Low Frequency Dynamics of Correlated Electron Systems

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Low Frequency Dynamics of Correlated Electron Systems

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Doped Mott-Hubbard Insulators

- spectral weight transfer
- spin/charge inhomogeneities

Magnetism

- inter-metallic ferromagnets
- ferromagnetic semiconductors
- magnetic resonances
- left-handed media

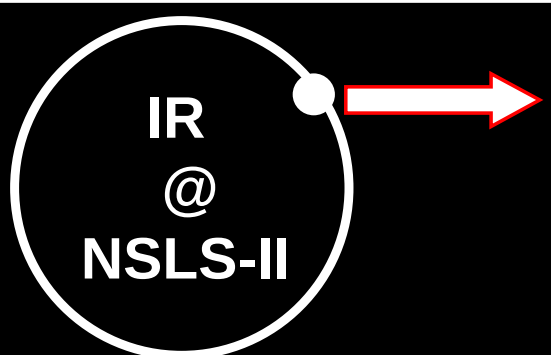
High-Tc superconductors

- inhomogeneous condensate
- pairing "glue"
- energetics

2D electron gas and FET structures

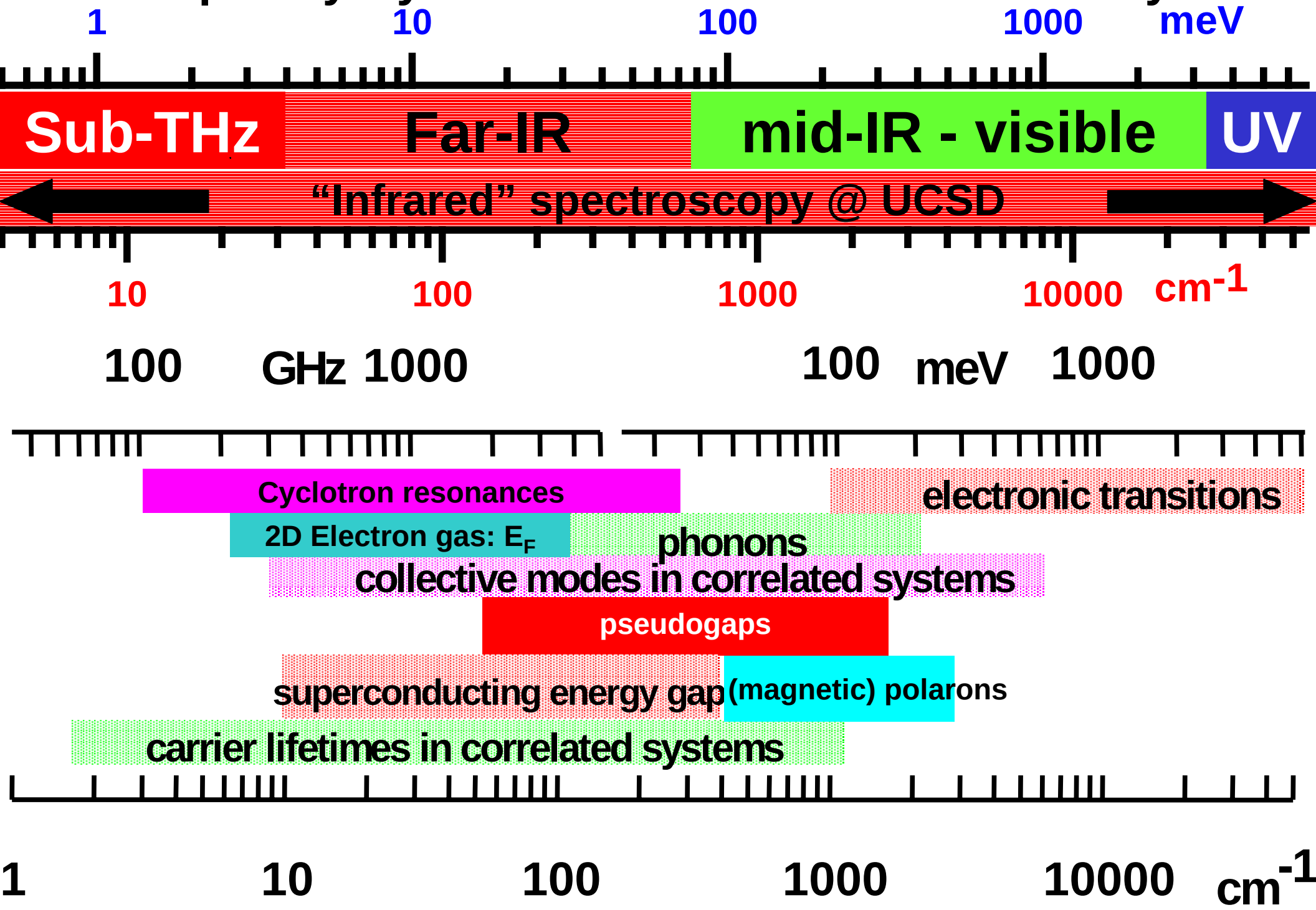
- magnetic
- organic FET

Experimental issues



New opportunities

Low Frequency Dynamics of Correlated Electron Systems



Low Frequency Dynamics of Correlated Electron Systems

1. Broad spectral coverage

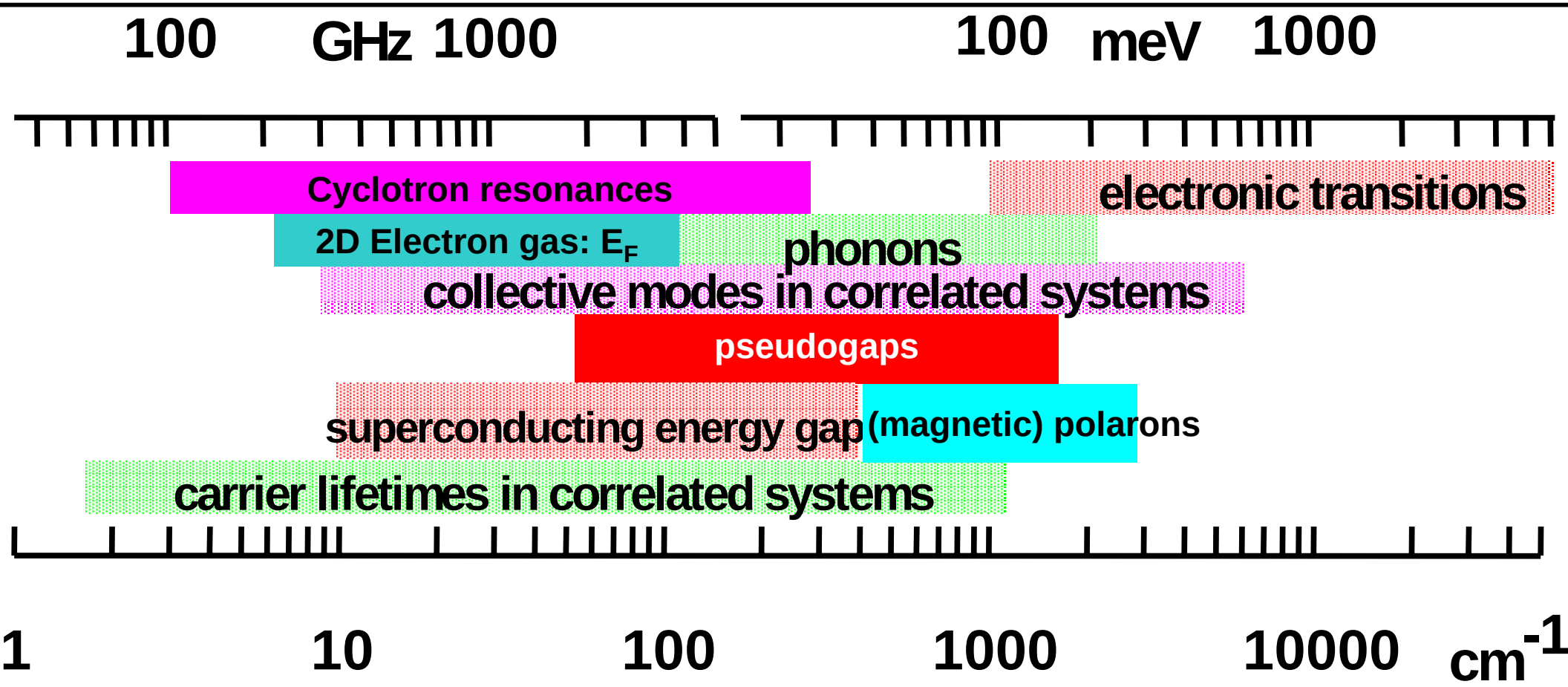
2. Optical constants: $\sigma_1(\omega) + i\sigma_2(\omega)$
   and sum rules

