Ultrafast transport and energy relaxation of hot electrons in Au/Fe/MgO(001) heterostructures analyzed by linear *time-resolved* photoelectron spectroscopy

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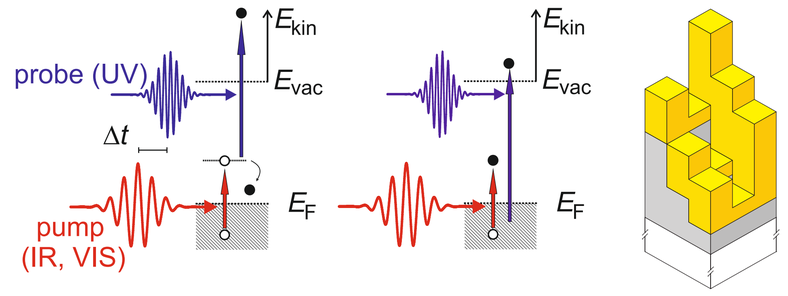
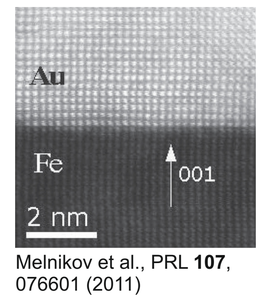
Open-Minded

Summary

- How does the interplay of transport and relaxation by secondary electron generation and e-ph coupling close to the Fermi-level work?
- What is the transport mechanism close to the Fermi-edge? Diffusive vs ballistic transport?
- *Time resolved* linear-photo-emission spectroscopy using 1.55 eV pump and 6 eV probe photons on a Au / Fe / MgO(001) thin film sample
- Front and back side pumping to distinguish local inelastic processes and non-local transport
- Back side pumping displays delay of thermalised electrons
- Front side pumping exhibits efficient transport of excited charge carriers into the bulk with Fe acting as a scattering layer

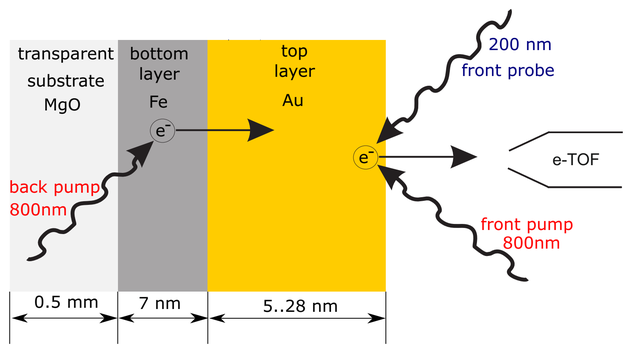
Experimental Methods and Samples





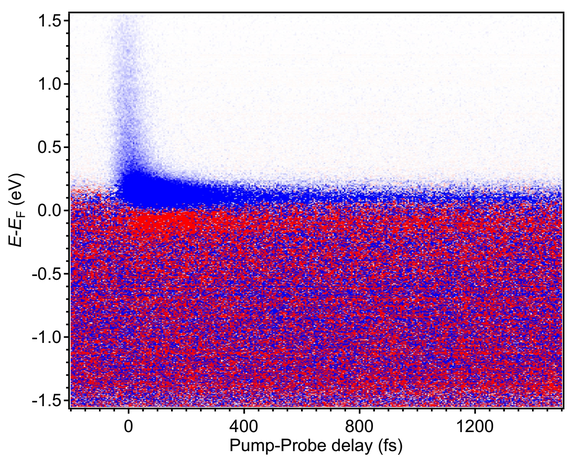
Melnikov et al., PRL **107**, 076601 (2011)

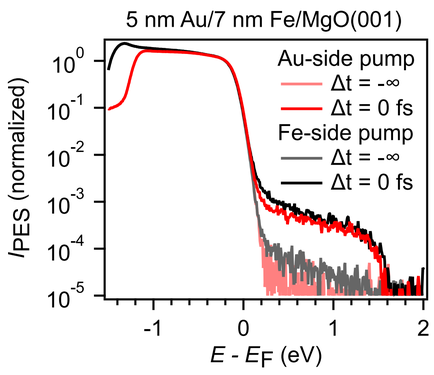
- Schemes of *time-resolved* linear photo-emission probing above (left) and below (right) the Fermi-level

