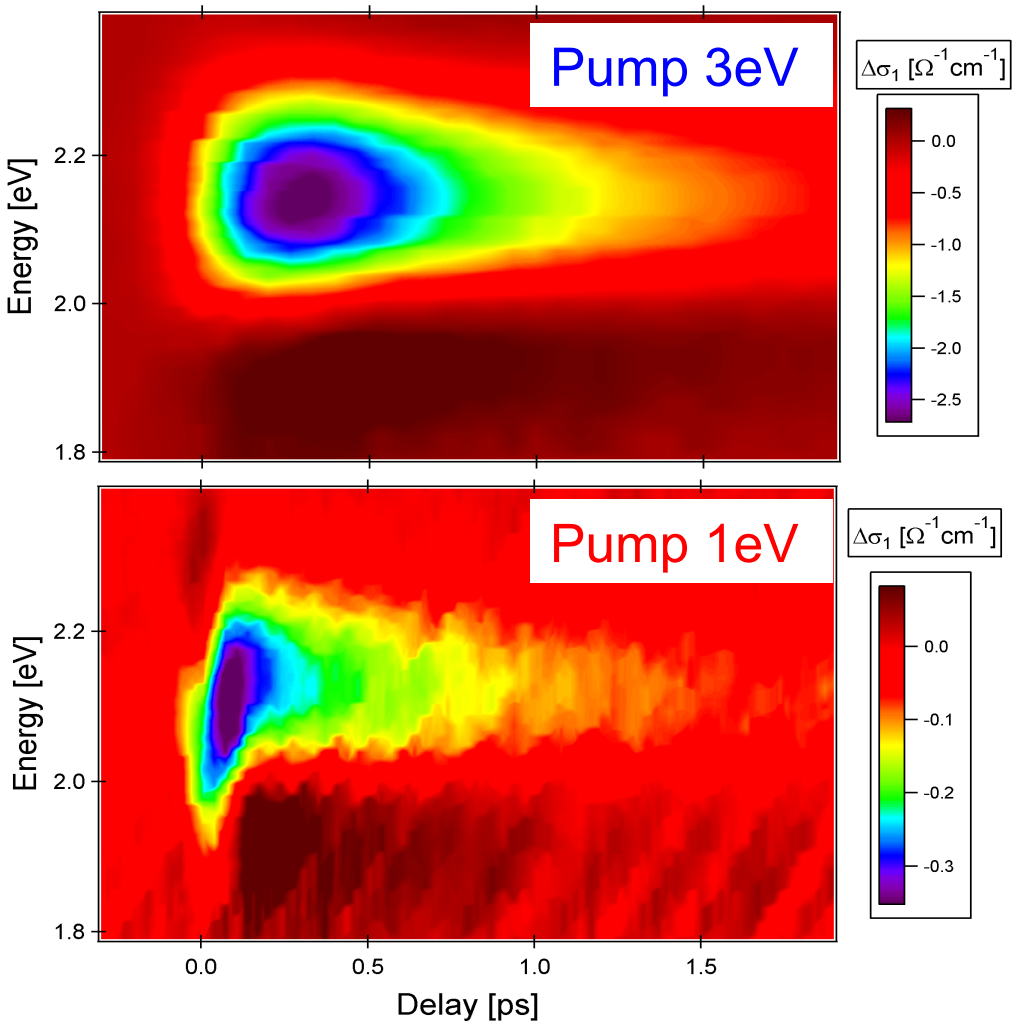

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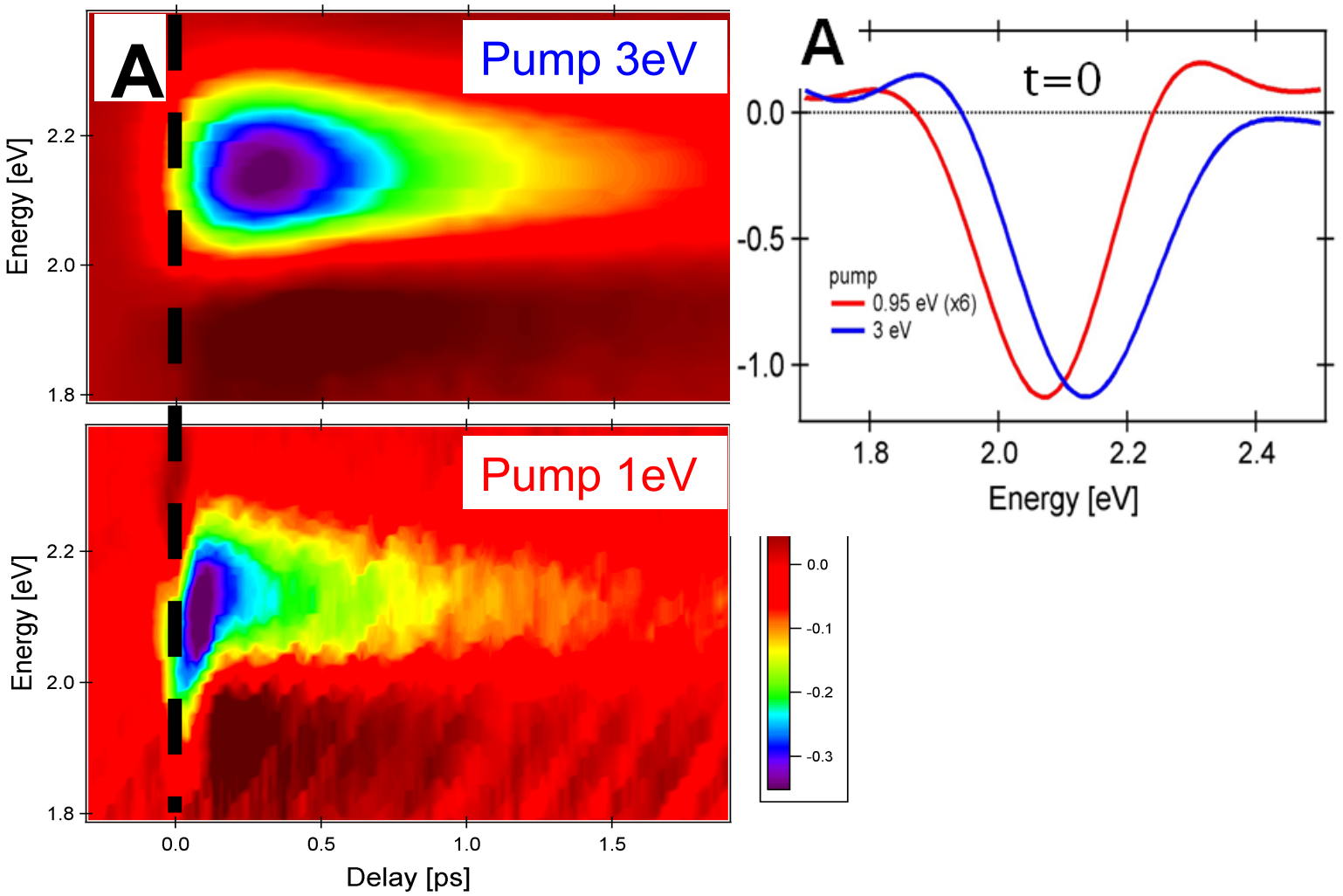

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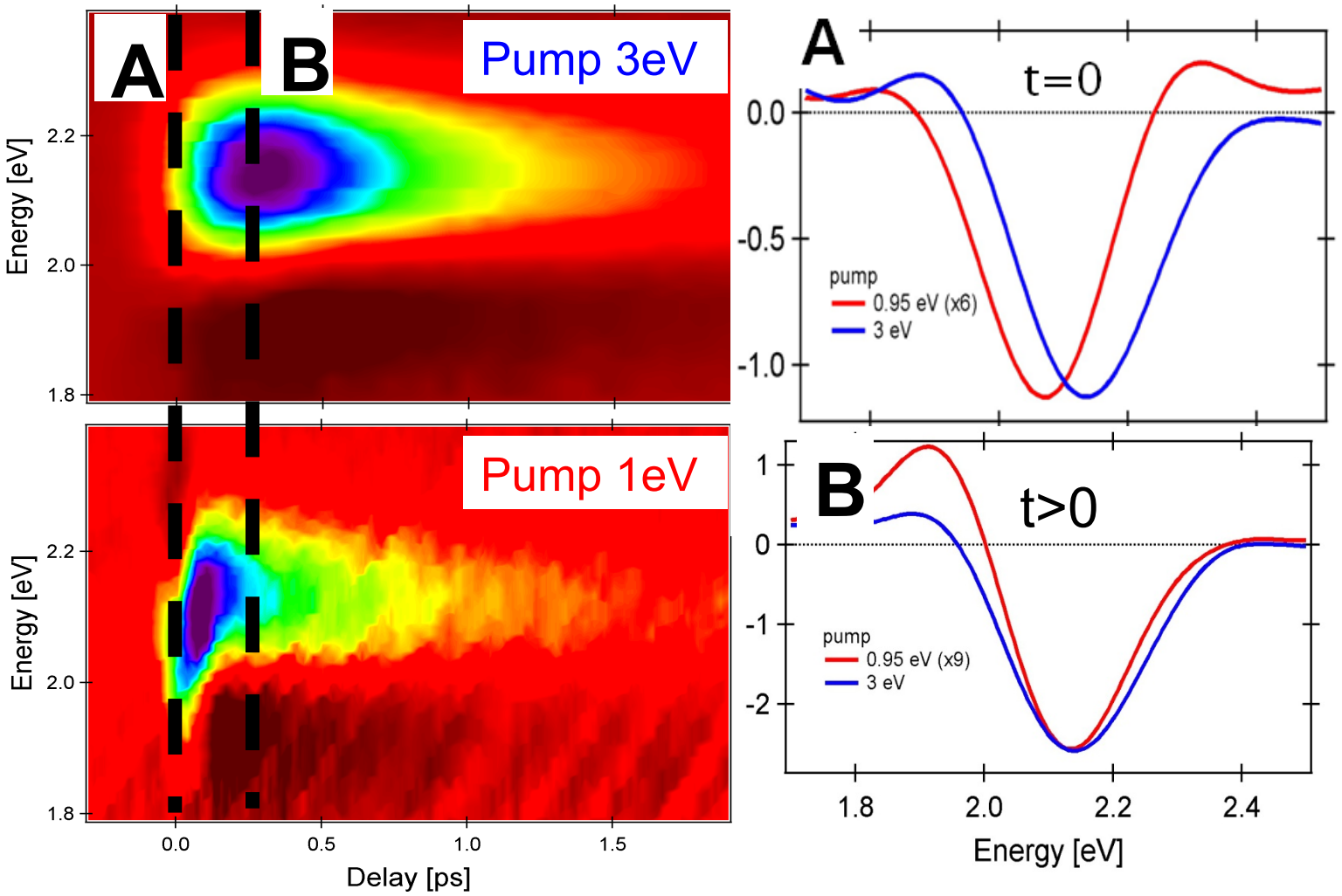

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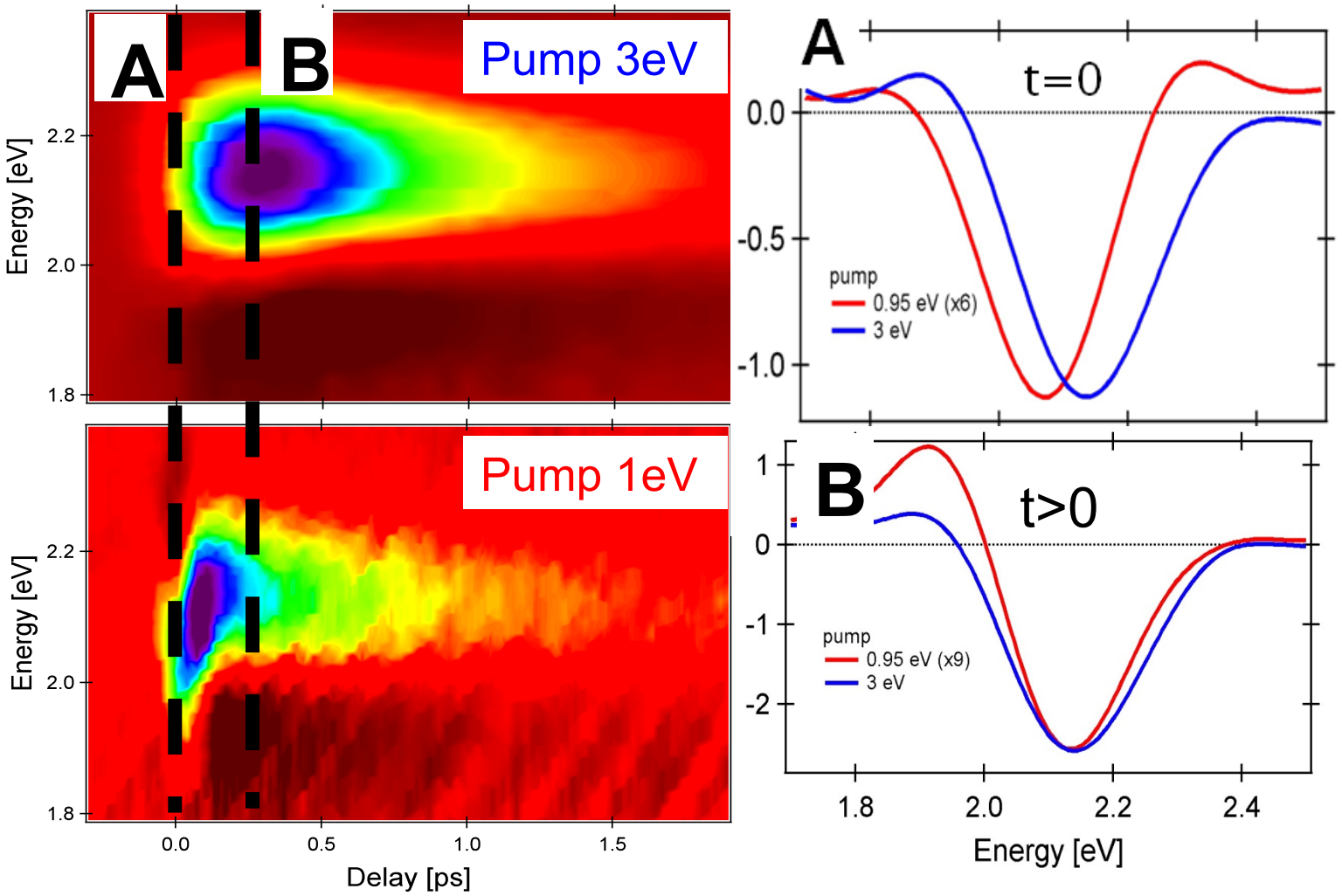

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Hubbard Holstein Hamiltonian

$$H = H_t + H_U + H_{EPI}$$

$$H_t = -t \sum_{i,\mu,\sigma} (\quad c^{\dagger}_{i+\mu,\sigma} c_{i,\sigma} + H.c.),$$ ← Hopping

$$H_U = U \sum_i (n_{i,\uparrow} - \frac{1}{2})(n_{i,\downarrow} - \frac{1}{2}),$$ ← e-e repulsion

$$H_{EPI} = \omega_0 \sum_i a_i^{\dagger} a_i + g\omega_0 \sum_i (a_i^{\dagger} + a_i)(1 - n_i).$$ ← Boson coupling

collaboration with N. Nagaosa, A. Mishchenko, G. De Filippis and V. Cataudella

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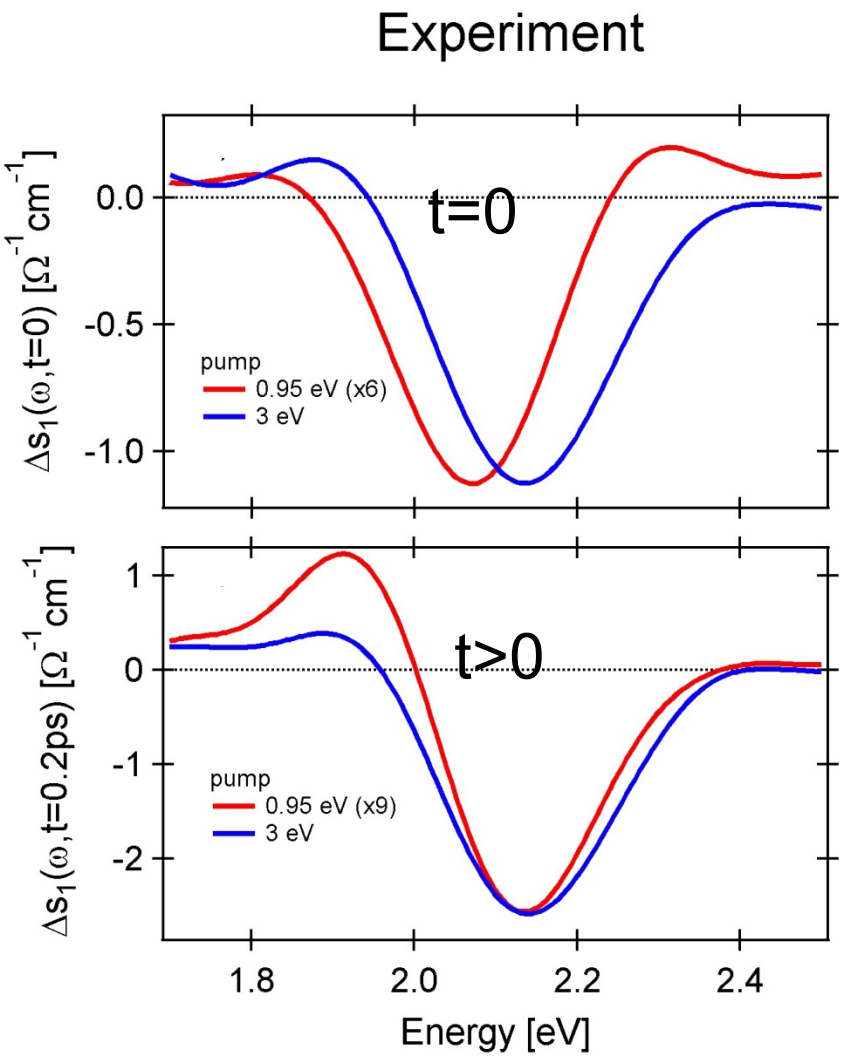
Experiment Vs. Theory



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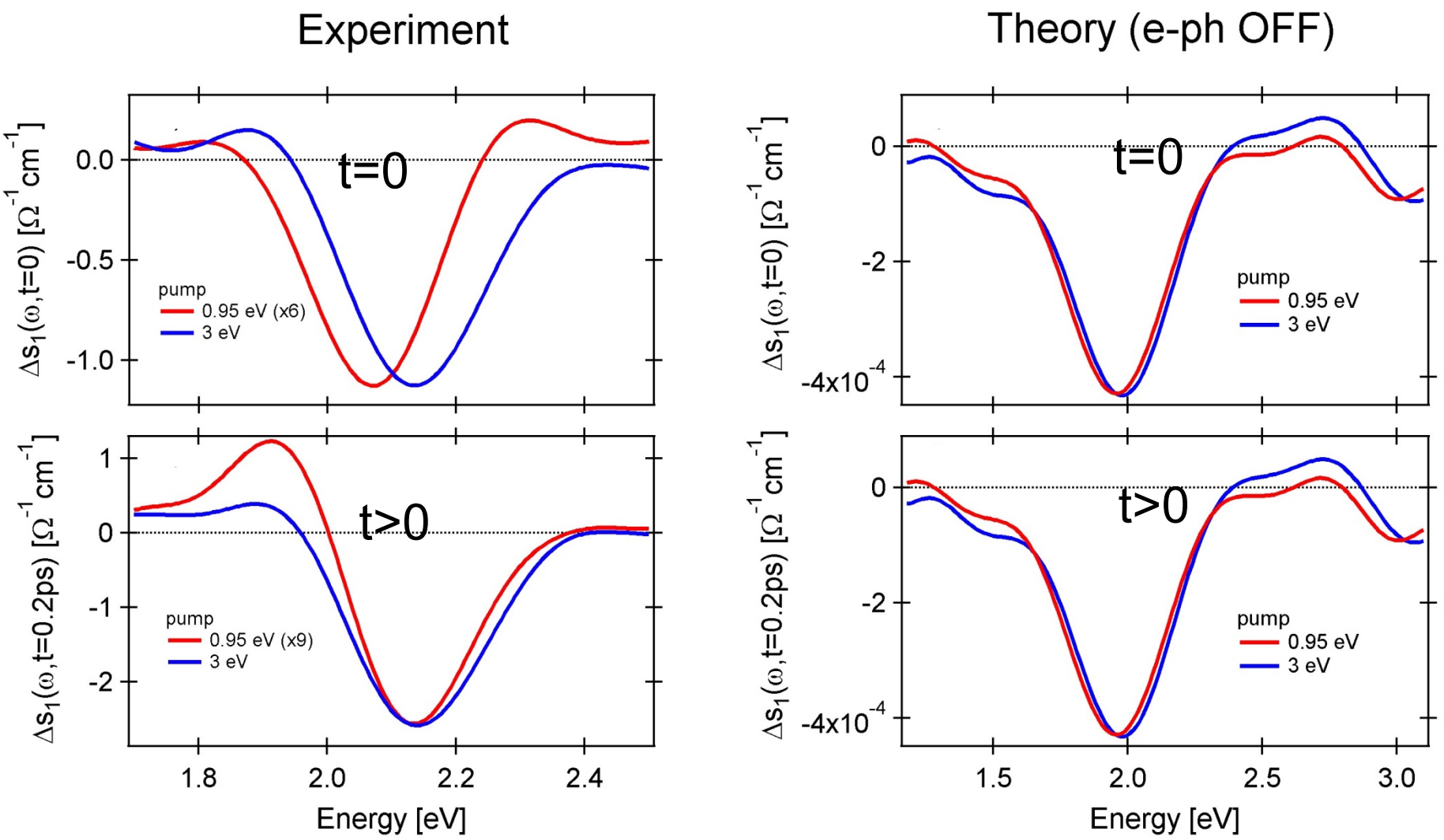

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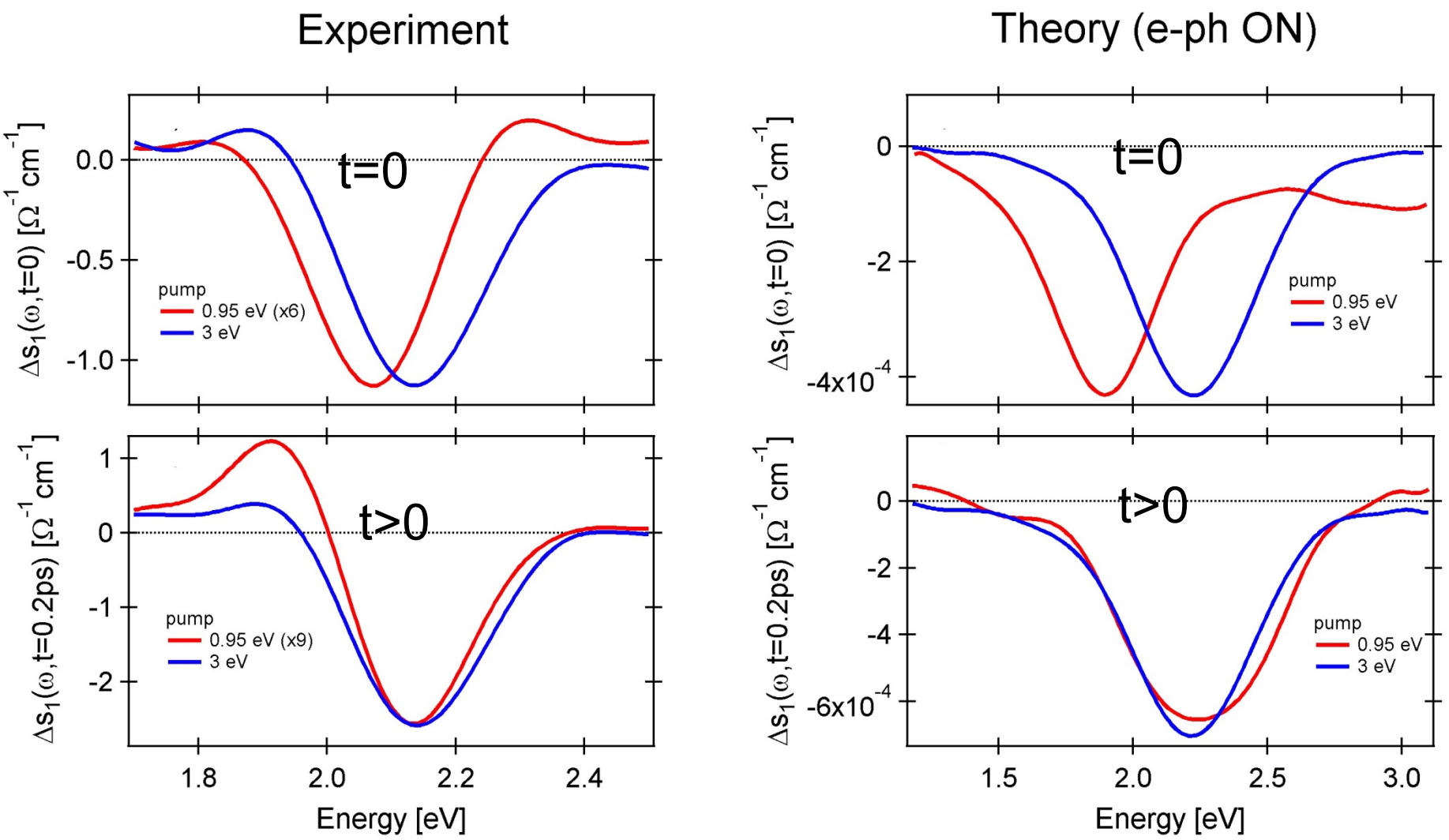
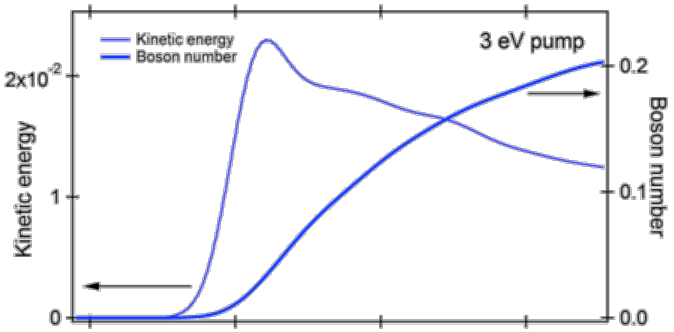
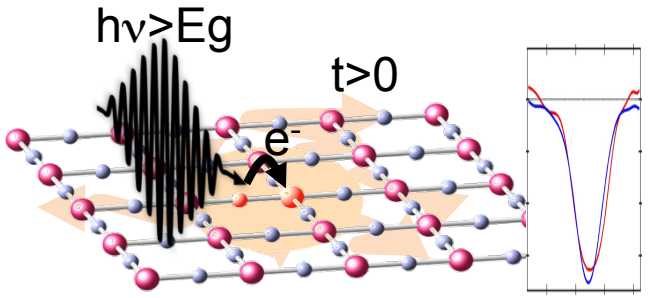