3. Anisotropy

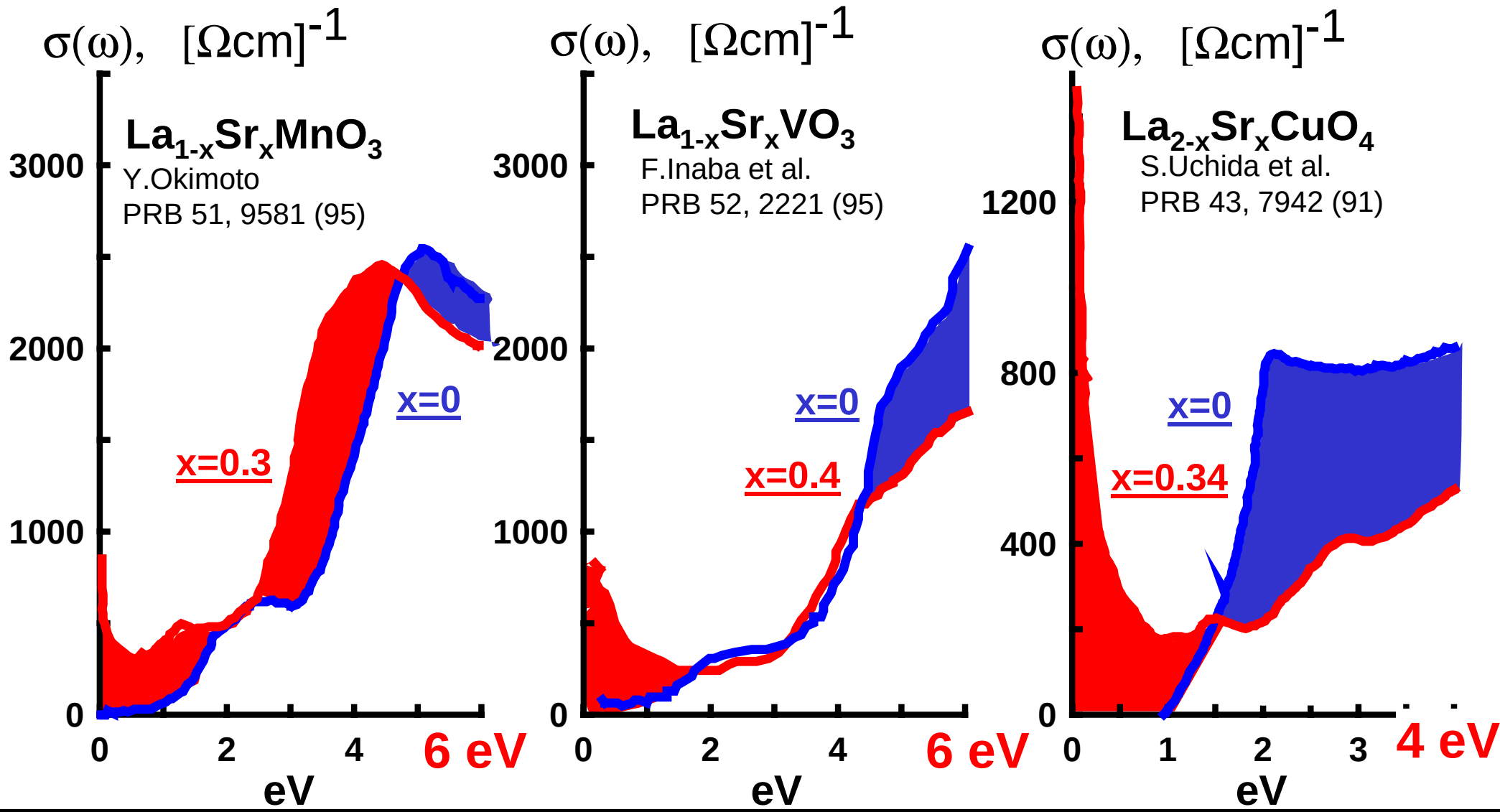
4. Large probing thickness

5. Micro-crystals

6. Extreme experimental conditions:
   mK temperatures
   high magnetic field
   high electric field
   ultra-high pressure



1. Doped Mott-Hubbard Insulators



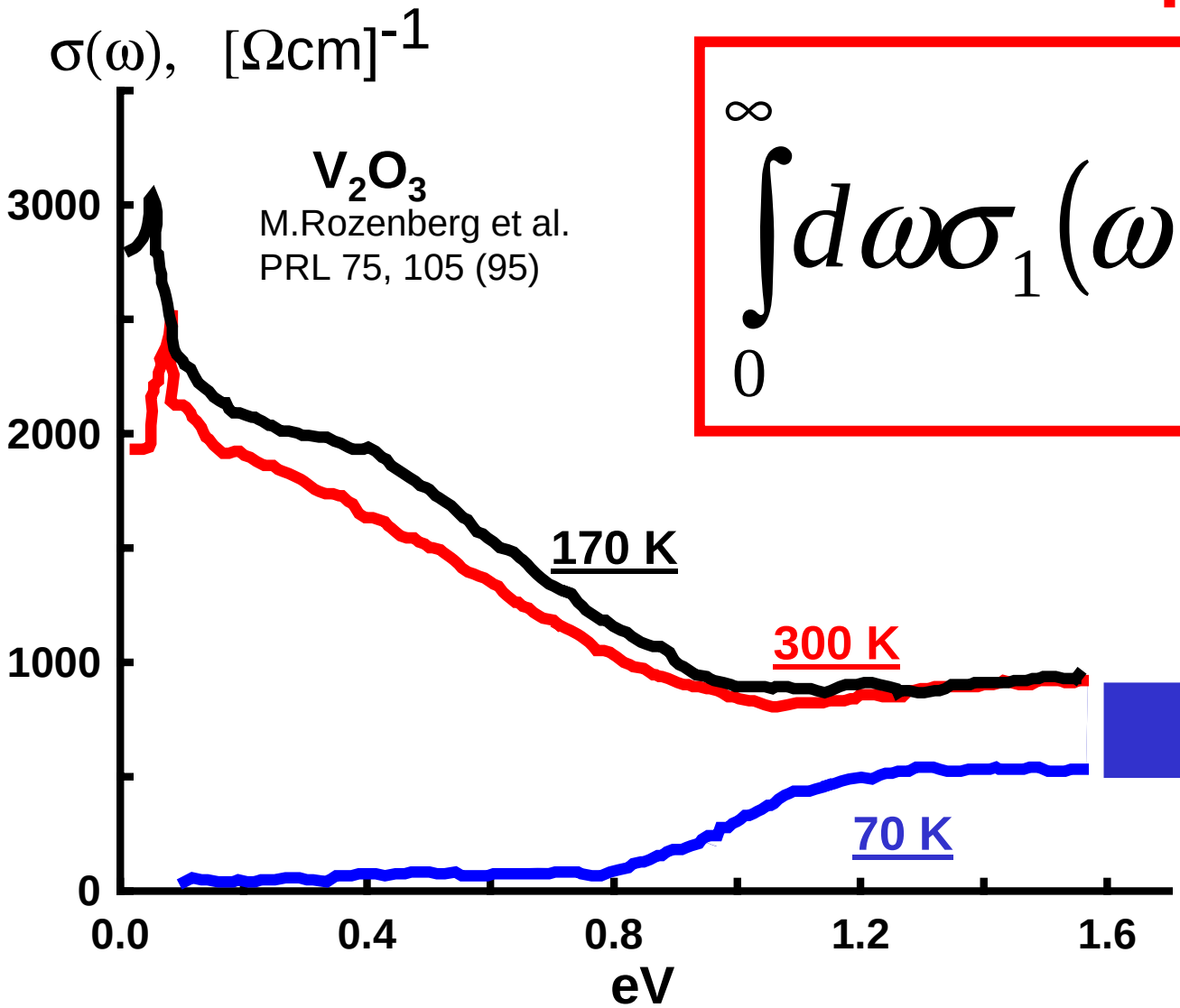
Experimental issues:

High-ω data is needed for KK analysis

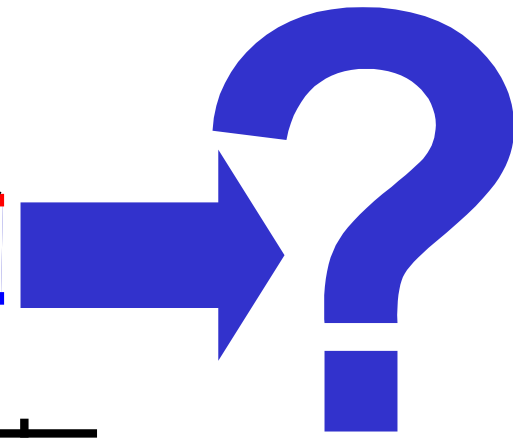
IR @ NSLS-II → **R(ω) data at ω < 36 eV**

Beam-line based ellipsometry

2. Doped Mott-Hubbard Insulators: T dependence



$$\int_0^\infty d\omega\,\sigma_1(\omega) = \frac{n}{m_e}$$



Experimental issues:

T, H dependence of σ(ω) over anomalously broad ω range

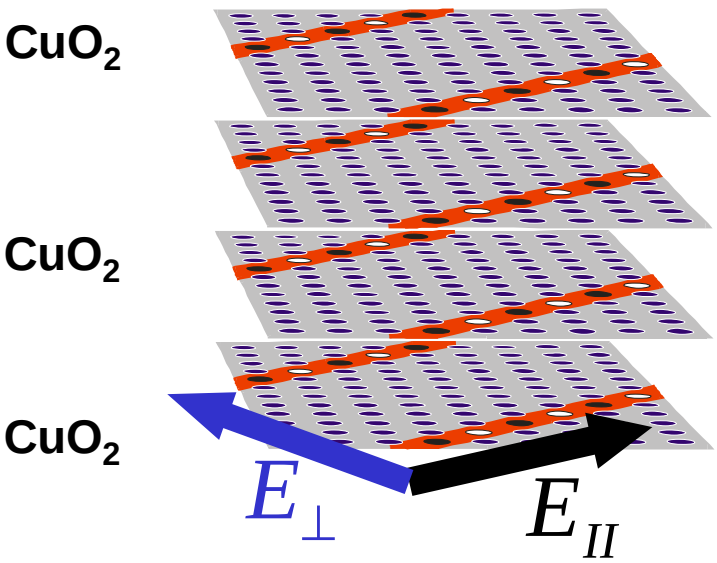
IR @ NSLS-II

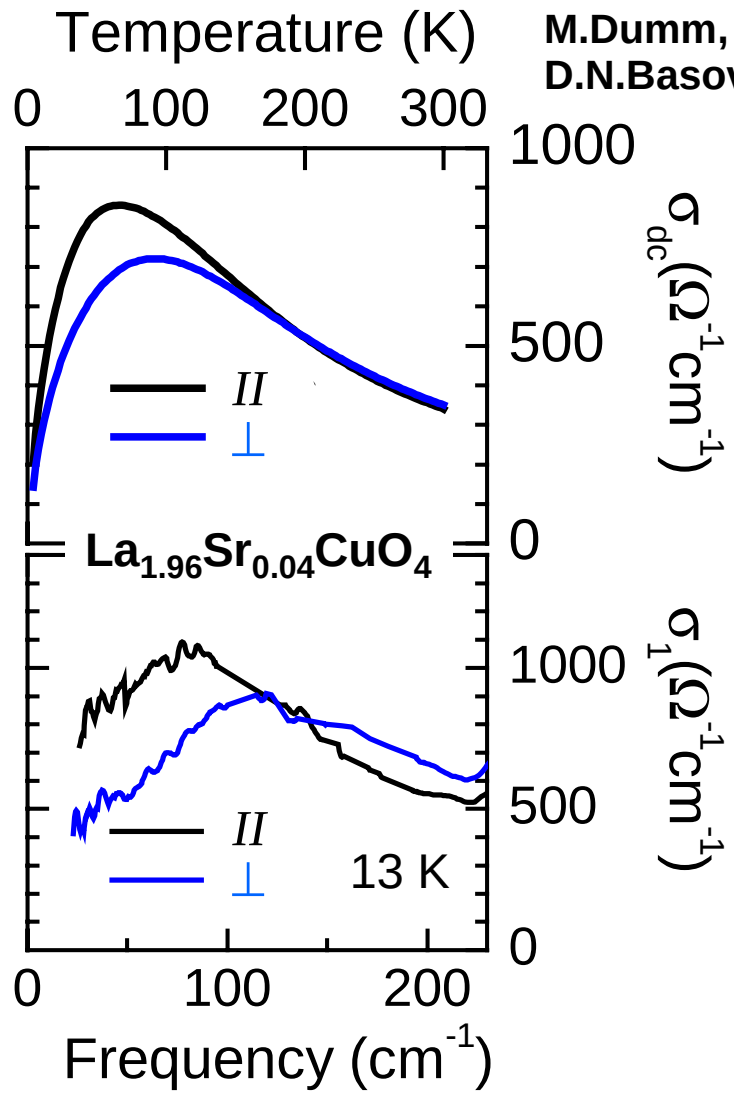
Accurate data over broad ω intervals

Beam-line based ellipsometry

3. Doped M-H Insulators: charge inhomogeneities

M.Dumm, S.Komiya, Y.Ando, D.N.Basov, PRL 91, 077004 (03).



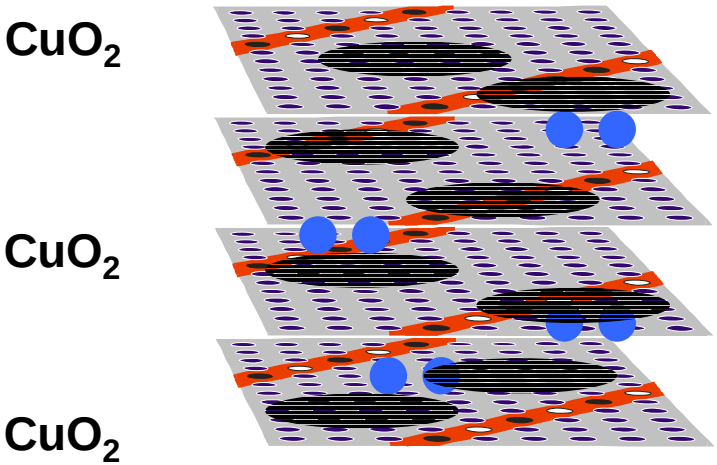


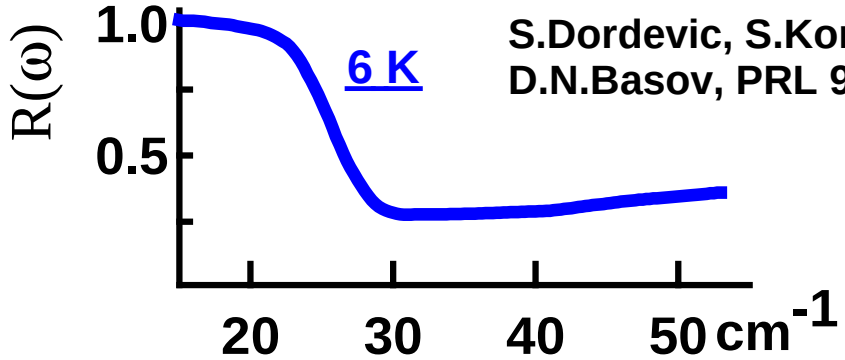
Experimental issues:

Micro-crystals

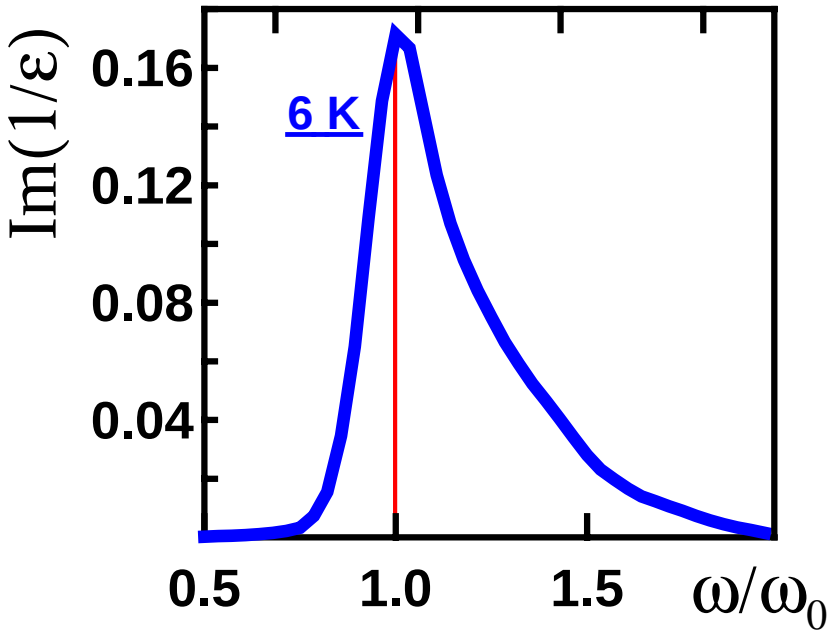
IR @ NSLS-II → **High intensity, Beam-line based IR microscopy Photo-induced effects**

4. Doped MH Insulators: inhomogeneous superconductivity



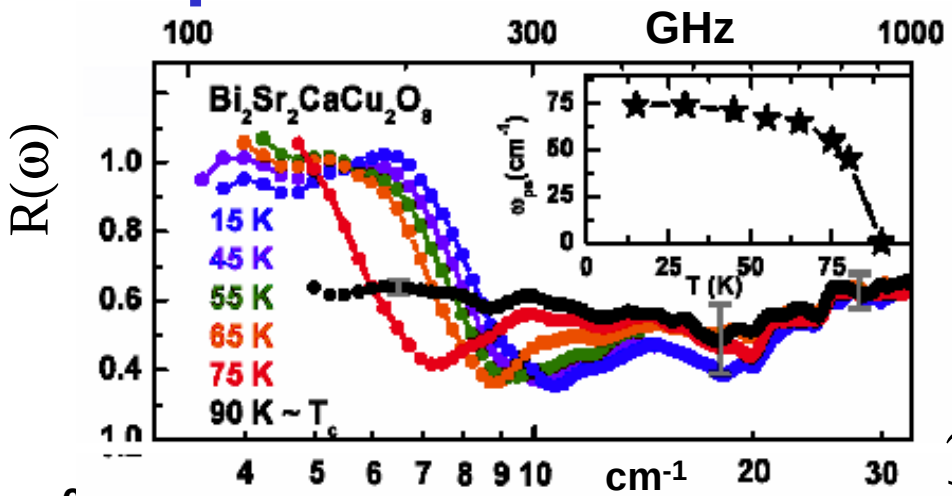


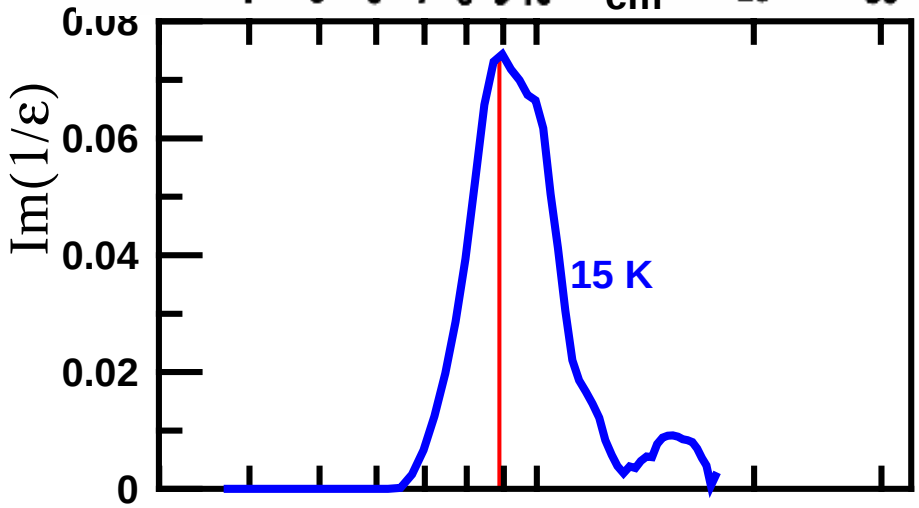
S.Dordevic, S.Komiya, Y.Ando, D.N.Basov, PRL 91, 167401 (03)



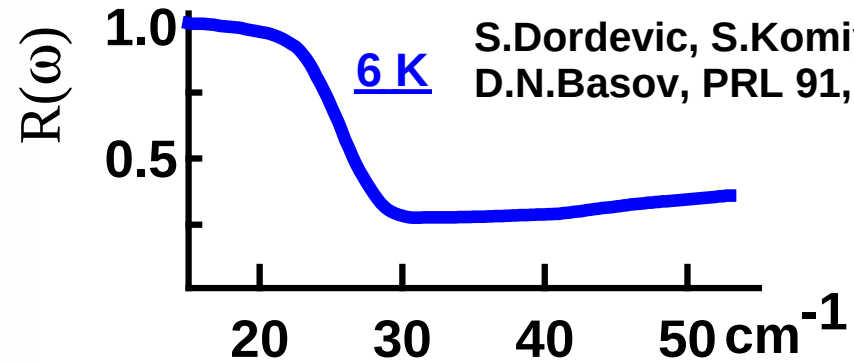
"Josephson plasmon microscopy"

