FOCUS

Mechanisms for Ultrafast Generation of Coherent Phonons, Polaritons and Spin Excitations

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University of Michigan

Scientific Potential of High Repetition-Rate, Ultra-short Pulse ERL X-ray Source

Cornell University

VIBRATIONS (PHONONS):
COHERENT AND SQUEEZED STATES

POLARITONS (LIGHT-TO COUPLED MODES)

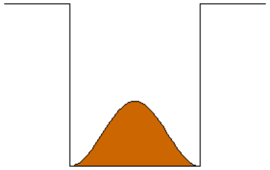
SPIN-FLIP EXCITATIONS, MAGNONS, SPIN SQUEEZING, 2DEG SPIN- DENSITY FLUCTUATIONS

PLASMONS, 2DEG CHARGE-DENSITY EXCITATIONS

SUPERCONDUCTING GAP EXCITATIONS

Coherent Fluctuations: Charge-Density vs. Spin-Density

SPIN ↑



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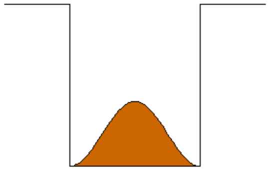

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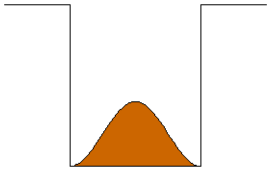

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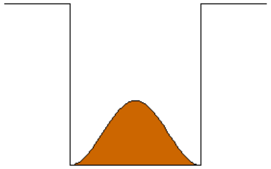
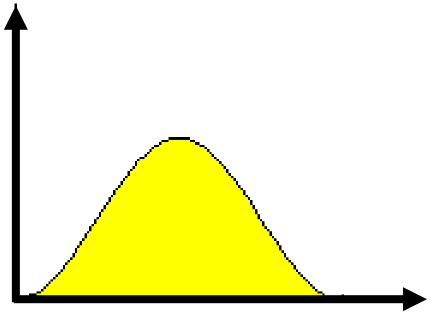
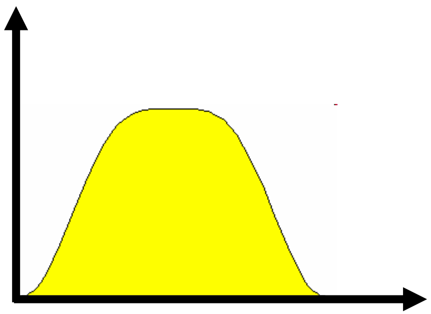


