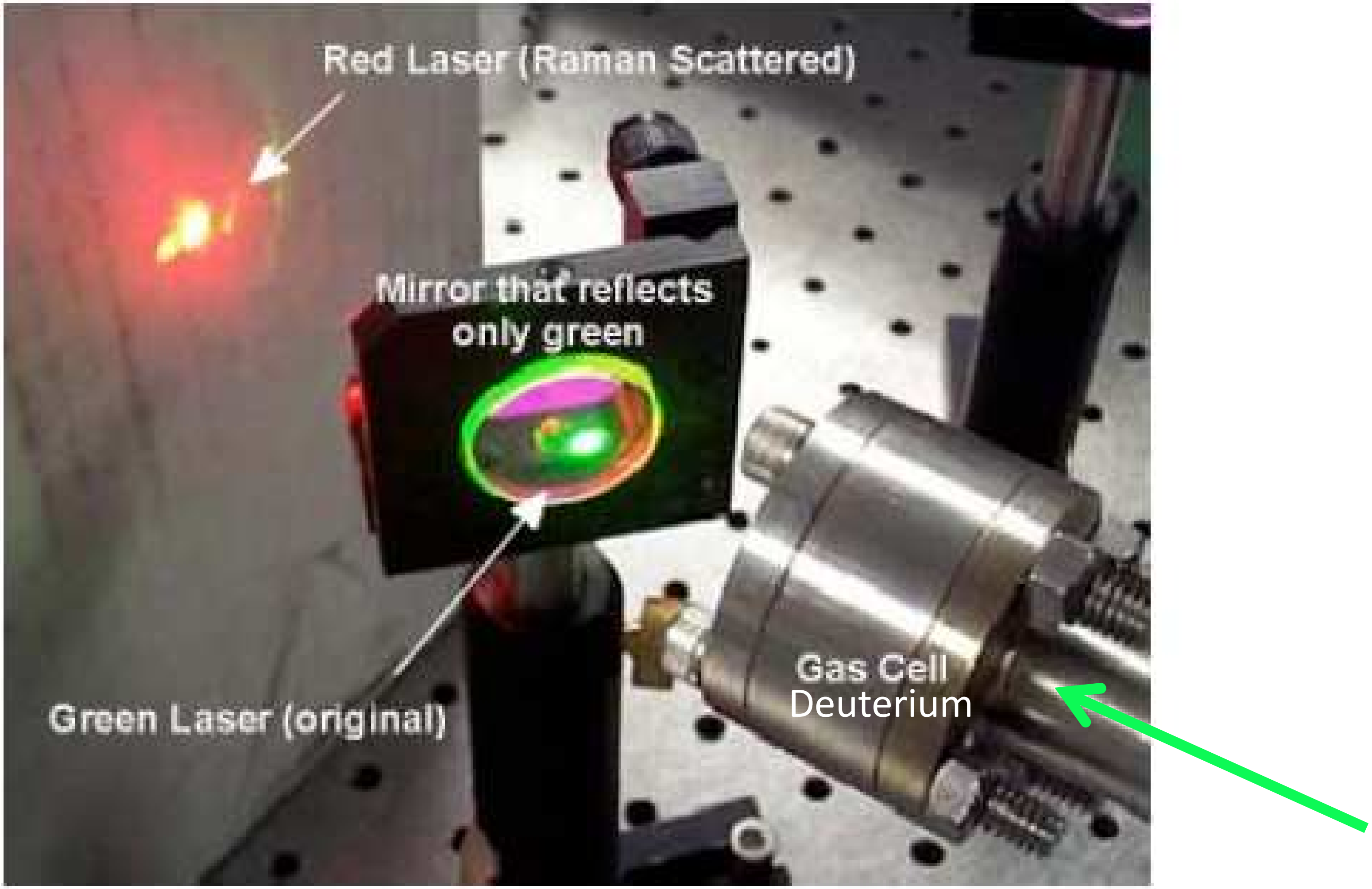
Light Scattering


Red Laser (Raman Scattered)
Mirror that reflects only green
Green Laser (original)
Gas Cell
Deuterium

A bit of history

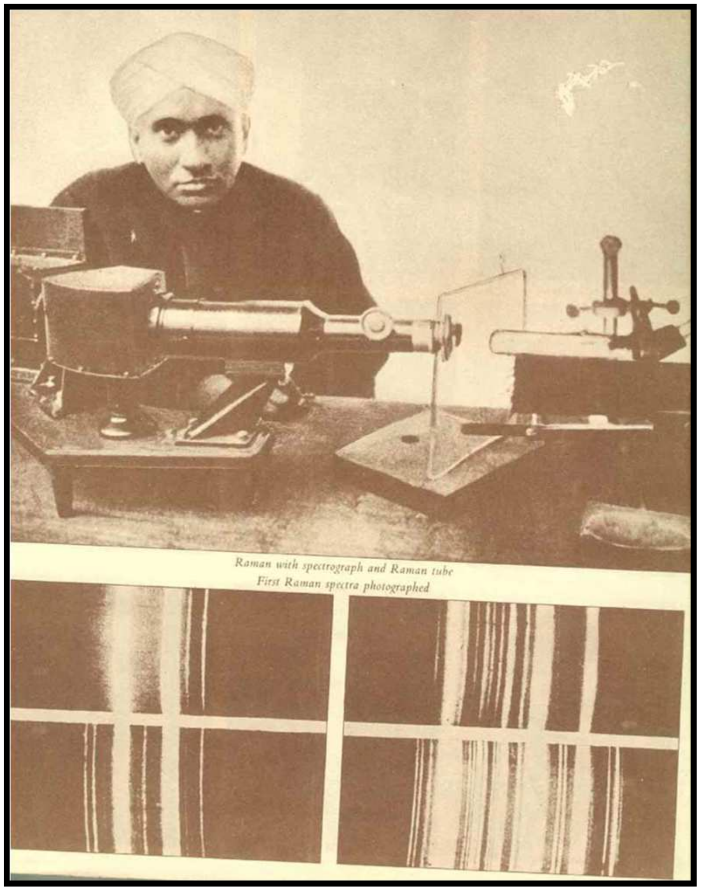
Inelastic Scattering of light was predicted theoretically in 1923 by A. Smekal

Experimental observation in 1928 by:

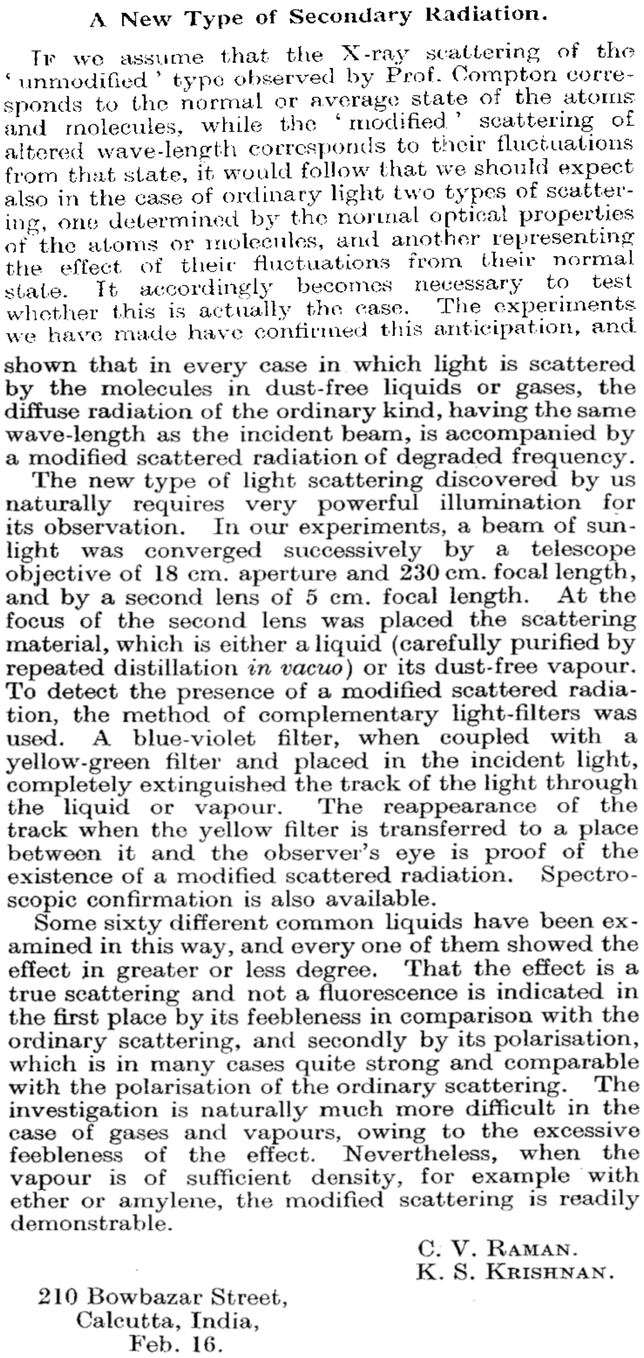
- C.V. Raman and K.S. Krishnan (Kalkutta)
- G. Landsberg and L. Mandelstam (Moscow)

Nobel Prize in 1930 for … C.V. Raman

A New Type of Secondary Radiation
C. V. RAMAN, K. S. KRISHNAN
Nature 121, 501-502 (31 March 1928)
A Change of Wave-length in Light Scattering
C. V. RAMAN
Nature 121, 619-619 (21 April 1928)
The Optical Analogue of the Compton Effect
C. V. RAMAN, K. S. KRISHNAN
Nature 121, 711-711 (5 May 1928)



Raman with spectrograph and Raman tube
First Raman spectra photographed



A New Type of Secondary Radiation.

