科技资料

Nonlinear Optics

PROCEEDINGS
SPIE—The International Society for Optical Engineering

Nonlinear Optics

Robert A. Fisher
John F. Reintjes
Chairs/Editors

18–19 January 1990
Los Angeles, California

Sponsored by
SPIE—The International Society for Optical Engineering

Published by
SPIE—The International Society for Optical Engineering
P.O. Box 10, Bellingham, Washington 98227-0010 USA
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Volume 1220

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Please use the following format to cite material from this book:
Author(s), "Title of Paper," *Nonlinear Optics*, Robert A. Fisher, John F. Reintjes, Editors, Proc. SPIE 1220, page numbers (1990).

Library of Congress Catalog Card No. 90-60159
ISBN 0-8194-0261-3

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INTRODUCTION

This two-day conference dealt with recent advances in the field of nonlinear optics. Several papers were given that described the growth and properties of new materials for nonlinear optical frequency conversion. Experimental papers describing the use of various materials for UV harmonic generation and parametric conversion were also given. Several aspects of phase conjugation, including applications to pointing and beam combining, effects of acoustic streaming, and the extension of optical techniques to the microwave regime were discussed. Recent results involving the use of stimulated Raman scattering for frequency conversion of rare gas halide excimer lasers were presented, and a discussion of beam quality degradation effects in stimulated Raman scattering of broadband radiation was also given. Noise characteristics in nonlinear optical systems and in saturable optical amplifiers were described, as were several aspects of photorefractive materials and their applications. Applications of photorefractive effects for beam combining and optical switching were also presented. Several other papers describing the properties of various photorefractive materials were not presented at the conference but are contained in this proceedings.

We especially thank the session chairs and the program committee for their help in assembling a most interesting and informative conference.

Robert A. Fisher
RA Fisher Associates

John F. Reintjes
Naval Research Laboratory

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SESSION 1

Chair
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Invited Paper

Properties and Applications of Photorefractive GaAs

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(Invited Paper)

ABSTRACT

Photorefractive semiconductors have the attractive features of fast response times and operation at near infrared wavelengths. This has opened some new research opportunities in the field of photorefractive nonlinear optics which is significant for applications in real-time image processing and optical computing. This paper presents recent experimental demonstrations of several basic optical information processing techniques using photorefractive GaAs crystals. The results of these demonstrations illustrate that photorefractive compound semiconductors has a great potential as a new medium for light beam interaction based on the dynamic holographic principle.

1. INTRODUCTION

Compound semiconductors, such as gallium arsenide (GaAs)[1,2], indium phosphide (InP)[1], and cadmium telluride (CdTe)[3] have been shown to exhibit photorefractive effect. Their photorefractive properties such as operation speed and wavelengths are quite different from those of conventional photorefractive oxides such as barium titanate, bismuth silicon oxide (BSO), and strontium barium niobate (SBN). Consequently, these materials have created some new research opportunities in the area of photorefractive nonlinear optics which are potentially useful for applications in real-time optical information processing.

In this paper, recent experimental demonstrations of several image processing and optical computing applications using liquid-encapsulated Czochralski (LEC)-grown, undoped, semi-insulating GaAs will be presented. However, the demonstrated application feasibility should extend to other compound semiconductors.

The figures of merit of compound semiconductors are known to be similar to those of conventional photorefractive oxides such as barium titanate, bismuth silicon oxide (BSO), and strontium barium niobate (SBN)[1]. The high carrier mobilities in photorefractive compound semiconductors provide these materials with a distinguishable advantage in the information processing speed, typically two to three orders of magnitude faster. Because of smaller energy band gaps in these materials, their operation wavelengths are in the near infrared range. Consequently, these materials are compatible with semiconductor lasers and diode-pumped Nd:YAG lasers. This is potentially valuable for making compact image processing systems and integrating them with optoelectronic components. High-quality and large-size photorefractive oxide crystals are difficult and expensive to make. On the other hand, because of the maturity in the semiconductor technology, some of the compound semiconductor crystals such as GaAs and InP are readily available in large-size and high-quality. The optical isotropy and the cubic symmetry group nature of the electro-optic coefficients of compound semiconductor crystals allow the polarization of the diffracted light to be rotated perpendicular to that of the read beam[4-6]. This can be used as a convenient method for separating the diffracted beam from background noises and also lead to other innovative applications. Photorefractive oxide materials usually have relatively long storage times. The life time of a volume hologram written in compound semiconductors are relatively short, typically on the order of seconds or shorter, mainly because of their small energy band gaps. However, these materials are still potentially useful as dynamic memory elements.

