



LIGHT-INDUCED MANIPULATION OF THE PHASE OF THE ORDER PARAMETER IN Ta_2NiSe_5

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Y. Lu³, T. Takayama^{3,4}, H. Takagi^{3,4}, E. Demler², N. Gedik¹

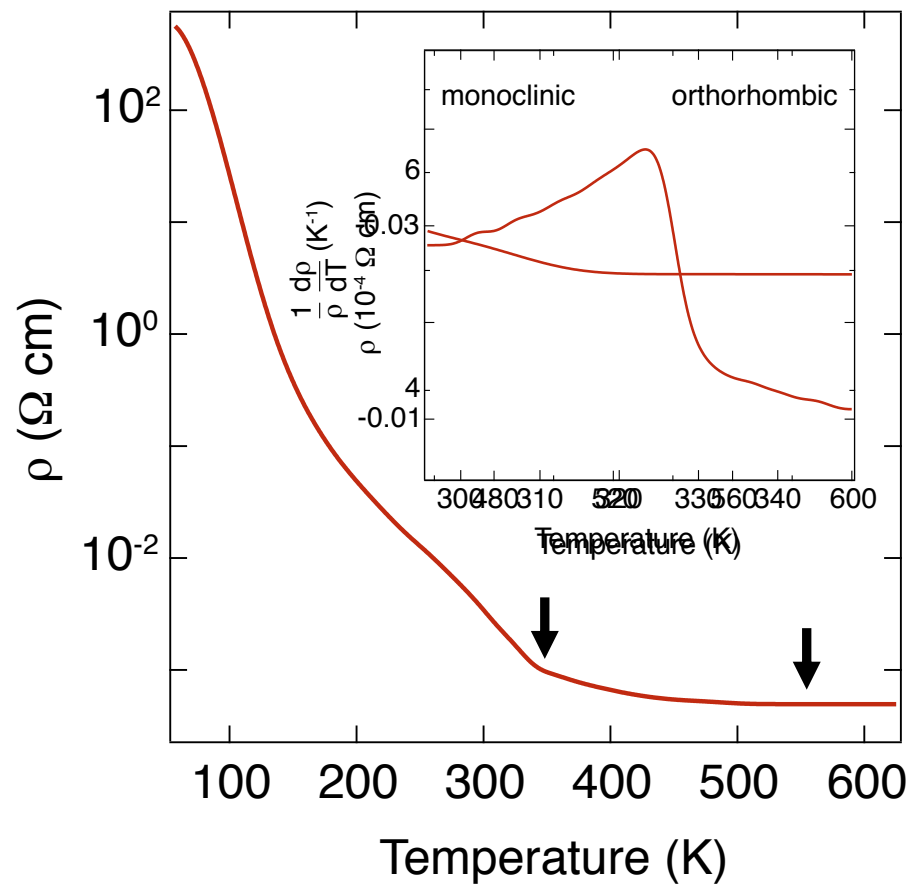
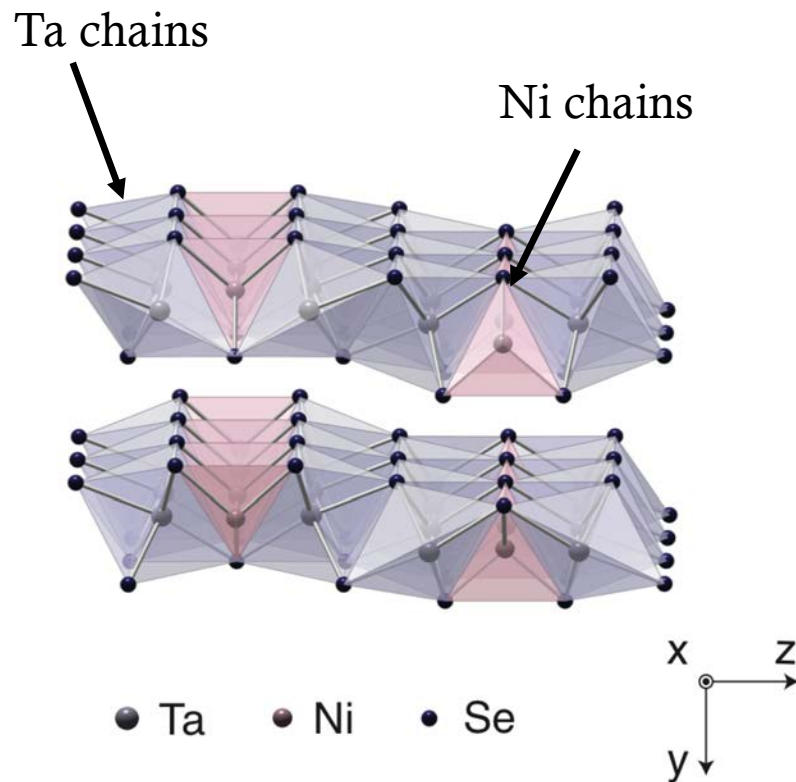
¹ Department of Physics, Massachusetts Institute of Technology, USA

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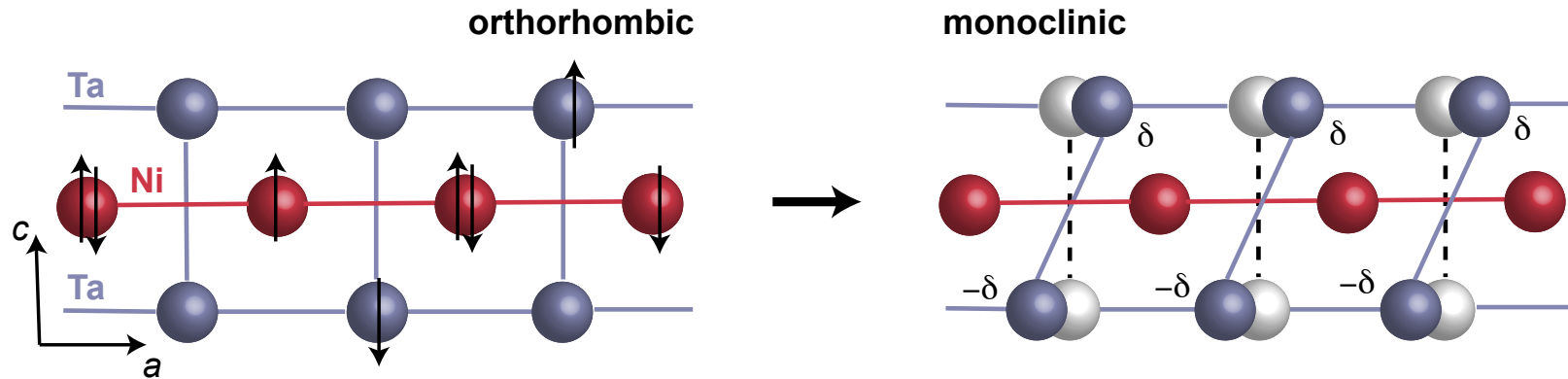
⁴ Max Planck Institute for Solid State Research, Stuttgart, Germany

