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DEGLI STUDI DI TRIESTE

T-ReX Research Group

Elettra Sincrotrone Trieste

Witnessing quasi-particle dynamics in strongly correlated electron system

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

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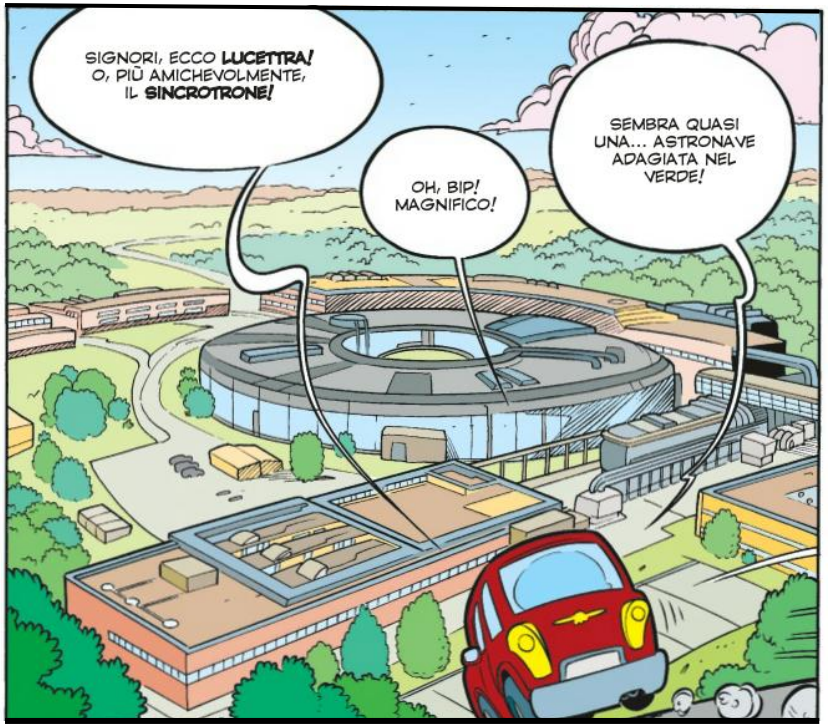

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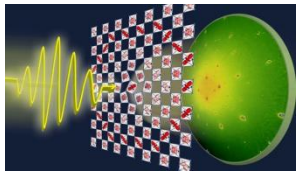
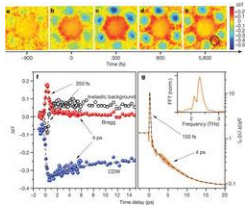
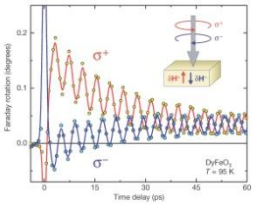
Time domain studies of complex materials

-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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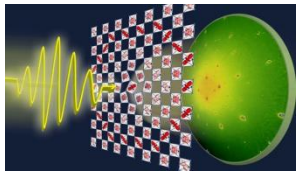

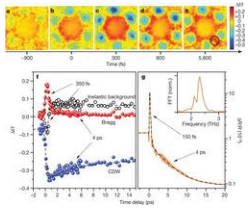

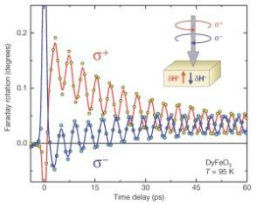

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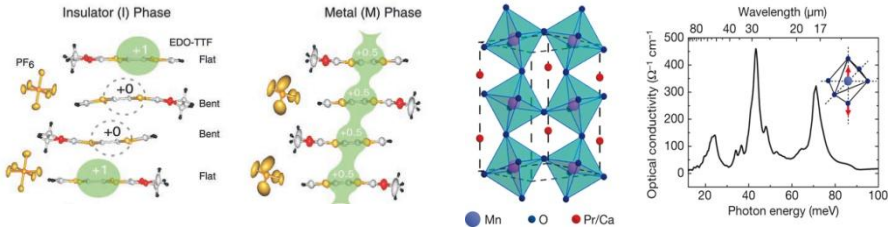
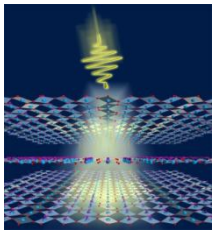
-Pump & Probe ⟹ Optical Control of Material



Science 307, 2005, Nature 449(2007)

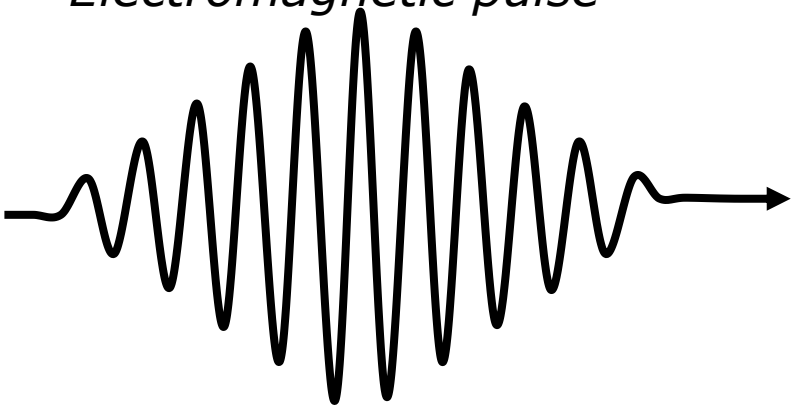
- ✓Photo-Induced phase transitions
- ✓Coherent control (IR and THz)
- ✓Light control of quantum coherent phases



Science 331, 2011

Pump & Probe

Electromagnetic pulse



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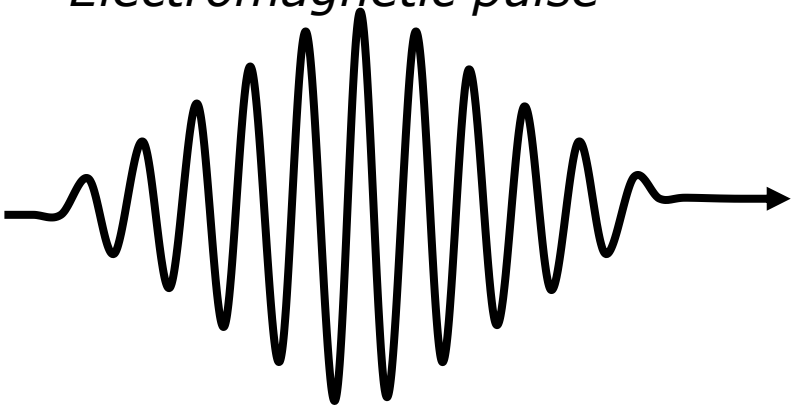
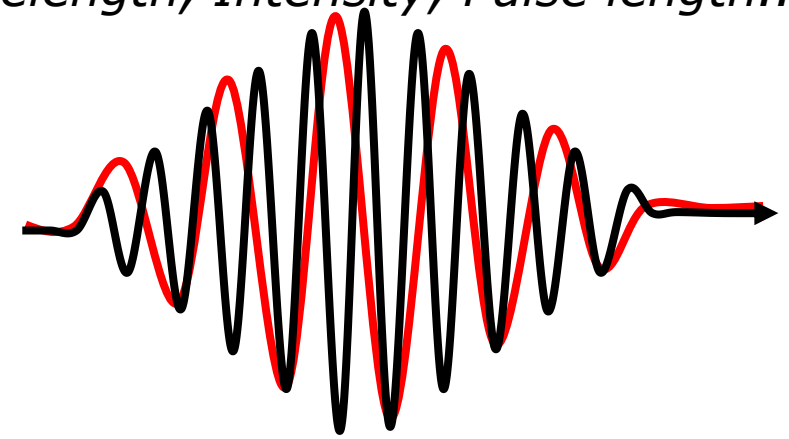


Wavelength, Intensity, Pulse length...



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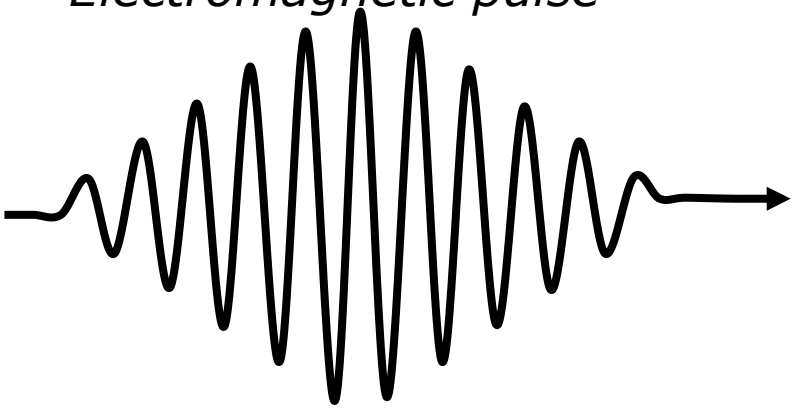

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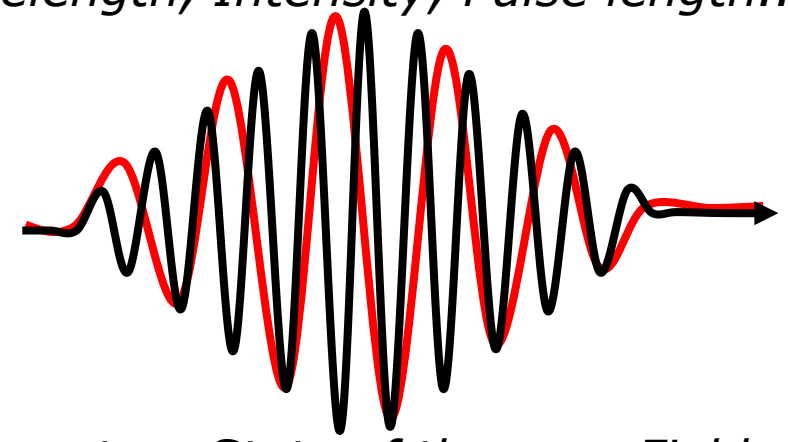
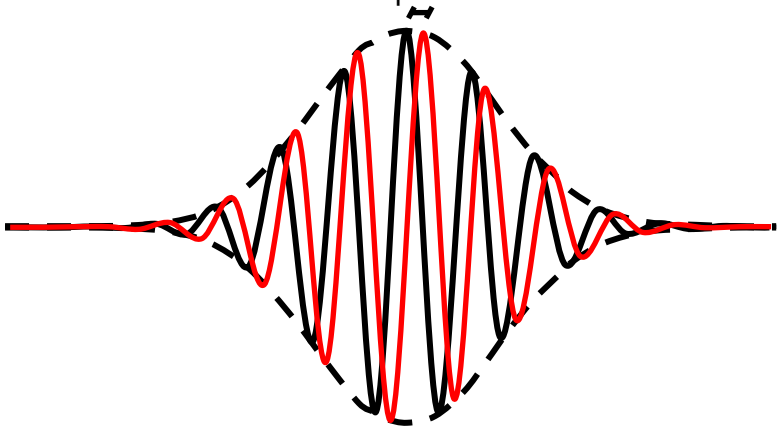
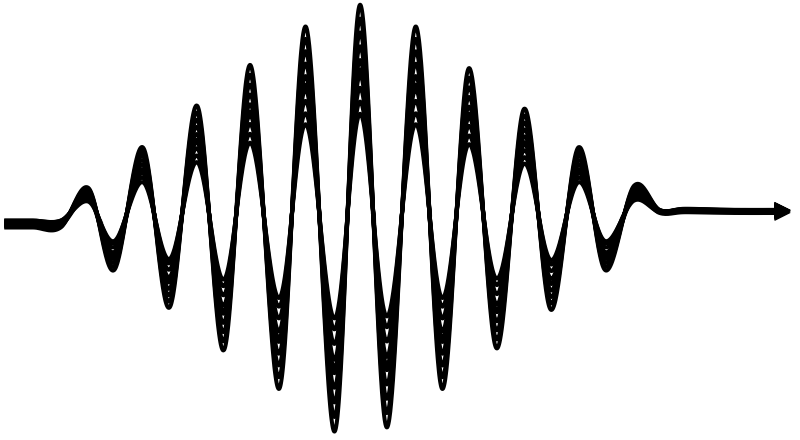


Carrier Envelope Phase

$\Delta\phi=\pi/2$



Quantum State of the e.m. Field



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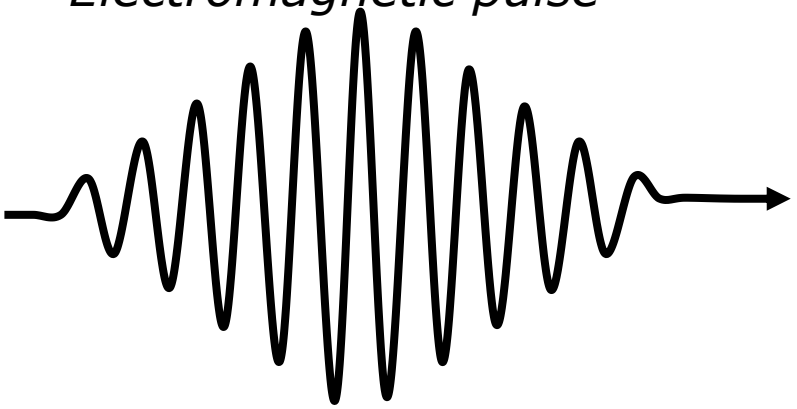

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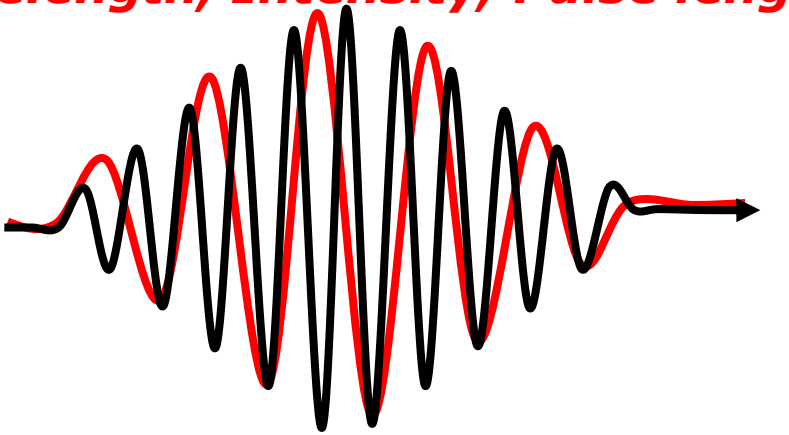

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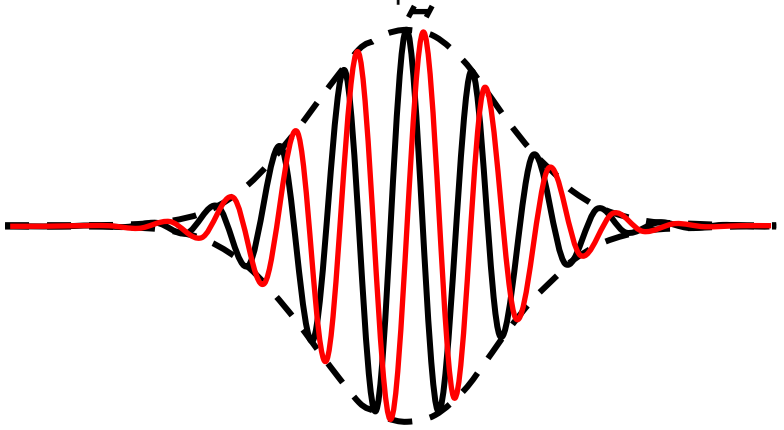

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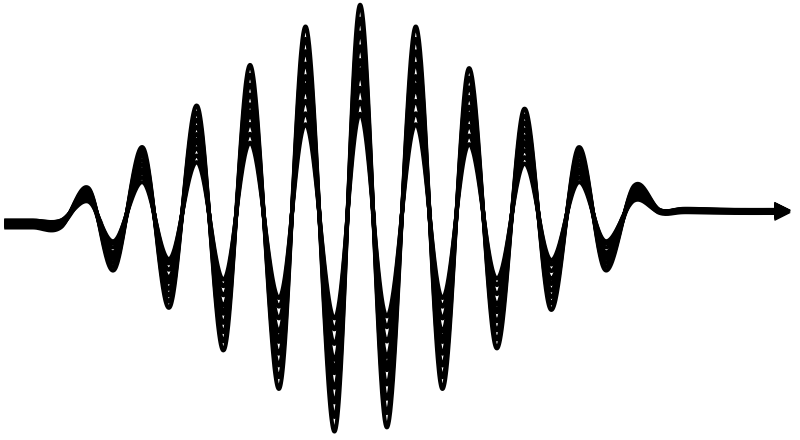
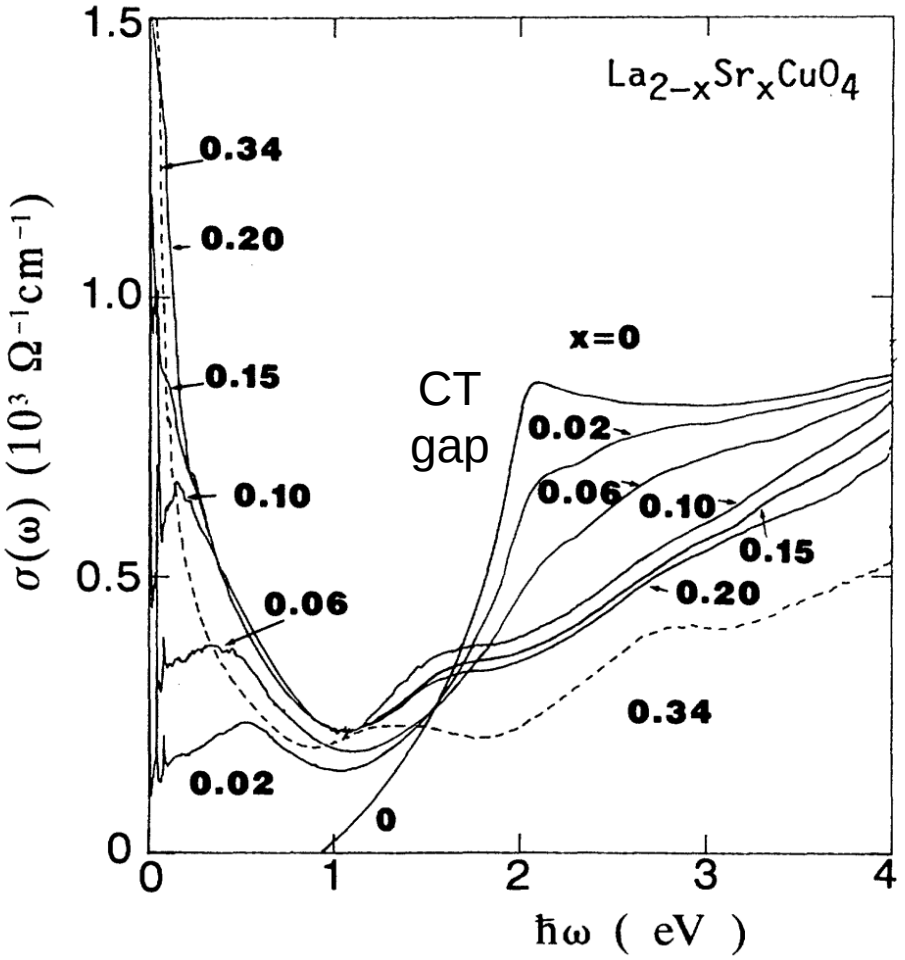