If we assume that the X-ray scattering of the 'unmodified' type observed by Prof. Compton corresponds to the normal or average state of the atoms and molecules, while the 'modified' scattering of altered wave-length corresponds to their fluctuations from that state, it would follow that we should expect also in the case of ordinary light two types of scattering, one determined by the normal optical properties of the atoms or molecules, and another representing the effect of their fluctuations from their normal state. It accordingly becomes necessary to test whether this is actually the case. The experiments we have made have confirmed this anticipation, and shown that in every case in which light is scattered by the molecules in dust-free liquids or gases, the diffuse radiation of the ordinary kind, having the same wave-length as the incident beam, is accompanied by a modified scattered radiation of degraded frequency.

The new type of light scattering discovered by us naturally requires very powerful illumination for its observation. In our experiments, a beam of sunlight was converged successively by a telescope objective of 18 cm. aperture and 230 cm. focal length, and by a second lens of 5 cm. focal length. At the focus of the second lens was placed the scattering material, which is either a liquid (carefully purified by repeated distillation *in vacuo*) or its dust-free vapour. To detect the presence of a modified scattered radiation, the method of complementary light-filters was used. A blue-violet filter, when coupled with a yellow-green filter and placed in the incident light, completely extinguished the track of the light through the liquid or vapour. The reappearance of the track when the yellow filter is transferred to a place between it and the observer's eye is proof of the existence of a modified scattered radiation. Spectroscopic confirmation is also available.

Some sixty different common liquids have been examined in this way, and every one of them showed the effect in greater or less degree. That the effect is a true scattering and not a fluorescence is indicated in the first place by its feebleness in comparison with the ordinary scattering, and secondly by its polarisation, which is in many cases quite strong and comparable with the polarisation of the ordinary scattering. The investigation is naturally much more difficult in the case of gases and vapours, owing to the excessive feebleness of the effect. Nevertheless, when the vapour is of sufficient density, for example with ether or amylene, the modified scattering is readily demonstrable.

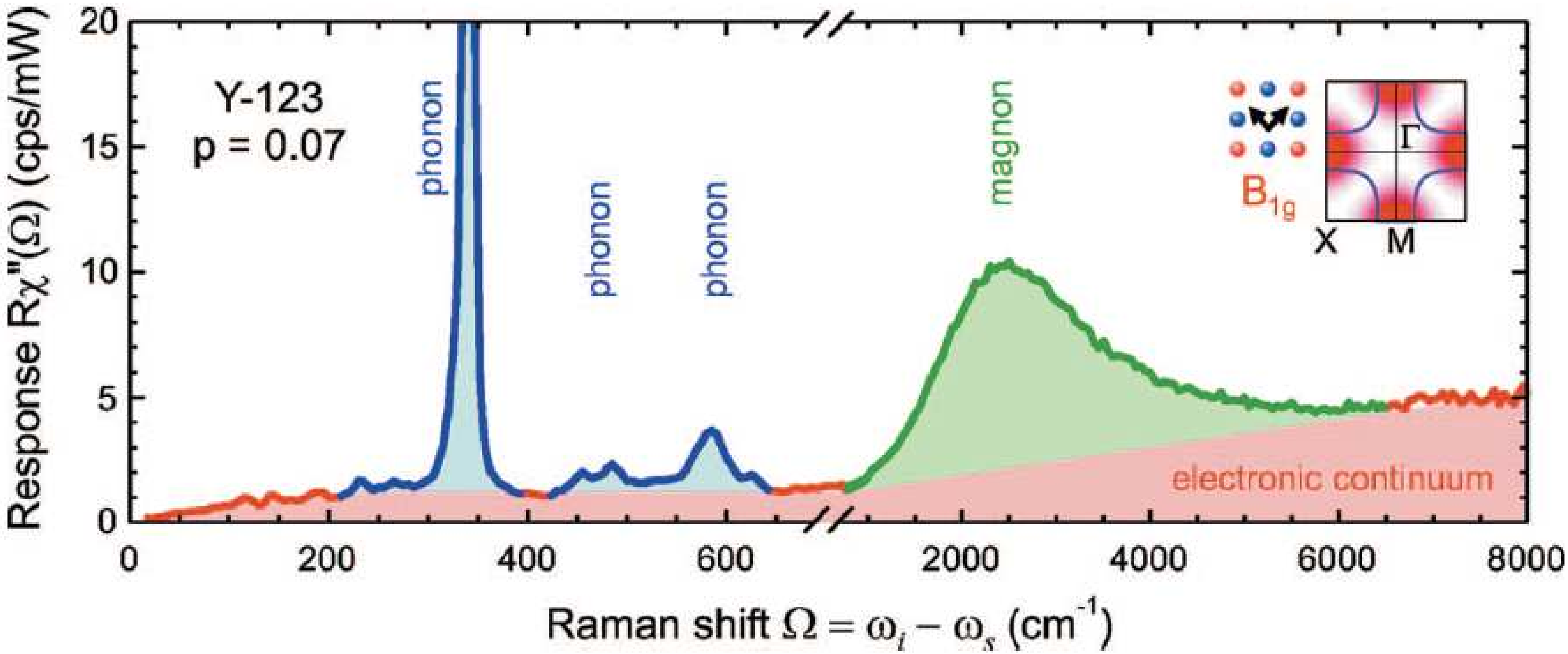
C. V. Raman.
K. S. Krishnan.