Ta₂NiSe₅

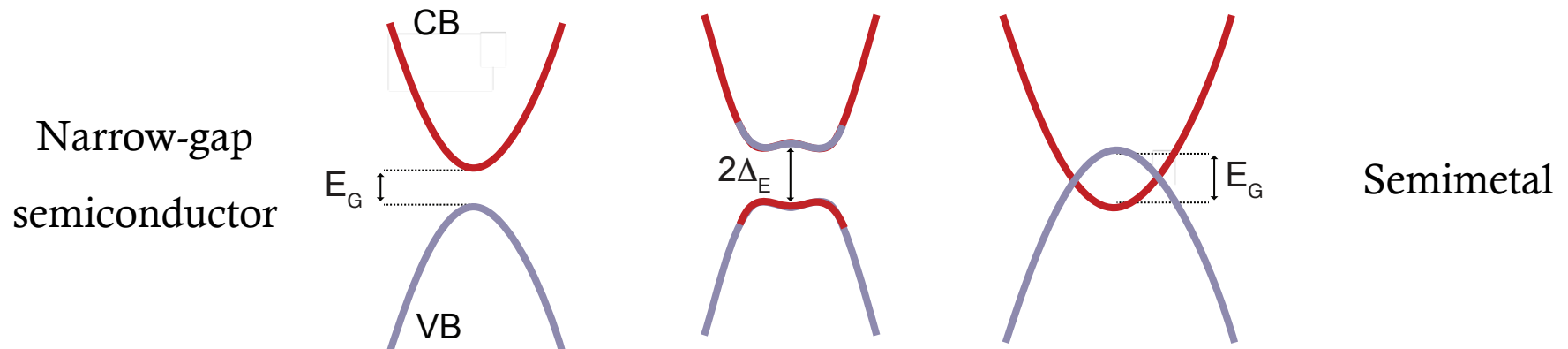


F. J. Di Salvo et al., J. Less-Comm. Metals 116, 51 (1986)

WHAT IS THE DRIVING FORCE?



Excitonic insulator



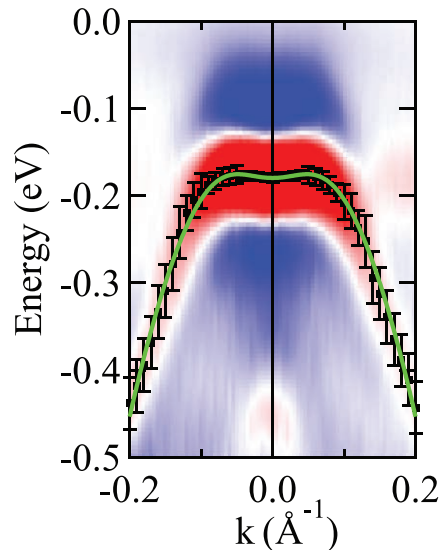
T. Kaneko, ..., Y. Ohta, Phys. Rev. B 87, 035121 (2013)

A. Nakano, ..., H. Sawa, Phys. Rev. B 98, 045139 (2018)

EVIDENCE FOR EXCITONIC INSULATOR

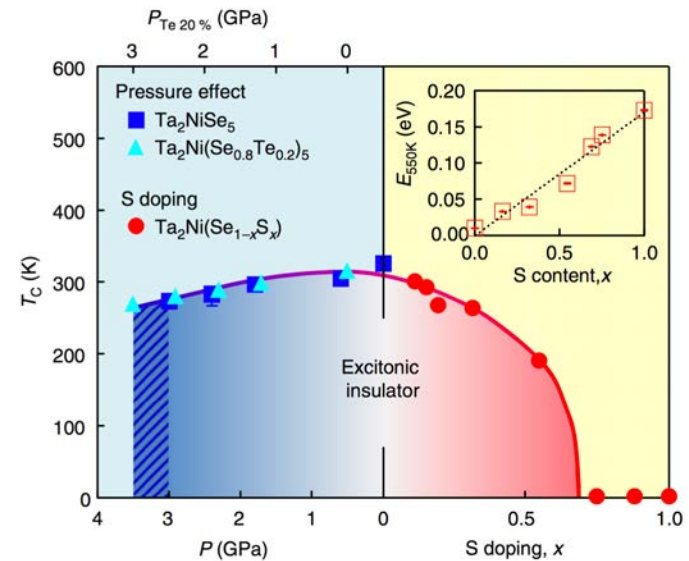
Flattening of the valence band top (ARPES)