CDF

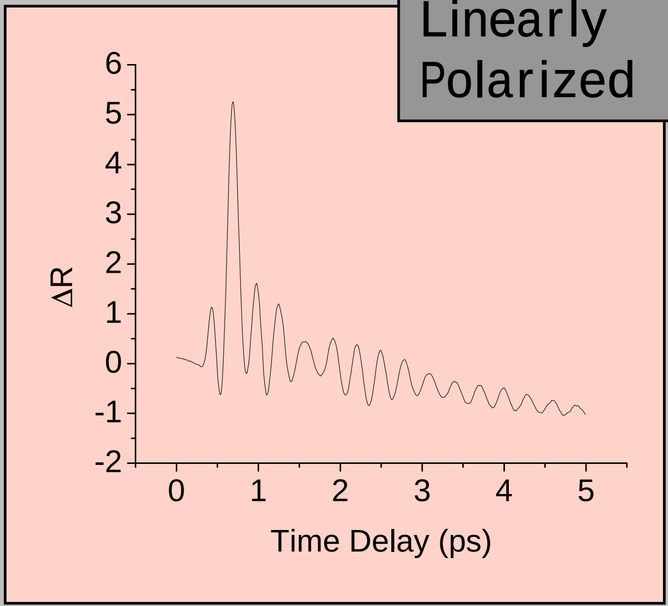


SDF

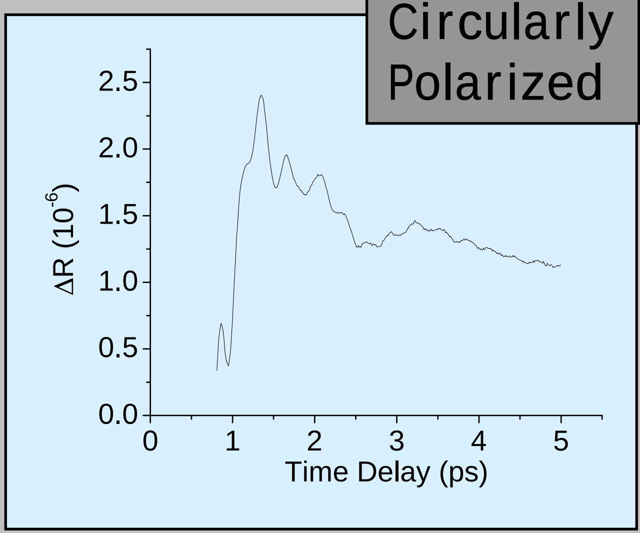


Charge-Density vs. Spin-Density Oscillations

Linearly Polarized



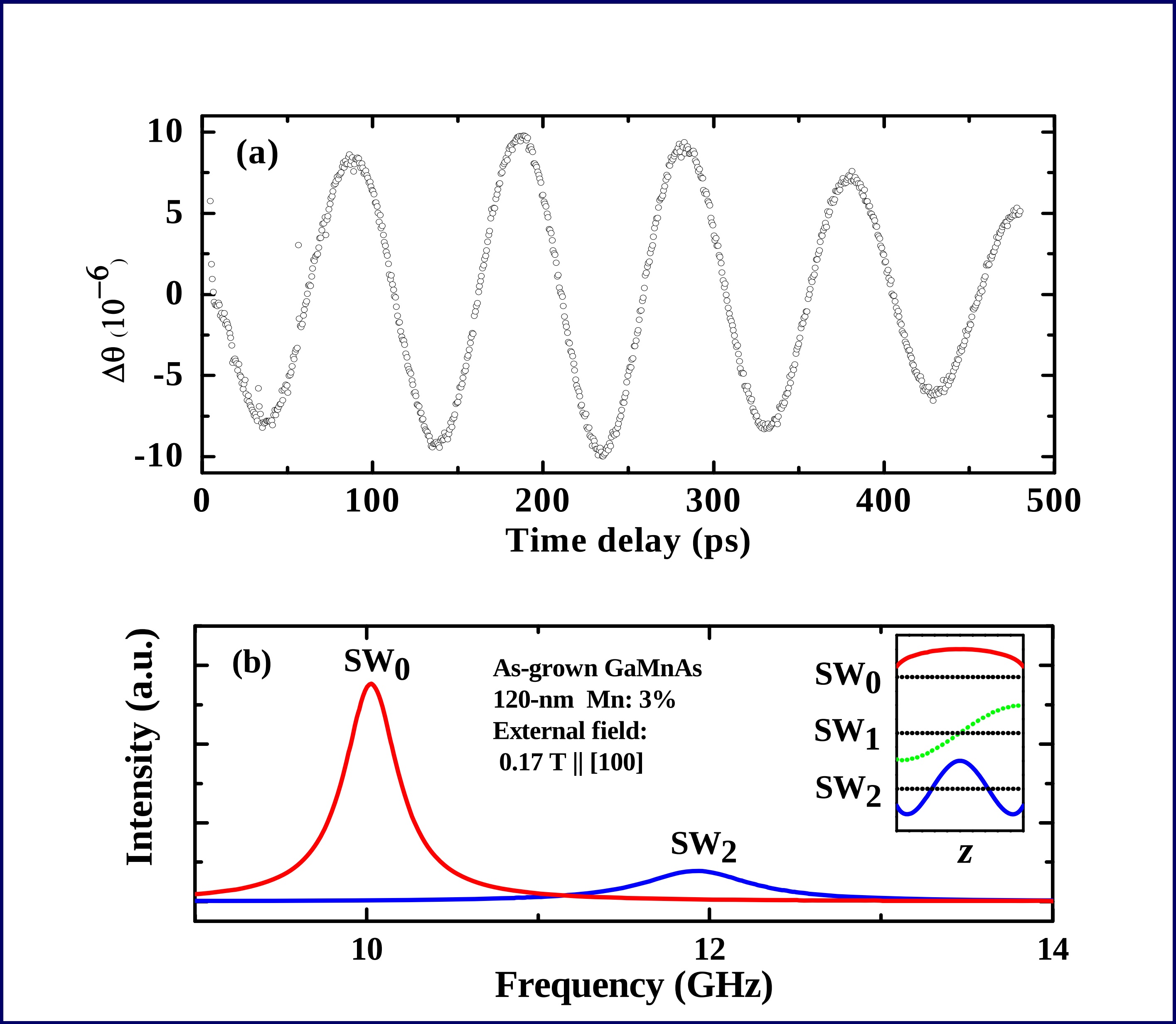
Circularly Polarized



Stimulated Raman Scattering

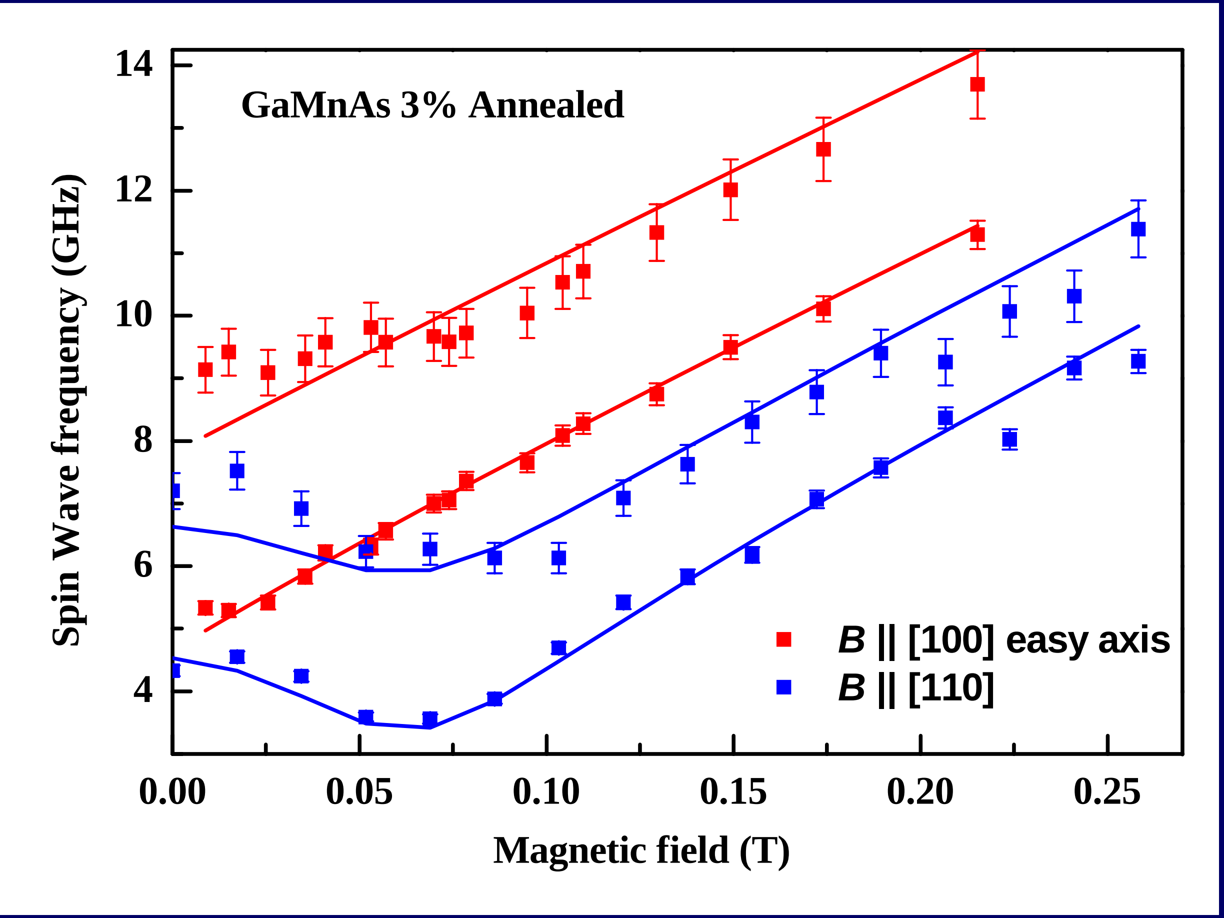
J. Bao, L. Pfeiffer, K. West and RM, Phys. Rev. Lett. **92** 236601 (2004)

$Ga_{1-x}Mn_xAs$: Time-resolved Magneto-Optical Kerr Measurements



D. Wang et al., unpublished

Dependence of the spin wave frequency on field for different directions

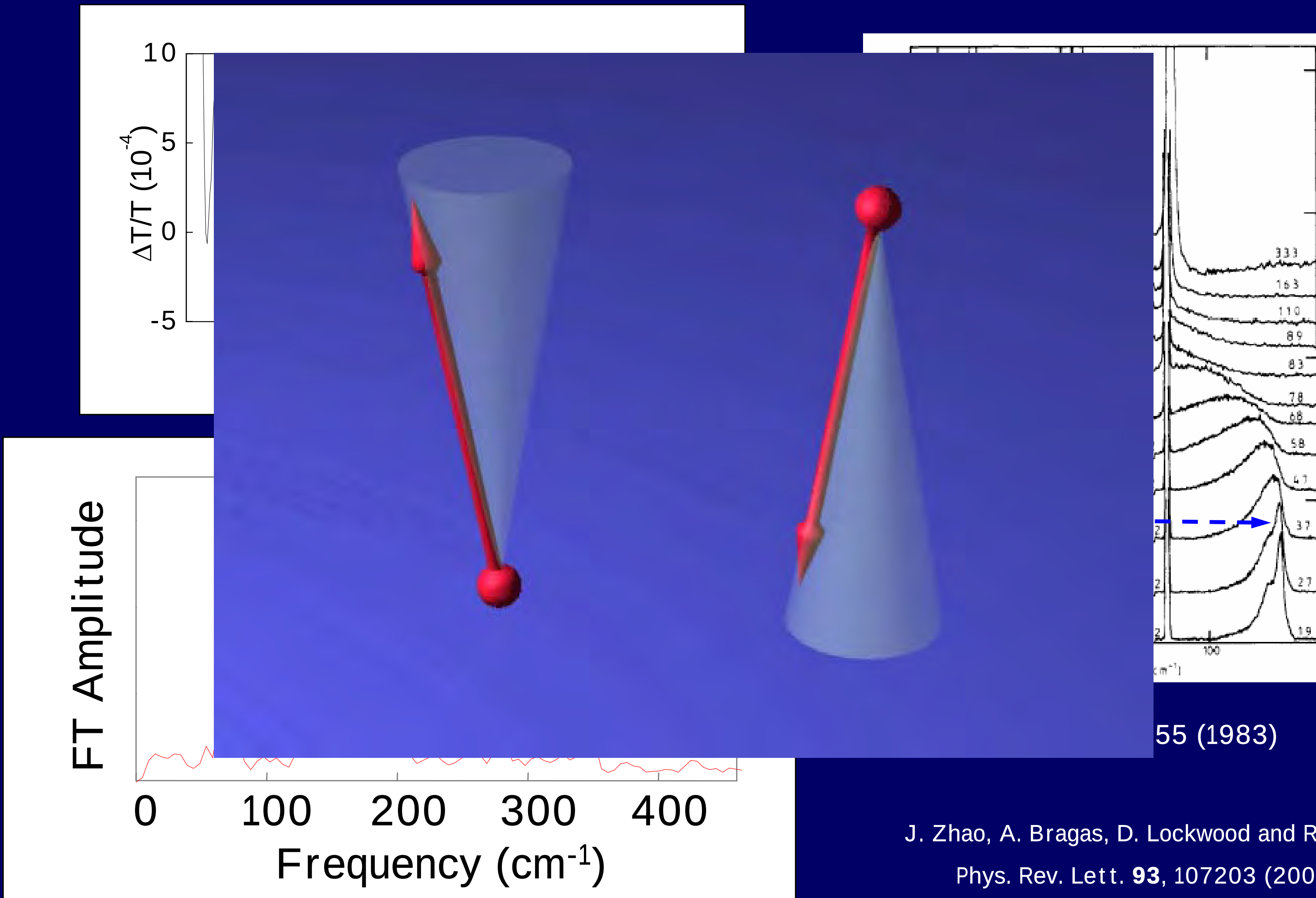


$$\omega = \gamma \sqrt{(H\cos(\varphi-\varphi_H) + \frac{2K_4}{m}\cos 4\varphi + Dk^2)(H\cos(\varphi-\varphi_H) + 4\pi m + \frac{K_4}{2m}(3+4\cos 4\varphi) - \frac{2K_2}{m} + Dk^2)}$$