210 Bowbazar Street,
Calcutta, India,
Feb. 16.

KUNGLIGA SVENSKA VETENSKAPSAKADEMIEN

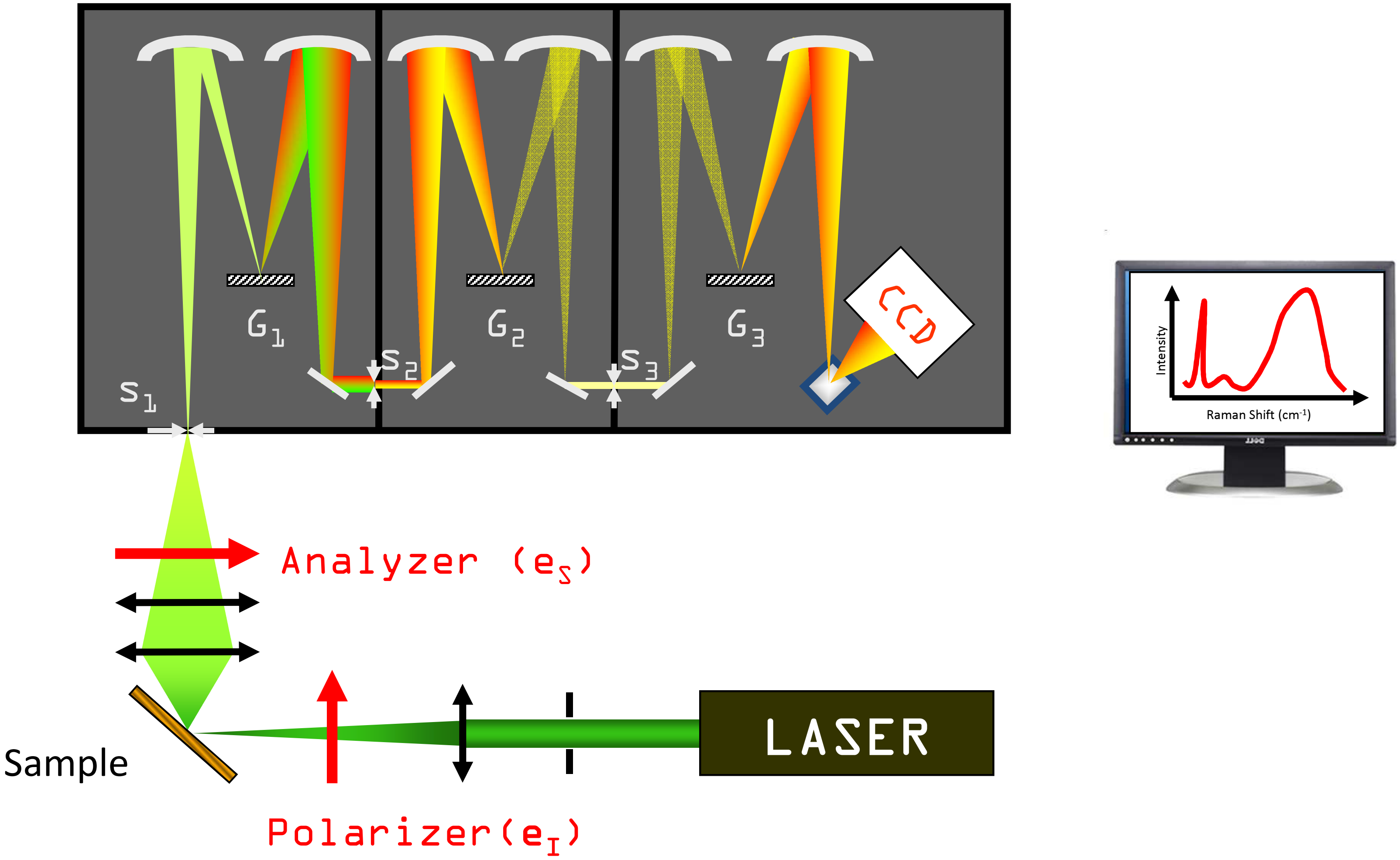
SIR CHANDRASEKHARA VENKATA RAMAN

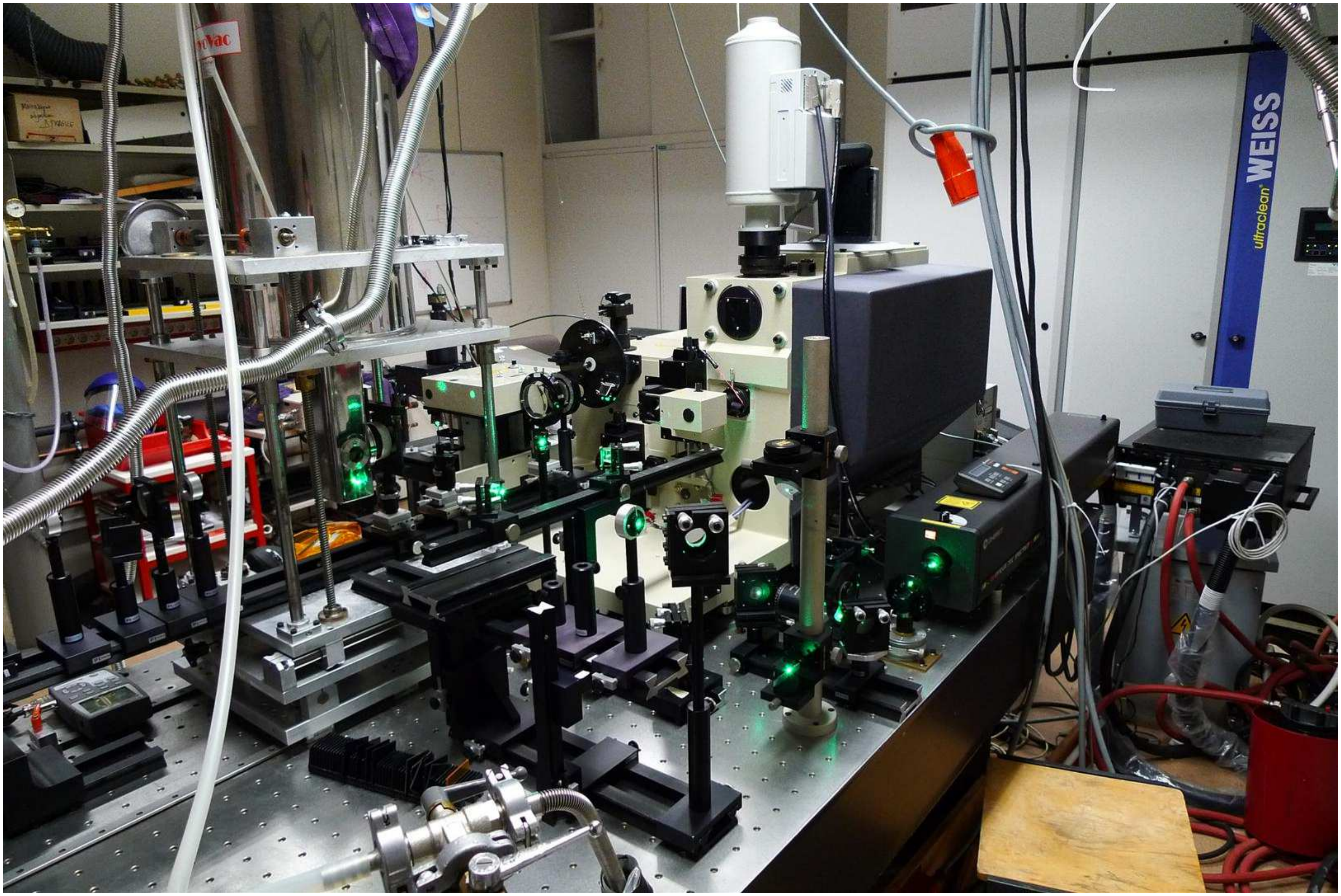
Typical Raman spectra of high Tc superconductor



T.P. Devereaux & R. Hackl, RMP ***79**, 175* (2007)

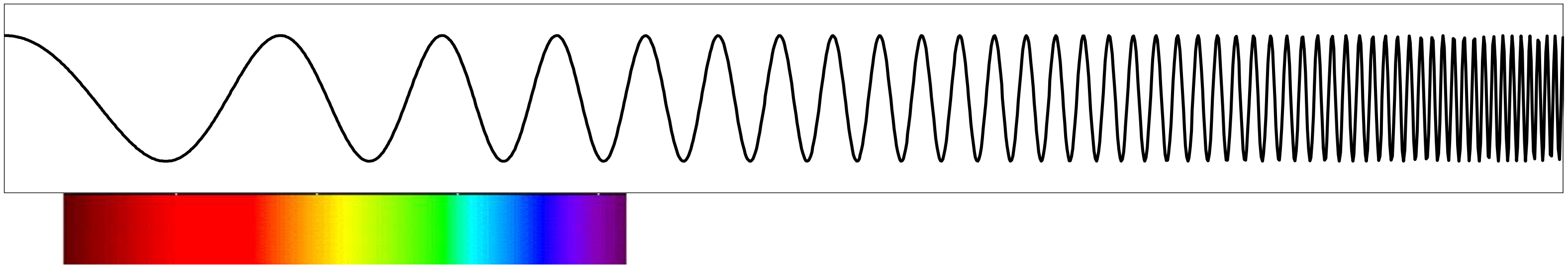
High resolution triple spectrometer




ultraclean WEISS

Inelastic scattering of higher energy photon is a very different story !!!

Max. Transfered Momentum Q ~0 Q ~ 1st BZ Q ~ several BZ



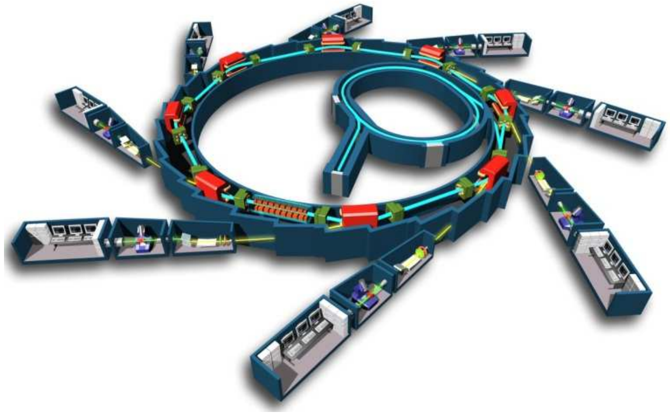
Wavelength 10^4 Å 10^3 Å 10^2 Å 10 Å 0.1 Å