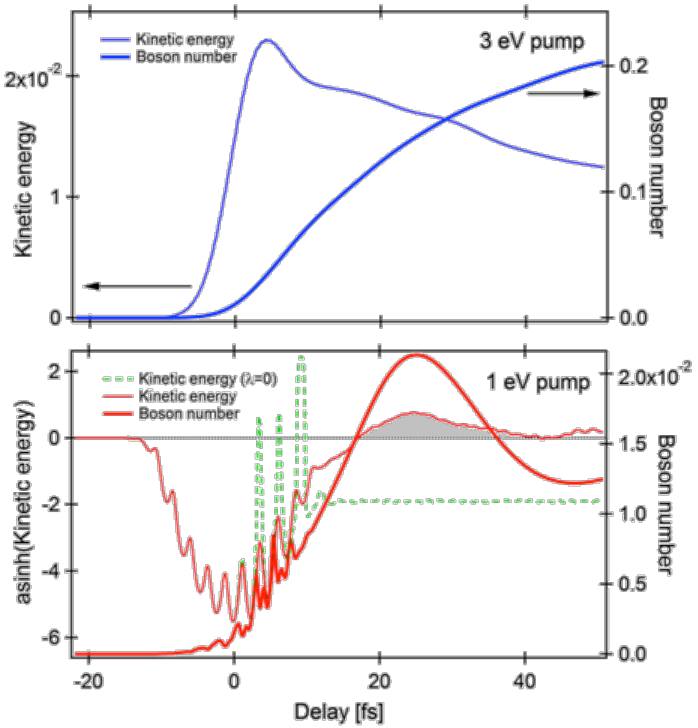
High Vs. Low-photon energy excitation

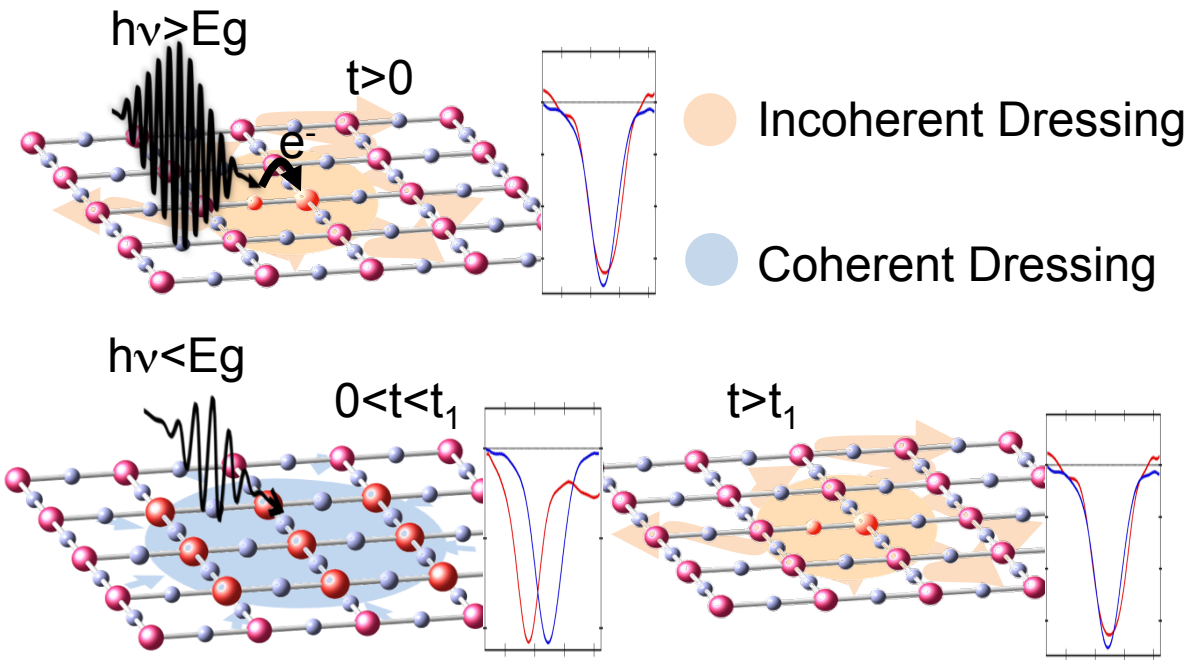




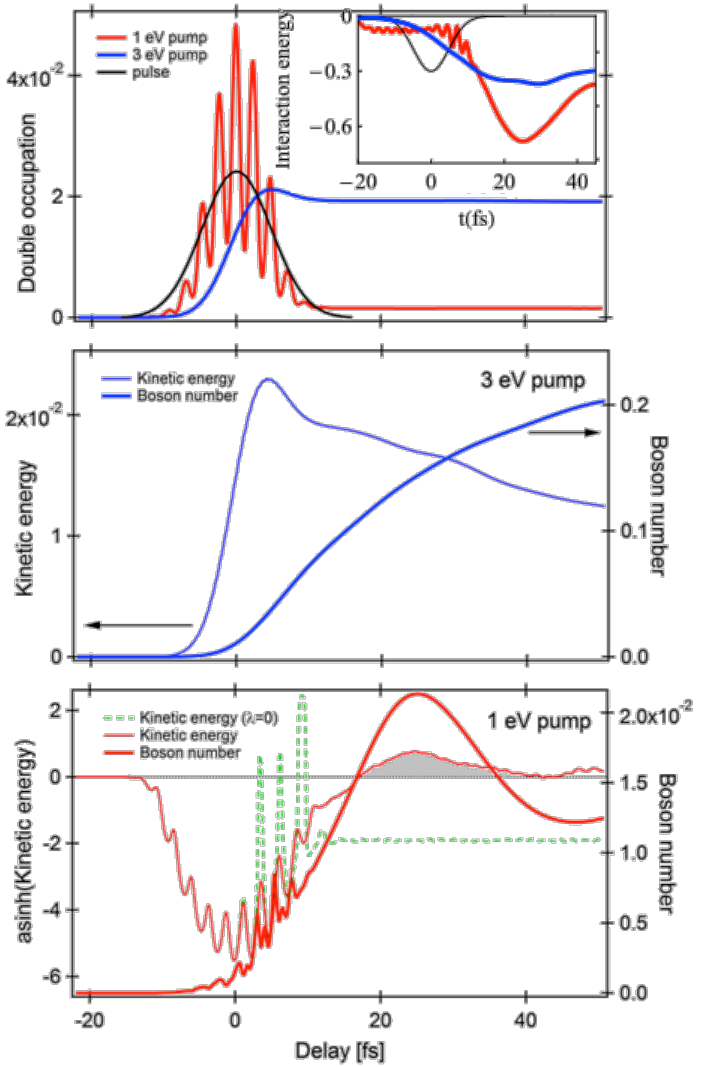
Incoherent Dressing

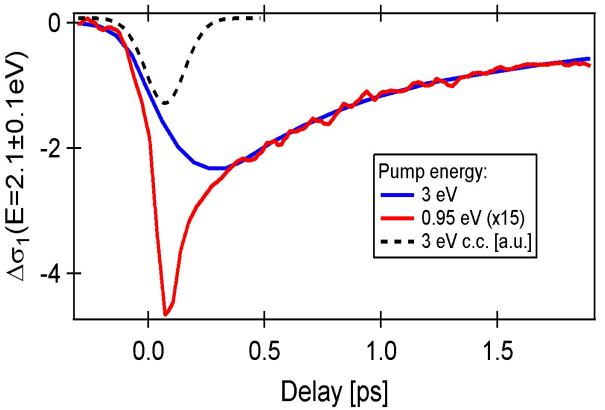
High Vs. Low-photon energy excitation

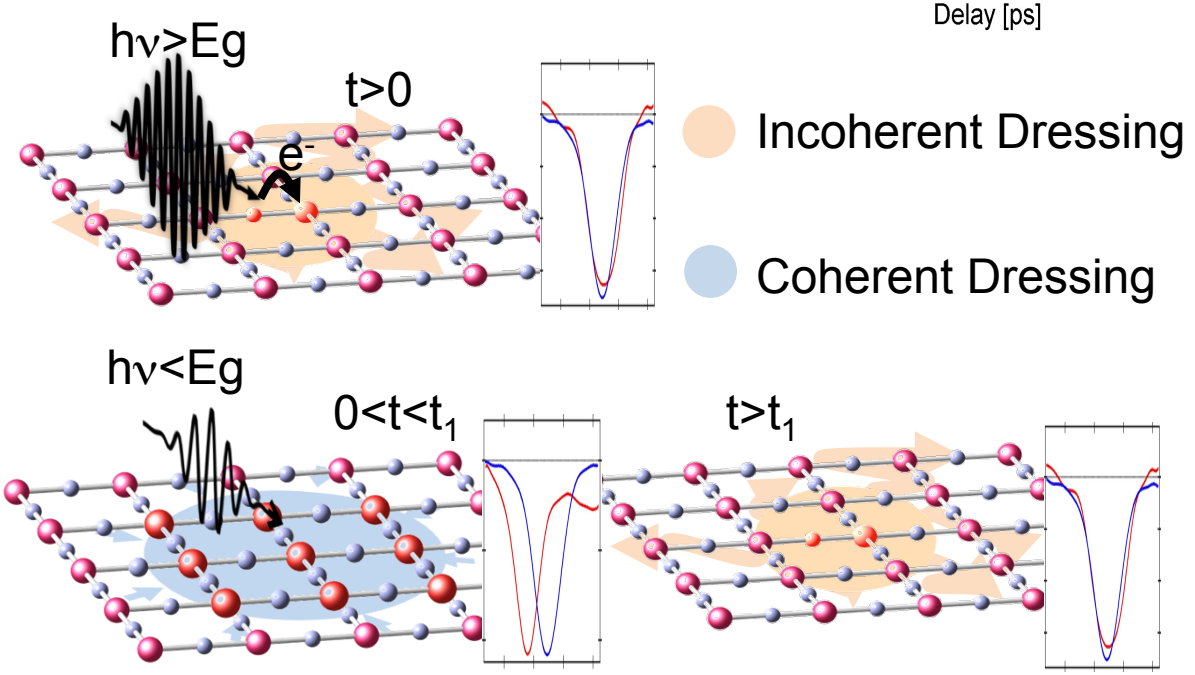




High Vs. Low-photon energy excitation







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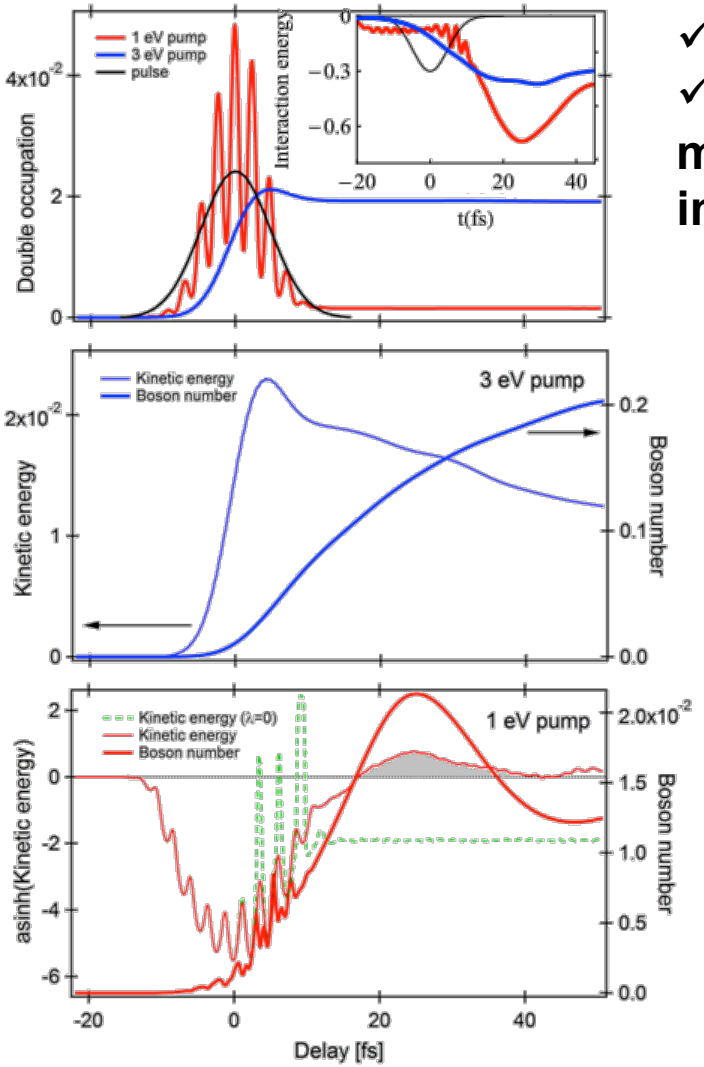
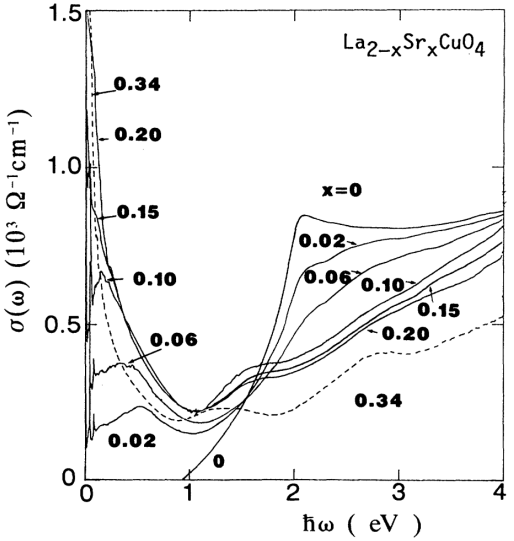
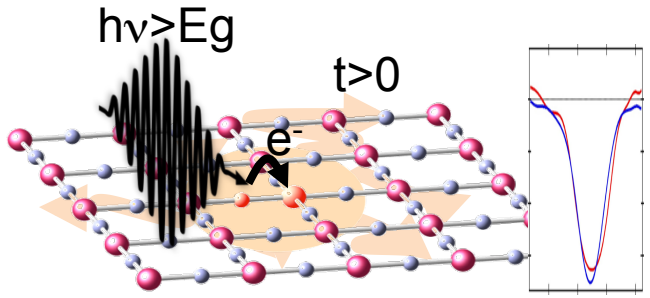


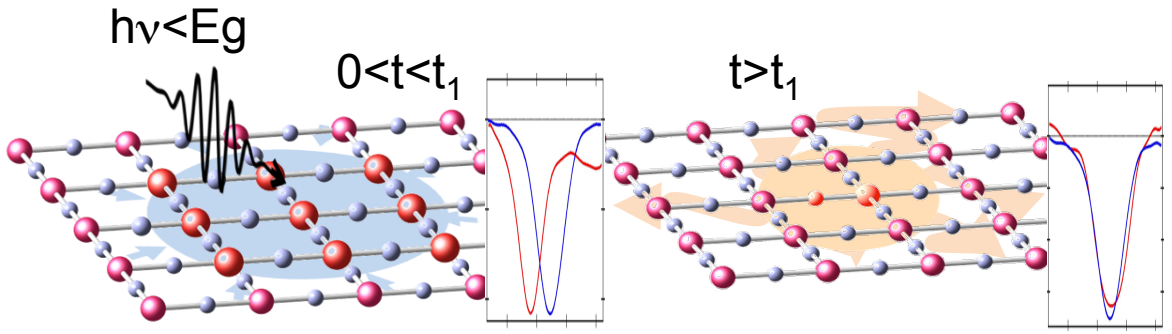
- ✓The boson is necessary
- ✓Will this excitation mechanism influence response in conducting systems?





Incoherent Dressing

Coherent Dressing



Nat. Comm. 5, 5112, 2014

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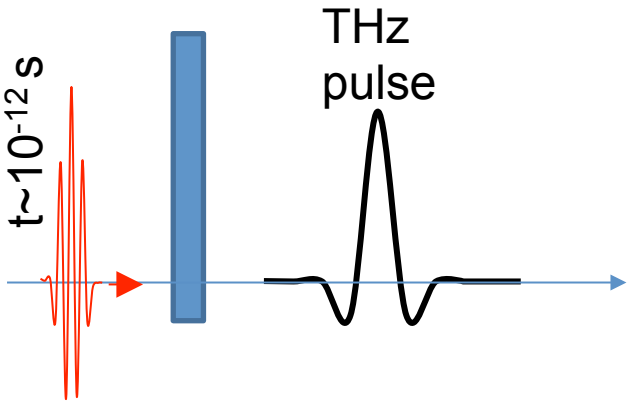
Generation and measurements of ultrashort THz pulse

Generation:
Optical Rectification



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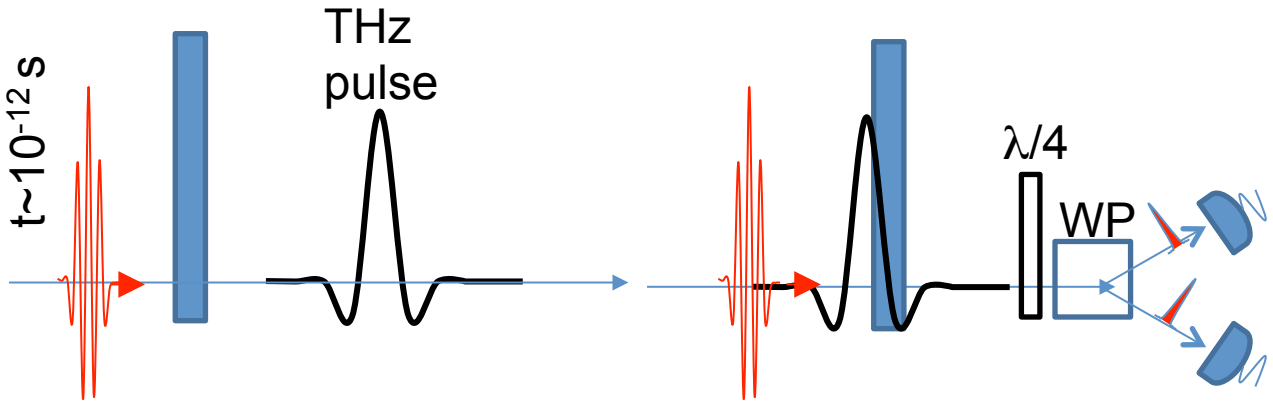
Electro optic sampling



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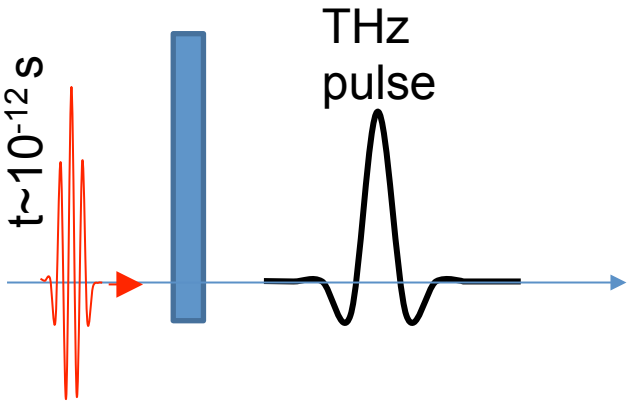

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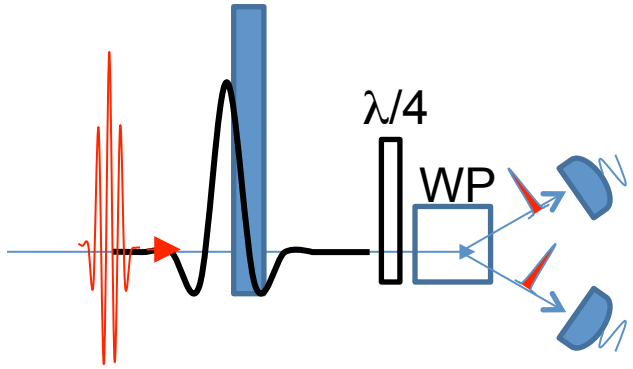

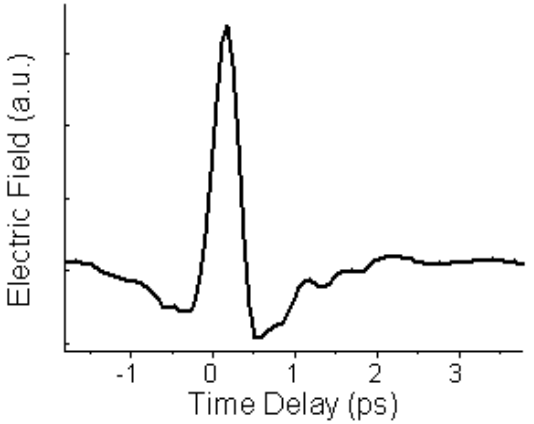

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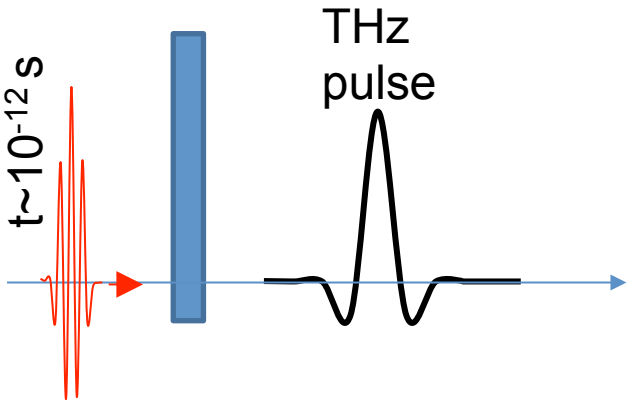

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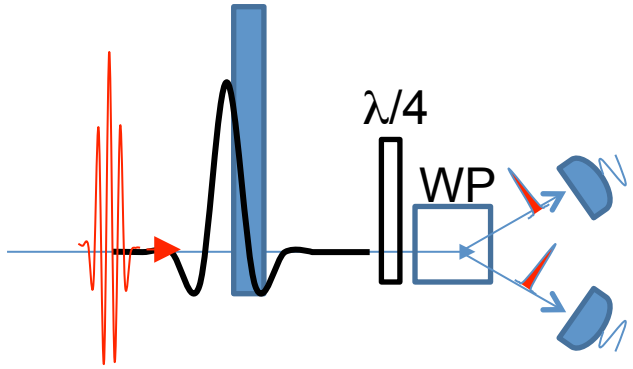
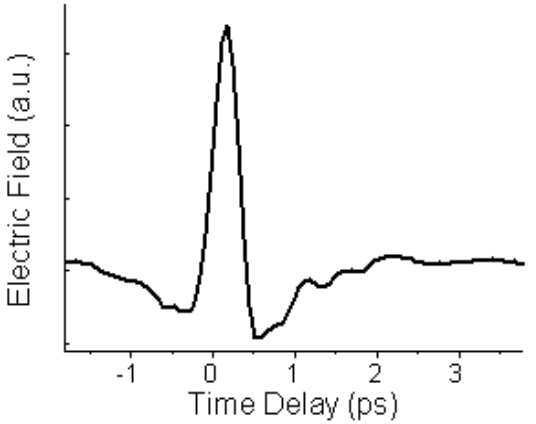
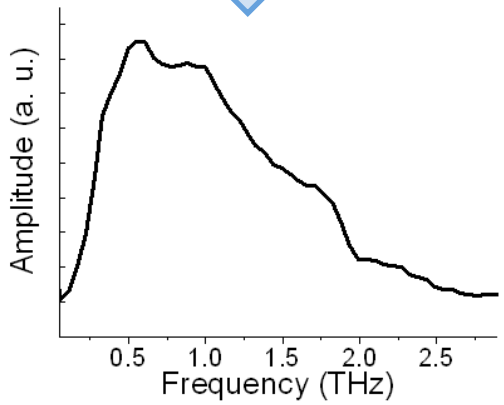




FT



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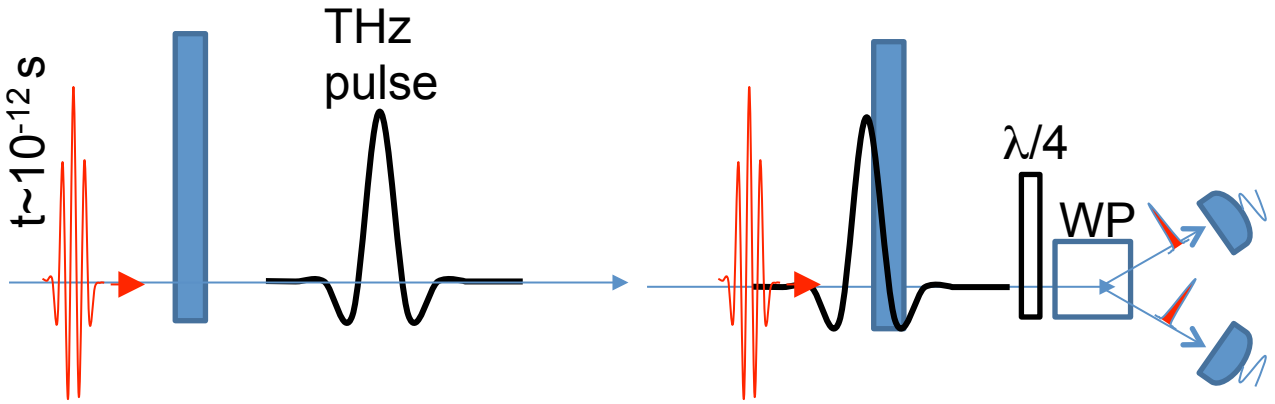

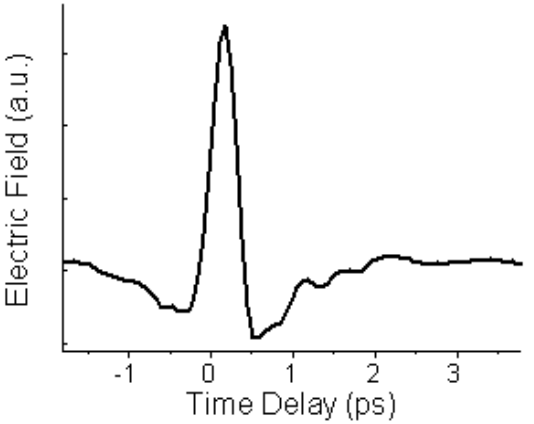

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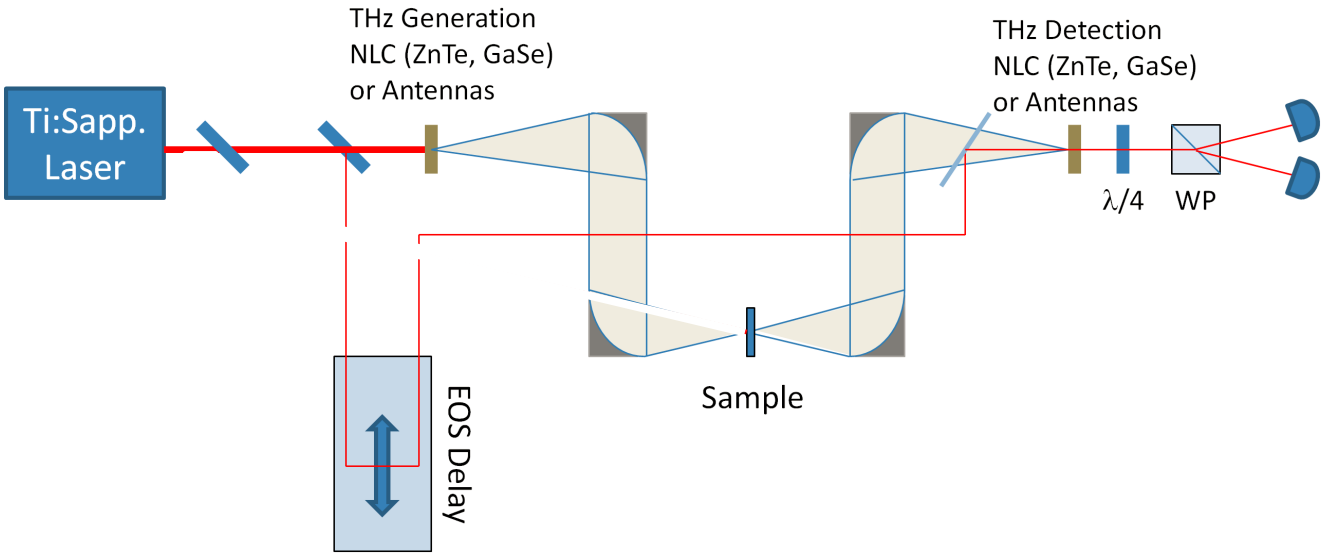

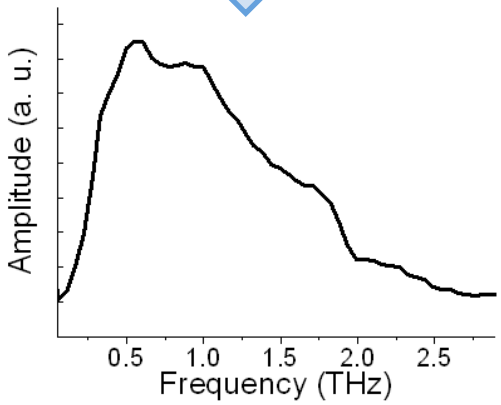

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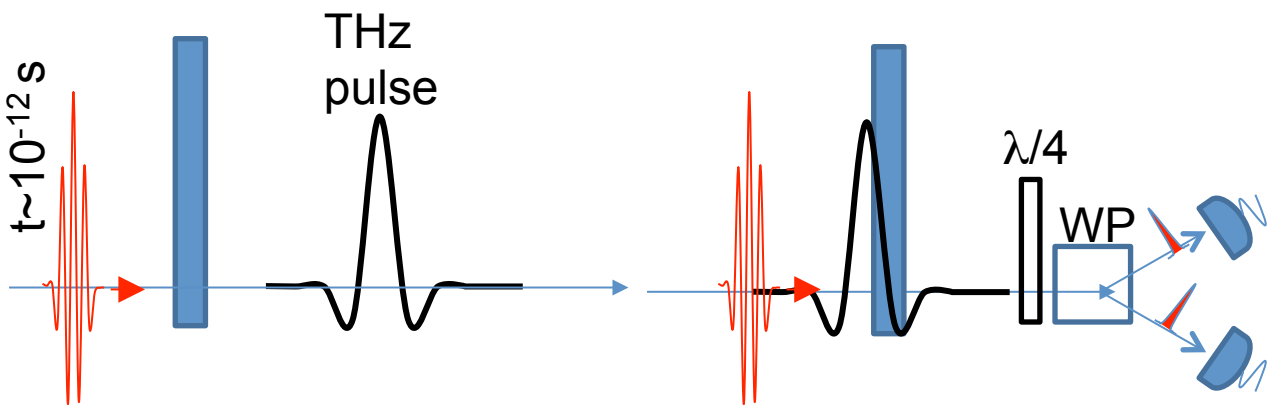