Angle between the magnetization and applied field

MAGNON SQUEEZING

Spontaneous RS

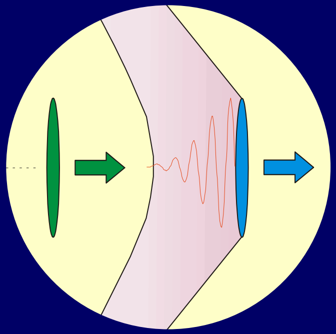


55 (1983)

J. Zhao, A. Bragas, D. Lockwood and RM

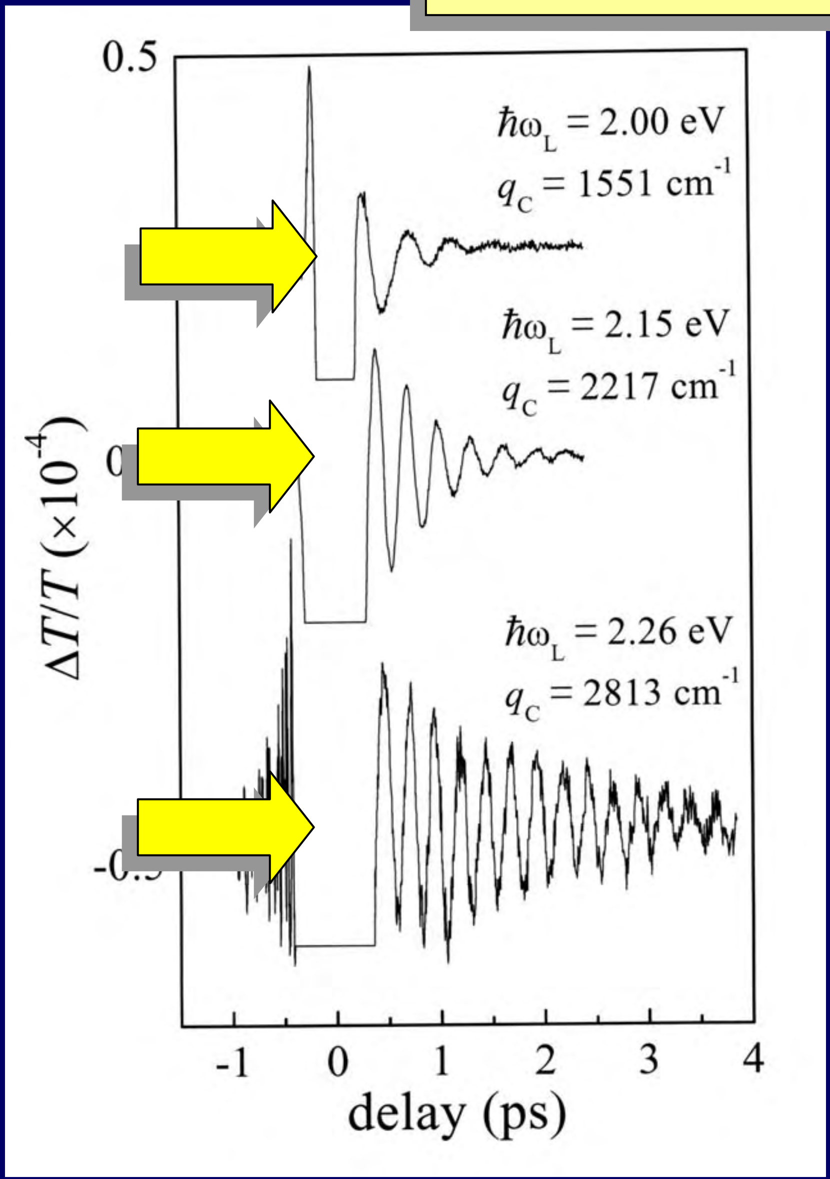
Phys. Rev. Lett. **93**, 107203 (2004)

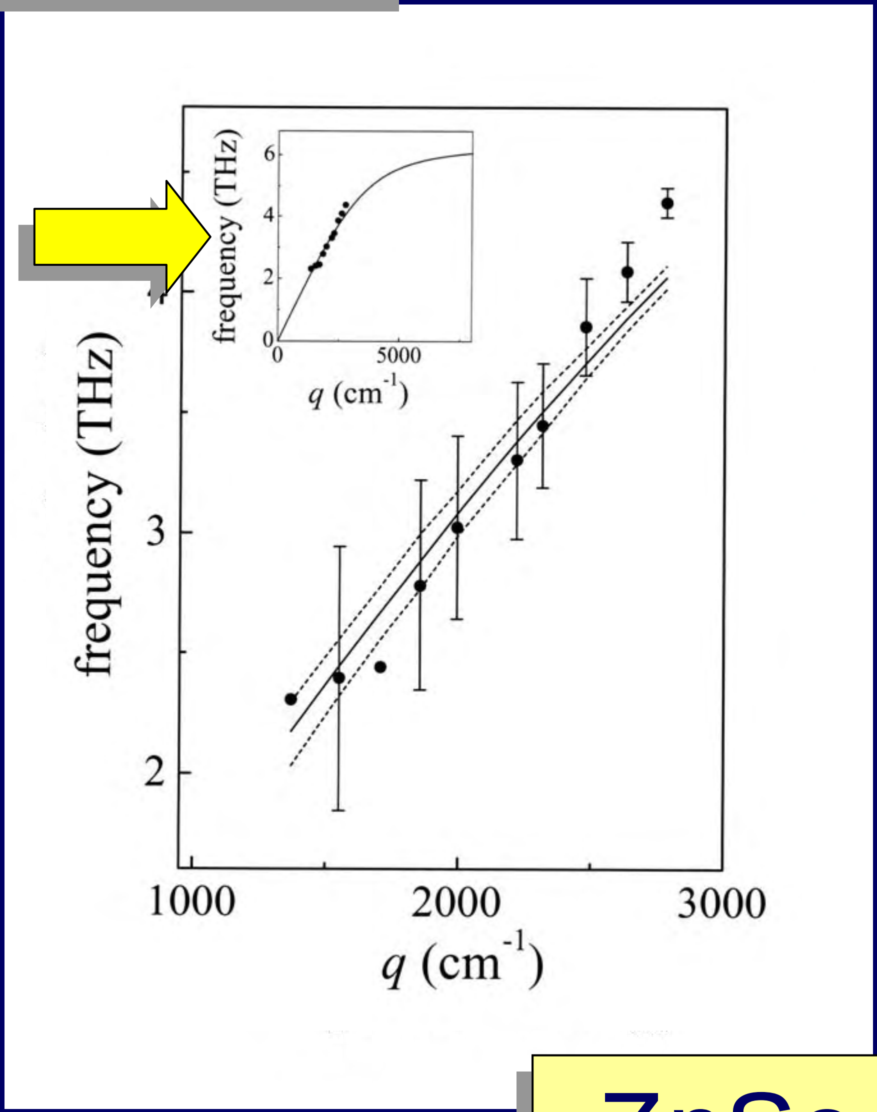
COHERENT POLARITONS AND CHERENKOV RADIATION



Propagation
Effects

PLANE OF DIPOLES
Science **291**, 627 (2001)