Optical properties of $La_{2-x}Sr_xCuO_4$



PRB 43 7942 1991

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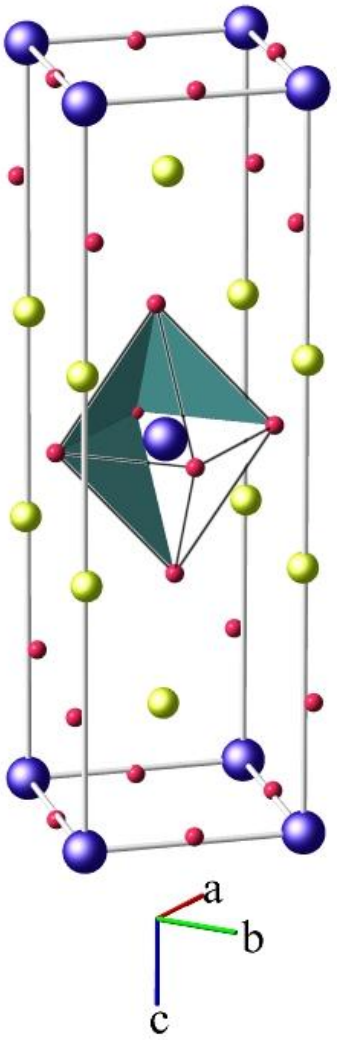
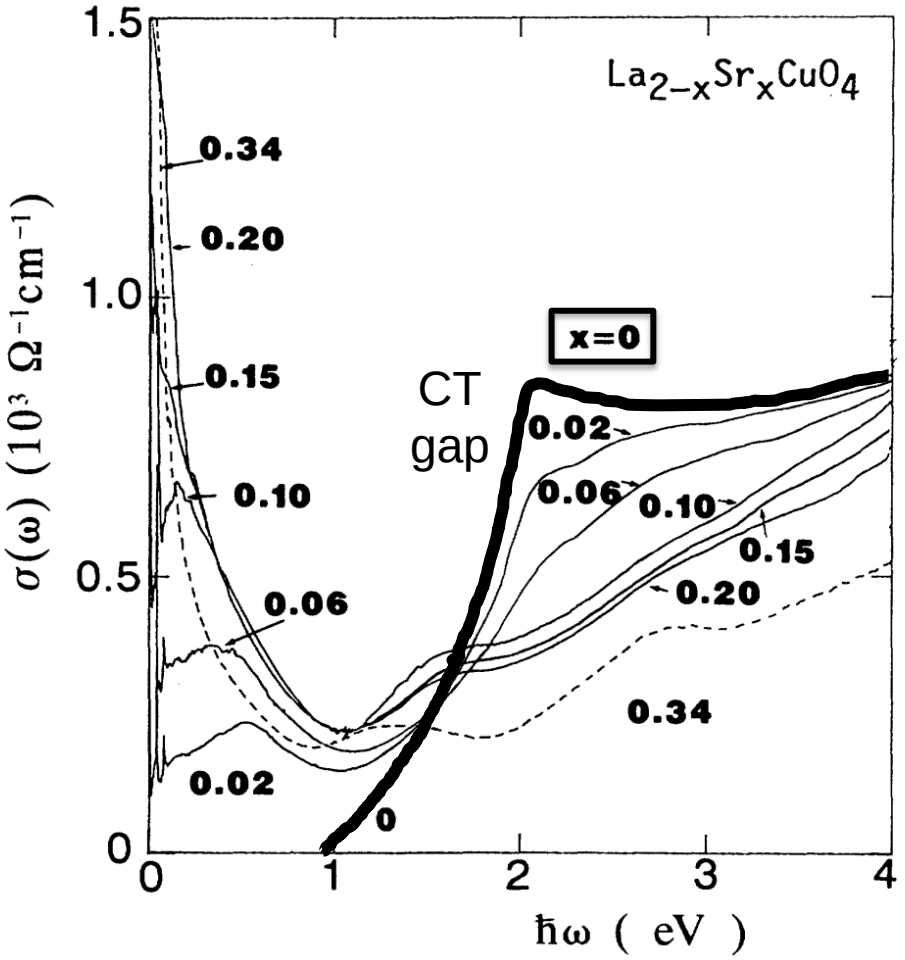
La_2CuO_4





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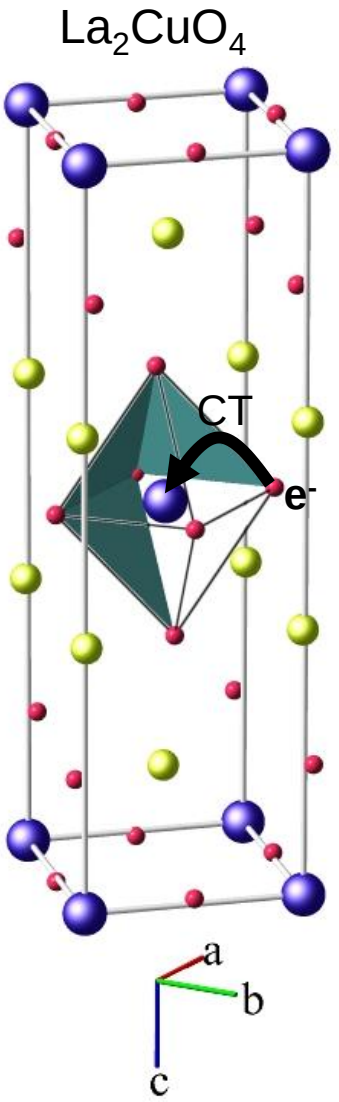

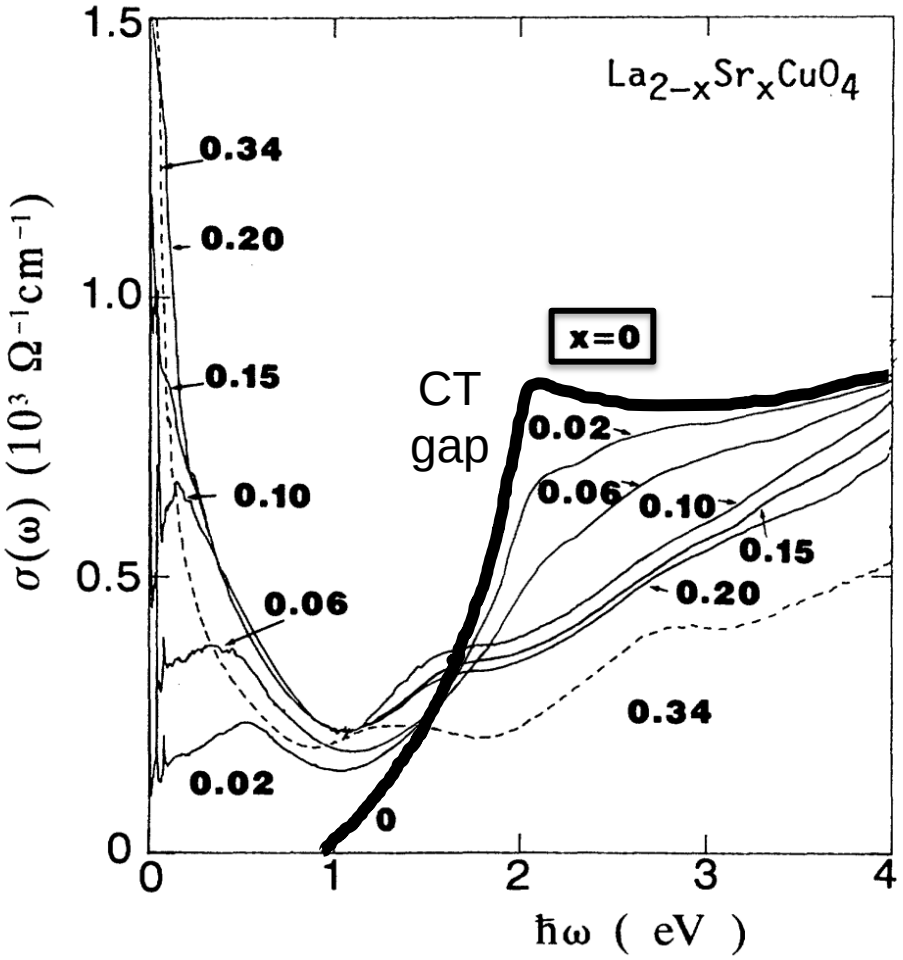

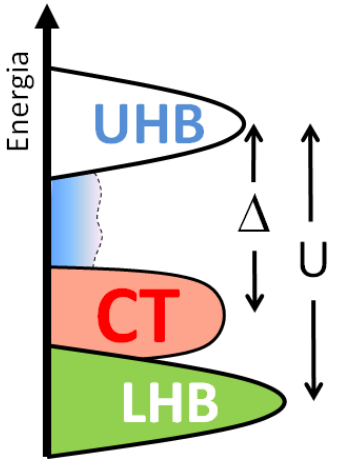

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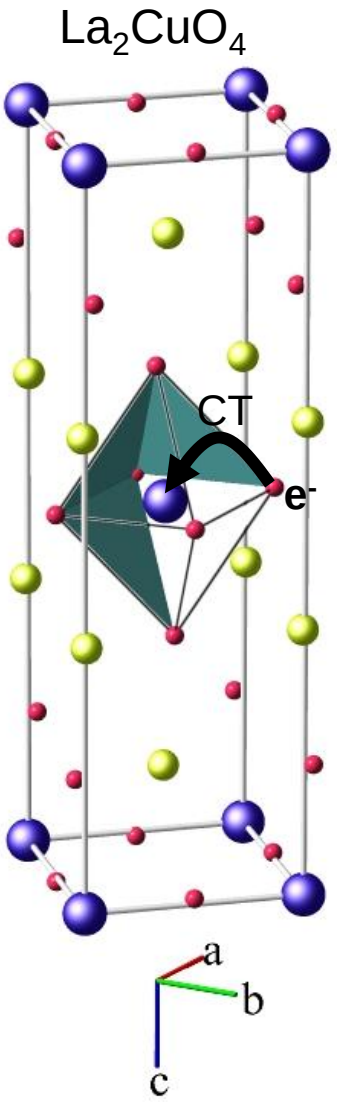

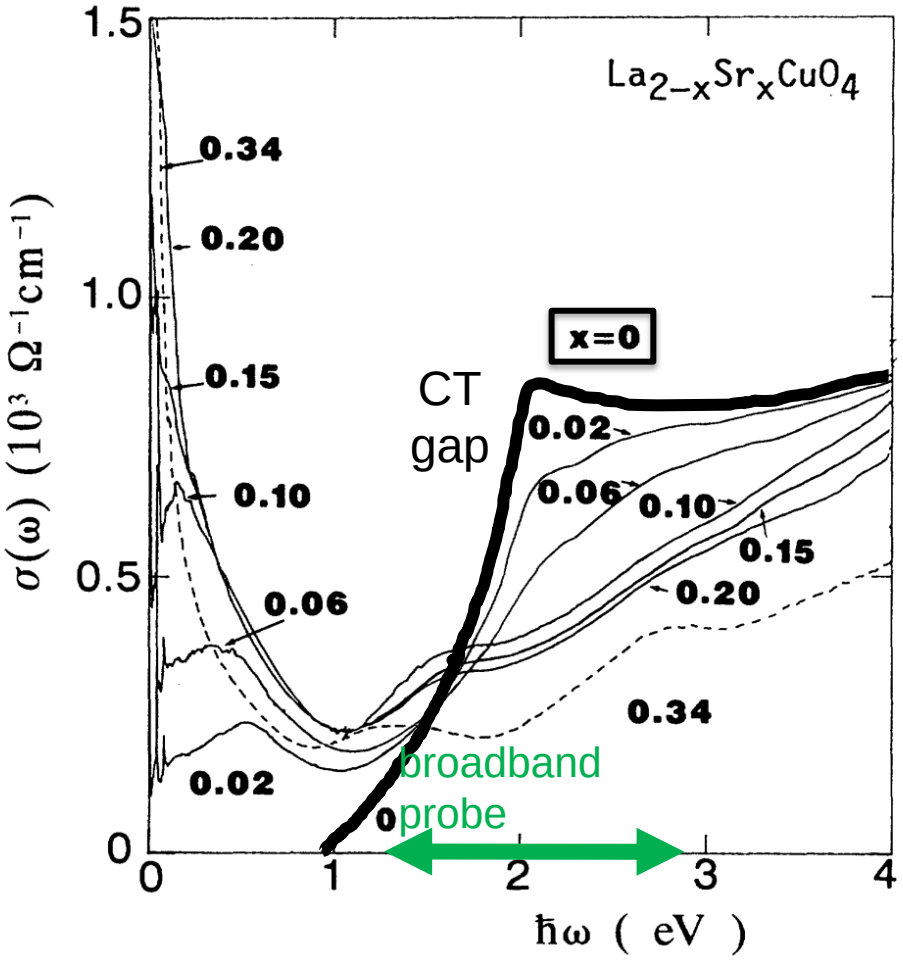

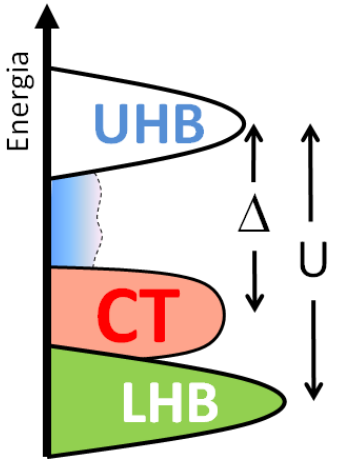

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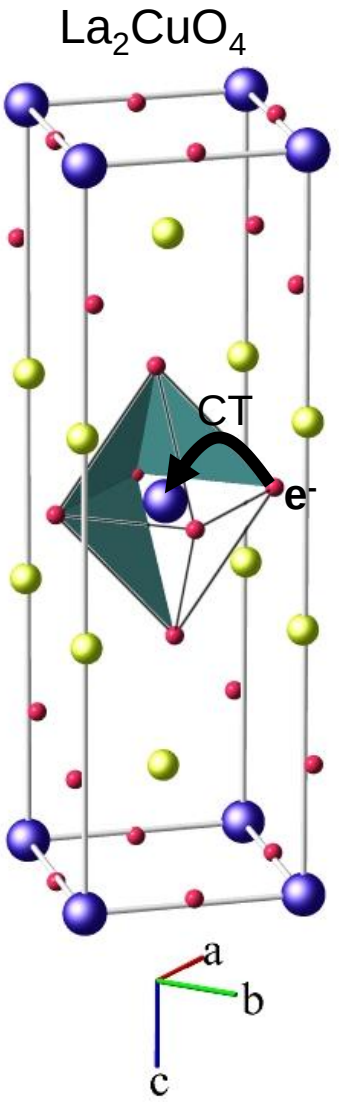