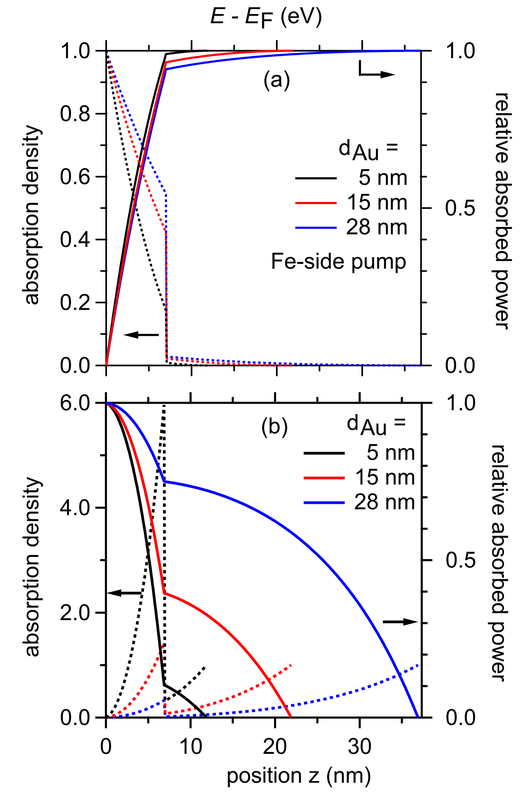


- Epitaxially grown MgO(001) / Fe / Au Samples
- Varying film sizes (5-28 nm) for thickness dependent measurements
- Pumping the sample using 1.55 eV photons and probing with 6 eV on the gold surface
- Detection in normal incidence by using an electron time-of-flight spectrometer

Photoelectronspectra and Laserabsorption Calculation

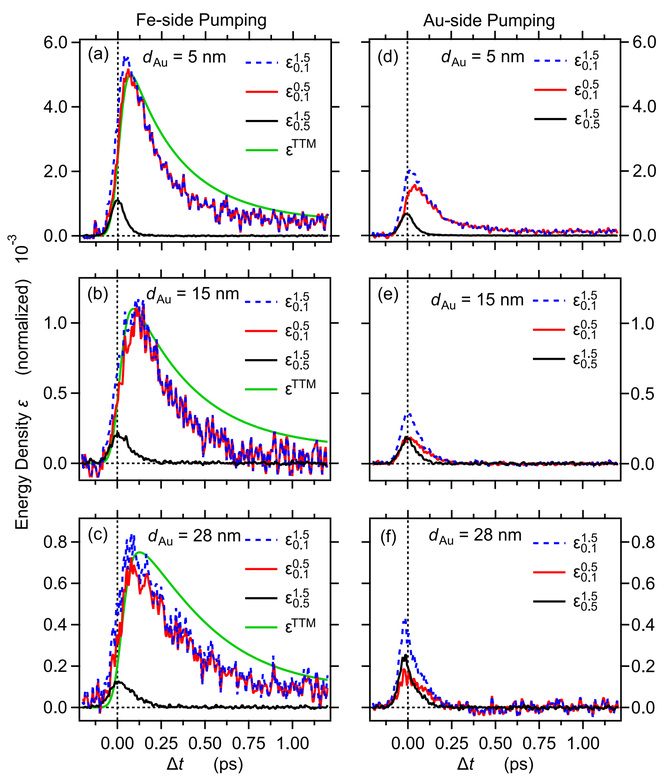






- Subtraction of linear photoemission background
- Blue indicates an increase in carriers, red a reduction
- Changes in the range of 2 orders of magnitude observed
- Changes in the secondary edge originate from different sample positions
- Fe-side pump has over 90% pump absorption in iron
- Au-side pump is more complicated with thin films showing considerable absorption in iron

