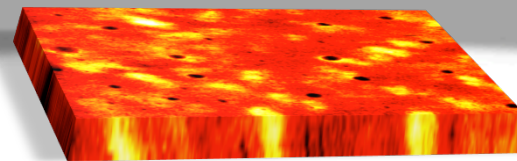


Quantum materials: insights from near field nano-optics

D.N. Basov, Columbia University



Support:

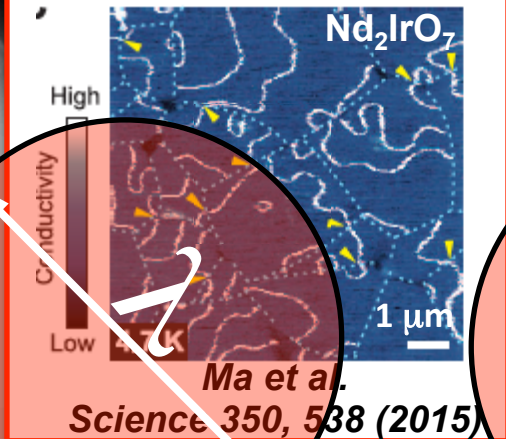


Quantum materials: insights from near field nano-optics

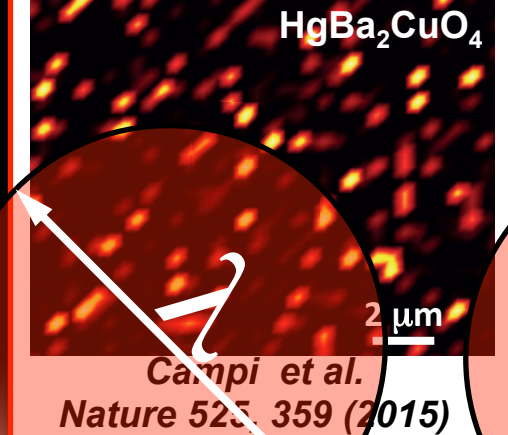
D.N. Basov, Columbia University



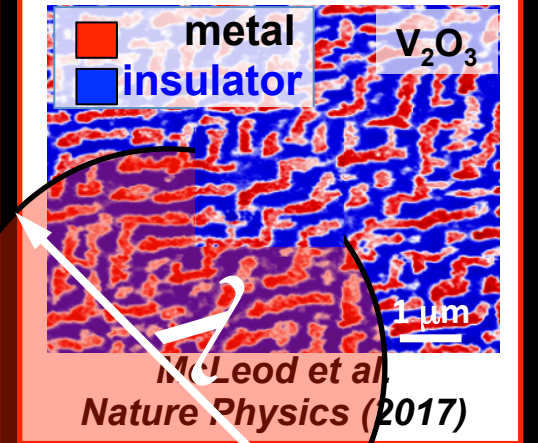
Domain walls/ Weyl states



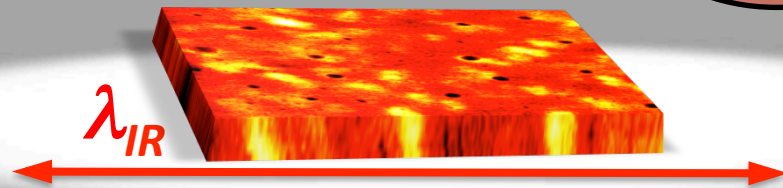
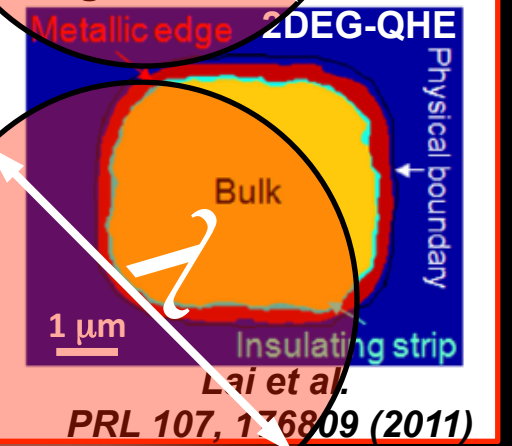
CDW droplets / cuprates



Phase separation / stripes

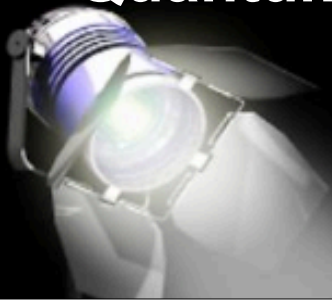


Edge currents & states



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Outline:

Why nano-light?

Phase transitions at the nanoscale

McLeod et al. Nature Physics (2017)

Jang et al. Nature Materials (2016)

Light-matter polaritons

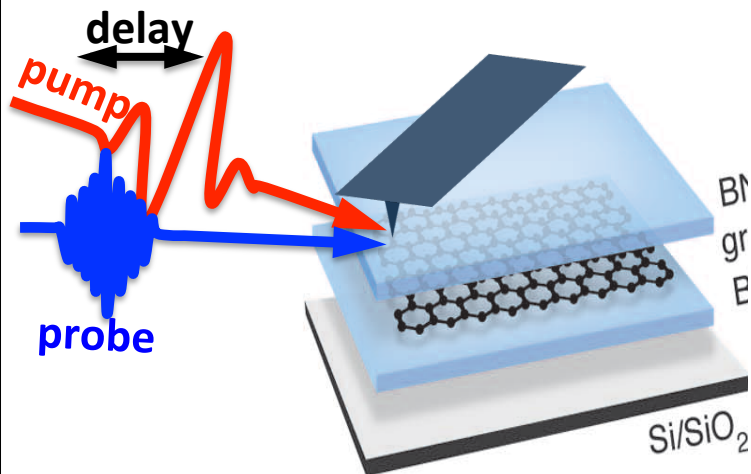
& search for Berry plasmons

Ni et al. Nature Phot 10 244 (16)

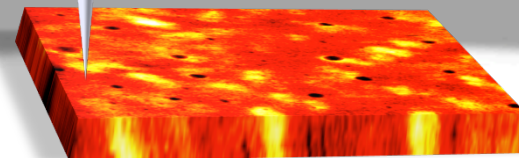
Basov et al. Science (2016)

‘Complete’ response function

$$\sigma(\omega, t, x, q)$$



Guangxin Ni et al.
Nature Photonics 10, 244 (2016)



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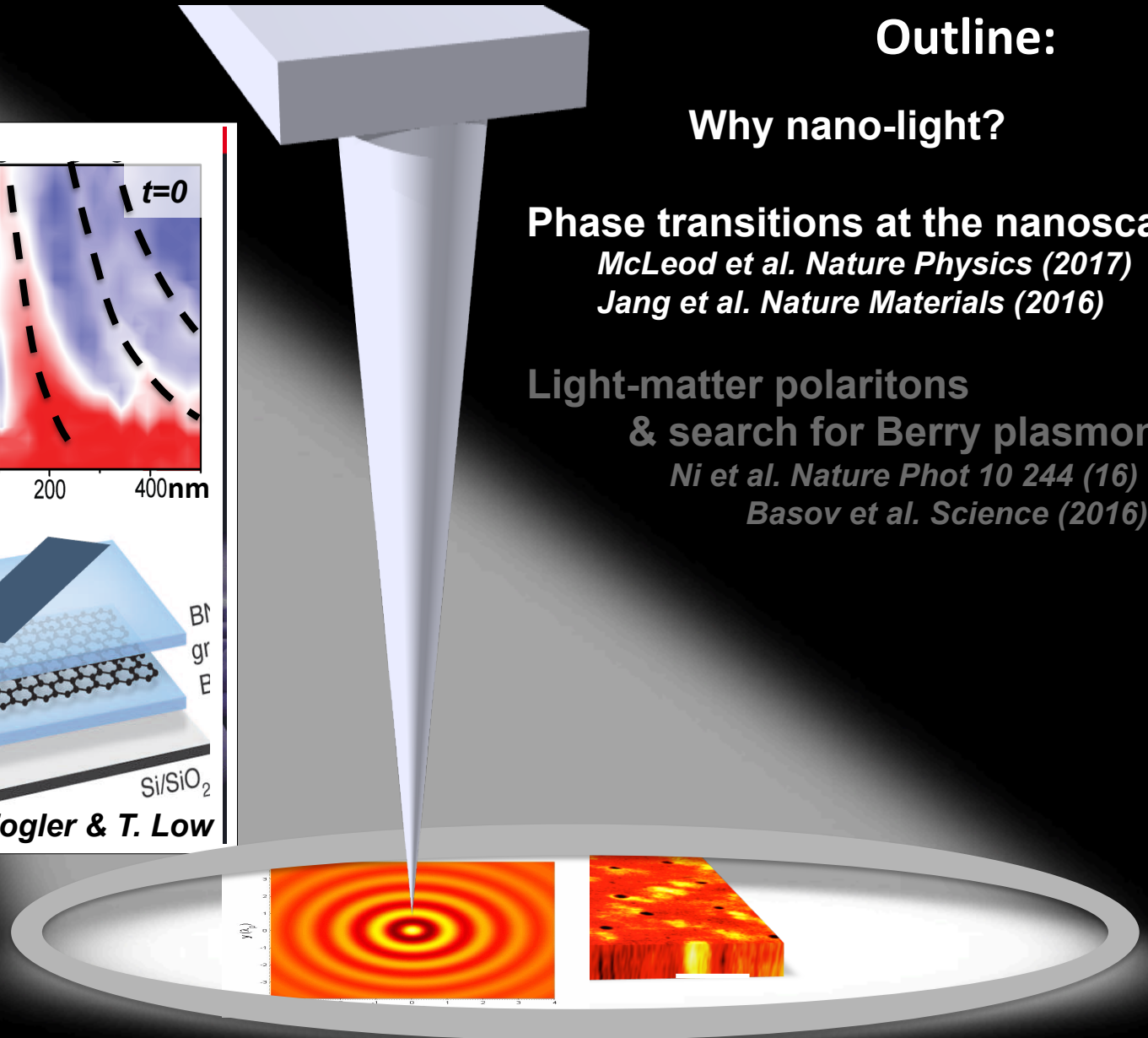
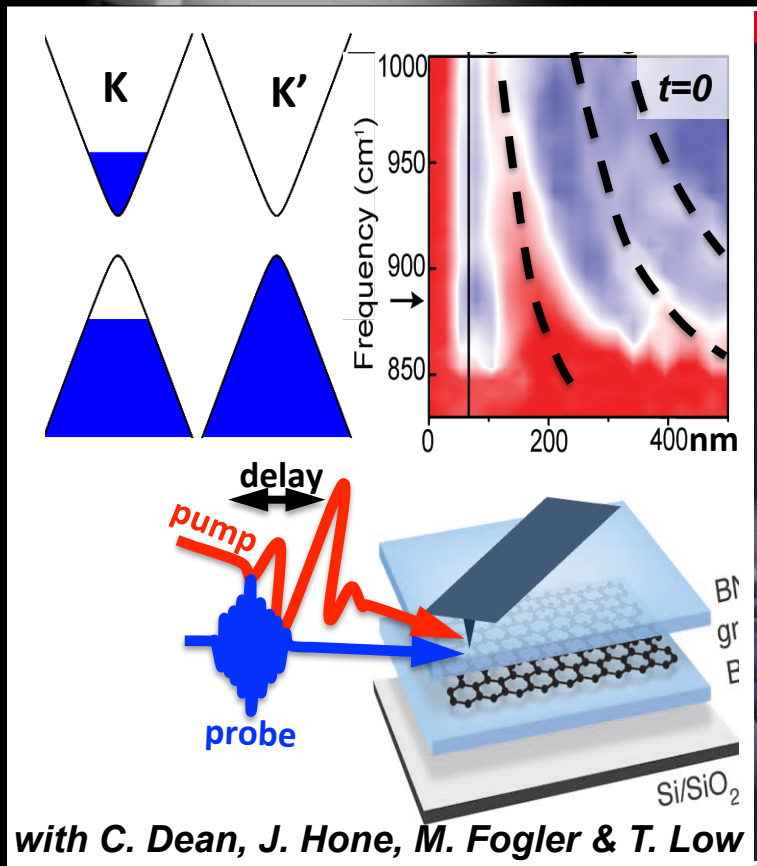
Jang et al. Nature Materials (2016)

