Optically Stimulated Insulator-Metal Transitions in VO_2

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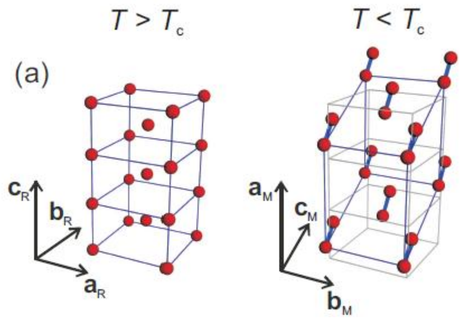
Abstract

There is a class of materials that change from an Insulator to a Metal when heated, and it is not well understood how this transition takes place: VO_2 is one of the most popular to study, as it has a transition temperature that is slightly above room temperature (68C). VO_2 can also be optically stimulated to make an Insulator-Metal transition using ultrafast pulses. When VO_2 undergoes the transition there is a change in the lattice structure, implying a Peierls transition, and a change in electronic properties, implying a Mott transition. We are studying the transition of VO_2 with a time resolved pump probe experiment, in order to better understand the mechanisms behind the transition.

Insulator-Metal Transition

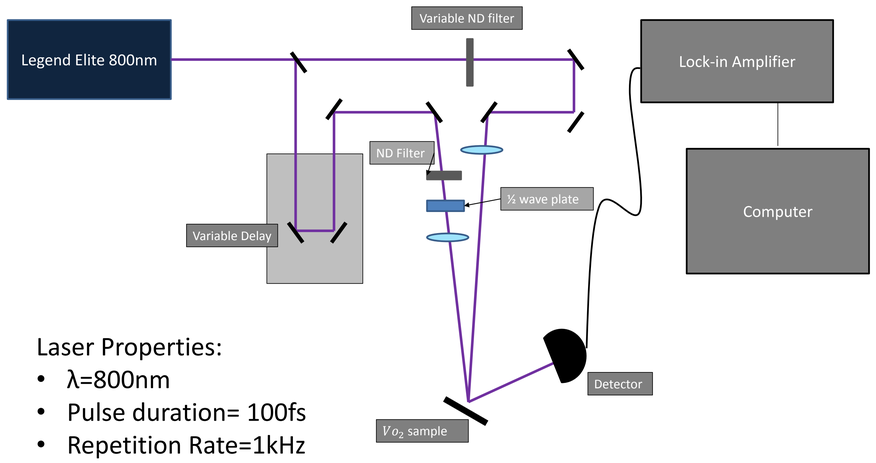
Mott or Peierls Transition?



High temperature metal phase: Rutile structure.

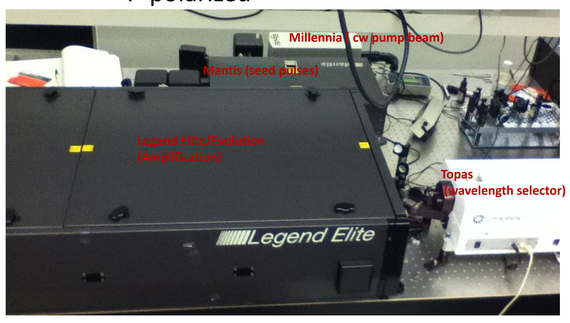
Low temperature insulator phase: monoclinic structure

Experimental Set Up

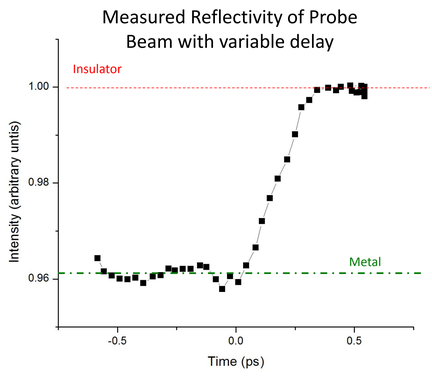


Laser Properties:

- λ=800nm
- Pulse duration= 100fs
- Repetition Rate=1kHz
- P-polarized

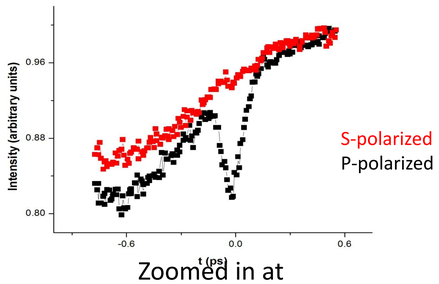


Ultrafast Laser System



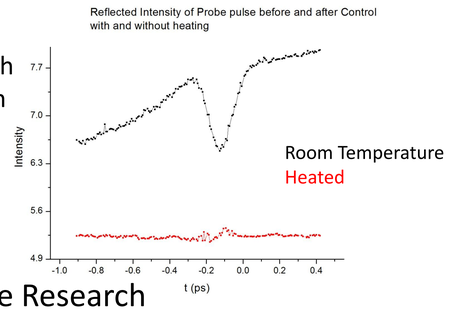
Relative Polarization of Pump and probe

- Rotating polarization of probe beam with half-wave plate
  - Strong initial dip disappears