Energy 1 eV 10 eV 100 eV 1 keV 100 keV

Raman Scattering

Soft x-ray
RIXS

Hard x-ray
IXS



VOLUME 15, NUMBER 25 PHYSICAL REVIEW LETTERS 20 DECEMBER 1965

RAMAN SCATTERING BY POLARITONS*

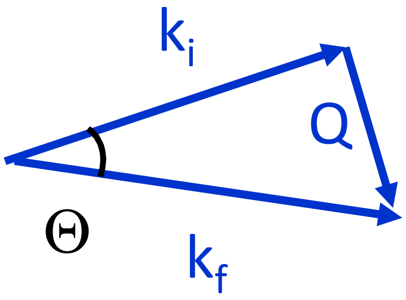
C. H. Henry

Bell Telephone Laboratories, Murray Hill, New Jersey

and

J. J. Hopfield

Plamer Physical Laboratory, Princeton University, Princeton, New Jersey



$$q^2 = \frac{\omega^2}{c^2}\left[\epsilon(\infty) + \frac{\epsilon(0)-\epsilon(\infty)}{1-\omega^2/\omega_{TO}^2}\right]$$

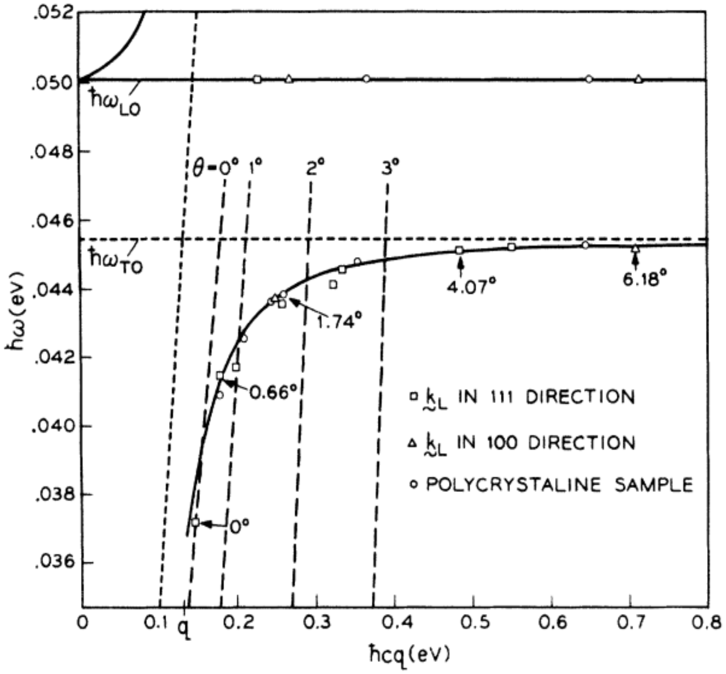
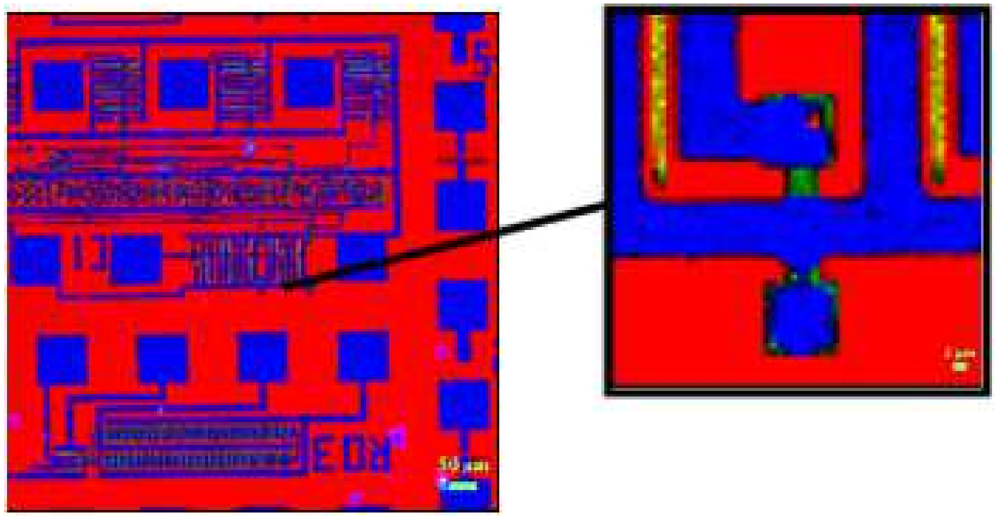
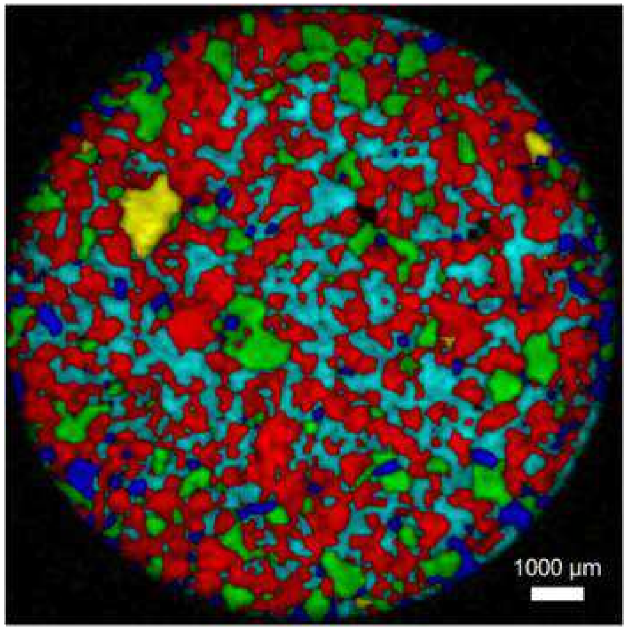


FIG. 2. A plot of the observed energies and wave vectors of the polaritons and of the LO phonons; the theoretical dispersion curves are shown by the solid lines. The dispersion curves for the uncoupled photons and phonons are shown by short-dashed lines. The values of energies and wave vectors which are kinematically possible at angle θ are shown by long-dashed lines. Some of the experimental angles θ are indicated next to the data points.

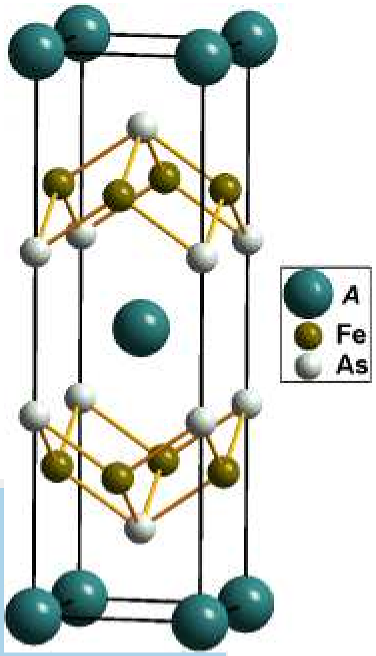


crystalline silicon (red), stressed silicon (yellow) and amorphous silicon (green). The blue areas correspond to a metal coating on the chip, which results in zero Raman signal.