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& search for Berry plasmons

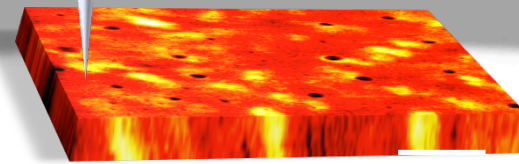
Ni et al. Nature Phot 10 244 (16)

Basov et al. Science (2016)



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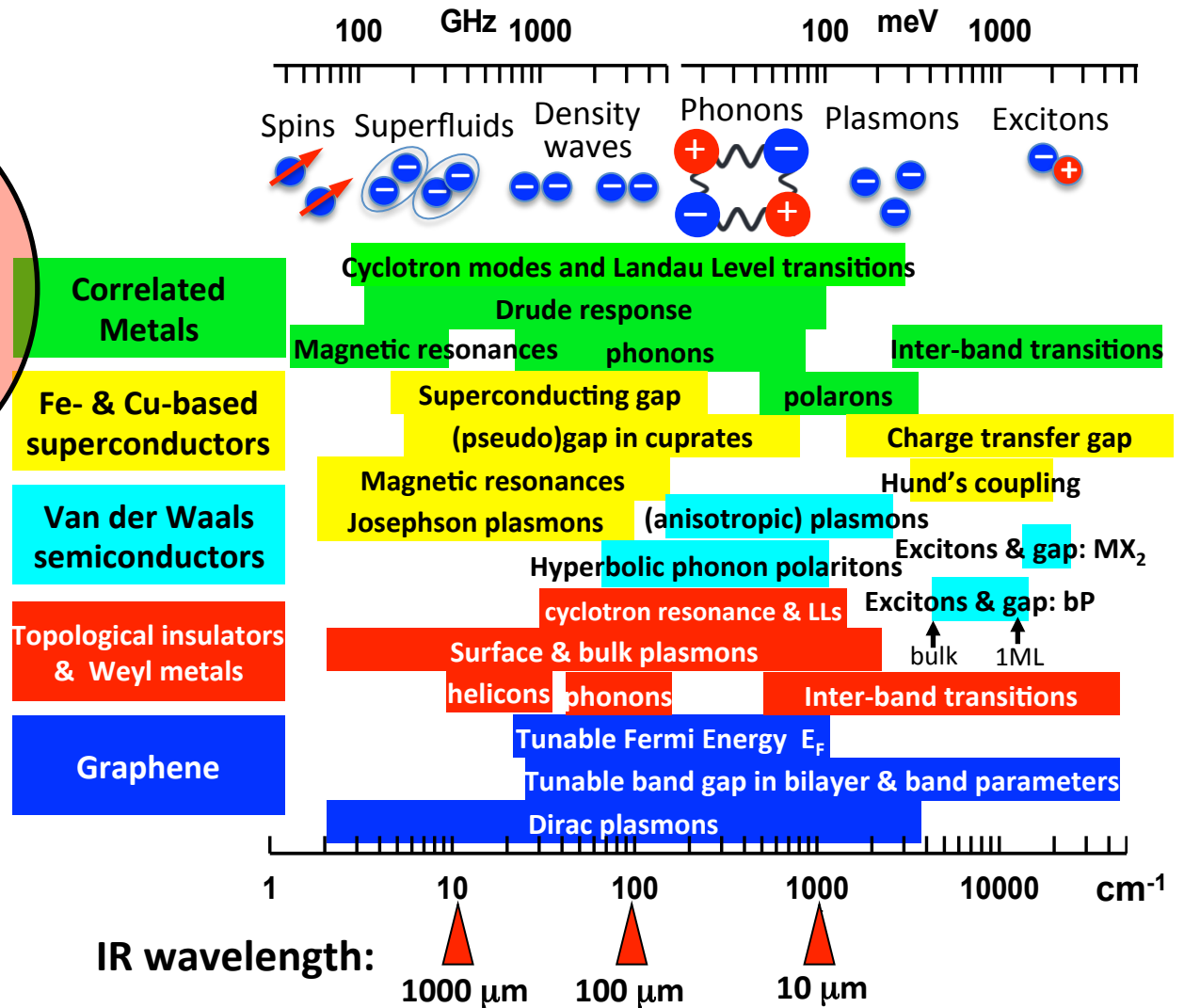
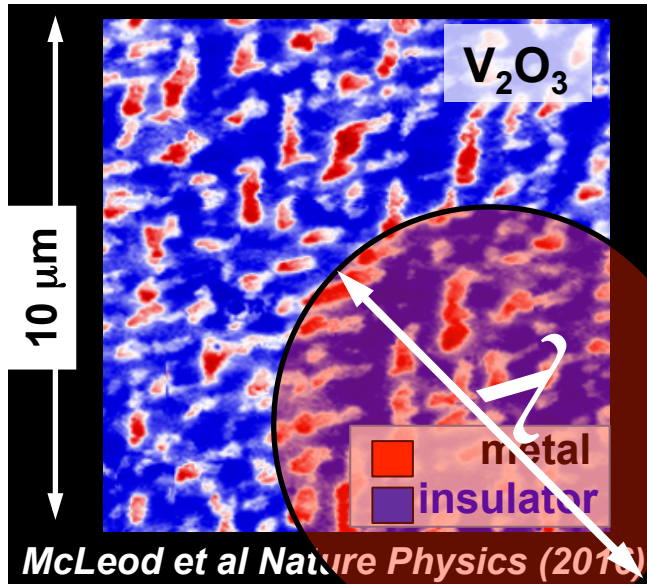
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Ni et al. Nature Phot 10 244 (16)

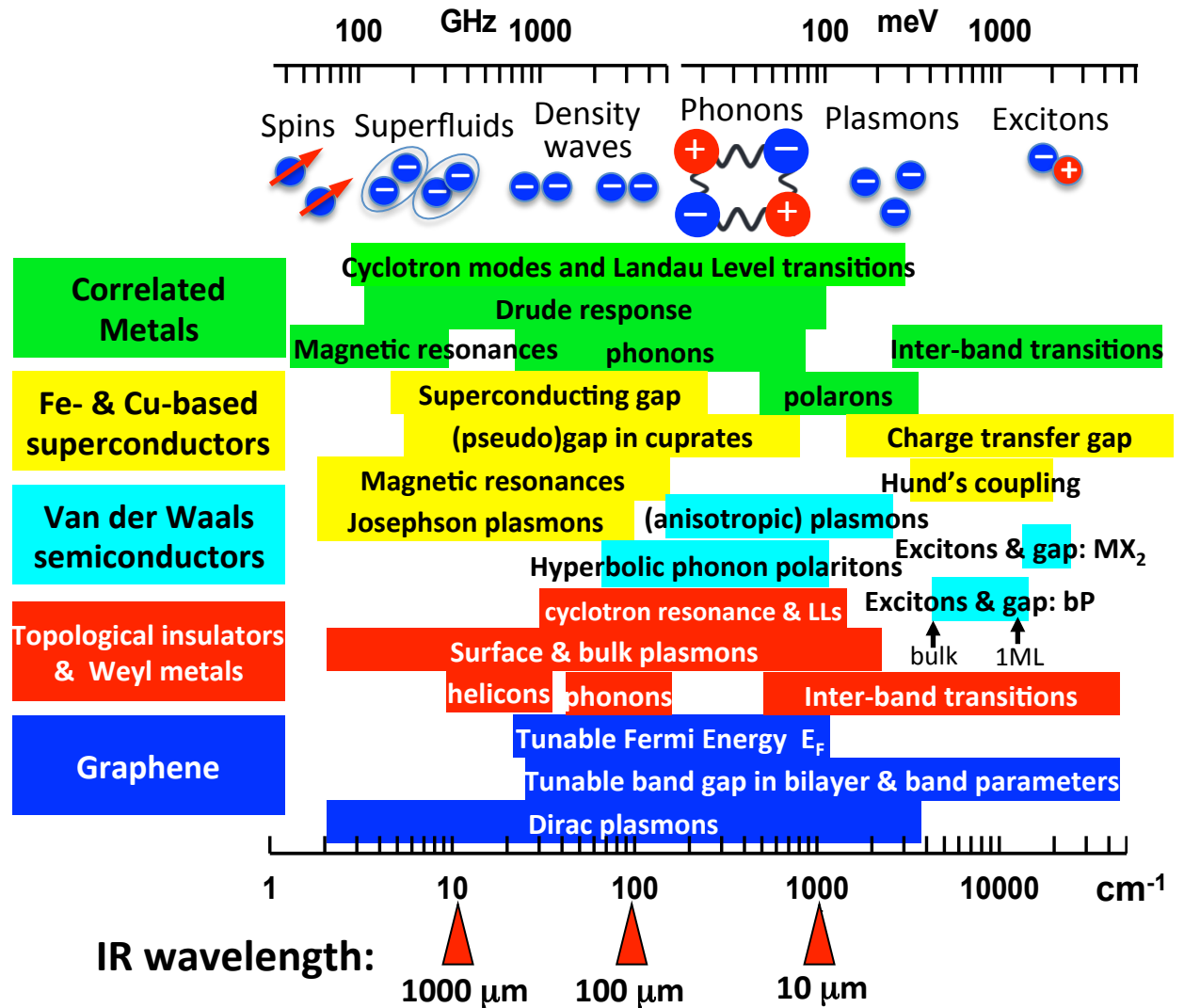
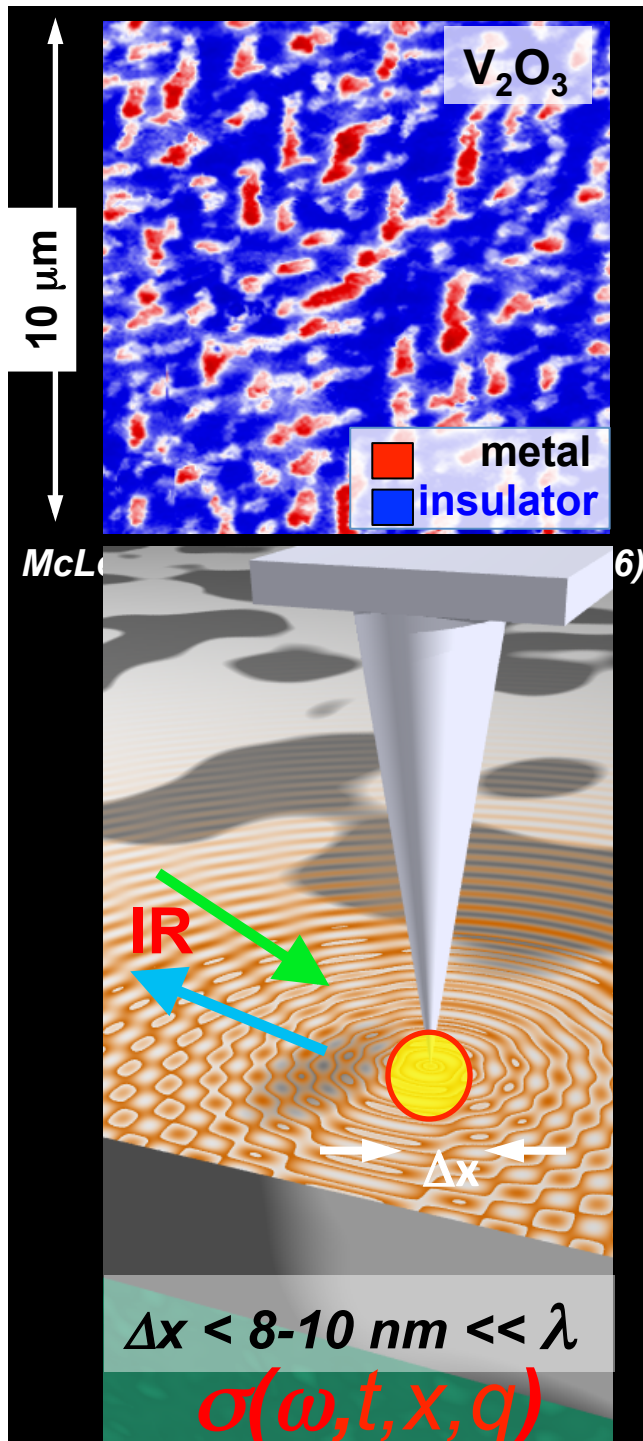
Basov et al. Science (2016)