K. Seki, ..., Y. Ohta, Phys. Rev. B 90, 155116 (2014)



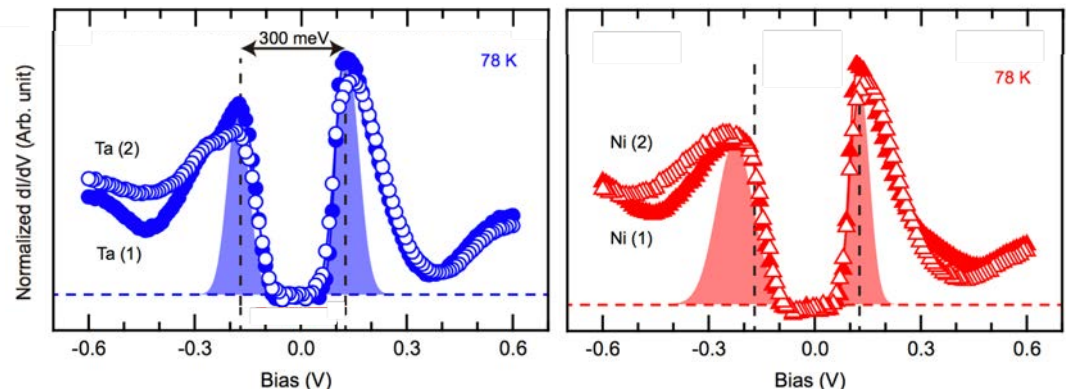
Transport measurements

Y. F. Lu, ..., A. V. Boris, Nat. Comm. 8, 14408 (2016)

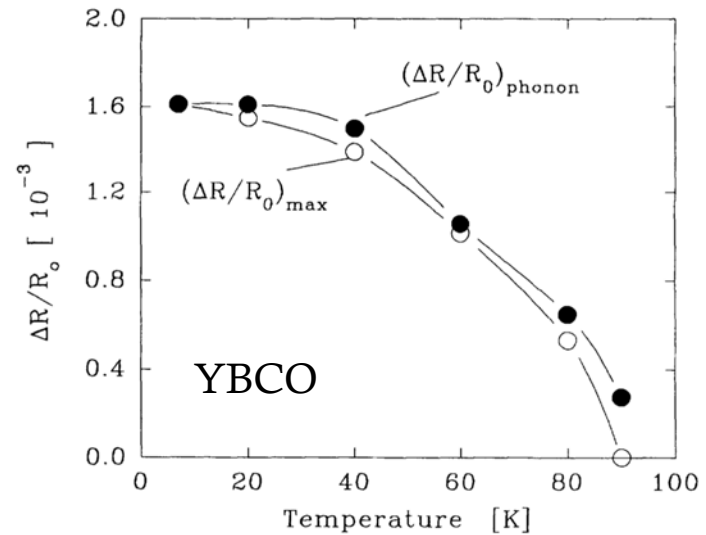
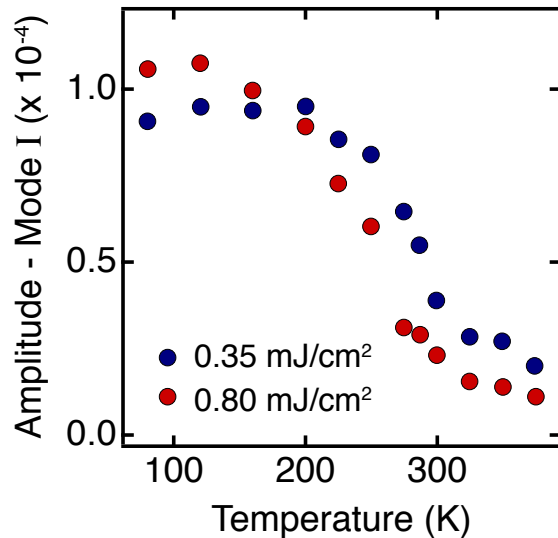
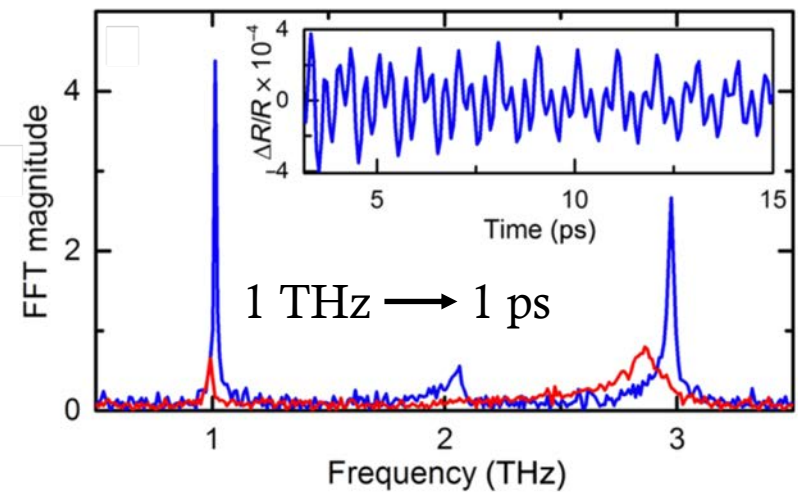
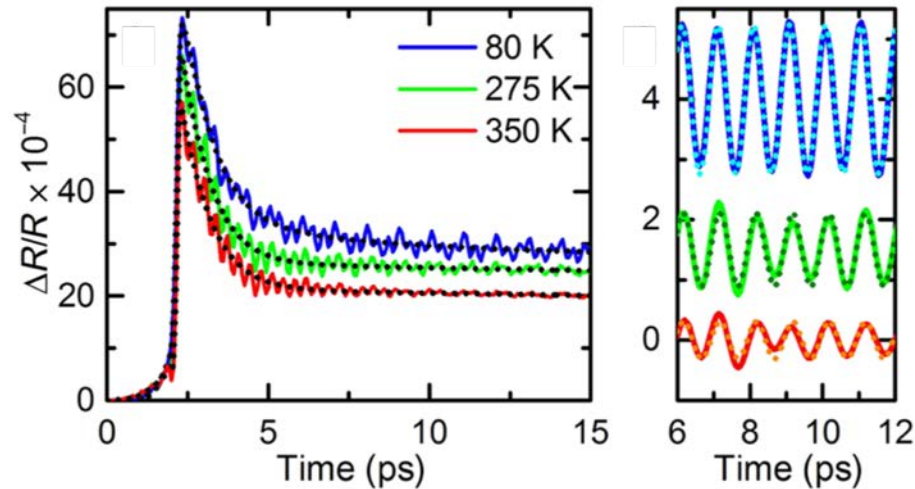


Interband interaction and band hybridization (STS)

J. Lee, C. Kang, et al.,
Phys. Rev. B 99, 075408 (2019)



ORDER PARAMETER



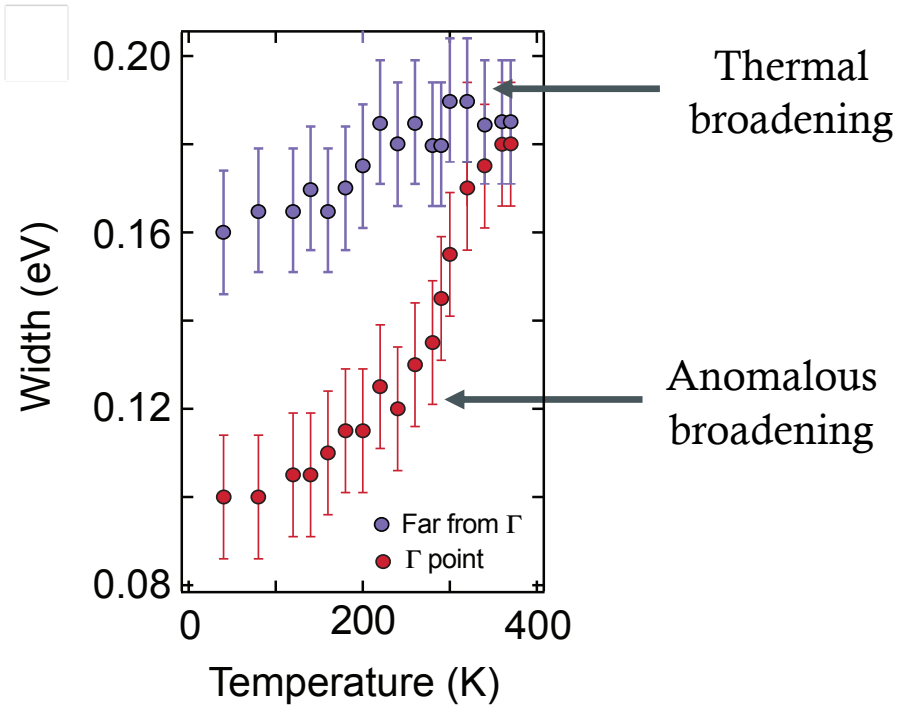
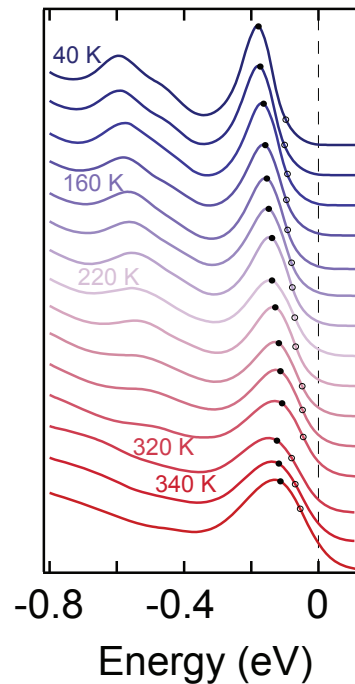
D. Werdehausen, ..., S. Kaiser,
Science Advances 4, 8652 (2018)