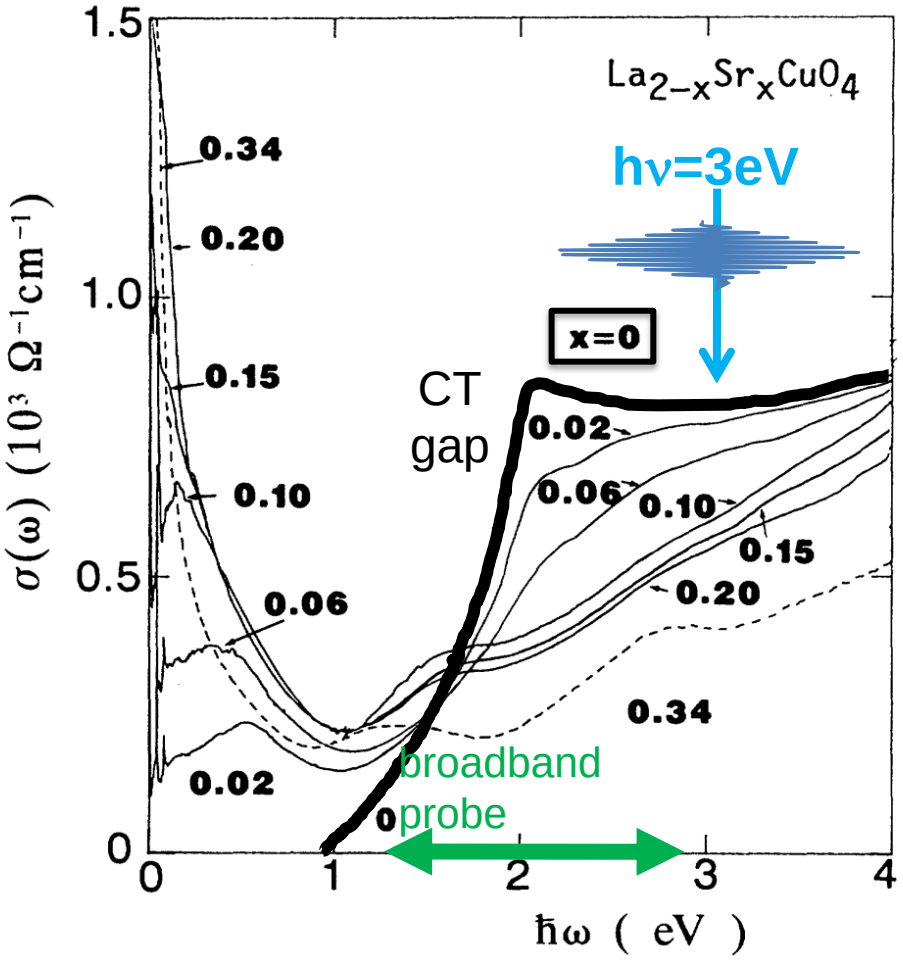

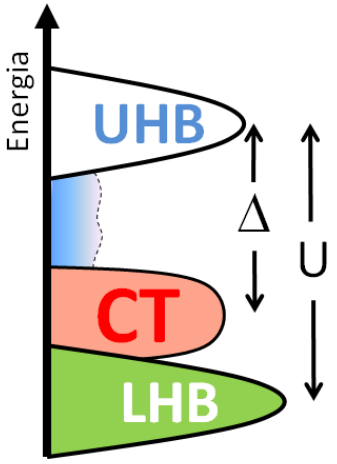

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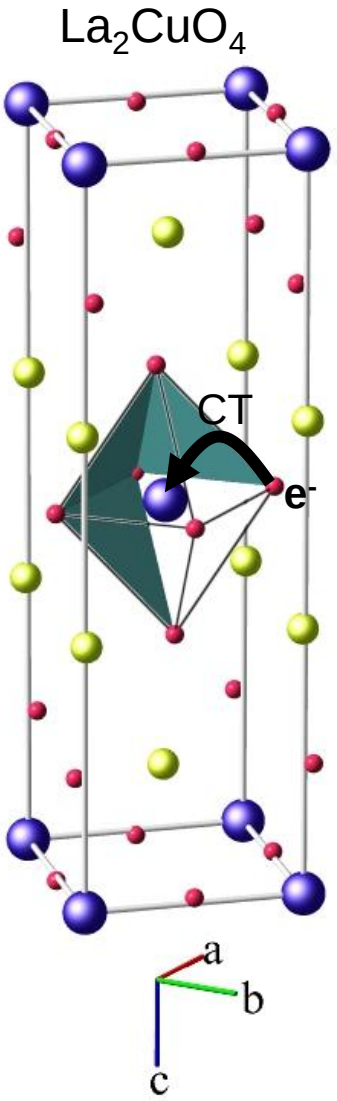

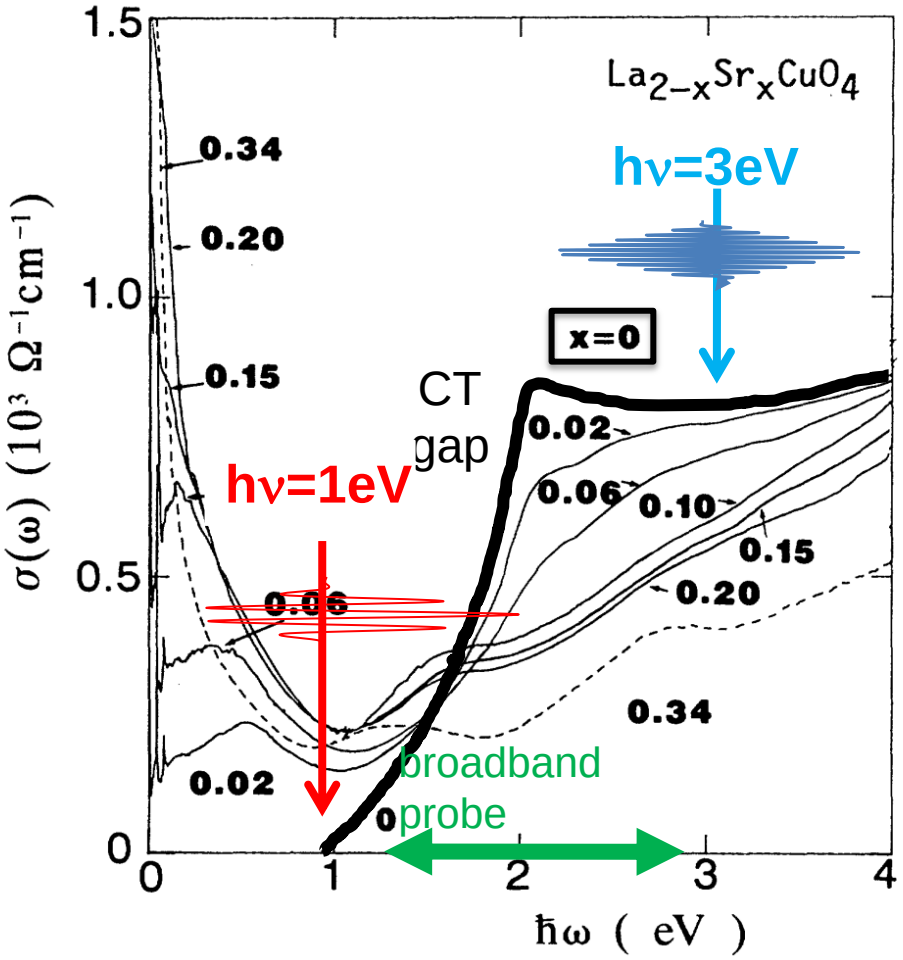

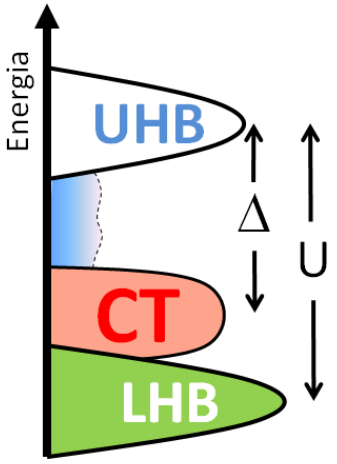

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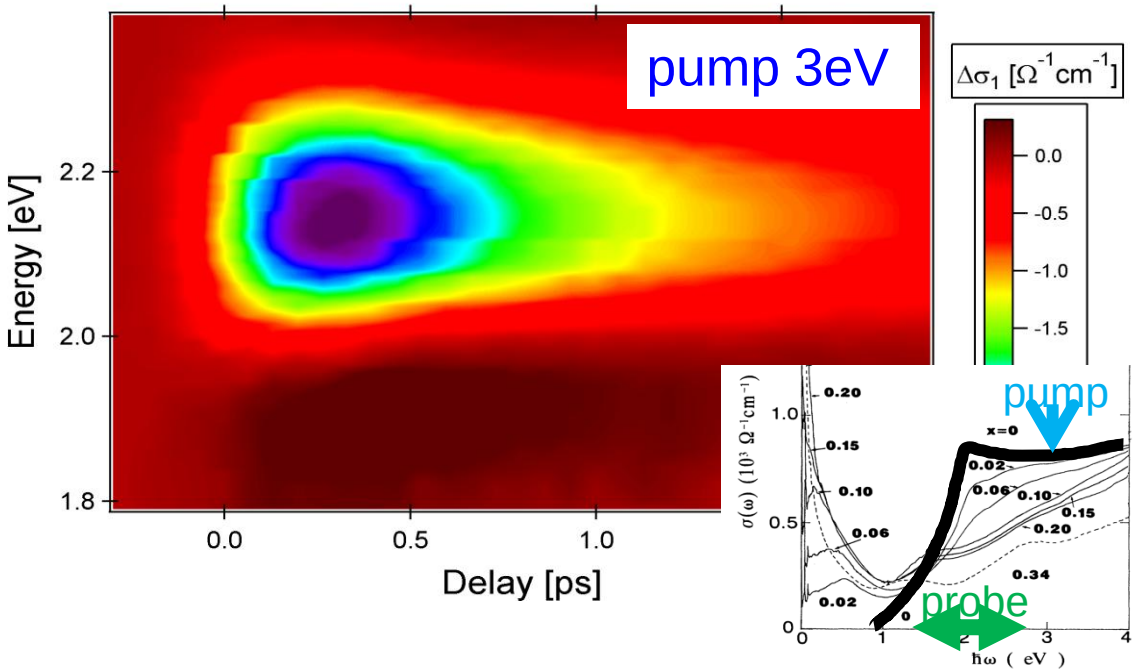
Selectivity of the excitation process



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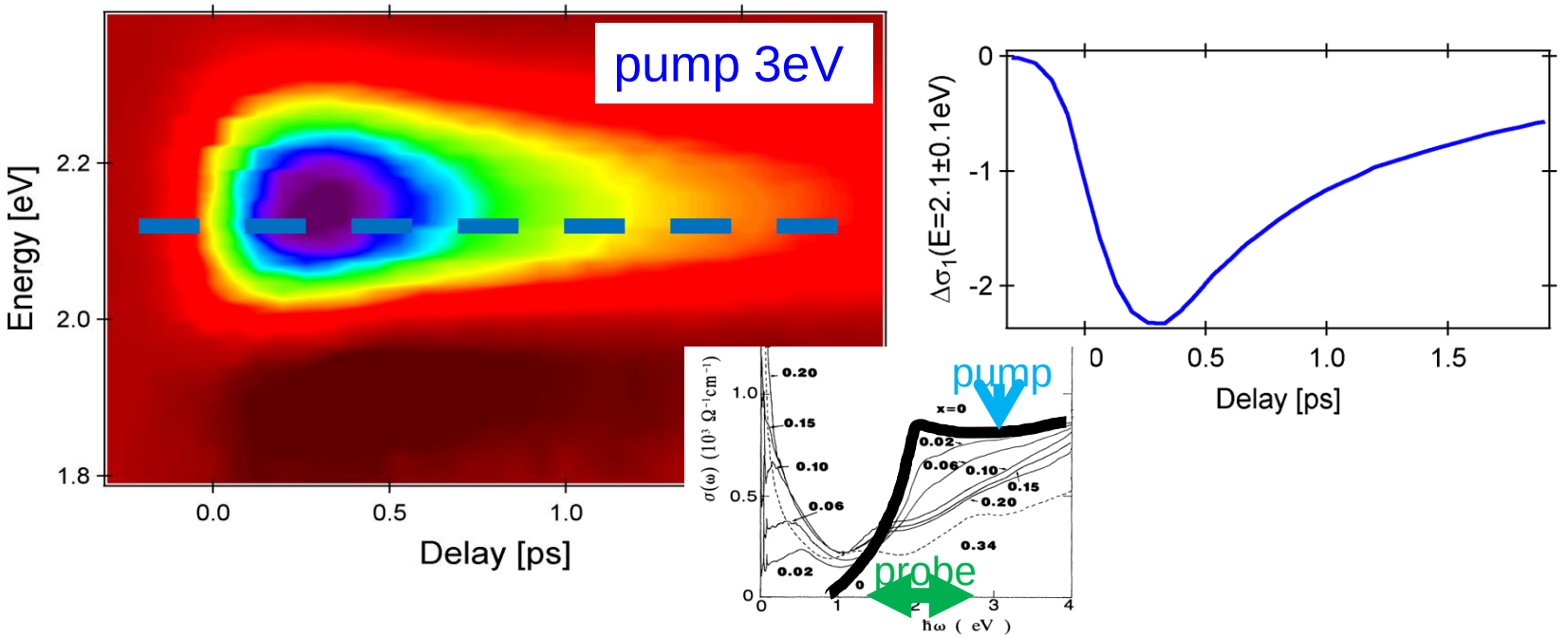

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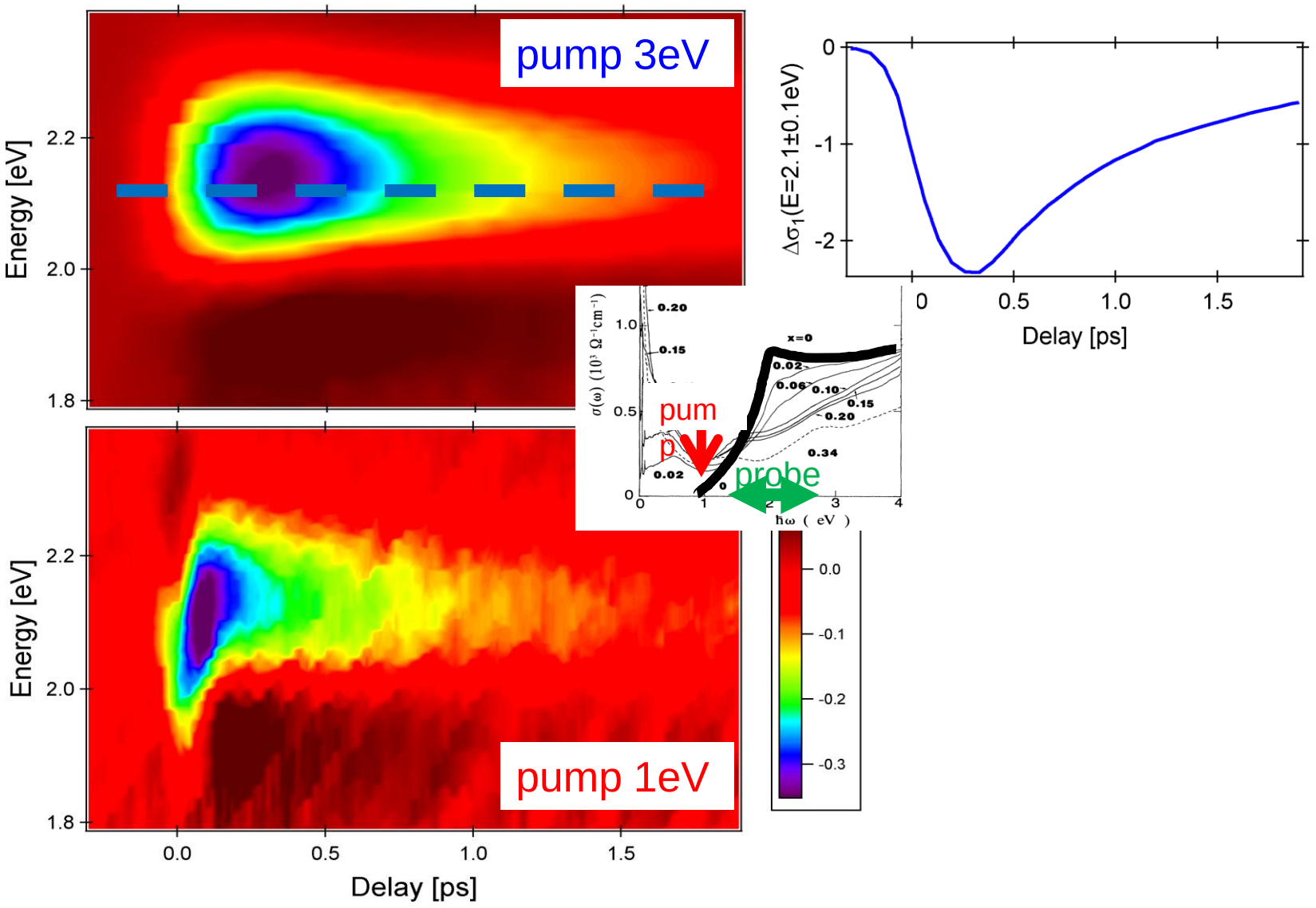