There are two generic configurations for optical information processing using the photorefractive effect, namely, two-beam coupling (or two-wave mixing) and four-wave mixing.

In the two-beam coupling configurations, two coherent beams intersect in a crystal and create an index grating via photorefractive effect. In general, the interference pattern of these beams and the induced index grating are 90 degrees out of phase. This leads to an unsymmetrical diffraction of the incident beams by this index grating and results in a net intensity transfer from one beam to another. If the intensity gain of one beam is larger than the absorption in the material, the intensity of this beam is amplified. This effect, initially observed in photorefractive $LiNbO_3$ crystals by Staebler and Amodei[7], can be used for amplifying the intensity of an information-bearing optical beam as initially demonstrated by Kukhtarev et. al[8] in $LiNbO_3$. Two-beam coupling together with the polarization switching property of GaAs crystals can also be used to implement spatial light modulation as recently demonstrated by Cheng et al[9].

In the four-wave mixing configurations, two coherent beams write an index grating and a third beam (which does not necessarily have the same wavelength as the write beams) reads the grating, creating a fourth (i.e. output) beam by diffraction. The four-wave mixing configuration is more useful and versatile. A number of basic optical information processing operations including phase conjugate imaging[10], correlation[11] and convolution, and matrix-vector multiplication[12], to name a few, have been demonstrated using GaAs in the degenerate four-wave mixing configuration. The crystals can be used in both the reflection and transmission modes, depending on the beam geometry and the crystal orientations. In general, the transmission mode has a faster response time but a smaller diffraction efficiency, whereas the reflection mode has a slower response time but a larger diffraction efficiency. This is because these two modes have different grating spacing ranges and the response time and the diffraction efficiency decreases as the grating spacing becomes larger.

2. PHOTOREFRACTIVE PROPERTIES OF GaAs

The mid-gap level in LEC-grown, undoped, semi-insulating GaAs, responsible for the photorefractive effect is known to be the EL-2 level, an arsenic anti-sit defect. This particular type of defect is also known to be responsible for compensating the residual electrical activity and making undoped crystals semi-insulating. The EL-2 level is located about 0.75 eV below the conduction band. Typical density of the defect in undoped, semi-insulating GaAs crystals currently

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available is on the order of 10^{16} cm^{-3}, among which only about 10^{15} cm^{-3} are in the empty state and act as acceptors. The electron mobility in photorefractive GaAs is typically about 5000 cm^2/sec-V, which is about four orders of magnitude larger than those of photorefractive oxides.

The response time of a photorefractive material is the time required for writing an index grating in this material. It depends on the beam intensities, grating periodicity, as well as material properties such as carrier mobility, donor concentration, photoionization cross section of the donor, and carrier capture rate of the acceptor. It has been reported that the response time in LEC-grown, undoped GaAs is about 1 millisecond[10] and 20 microseconds[2] under a total intensity of 0.1 and 4 W/cm^2, respectively. These values are, at least, about two orders of magnitude shorter than those of the oxides under the same intensities. The response time of GaAs can be in the picosecond time scale, if intense picosecond light pulses are used. For example, under a total intensity of $5x10^7$ W/cm^2, the response time of GaAs was reported to be 43 picoseconds[13]. However, the mechanism of this picosecond response photorefractive effect is different from the conventional photorefractive effect.