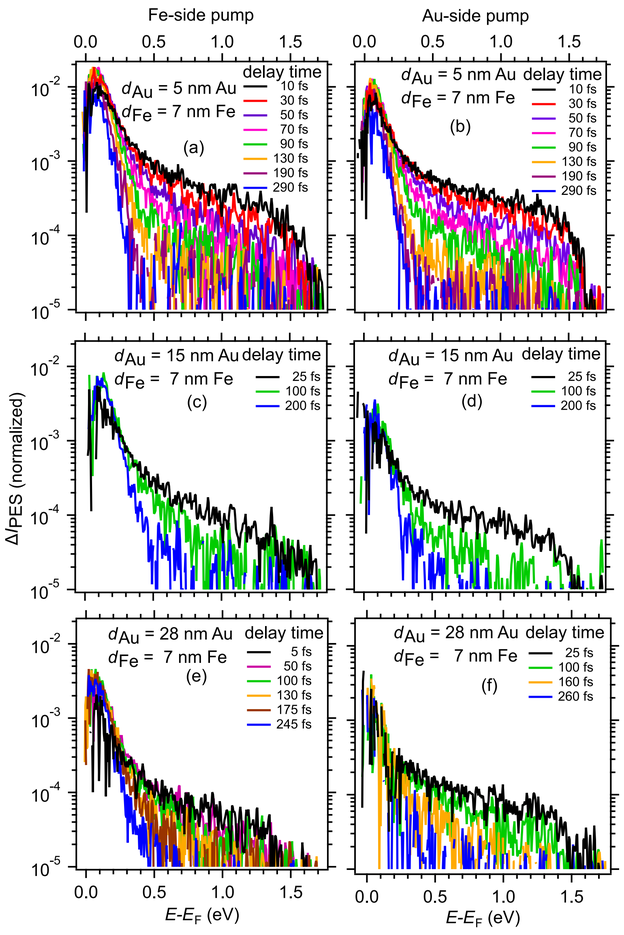
Comparison of Front and Back Side Pumping



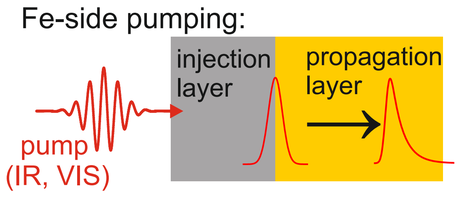
$$\epsilon_{E_1}^{E_2}(\Delta t) = \mathcal{C} \int_{E_1}^{E_2} \Delta n\,(E, \Delta t)\, E dE$$

- Fe-side absorption is stronger than Au-side
- Energy density decreases with increasing film thickness in Fe-side pumping
- Two temperature model overestimates the decay times
- Fe-side pump has most energy contained inside the low energetic states
- Au-side pump shows more homogenous distribution and fast transport of carriers into the Fe acting as a scattering layer

Distinguishing Hot and Thermalised Electrons

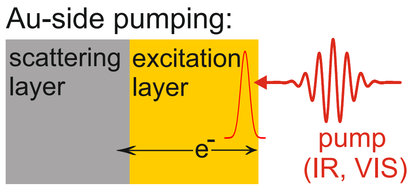


Fe-side pumping:

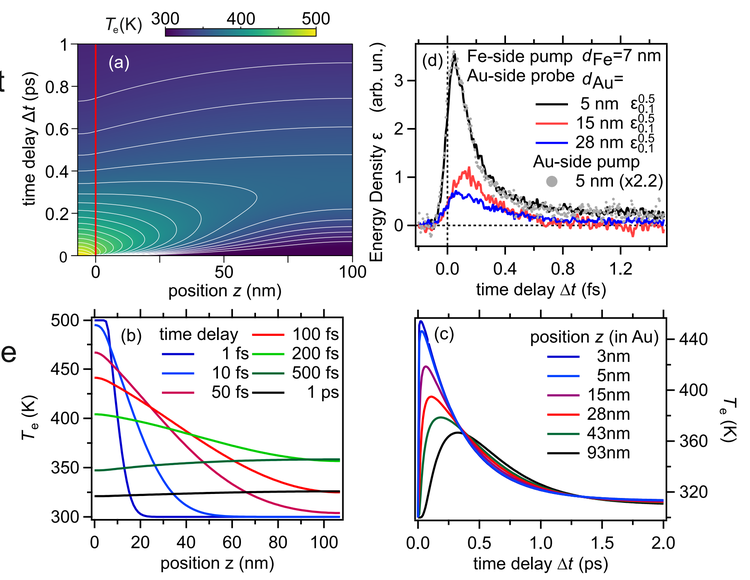


- Rapid depopulation of high energetic states >0.4 eV
- Beginning of electron thermalization during transport in Au for Fe-side pumping
- Repopulation by secondary electrons <0.4 eV in Fe-side excitation
- Highest energy carriers do not reach the surface at 28 nm at time zero

Au-side pumping:



- Two temperature model assumes diffusive transport and el-ph cooling
- Simulation of 100 nm thick film, interface modeled continously by a sigmoid function
- Qualitative agreement of the relaxation of 5 nm for both Au and Fe-side pump



Outlook

- Perform measurements at different fluence to study the dependence
- Measure Au thicknesses above 28 nm to derive a quantitative model and confirm two temperature model calculations
- Improve signal to noise ratio in order to see hole dynamics at energies below the Fermi-level
- Apply the method of back side pumped linear photo-emission spectroscopy to thin semiconductor systems