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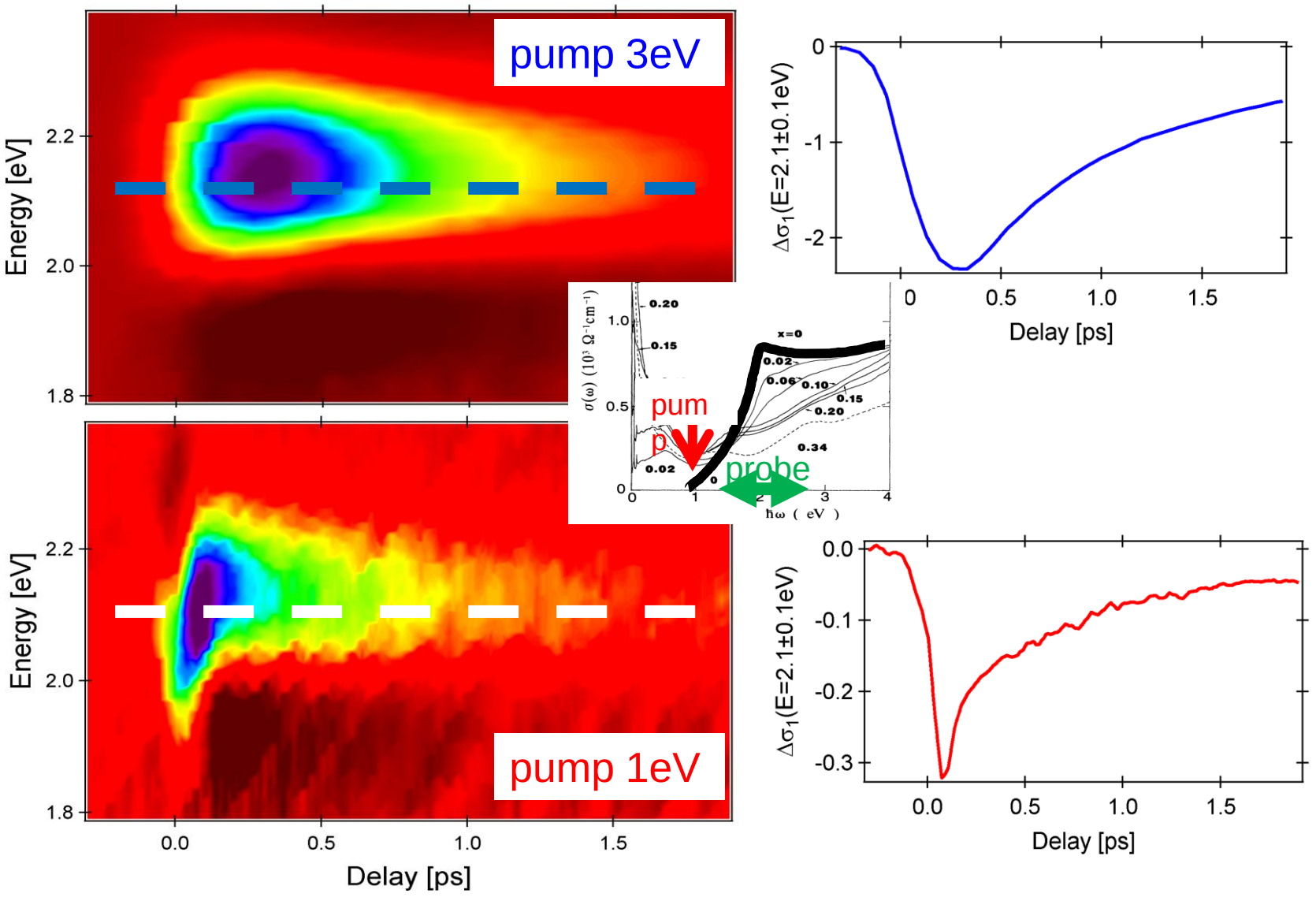

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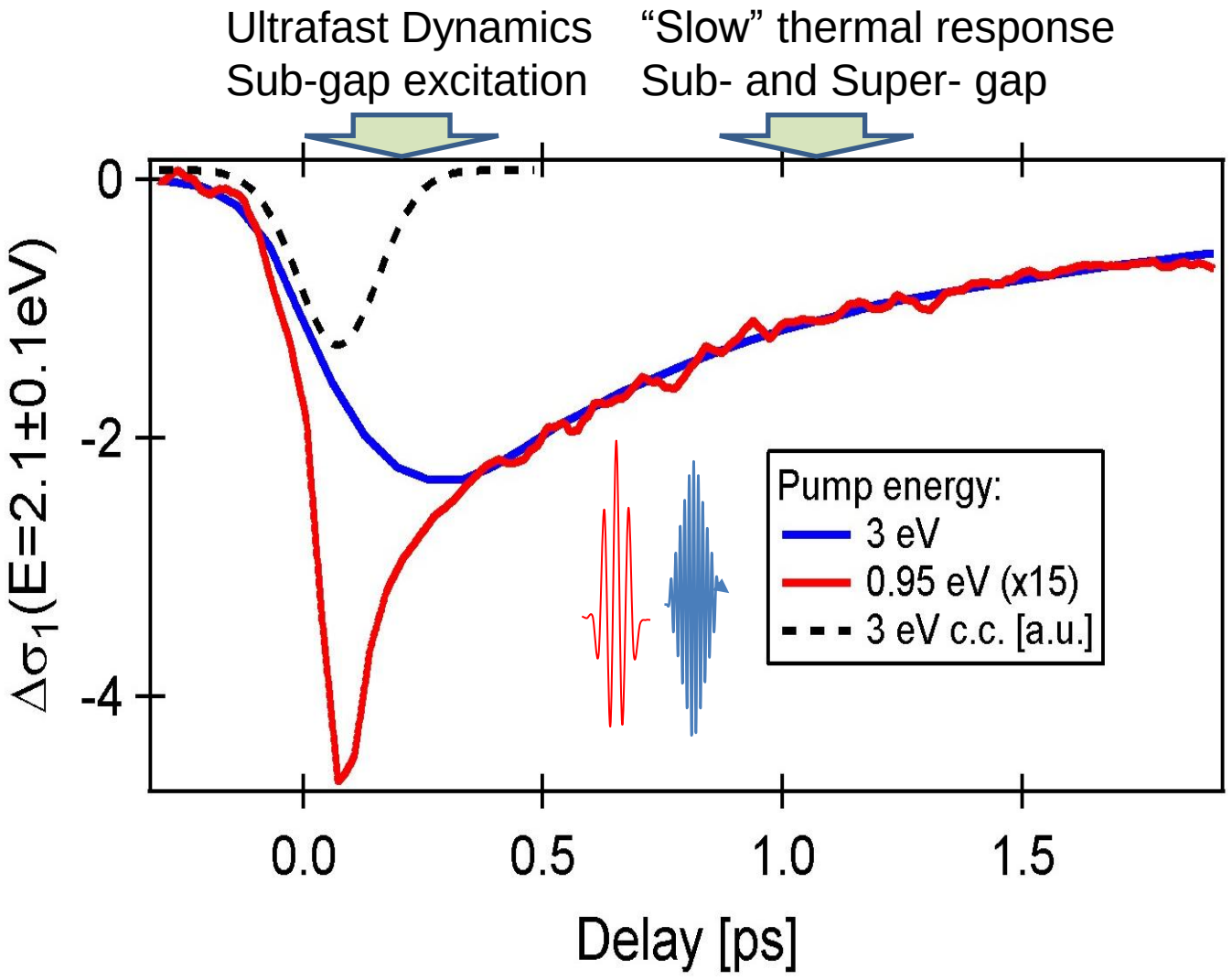

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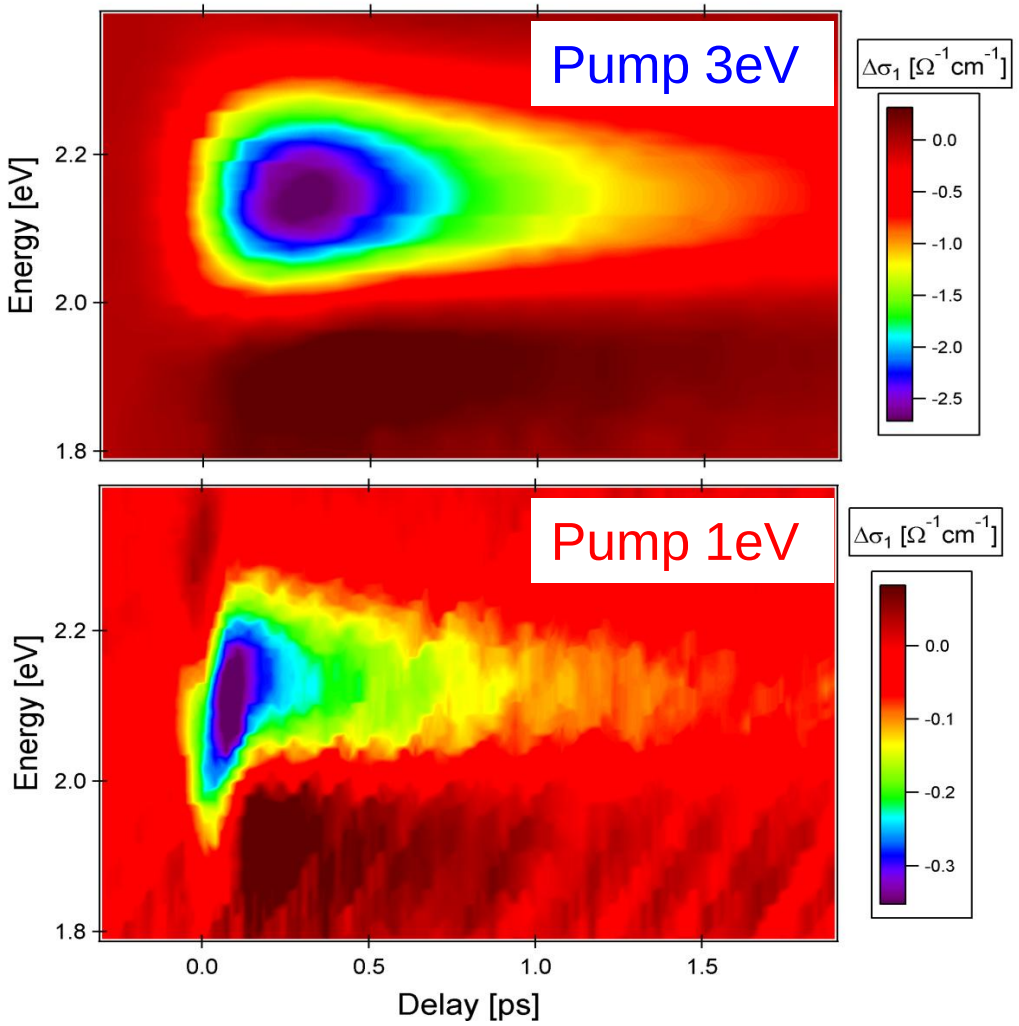

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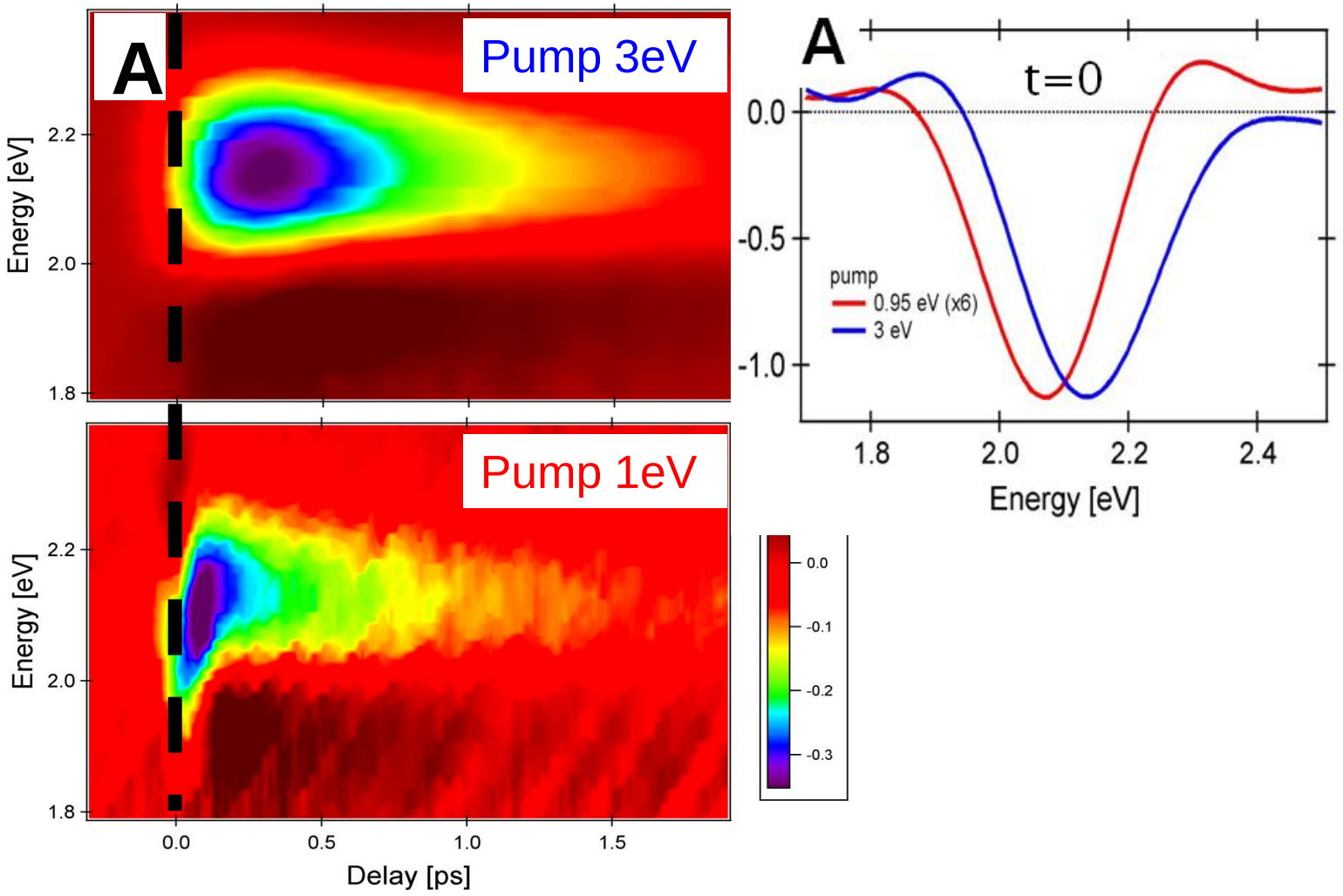

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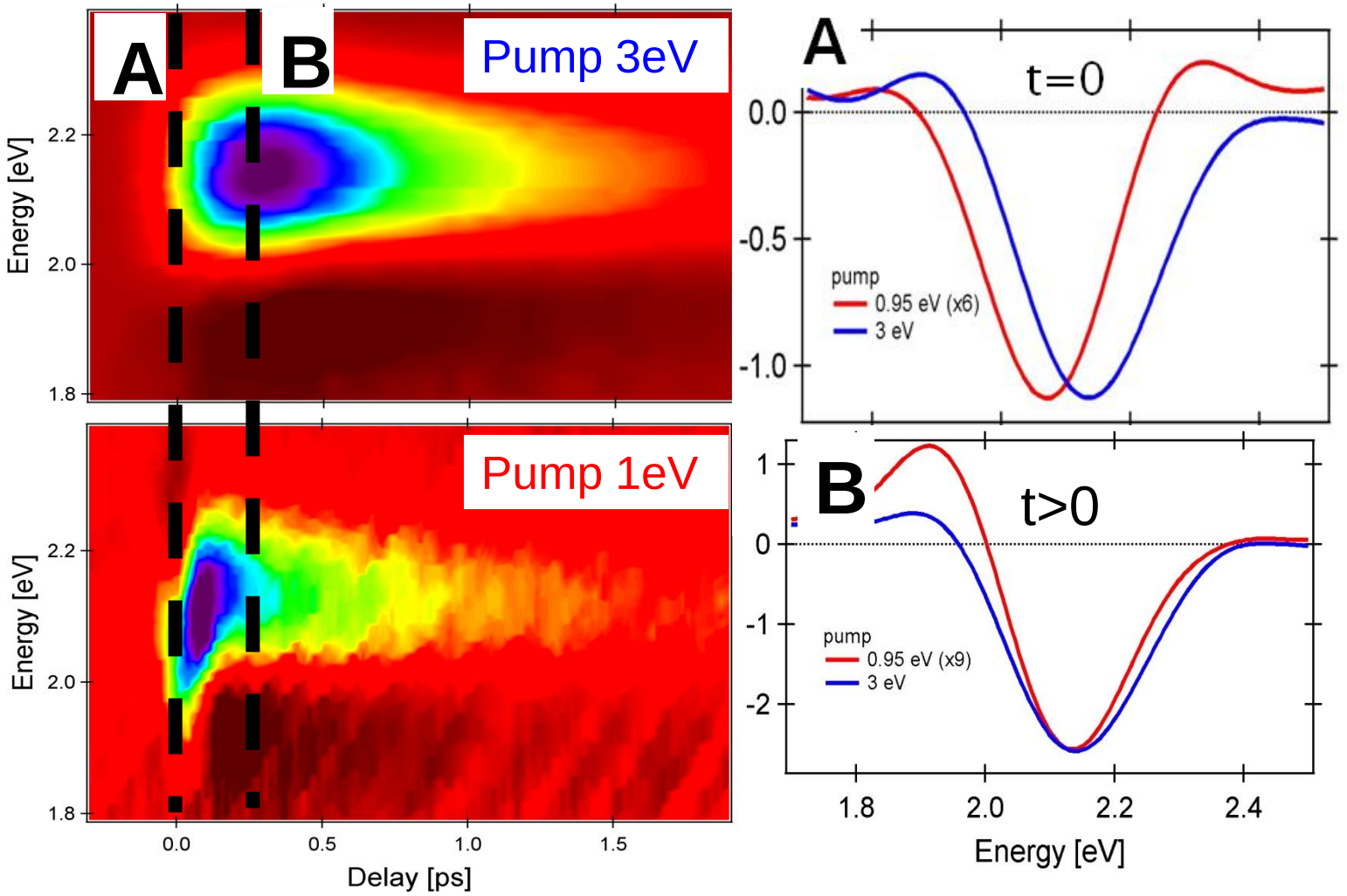