The volume holographic grating written in a photorefractive material has a finite lifetime. This lifetime determines the information storage time in the crystal. It is an important parameter for evaluating the information processing capability. For a given material, the read beam intensity and the grating periodicity are two parameters determining the lifetime. Recently, a beam coupling technique using a 1.15 micron He-Ne laser was employed to measure the grating lifetime in GaAs[9]. The largest lifetime measured is about 8 seconds under a read beam intensity of 0.7 mW/cm^2 with the grating periodicity being 0.63 microns. The measured value decreases to milliseconds as the read beam intensity and the grating periodicity increase to about 10 mW/cm^2 and 4 microns, respectively. In addition, the results suggest that lifetime is sensitive to residual imperfections in the crystal.

3. PHOTOREFRACTIVE GAIN AND PHASE-CONJUGATE REFLECTIVITY

The capability of obtaining a net photorefractive gain and a larger-than-unity phase conjugate reflectivity is critical in the evaluation of a new photorefractive material for optical information processing applications, because this not only allows the direct cascade of the processed optical signal from one operation to another, but also makes certain attractive operations such as self-pumped phase conjugation, double phase conjugation, and ring oscillation possible.

Recently, net two-beam coupling gain in GaAs[14-18] and InP[19-22] and larger-than-unity phase conjugate reflectivity[23,24] in GaAs were demonstrated. In particular, it is interesting to note that in Ref 22, a net photorefractive gain in InP was obtained even without the application of any electric field[22] and in Ref. 18 an extremely large two-beam coupling gain coefficient as high as 16 cm^{-1} was observed using the GaAs crystal and Franz-Keldysh electrorefractive effect with the moving grating technique. Furthermore, following the observations of net photorefractive gain in compound semiconductors, self-pumped phase conjugation in GaAs[25] and InP[26], and double phase conjugation[25] and ring resonantor[23,27] using GaAs have also been demonstrated later.

4. SPATIAL RESOLUTION OF GaAs FOUR-WAVE MIXING SYSTEMS

Four-wave mixing systems can resolve an image with a spatial resolution limited by the index grating periodicity which is a function of the wavelength and the incident angles. It has been demonstrated that degenerate four-wave mixing in a ruby crystal can produce phase conjugate images with a resolution better than 500 lines/mm using 0.514 microns laser light[28].

To investigate the spatial resolution of photorefractive GaAs optical processing systems, a vector-vector outer product and a nonlinear optical phase conjugation experiments were performed using Ronchi gratings as the input patterns. Figure 1 shows a sketch of the experimental setup used. The two input Ronchi gratings were placed in the probe beam and the pump beam 1, respectively, with their grating lines aligned perpendicular to each other. Then they were imaged by a lens on the crystal separately. A lens same as the one in pump beam 1 must also be placed in pump beam 2, because the pump beams must be phase conjugates of each other to ensure that the diffracted beam is the phase conjugate of the probe beam. To satisfy this condition, the two lenses in the pump beams must be placed two focal lengths apart from each other. In the crystal, the probe beam and the pump beam 1 can only write index gratings in the regions where the two input images overlap. As a result, the output of this setup is a two-dimensional rectangular dot array, namely the inner product of the input vectors. The experimental results (Figure 2) show that this setup could resolve the rectangular dot array clearly when a pair of 20 lp/mm Ronchi gratings were used. But it could not resolve the resultant dot array produced with a pair of 100 lp/mm Ronchi gratings. However, if the Ronchi grating in the pump beam 1 was removed, the line array picture of another Ronchi grating (namely the phase conjugate image of the input pattern in the probe beam) could be clearly seen. This is because the resolution in the inner-product experiment is limited by the lens imaging process involved in pump beam 1, while the resolution in the pure phase-conjugation experiment is limited by the grating spacing. In the latter, the limitation imposed by the lens imaging process is removed by the phase conjugate nature of the diffracted beam. When a 250 lp/mm Ronchi grating was used, the pure phase-conjugation setup also failed to resolve it.

In applications such as matrix-vector multiplication and demultiplexing summation of the dot intensities along each column or row is needed. This can be done by placing a cylindrical lens in the output beam about a focal length from the camera, as illustrated in Figure 1. Figure 3 shows an enlarged image of the summed result, revealing that resultant elements are reasonably uniform. Note that there are three duplicates of the summation pattern (dotted line) at the output instead of just one. These duplicates have arisen from the Fourier-transform operation on the periodic distribution of the column elements by the cylindrical lens. The input patterns used in this experiment were 20 lp/mm Ronchi gratings.