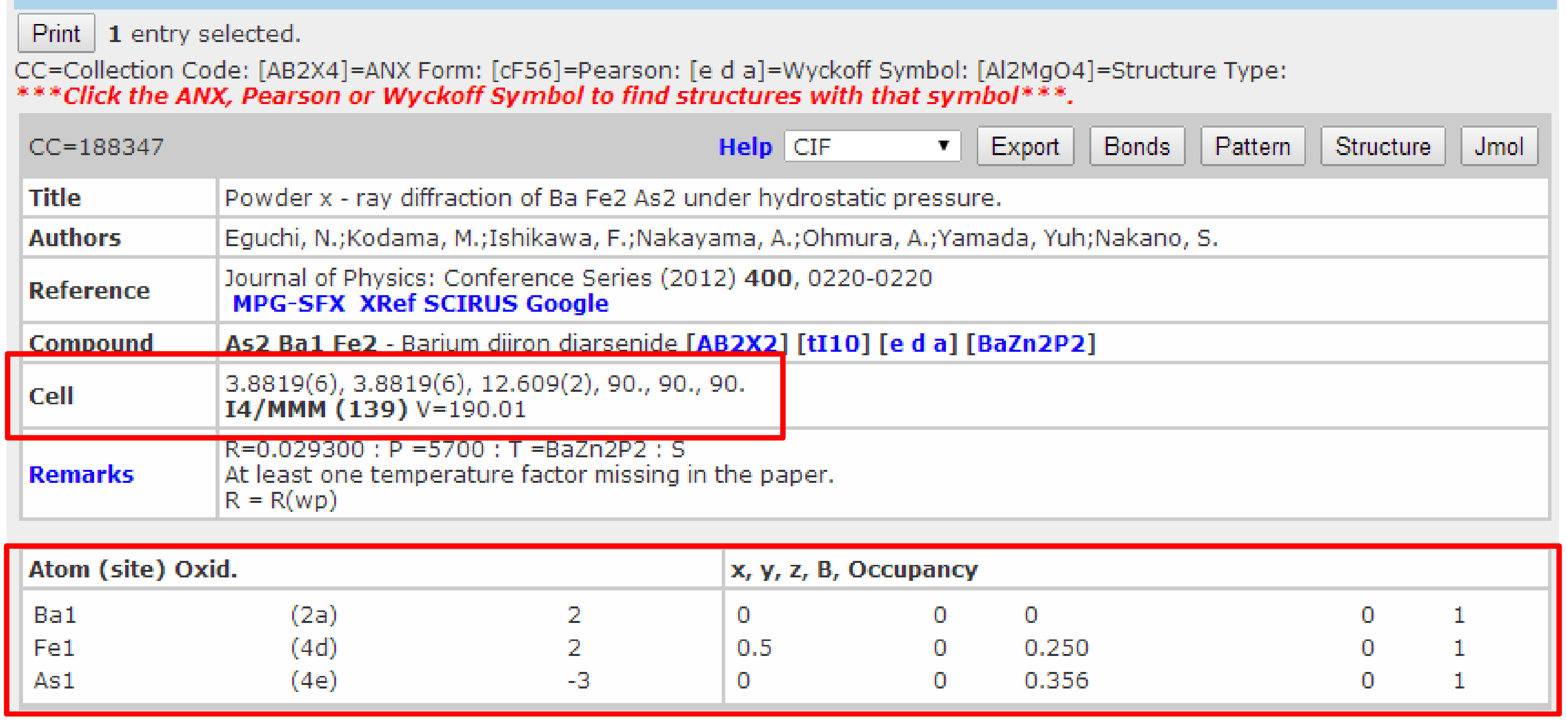
www.horiba.com

Example : BaFe$_2$As$_2$



ICSD for WWW

Details of the selected entries



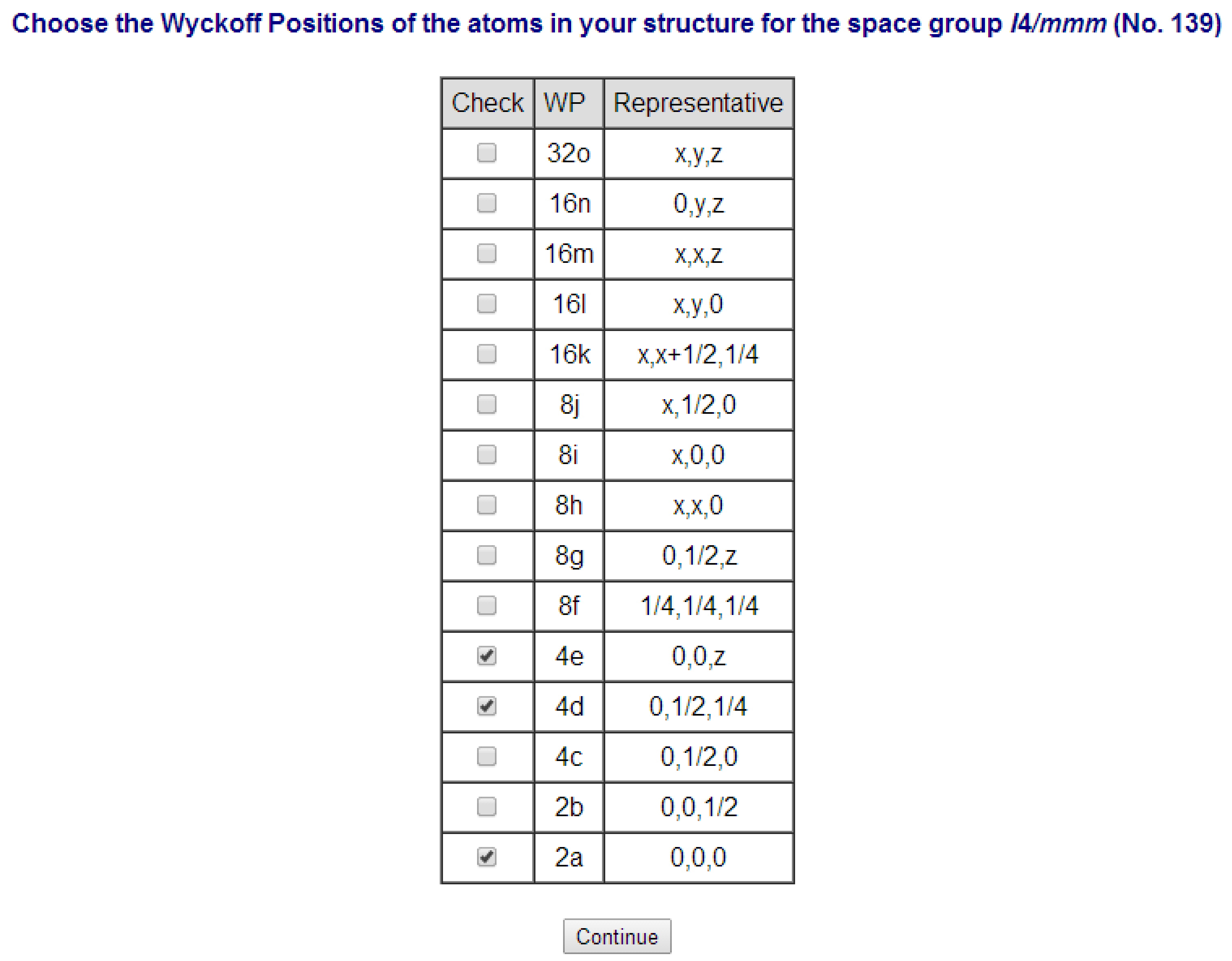
Print **1** entry selected.

CC=Collection Code: [AB2X4]=ANX Form: [cF56]=Pearson: [e d a]=Wyckoff Symbol: [Al2MgO4]=Structure Type:

****Click the ANX, Pearson or Wyckoff Symbol to find structures with that symbol***.*

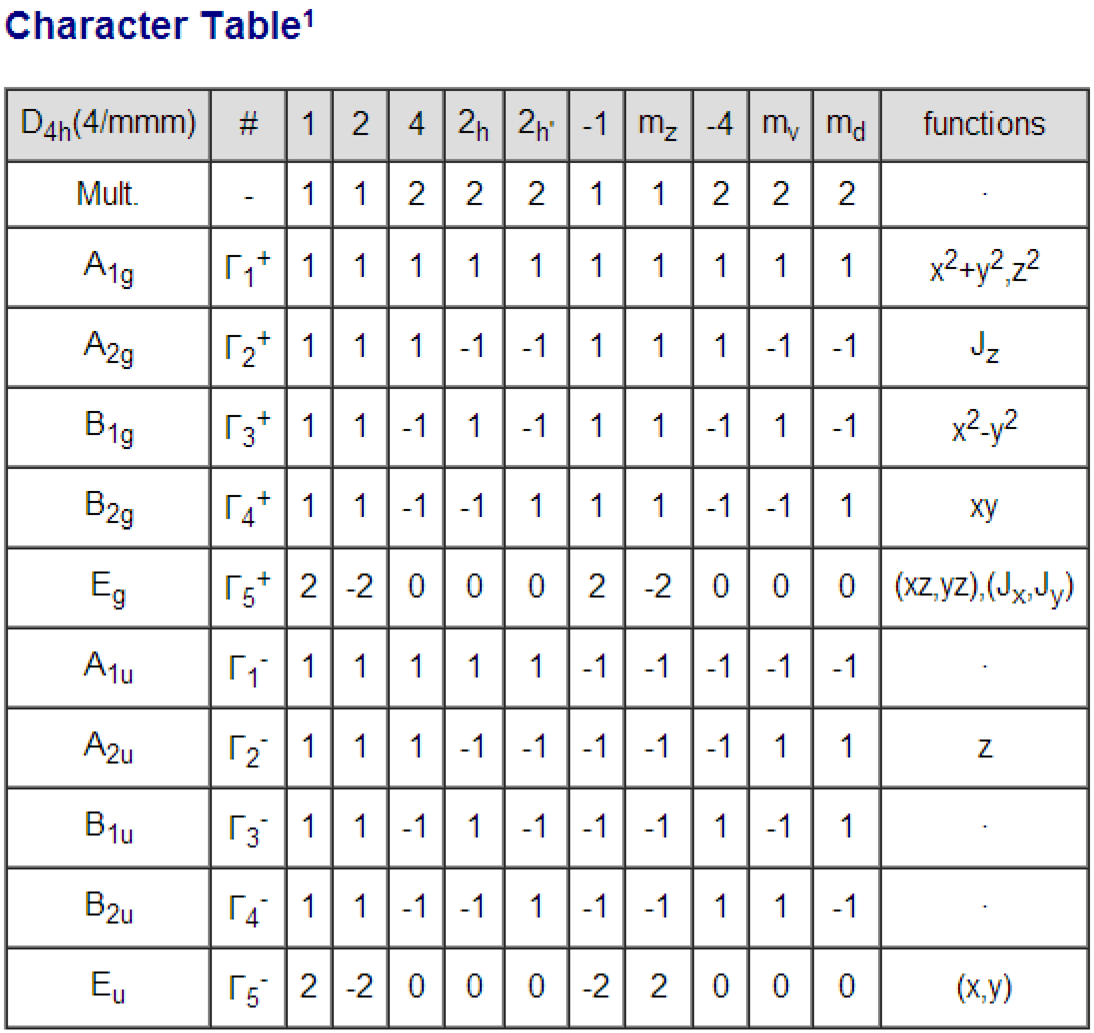
Title	Powder x - ray diffraction of Ba Fe2 As2 under hydrostatic pressure.
Authors	Eguchi, N.;Kodama, M.;Ishikawa, F.;Nakayama, A.;Ohmura, A.;Yamada, Yuh;Nakano, S.
Reference	Journal of Physics: Conference Series (2012) **400**, 0220-0220 **MPG-SFX XRef SCIRUS Google**
Compound	**As2 Ba1 Fe2** - Barium diiron diarsenide **[AB2X2] [tI10] [e d a] [BaZn2P2]**
Cell	3.8819(6), 3.8819(6), 12.609(2), 90., 90., 90. **I4/MMM (139)** V=190.01
Remarks	R=0.029300 : P =5700 : T =BaZn2P2 : S At least one temperature factor missing in the paper. R = R(wp)