Quantum materials and infrared nano-optics



D.N. Basov, M.Fogler, A.Lanzara, F. Wang and Y. Zhang, *RMP* 86, 959 (2014)
 D.N. Basov, R.A. Averitt, D. van der Marel, M. Dressel, K. Haule *RMP* 83, 471 (2011)
 D.N. Basov and A.V. Chubukov *Nature-Physics* 7, 272 (2011)

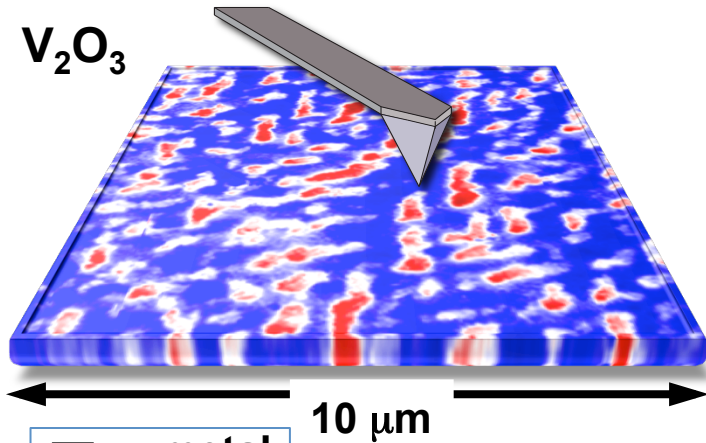
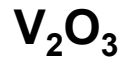
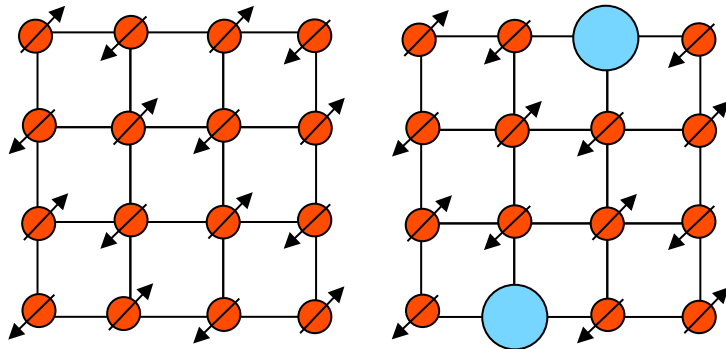
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D.N. Basov, M.Fogler, A.Lanzara, F. Wang and Y. Zhang, *RMP* 86, 959 (2014)
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McLeod et al Nature Physics (2016)

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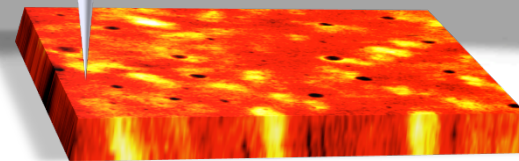
Jang et al. Nature Materials (2016)

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& search for Berry plasmons

Ni et al. Nature Phot 10 244 (16)

Basov et al. Science (2016)



V_2O_3 : a prototypical Mott insulator

VOLUME 3, NUMBER 1

PHYSICAL REVIEW LETTERS

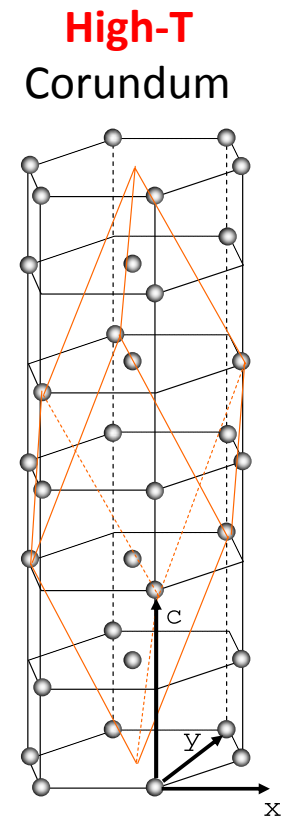
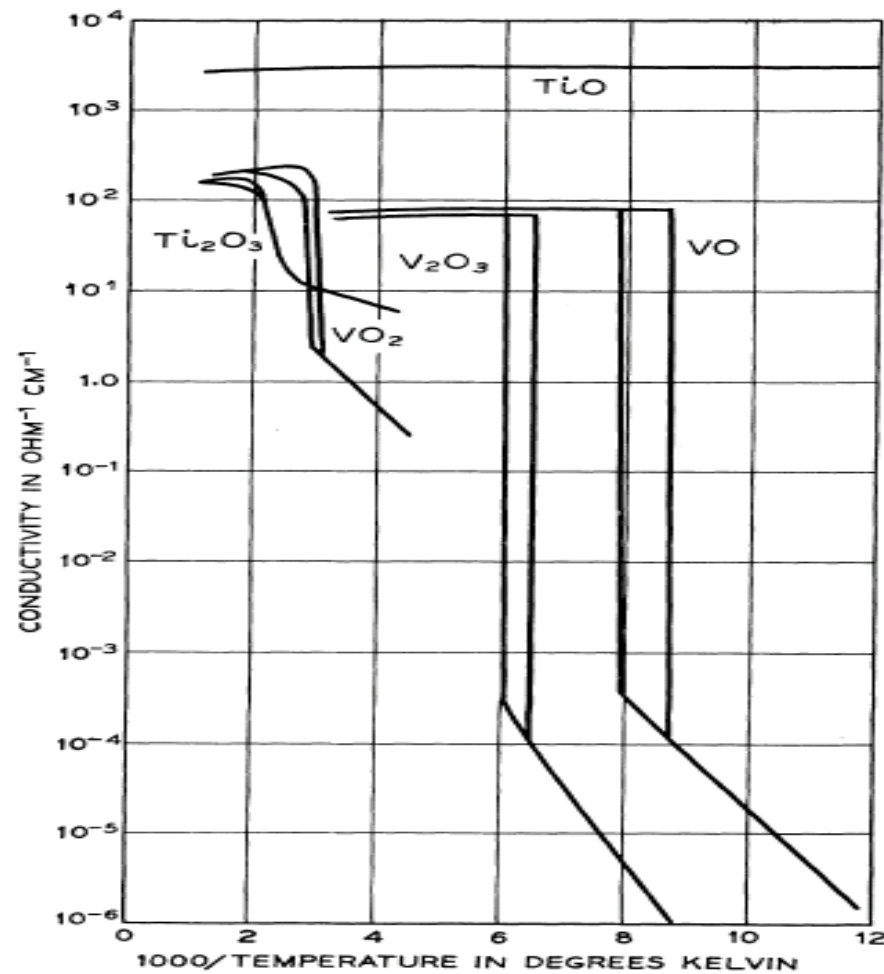
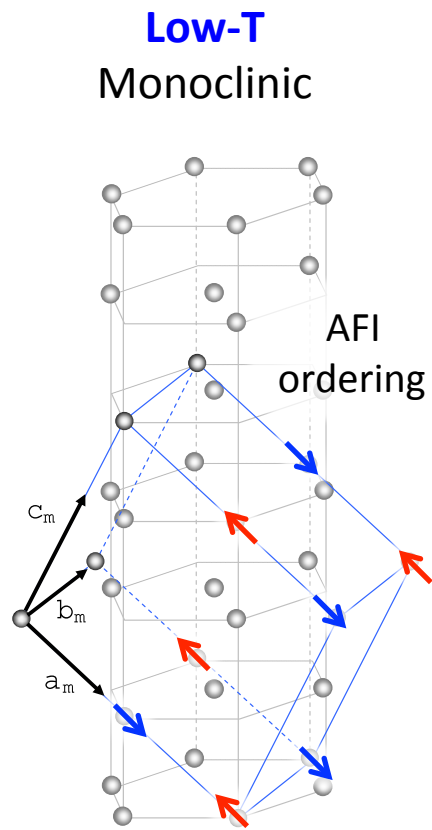
JULY 1, 1959

OXIDES WHICH SHOW A METAL-TO-INSULATOR TRANSITION AT THE NEEL TEMPERATURE

F. J. Morin

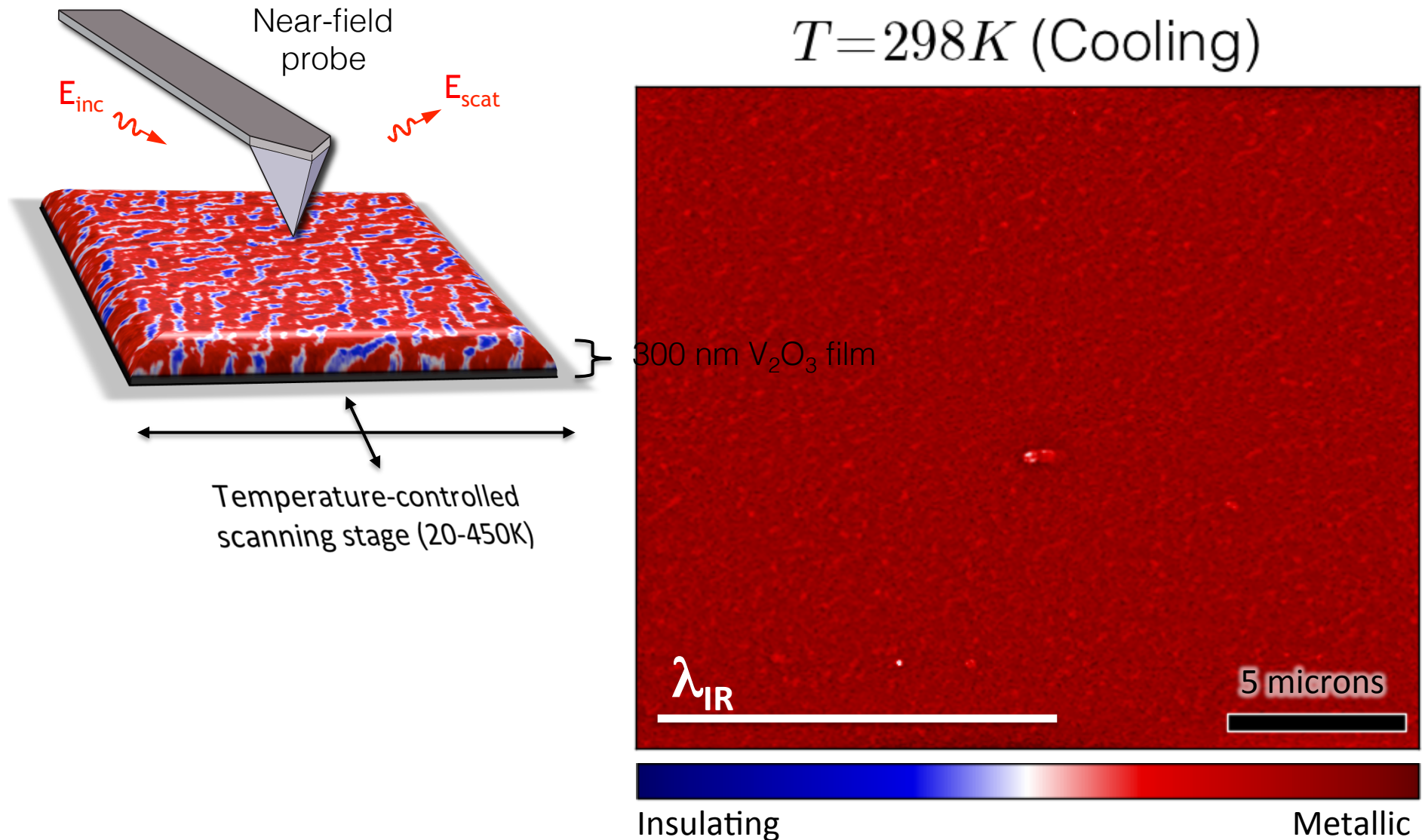
Bell Telephone Laboratories, Murray Hill, New Jersey

(Received June 5, 1959)



Phase separation in V_2O_3 : insights from IR nano-imaging

With Ivan Schuller (UCSD)