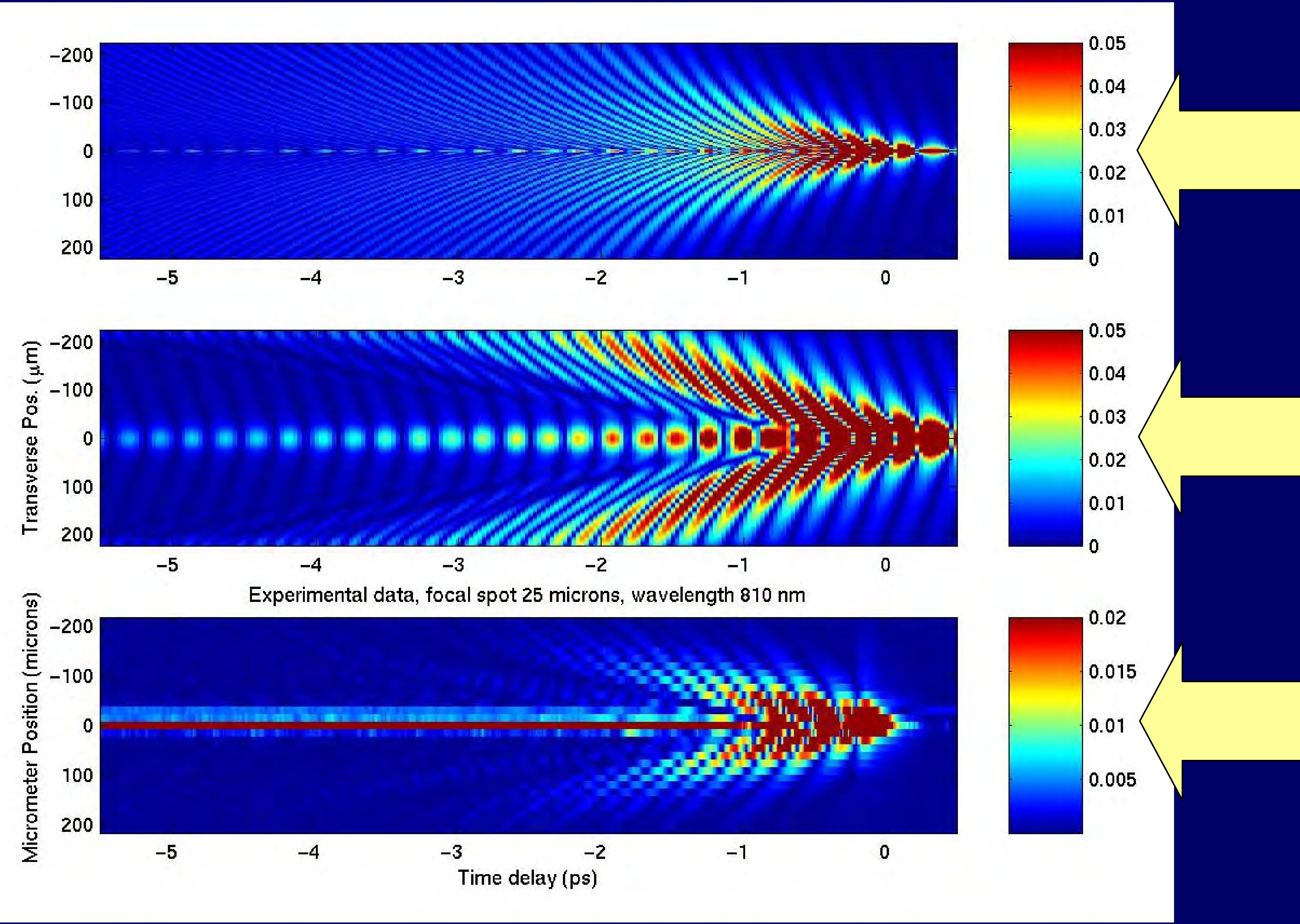




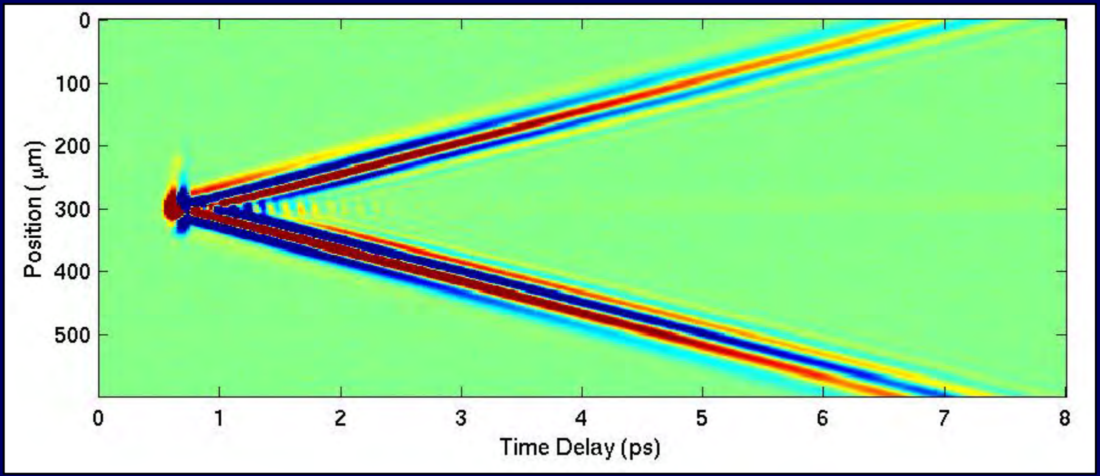
ZnSe

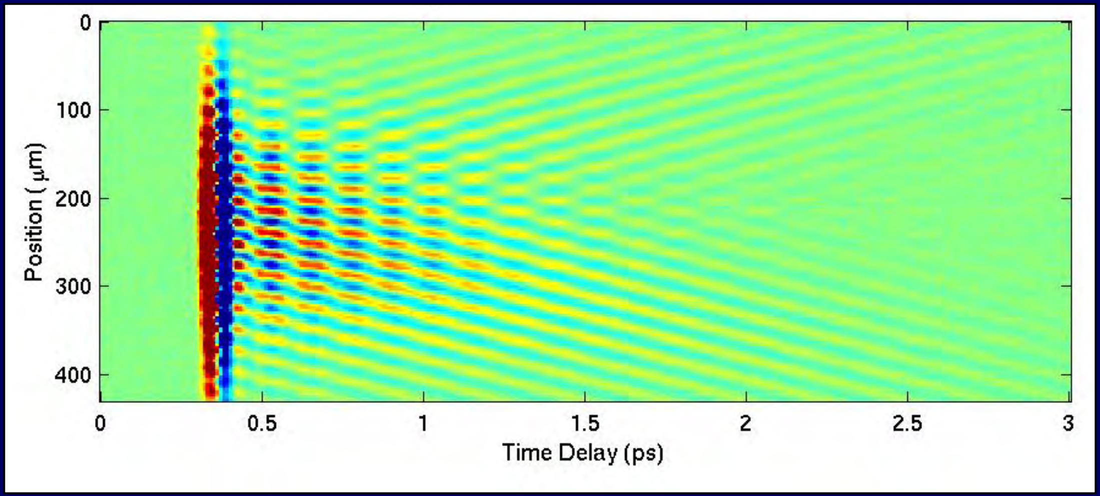
POINT DIPOLE
Physica B, **316-317**, 55 (2002)

ZnTe: $v = 0.31c$ (subluminal)



$LiTaO_3$: $v = 3.07c$ (superluminal)