Atom (site) Oxid.			**x, y, z, B, Occupancy**				
Ba1	(2a)	2	0	0	0	0	1
Fe1	(4d)	2	0.5	0	0.250	0	1
As1	(4e)	-3	0	0	0.356	0	1



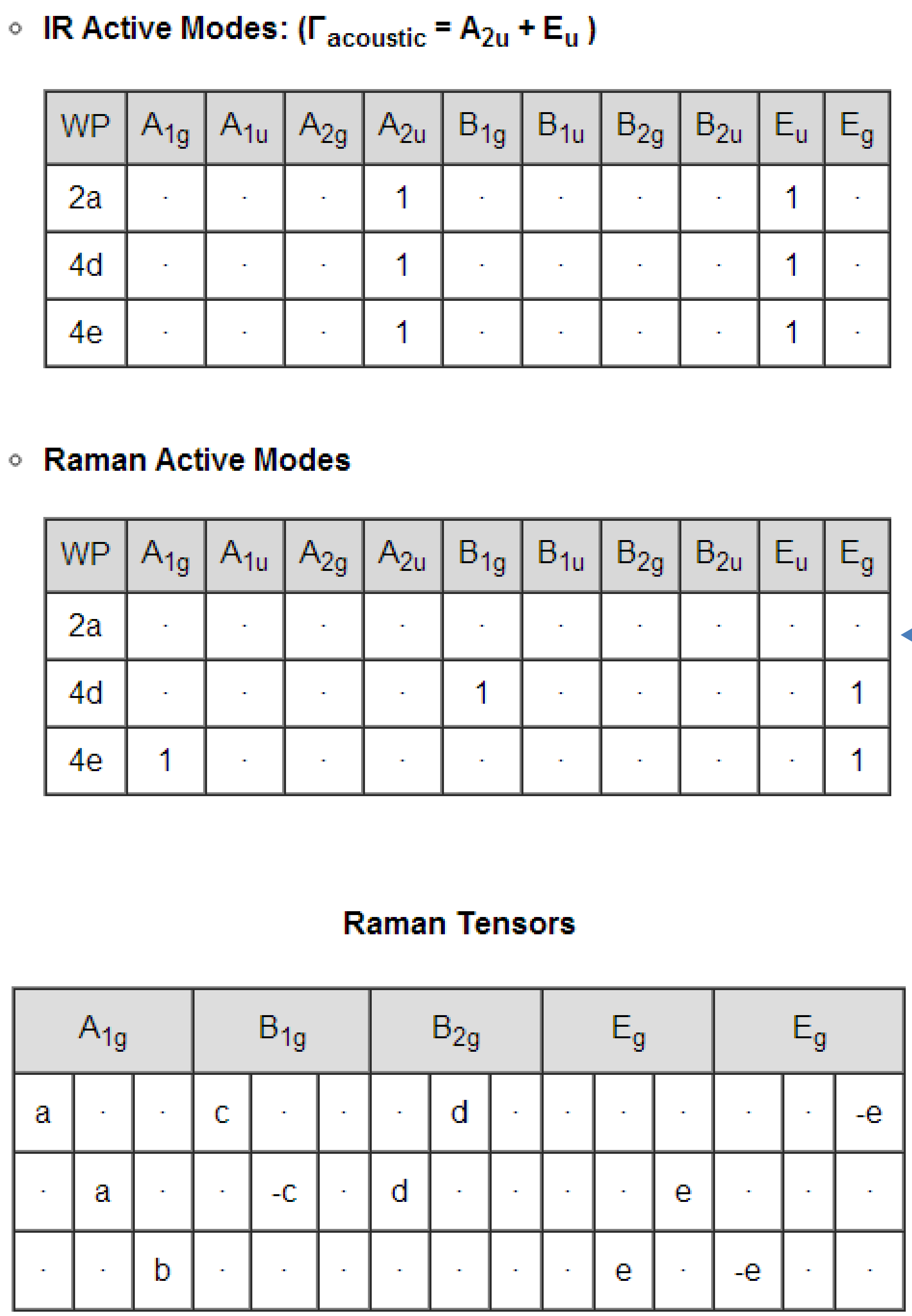
Choose the Wyckoff Positions of the atoms in your structure for the space group *I4/mmm* (No. 139)

Check	WP	Representative
☐	32o	x,y,z
☐	16n	0,y,z
☐	16m	x,x,z
☐	16l	x,y,0
☐	16k	x,x+1/2,1/4
☐	8j	x,1/2,0
☐	8i	x,0,0
☐	8h	x,x,0
☐	8g	0,1/2,z
☐	8f	1/4,1/4,1/4
☑	4e	0,0,z
☑	4d	0,1/2,1/4
☐	4c	0,1/2,0
☐	2b	0,0,1/2
☑	2a	0,0,0



Character Table[1]

D_{4h}(4/mmm)	#	1	2	4	2_h	$2_{h'}$	-1	m_z	-4	m_v	m_d	functions
Mult.	-	1	1	2	2	2	1	1	2	2	2	.
A_{1g}	Γ_1^+	1	1	1	1	1	1	1	1	1	1	x^2+y^2,z^2
A_{2g}	Γ_2^+	1	1	1	-1	-1	1	1	1	-1	-1	J_z
B_{1g}	Γ_3^+	1	1	-1	1	-1	1	1	-1	1	-1	x^2-y^2
B_{2g}	Γ_4^+	1	1	-1	-1	1	1	1	-1	-1	1	xy
E_g	Γ_5^+	2	-2	0	0	0	2	-2	0	0	0	$(xz,yz),(J_x,J_y)$
A_{1u}	Γ_1^-	1	1	1	1	1	-1	-1	-1	-1	-1	.
A_{2u}	Γ_2^-	1	1	1	-1	-1	-1	-1	-1	1	1	z
B_{1u}	Γ_3^-	1	1	-1	1	-1	-1	-1	1	-1	1	.
B_{2u}	Γ_4^-	1	1	-1	-1	1	-1	-1	1	1	-1	.
E_u	Γ_5^-	2	-2	0	0	0	-2	2	0	0	0	(x,y)



- **IR Active Modes: ($\Gamma_{acoustic} = A_{2u} + E_u$)**

WP	A_{1g}	A_{1u}	A_{2g}	A_{2u}	B_{1g}	B_{1u}	B_{2g}	B_{2u}	E_u	E_g
2a	·	·	·	1	·	·	·	·	1	·
4d	·	·	·	1	·	·	·	·	1	·
4e	·	·	·	1	·	·	·	·	1	·

IR optic

$2A_{2u} + 2E_u$

- **Raman Active Modes**

WP	A_{1g}	A_{1u}	A_{2g}	A_{2u}	B_{1g}	B_{1u}	B_{2g}	B_{2u}	E_u	E_g
2a	·	·	·	·	·	·	·	·	·	·
4d	·	·	·	·	1	·	·	·	·	1
4e	1	·	·	·	·	·	·	·	·	1

