Acousto Optic Phenomena: Raman Nath Effect: potential for phase detection and correction:

Consider a medium with a refractive index profile:

$$\Delta n(x,t) = \Delta n \, \mathrm{Cos}\,(Qx + \Omega t)$$

and let it be illuminated by a beam of light , traveling in the z- direction, having a corrugated wave front : $\delta\varphi(x,t)$.

Then the total phase of light is:

$$\varphi\,(x,t) = \Delta\varphi + \delta\varphi$$

with

$$\delta\varphi = \Delta\varphi \cos\,(Qx + \Omega t)$$

where, with $k = 2\pi/\lambda$, λ being the wave length of light

$$\Delta\varphi = k \, L \, \Delta n.$$

How to create such a profile?

Send sound (i.e. elastic wave) in the medium, i.e. a stress wave

$$\Delta p(x,t) = \Delta p \cos\,(Qx + \Omega t)$$

where $Q = 2\pi/\Lambda$ and $\Omega = S.\,Q$, Λ being the wave length of the sound wave and S being the velocity of sound in the medium.

The stress waves can be sent by a activating an ultrasonic transducer.

Ω is in the Mega Hertz range.

Such a system acts as a phase grating. Can it diffract the light?

Possibility first suggested by Brillouin, Debye and Sears.

Experimentally demonstrated by Raman and Nath. It was shown by them that the diffraction peaks occur at $v_x = \pm nQ$ and their intensities are $J_n^2(\Delta\varphi)$

Thus they proved that light could be diffracted by sound waves in media.

It is easy to see: $\Delta n = (\partial n/\partial p)_s \, \Delta p$

Incident light :

$$E(x,t) = y_0\, E \cos (kx + \omega t + \delta\varphi(x,t)) + z_0\, E \cos (kx + \omega t + \delta\varphi(x,t))$$

Introduce a phase difference $\pi/2$ between them.

The waves then become:

$$E(x,t) = y_0\, E \cos (kx + \omega t + \delta\varphi(x,t)) + z_0\, E \sin (kx + \omega t + \delta\varphi(x,t))$$

Pass both through the same Raman Nath cell.

$$E(x,t) = y_0\, E \cos (kx + \omega t + \delta\varphi(x,t) + \Delta\varphi(x,t)) + z_0\, E \sin (kx + \omega t + \delta\varphi(x,t) + \Delta\varphi(x,t))$$

Let the waves now interfere in the screen. The intensity at $v_x = k\, X/\sqrt{(X^2 + Z^2)}$ on the screen is given by:

For the y_0 wave:

$I(v_x) = F_0 + F_1 \cos \psi_{12}(t) + F_2 \sin \psi_{12}(t)$

Where

$F_0 = J_0^2(\Delta\varphi)\int \cos(v_x x + \chi(x))\,dx + 2\,\Sigma\, J_n^2(\Delta\varphi) \int \cos(nQx + v_x x + \chi(x))\,dx$

$F_1 = 2\Sigma \int J_{2n}(2\Delta\varphi \sin(Qx/2)) \cos(v_x x + \chi(x))\,dx \;\; [\cos(2n\Omega t)]$

$F_2 = -\; 2\Sigma \int J_{2n+1}(2\Delta\varphi \sin(Qx/2)) \sin(v_x x + \chi(x))\,dx \;\; [\sin((2n+1)\Omega t)]$

$\chi(x) = \delta\varphi(x_1) - \delta\varphi(x_2)$

$x = x_1 - x_2$

The time independent term, i.e. the F_0 term is the Raman Nath term.

2.For the z_0 wave:

$I(v_x) = F_0 + F_3 + F_4$

With
$F_3 = 2\Sigma \int J_{2n+1}(2\Delta\varphi \sin(Qx/2)) \cos(v_x x + \chi(x))\,dx \;\; [\sin((2n+1)\Omega t)]$

$F_4 = F_1 = 2\Sigma \int J_{2n}(2\Delta\varphi \sin(Qx/2)) \sin(v_x x + \chi(x))\,dx \;\; [\cos(2n\Omega t)]$

Need phase sensitive spectrum analyzer detecting the $[\sin((2n+1)\Omega t)]$, $[\cos(2n\Omega t)]$ modes of oscillation of the light intensity in the y_0 and the z_0 modes of polarization of the two beams giving

$\int J_{2n+1}(2\Delta\varphi \sin(Qx/2)) \sin(v_x x + \chi(x))\,dx$

$\int J_{2n}(2\Delta\varphi \sin(Qx/2)) \cos(v_x x + \chi(x))\,dx$

$\int J_{2n+1}(2\Delta\varphi \sin(Qx/2)) \cos(v_x x + \chi(x))\,dx$
$\int J_{2n}(2\Delta\varphi \sin(Qx/2)) \sin(v_x x + \chi(x))\,dx$

Put $v_x = 0$, it is easy to see that we are getting the Fourier transforms of the phase terms, without computation but by phase sensitive detection alone.

TIME IS SAVED.

IND EFFECTIVE INVERSION ALGORITHMS

What if we did not have the sound wave?

Intensity would have been given by the F_0 term, which has:

$$\int \cos \chi(x) \cos (v_x x)\, dx - \int \sin\chi(x) \sin(v_x x)\, dx$$

No way to separate the two.

Here the experiment does it

Computational schemes have much better chance of success and faster.

How many channels do you need for phase correction?

For atmospheric seeing, it should be $(R/r_0)^2$ channels.

As first experiment, use rough surfaces, characterized by electron microscopy or tunneling microscopy as test objects whose surface profiles are to be recovered and matched with the electron microscopy and tunneling microscopy results.

Raman Nath experiment with phase sensitive detection can be set up in Hosakote Campus. Characterization of test surfaces , to develop the method can be done elsewhere.

Raman Nath are two different people.

Raman Nath Effect has no connection with ANY Ramanath, living or non living.