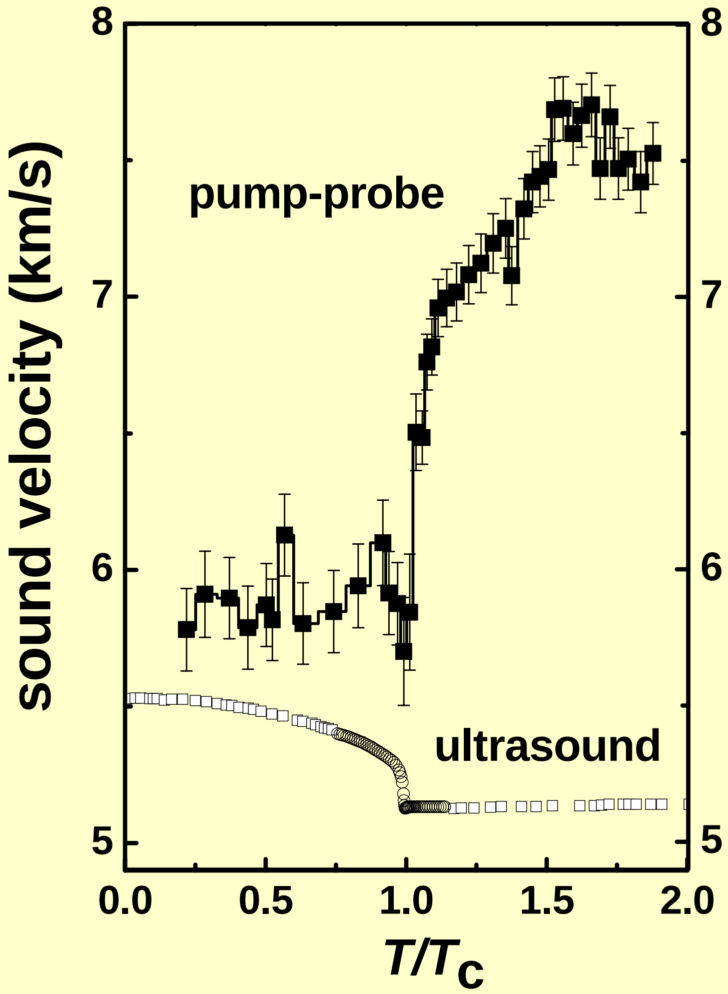


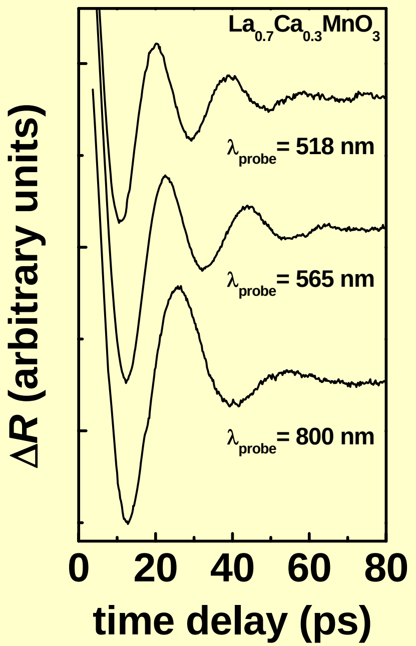


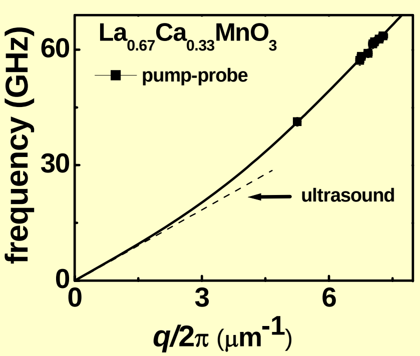
CHERENKOV RADIATION

J. Wahlstrand and RM, Phys. Rev. B **68**, 054301 (2003).

Anomalous First-to-Zero Sound Crossover in $La_{1-x}Ca_xMnO_3$

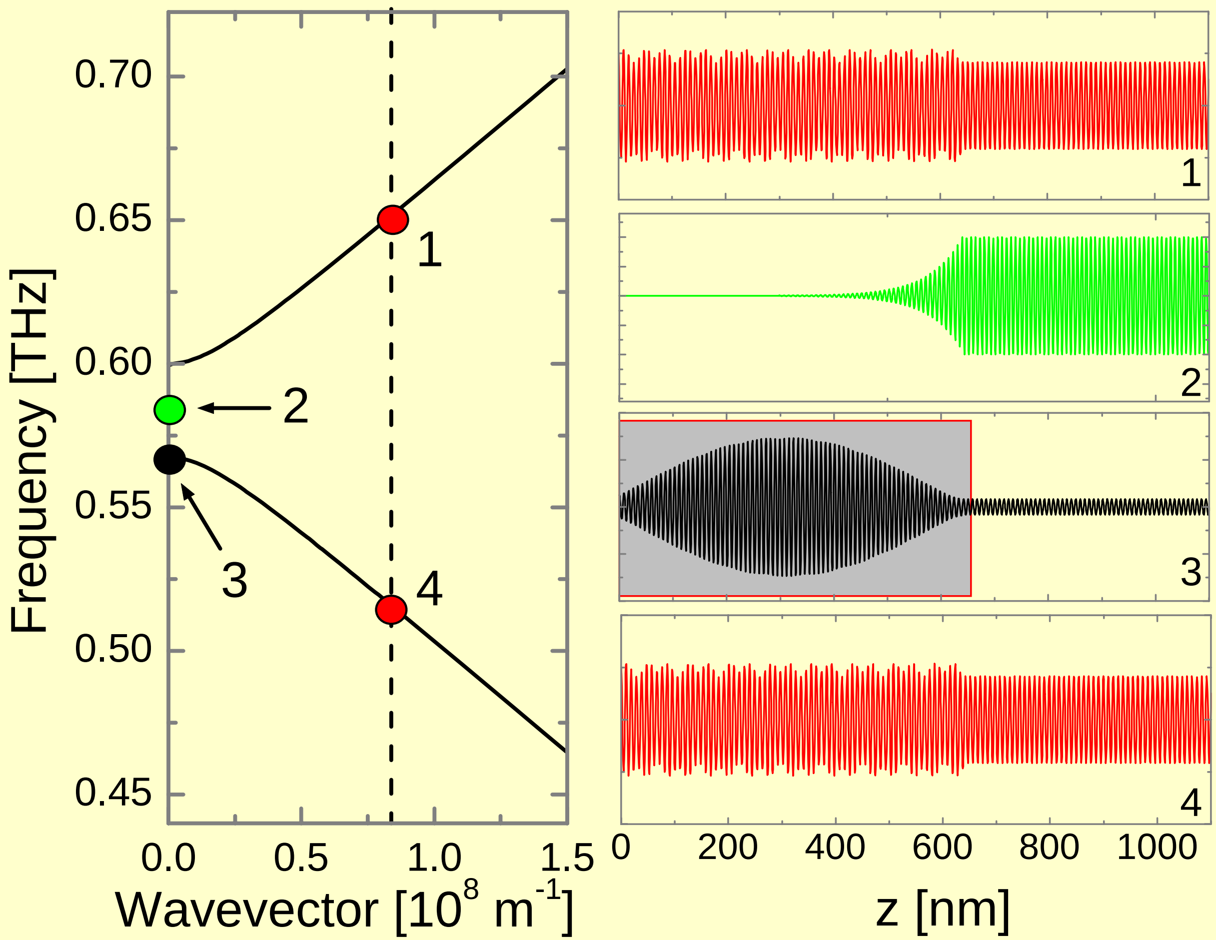