5. NON-DEGENERATE FOUR-WAVE MIXING CONFIGURATION

In the non-degenerate four-wave mixing configuration, one can write the information-bearing grating with one wavelength and read it with another. Figure 4 shows the schematic diagram of the experimental setup and the result of an image transfer operation using non-degenerate four-wave mixing in GaAs. The write beams and read beam were obtained from a 1.06 micron Nd:YAG laser and a 1.3 micron GaInAs/InP semiconductor laser, respectively. Due to a different Bragg angle condition, note that the read beam and the phase conjugate beam are not anti-parallel with write beam 1 and write beam 2, respectively, as they should be in the case of degenerate four-wave mixing. A potential use of non-degenerate four-wave mixing is that if the information-bearing index grating is to be preserved after the readout operation, one can read the grating with a longer wavelength that does not erase the grating.

6. MULTIPLE HOLOGRAMS IN PHOTOREFRACTIVE CRYSTALS

It is well-known that photorefractive crystals are volume holographic media. Because of the nature of volume (or thick) holograms, in principle, it is possible to read and write multiple volume holograms with slightly different orientations superimposed in the same photorefractive crystal without causing notable cross talk. Figure 5 shows the schematic diagram and results of a multiple hologram writing and reading experiment. The "common" write beam generates a hologram with each of the image-bearing write beams. Each hologram carries a different spatial information and is superimposed on another in the crystal. The read beam is diffracted by each hologram separately. The output beams are then coupled out by a beam splitter and captured by a CCD camera. There was no significant cross talk observed between the two output images in the experiment.

7. PHASE CONJUGATE INTERFEROMETRY

A GaAs phase conjugate interferometer performing several basic computing operations has been demonstrated. The operations included image subtraction, coherent and incoherent image addition, image inversion, OR and exclusive OR (XOR) logic operations. In addition, the time characteristics of this interferometer was measured, indicating that there is a great potential of using photorefractive GaAs for high-speed and high-resolution novelty detection and target tracking applications[29]. The GaAs phase conjugate interferometer not only has a high operation speed, but also makes the system immune to low frequency vibration and fluctuation. The latter is due to the fact that the light-induced grating can follow the variation induced by low frequency fluctuation. However, this phenomenon does not necessarily restrict the detection of slowly changing or moving objects when the interferometer is used as a novelty filter.

Figure 6 gives a sketch of the configuration used for the experiment. A 1.06 micron light beam from a Nd:YAG laser entering from the left of the figure is split into two beams at a beam splitter (BS). Both reflected and transmitted beams from BS, S1 and S2, are incident onto a GaAs crystal after passing through different optical paths and transparencies. Each probe beam (S1 or S2) creates an index grating with a coherent pump beam (PB1). Each grating has a slightly different orientation with respect to each other. Another pump beam (PB2), also from the same YAG laser, travels against the direction of PB1 and enters the crystal from the opposite surface. Parts of this beam are diffracted at the two gratings, forming two phase conjugate beams, PC1 and PC2, which travel against S1 and S2, respectively. Then, these two beams combine at BS and form an output beam which is imaged on a CCD camera or an infrared vidicon camera. The output image is the interference pattern of PC1 and PC2 and its appearance can be influenced by the alignment of S1, S2, PB1 or PB2 in a way similar to that observed in BSO[30]. In this study, we observed that, when two pump beams are well-aligned and are perfect phase conjugates of each other, the output image is always a destructive interference pattern of PC1 and PC2 and is insensitive to slight alignment change of S1 or S2. However, a small vertical adjustment in the alignment of PB2 can change the output from a completely destructive pattern to a completely constructive pattern. Further vertical adjustment can produce alternating destructive and constructive patterns. When the two pump beams are not perfect phase conjugates of each other, slight adjustment of S1 or S2 can produce alternating constructive and destructive interference patterns.