No Barium

Raman mode

Total Raman

$1A_{1g} + 1B_{1g} + 2E_g$

Raman Tensors

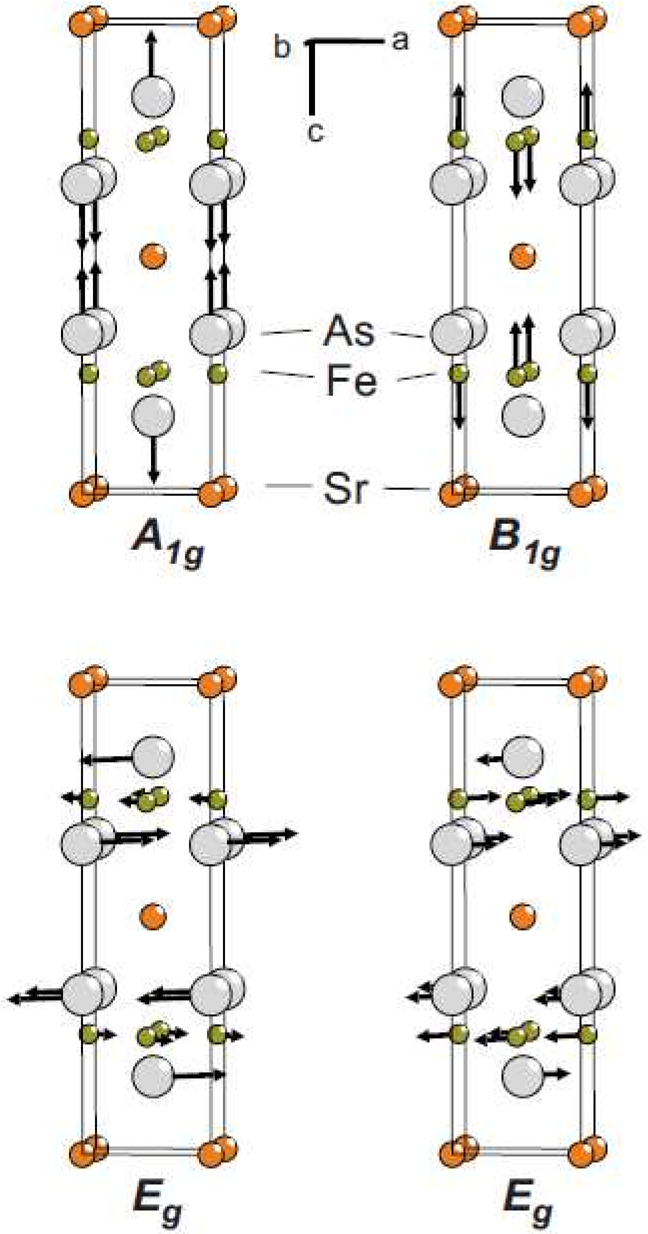
A_{1g}			B_{1g}			B_{2g}			E_g			E_g		
a	·	·	c	·	·	·	d	·	·	·	·	·	·	-e
·	a	·	·	-c	·	d	·	·	·	·	e	·	·	·
·	·	b	·	·	·	·	·	·	·	e	·	-e	·	·

Irrep: A_{1g}

M	4e	A_{1g}
X_1	(0,0,z)	·
Y_1		·
Z_1		-1
X_2	(0,0,-z)	·
Y_2		·
Z_2		1

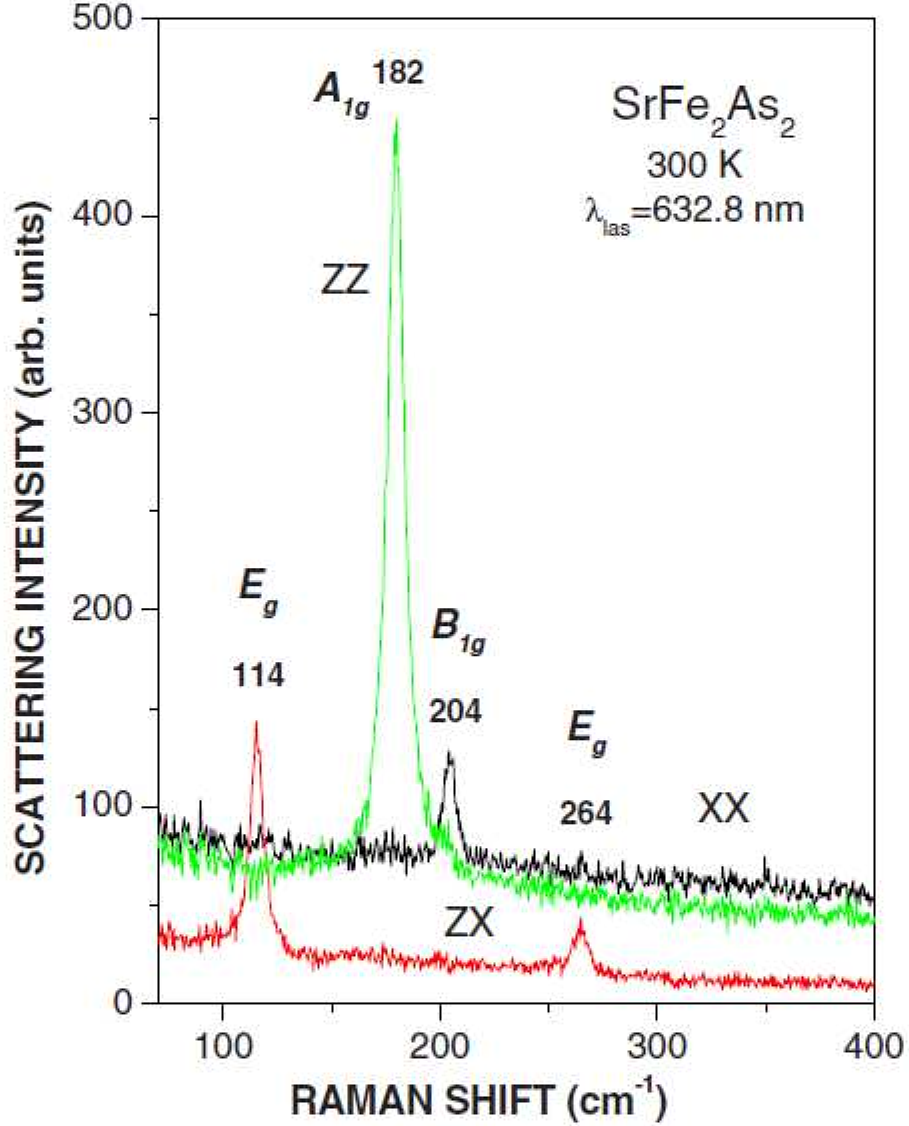
Irrep: A_{2u}

M	4e	A_{2u}
X_1	(0,0,z)	·
Y_1		·
Z_1		1
X_2	(0,0,-z)	·
Y_2		·
Z_2		1



Selection Rules

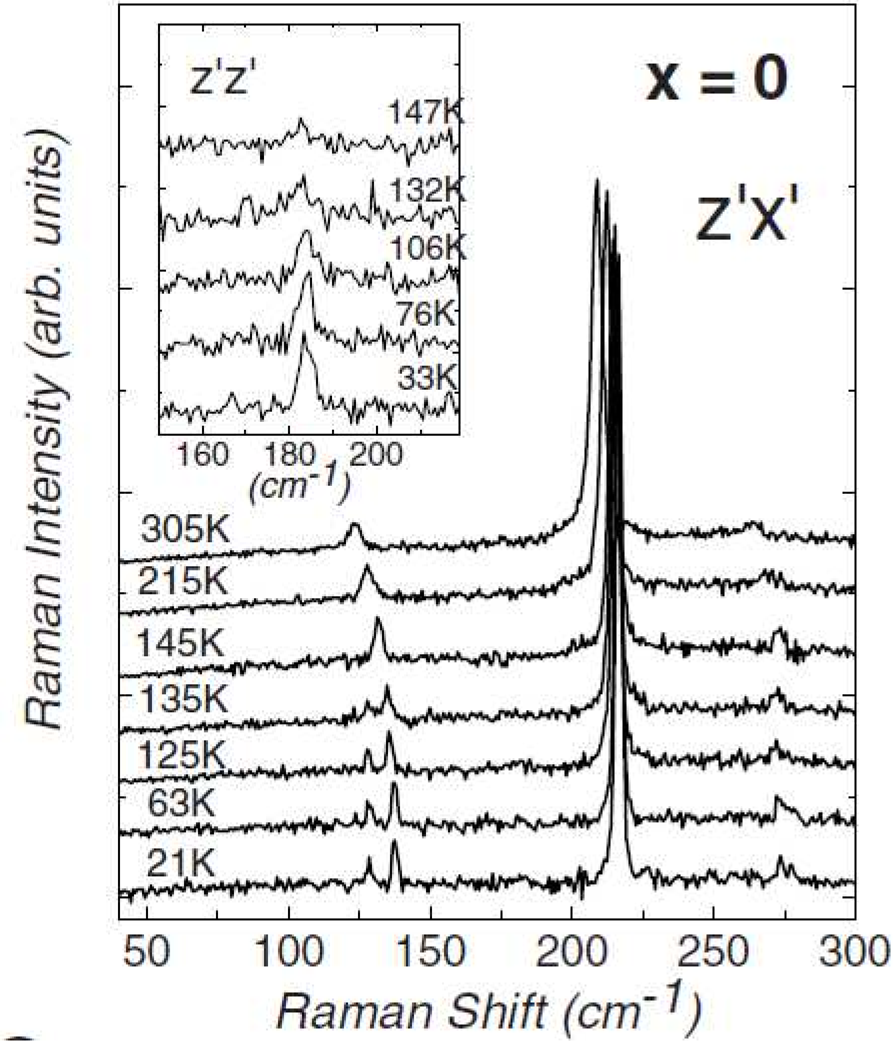
Polarisations des photons incidents et diffusés