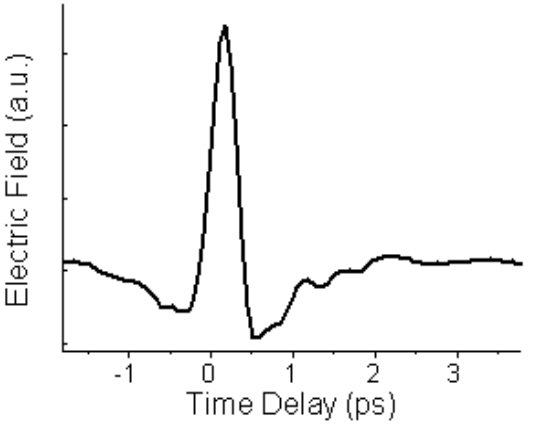

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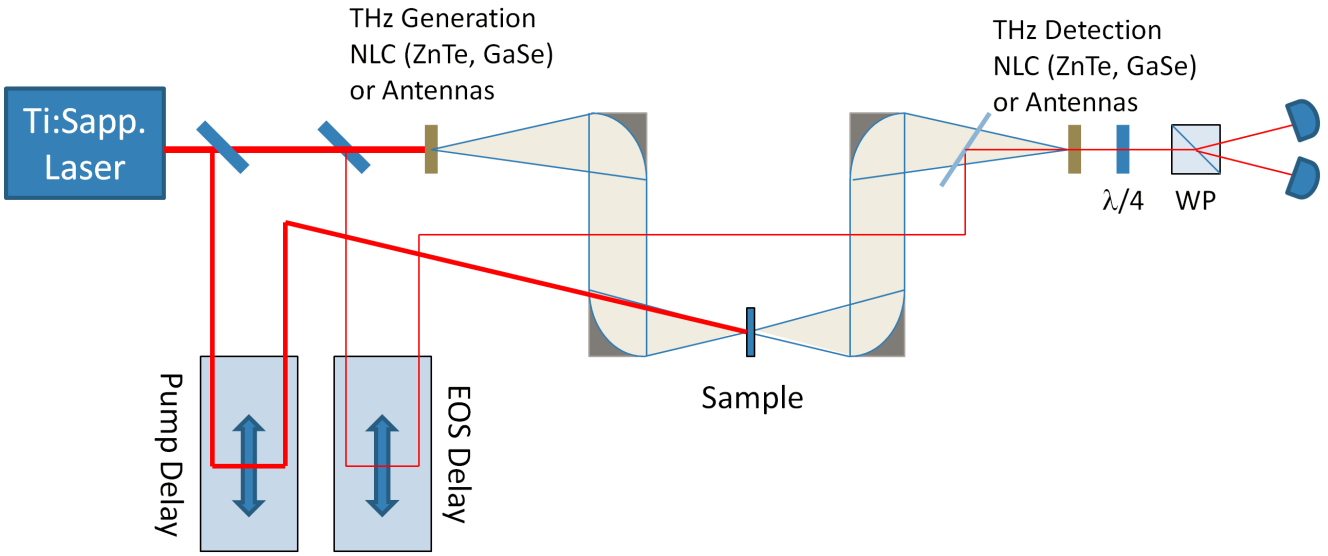
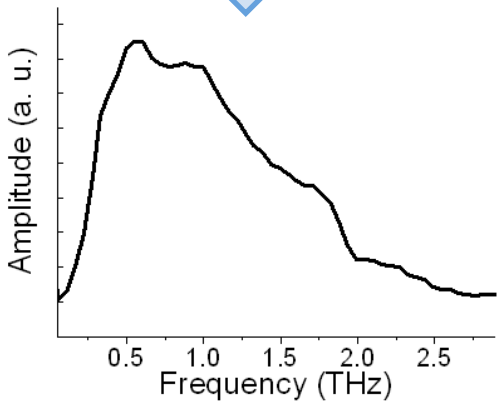
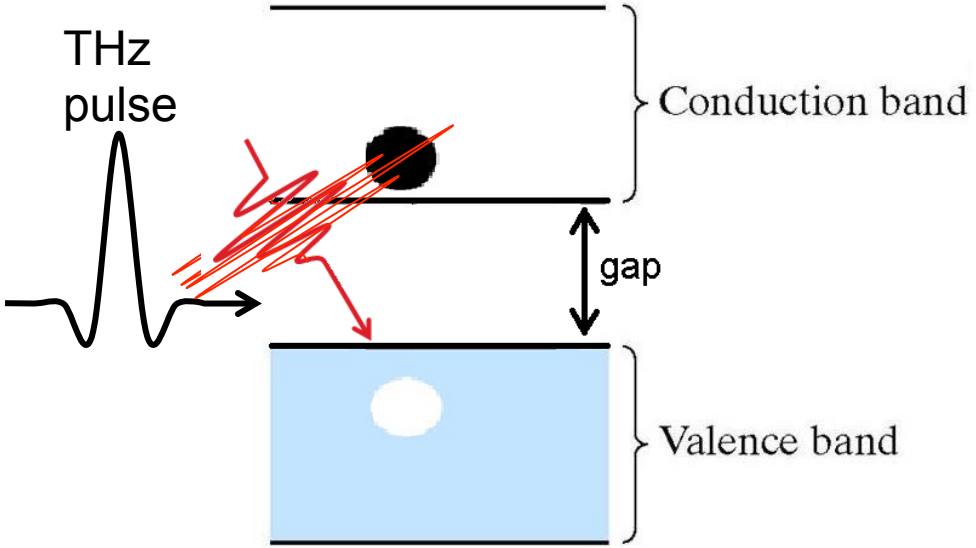
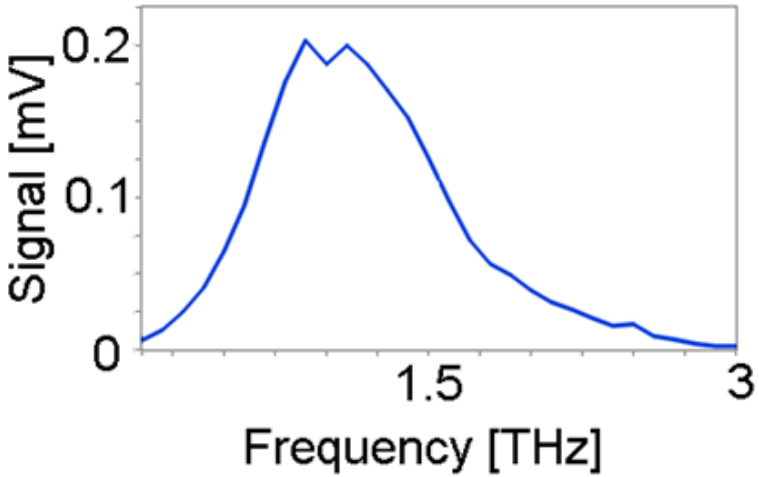




Test examples: Transmission on silicon



Equilibrium Transmission



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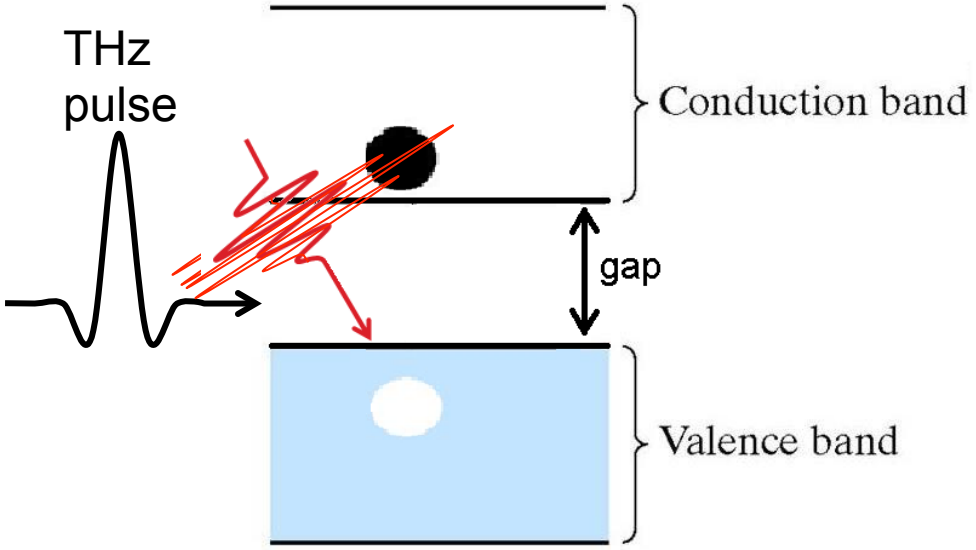

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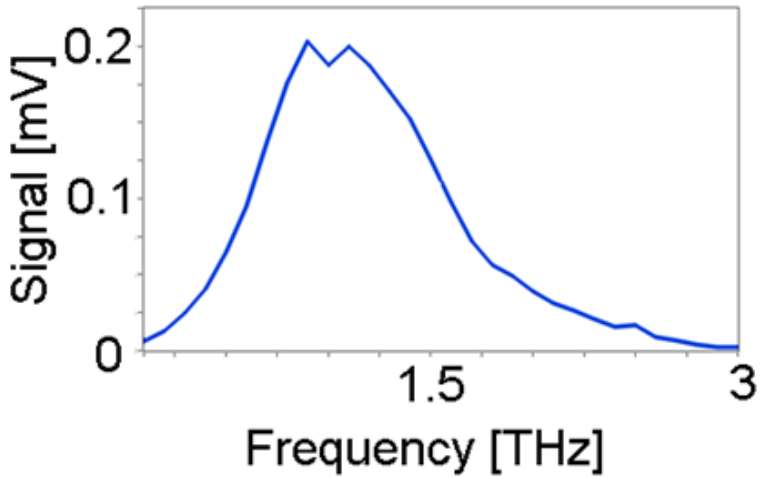
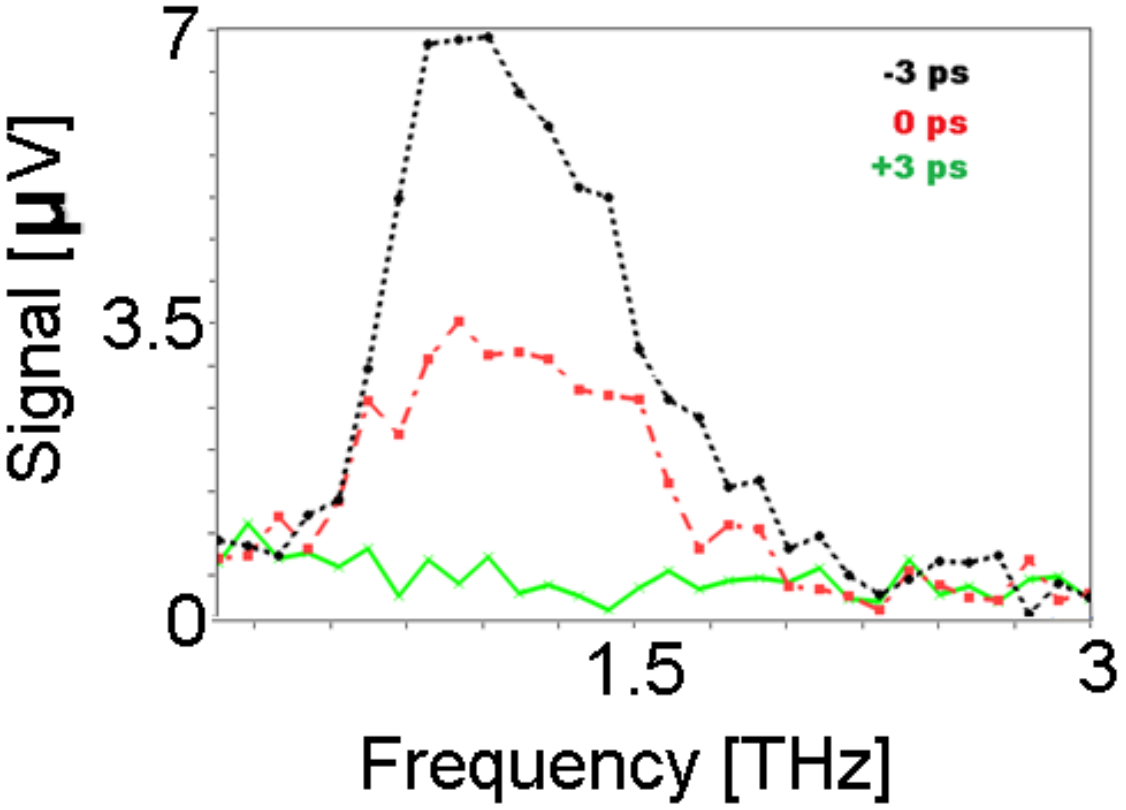


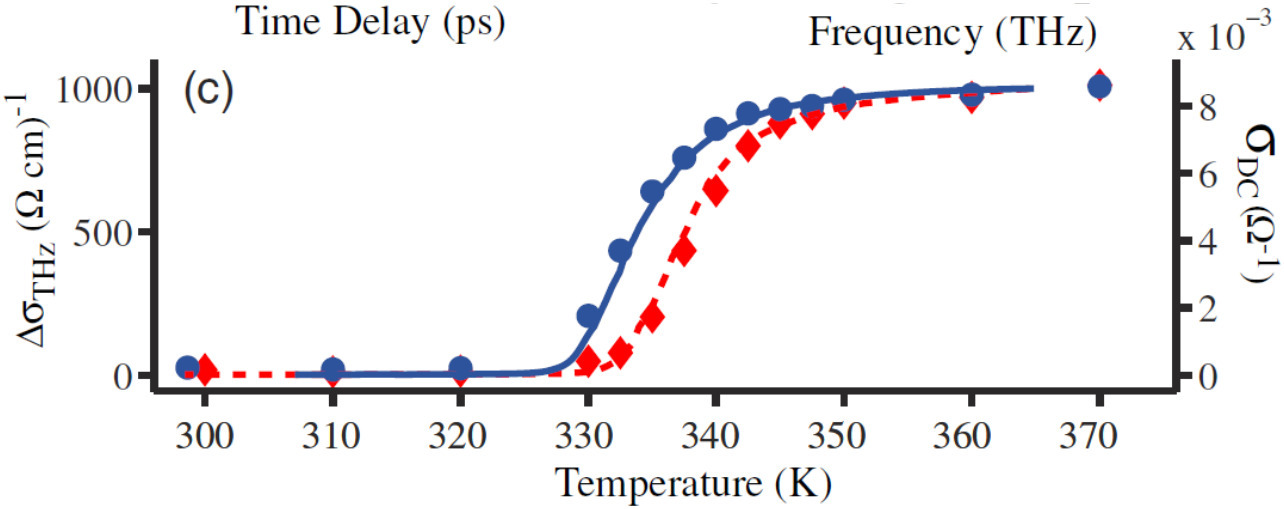
Time domain changes in Transmission



Fabio Novelli Phd Thesis

Metal-insulator transition in VO_2 single crystal

- ✓ Static changes in THz trasmittivity
- ✓ Temperature dependence of DC conductivity



PRL, 226401 (2007)

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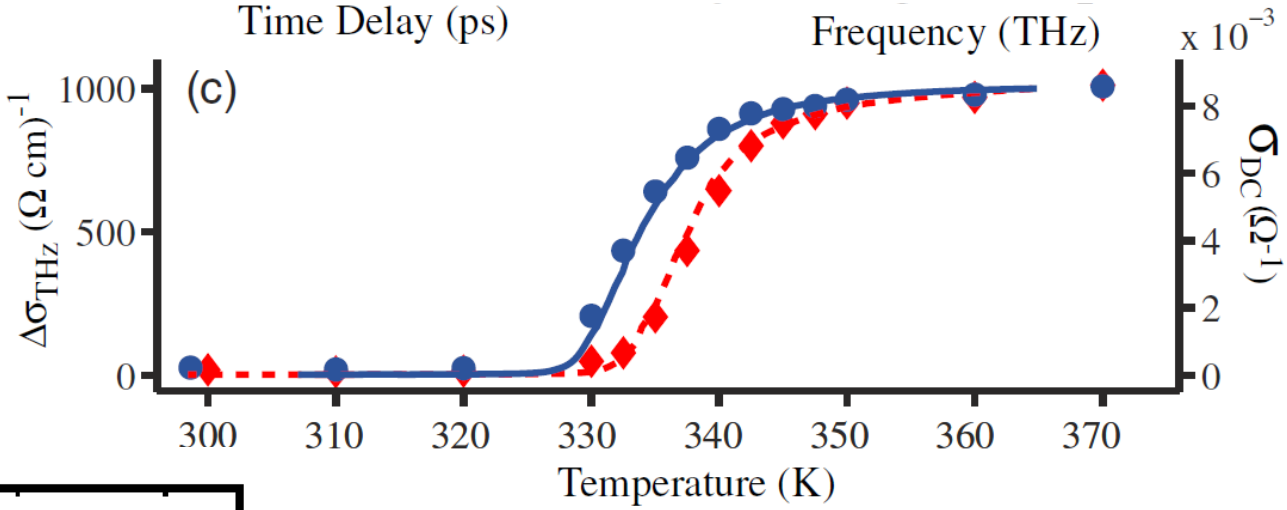
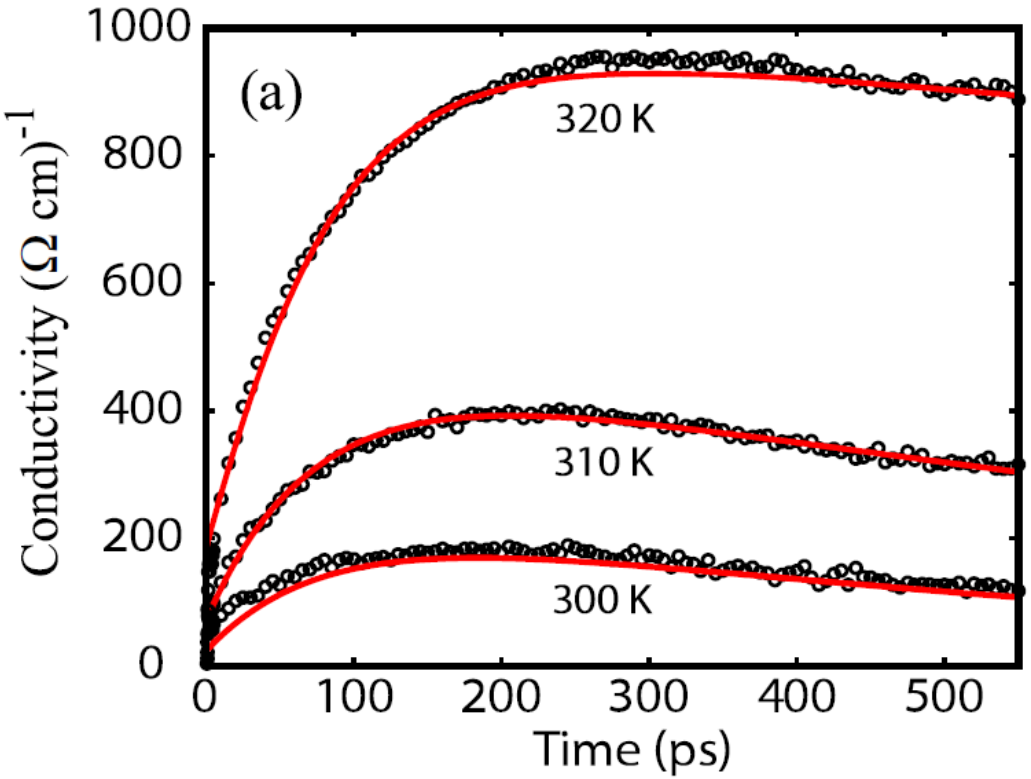




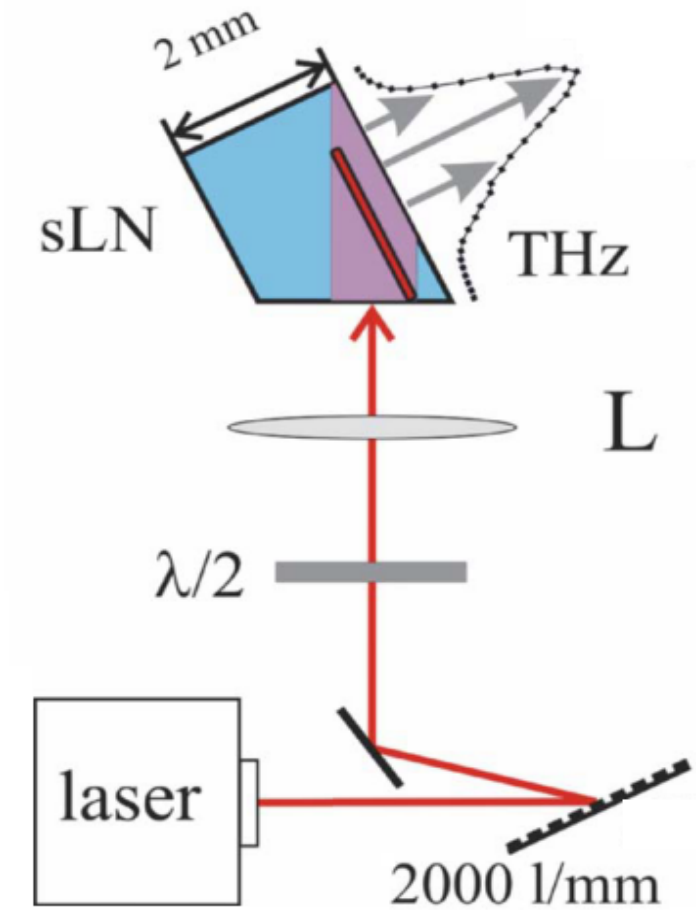
- ✓ Light driven formation of a metallic phase
- ✓ Detail studies of the nucleation processes

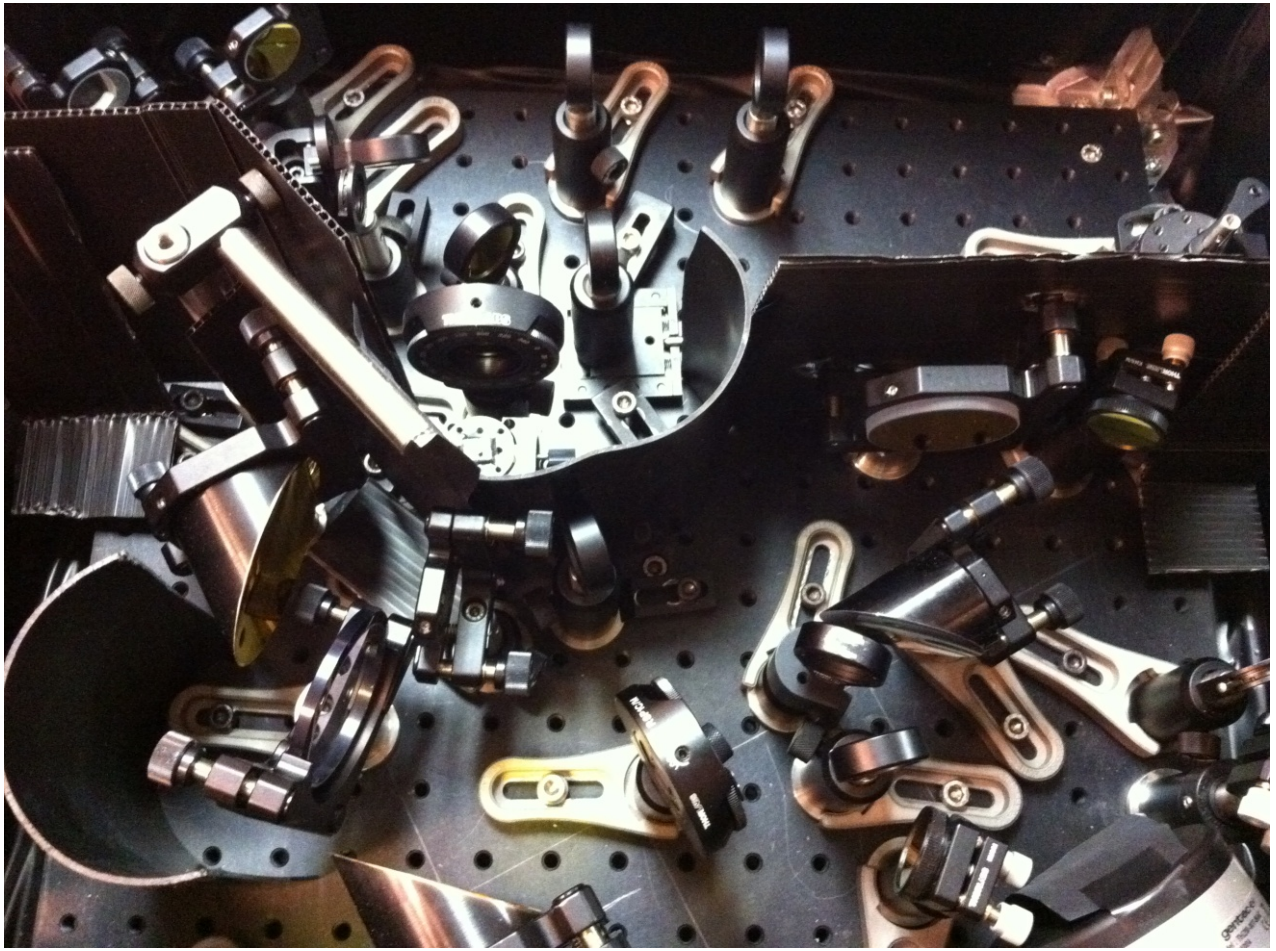
PRL, 226401 (2007)

Can we use THz pulses as pump?