4. Doped MH Insulators: inhomogeneous superconductivity

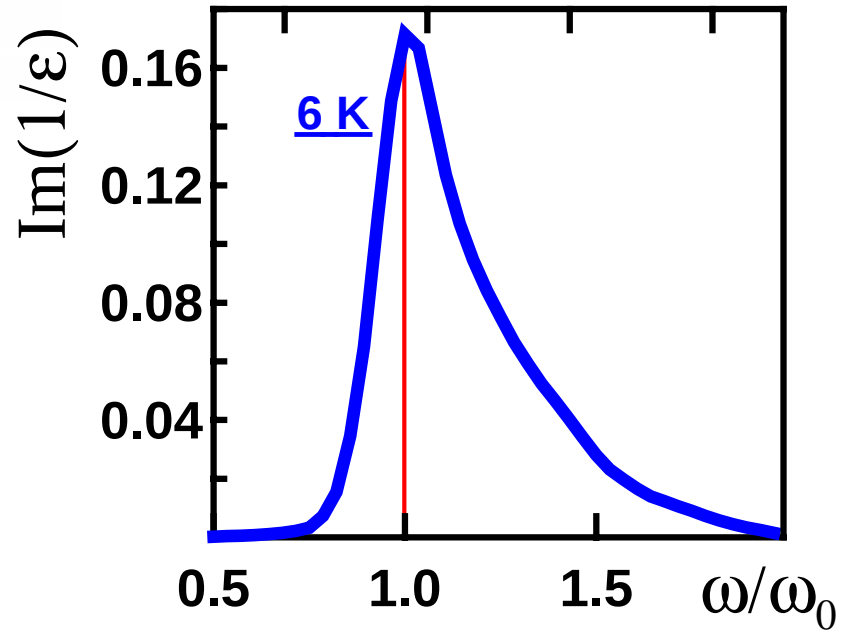




E.J.Singley et al. PRB (in press)
ALS-BESSY collaboration



S.Dordevic, S.Komiya, Y.Ando, D.N.Basov, PRL 91, 167401 (03)



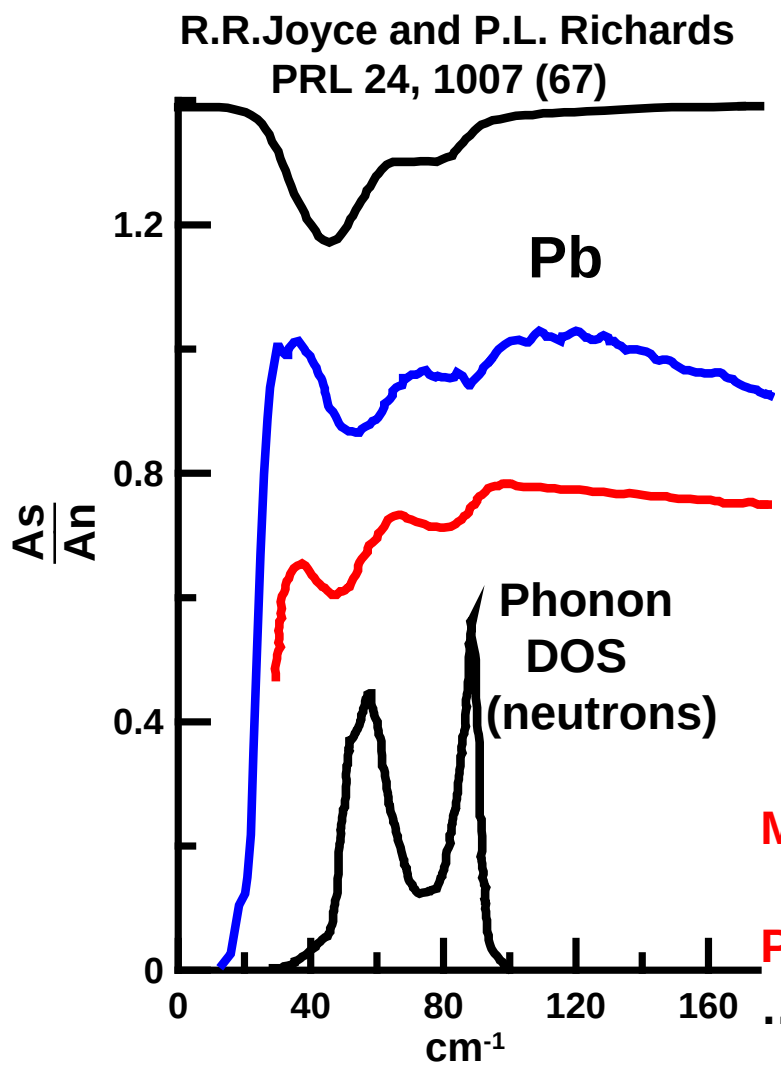
"Josephson plasmon microscopy"

Experimental issues:

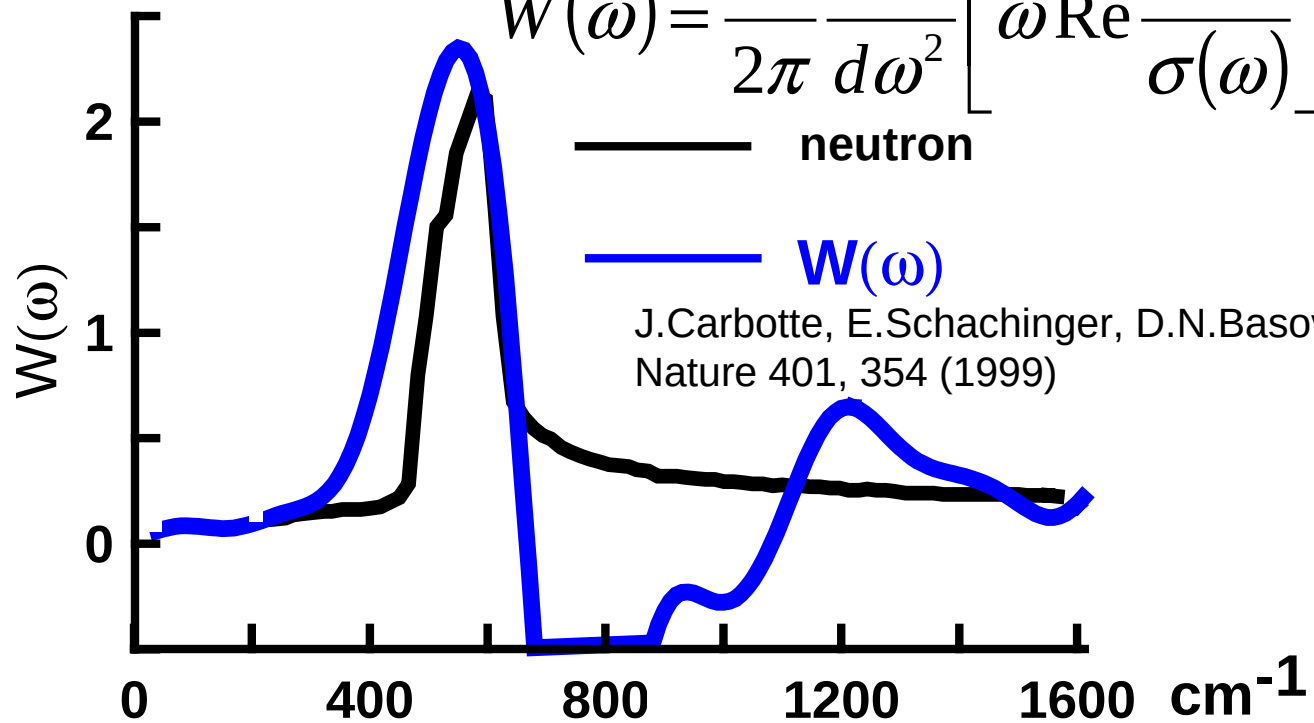
Sub-THz ω region

IR @ NSLS-II → "coherent" radiation

5. High-T_C superconductivity: pairing interaction



$$W(\omega) = \frac{1}{2\pi}\frac{d^2}{d\omega^2}\left[\omega \mathrm{Re}\frac{1}{\sigma(\omega)}\right]$$



J.Carbotte, E.Schachinger, D.N.Basov
Nature 401, 354 (1999)

Magnetic? P.D.Johnson RPL 87, 177007 (01), Hwang et al. Nature (04)

consistent with ARPES, tunneling,

Phonons? /A.Lanzara et al. Nature 412, 510 (2001)/

… but no isotope effect /N.Wang et al. PRL 89, 87003 (03)

??????

Experimental issues:

Second derivative of $1/\tau(\omega)$

IR @ NSLS-II → **Beamline-based ellipsometry**

Magneto-optics

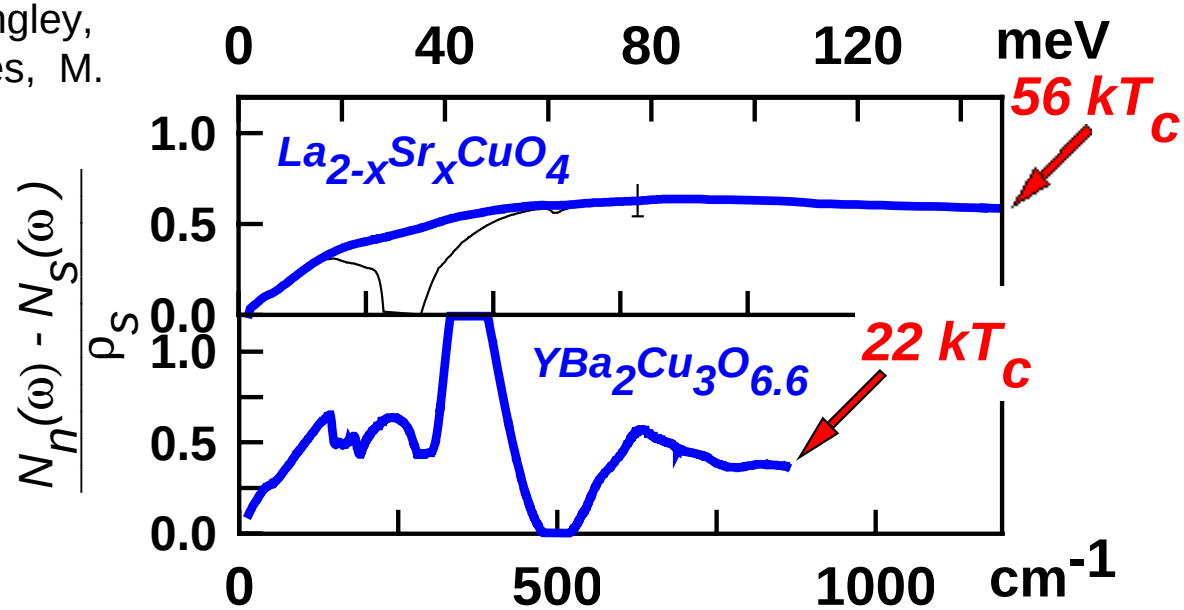
6. High-T_C superconductivity: energetics at $T \ll T_C$