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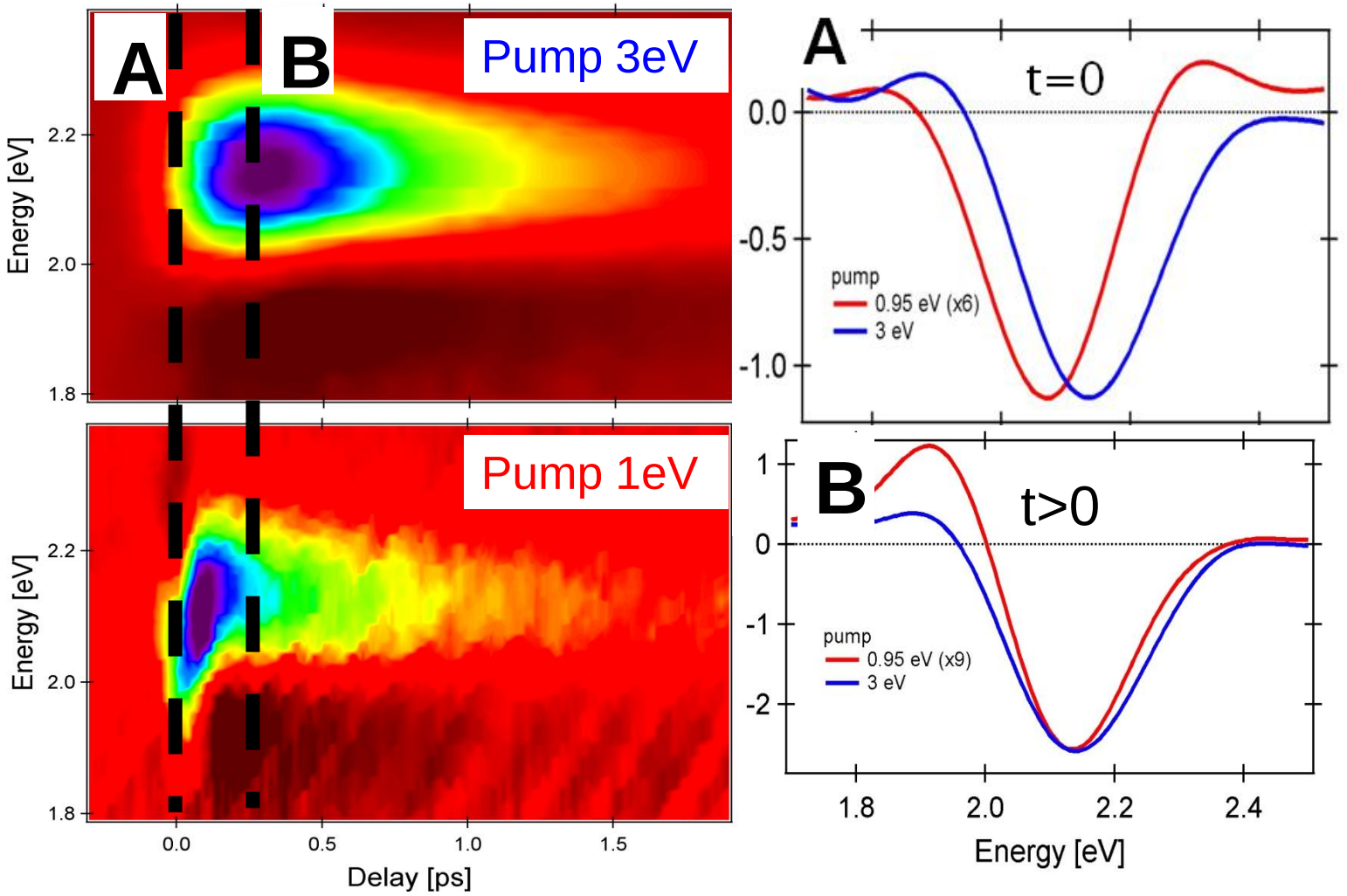

Hubbard Holstein Hamiltonian

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

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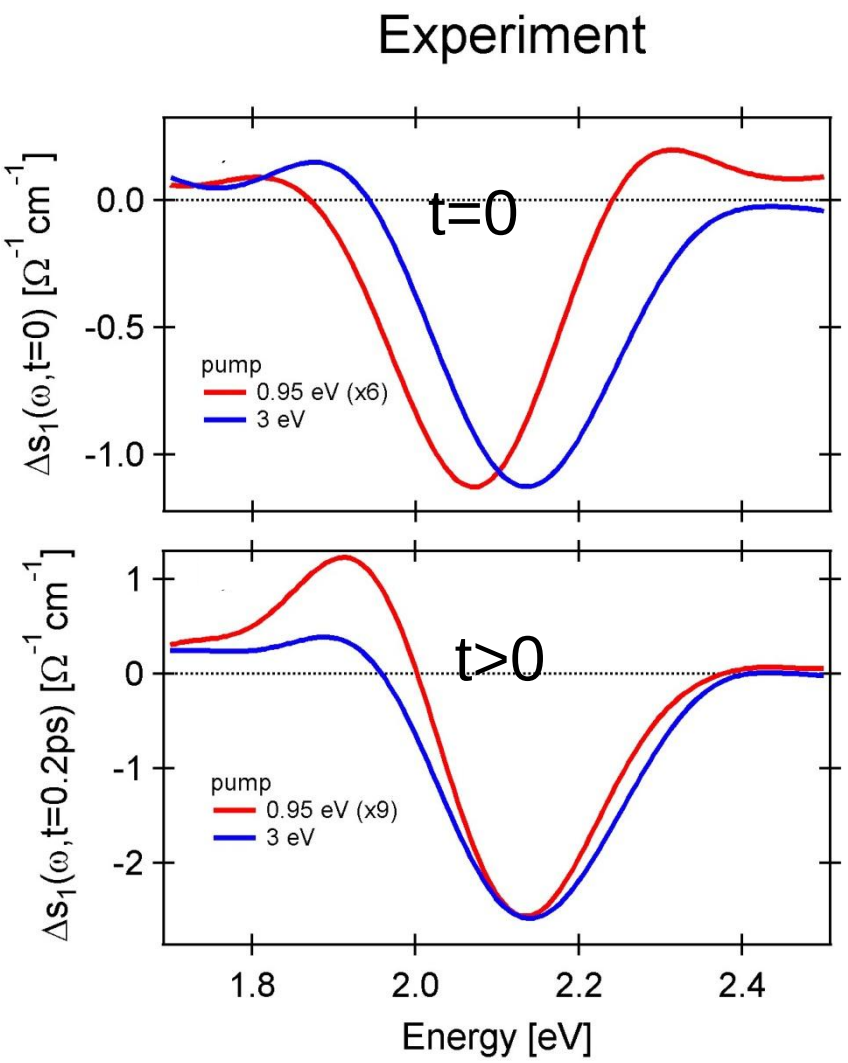
Experiment Vs. Theory



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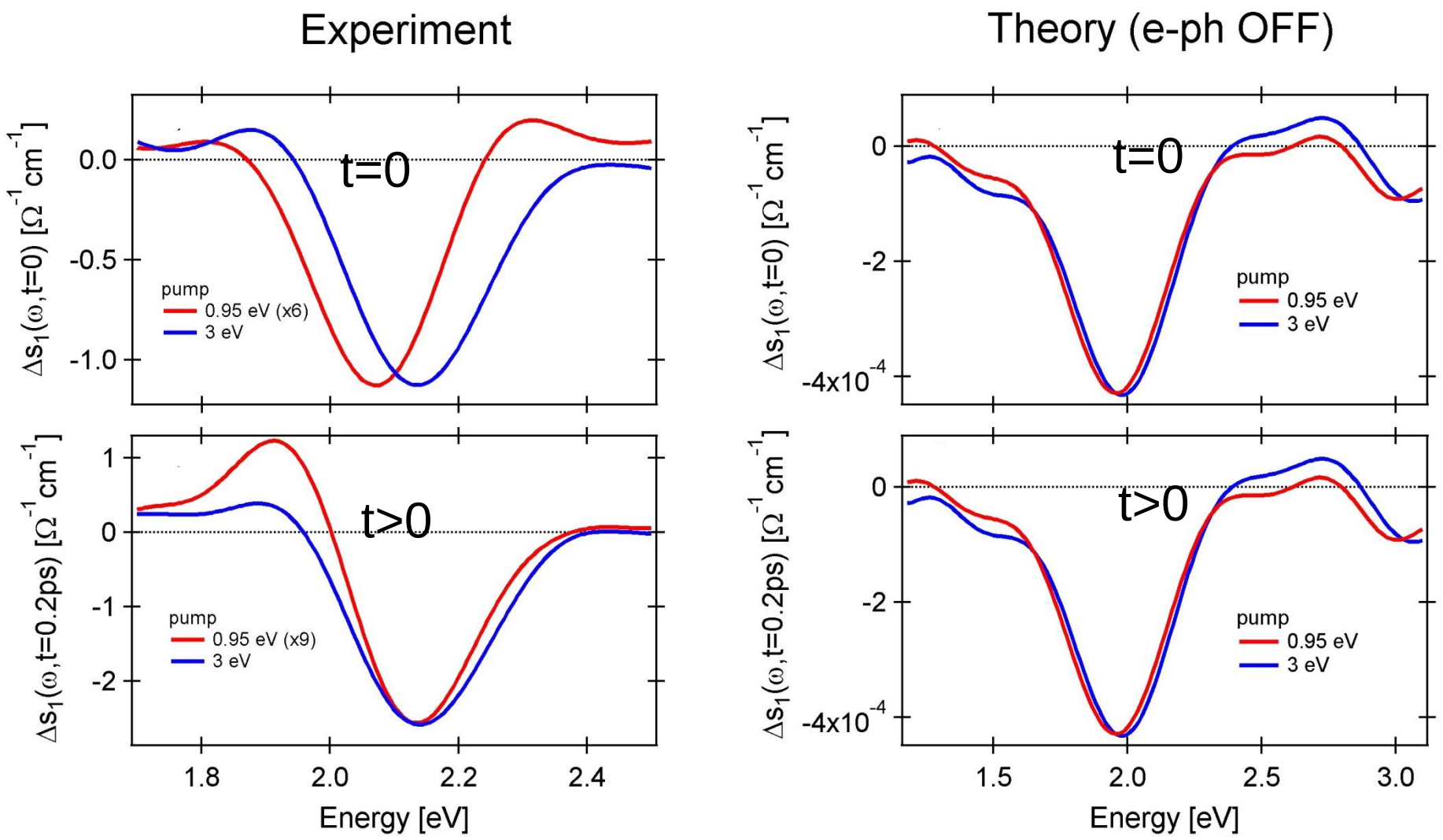

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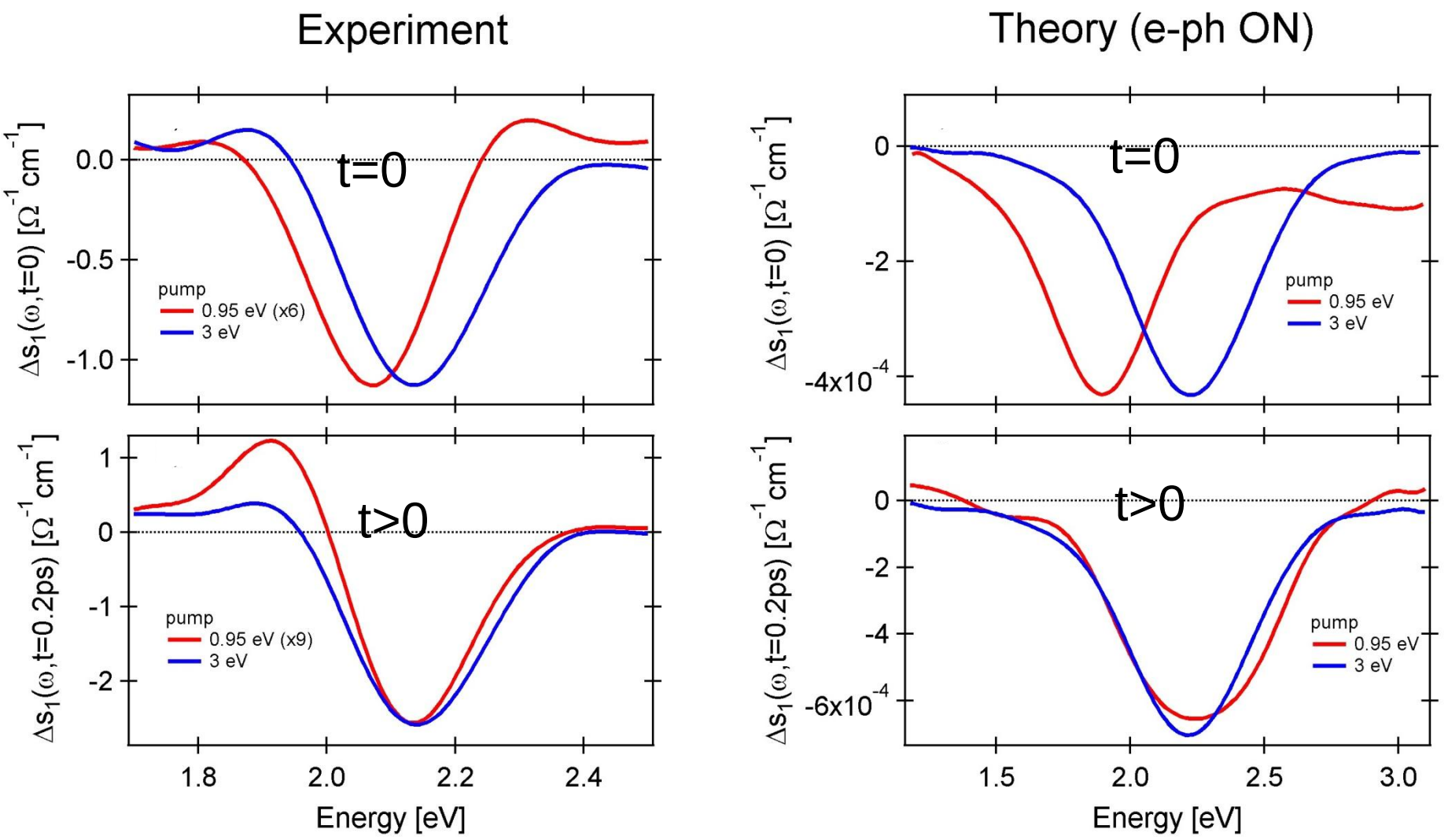
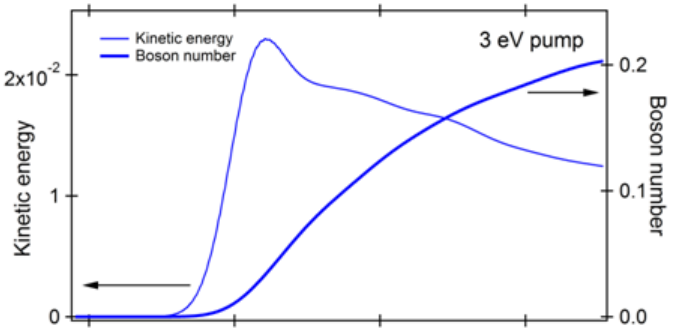
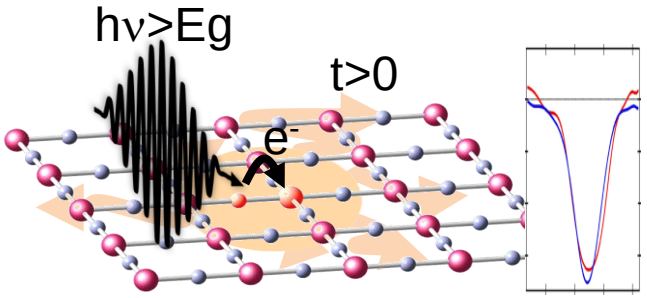