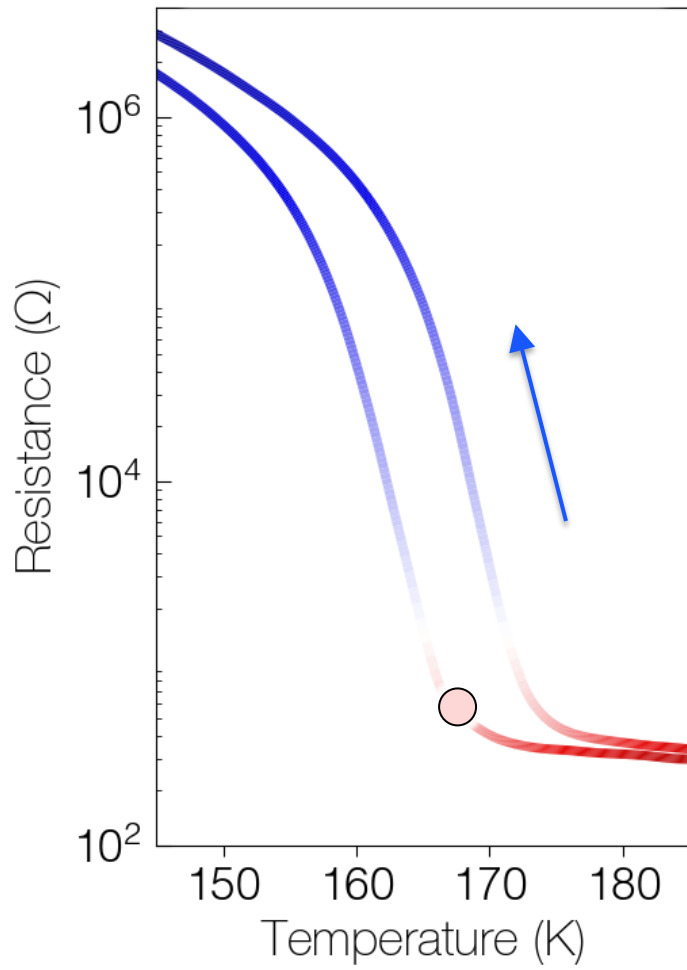


A. McLeod et al. *Nature Physics* 13, 80 (2017)

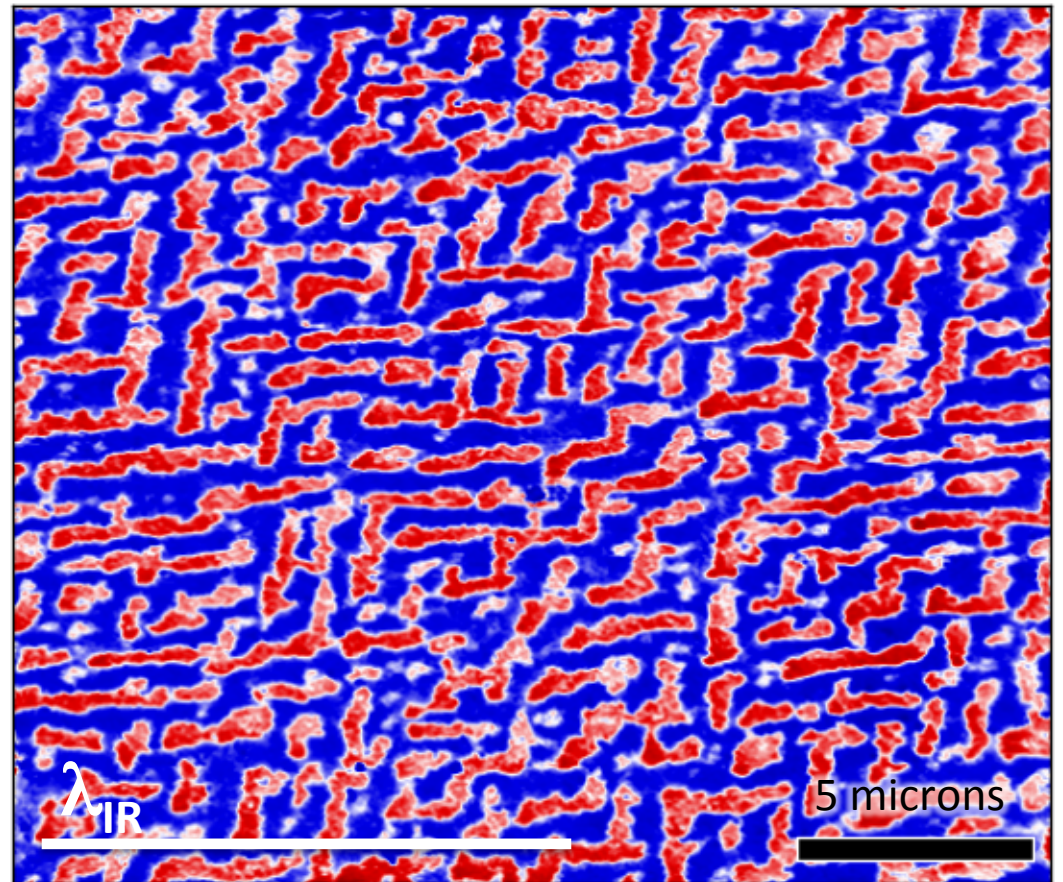
Phase separation in V_2O_3 : insights from IR nano-imaging

With Ivan Schuller (UCSD)

In situ resistance



$T = 167\text{K}$ (Cooling)



Insulating

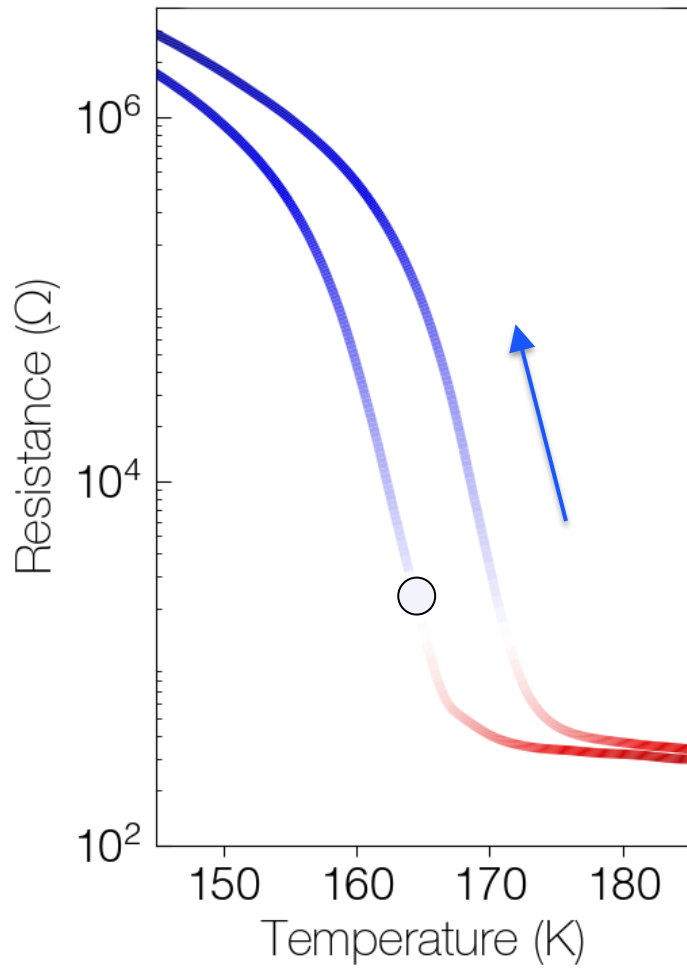
Metallic

A. McLeod et al. *Nature Physics* 13, 80 (2017)

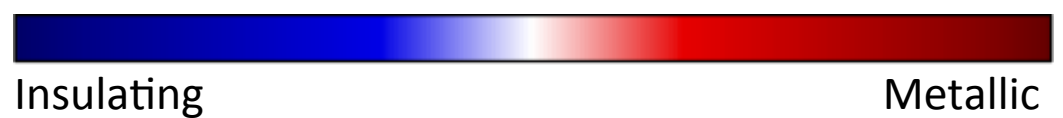
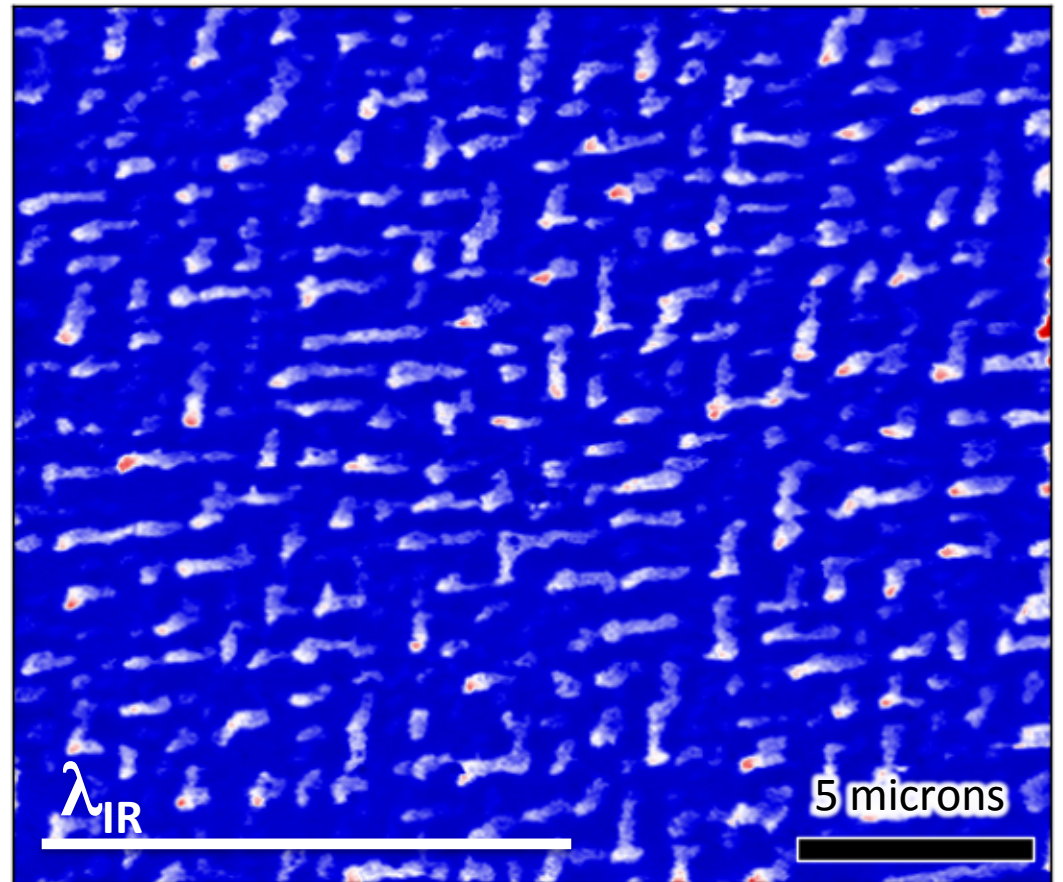
Phase separation in V_2O_3 : insights from IR nano-imaging

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In situ resistance

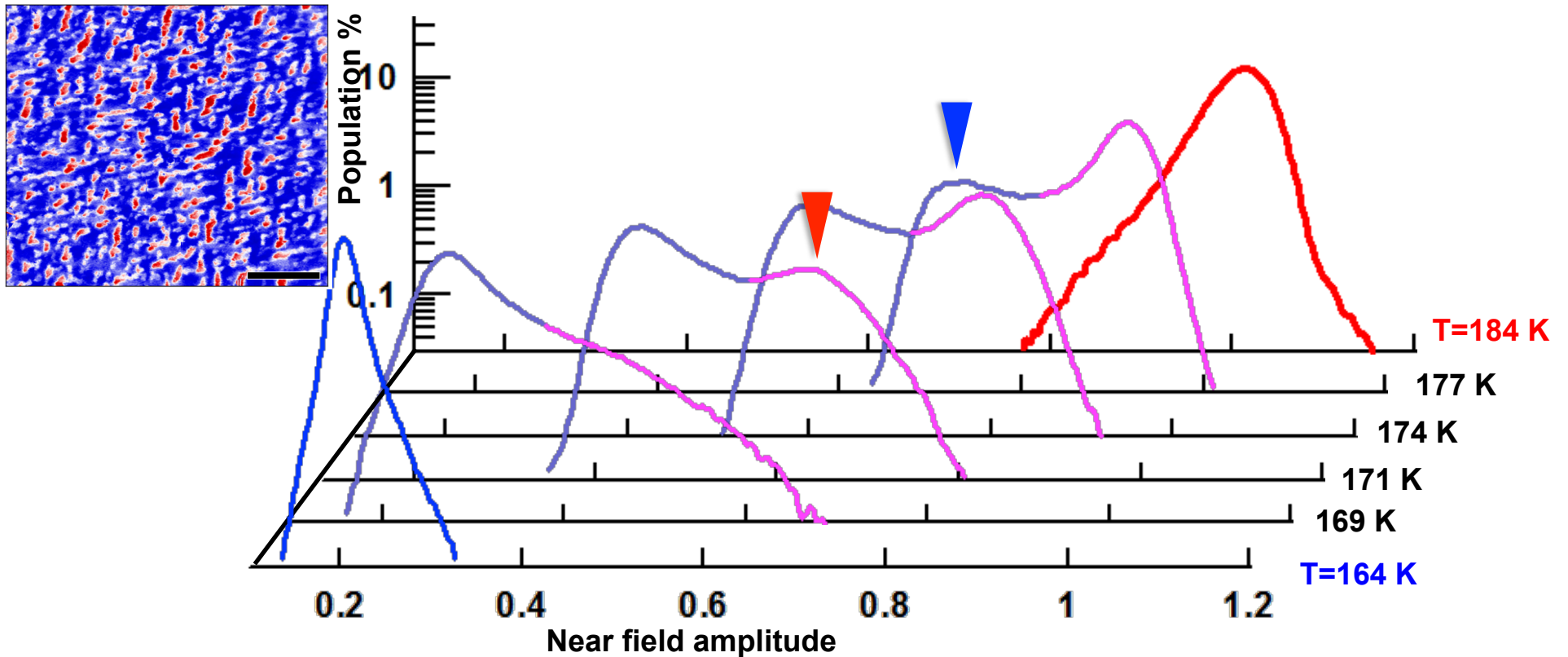


$T = 164K$ (Cooling)