B. Friedl, M. Cardona, Sol. State Comm. 78, 4 (1991)
W. Albrecht, et al., Phys. Rev. Lett. 69, 1451 (1992)

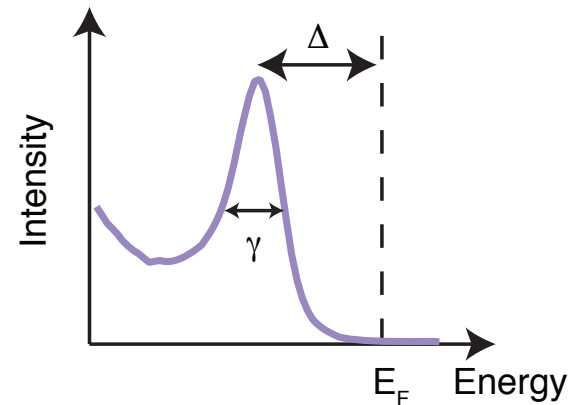
WHAT IS THE HIGH-TEMPERATURE PHASE?

Y. Wakisaka et al.,
J. Supercond. Nov.
Magn. 25, 1231-1234
(2012)

K. Sugimoto et al.,
Phys. Rev. Lett.
120, 247602 (2018)



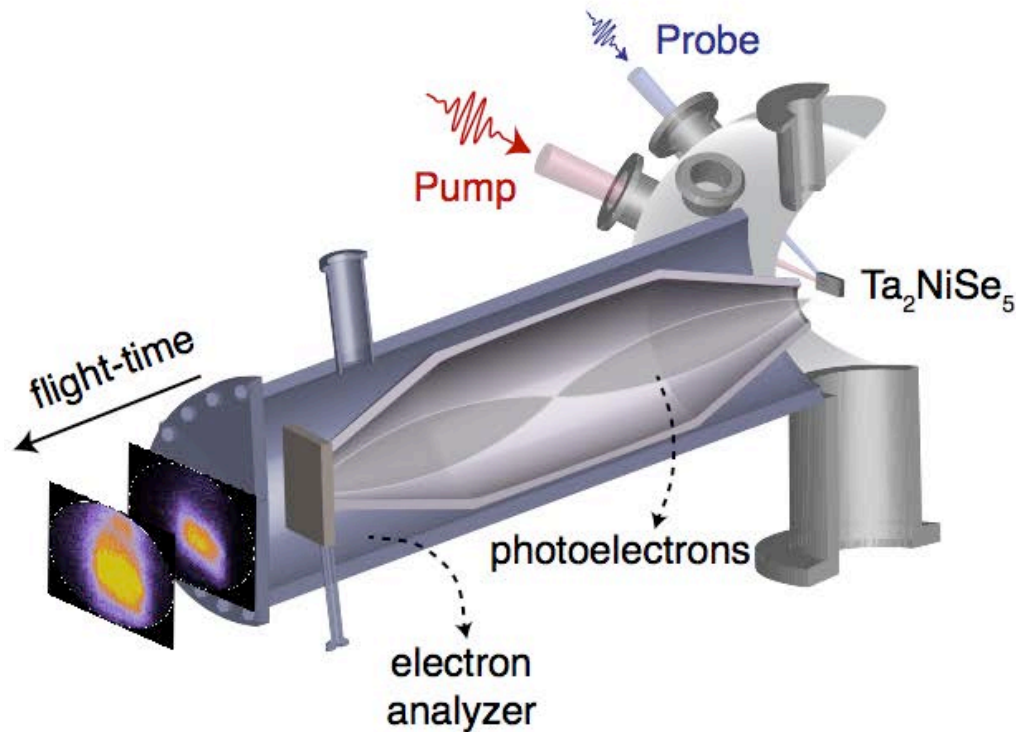
- Gap size (Δ) related to pairing strength U_{eh}
- Linewidth (γ) related to phase coherence



TIME-RESOLVED ARPES



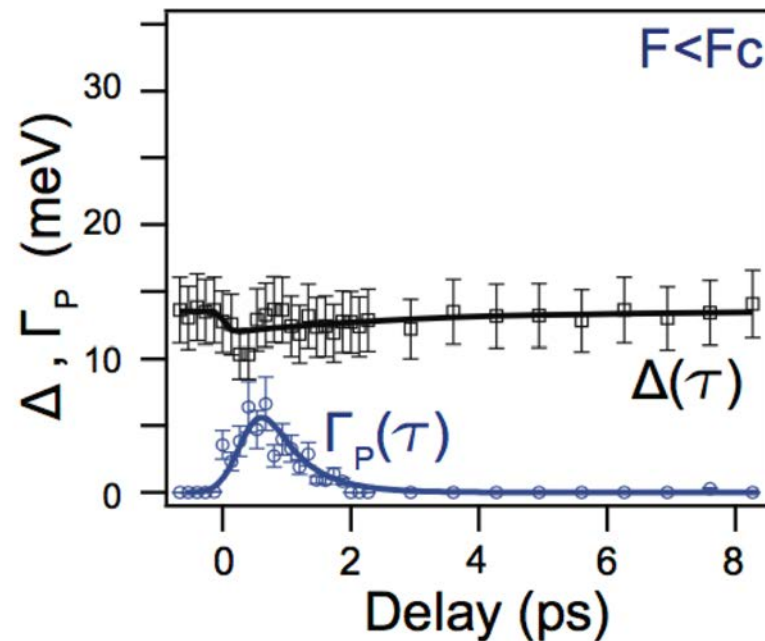
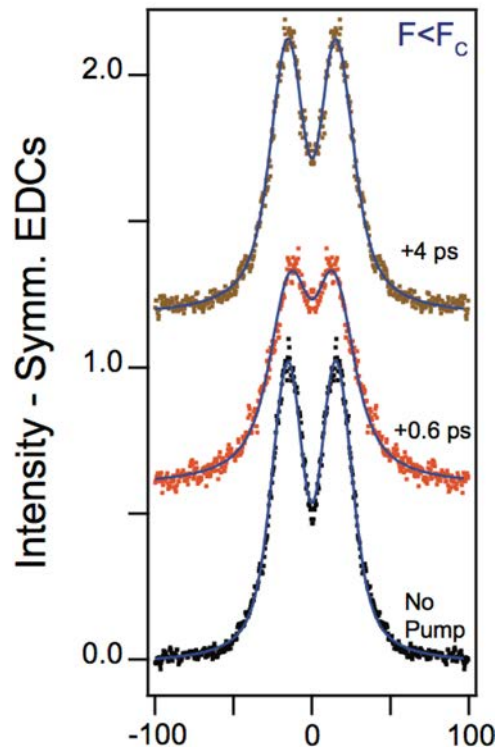
Couple the driving field of the pump pulse to the phase of the order parameter