Using THz as a pump

The table-top intense THz Source





Zs.Bor and B.Racz,*Opt.Comm.* **54**,165(1985)
J.Hebling et al.,*J.Opt.Soc.Am.B* **25**,B6(2008)

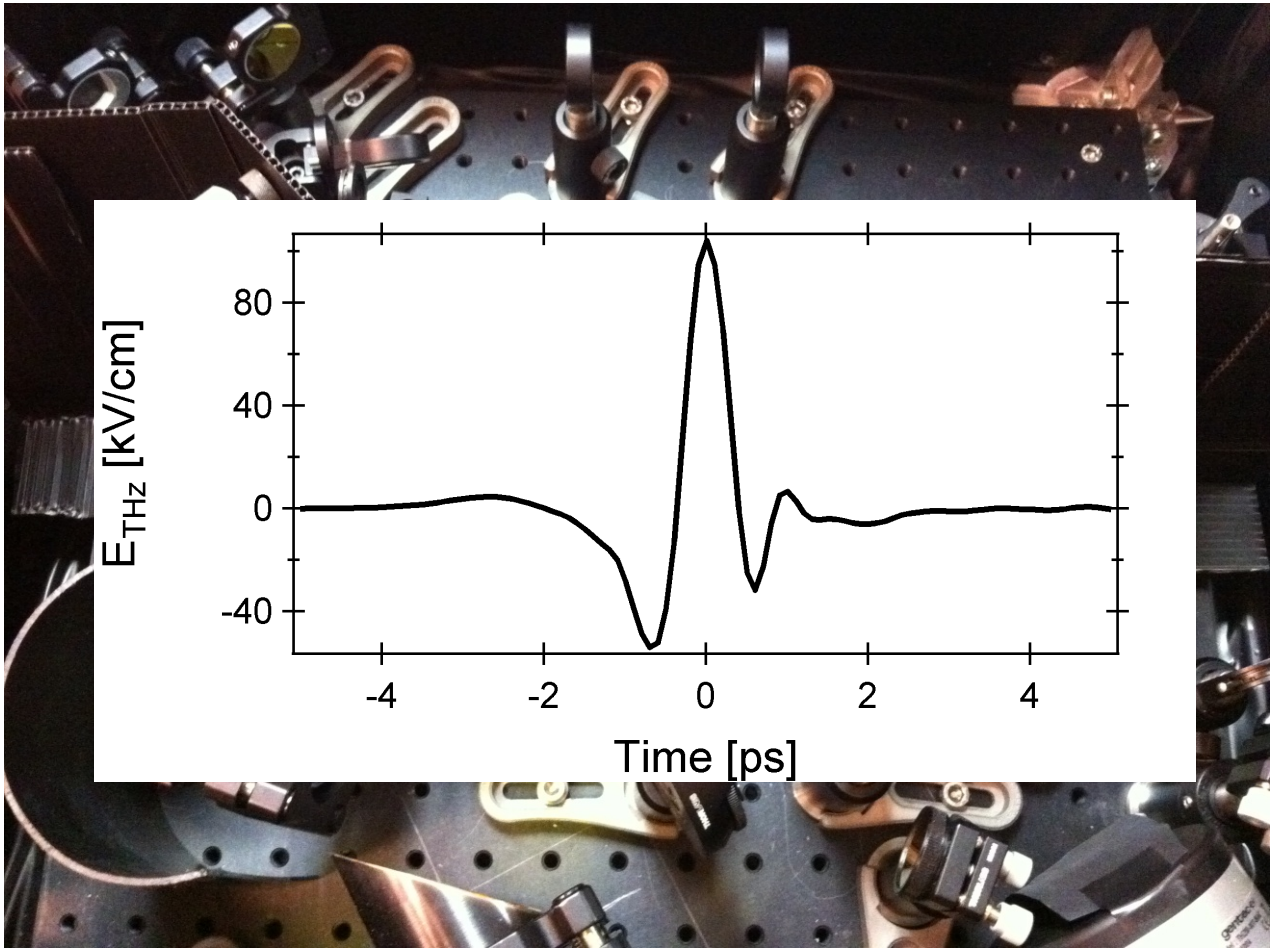
The table-top THz Source

$\eta \geq 10^{-4}$

$\geq$ 100 nJ/pulse

$\geq$ 10 $\mu J/cm^2$ fluence

$E_{THz} \approx$ 100 kV/cm



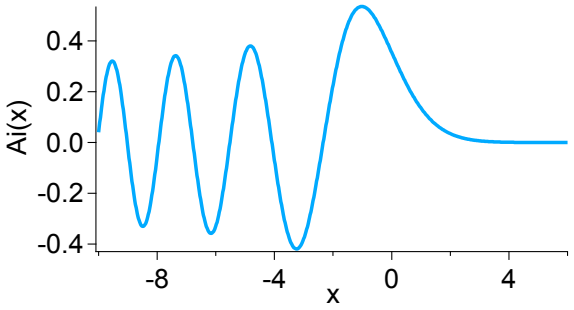
The Franz-Keldysh effect

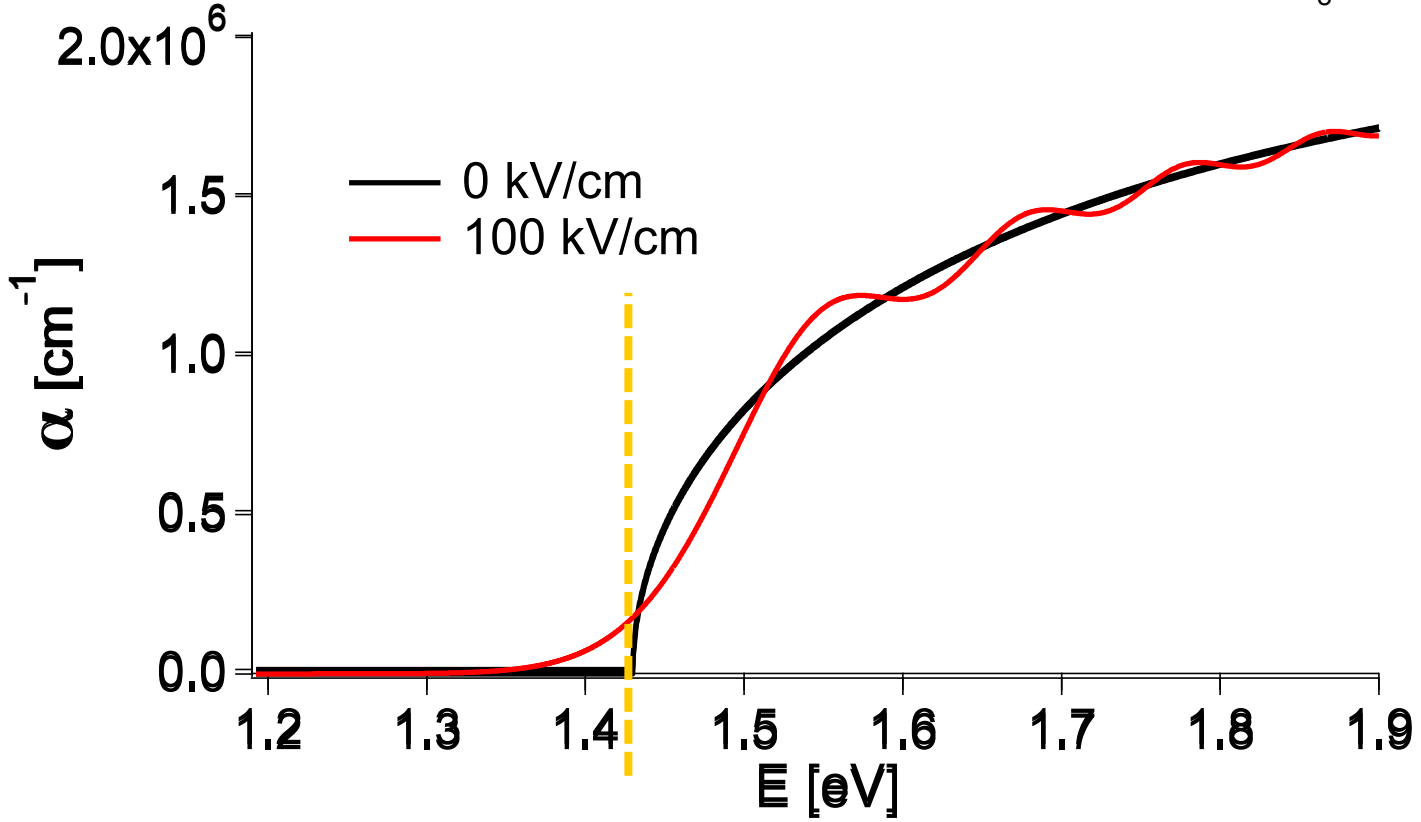
✓Renormalization of the semiconductor gap with the application of a static field.

$$\left(-\frac{\hbar^2}{2\mu}\nabla_r^2 - e\mathrm{E}z\right)\varphi(r) = E_r\varphi(r)$$

$$\varphi_z(\xi) \propto Ai(\xi)$$

$$\xi = \left(\frac{2\mu}{\hbar^2}|e|\mathrm{E}\right)^{1/3}\left(z + \frac{E_z}{e\mathrm{E}}\right)$$

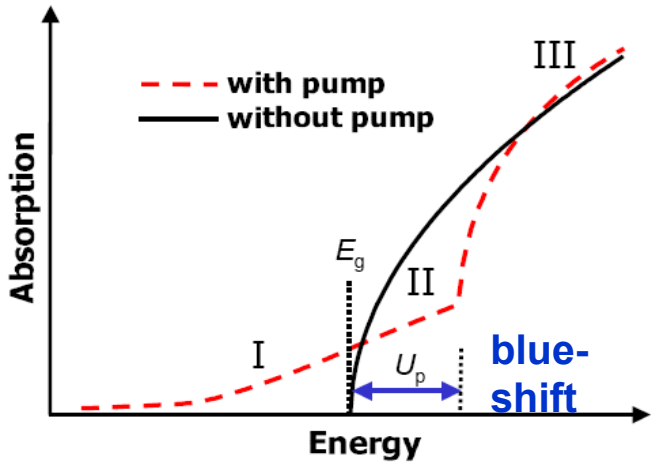




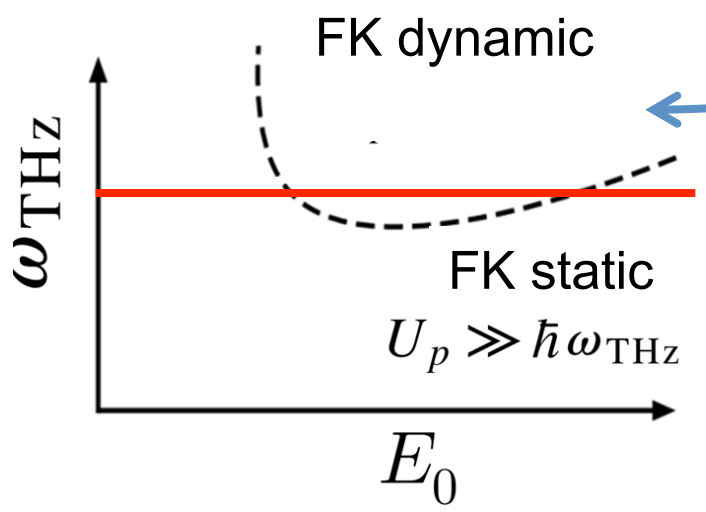
T-ReX Research Group

Elettra Sincrotrone Trieste

Static Vs. Dynamic Franz-Keldysh effect



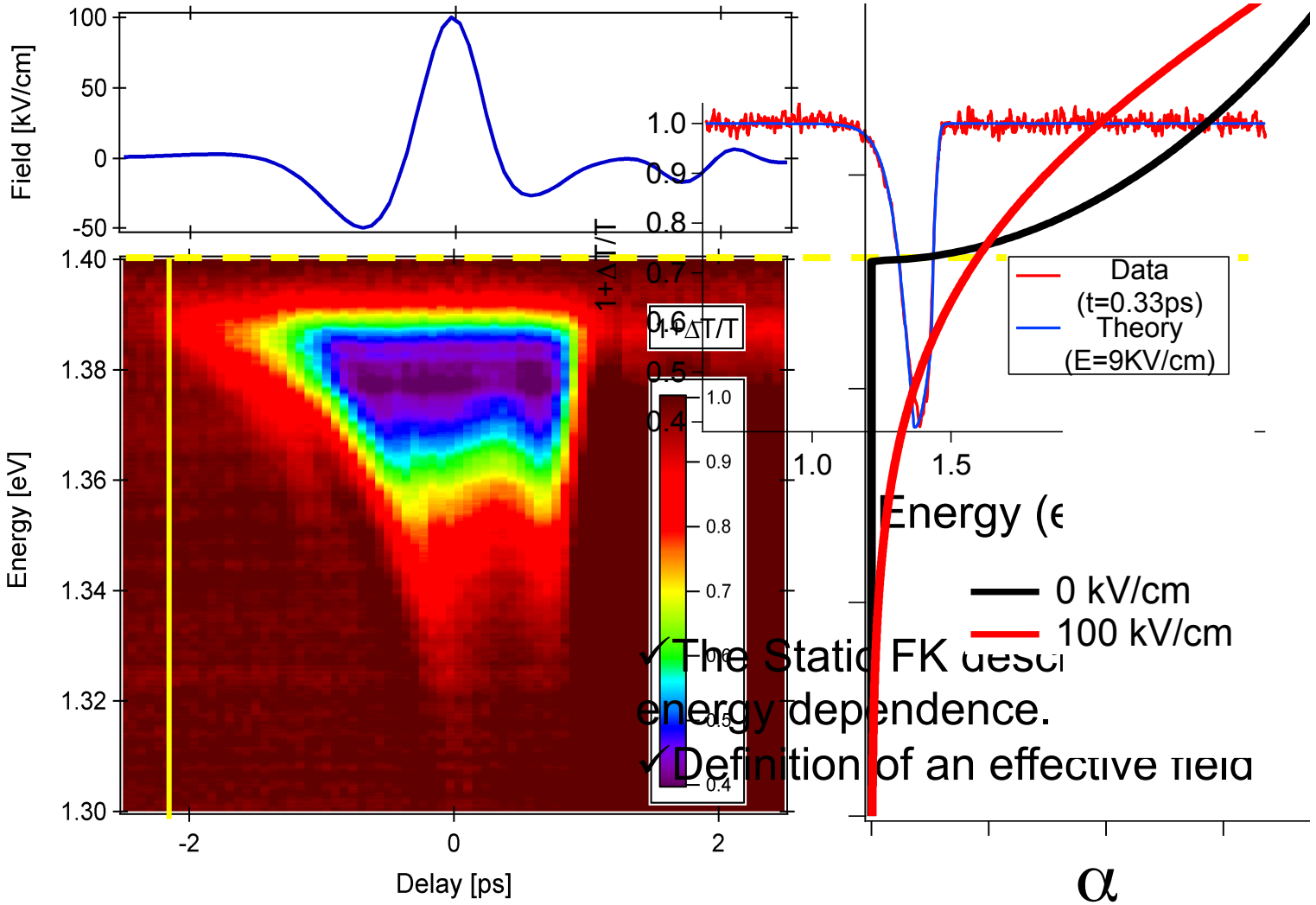
$$U_P = \frac{e^2 \mathrm{E}_0^2}{4m\omega_{THz}^{\ 2}} = \omega_{THz}\gamma$$



$$\propto \int |I(t)|^2 dt$$

$$\propto \mathrm{E}(\mathrm{t})$$

The Franz-Keldysh effect



✓The Static FK desc
energy dependence.
✓Definition of an effective field

Nat: Sci. Rep. **3**, 1227 (2013)

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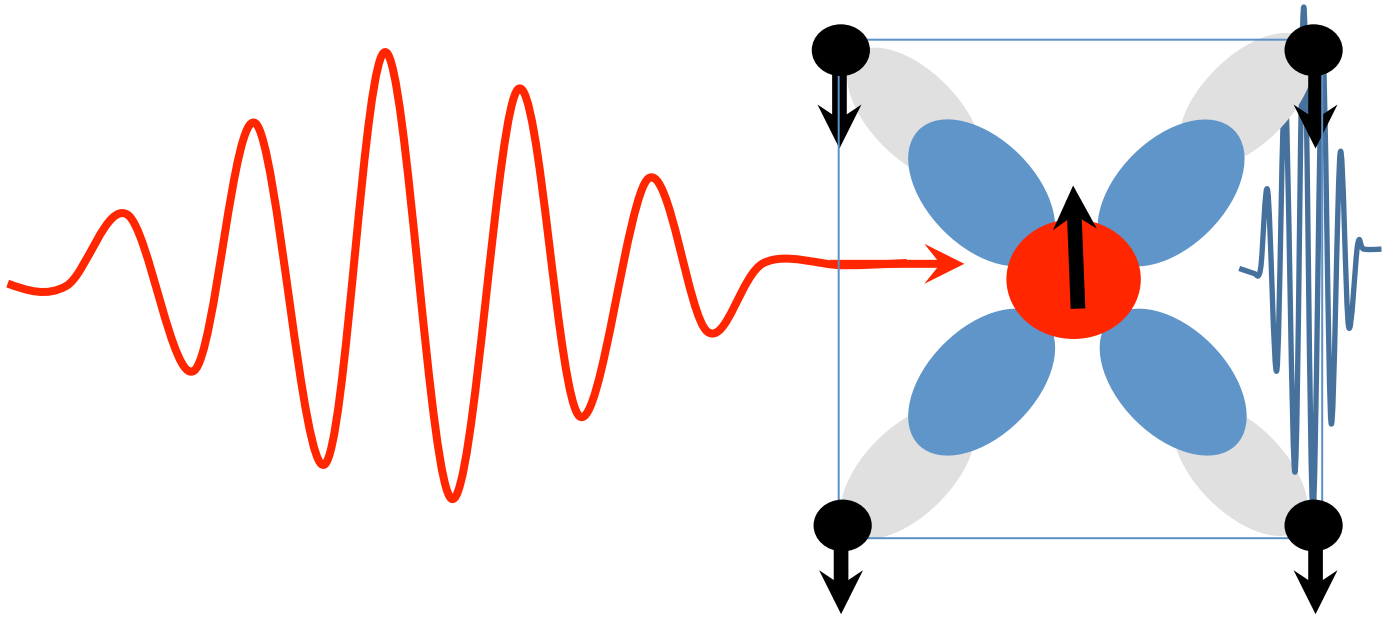
Can we resonantly excite phonon modes?



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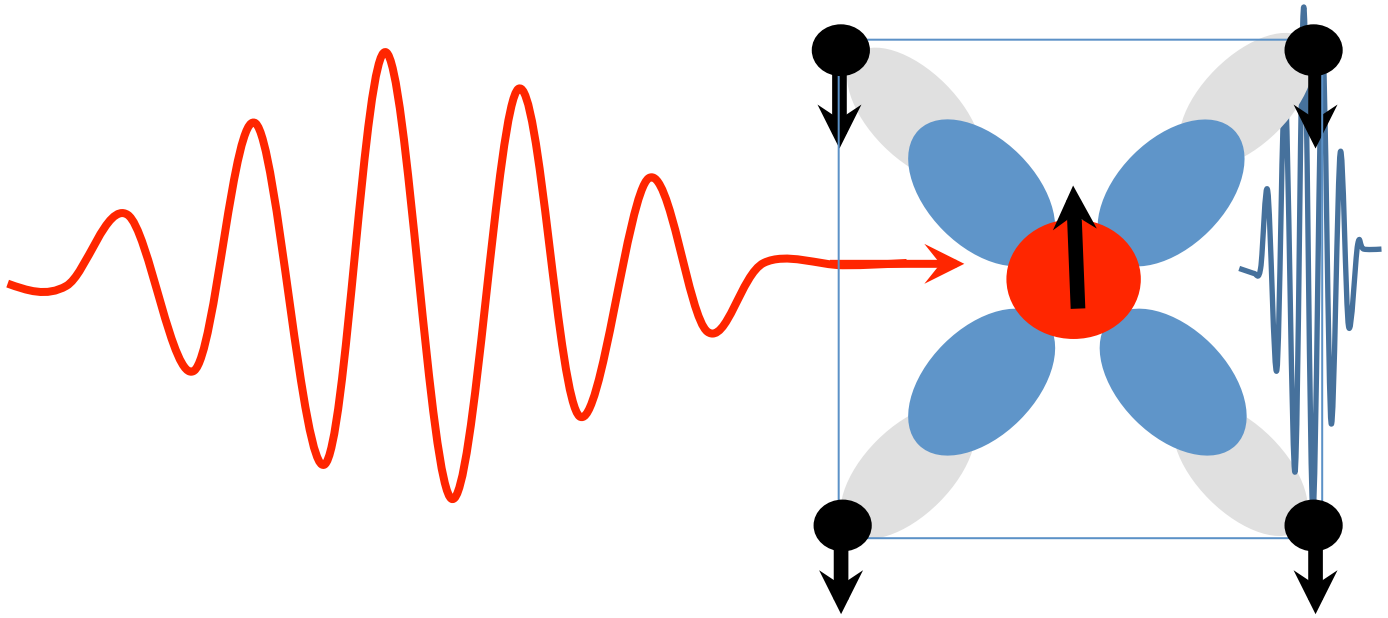
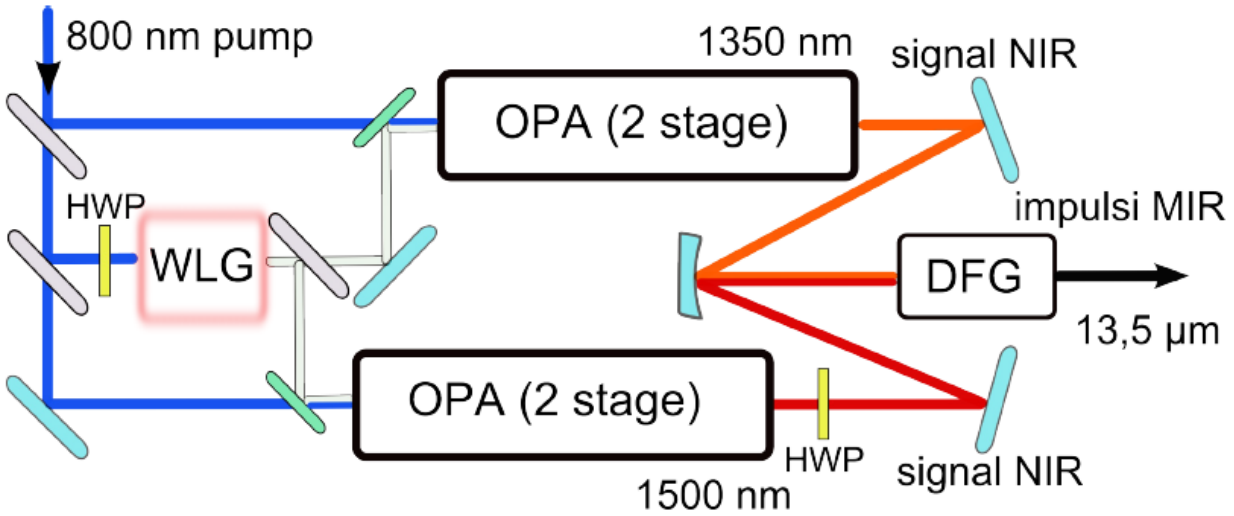


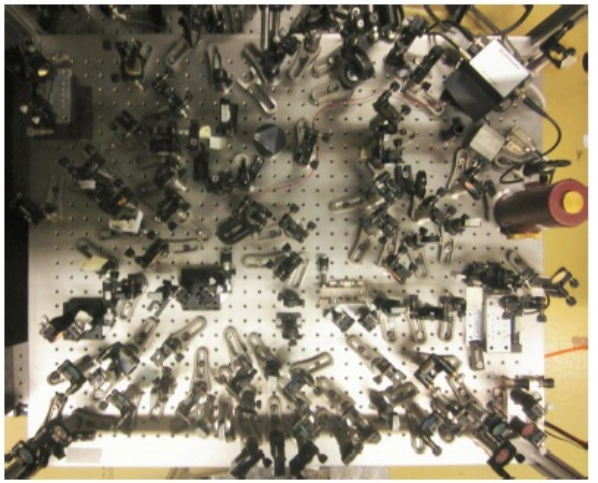
- ✓ Revealing the non-adiabatic resonse of electron
- ✓ Amplitude and phase resolution
- ✓ **Optical control of material properties**

Science 331, 189 (2011)*; Nature Material 12, 882 (2013)
Nat. Photonics 5,485 (2011), Nat. Materials 12, 535 (2013)

Can we resonantly excite phonon modes?

A cascade of non-linear processes to generate carrier envelope phase stable mid-IR pulses?





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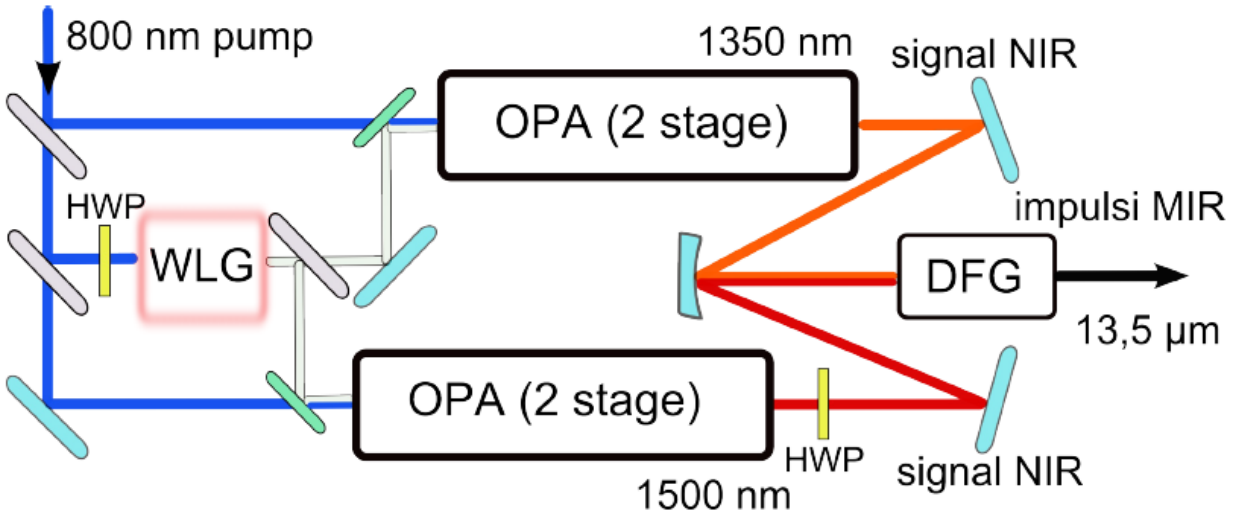
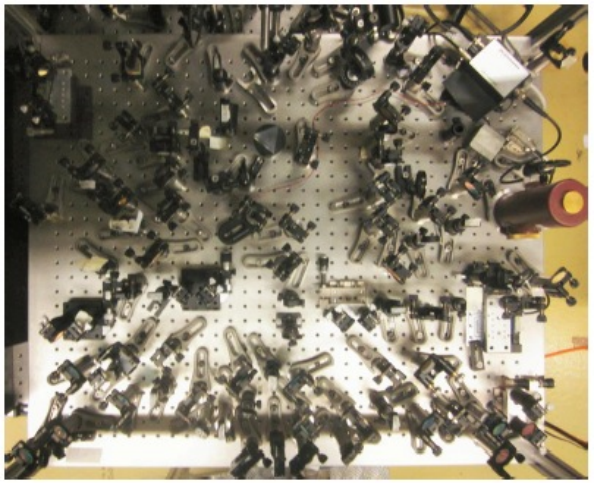
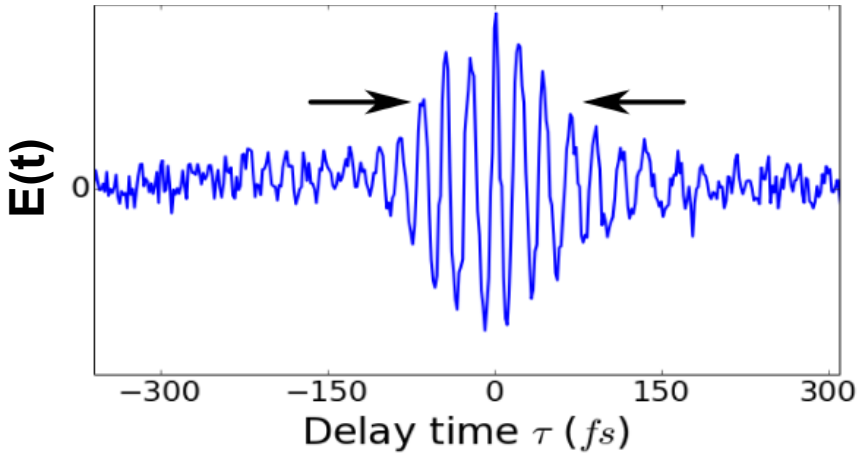
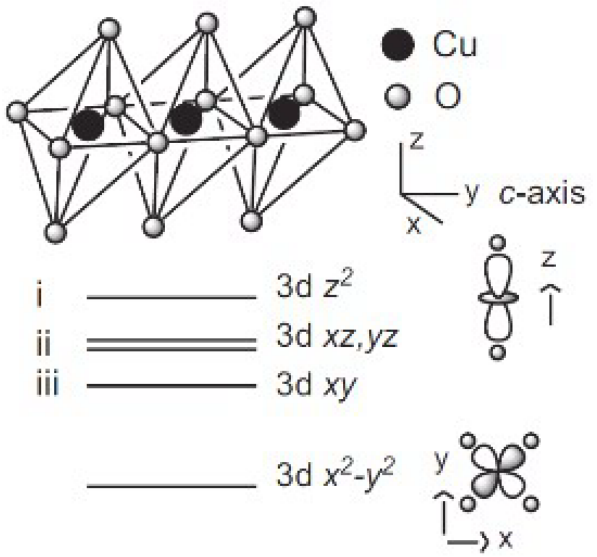


