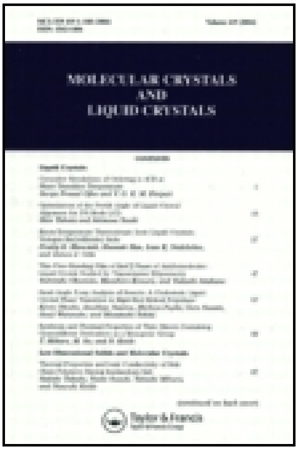

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Probe Beam Amplification Via Two and Four Wave Mixing in a Kerr-Like (Liquid Crystal) Medium

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PROBE BEAM AMPLIFICATION VIA TWO AND FOUR WAVE MIXING IN A KERR-LIKE (LIQUID CRYSTAL) MEDIUM

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Abstract

Probe beam amplification in a Kerr-like medium, e.g. a nematic liquid crystal film via 2-wave mixing is possible if it is stoke shifted relative to the pump beam. We report experiment observation of this effect and contribution from other multi-wave mixing effects.

Introduction

Two wave mixings, which were observed as early as the 60's by several workers, have received considerable renewed interests recently. In particular, for photorefractive materials where the medium responses are nonlocal (i.e. the refractive index grating is shifted relative to the intensity grating formed by the two incident light), these weak beam amplification effects have led to several interesting applications. For Kerr-like medium, i.e. where there is no phase shift between these two gratings, the gain of the weak beam via two wave mixing process can be achieved if a small frequency shift is imparted on the weak beam relative to the strong pump beam. As analyzed by Yeh[1] recently, for a Kerr medium, the complex phase shift imparted on the refractive index grating is related to the frequency shift Ω by

$$\phi = -\tan^{-1} \Omega\tau \qquad (1)$$

where τ is the relaxation time of the medium. The frequency shift ϕ appears in the coupled wave equations for the amplitudes A_1 and A_2 of two laser beams in a typical pump probe experiment set up.

$$\frac{\partial A_1}{\partial z} = \frac{-i\omega^2 n_o n_2 e^{-ix}}{2k\ c^2} \left| A_2 \right|^2 A_1 \qquad (2)$$

$$\frac{\partial A_2}{\partial z} = \frac{-i\omega^2 n_o n_2 e^{-i\phi}}{2kc^2} \left| A_1 \right|^2 A_2 \qquad (3)$$

where z is the direction of propagation of the wave, k is the propagation constant along z, ω is the frequency of the light, n_o is refractive index of the medium in the absence of optical field interactions, and n_2 is the nonlinearity coefficient. An exact solution of equation (2) and (3) shows that for $\phi=0$, no gain or loss mechanism is possible.

In our experiment, the strong and a much weaker probe beams are derived from a linearly polarized A_r^+ laser (5145 Å line). The liquid crystal used is a hometropically aligned PCB (Pentyl-cyano-biphenyl) nematic film of 200μm thick. The lasers propagate at an angle β relative to the nematic axis. The film is maintained at room temperature (22°C). The crossing angle between the two lasers are varied from about 1/300 to 10^{-2} radians. Frequency shifting of the probe beam is achieved by translating a mirror that directs the beam to the sample at a rate of one optical wavelength/sec^2.

Figures 1a-c summarize some of the experimental results, obtained for a pump to probe beam ratio of about 200:1. The laser beam size is about 3mm^2, and the pump power is about 35mWatt.

At a crossing angle of 0.007 radian, for example, one notes that the probe beam experiences no gain (circle). When the probe frequency is downshifted, there is a gain (triangle). On the other hand, if the probe beam is frequency upshifted, it experiences a loss (square). A measurement of the probe gain at this crossing angle also shows that the gain is an increasing function of the pump: probe beam ratio m, reaching a "saturated" value at m≈100.