LIGHT-INDUCED COLLAPSE OF PHASE COHERENCE

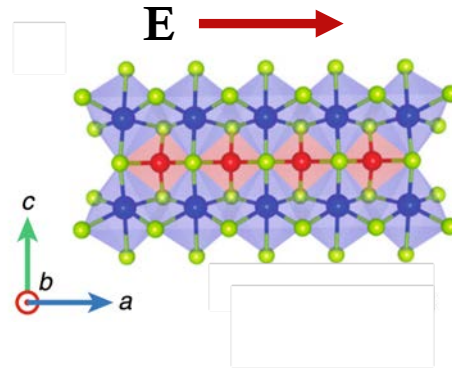
Strong similarities with the response of the Cooper pair condensate in cuprates

Bi-2212



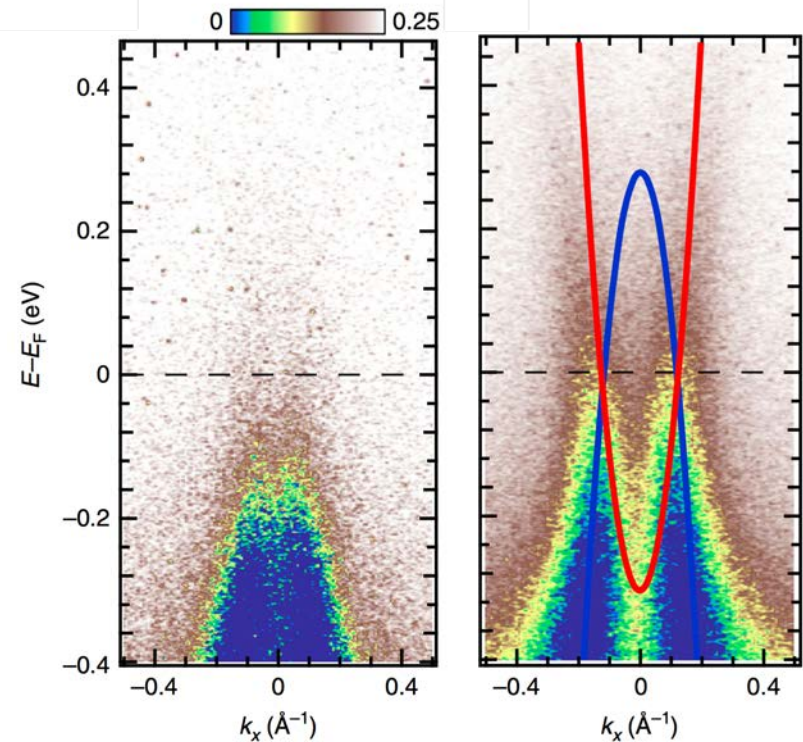
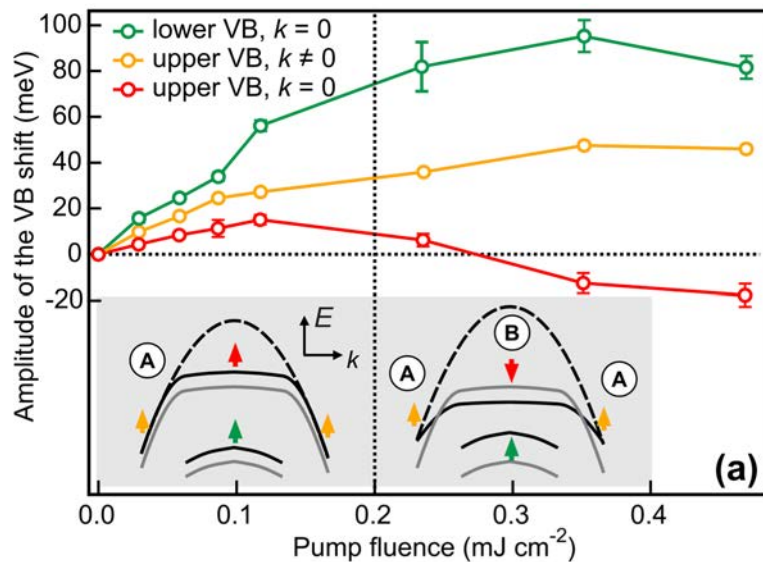
F. Boschini, ..., and A. Damascelli, Nature Materials 17, 416 (2018)