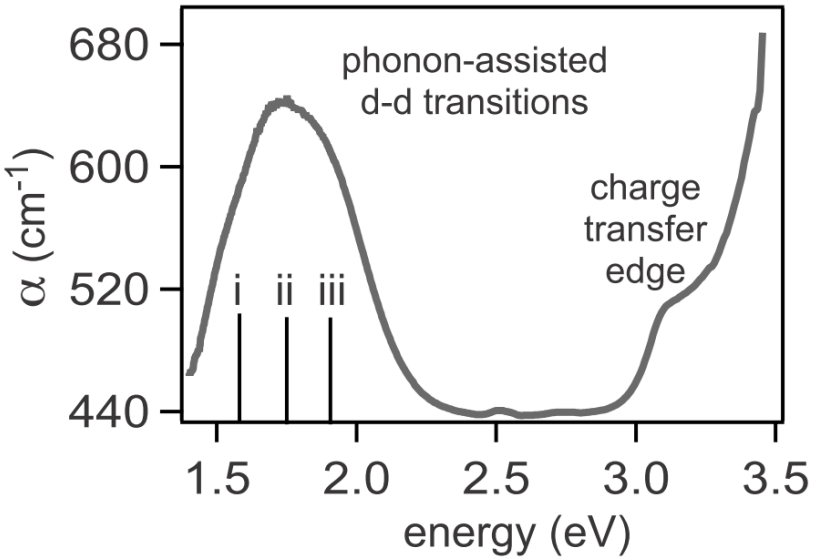




- ✓ Ultrashort pulses in the mid-IR
- ✓ 5<λ<16μm
- ✓ E>1μJ/pp

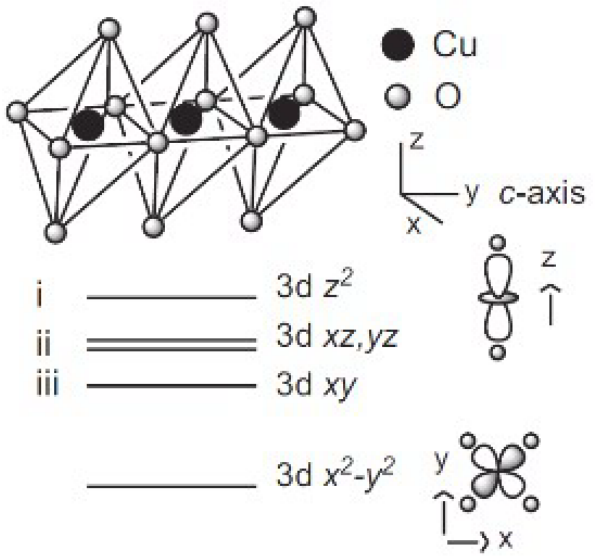
Phonon Pump in CuGeO3

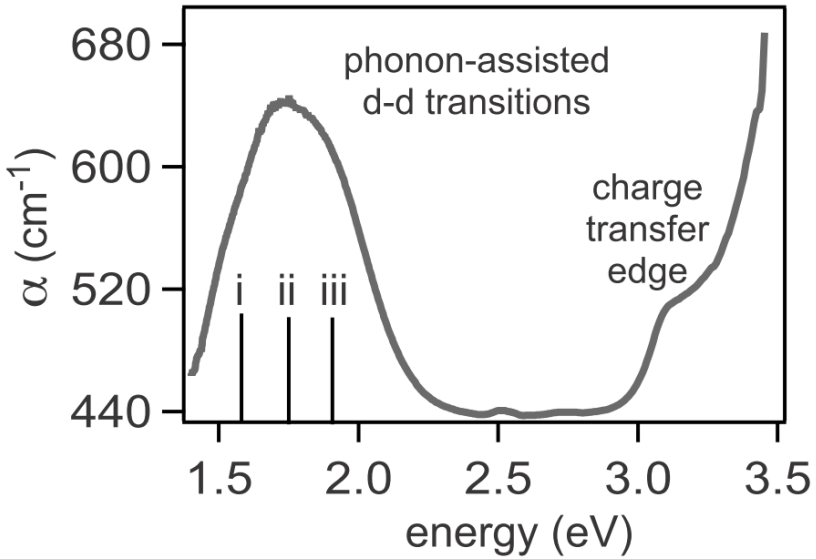


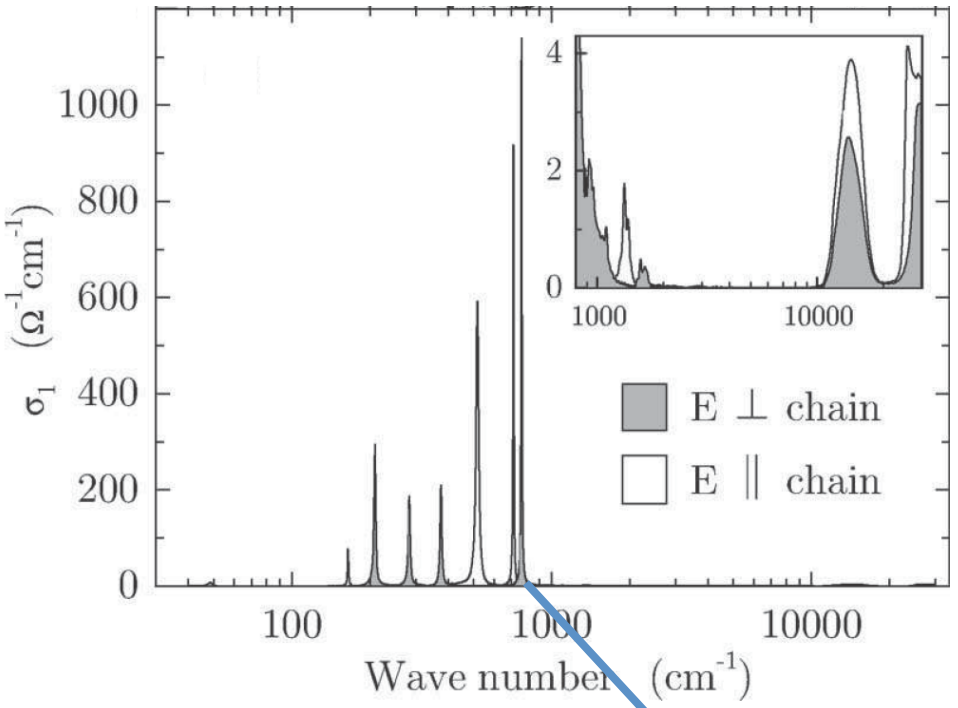


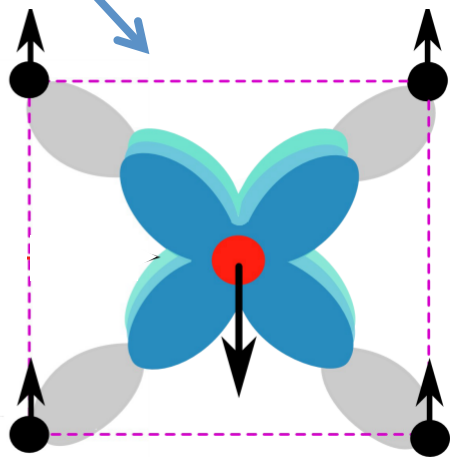
Prb, 80, 235139

Phonon Pump in CuGeO3



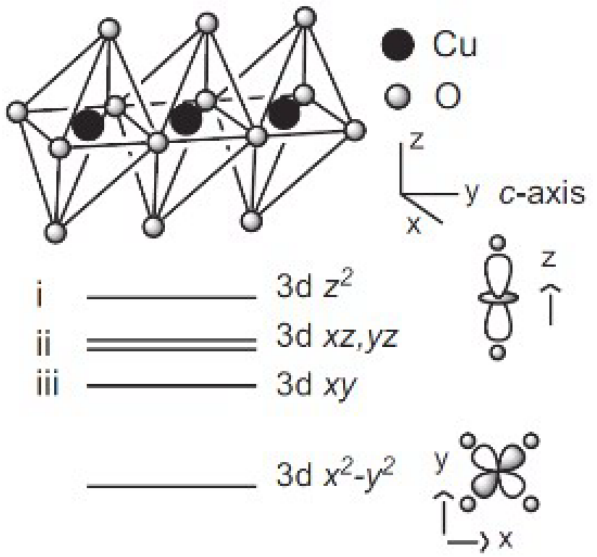


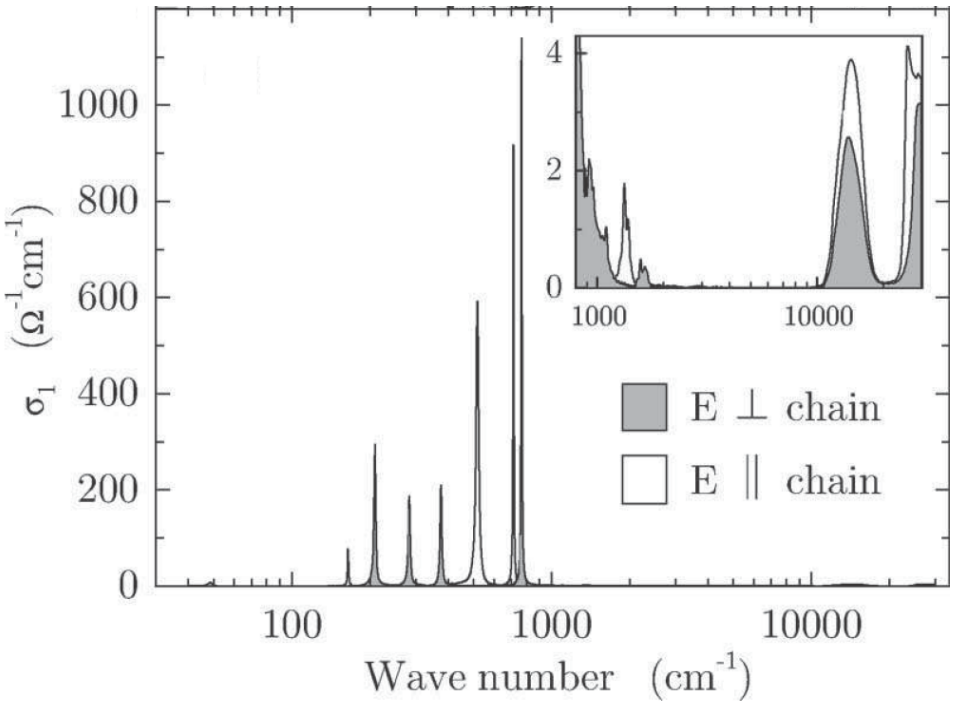


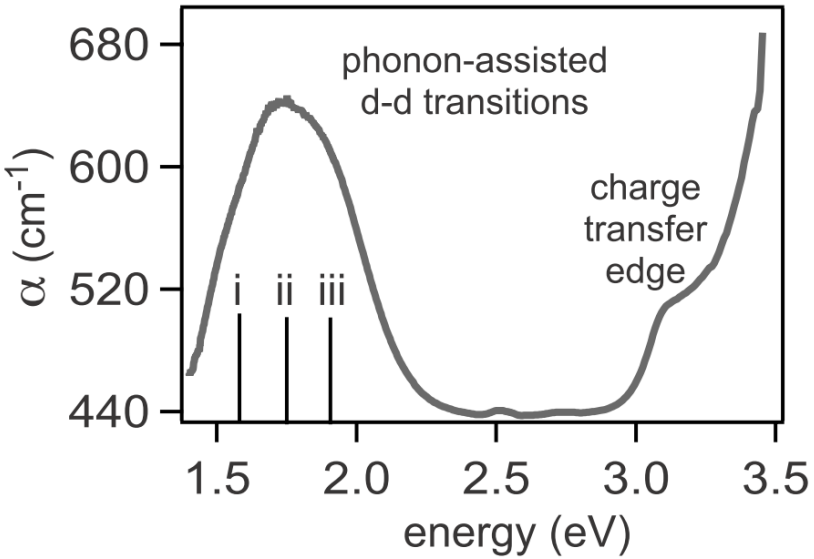


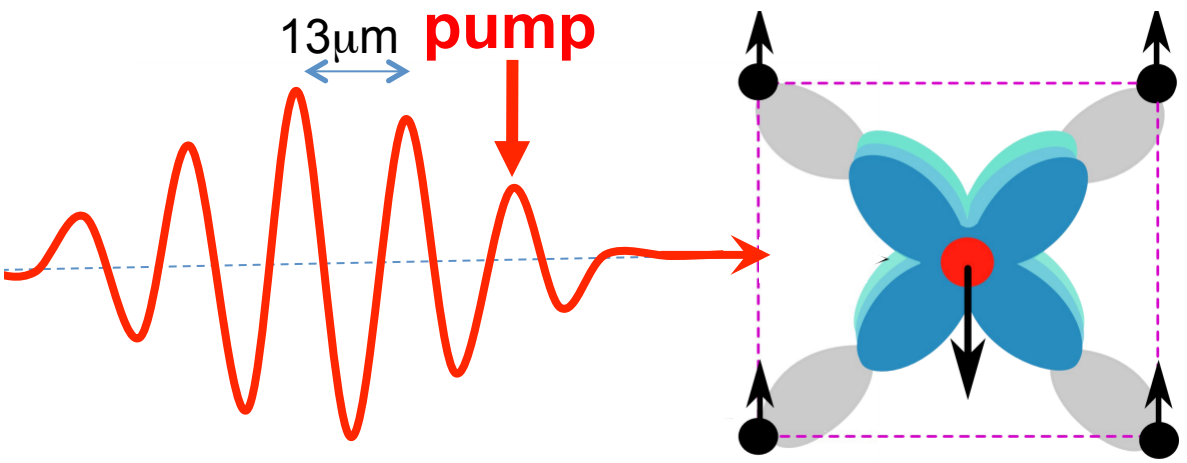
Prb, 80, 235139; Prb, 61, 12063

Phonon Pump in CuGeO3









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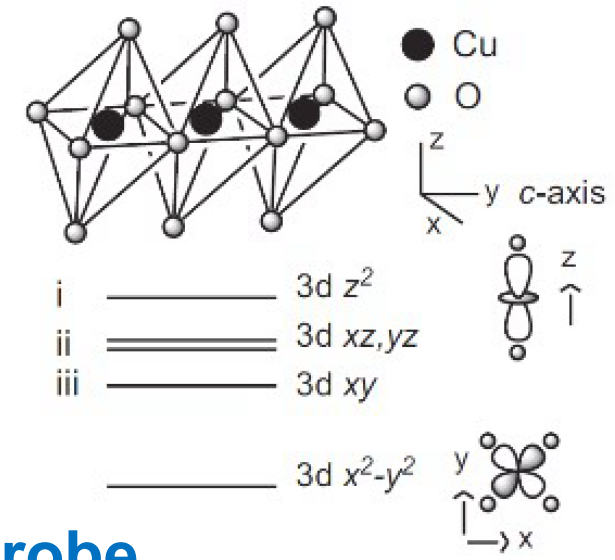
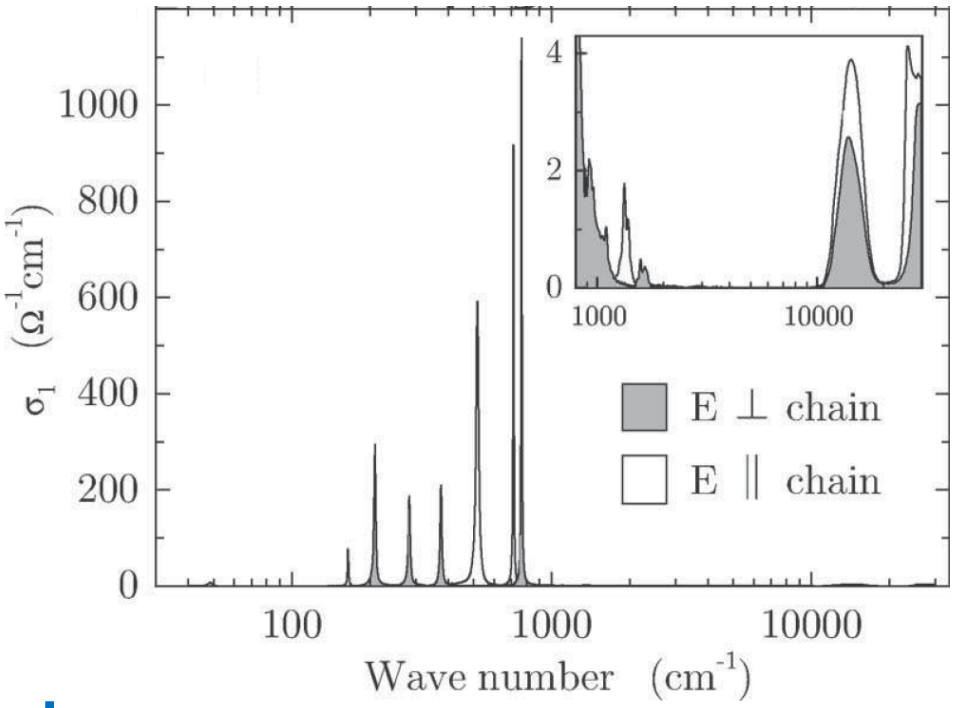
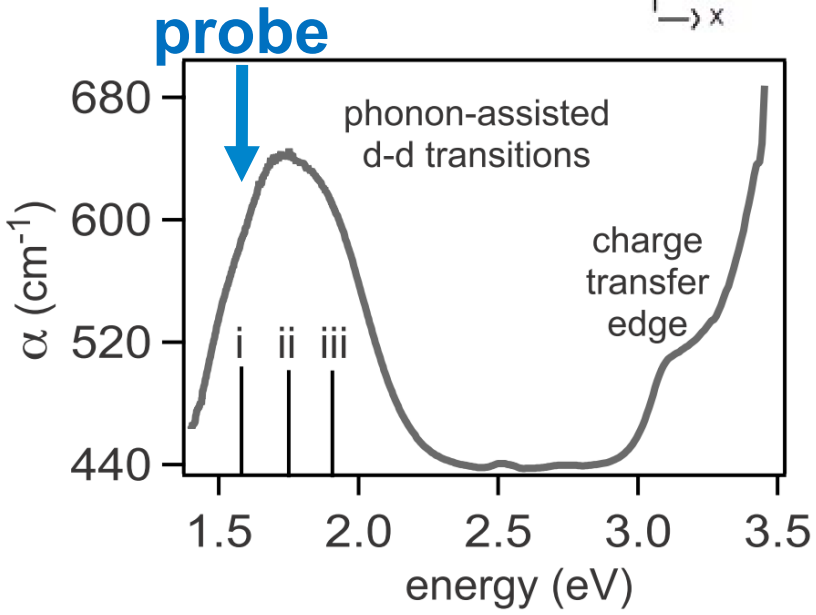
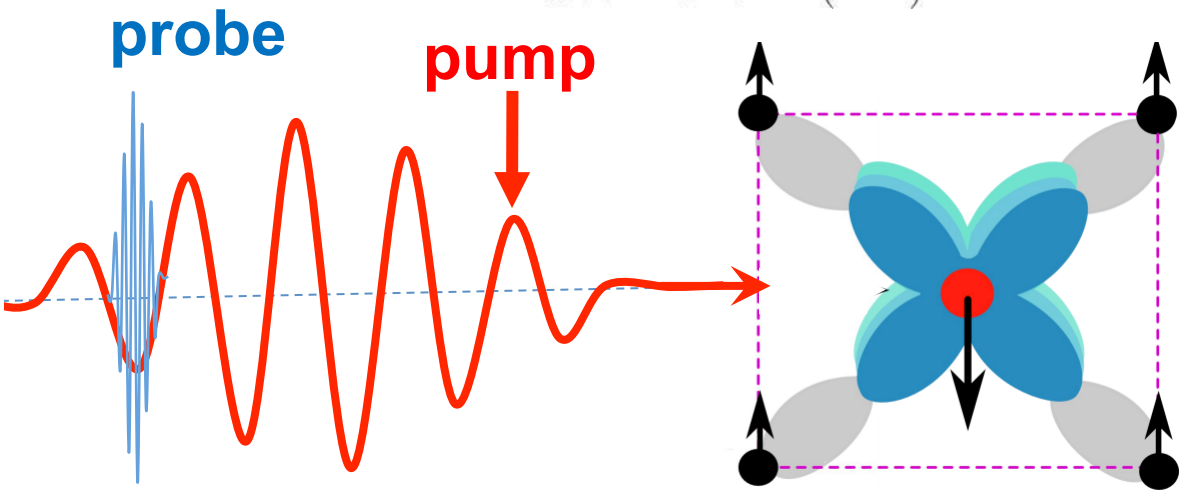
Phonon Pump in CuGeO3









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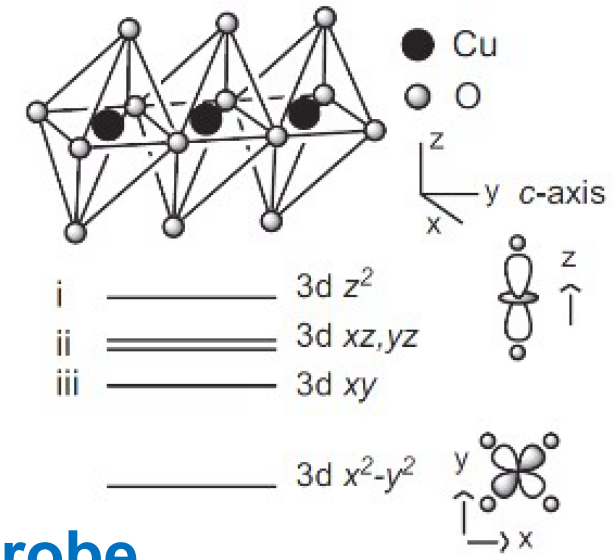
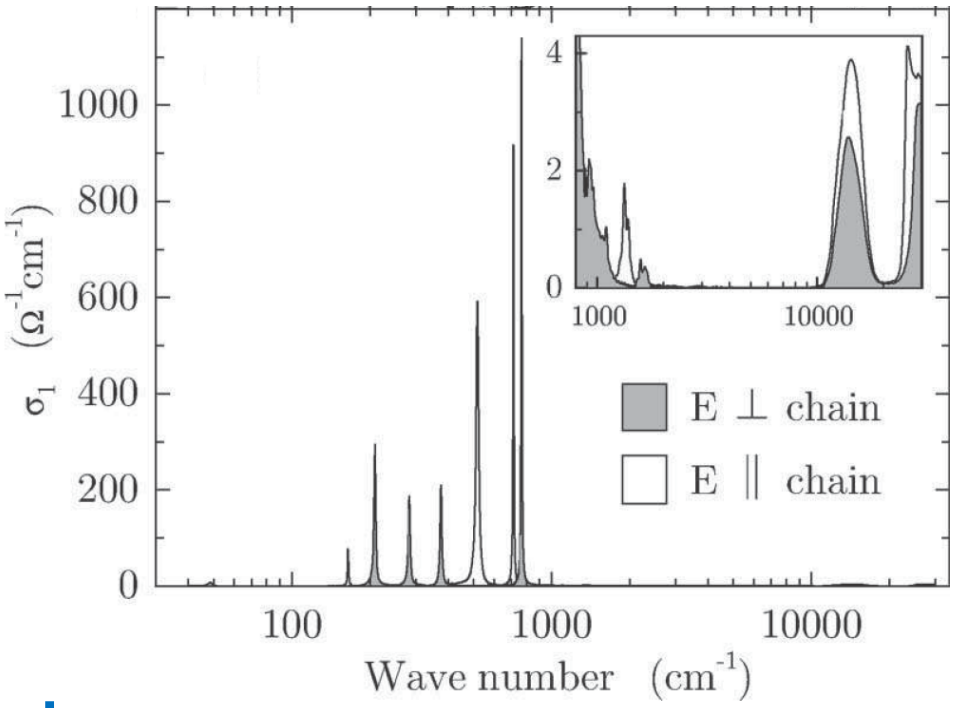
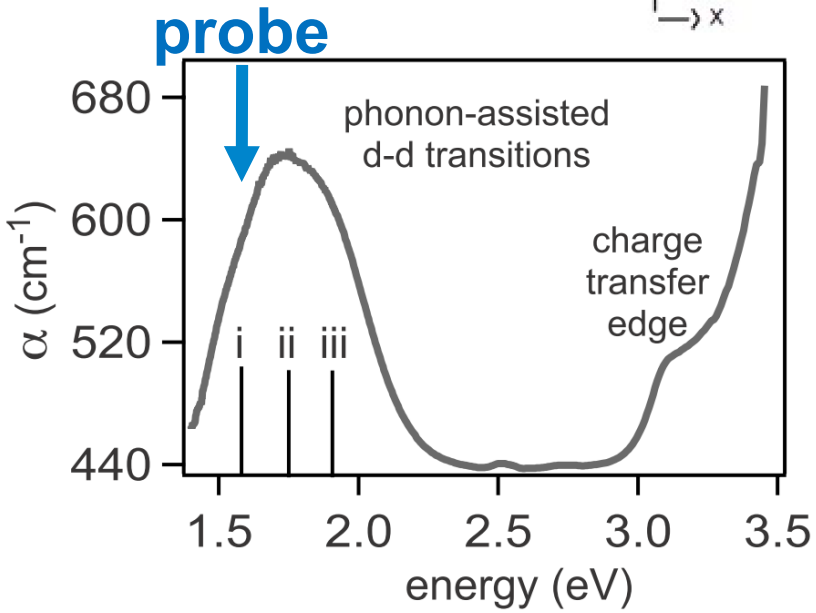
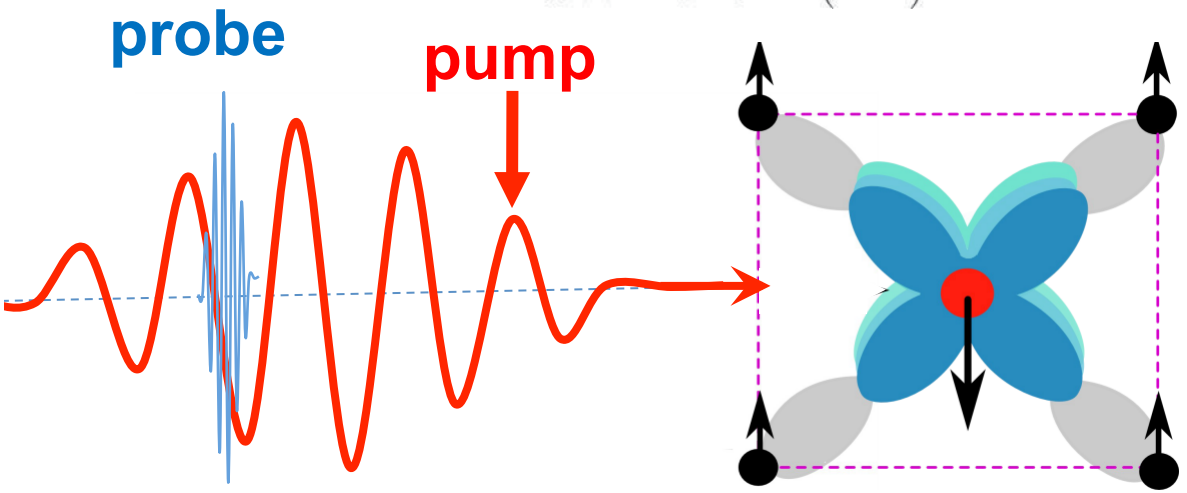
Phonon Pump in CuGeO3