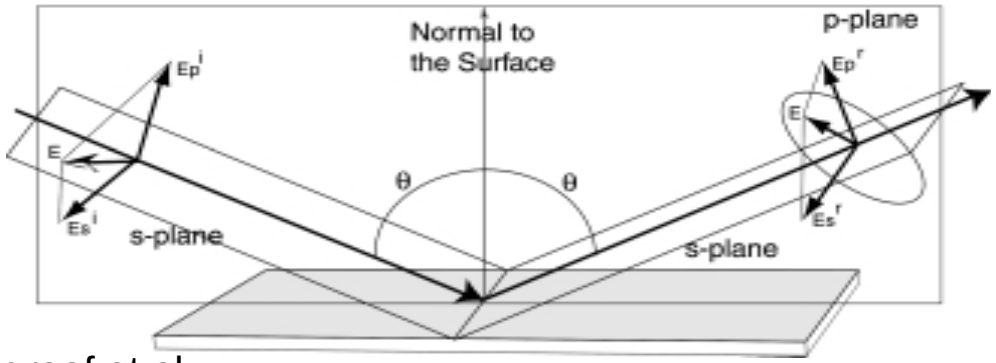
D.N. Basov, S.I. Woods, A.S.Katz, E.J. Singley, R.C. Dynes, M. Xu, D.G. Hinks, C.C. Homes, M. Strongin, Science 283, 49 (1999)

kinetic energy sum rule

$$\int_0^W \sigma_1 d\omega = -K_r$$

gordon/fig/form-for-fig4-all





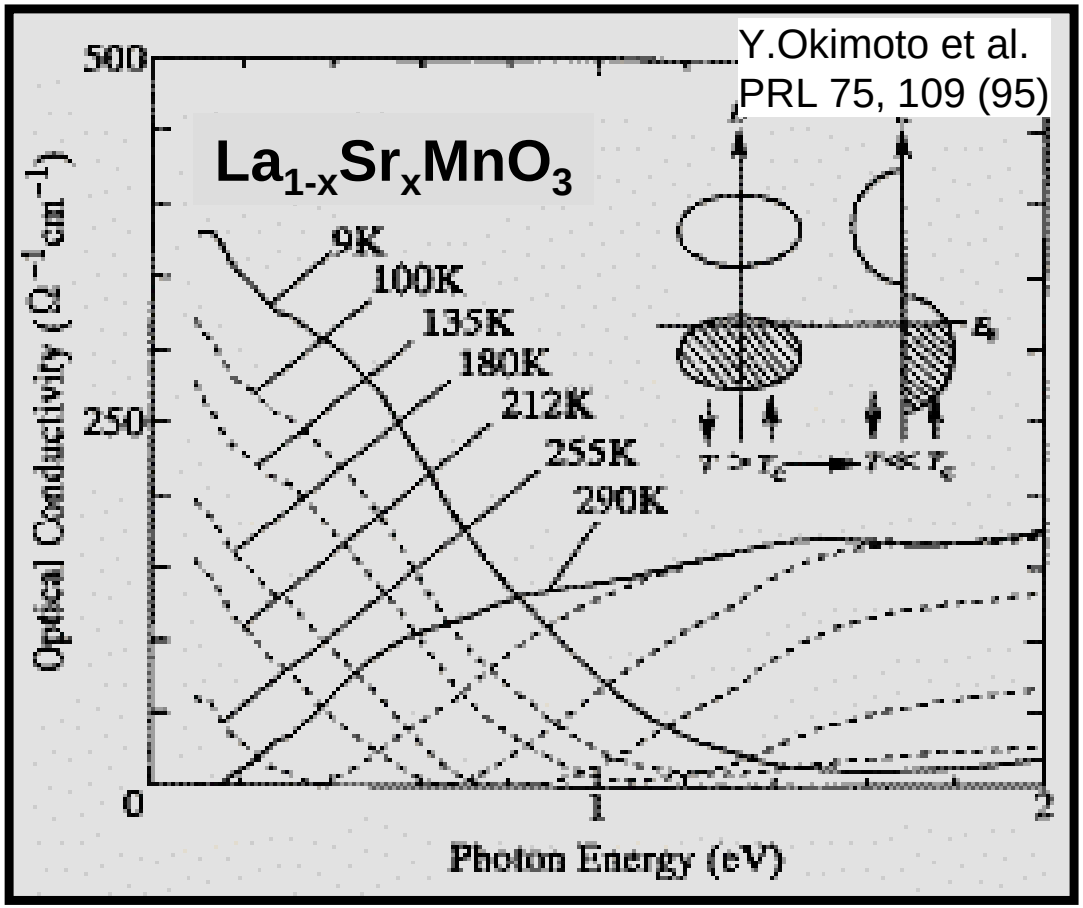
H.J.A.Molengraaf et al. Science 295, 2239 (2002)

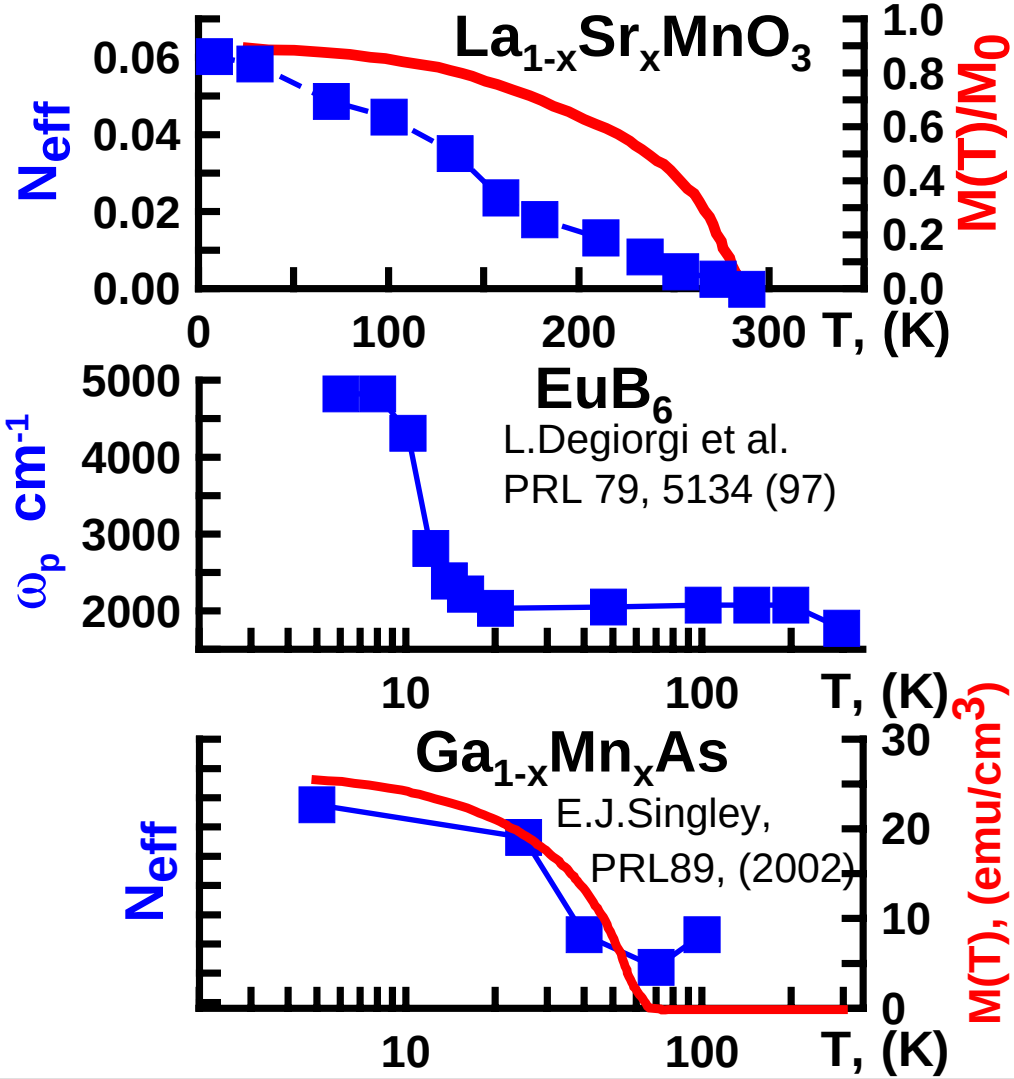
Experimental issues:

Small effects involving broad ω range

IR @ NSLS-II → **Synchrotron-based ellipsometry**

7. Magnetism: itinerant intermetallic ferromagnets





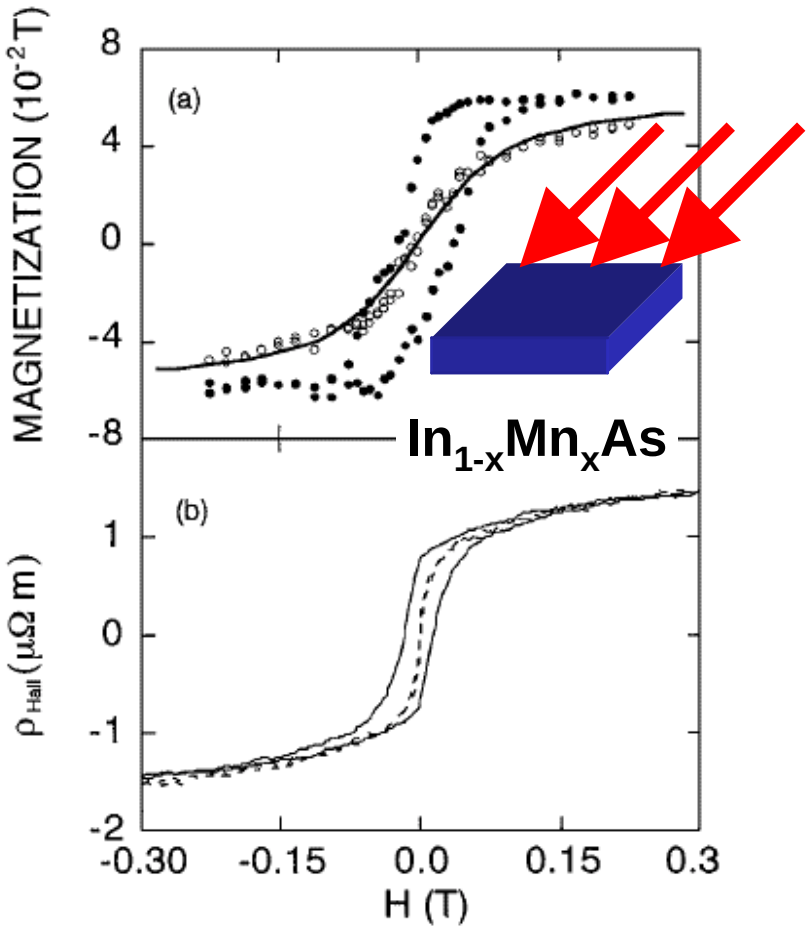
Experimental issues:

Bandwidth?

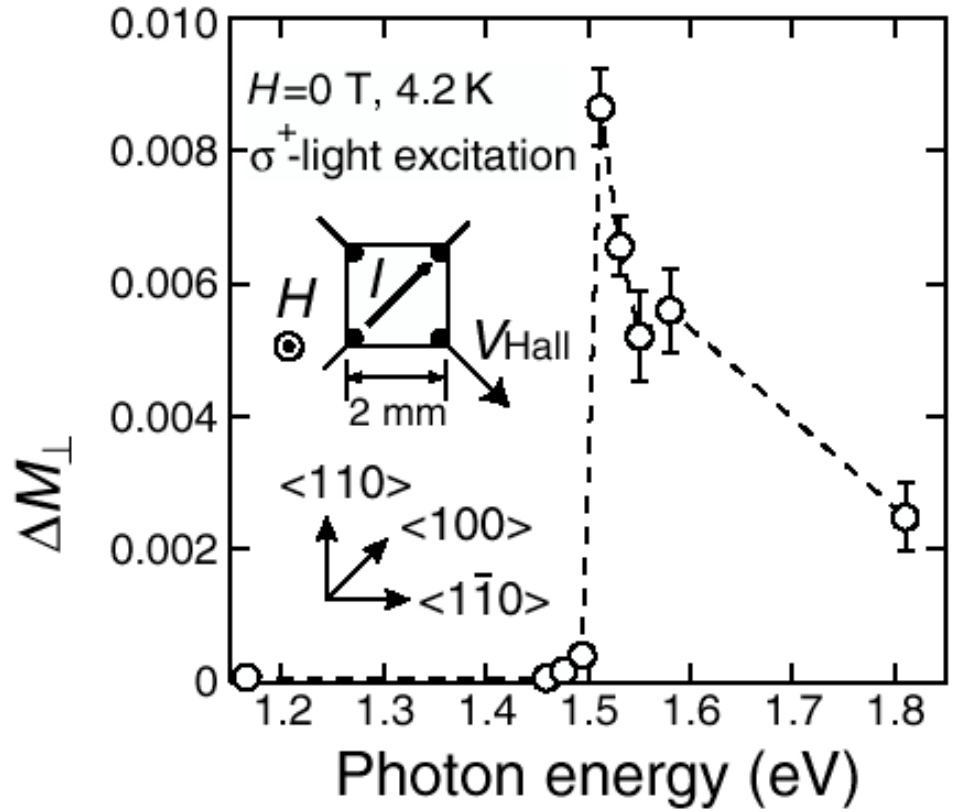
"Undressing" effect?

IR @ NSLS-II → **Beamline-based ellipsometry**

8. Magnetism: optical control of magnetic state



S.Koshihara et al. PRL78, 4617 (1997)

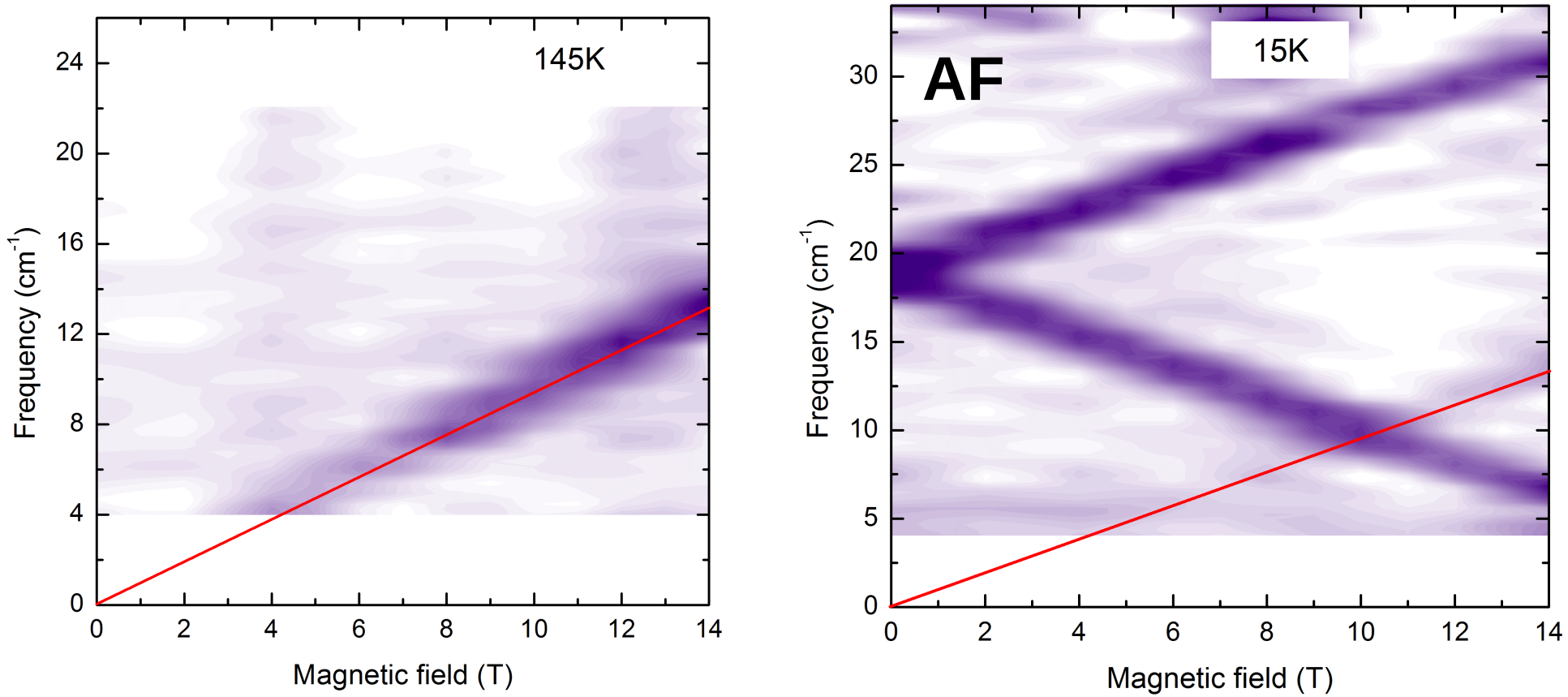


A.Oiwa, Y.Mitsumori, T.Slupinski, H.Munekata, PRL 88, 137202 (2002)

IR @ NSLS-II → **Pump-probe experiments**

9. Magnetism: AF resonance in the frequency domain

$LaMnO_3$



L. Mihály, D. Talbayev, L. F. Kiss, J. Zhou, T. Fehér, and A. Jánossy Phys. Rev. B 69, 024414 (2004)

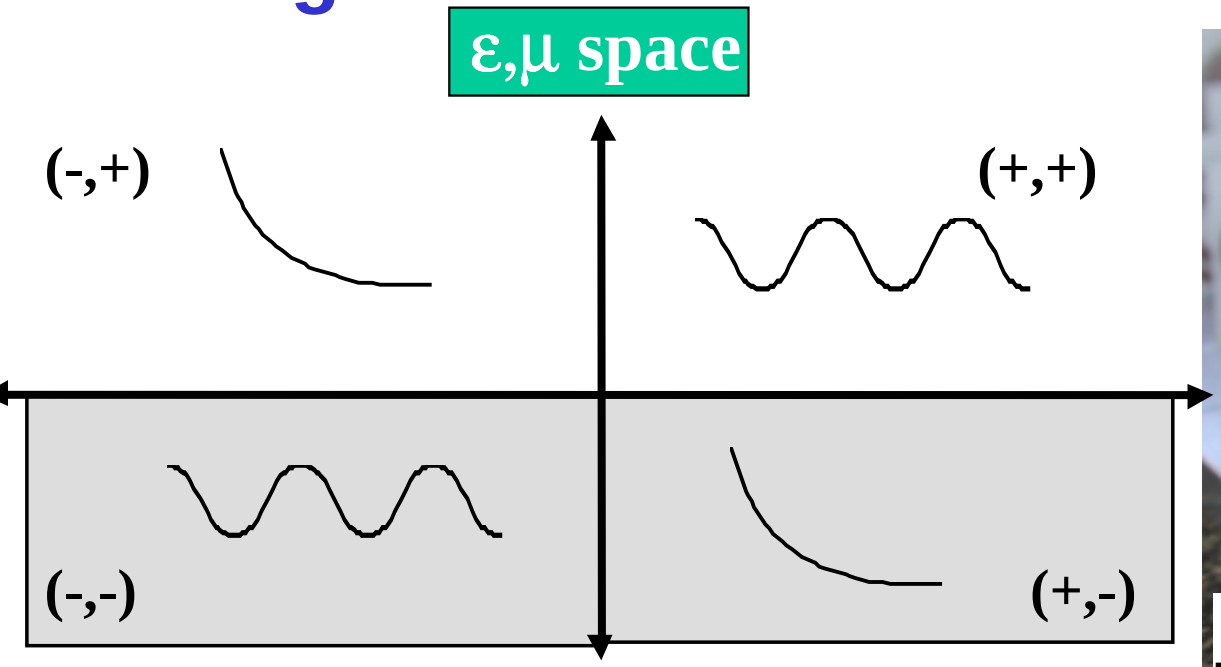
Experimental issues:

Sub-THz region

Small transmission

IR @ NSLS-II → **Intensity!**

10. Magnetic resonances and “Left-handed” media

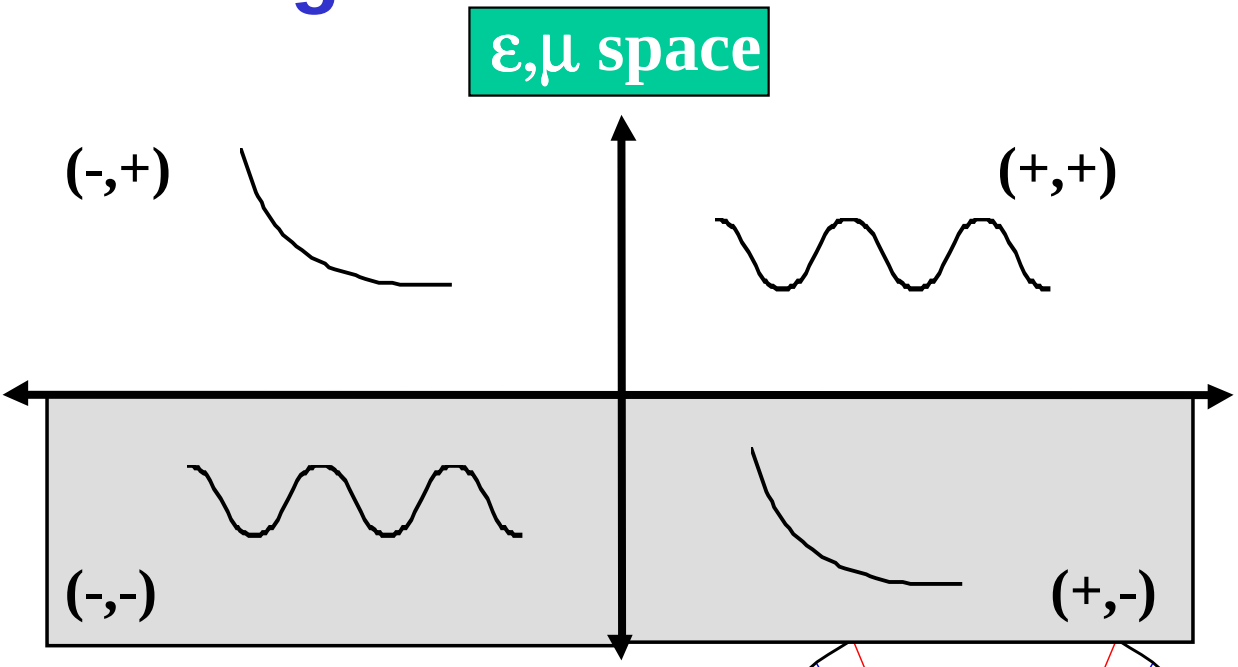


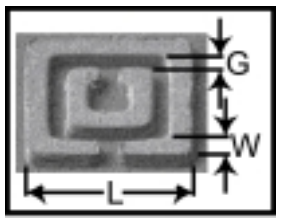
V.G.Veselago
Sov. Phys. Uspekhi 10, 509 (1968)

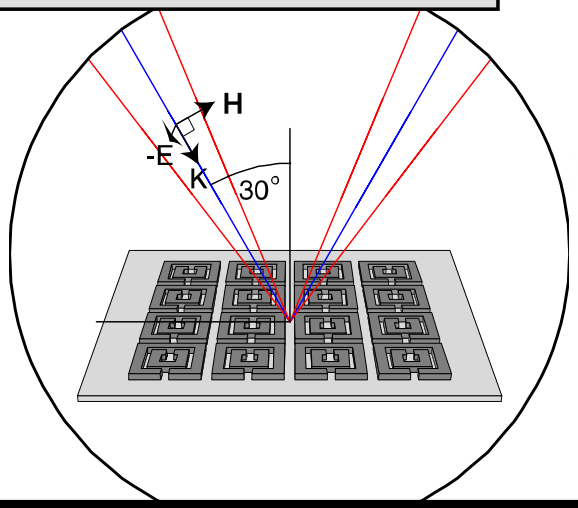
Irrelevant? → **Split-ring resonator design** →

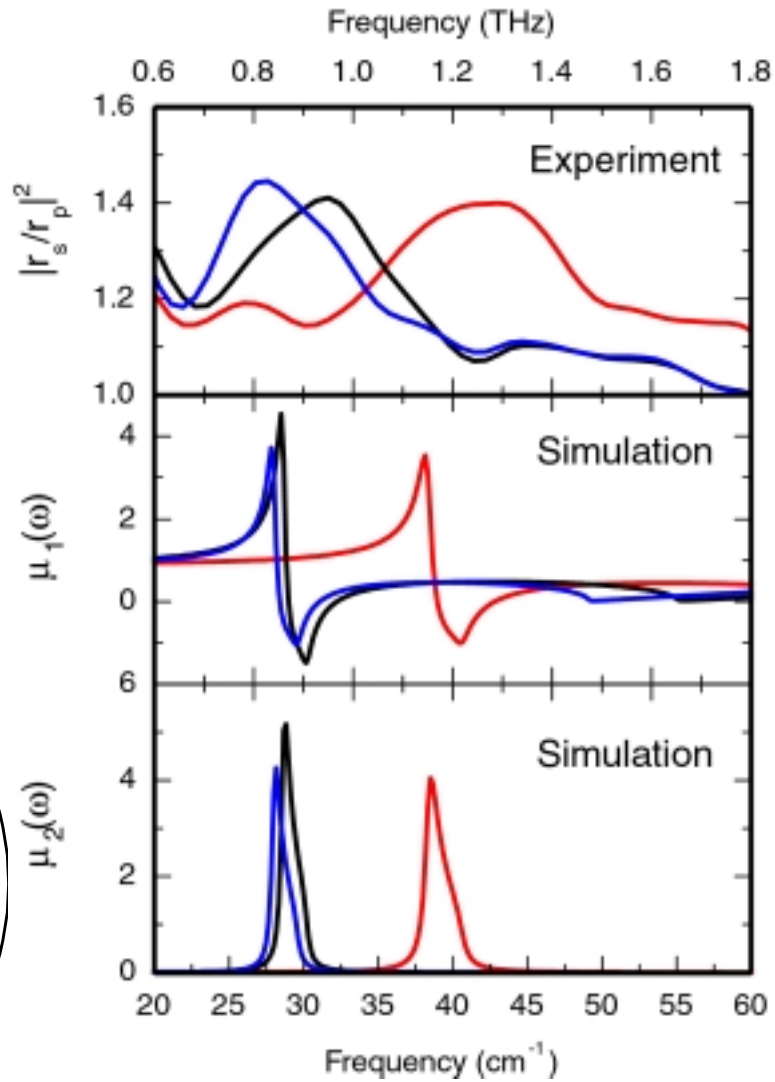
J.B. Pendry et al.
PRL 76, 4773 (1996)

10. Magnetic resonances and "Left-handed" media









T.J. Yen, et al. Science 303, 1494 (04)

Experimental challenges:

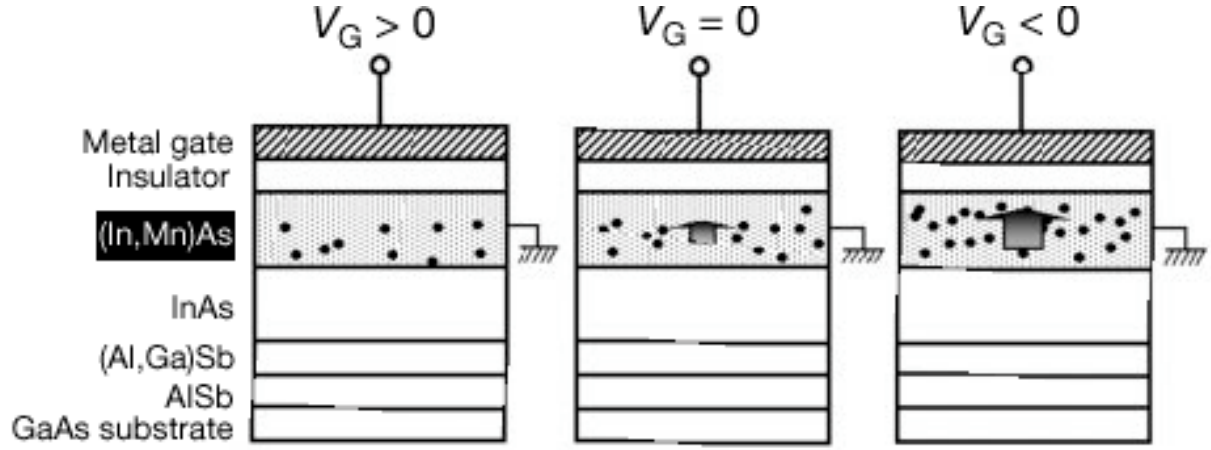
1. Tunable?
- Real materials?