RESONANT EXCITATION ALONG THE CHAINS



Photoinduced transition

Change of the gap size

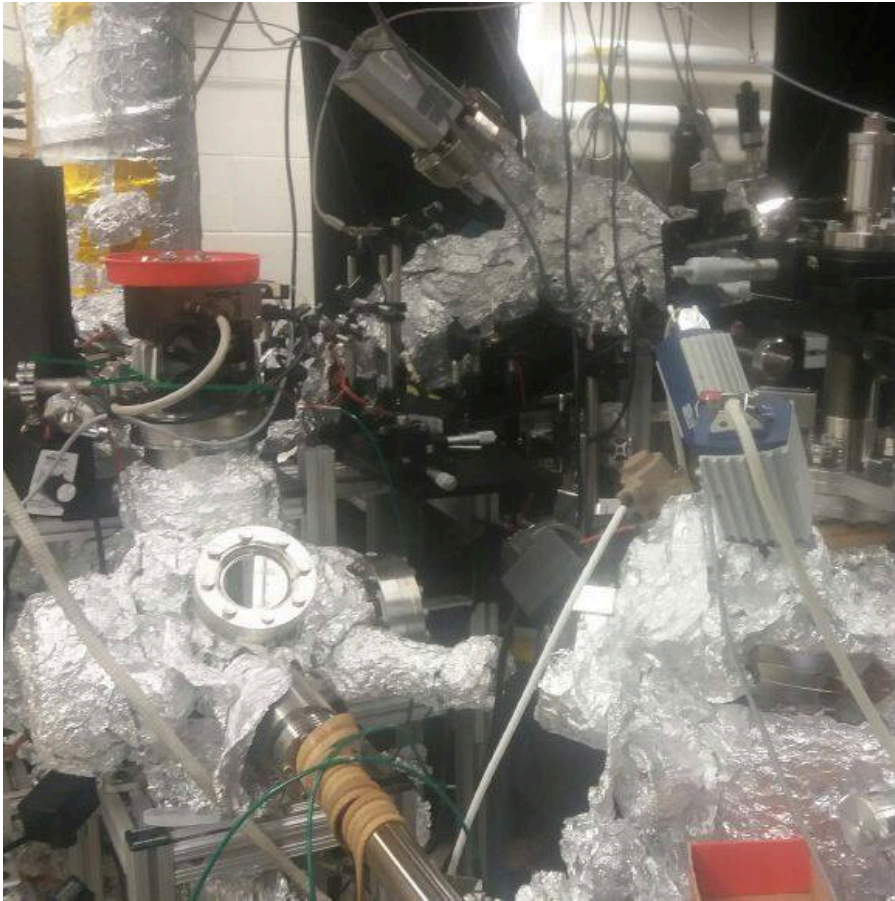


S. Mor, ..., D. Golez, et al.,
Phys. Rev. Lett. 119, 086401 (2017)

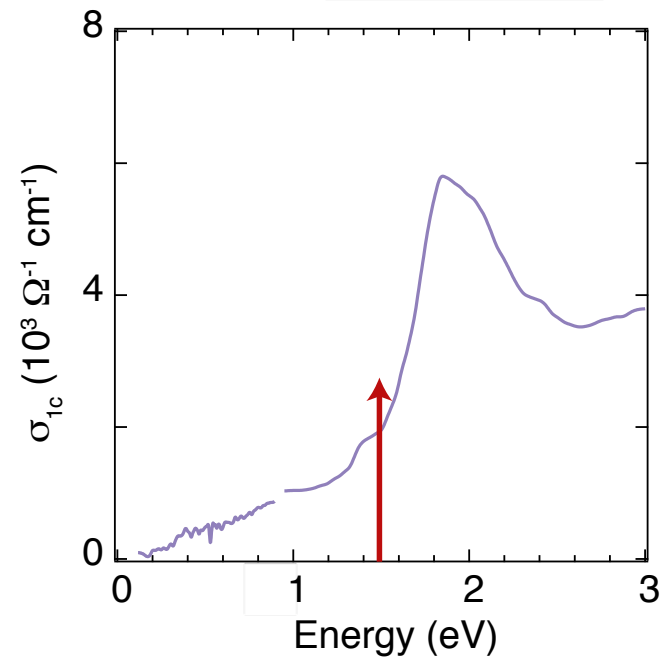
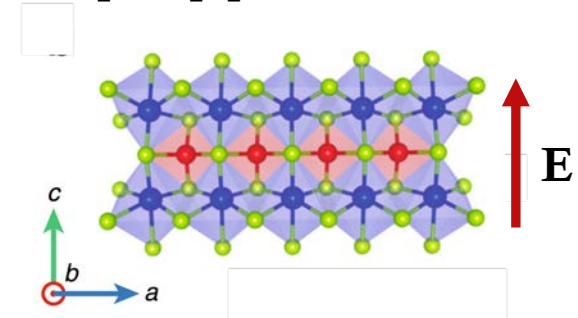
K. Okazaki, ..., H. Sawa, et al.,
Nat. Comm. 9, 4322 (2018)