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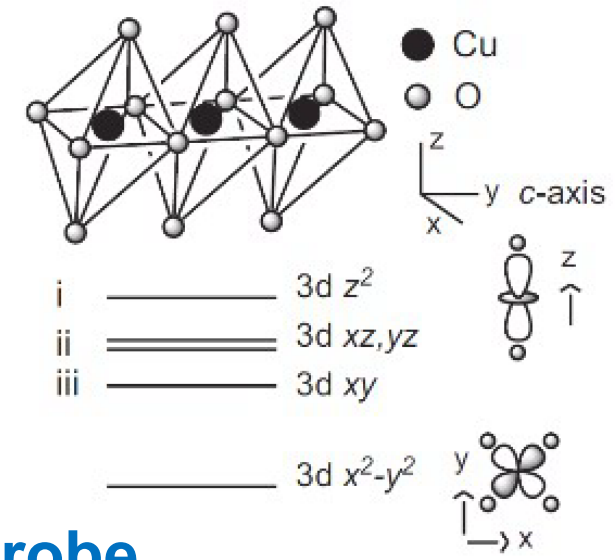
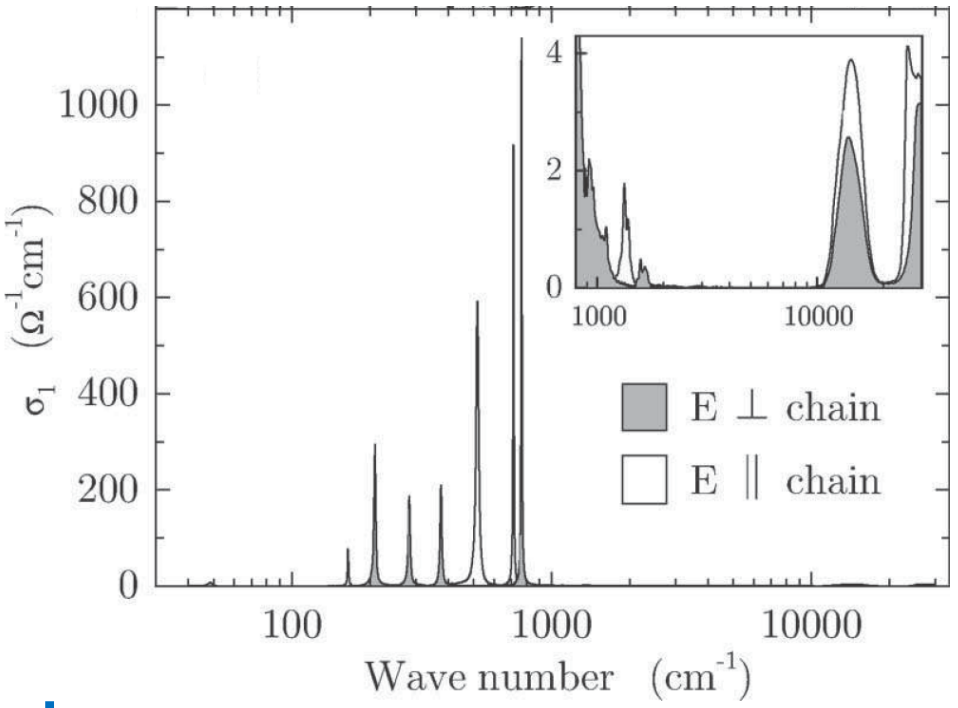
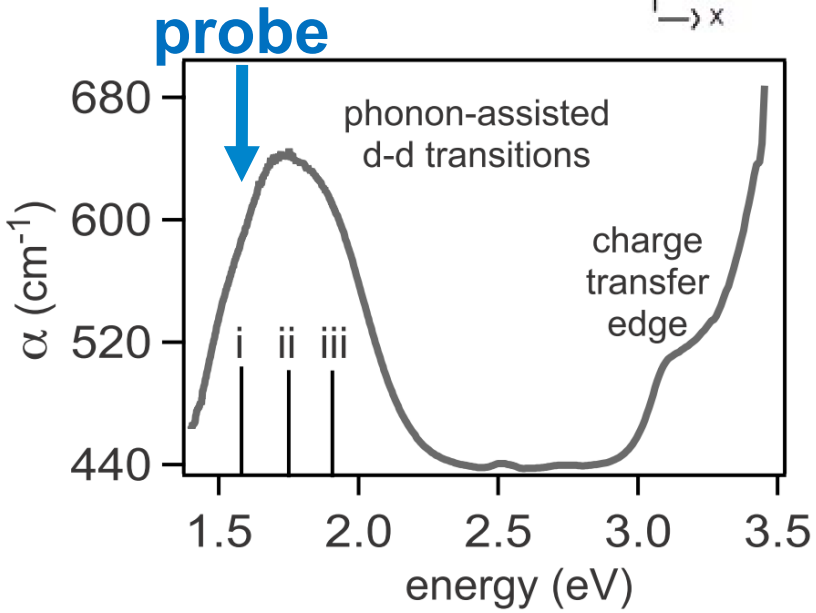
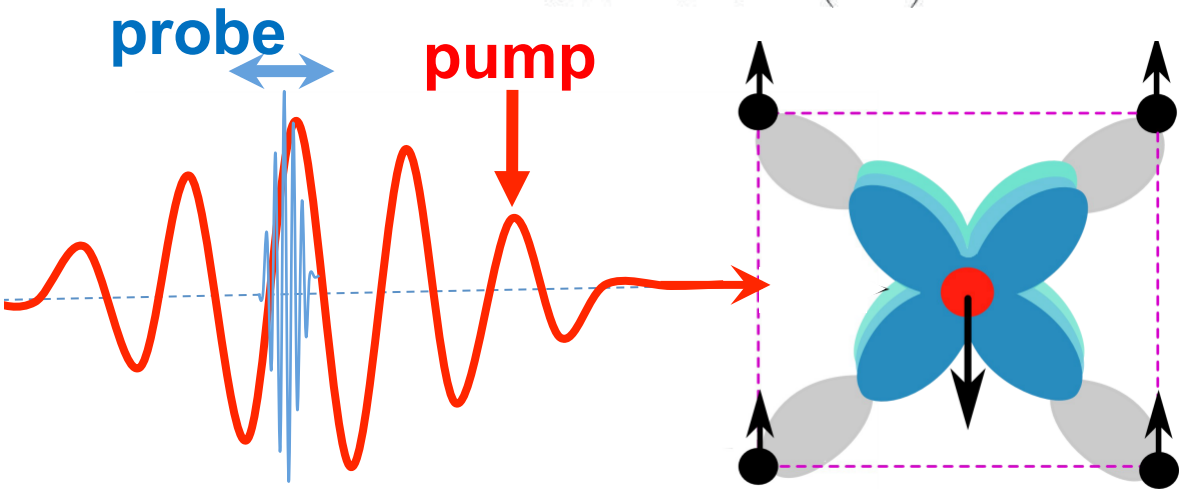
Phonon Pump in CuGeO3



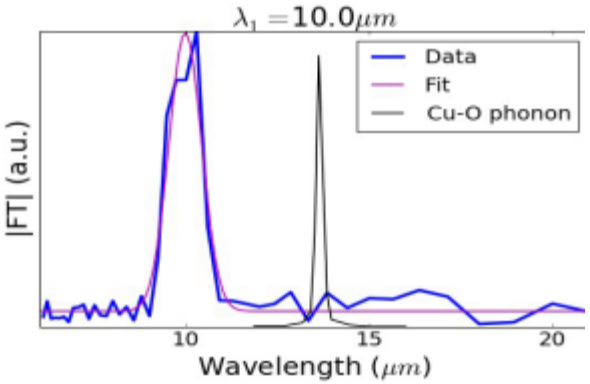


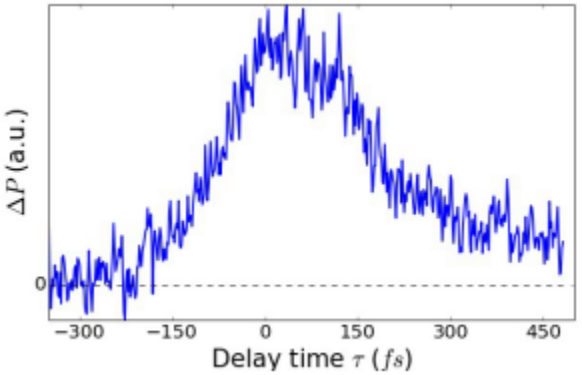




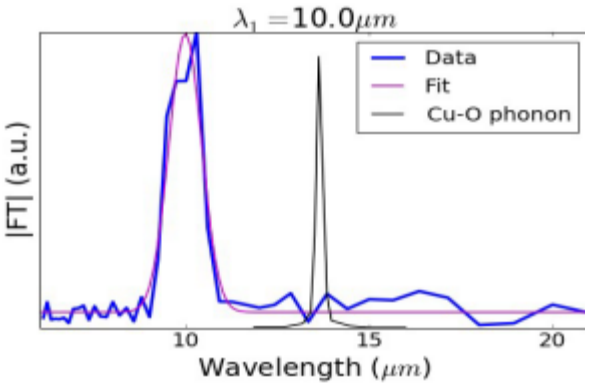
Prb, 80, 235139; Prb, 61, 12063

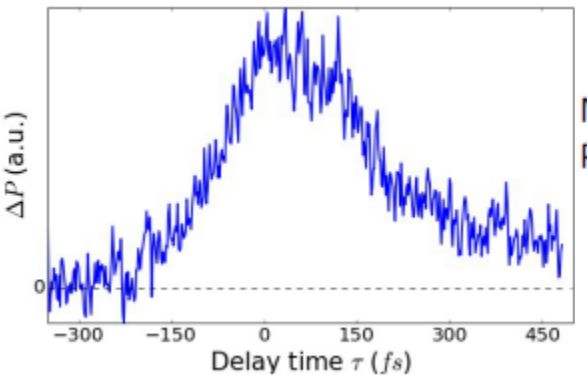
Phonon Pump in CuGeO3

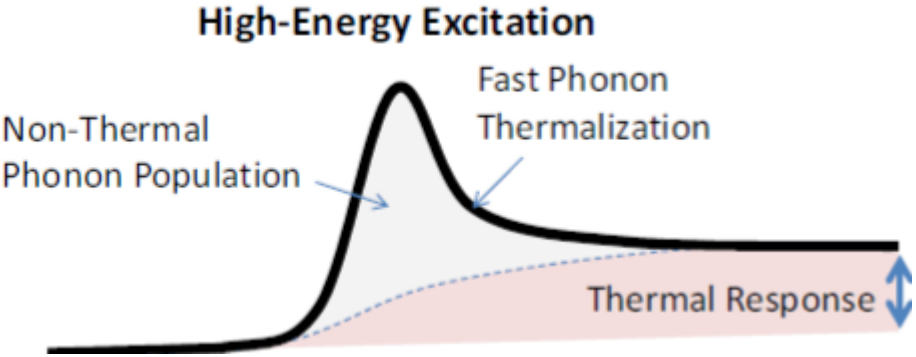




Phonon Pump in CuGeO3







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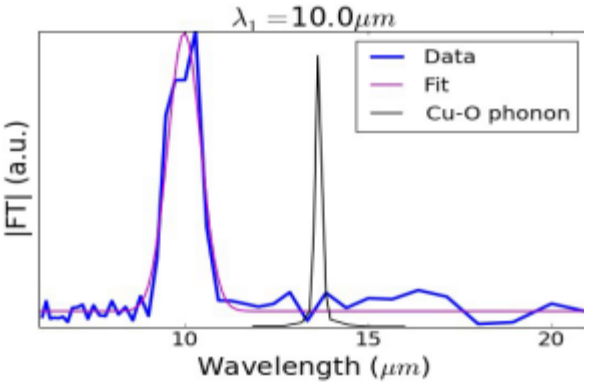
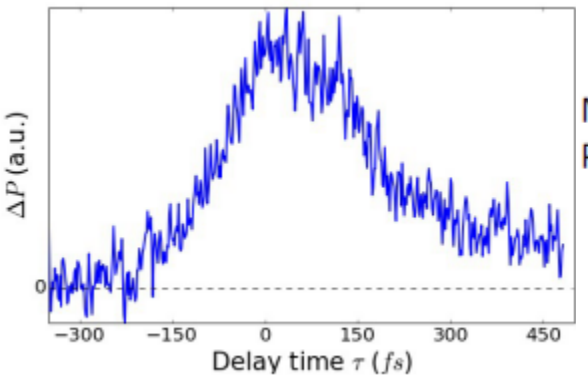
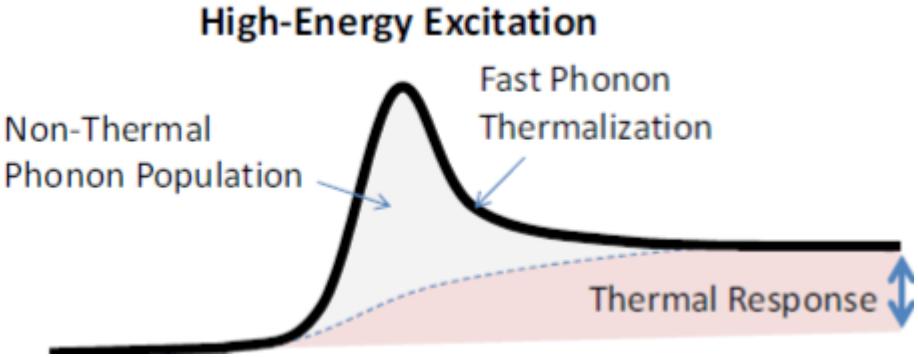
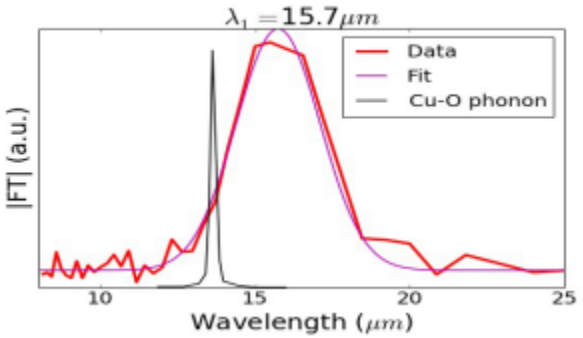
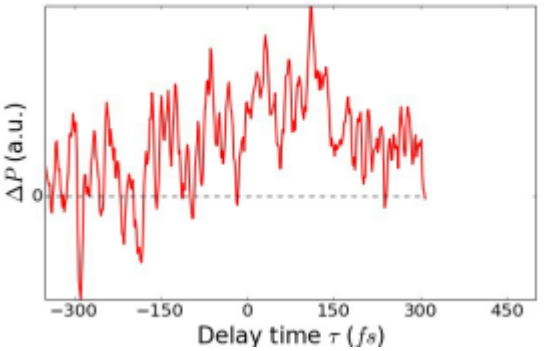
Phonon Pump in CuGeO3