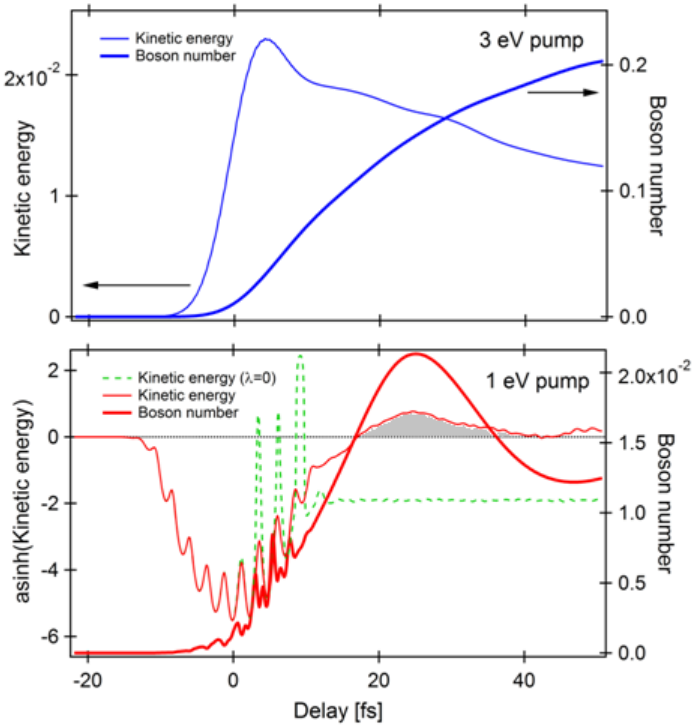
High Vs. Low-photon energy excitation

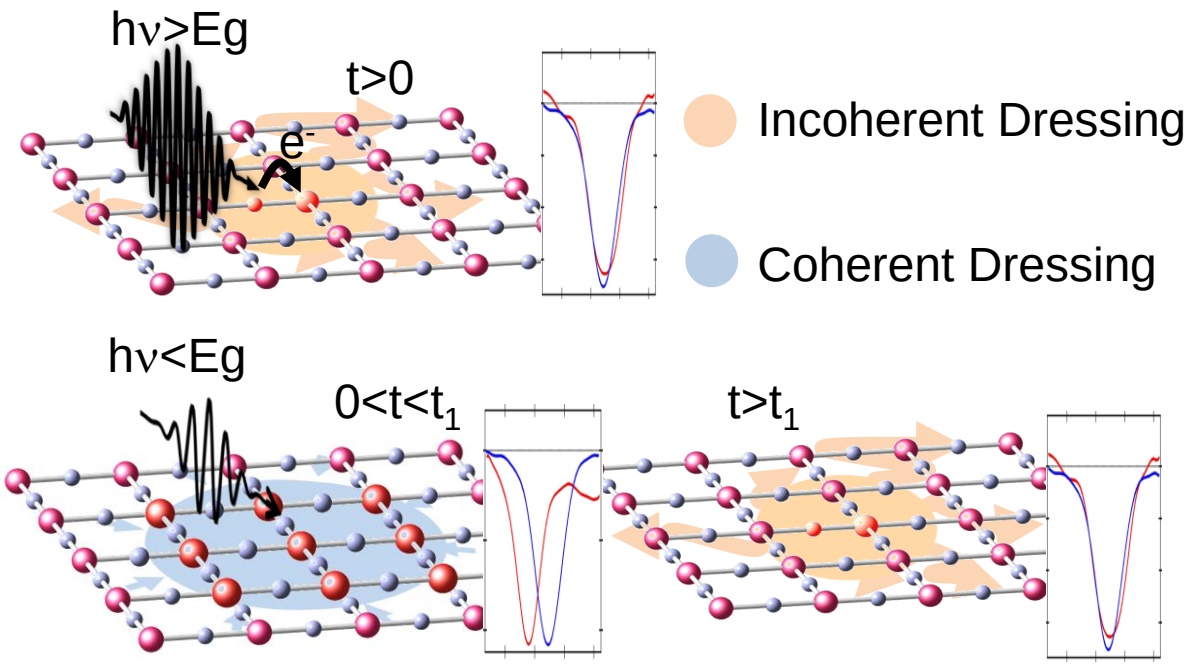




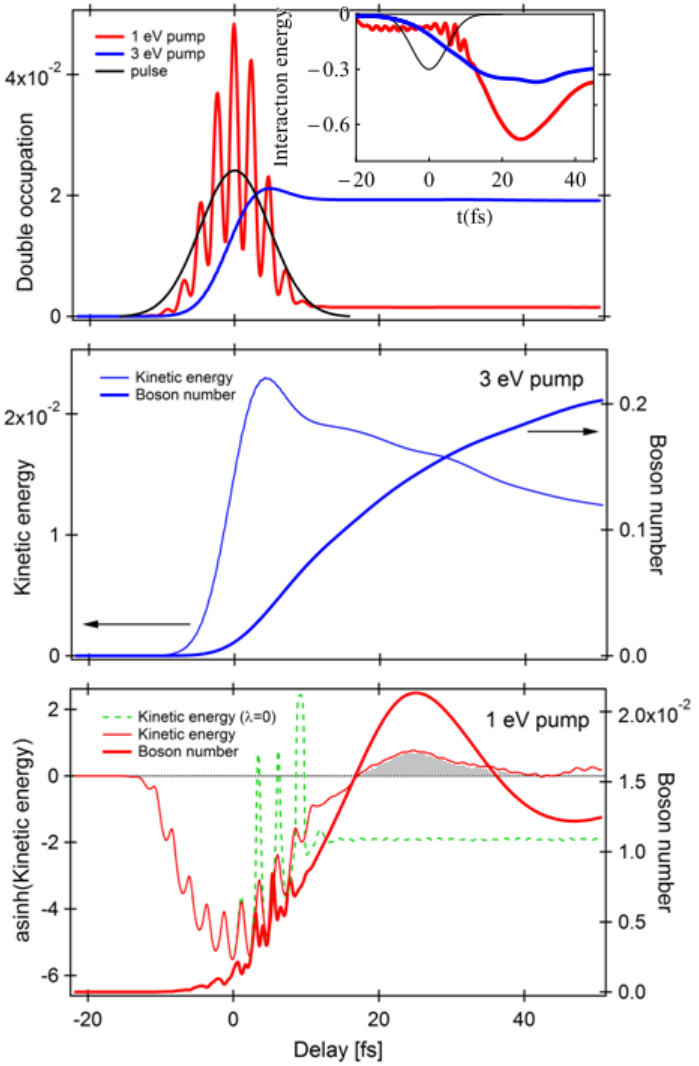
Incoherent Dressing

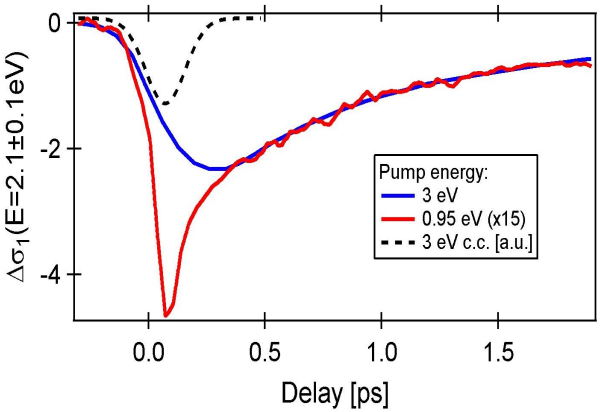
High Vs. Low-photon energy excitation

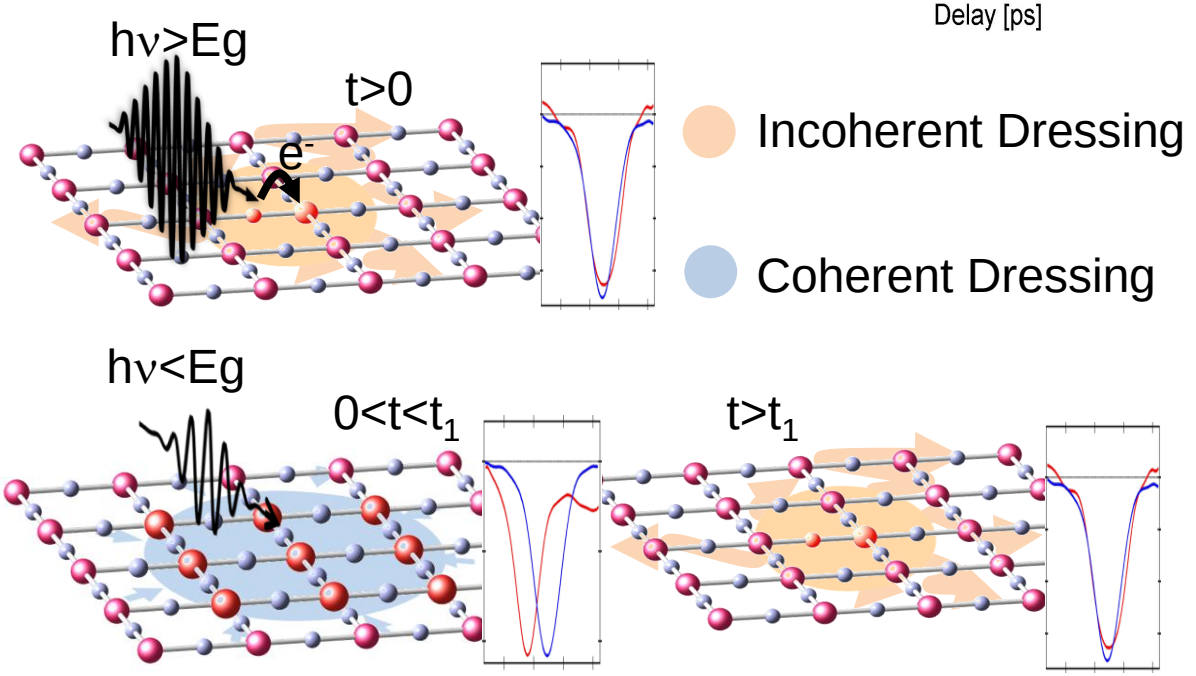




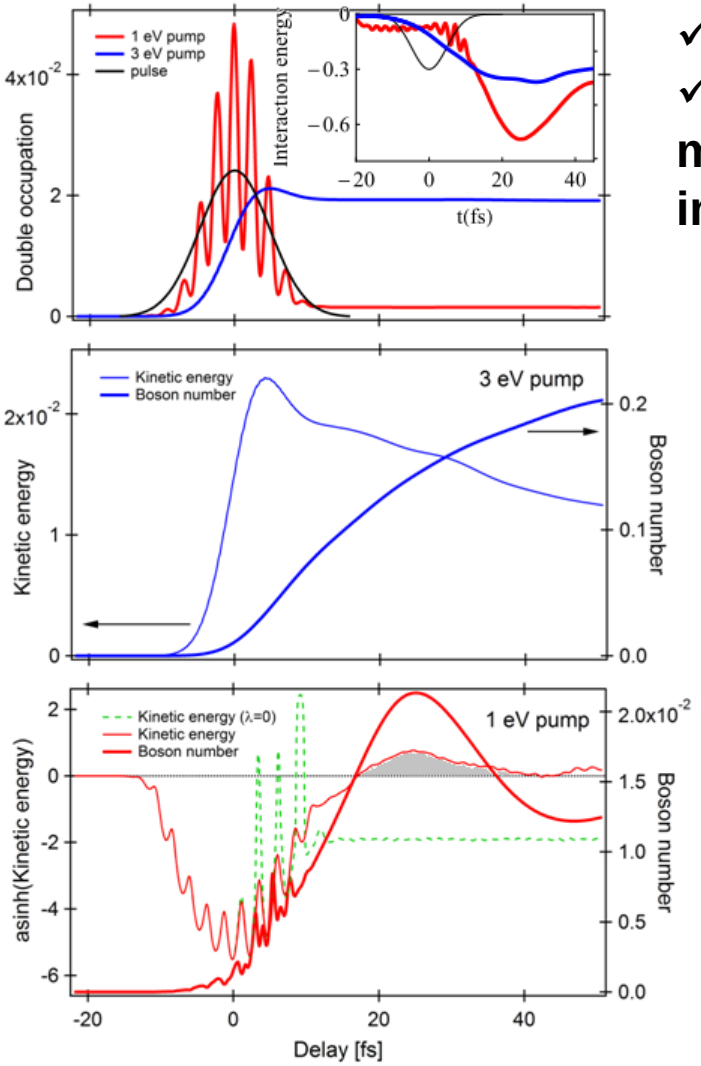
High Vs. Low-photon energy excitation



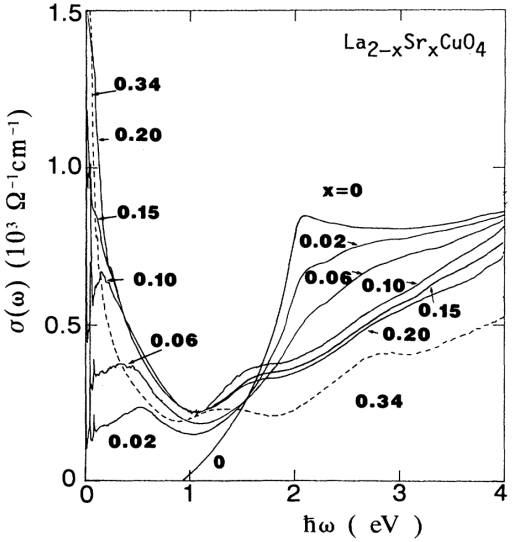


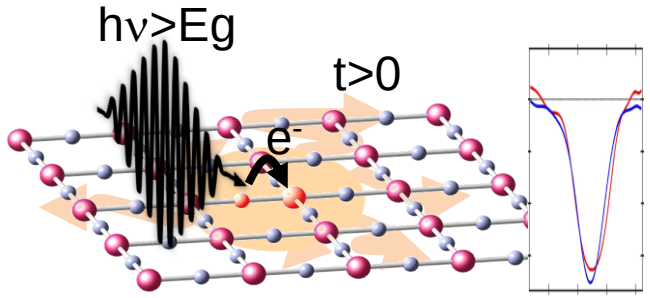


High Vs. Low-photon energy excitation



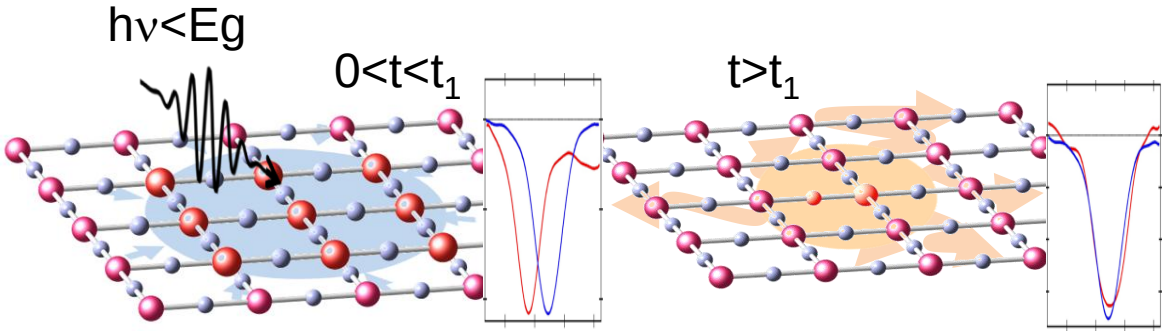
- ✓**The boson is necessary**
- ✓**Will this excitation mechanism influence response in conducting systems?**





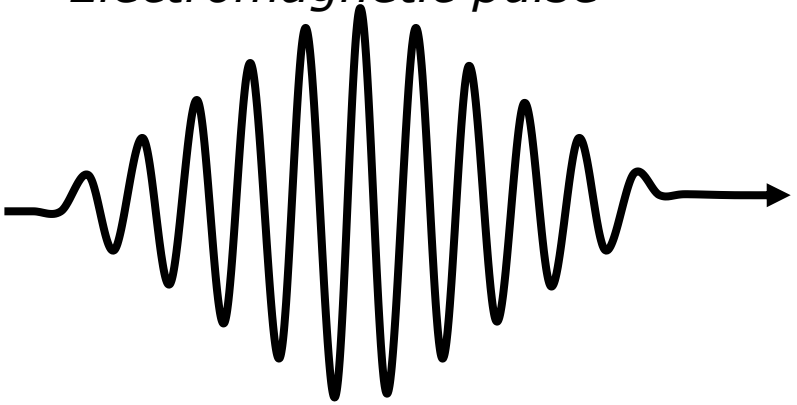
Incoherent Dressing

Coherent Dressing



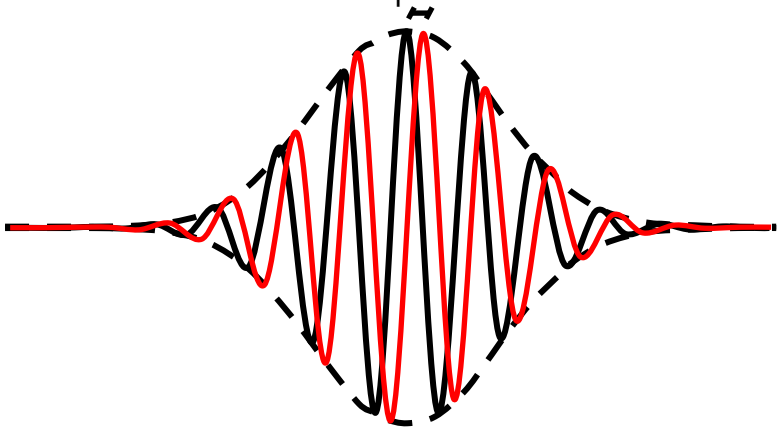
Nat. Comm. 5, 5112, 2014

Electromagnetic pulse

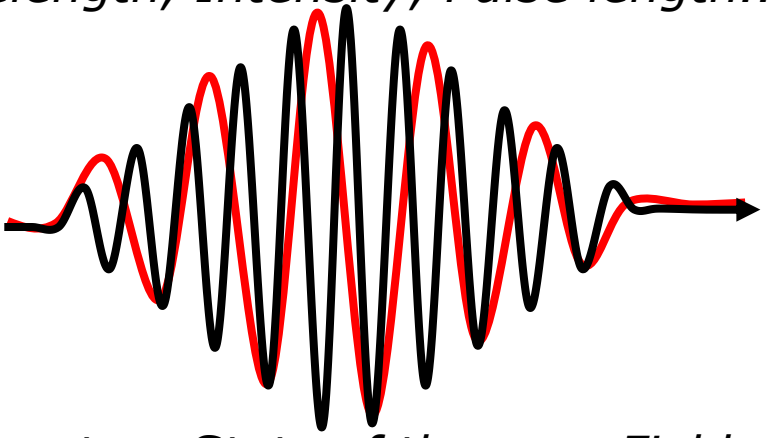


Carrier Envelope Phase

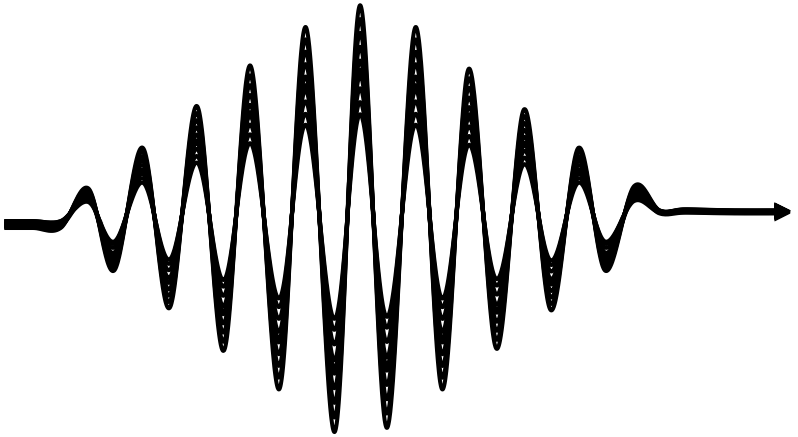
$\Delta\phi=\pi/2$



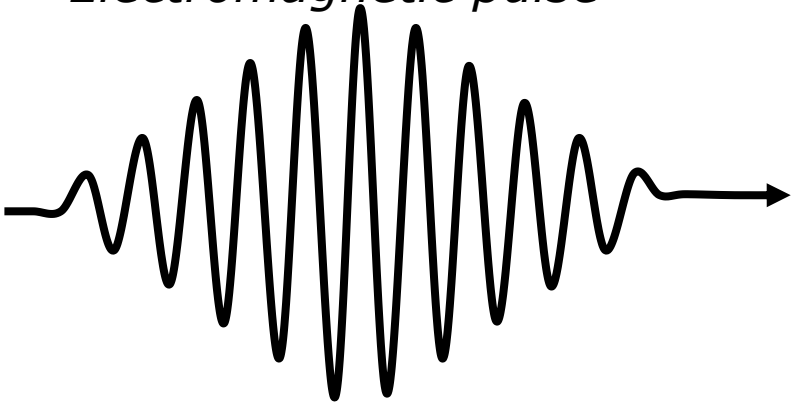
Wavelength, Intensity, Pulse length...