OFF-RESONANT EXCITATION

Advantage of our set-up: very good control of the pump polarization

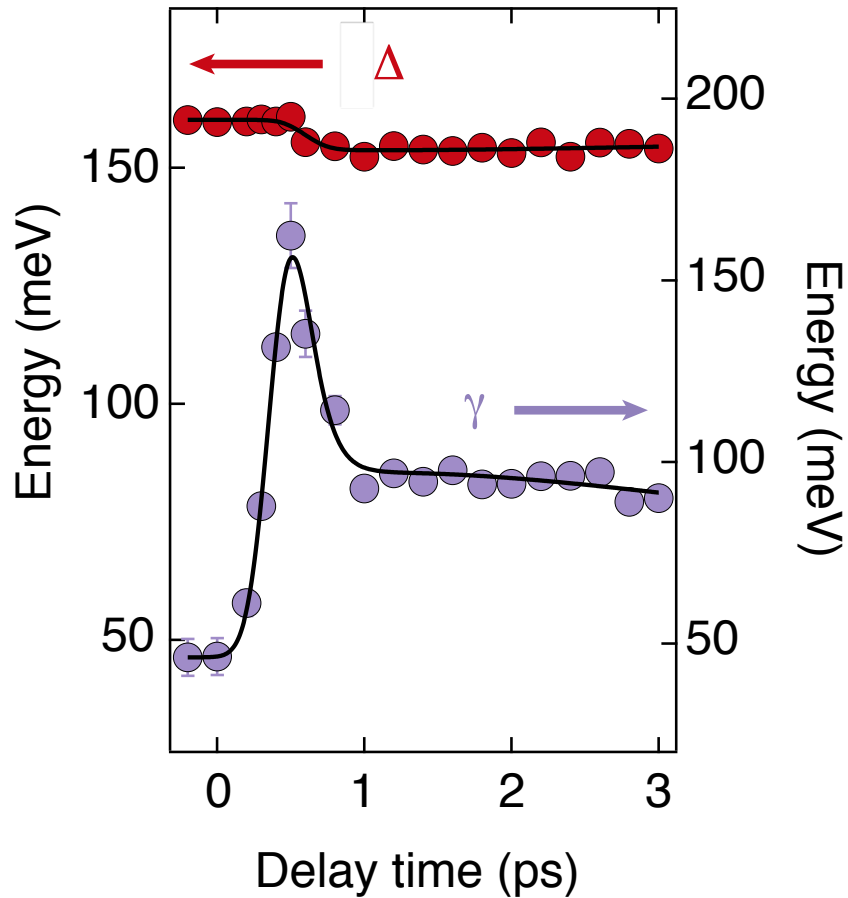


Gedik group, MIT

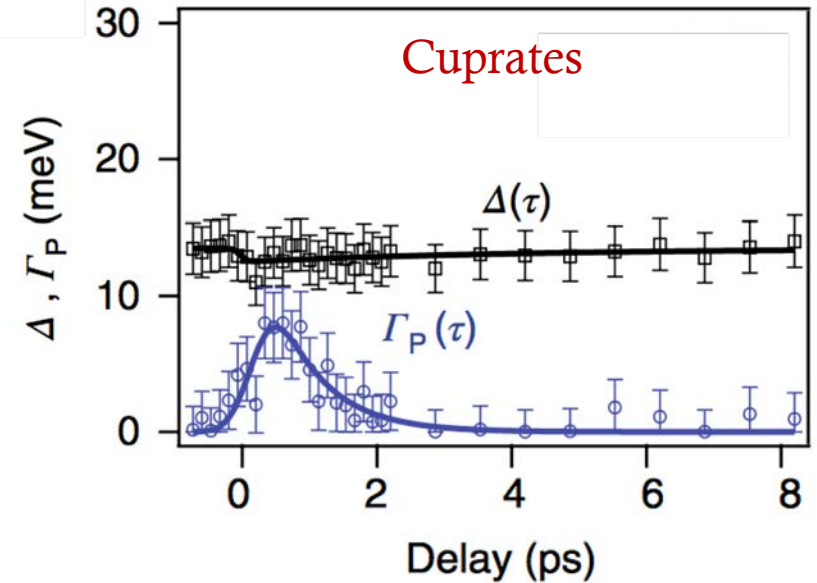


T. I. Larkin, ..., A. V. Boris,
Phys. Rev. B 95, 195144 (2017)

PHENOMENOLOGICAL FIT



Pump pulse changes
the imaginary part
of the self-energy



F. Boschini, ... and A. Damascelli,
Nat. Mat. 17, 416 (2018)

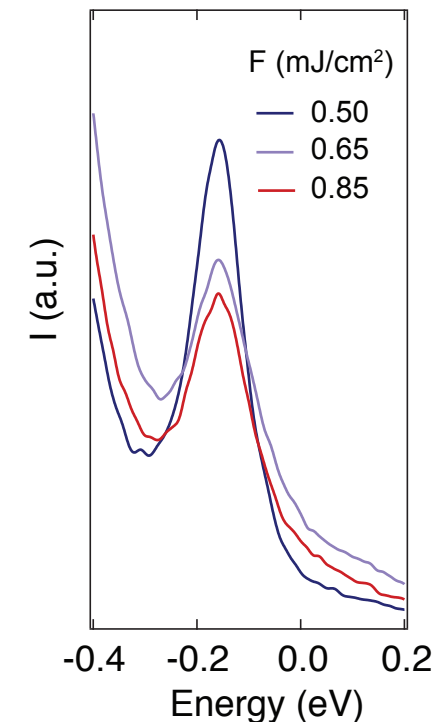
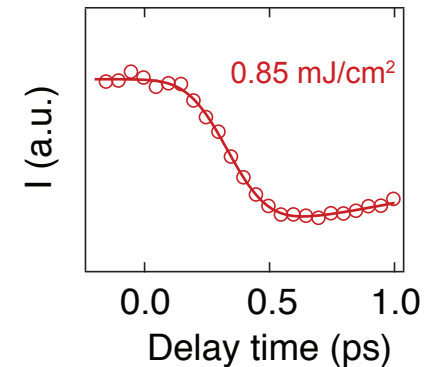
What is the mechanism behind
the broadening?

POSSIBLE MECHANISMS

Rise time of 0.5 ps **not** compatible with...

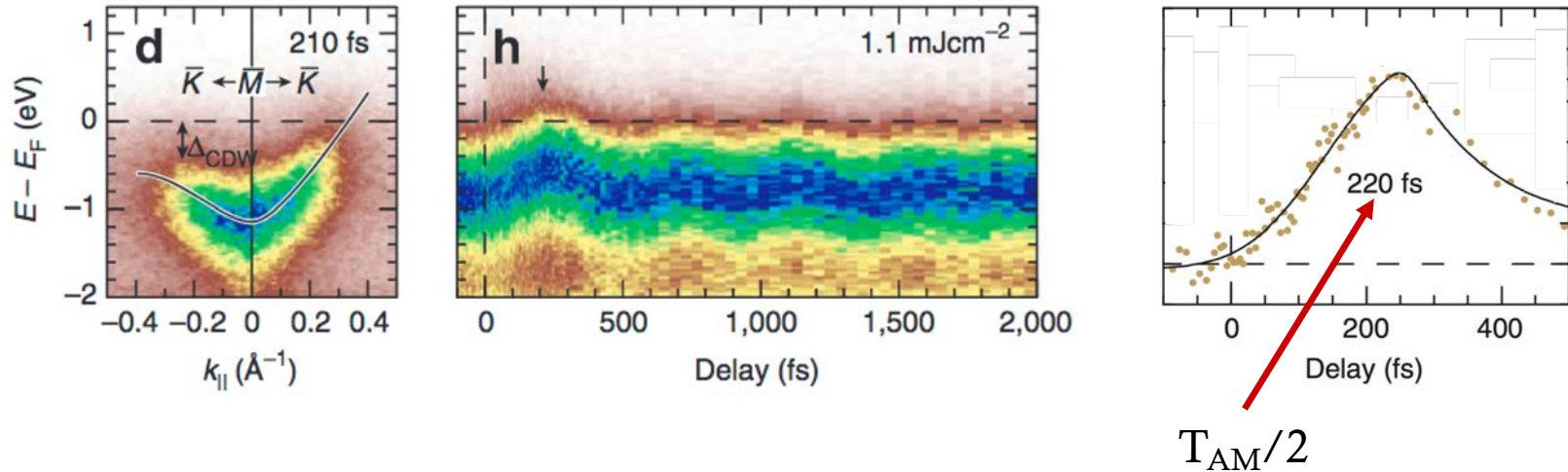
- electronic screening of U_{eh} (as in semimetals)
- intraband cooling (as in semiconductors)
- an increase in the lattice temperature
- an increase in the electronic temperature
- the avalanche multiplication of quasiparticles

**Intrinsic phenomenon evolving on the timescale
of a strongly coupled collective mode**



ELECTRON-BOSON COUPLED DYNAMICS

1T-TaS₂ (Peierls gap)