A. McLeod et al. *Nature Physics* 13, 80 (2017)

V_2O_3 : hidden phases in the insulator to metal transition region

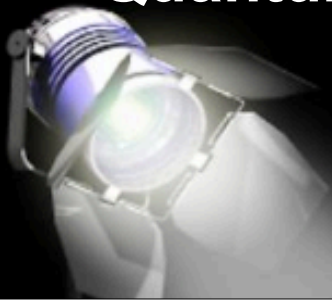


B. Spivak & S. A. Kivelson. *Ann Phys* 321 **2071**, 255–256 (2005).

A. McLeod et al. *Nature Physics* 13, 80 (2017)

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D.N. Basov, Columbia University



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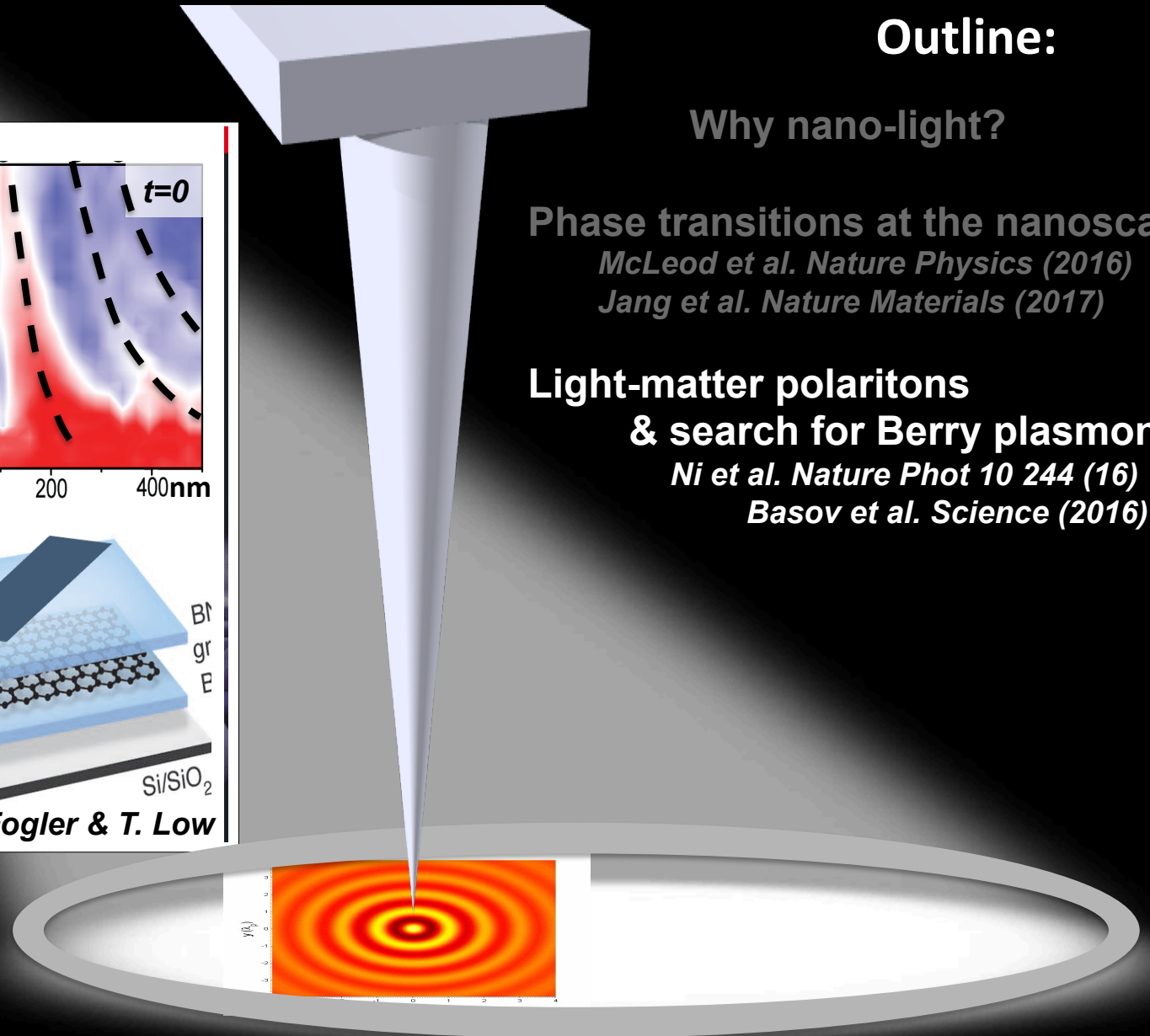
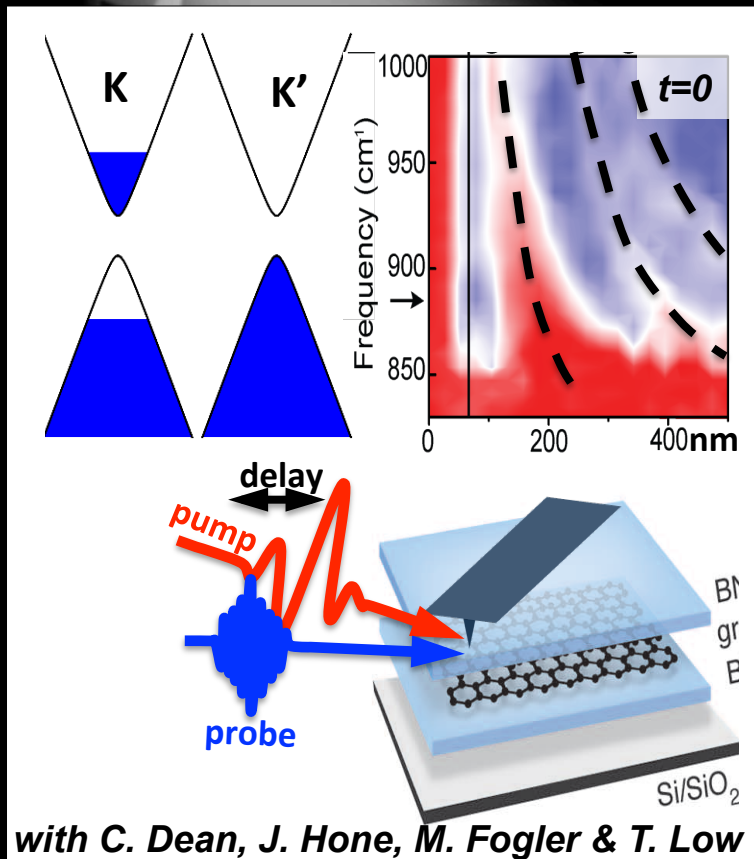
Jang et al. Nature Materials (2017)

Light-matter polaritons

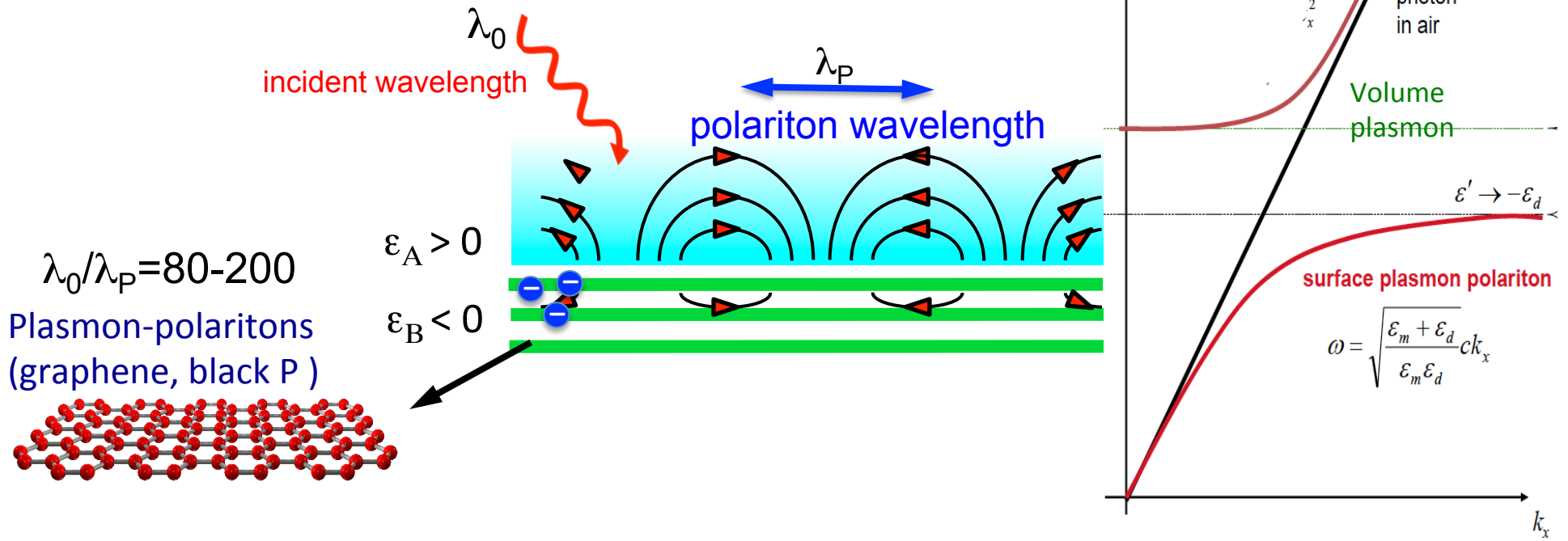
& search for Berry plasmons

Ni et al. Nature Phot 10 244 (16)

Basov et al. Science (2016)