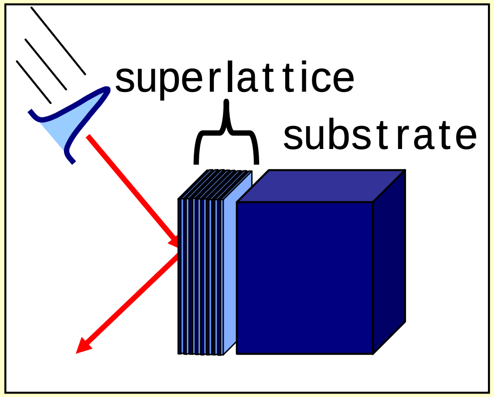
Y. Ren et al., unpublished

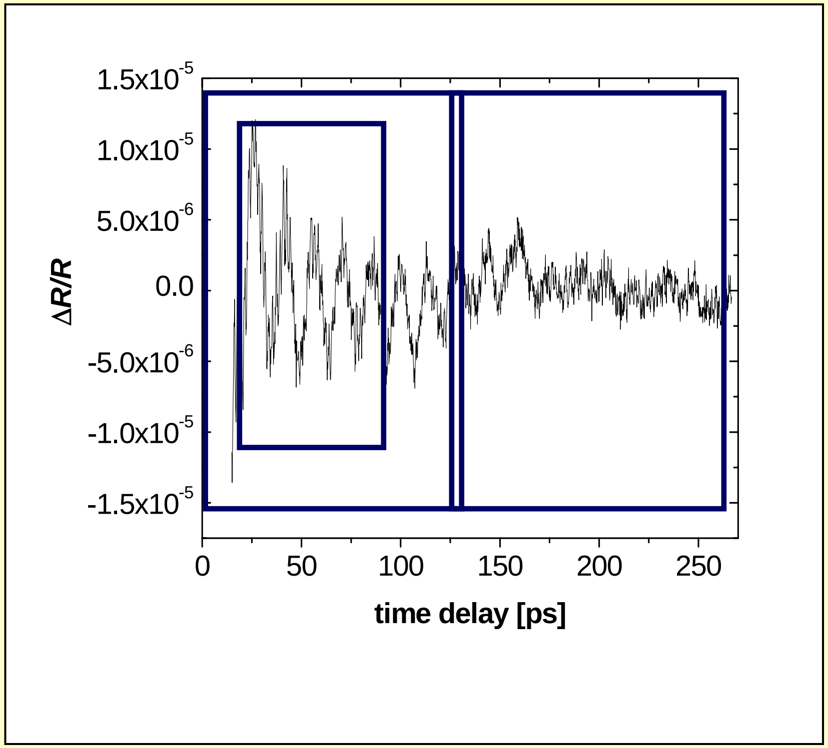
Propagating and Surface Avoiding Modes

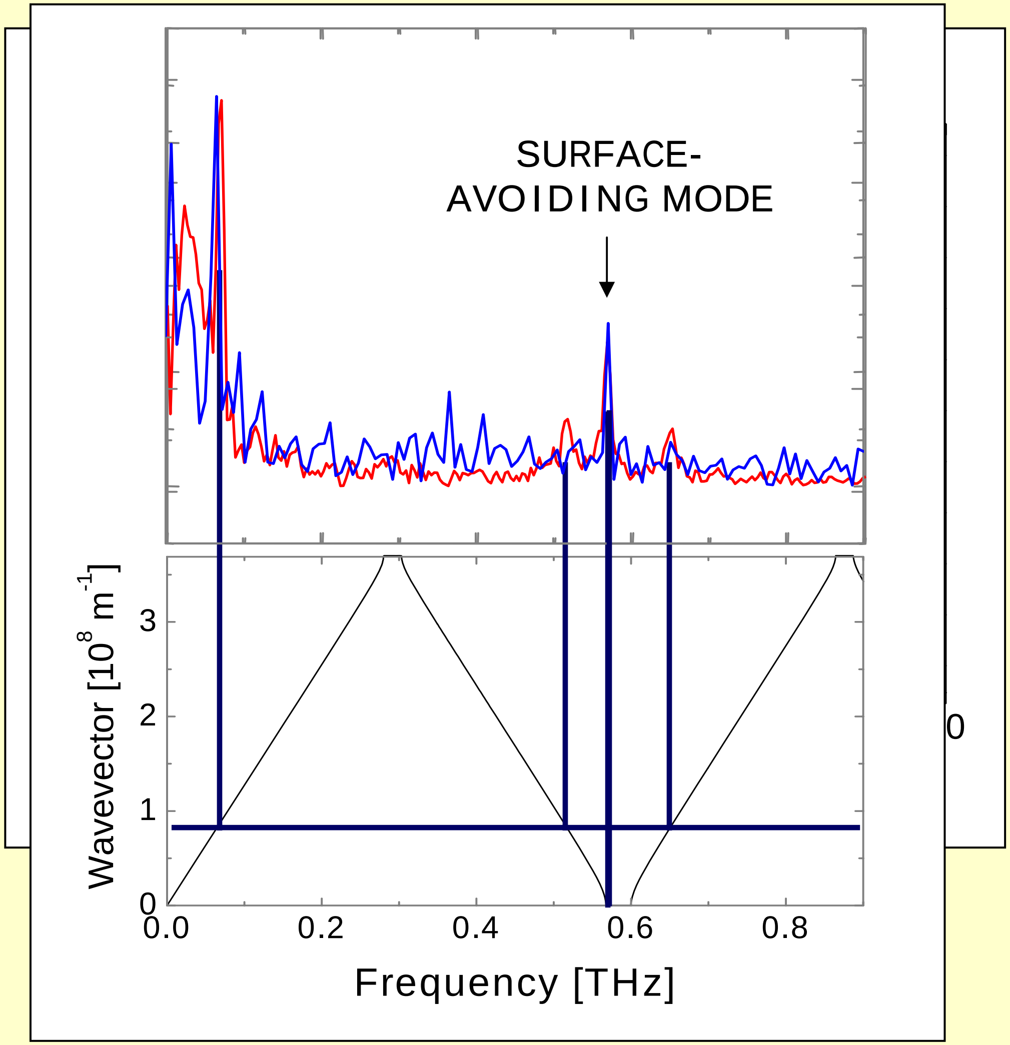


M. Trigo et al., unpublished

Propagating and Surface Avoiding Modes

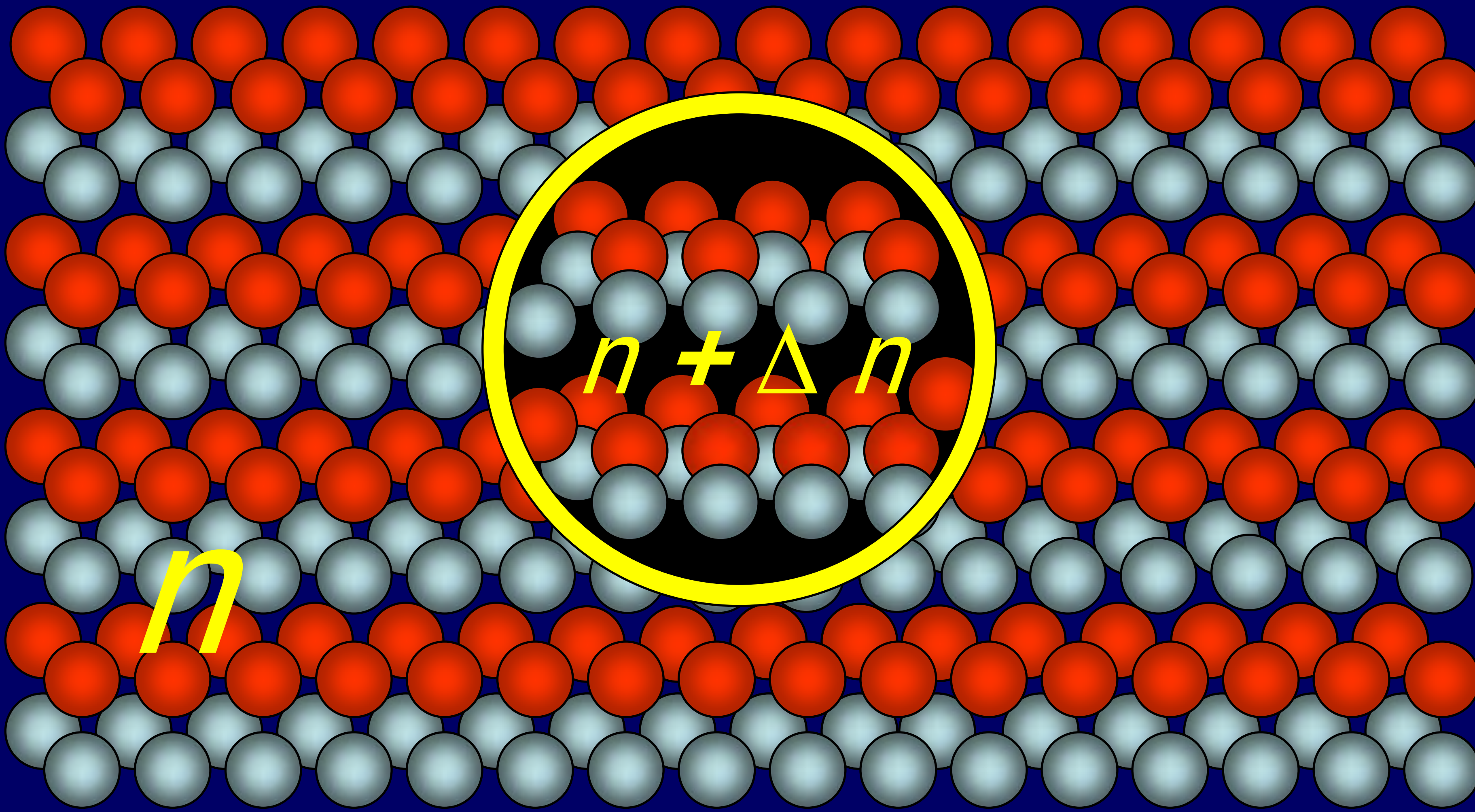






WHAT ARE THE MECHANISMS?