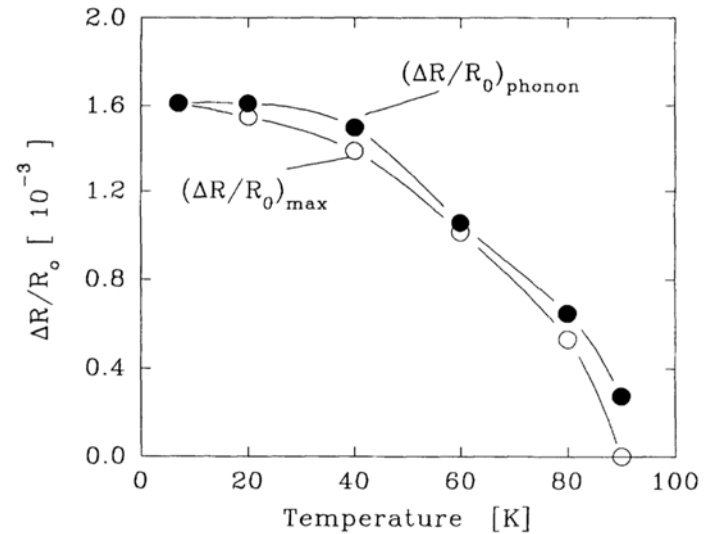
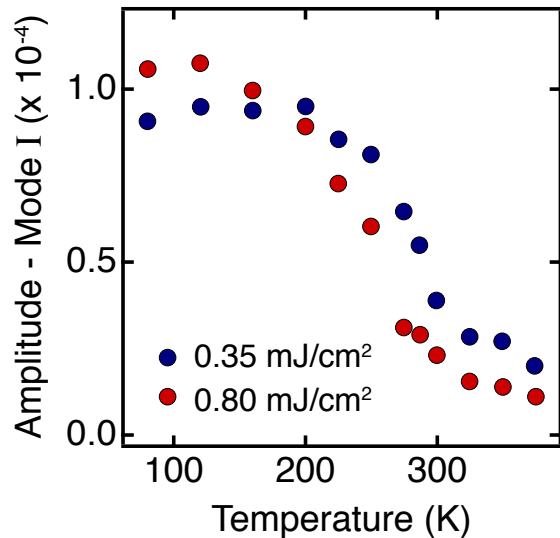
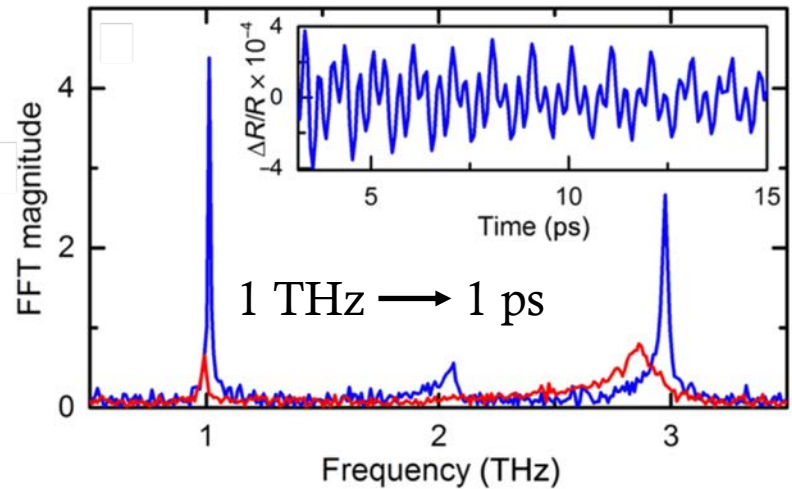
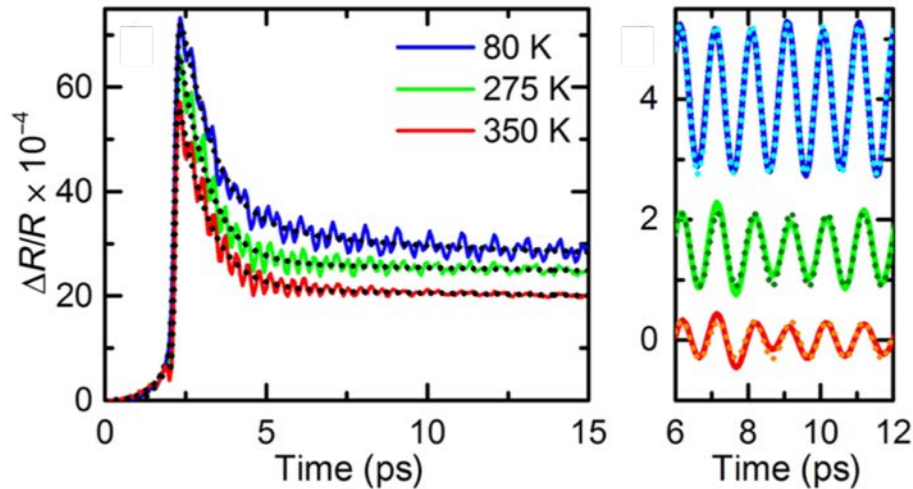
If the gap arises from the interplay between the electrons and a bosonic mode, its response cannot proceed faster than half the oscillation cycle of the coupled mode

F. Schmitt...and Z. X Shen, Science 321, 5896 (2008)

J. C. Petersen...and A. Cavalleri, Phys. Rev. Lett. 107, 177402 (2011)

S. Hellmann...and K. Rossnagel al., Nat. Comm. 3, 1069 (2012)

ORDER PARAMETER



D. Werdehausen, ..., S. Kaiser,
Science Advances 4, 8652 (2018)

B. Friedl, M. Cardona, Sol. State Comm. 78, 4 (1991)
W. Albrecht, et al., Phys. Rev. Lett. 69, 1451 (1992)

CONCLUSIONS

- Phonons play a vital role in the order parameter

PHYSICAL REVIEW B **90**, 195118 (2014)

Fate of the excitonic insulator in the presence of phonons

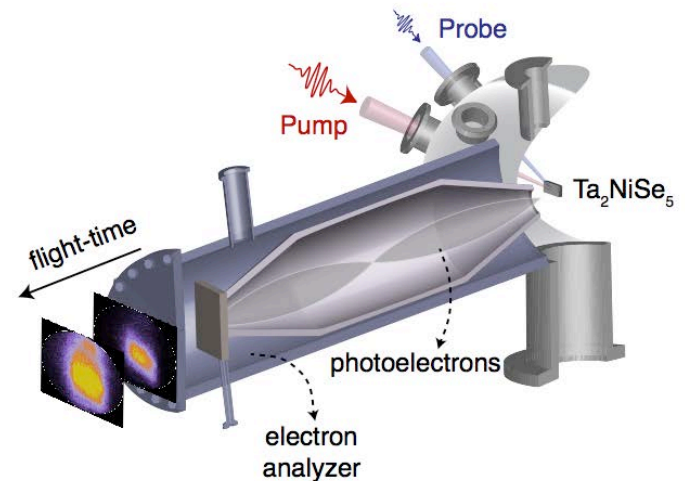
B. Zenker,¹ H. Fehske,¹ and H. Beck²

¹*Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, D-17489 Greifswald, Germany*

²*Département de Physique and Fribourg Center for Nanomaterials, Université de Fribourg, CH-1700 Fribourg, Switzerland*

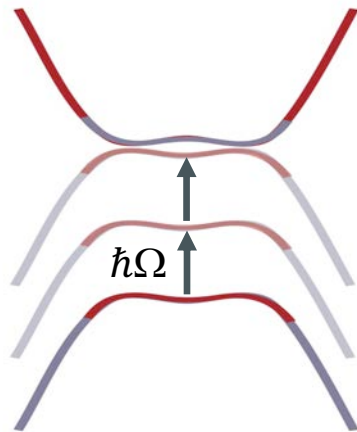
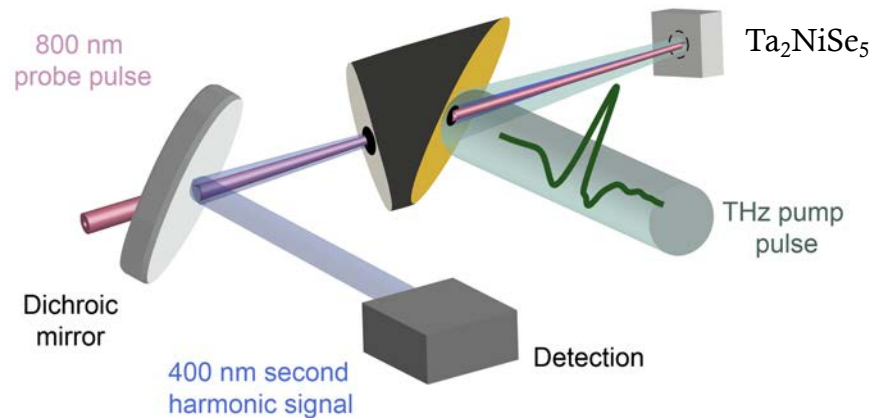
(Received 17 July 2014; revised manuscript received 15 October 2014; published 11 November 2014)

- Off-resonant laser pulses couple directly to the phase of the order parameter, leaving the amplitude unperturbed.



PERSPECTIVES

High-field THz schemes to drive the 1 THz mode out of equilibrium and find possible signatures of the coupled massive phase mode (in collaboration with Keith Nelson, MIT).



TrARPES with half-gap photoexcitation: Floquet dressing of the electronic structure

ACKNOWLEDGEMENTS



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