Quantum State of the e.m. Field



Electromagnetic pulse



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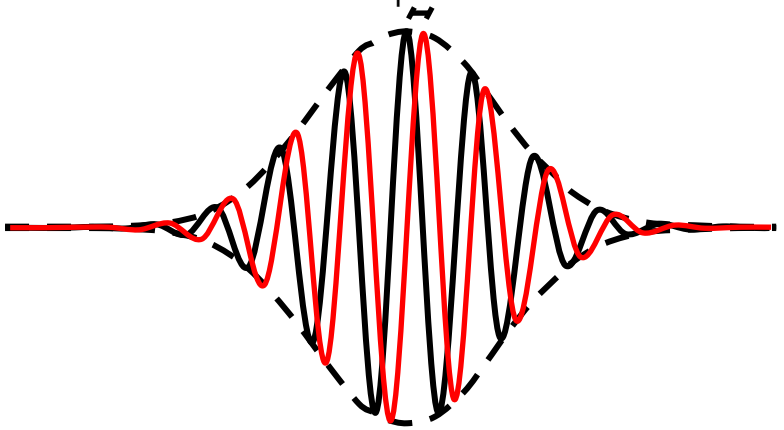

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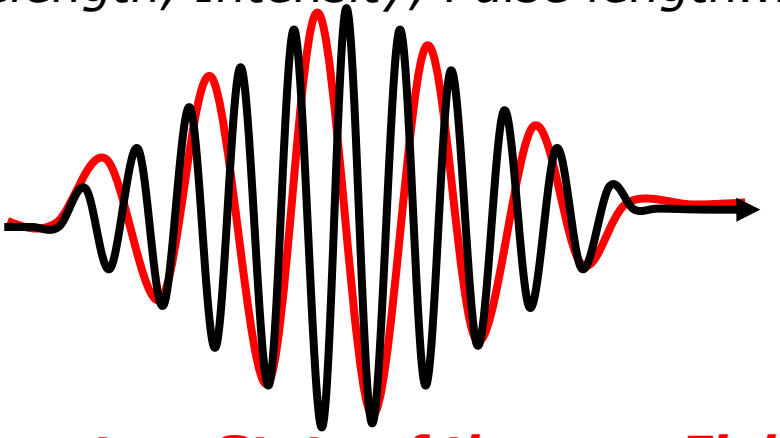
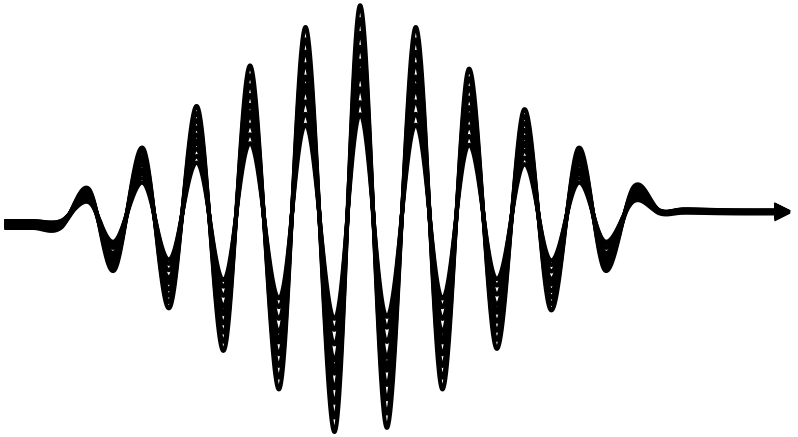


Quantum State of the e.m. Field

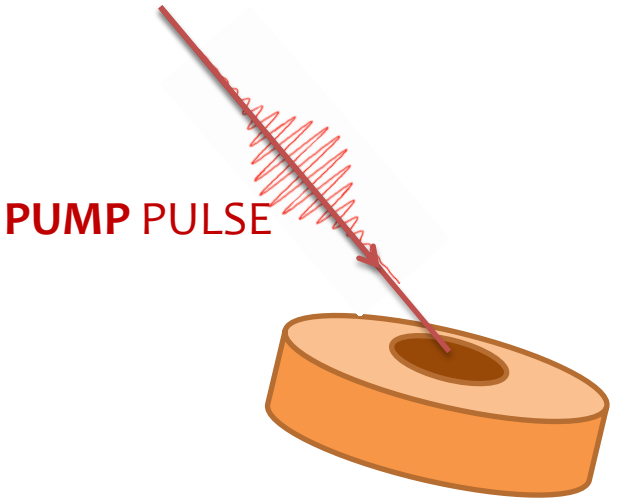


Quantum Optics for studying **Condensed Matter** out of equilibrium

Experimental **Quantum Optics**
Measurements of quantum states of light

→

Study of out of equilibrium states in
Condensed Matter: Pump&Probe



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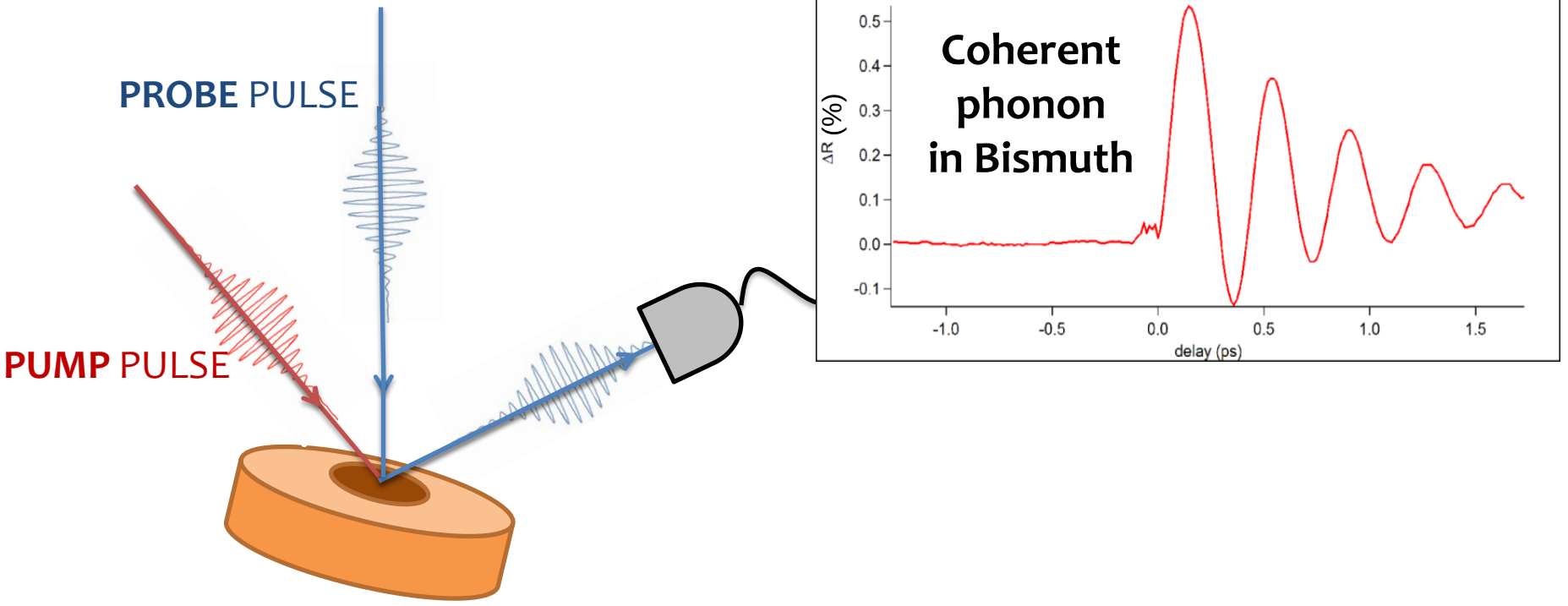

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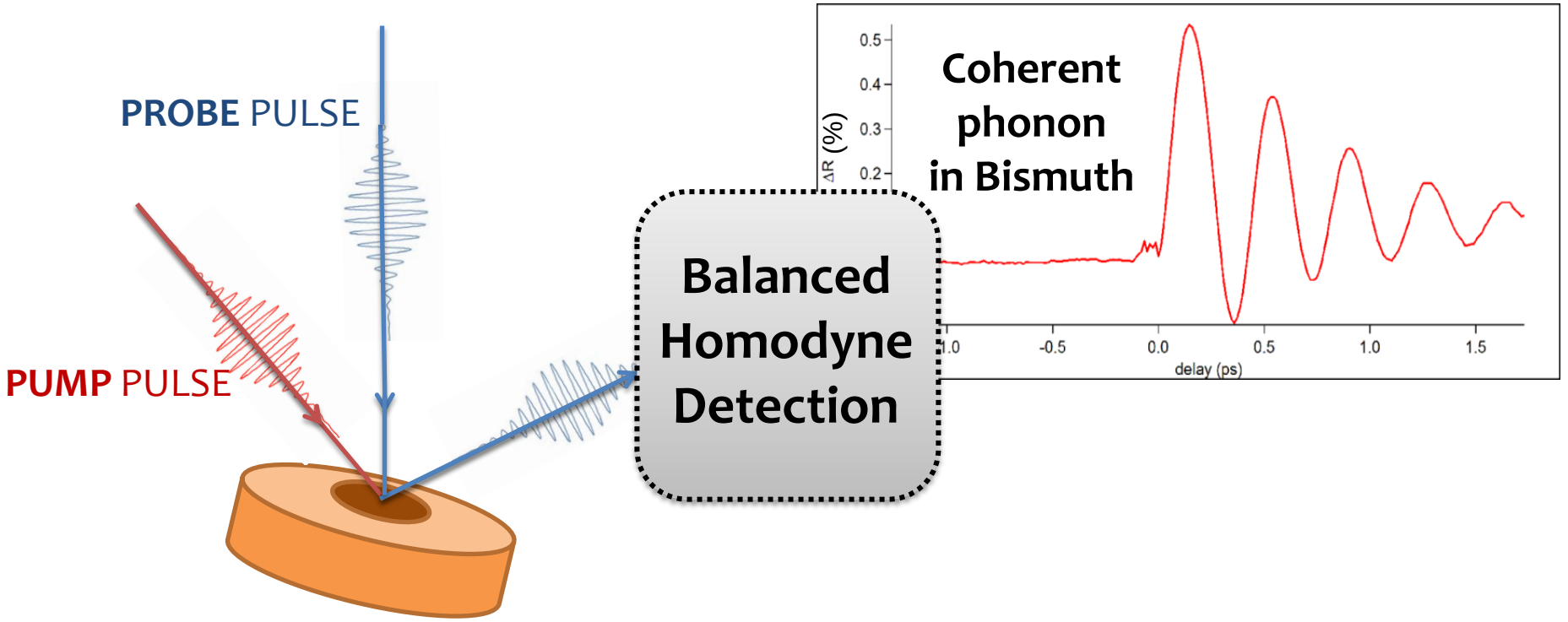

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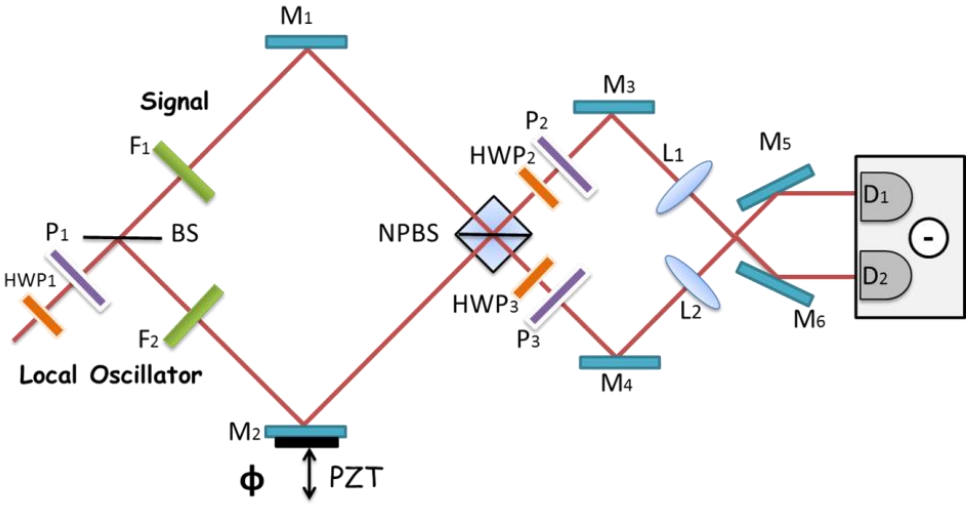

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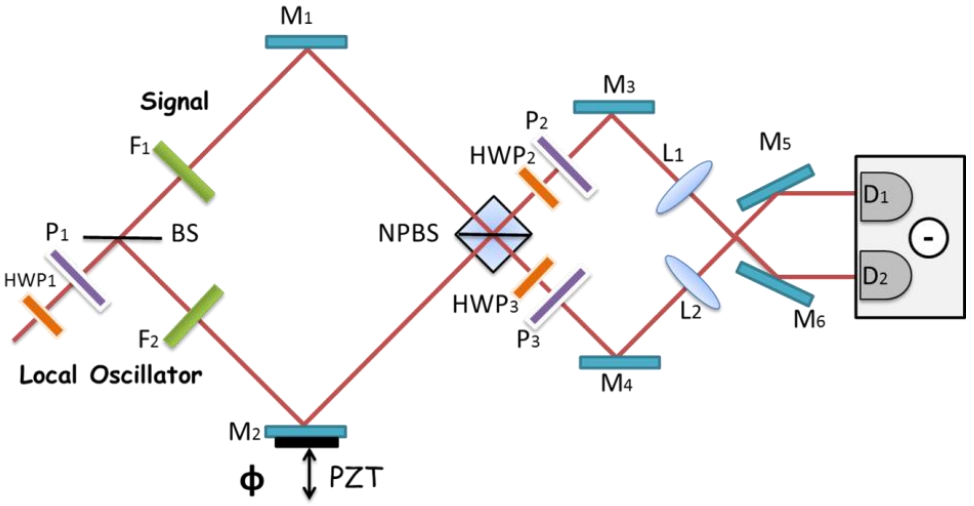
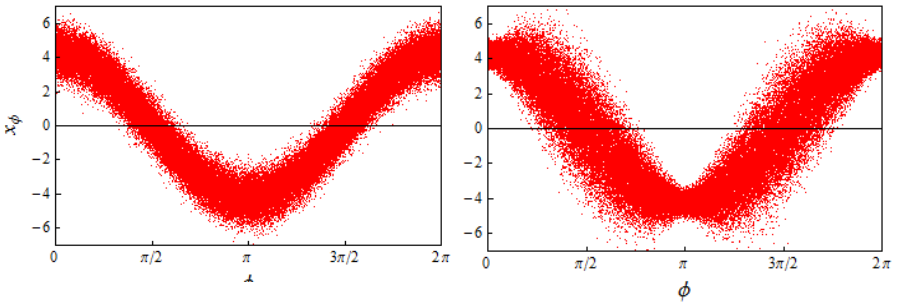


Coherent state N ≈ 9 Squeezed state N ≈ 9



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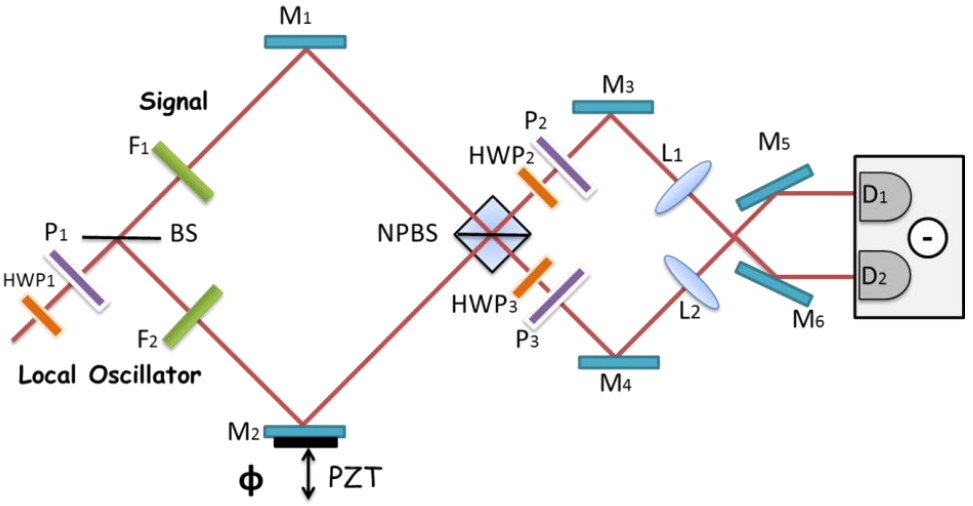
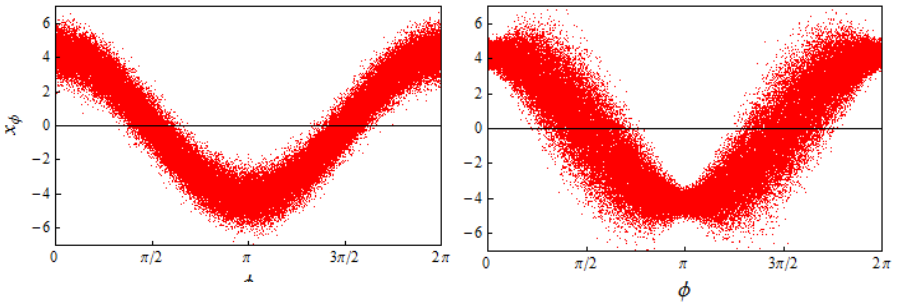
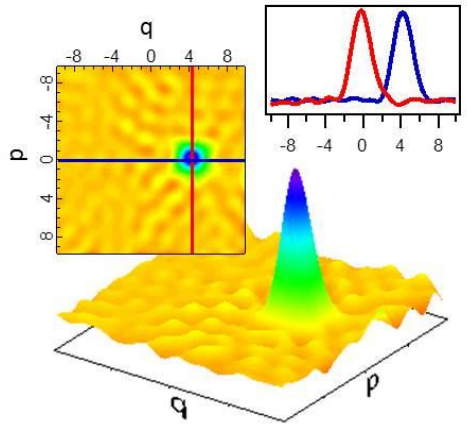