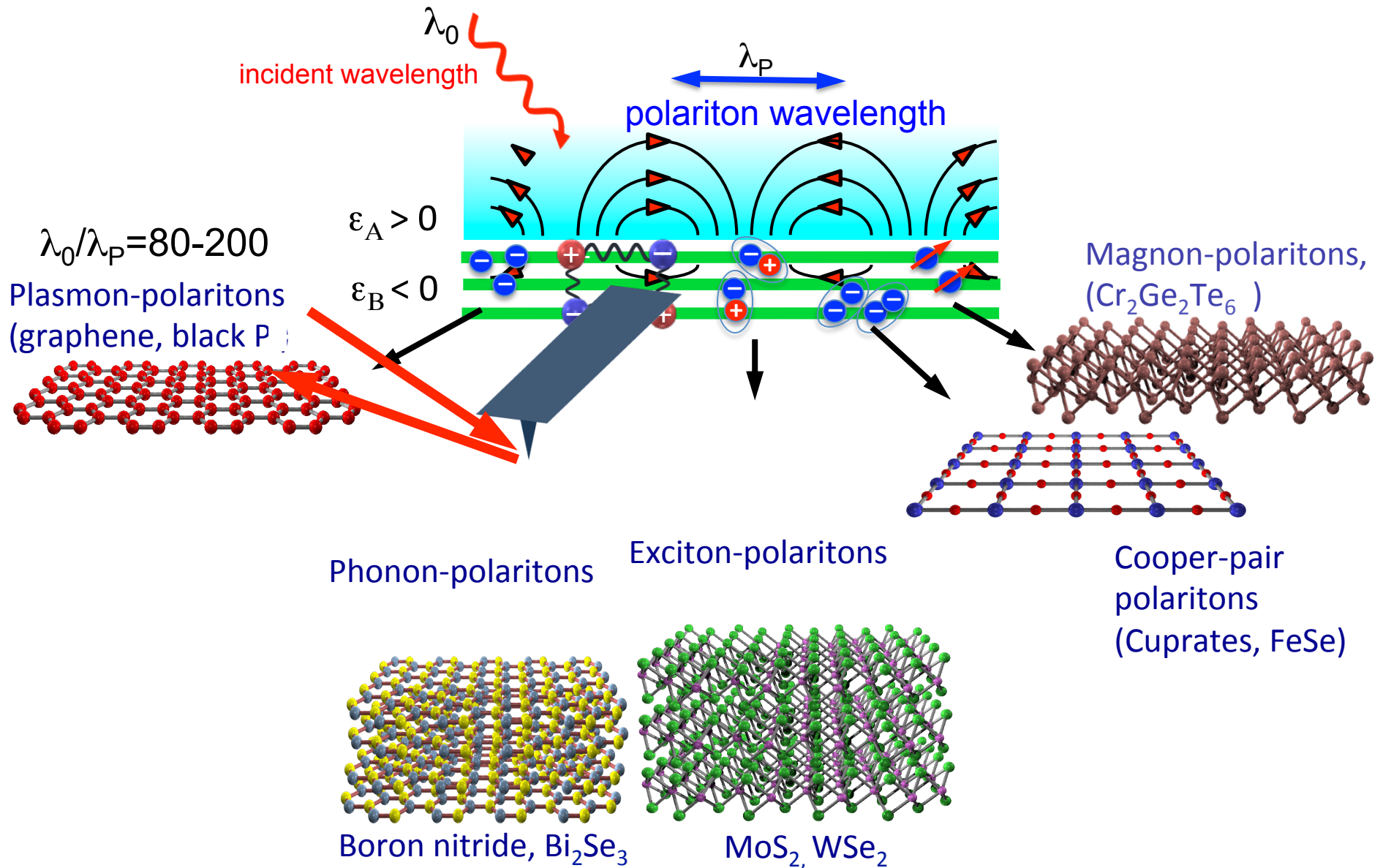


On surface plasmon polaritons

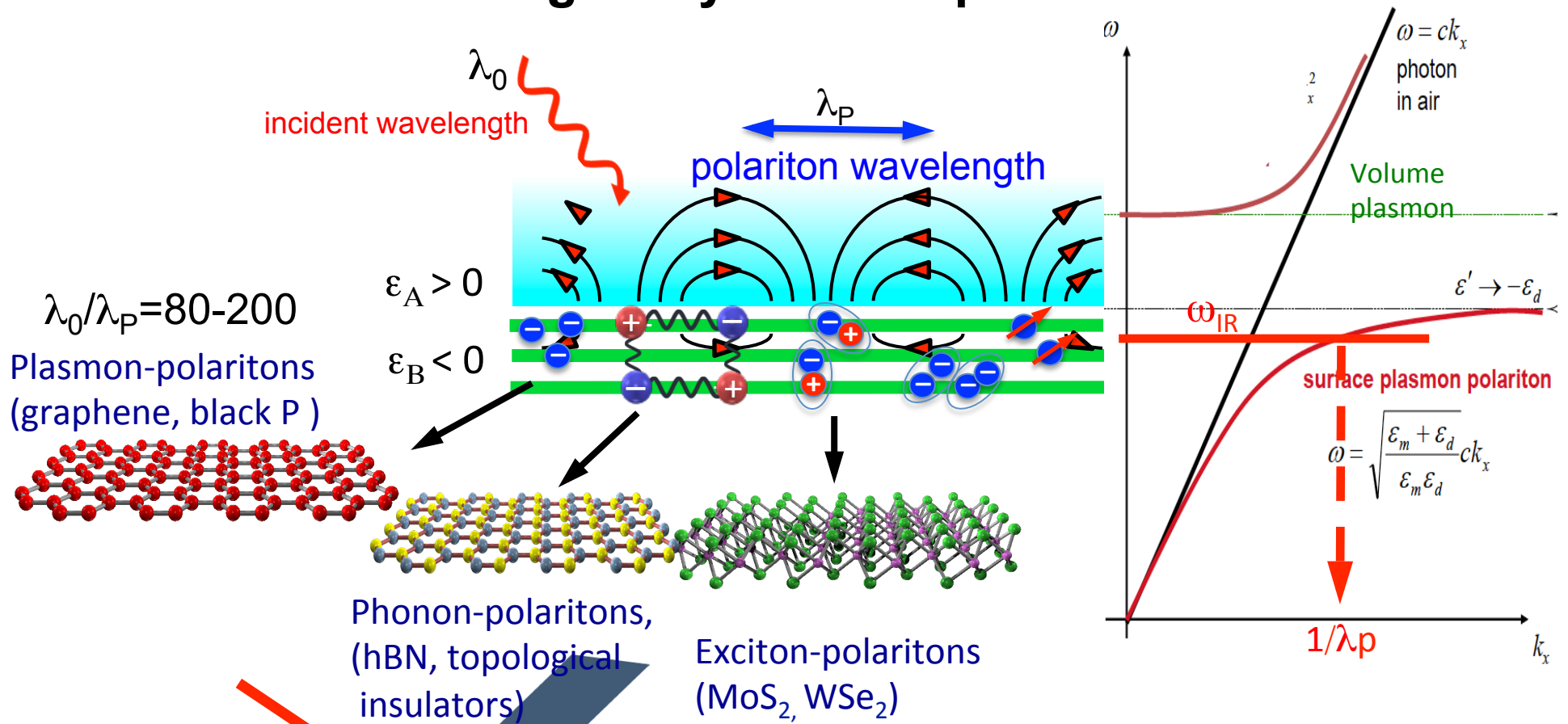


Phonon-polaritons,
 (hBN, topological
 insulators)

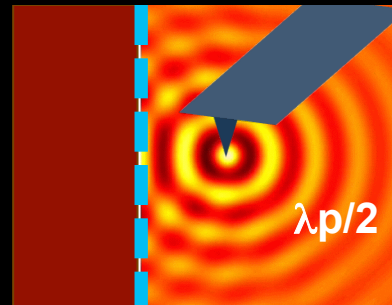
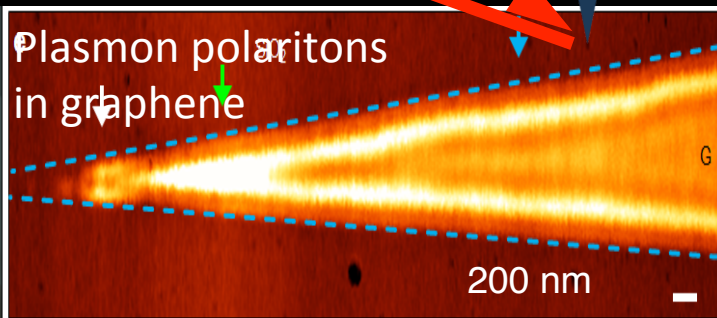
On many kinds of polaritons in van der Waals materials



Visualizing many kinds of polaritons...

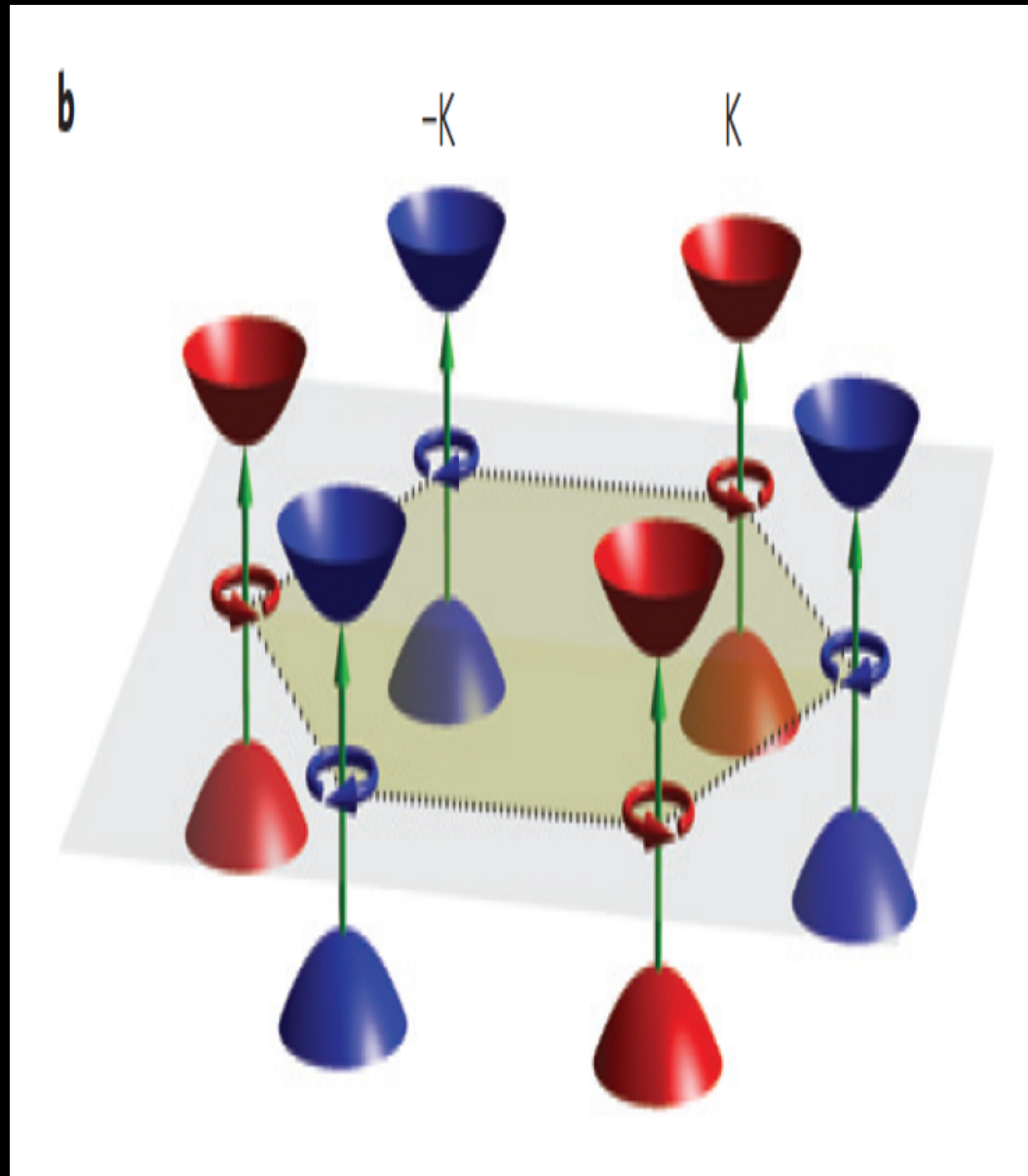
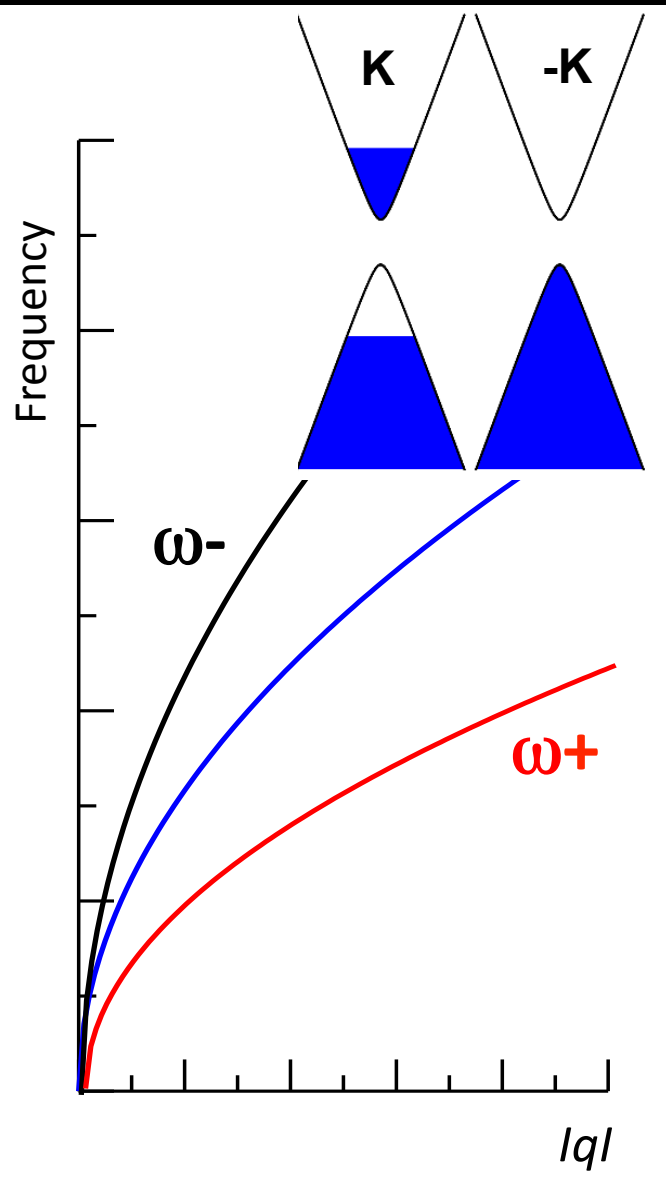