What is interesting about figures 1b is that at smaller crossing angle, the probe beam experiences a large gain even without the frequency shift. We attribute this gain as arising from four wave mixing process involving the scattering of the pump beam (into the probe beam direction) from a grating formed by the pump beam with the diffracted beam on the side of the pump beam. Our experimental result shows that imparting a negative frequency shift to the probe further enhances this gain while a positive frequency shift causes loss.

The overall dependence of the gain on the wave mixing angle is also consistent with our earlier theory and observation that increasing the wave mixing angle, i.e. smaller grating constant, will diminish the molecular reorientational response[3]. This is due to the fact that molecules situated at the intensity minima will create torques on molecules at the intensity maxima that reorient with respect to the field. Maximal response is obtained for grating constant on the order of, or larger than the nematic film thickness.

A complete detailed account of the theory and experiments will be presented in a longer article elsewhere.

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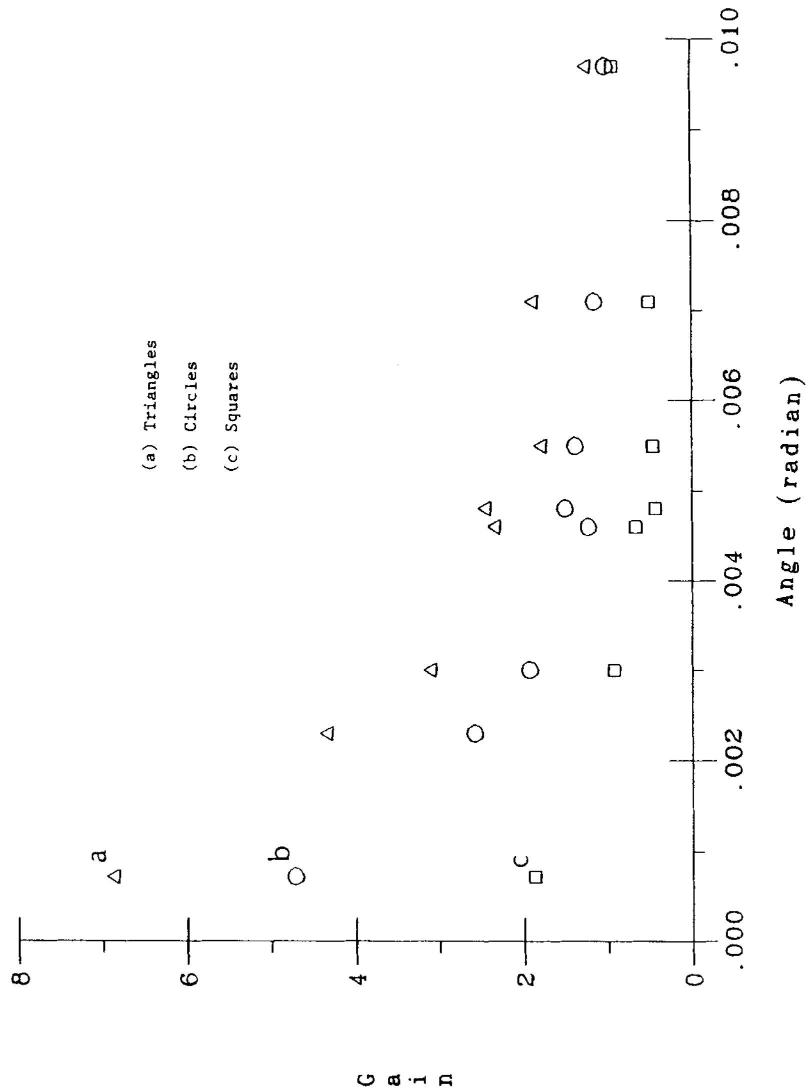
Figures

Figure 1a Triangles: observed probe beam gain as a function of the wave mixing angle when frequency downshifted.

Figure 1b Same as 1a, but no frequency shift.

Figure 1c With positive probe beam frequency shift.


Gain
Angle (radian)
(a) Triangles
(b) Circles
(c) Squares
a
b
c
0
2
4
6
8
.000
.002
.004
.006
.008
.010