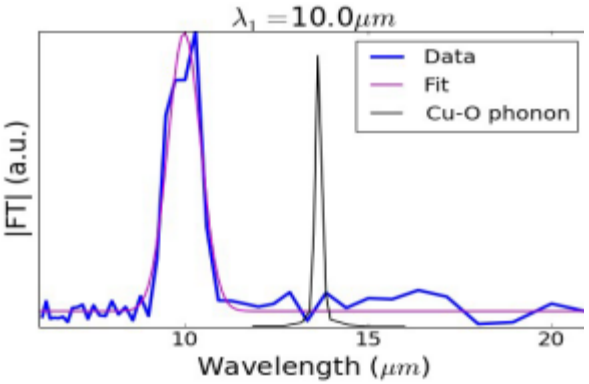


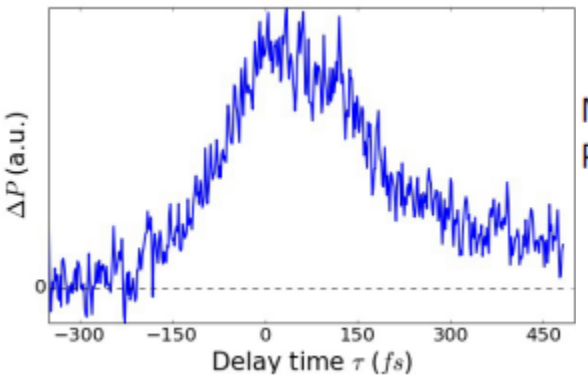


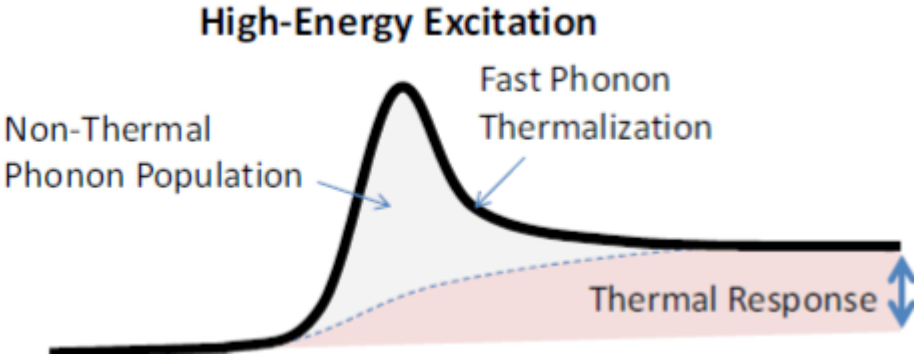


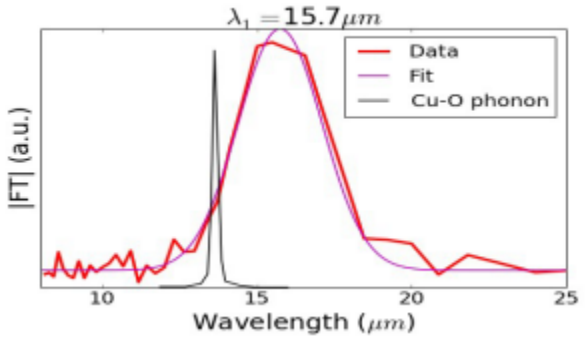


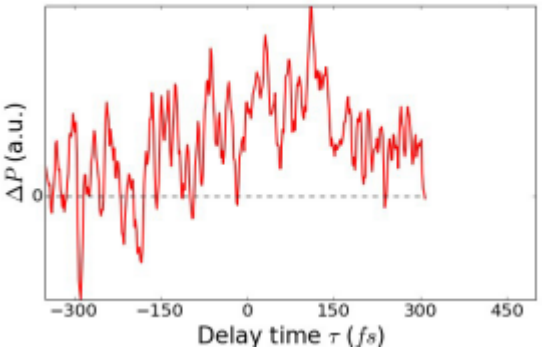
Phonon Pump in CuGeO3

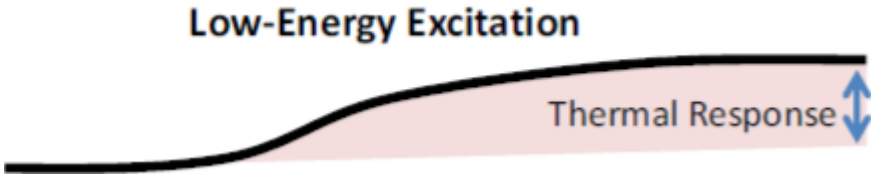




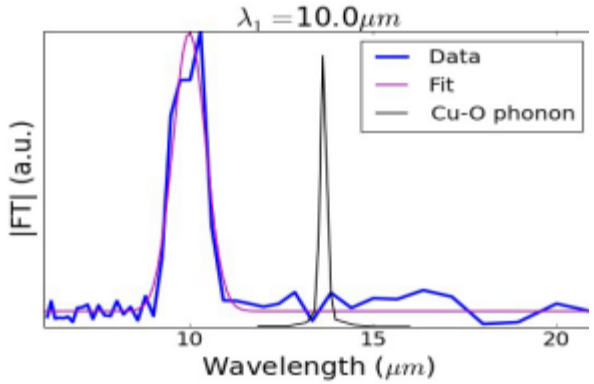


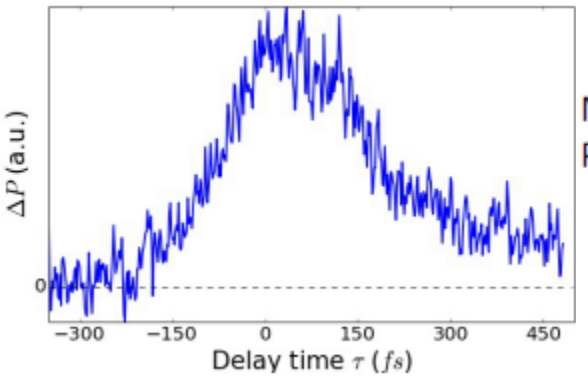


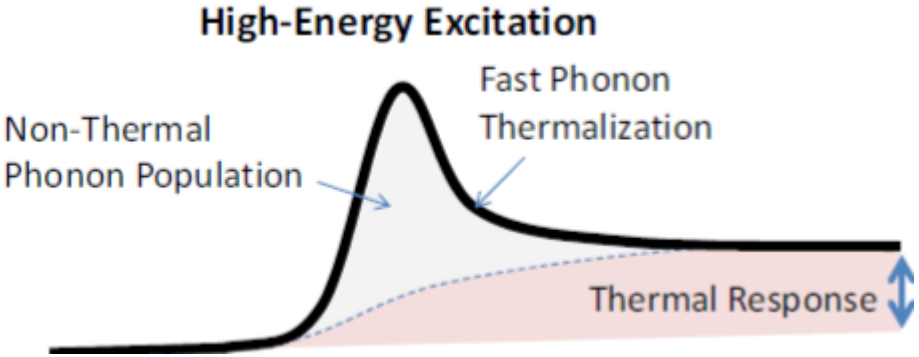


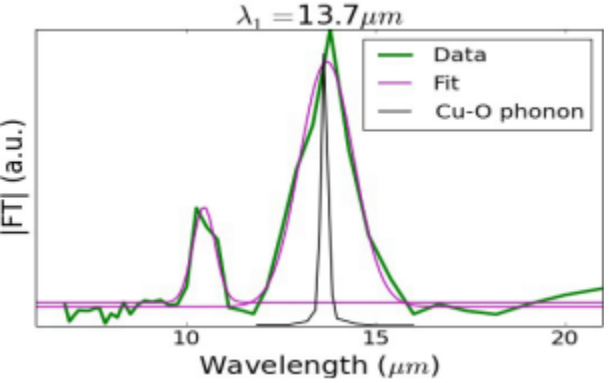


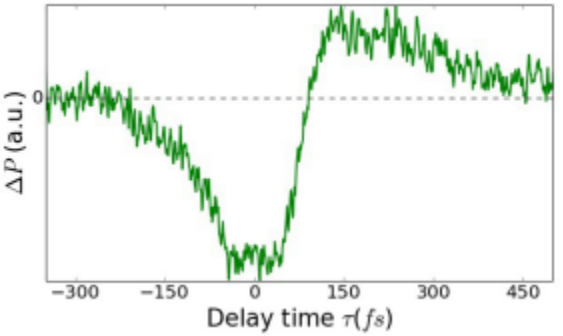
Phonon Pump in CuGeO3

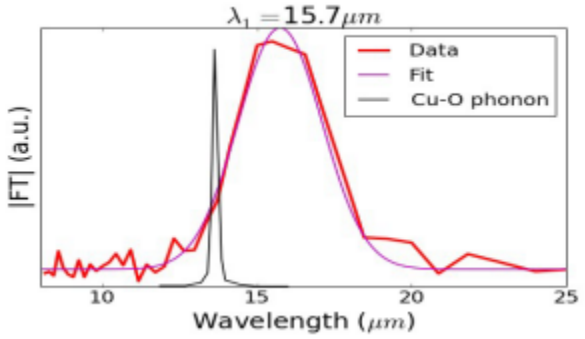


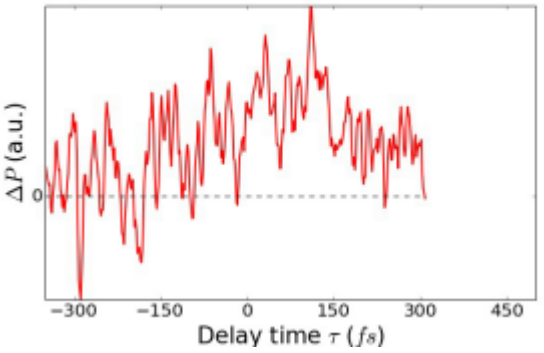


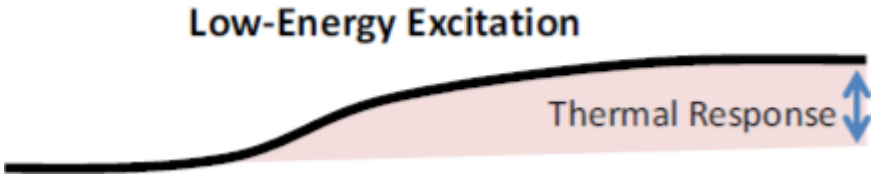




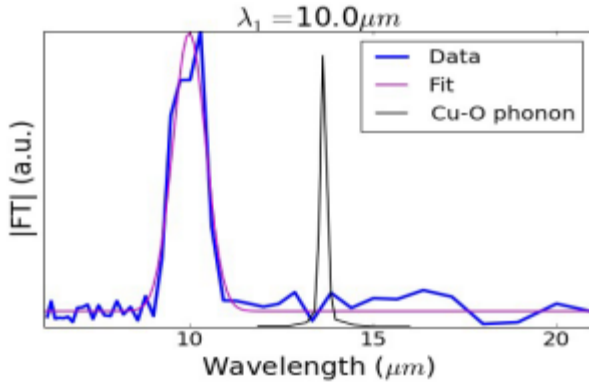


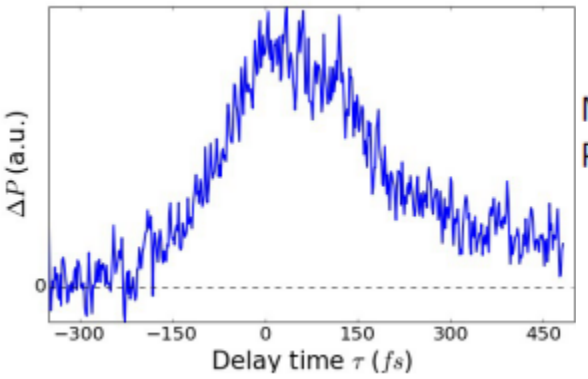


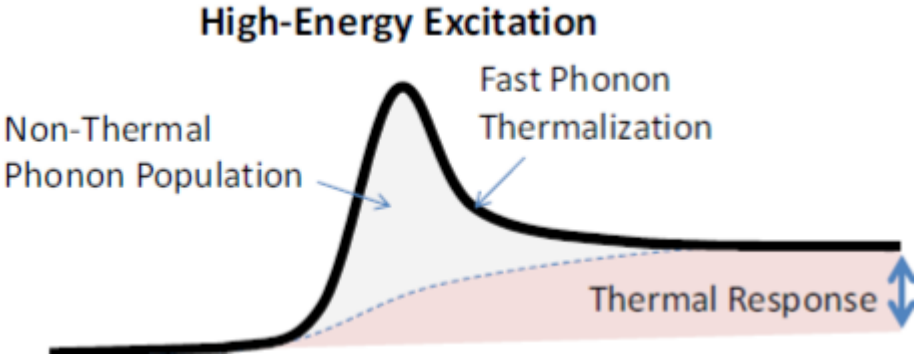


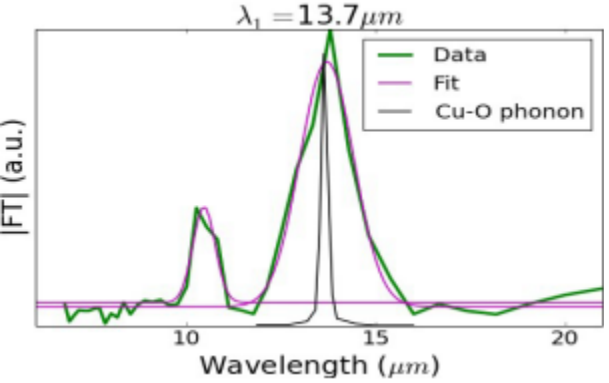


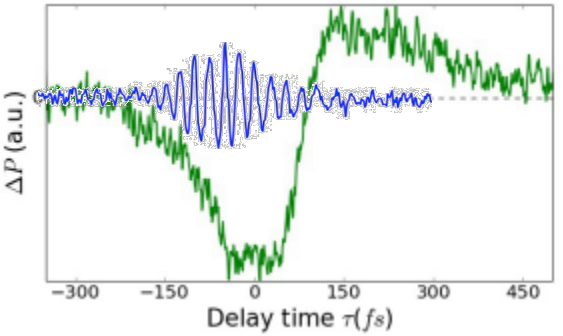
Phonon Pump in CuGeO3

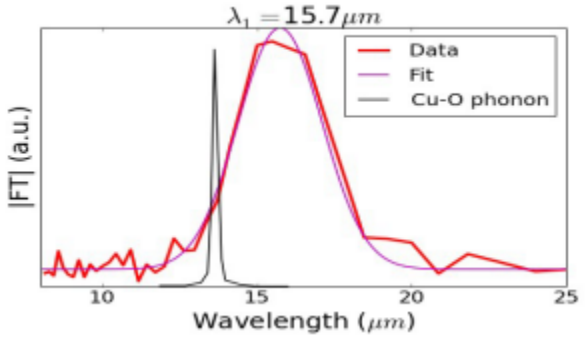


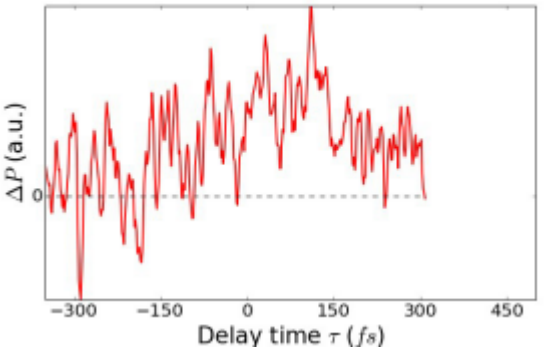


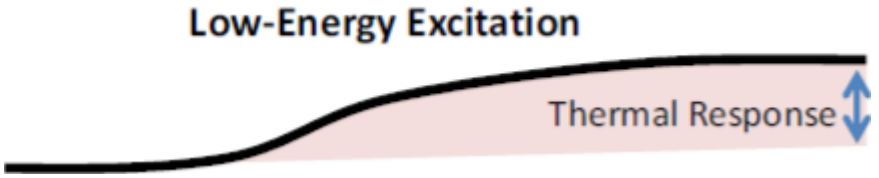




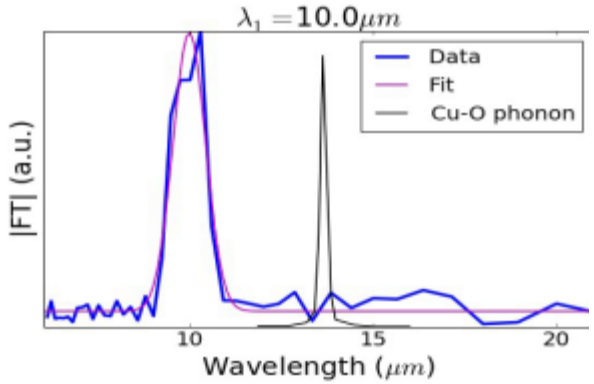


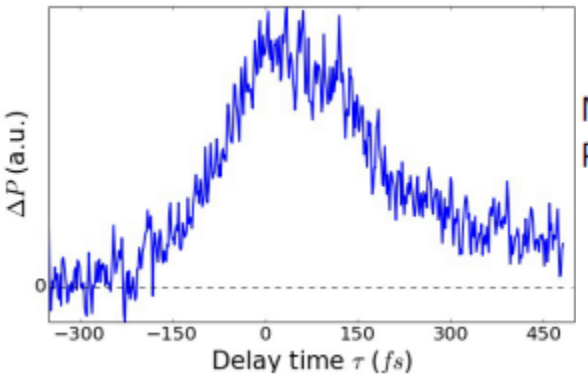


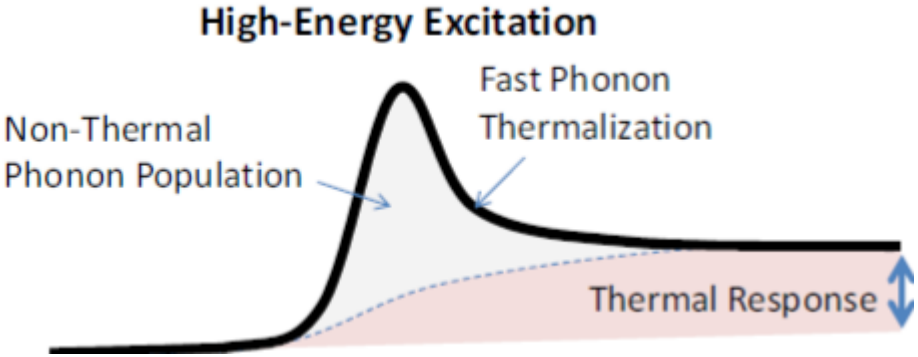


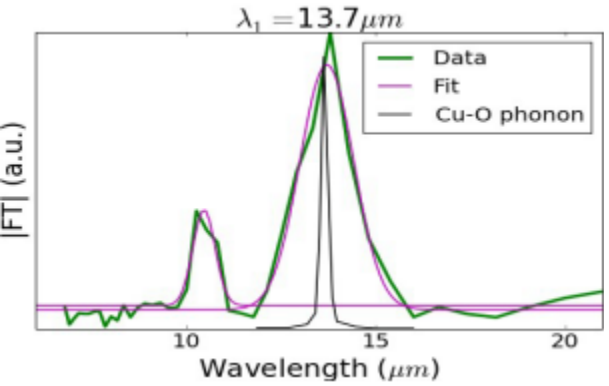


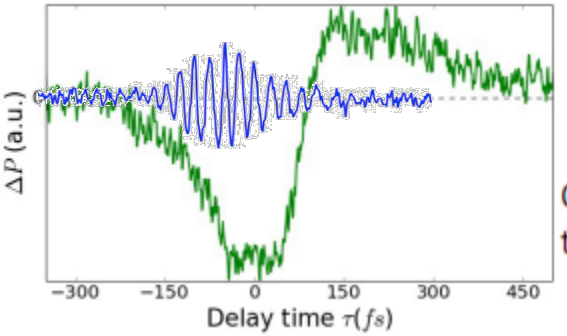
Phonon Pump in CuGeO3

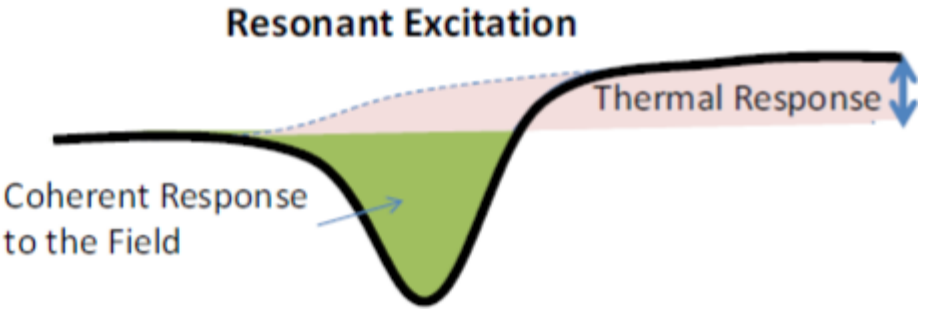


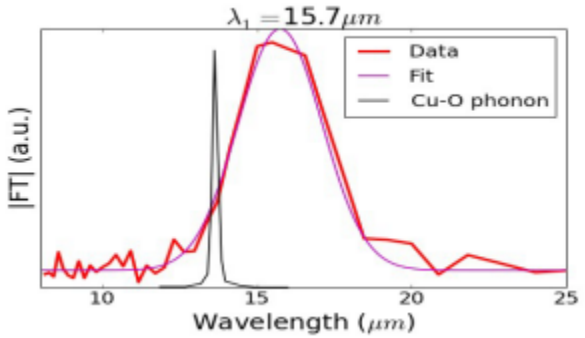


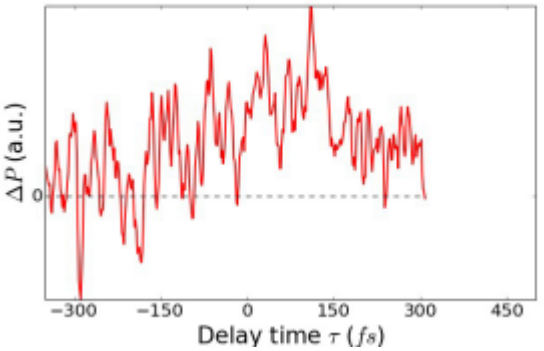


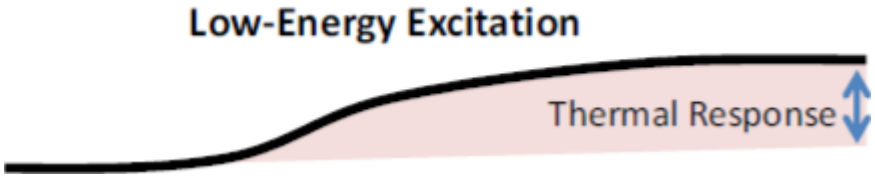












Outline

- ✓ **Equilibrium Optical Spectroscopy**
  - -The optical conductivity in the Visible and Near-IR
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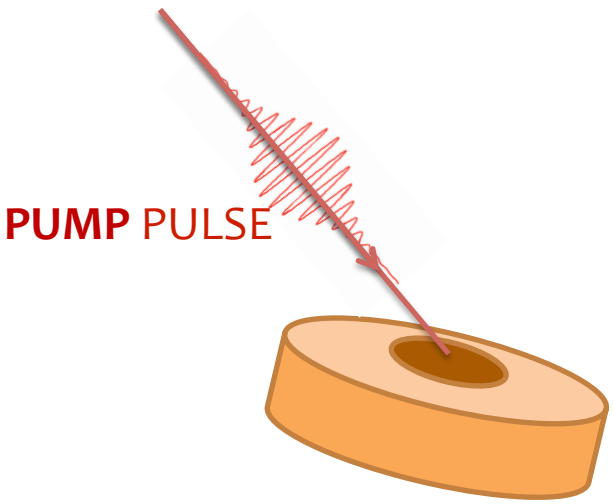
Basic idea

Quantum Optics:
measuring quantum states of light

Ultrafast processes in **Condensed Matter:** Pump&Probe



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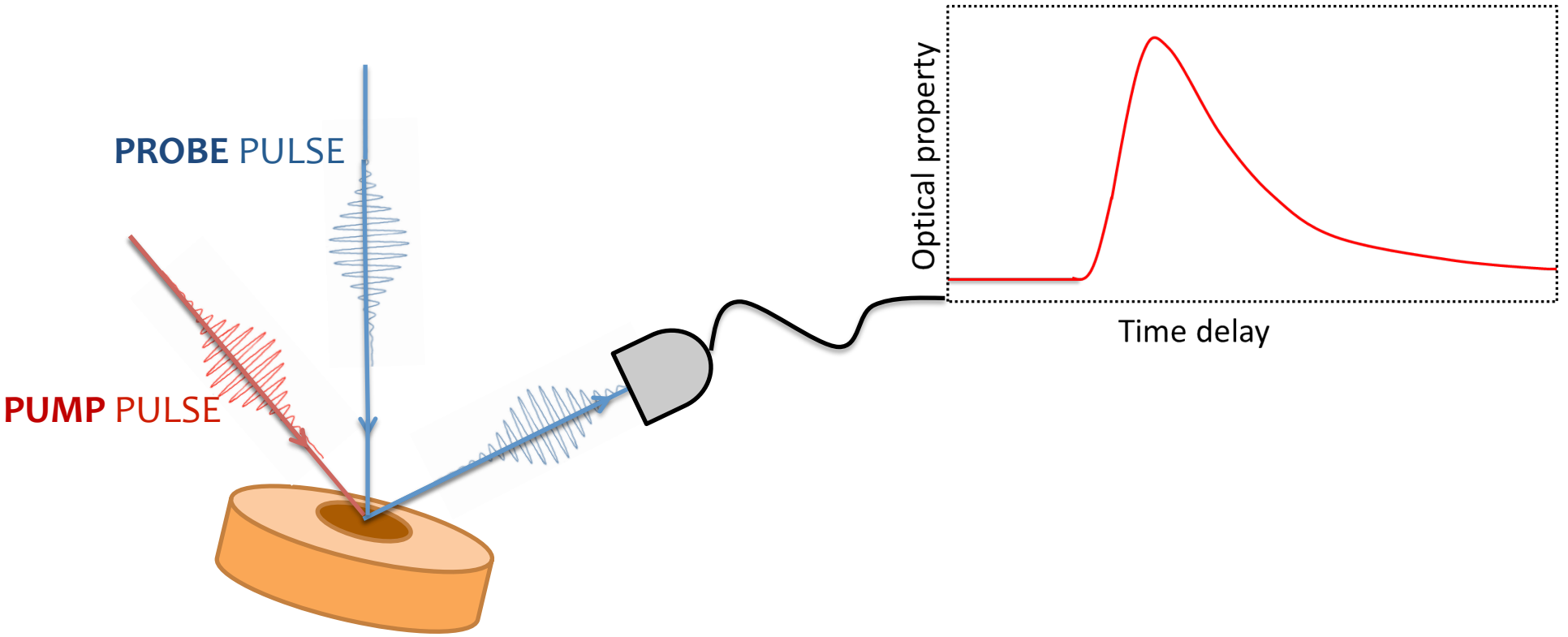

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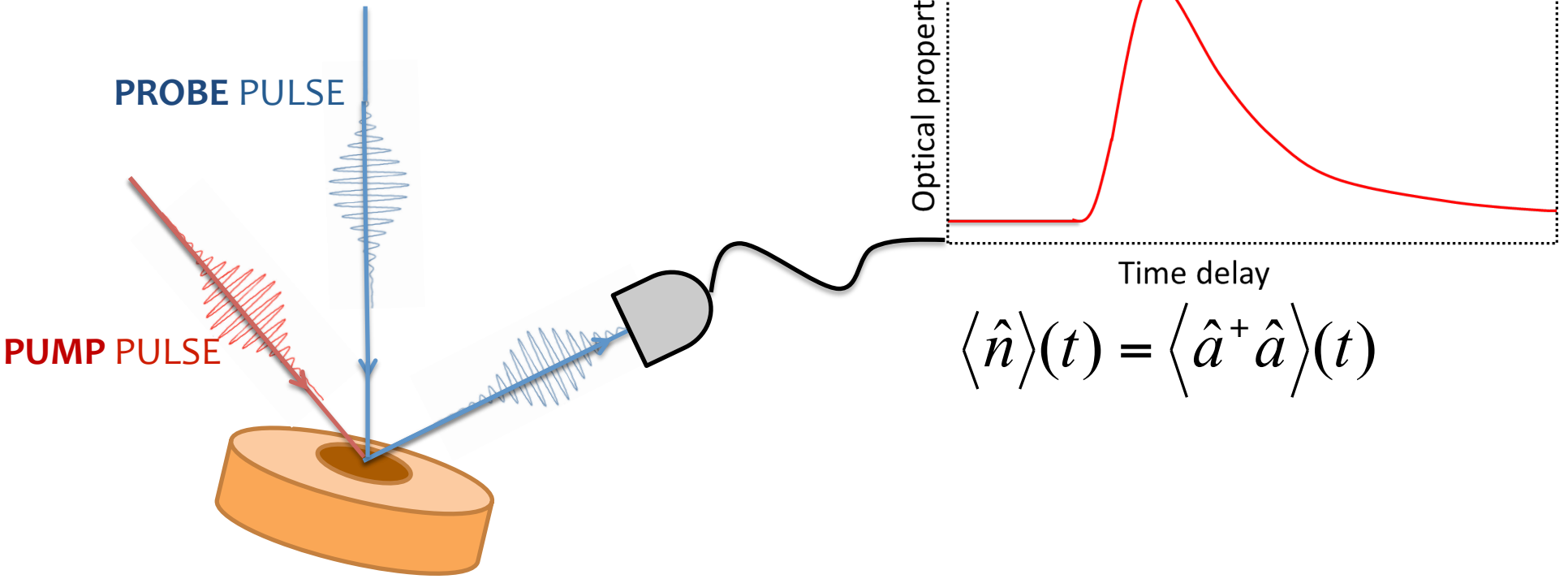

$$\langle \hat{n} \rangle (t) = \langle \hat{a}^{+} \hat{a} \rangle (t)$$

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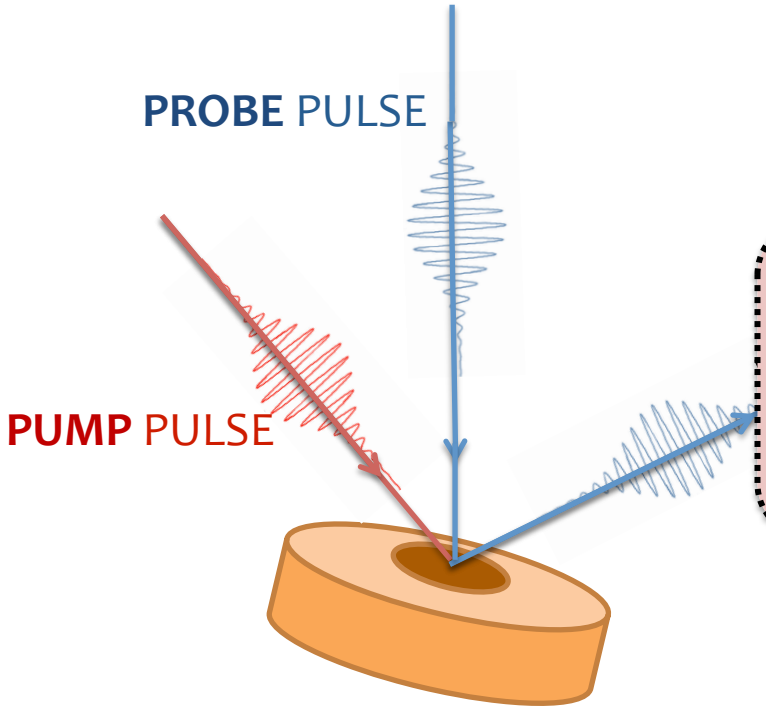
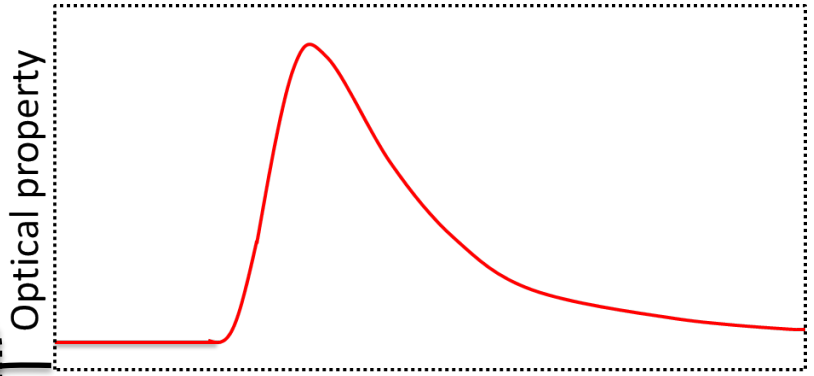


Quantum statistic detection



$$\langle \hat{n} \rangle(t) = \langle \hat{a}^{+} \hat{a} \rangle(t)$$

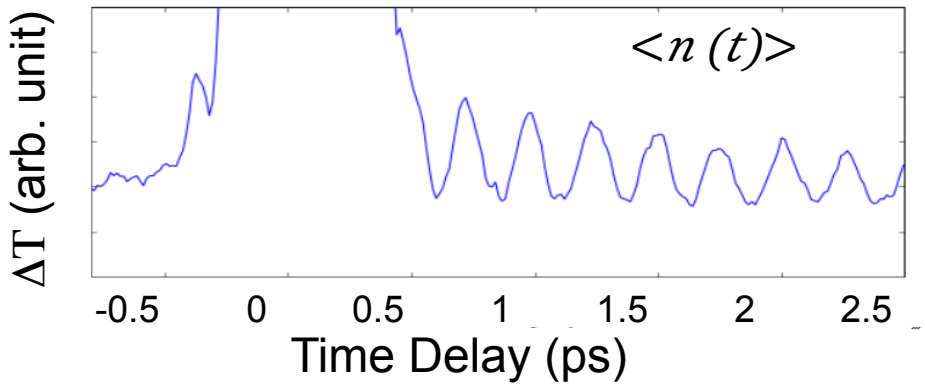
$$\langle \hat{n}^{2} \rangle(t)$$

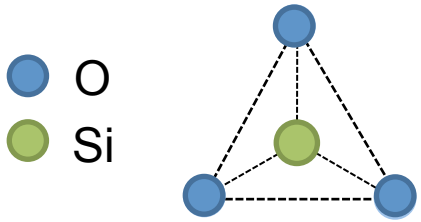
$$\vdots$$

$$\langle \hat{n}^{k} \rangle(t)$$

Nature Comm. 6, 10249 (Dec. 2015)

Higher order: Pump and Probe α-quartz





Coherent Motion

Nature Comm. 6, 10249 (Dec. 2015)

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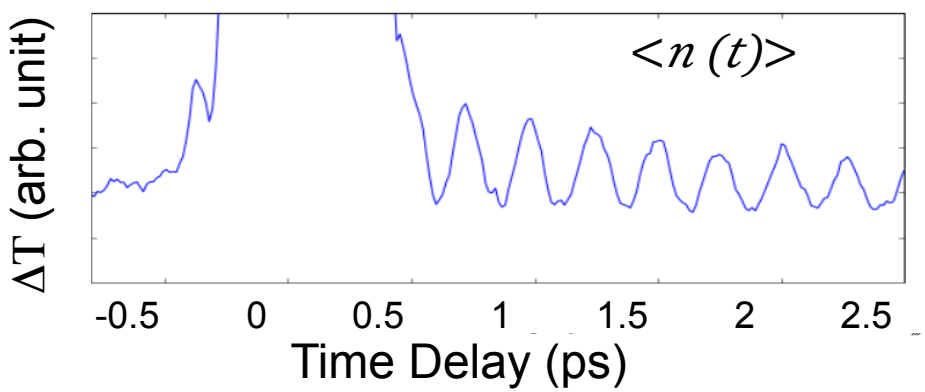
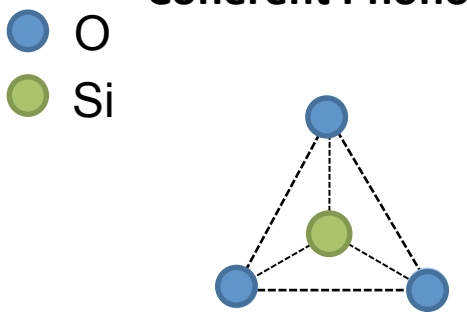
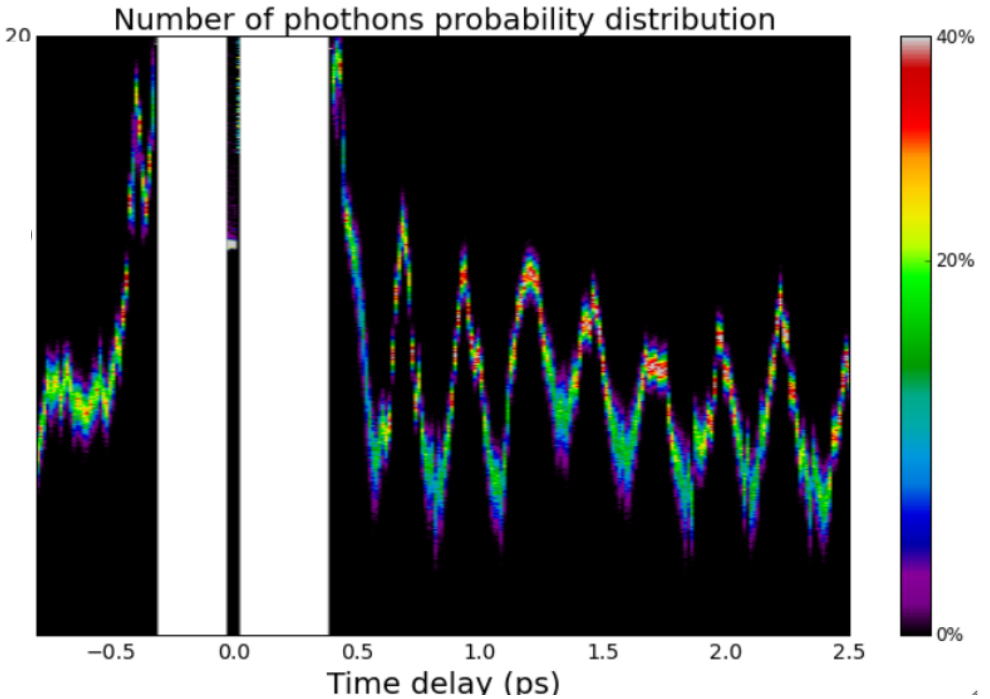




Coherent Phonon



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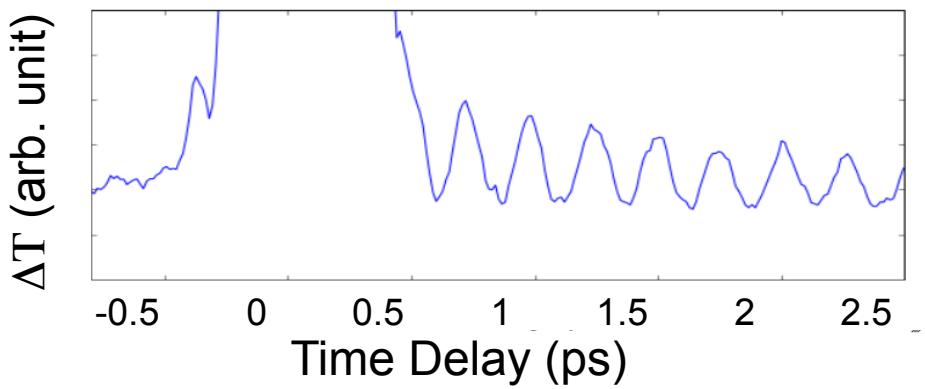
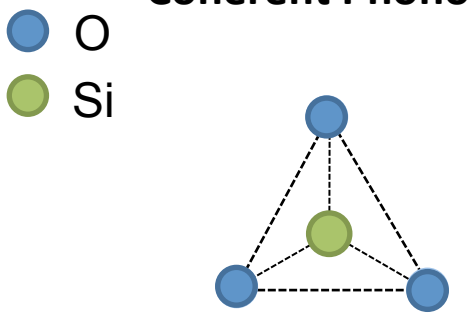
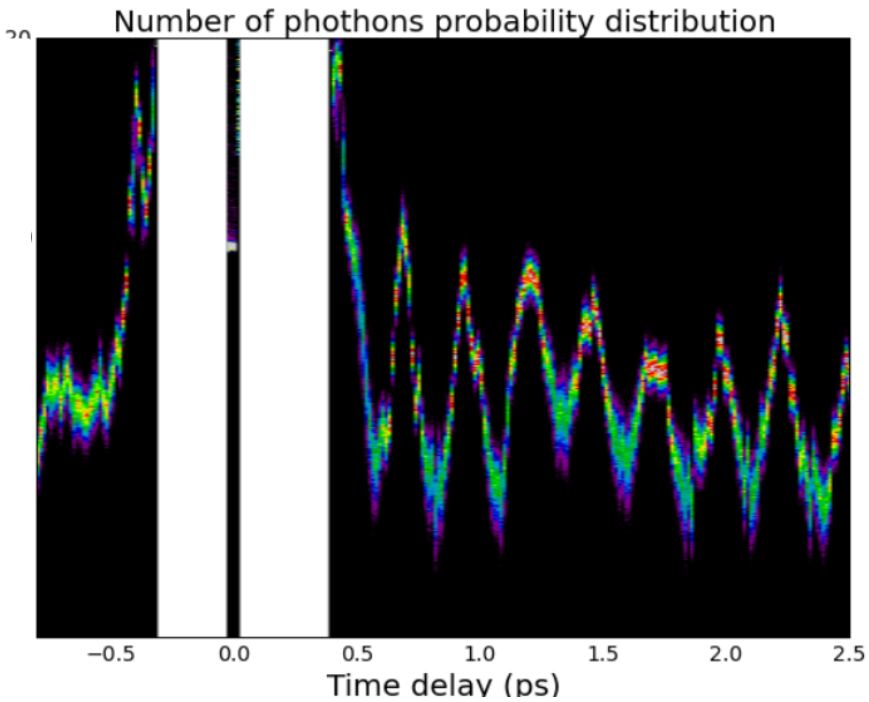
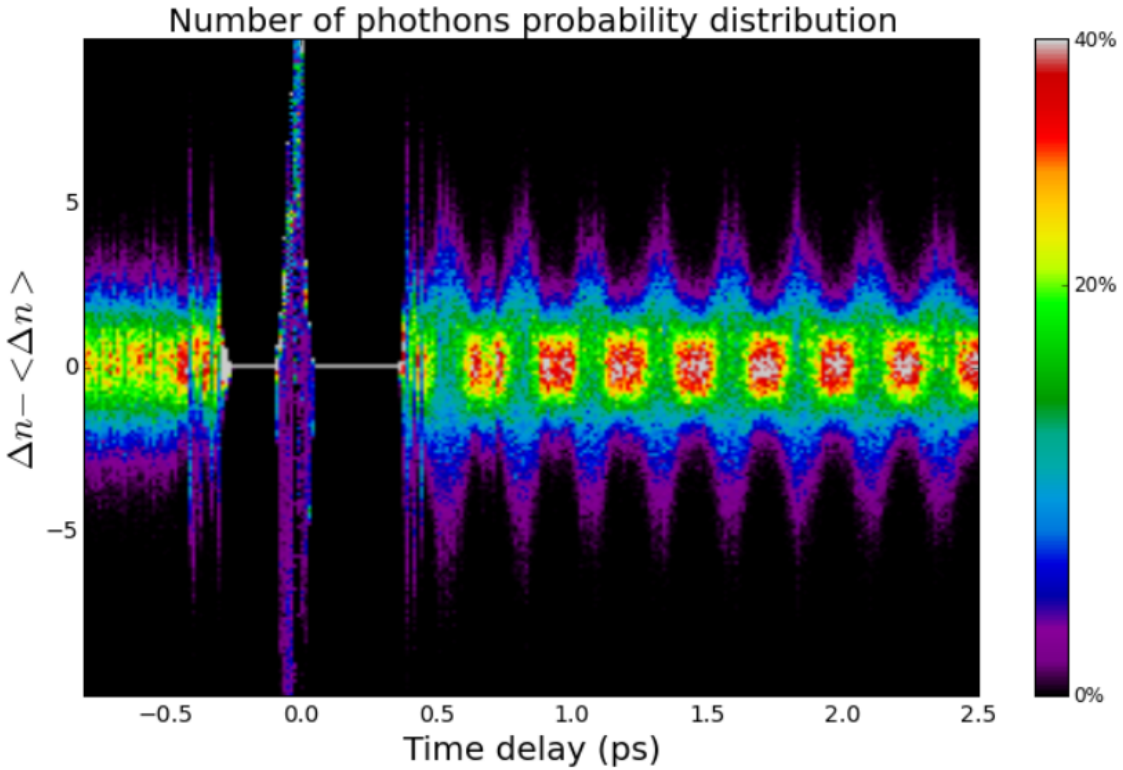