According to the work of Vainos, et. al.[30], the output intensity can be written as

$$I_{out} \approx T_1^2 + T_2^2 + 2T_1T_2\cos(\pi + \Delta\phi), \qquad (1)$$

where T_1 and T_2 are the intensity transmission coefficients for transparencies T1 and T2, and $\Delta\phi$ is the phase difference between the phase conjugate beams at BS. For true phase conjugation and a lossless beam splitter, $\Delta\phi = 0$ and then image subtraction $(T_1 - T_2)^2$ is observed. If one transparency is removed under this condition, the inverse of the image on the other transparency is achieved. By slightly adjusting the alignment of one input beam, e.g. S1, $\Delta\phi$ changes because the corresponding phase conjugate beam may be slightly off from true phase conjugation. Consequently, other operations become possible. For examples; when $\Delta\phi = \pi$, coherent addition, i.e. $I_{out} \propto (T_1 + T_2)^2$ is obtained; when $\Delta\phi = \pi/2$, incoherent addition, i.e. $I_{out} \propto (T_1^2 + T_2^2)$, is observed; and when $\Delta\phi = 2\pi/3$, logic OR operation, i.e. $I_{out} \propto (T_1^2 + T_2^2 - T_1T_2)$, can be obtained. Figure 7 gives a set of photographs and intensity scans for all the above-stated operations obtained experimentally. The different operations were achieved by vertical adjustment of the alignment of PB2 as illustrated in the sketch of the experimental setup. It was observed that the system is always stable in spite of the operation type. The result shows there is a potential of developing a fast and versatile GaAs-based optical processor capable of performing any of the above-mentioned operations.

The temporal response of this GaAs phase conjugate interferometer is interesting. If the length of an optical path of one beam, say S1, is suddenly changed and the grating formation is faster than the path length alteration, there is no observable change in the resultant interference pattern. On the other hand, if the grating formation is slower than the path length change, the two phase conjugate beams are temporarily out of their original phase relationship and a transient signal appears. This transient signal can be either positive or negative depending on the original output pattern, destructive or constructive, respectively. The rise time of the signal is equal to the time of path length change and the decay time is roughly equal to the grating formation time in the material. This phenomenon can be used for optical novelty filtering as demonstrated by Anderson and co-workers[31] using $BaTiO_3$.

An experiment was performed to examine time dependence of the signal induced due to a rapid optical path change. A mirror in the interferometer (see Figure 6) was mounted on a piezoelectric transducer by which the mirror position became controllable by an electrical voltage. In addition, the camera was replaced by a

Ge photodetector. Figure 8 shows time scan curves of the signal from the photodetector (upper curves) under two different mirror moving conditions due to the different time variation of the electrical voltage on the transducer (lower curves). The data in Figure 8A illustrate clearly that the resultant interference signal was not changed if the characteristic time of mirror motion is much longer than that of the grating formation time. This observation illustrates an advantage of using fast photorefractive materials, such as GaAs, for making a phase conjugate interferometer which is immune to low frequency vibration.

The data in Figure 8B illustrate the time characteristics of the interferometer when the mirror moves much faster than the formation time of the index grating. The sharp rise of the signal is due to the loss of the interferometer balance caused by the sudden change in one of the optical paths. The decay of the signal is due to the formation of a new index grating in response to the mirror movement. This observation is similar to that in $BaTiO_3$ reported by Anderson and co-workers[31]. However, the grating formation time in the GaAs sample is about 5 milliseconds, which is about two orders of magnitude faster than that in $BaTiO_3$. Because of the lack of beam intensity information of the $BaTiO_3$ experiment, a direct comparison in grating formation time of the two materials is not possible. Our comparison is consistent with that of Yeh[32] in which response times of several photorefractive materials are compared.

It is worthwhile to note that our experiment was carried out on an optical table without compressed air in its legs. The table was on a so-called "computer" floor which is not very rigid. An interferometer with ordinary mirrors on that table can not function well. We were able to obtain stable interference patterns, even when there were persons walking around the table during the experiment. These observations illustrate that the fast GaAs system has a high degree of immunity to the low frequency mechanical vibration and air turbulence. The material response time under the present experimental condition was measured to be about 5 milliseconds, consistent with this vibration immunity concept.