Coherent state N ≈ 9 Squeezed state N ≈ 9

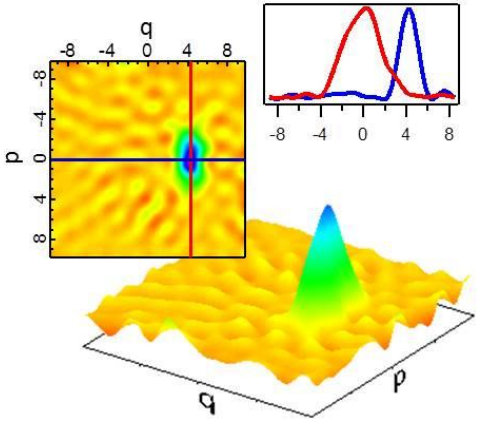


WIGNER FUNCTION RECONSTRUCTION

Coherent state $D(\alpha)|0\rangle$



Coherent-squeezed state $D(\alpha)S(\xi)|0\rangle$



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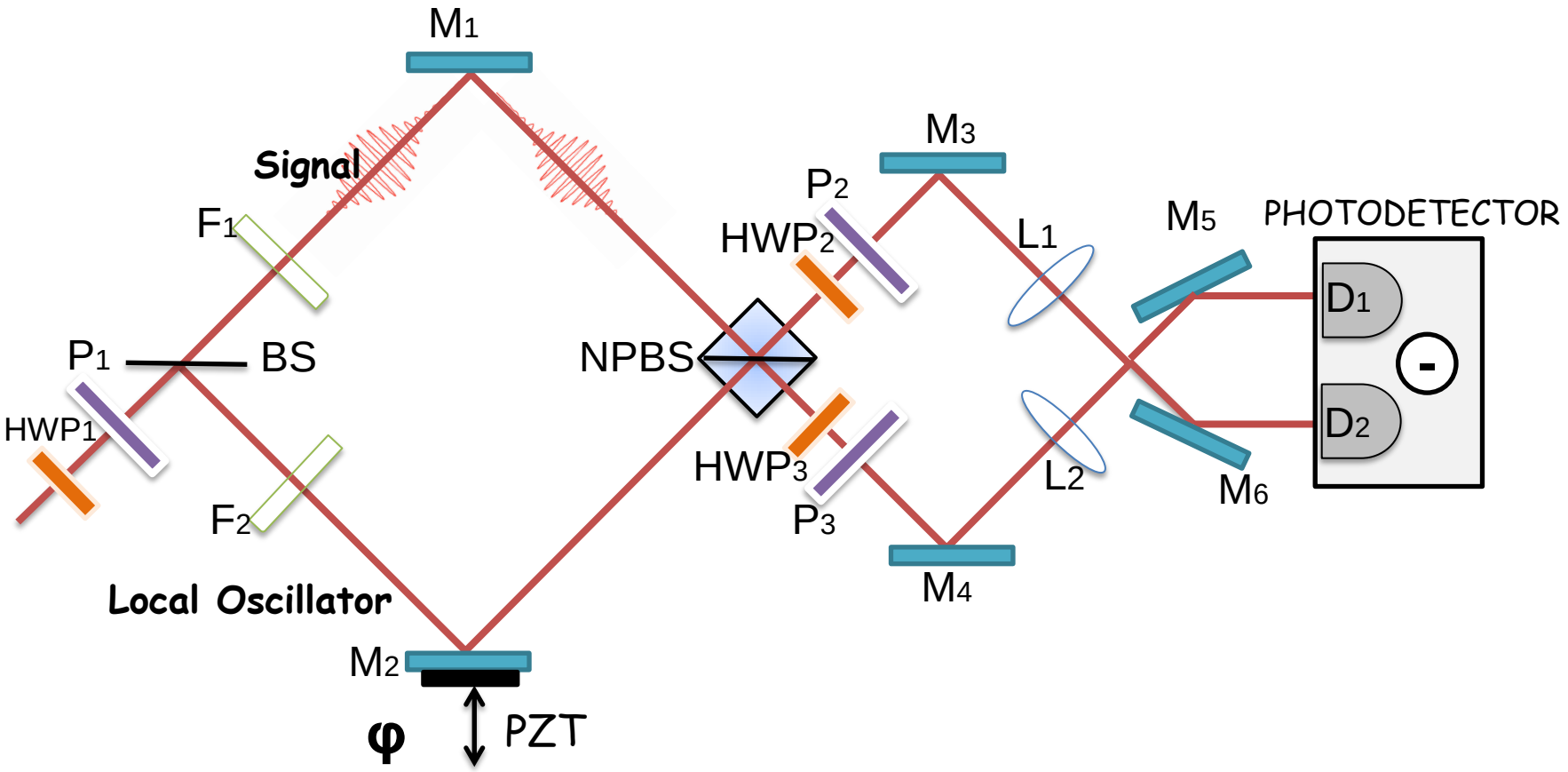
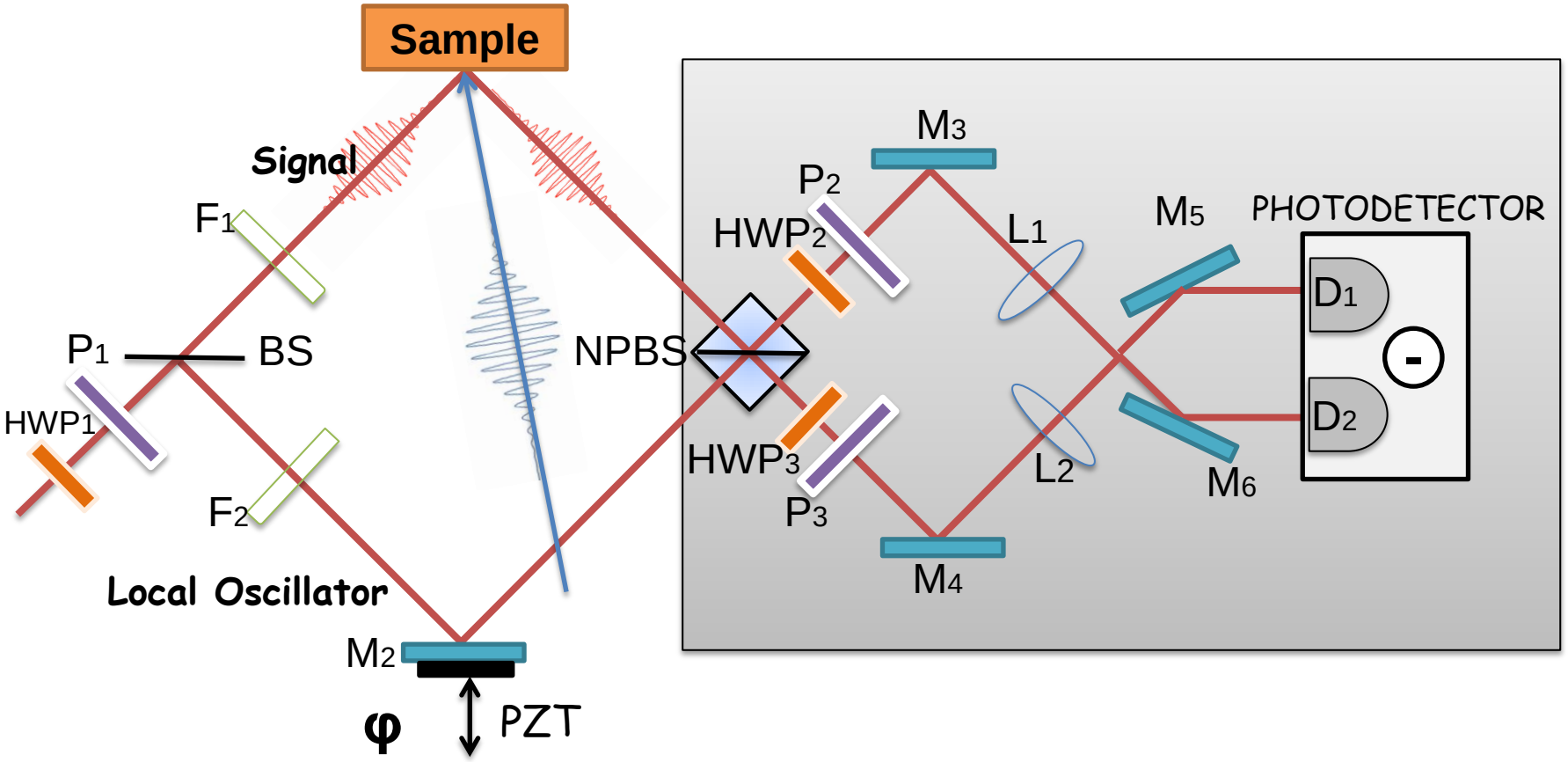
New Journal of Physics 16 (2014) 043004

Combining Homodyne and Pump&Probe



Combining Homodyne and Pump&Probe



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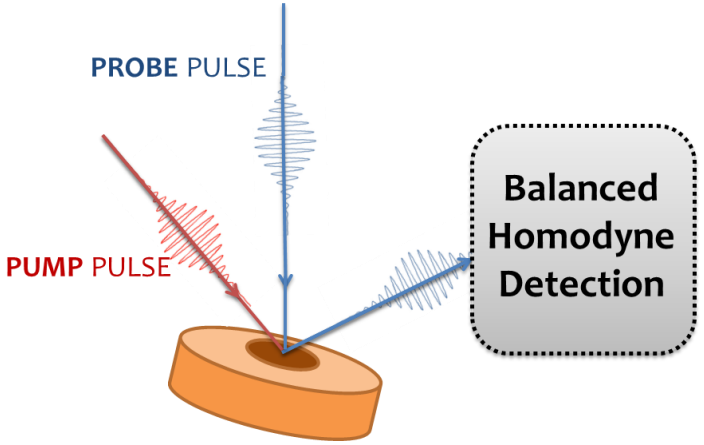
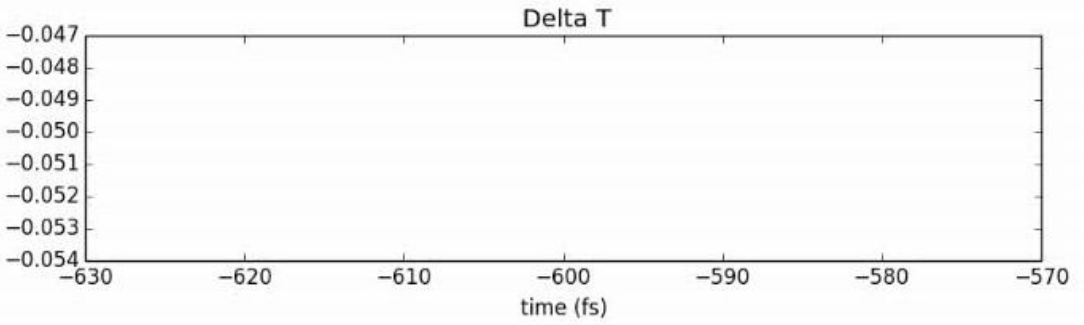
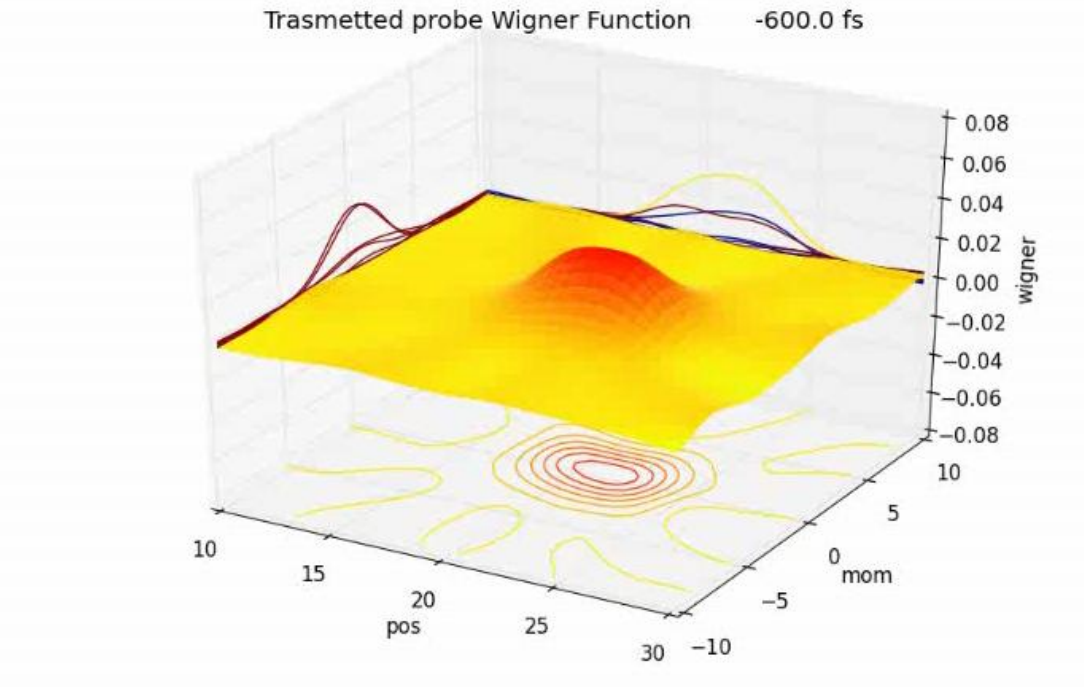






Conclusions and perspectives

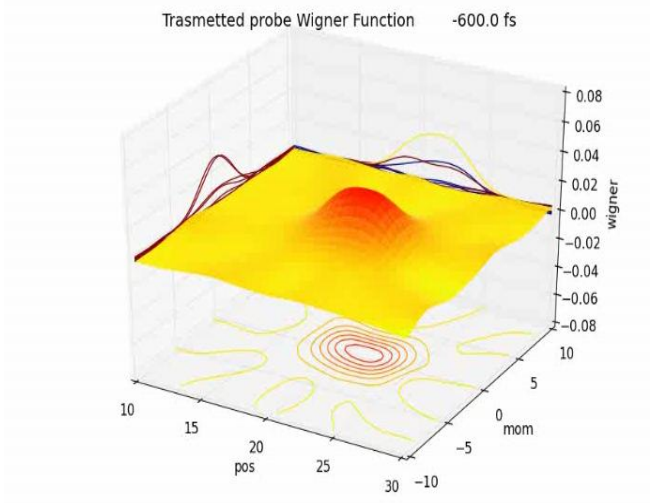
✓**The light pulses do not "just" inject energy into the system!**

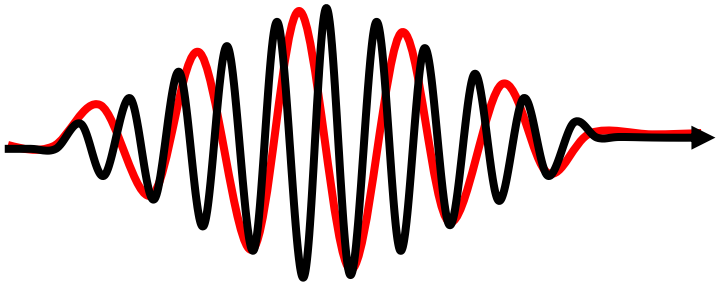
✓**Wavelength dependent responses of the low energy boson**

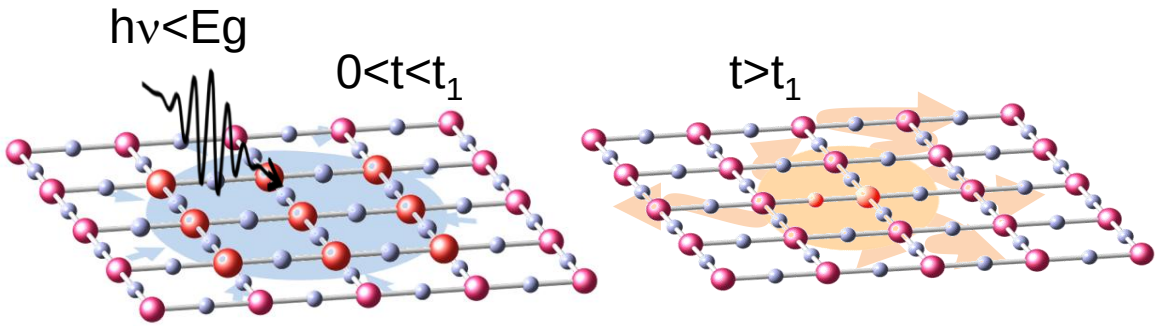
✓**Coherent response of low energy degrees of freedom**

✓**Full treatment of light matter interaction is needed beyond effective temperature models**

✓**Time domain tomographic quantum state reconstruction**







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