WHAT ARE THE MECHANISMS? DETECTION vs. GENERATION



$$n \rightarrow n + \Delta n \quad (\Delta n \propto Q\,,\ Q^2,\ Q^3, \ldots)$$

LASER-INDUCED IMPULSIVE EXCITATION OF ATOMS

DISPLACEMENTS
($u \equiv$ ions ; $Q \equiv$ phonons)

⇩

CHANGE IN DIELECTRIC RESPONSE

⇩

CHANGE IN ENERGY DENSITY

⇩

FORCE DENSITY

ELECTROMAGNETIC ENERGY DENSITY

$$U = \varepsilon \left| E(\mathbf{r},t) \right|^2 / 8\pi$$

$$\delta\varepsilon = \sum_{im} (\partial\varepsilon / \partial u_{im}) \; u_{im} + \sum_{ijmn} (\partial^2\varepsilon / \partial u_{im} \partial u_{jn}) \; u_{im} u_{jn} + \ldots$$

$$\delta U \approx \delta\varepsilon_{\mathbf{k}=0} \left| E(\mathbf{r},t) \right|^2 / 8\pi = \frac{\left| E(\mathbf{r},t) \right|^2}{8\pi} \times$$

$$\sum_{s} (\partial\varepsilon / \partial Q_{s,\mathbf{k}=0}) \; Q_{s,\mathbf{k}=0} + \sum_{st,\mathbf{k}} (\partial^2\varepsilon / \partial Q_{s,\mathbf{k}} \partial Q_{t,-\mathbf{k}}) Q_{s,\mathbf{k}} Q_{t,-\mathbf{k}} + \ldots.$$

$$F \propto \left| E^2(t) \right|$$

FIRST-ORDER IMPULSIVE FORCE

$$F \propto Q_{\mathbf{k}} \left| E^2(t) \right|$$

SECOND-ORDER IMPULSIVE CHANGE OF FREQUENCY

IMPULSIVE STIMULATED RAMAN SCATTERING

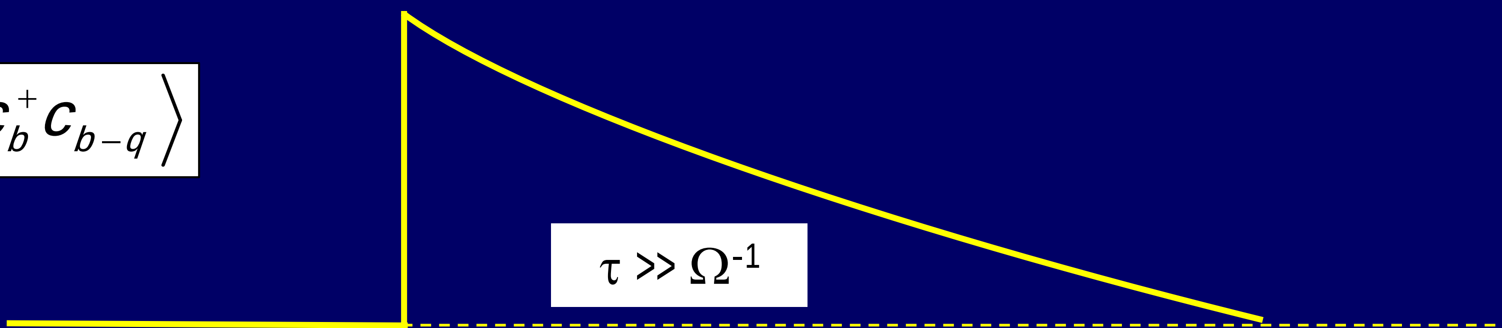
ABOVE THE GAP: DISPLACIVE EXCITATION

$$H = \sum_b \varepsilon_b c_b^+ c_b + \frac{1}{2} \sum_q (P_q^2 + \Omega_q^2 Q_q^2) + \sum \Xi_{kk'} Q_{k-k'} c_k^+ c_{k'}$$

⇒

$$\ddot{Q}_q + \Omega_q^2 \left\langle Q_q \right\rangle = -\sum_k \Xi_{k,k-q} \left\langle c_k^+ c_{k-q} \right\rangle$$

$$F \propto \left\langle c_b^+ c_{b-q} \right\rangle$$

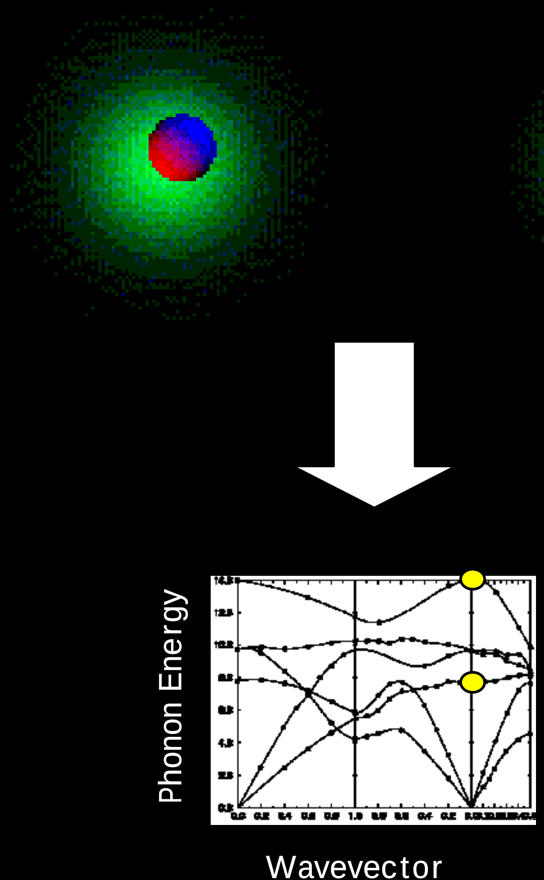


$$F(\Omega) \propto \left[\frac{d\,\mathrm{Re}(\varepsilon)}{d\omega} + 2i\,\mathrm{Im}\,\varepsilon / \Omega \right] \int_{-\infty}^{+\infty} e^{i\Omega t} \, |E(t)|^2 \, dt$$

TWO RAMAN TENSORS: T. Stevens, J. Kuhl and RM

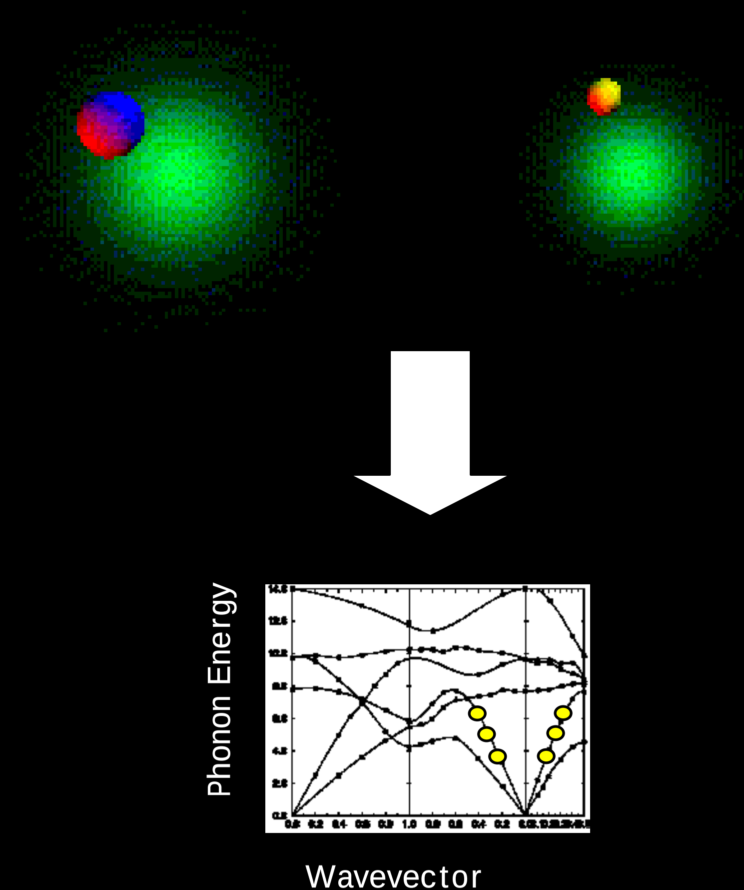
Phys. Rev. B **65**, 144304 (2002)