Polaritonic images: a tool to study New Physics of quantum materials



Fei et al Nature 487, 82 (2012)
 Chen et al. Nature 487, 77 (2012)

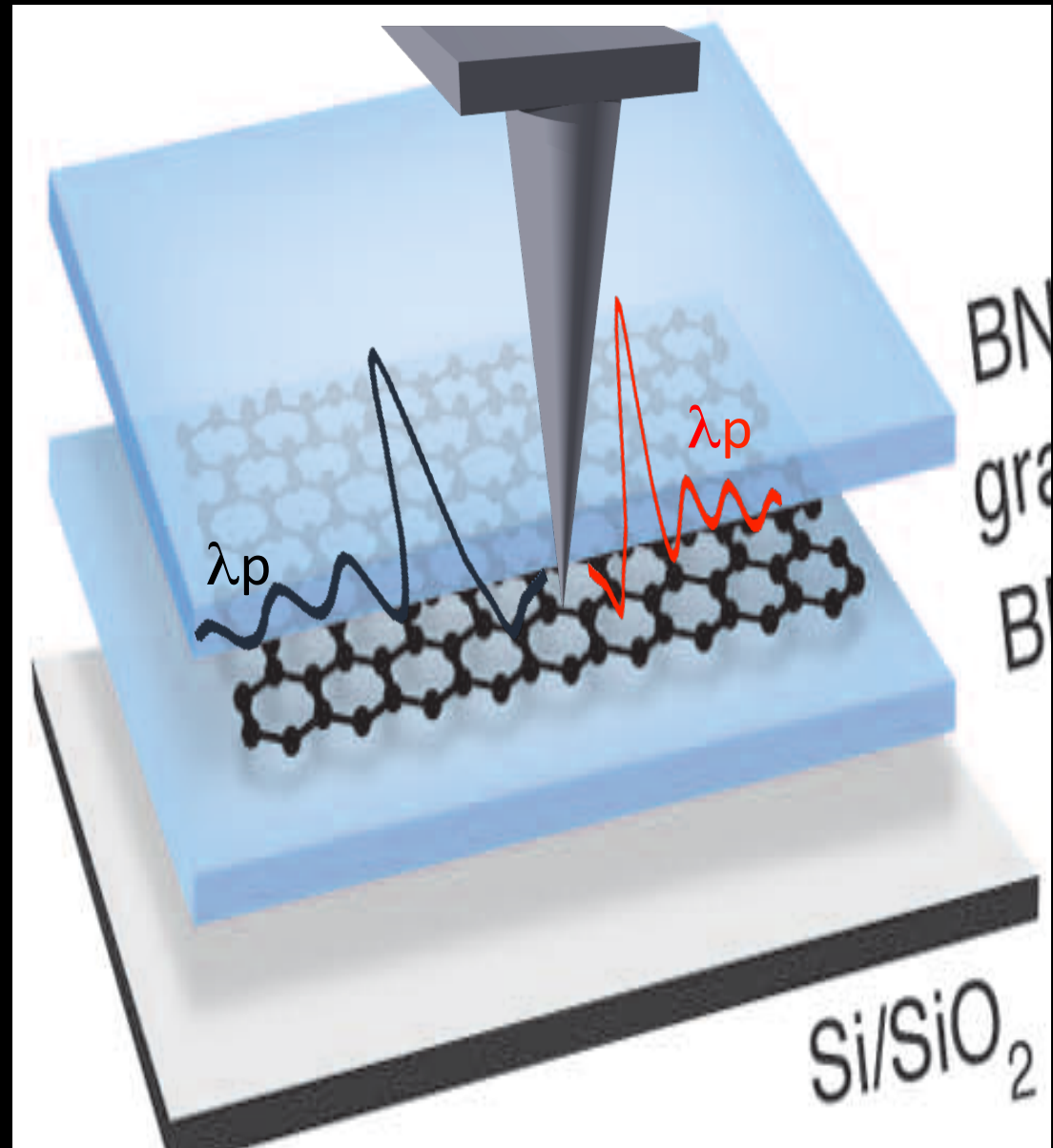
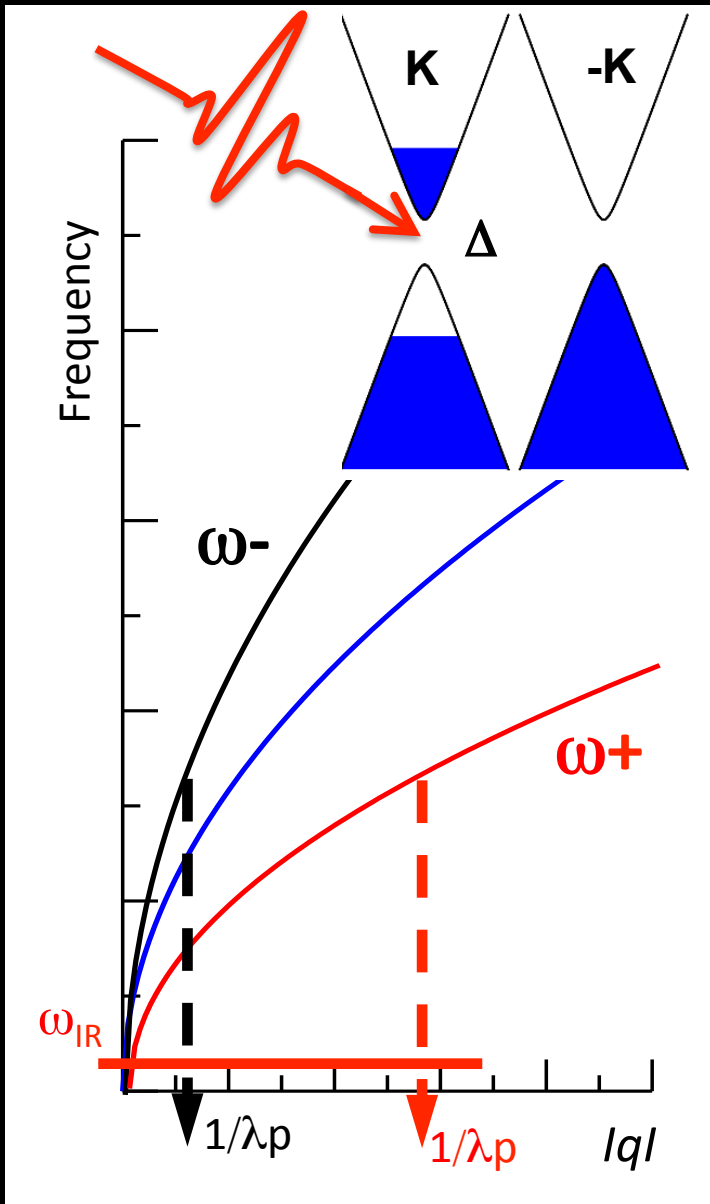
Plasmons in gapped Dirac materials: Berry plasmons



*L. Levitov, G.Refael, J.Song,
N.Fang, S. Das Sarma, T.Low, ...*

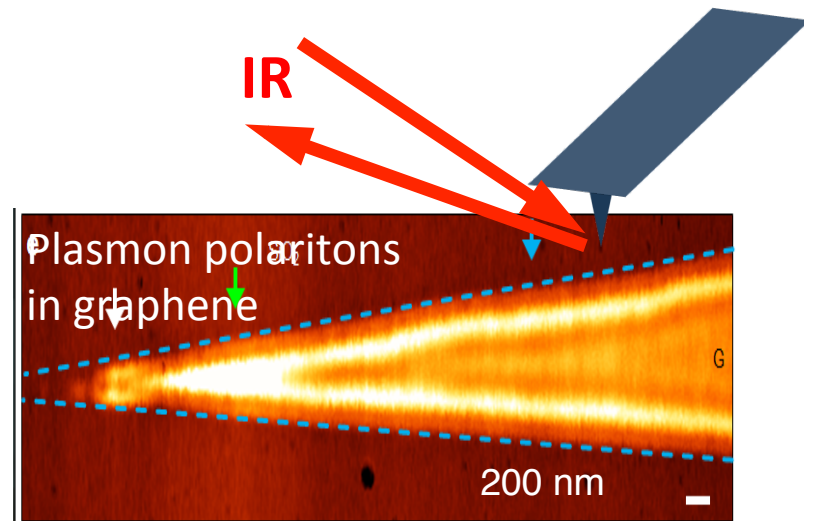
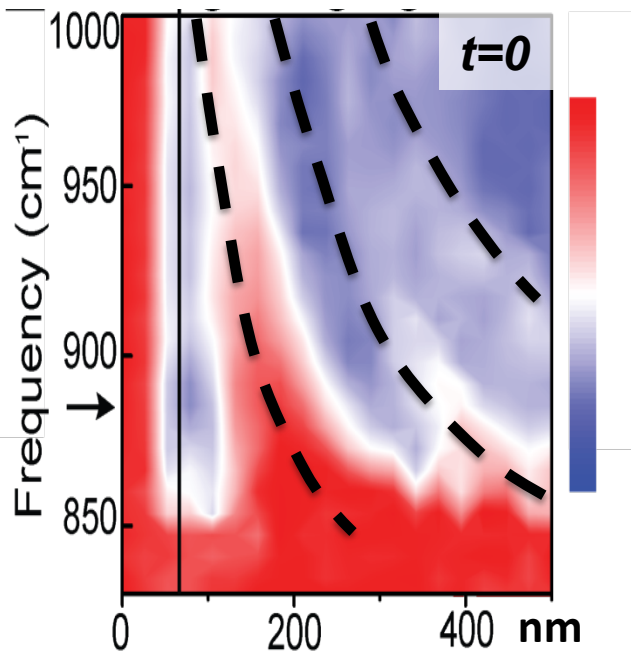
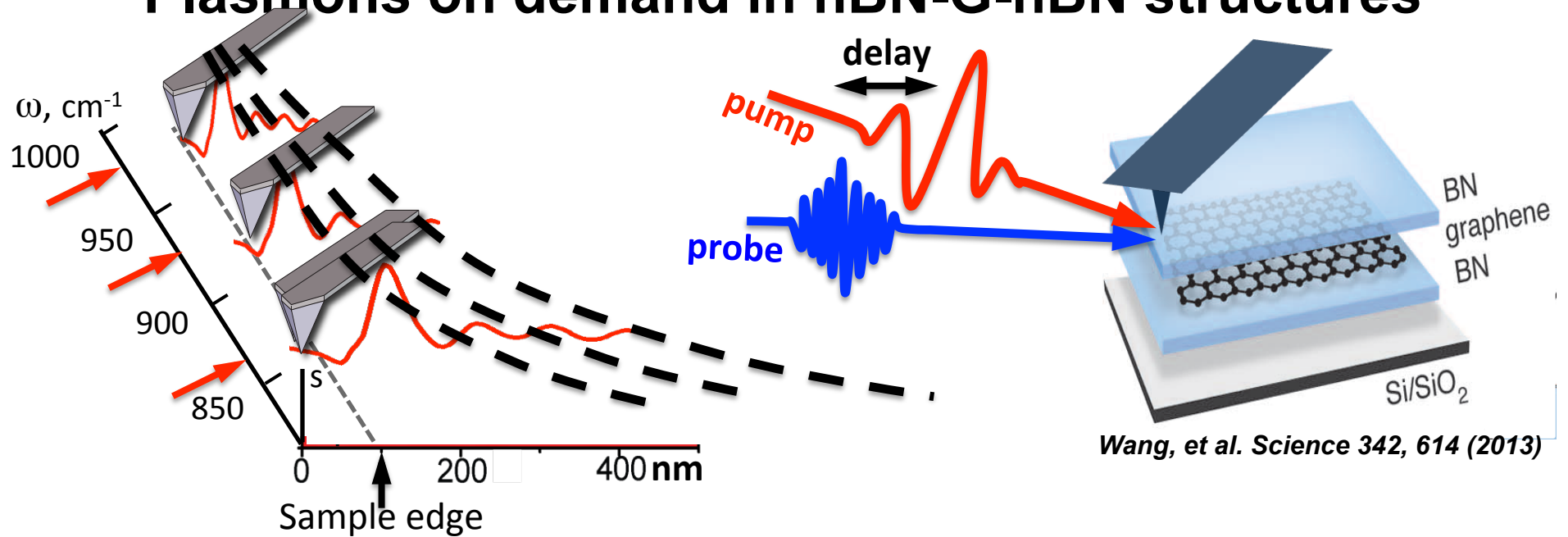
Bi-layer graphene, MoS₂, many other...