8. SUMMARY

We have reviewed the photorefractive properties of GaAs and some of their potential applications in the area of optical information processing and optical computing. These reviewed results should in general extend to describe the properties and applications of other photorefractive compound semiconductors. Due to their fast response times, photorefractive GaAs crystals are potentially useful for high-speed applications as well as dynamic memory media. Because of their near-infrared operation wavelengths, GaAs can be potentially integrated with other compact semiconductor-based devices such as semiconductor lasers, laser-diode pumped solid state lasers, and some optoelectronic components. This allows more compact optical information processing systems to be build with GaAs. The experimental demonstrations mentioned in this paper include spatial light modulation, phase conjugate imaging, optical correlation and convolution, high-resolution vector-vector inner product and matrix-vector multiplication, multiple-hologram phase conjugate imaging, non-degenerate image transfer, and optical logic operations and novelty detection based on phase-conjugate interferometer. Furthermore, a phase-conjugate imaging resolution better than

100 lp/mm has also been observed. All these demonstrations have been done successfully using GaAs without any applied electric field. Some nonlinear optical phenomena that require a high two-beam coupling gain or phase-conjugate reflectivity have also been demonstrated using GaAs and/or InP with applied electric field. These include self-pumped and double phase conjugations, and ring oscillation. The demonstrations mentioned in this paper indicate that there is a great potential of using GaAs crystals and other photorefractive compound semiconductors for real-time optical information processing applications.

9. ACKNOWLEDGEMENT

The authors wish to thank Drs. F.C. Wang and M.F. Rao for providing them with the GaAs crystals. The work described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, and was sponsored by the Defense Advanced Research Projects Agency and the Strategic Defense Initiative Organization/Innovative Science and Technology through an agreement with the National Aeronautics and Space Administration.

10. REFERENCES

1. A.M. Glass, A.M. Johnson, D.H. Olsen, W. Simpson, and A.A. Ballman, "Four-wave mixing in semi-sinsulating InP and GaAs using the photorefractive effect," Appl. Phys. Lett., 44, pp. 948-950 (1984).

2. M.B. Klein, "Beam coupling in undoped GaAs at 1.06 μm using the photorefractive effect," Opt. Lett., 9, pp. 350-352 (1984).

3. R.B. Bylsma, P.M. Bridenbaugh, D.H. Olson, and A.M. Glass, "Photorefractive properties of doped cadmium telluride," Appl. Phys. Lett. 51, pp. 889-891 (1987).

4. P. Yeh, "Photorefractive two-beam coupling in cubic crystals," J. Opt. Soc. Am. B, 4, p. 1382 (1987).

5. A. Partovi, E. Garmire, and L.J. Cheng, "Enhanced beam coupling modulation using the polarization properties of photorefractive GaAs," Appl. Phys. Lett. 51, pp. 299-301 (1987).

6. L.J. Cheng and P. Yeh, "Cross-polarization beam coupling in photorefractive GaAs crystals," Opt. Lett. , 13, pp. 50-52 (1988).

7. D.L. Staebler and J.J. Amodei, "Coupled-wave analysis of holographic storage in $LiNbO_3$," J. Appl. Phys. 43, pp. 1042-1049 (1971).

8. N.V. Kukhtarev, B. Markov, S.G. Odulov, M.S. Soskin and V.L. Vinetsskii, "Holographic storage in electrooptic crystals. I. steady state," Ferroelectrics 22, p. 949 (1979); "Holographic storage in electrooptic crystals. II. beam coupling-light amplification," 22, p. 961 (1979).

9. L.J. Cheng, G. Gheen, T.H. Chao, H.K. Liu, A. Partovi, J. Katz, and E. Garmire, "Spatial light modulation by beam coupling in GaAs crystals," Opt. Lett., 12, pp. 705-707 (1987). L.J. Cheng, G. Gheen, F.C. Wang, and M.F.

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