B_{1g}

$$\overset{e_S}{\begin{pmatrix}0\\0\\1\end{pmatrix}}\begin{bmatrix}c&0&0\\0&-c&0\\0&0&0\end{bmatrix}\overset{e_I}{\begin{pmatrix}0\\0\\1\end{pmatrix}}=0$$

$$\overset{e_S}{\begin{pmatrix}1\\0\\0\end{pmatrix}}\begin{bmatrix}c&0&0\\0&-c&0\\0&0&0\end{bmatrix}\overset{e_I}{\begin{pmatrix}1\\0\\0\end{pmatrix}}=2c$$



Eg mode splitting ⇒ structural phase transition

PHYSICAL REVIEW B VOLUME 8, NUMBER 6 15 SEPTEMBER 1973

Resonant First- and Second-Order Raman Scattering in GaP

B. A. Weinstein* and Manuel Cardona
Max-Planck-Institut für Festkörperforschung, Stuttgart, Bundesrepublik Deutschland

(Received 30 March 1973)

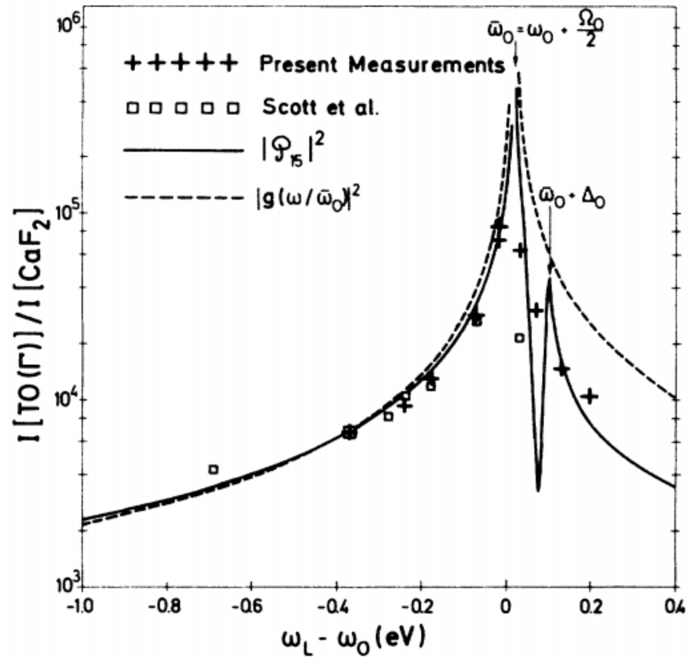
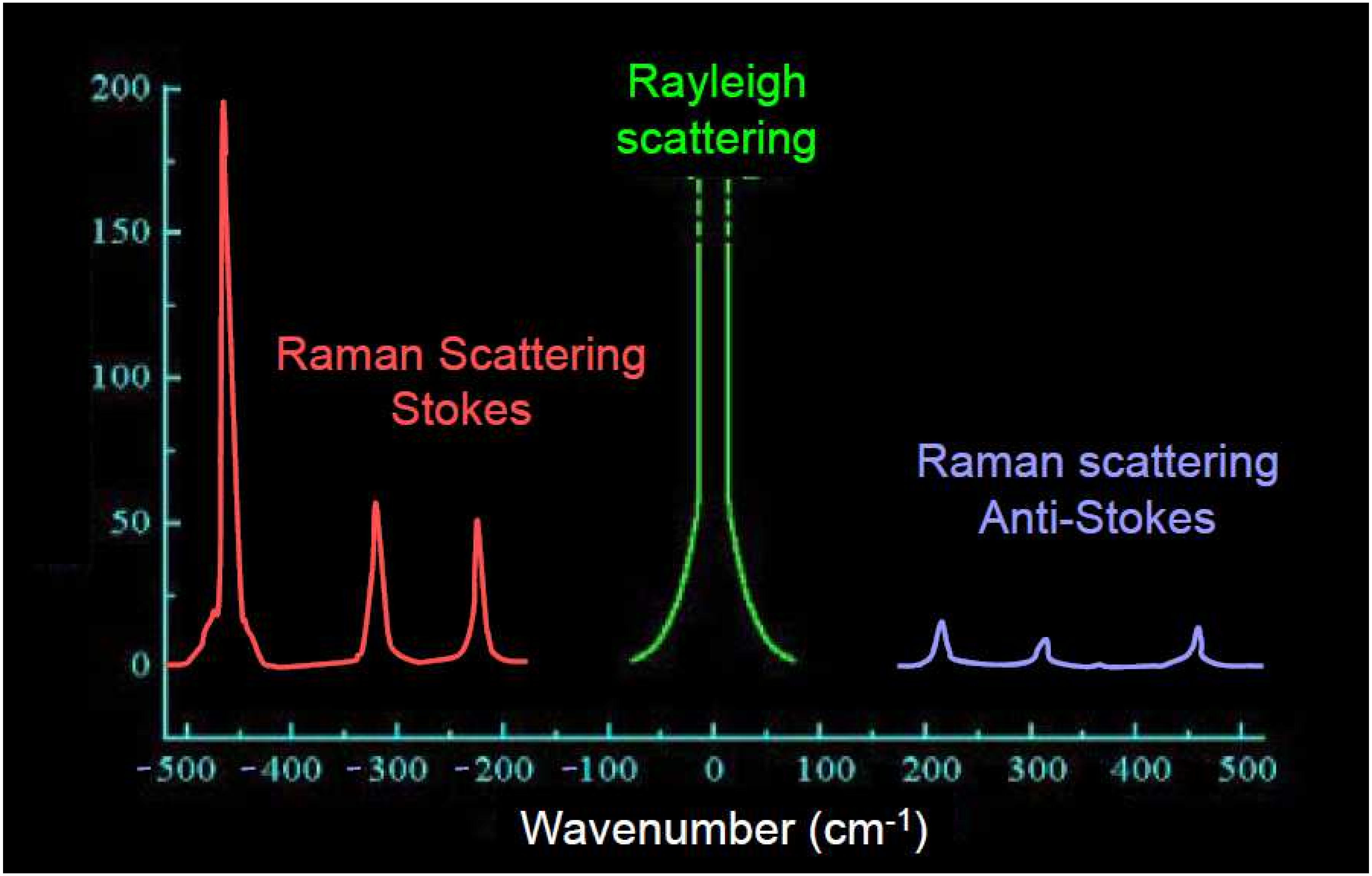


FIG. 3. Raman cross section as a function of incident photon energy for the first-order allowed TO (Γ) phonon. The room-temperature E_0 gap is the zero of the horizontal scale. The data of Ref. 12 (squares) have been adjusted to correspond to our data (crosses) at $\omega_L - \omega_0 = -0.367$ eV. The functions $\mathcal{P}_{15}$ [Eq. (7)] and g [Eq. (8)] have also been adjusted to fit the same data points with a multiplicative constant. As explained in the text, the data have been corrected for absorption, spectrometer response, statistical factors, etc.


Rayleigh
scattering
Raman Scattering
Stokes
Raman scattering
Anti-Stokes
200
150
100
50
0
-500
-400
-300
-200
-100
0
100
200
300
400
500
Wavenumber (cm-1)