Coherent Phonon







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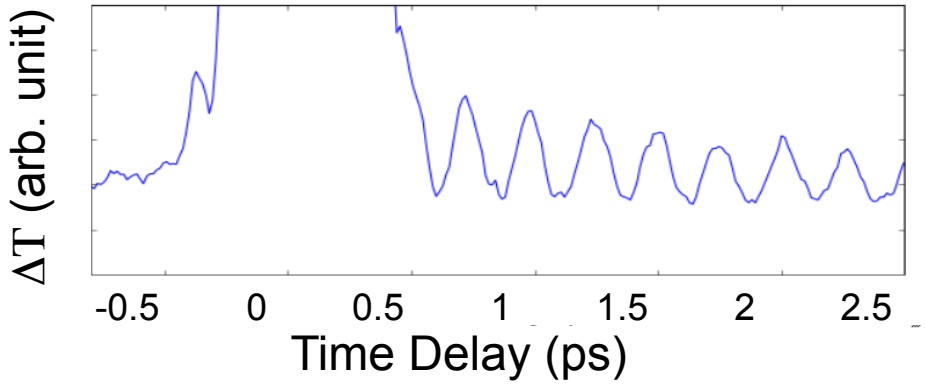
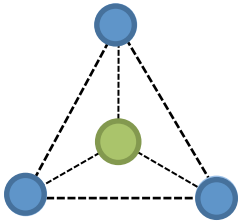
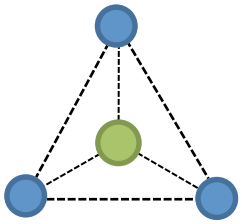


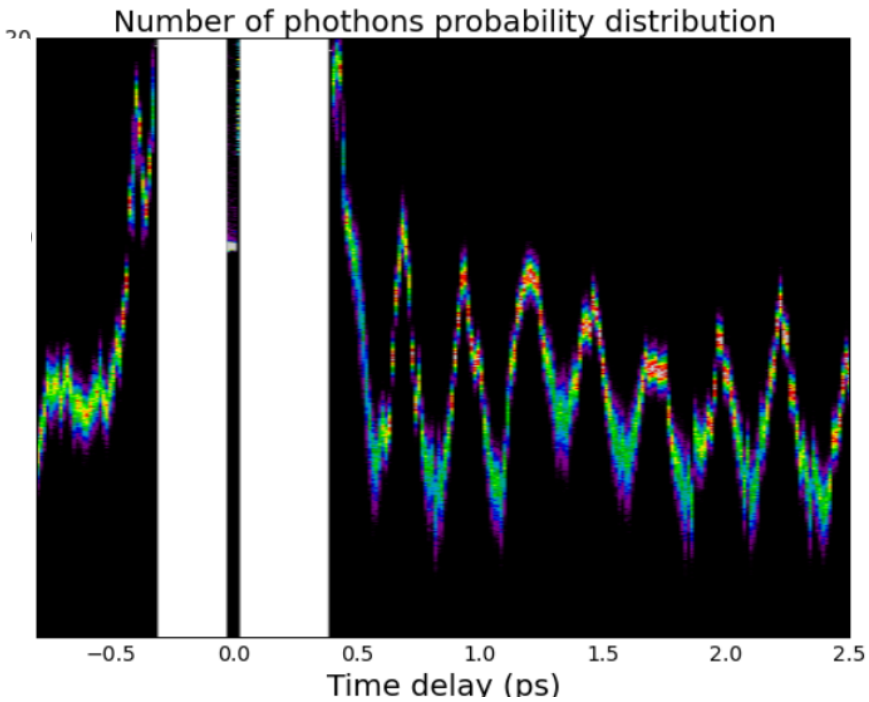
O
Si

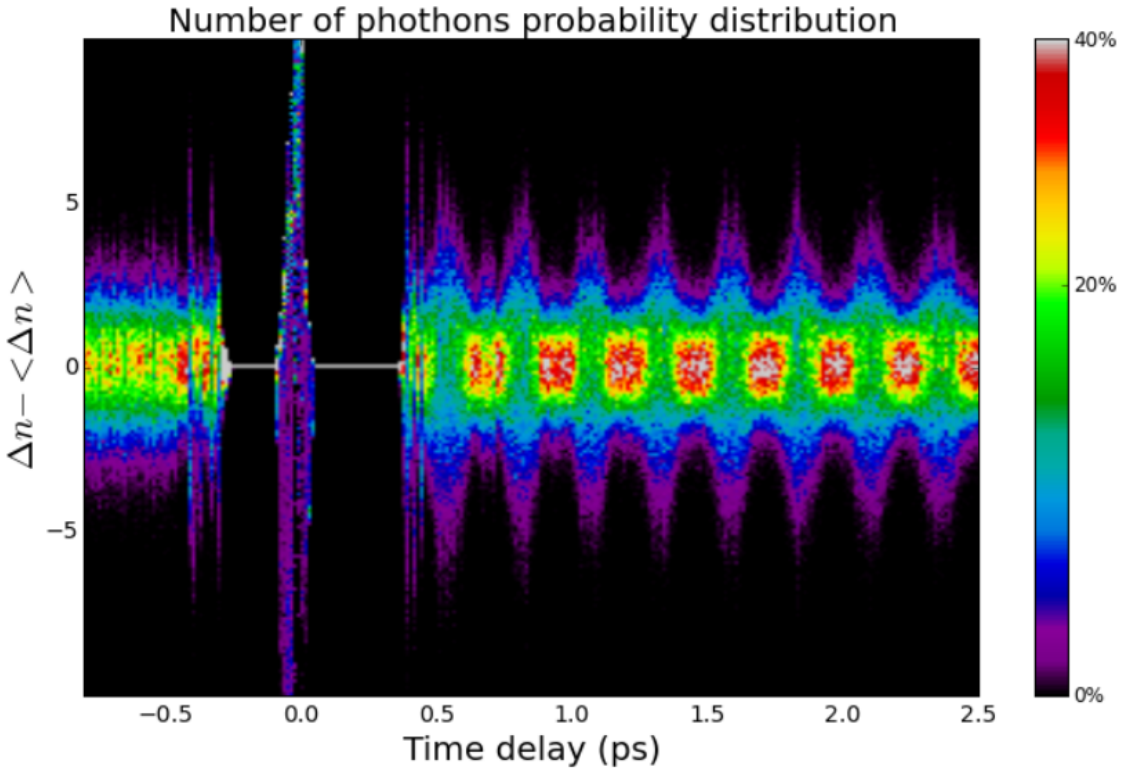
Coherent Phonon



Fluctuation Distribution







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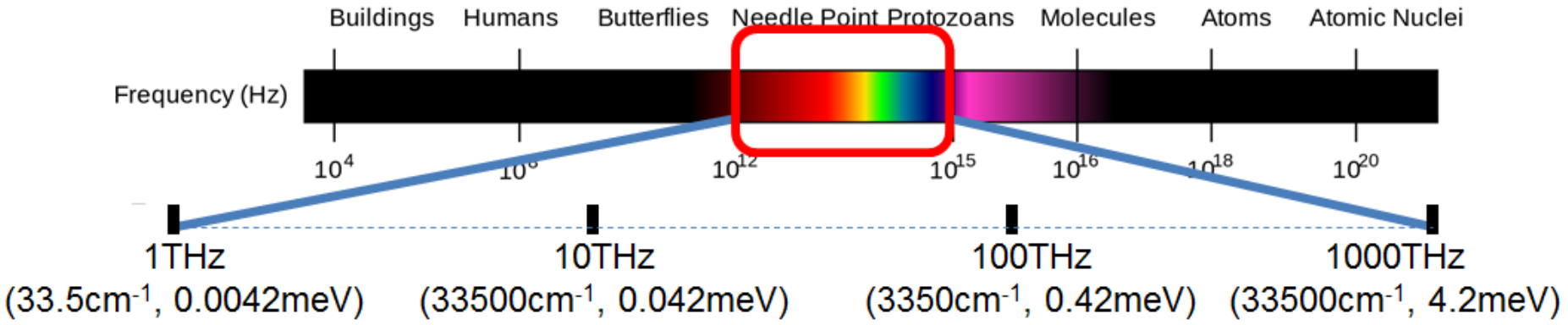
T-ReX Research Group

Elettra Sincrotrone Trieste

Technology overview

Table top techniques are a nice complement to synchrotron and FEL facilities



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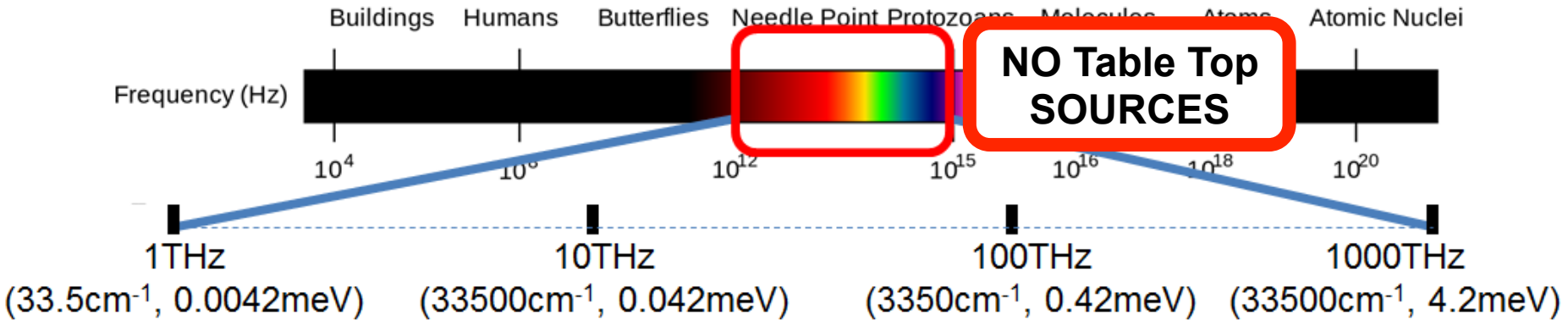
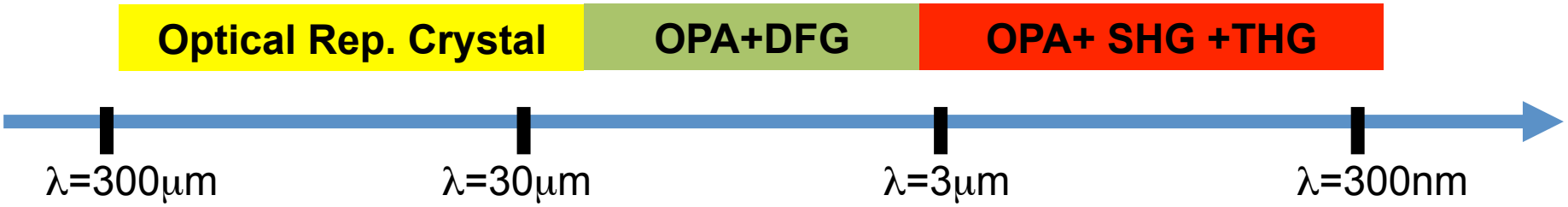


Non-Equilibrium probes



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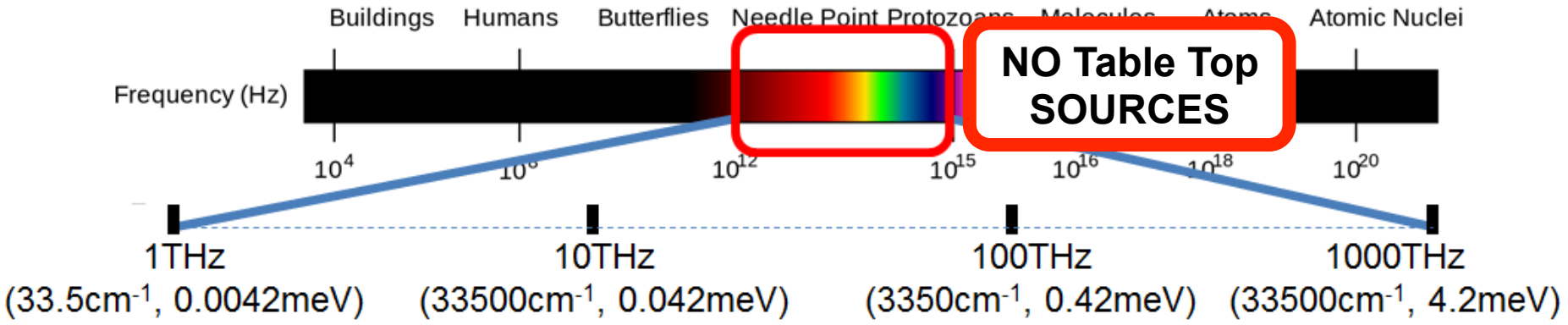

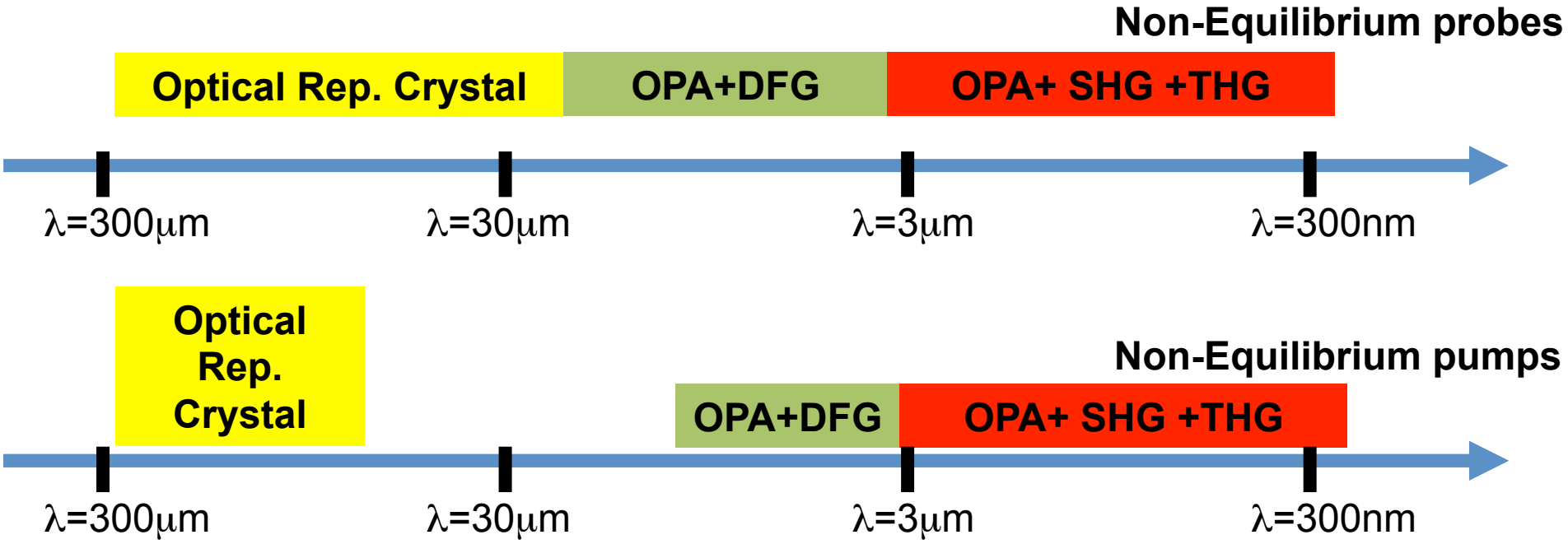

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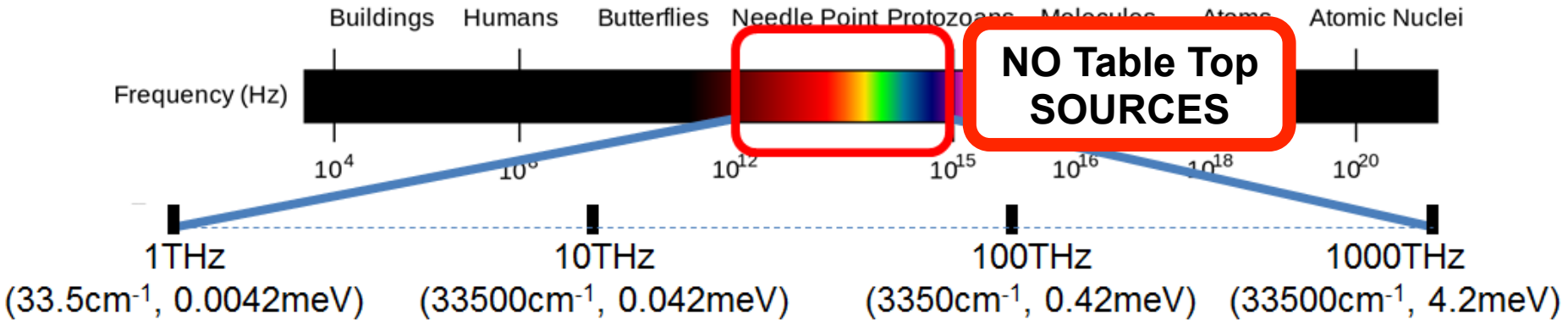
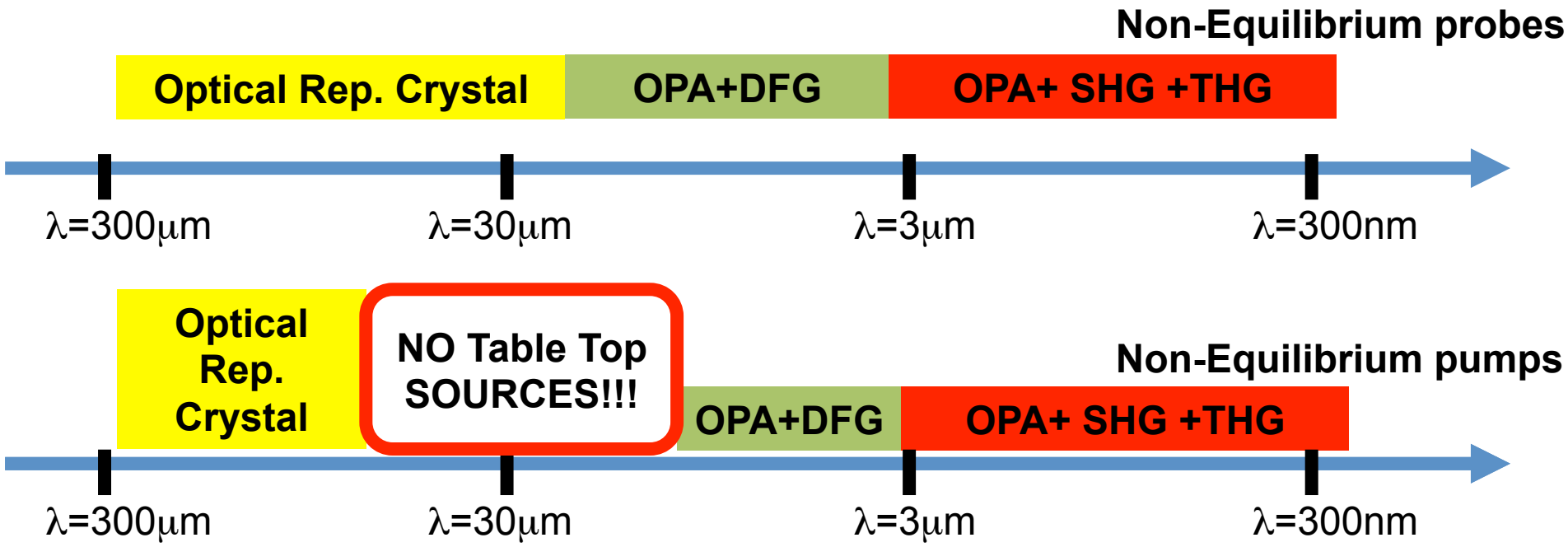


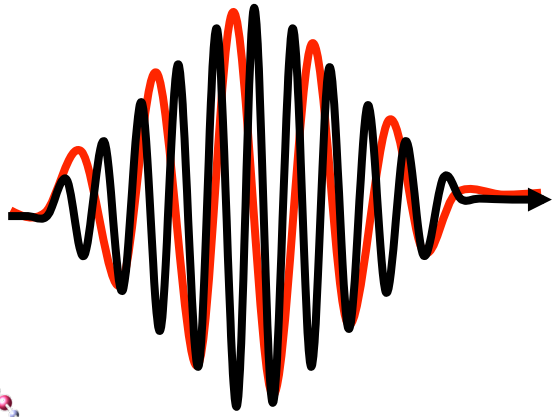


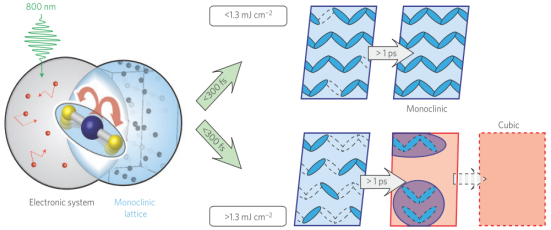
Conclusions

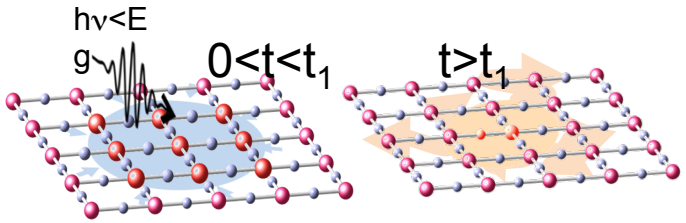
✓**The light pulses do not "just" inject energy into the system**

✓**Classical Parameters** of the light pulses:

- Spectrally selective excitation to understand equilibrium
- Selective excitation to control functionalities

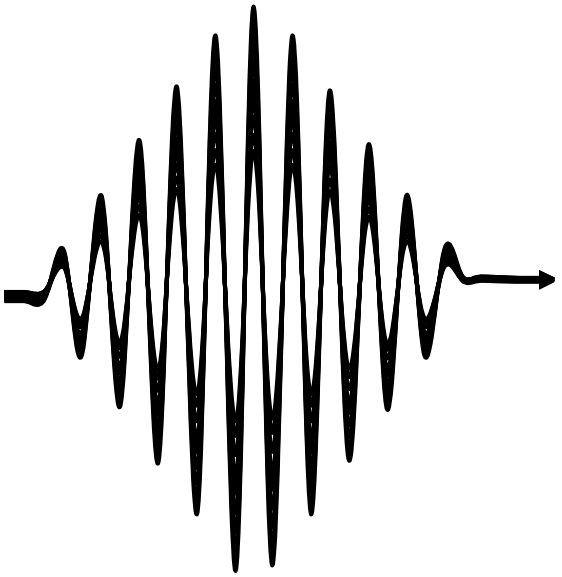


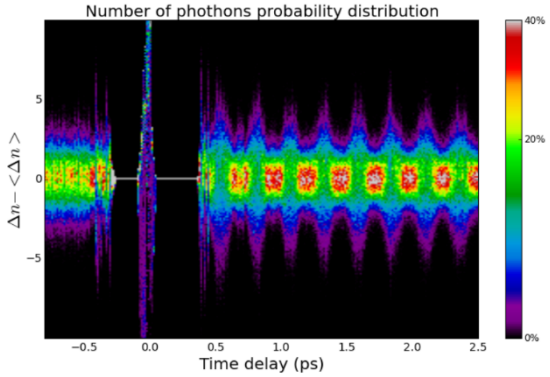


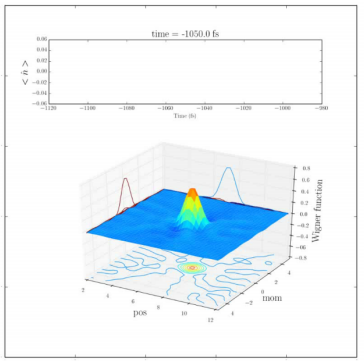


✓ Use the **Quantum State** of light pulses as a spectroscopic tool

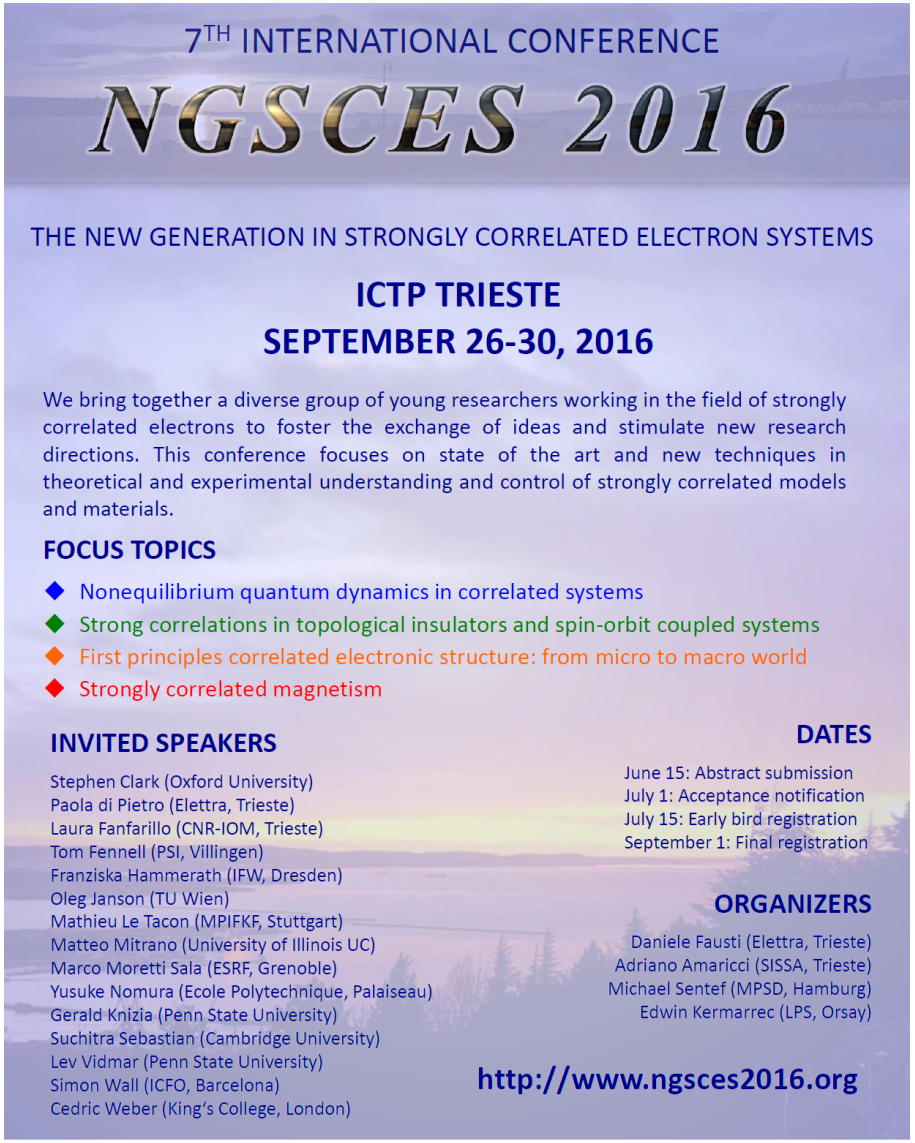
- Photon number fluctuation (Coh. Vs. Squeezed states)
- Quantum state reconstruction







Advert


7TH INTERNATIONAL CONFERENCE
NGSCES 2016
THE NEW GENERATION IN STRONGLY CORRELATED ELECTRON SYSTEMS
ICTP TRIESTE
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Strong correlations in topological insulators and spin-orbit coupled systems
First principles correlated electronic structure: from micro to macro world
Strongly correlated magnetism
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Paola di Pietro (Elettra, Trieste)
Laura Fanfarillo (CNR-IOM, Trieste)
Tom Fennell (PSI, Villingen)
Franziska Hammerath (IFW, Dresden)
Oleg Janson (TU Wien)
Mathieu Le Tacon (MPIFKF, Stuttgart)
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Marco Moretti Sala (ESRF, Grenoble)
Yusuke Nomura (Ecole Polytechnique, Palaiseau)
Gerald Knizia (Penn State University)
Suchitra Sebastian (Cambridge University)
Lev Vidmar (Penn State University)
Simon Wall (ICFO, Barcelona)
Cedric Weber (King's College, London)
DATES
June 15: Abstract submission
July 1: Acceptance notification
July 15: Early bird registration
September 1: Final registration
ORGANIZERS
Daniele Fausti (Elettra, Trieste)
Adriano Amaricci (SISSA, Trieste)
Michael Sentef (MPSD, Hamburg)
Edwin Kermarrec (LPS, Orsay)
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