COHERENT PHONON FIELD



K=0

SQUEEZED PHONON FIELD

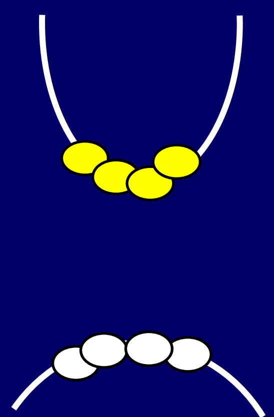


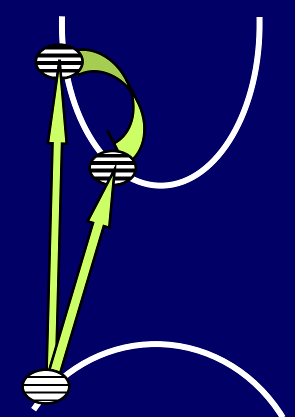
$\mathbf{K_1+K_2}=0$

DECP vs. COHERENT RAMAN SCATTERING

$$F_{DECP} \propto \sum_b \langle c_b^+ c_b \rangle$$

$$F_{RS} \propto \sum_b \langle c_b^+ c_{b-q} \rangle$$





incoherent → coherent

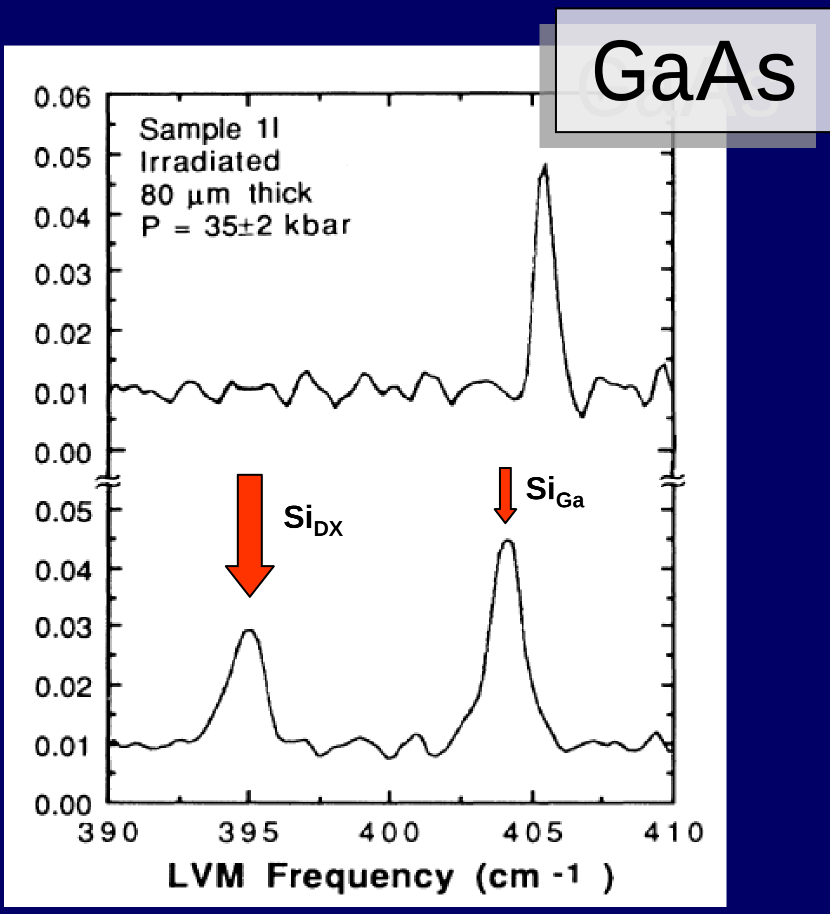
A-type modes

Long-lived Raman coherence

All Raman-allowed modes

Good (?) ERL Idea

Time Resolved EXAFS: Impurity Mode Identification



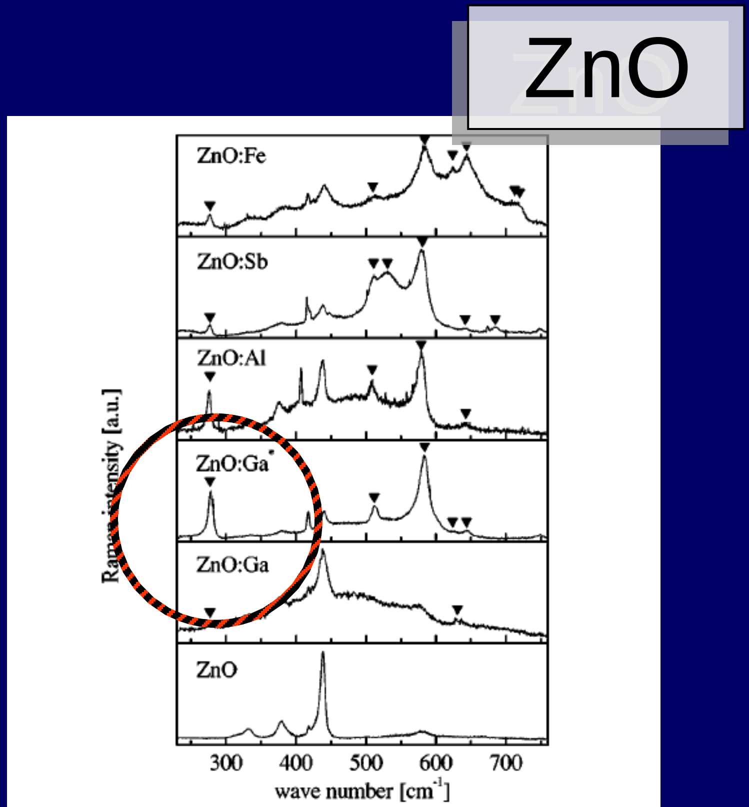


FIG. 2. Polarized micro-Raman spectra in the $x(yy)x'$ scattering configuration for undoped, Ga, Al, Sb, and Fe doped ZnO thin films on sapphire. The ZnO:Ga* film was grown in N_2O atmosphere, all other samples were grown in O_2 atmosphere. Triangles denote additional modes.

VOLUME 66, NUMBER 6 PHYSICAL REVIEW LETTERS 11 FEBRUARY 1991

Local-Vibrational-Mode Spectroscopy of *DX* Centers in Si-Doped GaAs under Hydrostatic Pressure

J. A. Wolk,[1,2] M. B. Kruger,[1] J. N. Heyman,[1] W. Walukiewicz,[2] R. Jeanloz,[3] and E. E. Haller[2,4]

APPLIED PHYSICS LETTERS VOLUME 83, NUMBER 10 8 SEPTEMBER 2003

Raman scattering in ZnO thin films doped with Fe, Sb, Al, Ga, and Li

C. Bundesmann,[a] N. Ashkenov, M. Schubert, D. Spemann, T. Butz, E. M. Kaidashev,[b] M. Lorenz, and M. Grundmann

Silicon K-shell: 1.84 keV

Gallium K-shell: 10.4 keV

Time Resolved EXAFS: Impurity Mode Identification