IR @ NSLS-II

→ Photo-doping
FET-doping
IR ellipsometry

11. FET structures:

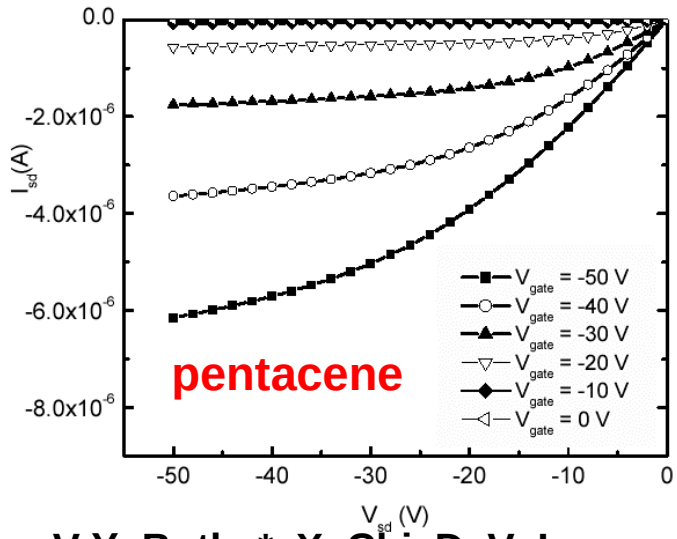
FM semiconductors



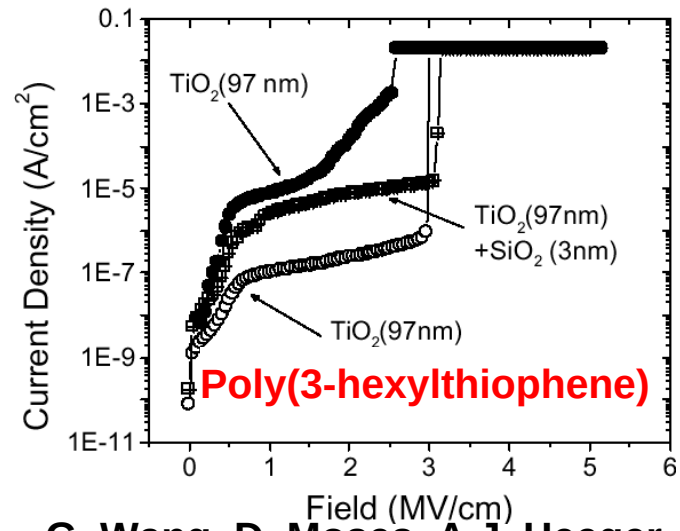
H. Ohno, D. Chiba, F. Matsukura, T. Omiya, E. Abe, T. Dietl, Y. Ohno& K. Ohtani, Nature 408, 944 (2000).

Organic molecular crystals

Polymers

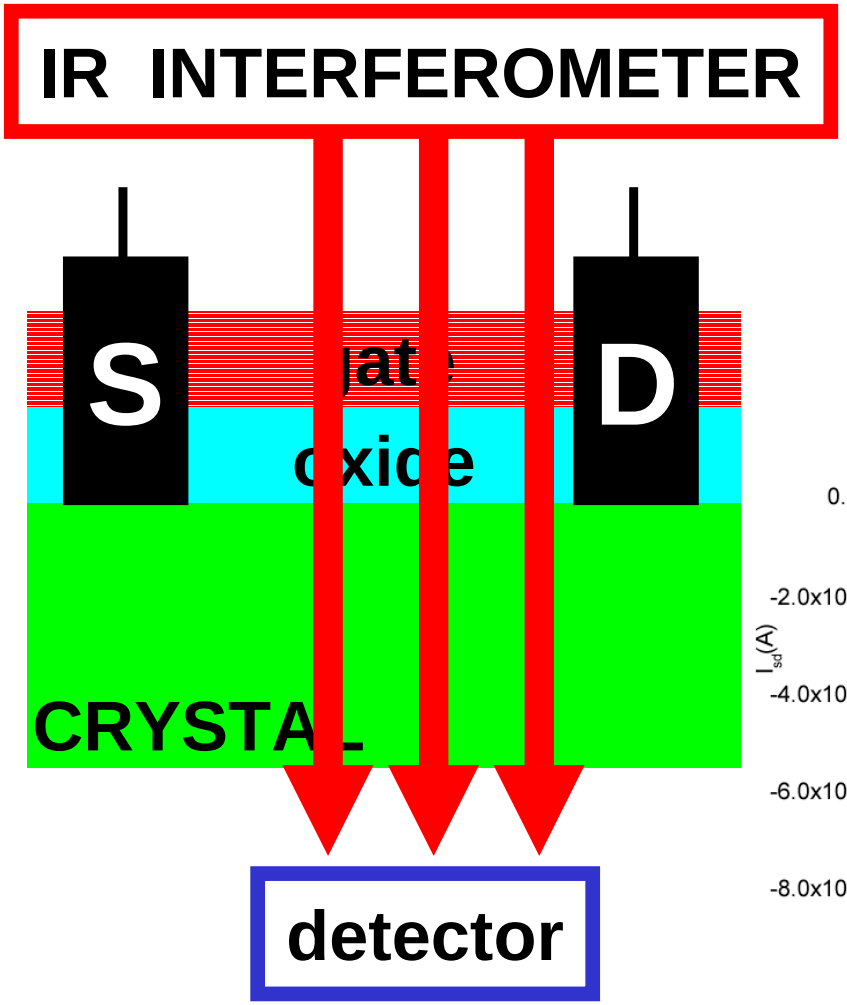


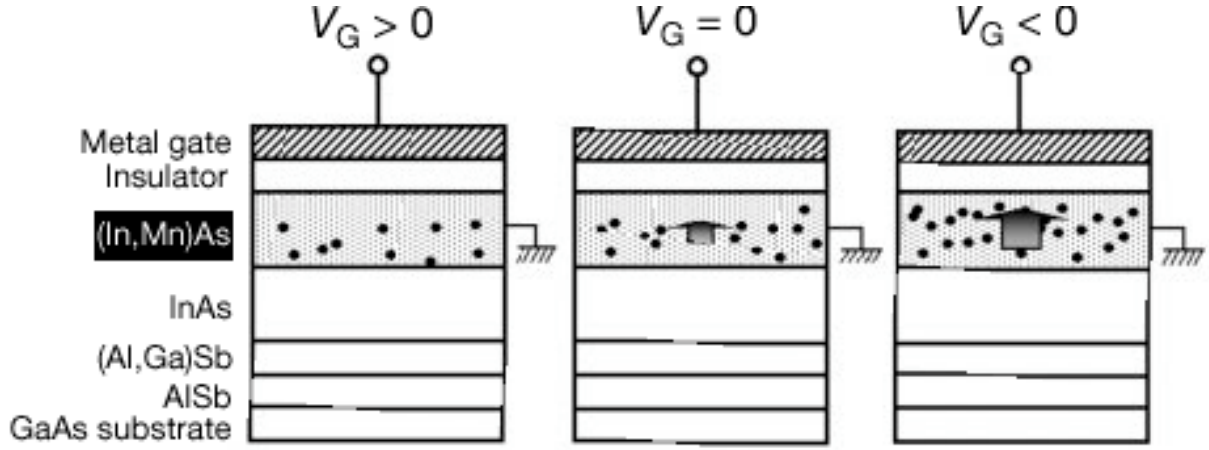
V.Y. Butko*, X. Chi, D. V. Lang, A.P. Ramirez APL 83, 4773 (03)



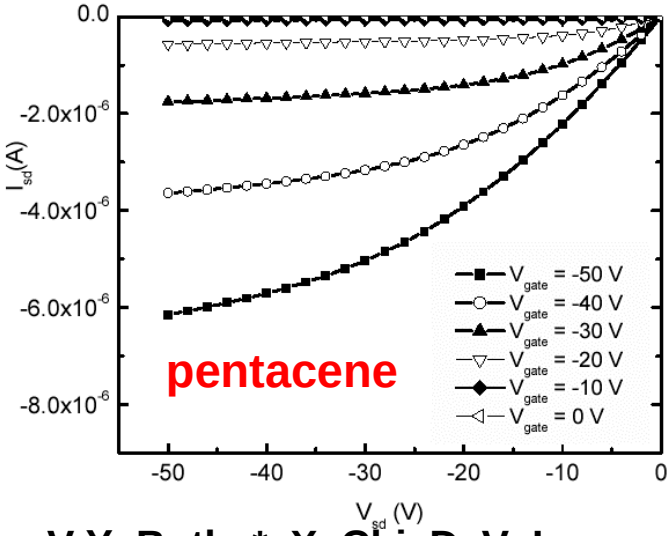
G. Wang, D. Moses, A.J. Heeger, J. Applied Phys. 95, 316 (04)

11. FET structures

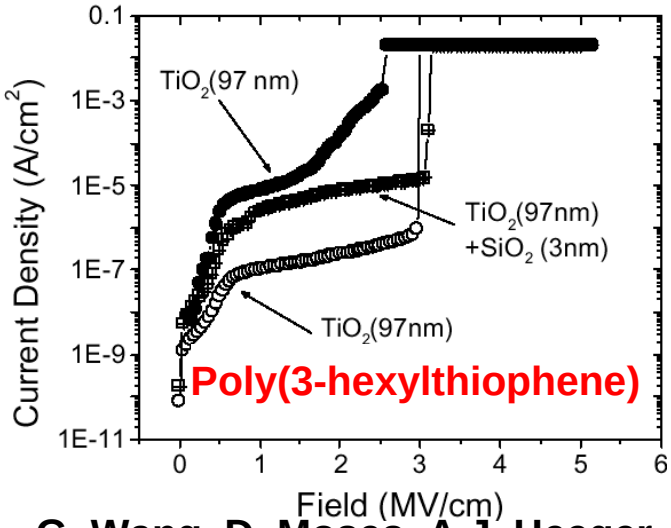




H. Ohno, D. Chiba, F. Matsukura, T. Omiya, E. Abe, T. Dietl, Y. Ohno& K. Ohtani, Nature 408, 944 (2000).



V.Y. Butko*, X. Chi, D. V. Lang, A.P. Ramirez APL 83, 4773 (03)



G. Wang, D. Moses, A.J. Heeger, J. Applied Phys. 95, 316 (04)

IR Spectroscopy @ NSLS-2 and Correlated Electron Systems

- Instruments for broad range spectroscopy:
  (80 GHz - 30 eV)

- “Coherent” radiation for sub-THz region

- Spectroscopic ellipsometry

- Pump-probe experiments

- Micro-sample capabilities

- High magnetic field