Plasmons in gapped Dirac materials: Berry plasmons



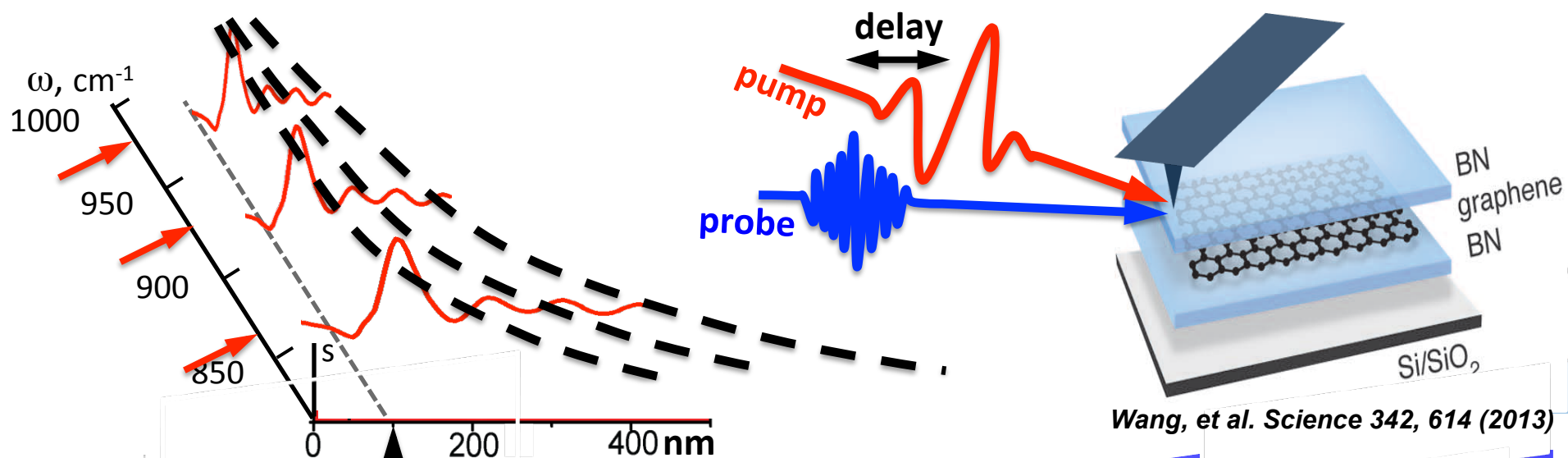
*L. Levitov, G.Refael, J.Song,
N.Fang, S. Das Sarma, T.Low, ...*

Plasmons on demand in hBN-G-hBN structures

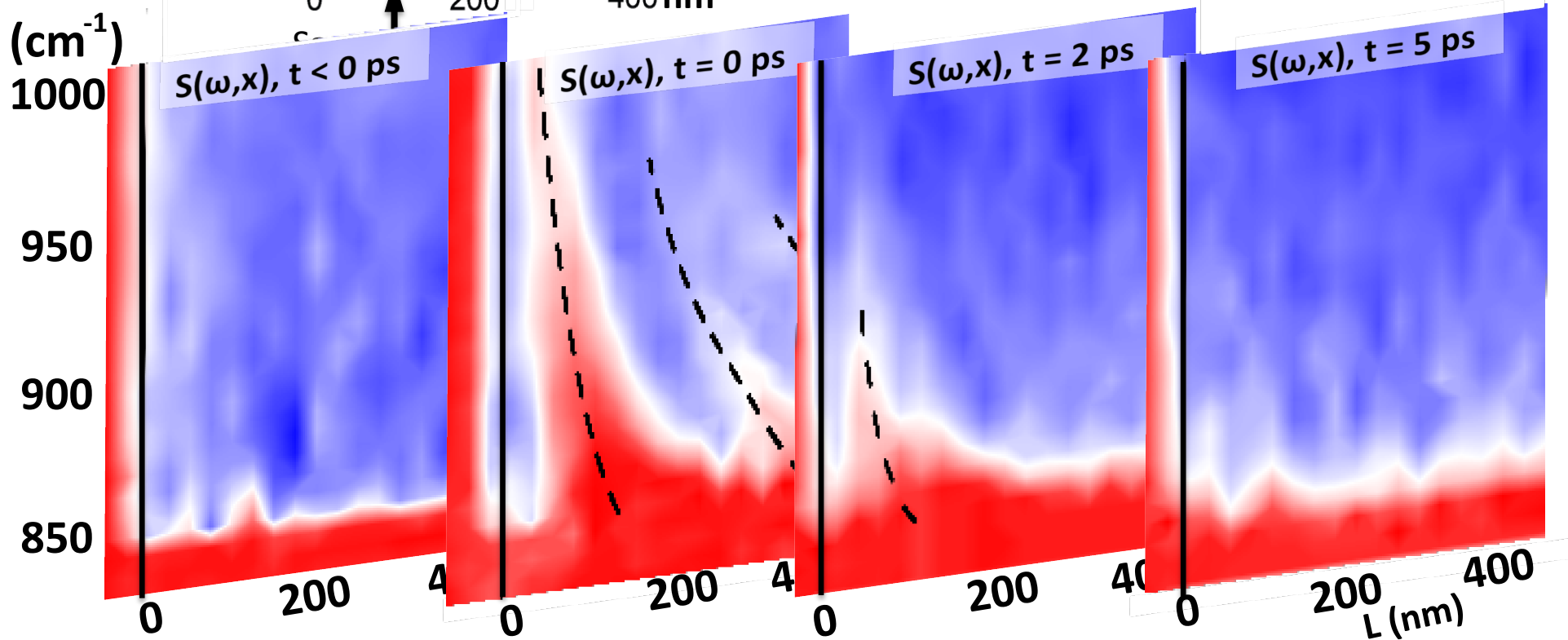


Guangxin Ni et al. (*Nature Photonics* 10, 244 2016)

Hyper-spectral images of non-equilibrium plasmons

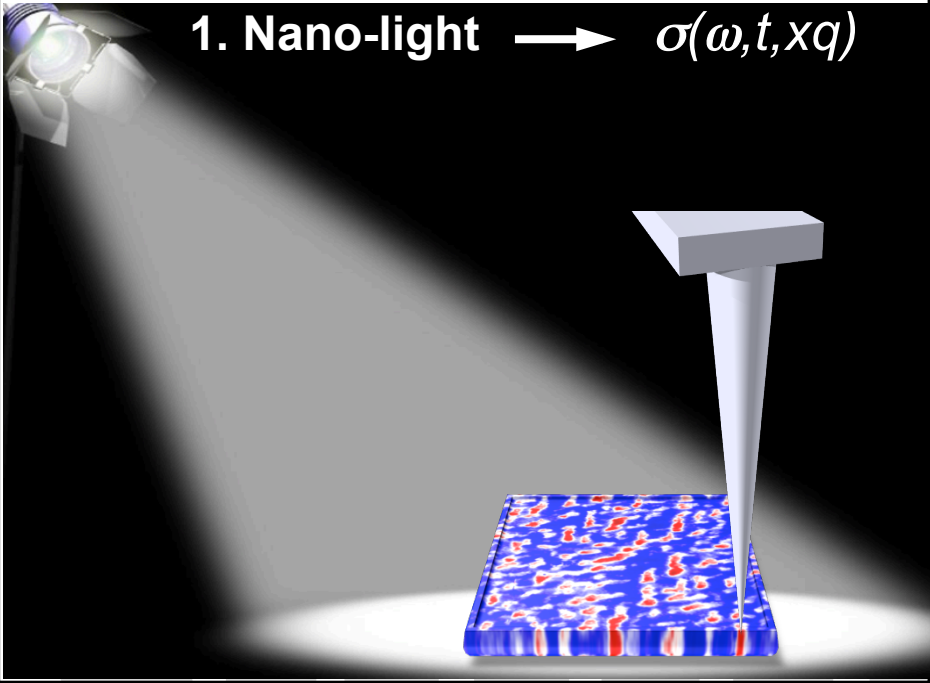


Wang, et al. *Science* 342, 614 (2013)

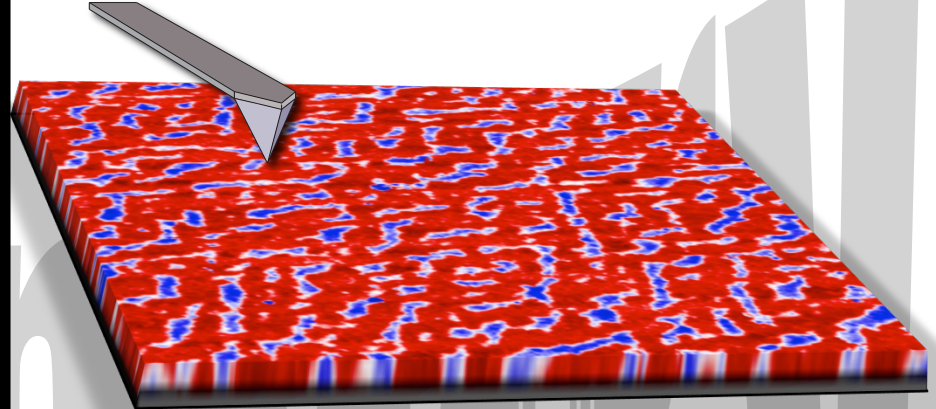


Guangxin Ni et al. (*Nature Photonics* 10, 244 2016)

1. Nano-light $\rightarrow \sigma(\omega, t, x, q)$

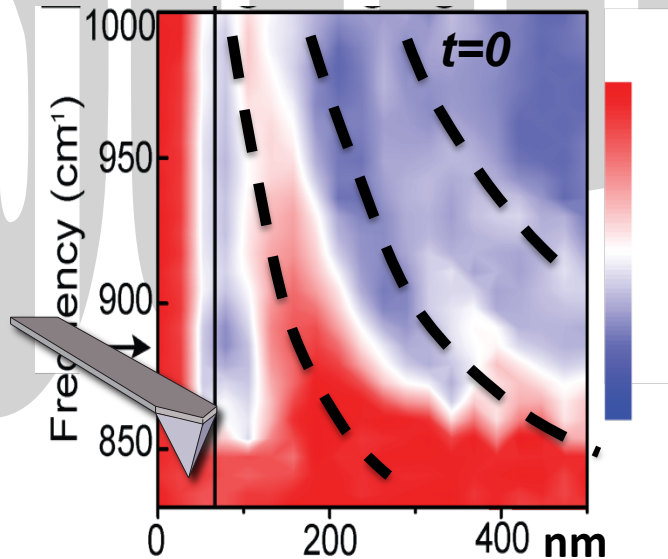


2. New electronic phases in oxides



A. McLeod et al. *Nature Physics* 13, 80 (2017)
J. Zhang et al. *Nature Materials* 15, 956 (2016)

4. Search for Berry plasmons



Guangxin Ni et al. *Nature Photonics* 10, 244 (2016)

3. Spectroscopy & imaging with polaritons



D.N. Basov et al. *Science* (2016)