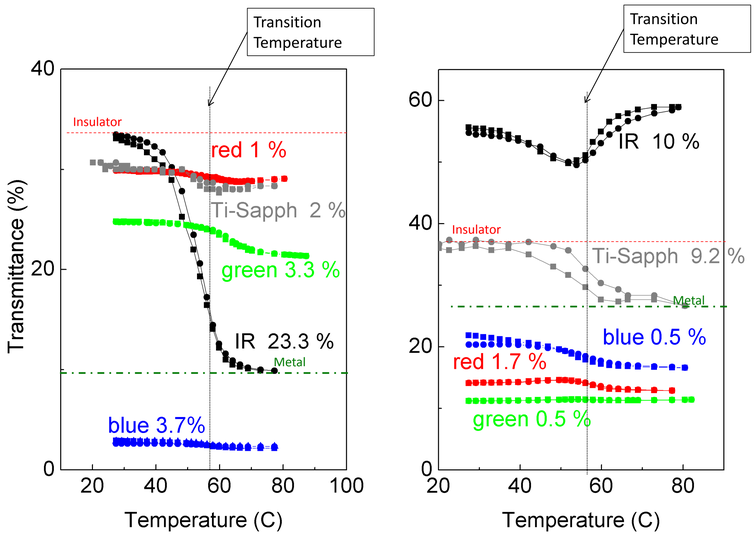


Probe Beam rotated by half-wave plate to s-polarization

Zoomed in at transition point: both with sample at room temperature and heated to metal phase

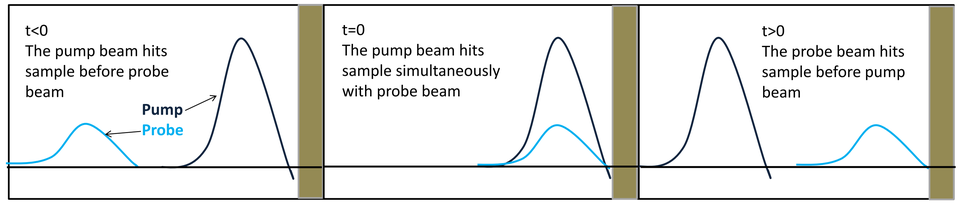


Optical Properties Over Heat Induced Insulator Metal Transition

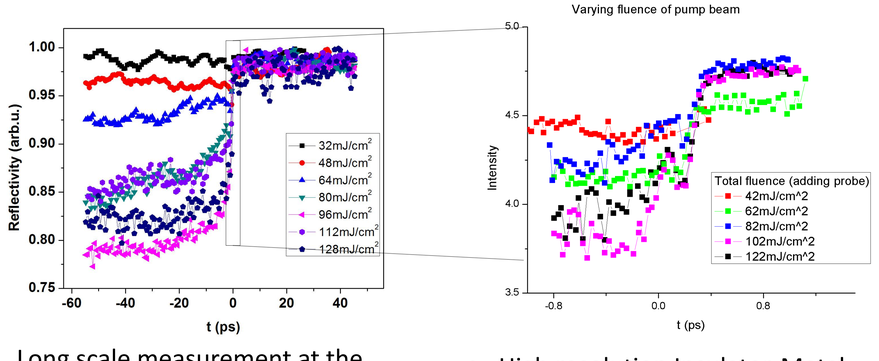


- CW measurements
- Ti-Sapphire λ=800nm, like our pulsed beam

Variable Delay in Pump-Probe Experiment



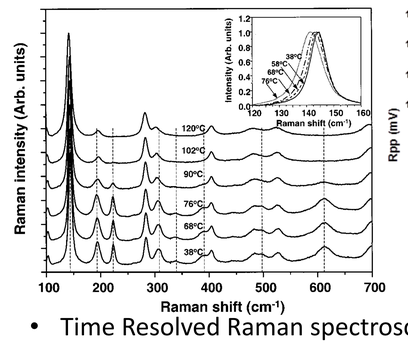
Variation in Laser Fluence



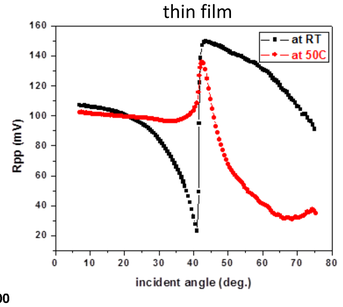
- Long scale measurement at the Insulator-Metal Transition with varying fluence
- High resolution Insulator-Metal Transition with varying fluence

Future Research

Raman spectrum of VO_2 thin film



Surface Plasmon Polaritons of VO_2 thin film



- Time Resolved Raman spectroscopy
  - Compare rate of change in structural properties to change in electronic properties
- Insulator-Metal Transition at low temperatures
- Surface Plasmon Resonance (optical switches)

Conclusion

We have been able to induce a transition from insulator to metal in VO_2 think films with a pulsed beam: the strength of the transition depends on the fluence of the incident beam. The strong dip in reflectivity that happens right after the pump pulse hits the sample disappears when we make either beam orthogonal to the other. We still see a dip even when the sample is heated to the metal phase, which implies this is an interference effect rather than a feature of the transition. In the future we hope to look at the time resolved Raman Spectroscopy in order to see how the crystalline structure changes over time, and compare it to the change in electronic properties. Also we plan to look at how surface plasmons travel through layers of thin films of VO_2, RuO_2, and gold.

References

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[2] A. Pashkin, C. K¨ubler, H. Ehrke, R. Lopez, A. Halabica, R. F. Haglund, Jr., R. Huber, and A. Leitenstorfer, "Ultrafast Insulator-Metal Phase Transition in VO2 Studied by Multiterahertz Spectroscopy", Phys. Rev. B **83**, 195120 (2011)

[3] G. I. Petrov, V. V. Yakovlev, and J. Squier, "Raman microscopy analysis of phase transformation mechanisms in vanadium dioxide", Appl. Phys. Lett. 81, 1023 (2002)

Acknowledgements

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