GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: May 1, 1980

Project Title: Photorefractive Effect and Volume Grating Diffraction in Electro-Optic Crystals

Project No: E-21-613

Project Director: Dr. Thomas K. Gaylord

Sponsor: National Science Foundation

Agreement Period: From March 1, 1980 Until August 31, 1982 (Grant Period)

Type Agreement: Grant No. ECS-7919592, dated April 17, 1980

Amount:
$50,000 NSF (E-21-613)
10,492 GIT (E-21-352)
$60,492 TOTAL

Reports Required: Annual Progress Report(s); Final Project Report

Sponsor Contact Person (s):

Technical Matters

NSF PROGRAM OFFICIAL

Elias Schutzman
Program Director for Electrical Optical Communications
Division of Electrical Computer and Systems Engineering
Directorate for Engineering and Applied Science
National Science Foundation
Washington, D. C. 20550
(202) 357-9618

Contractual Matters (thru OCA)

NSF GRANTS OFFICIAL

Hugh L. Lyon
AAEO/EAS Branch, Section II
Division of Grants and Contracts
Directorate for Administration
National Science Foundation
Washington, D. C. 20550
(202) 357-9602

Defense Priority Rating: N/A

Assigned to: Electrical Engineering (School/[redacted])

COPIES TO:

- Project Director
- Division Chief (EES)
- School/Laboratory Director
- Dean/Director—EES
- Accounting Office
- Procurement Office
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- Project Code (GTRI)
- Other C. E. Smith

OA 3/(2/76)

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION SHEET

Date 5/18/83

Project Title: Photorefractive Effect and Volume Grating Diffraction in Electro-Optic Crystals

Project No: E-21-613

Project Director: Dr. Thomas K. Gaylord

Sponsor: National Science Foundation

Effective Termination Date: 8/31/82

Clearance of Accounting Charges: 8/31/82

Grant/Contract Closeout Actions Remaining:

- [ ] Final Invoice and Closing Documents
- [x] Final Fiscal ~~Report~~ Acctg. (FCTR)
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other _____

Assigned to: Elect. Engr. (School/~~Laboratory~~)

COPIES TO:

Administrative Coordinator	Research Security Services	EES Public Relations (2)
Research Property Management	Reports Coordinator (OCA)	Computer Input
Accounting	Legal Services (OCA)	Project File
Procurement/EES Supply Services	Library	Other Gaylord

FORM OCA 10:781

E 21-612

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF ELECTRICAL ENGINEERING
ATLANTA, GEORGIA 30332

OPTICS LABORATORY
TELEPHONE: (404) 894-2931

July 14, 1981

Dr. Elias Schutzman
Electrical, Computers, and
Systems Engineering
National Science Foundation
Washington, DC 20550

Subject: Annual Progress Report for NSF Grant No. ECS-7919592, "Photorefractive Effect and Volume Grating Diffraction in Electro-Optic Crystals" (covering 1 March 1980 to 28 February 1981)

Dear Dr. Schutzman:

Significant progress has been made during the first year of the above research grant.

An investigation of realistic finite-volume gratings together with finite-extent laser beams has lead to a simplified analysis of this complicated diffraction problem. These results are reported in:

Moharam, M. G., Gaylord, T. K., and Magnusson, R., "Bragg diffraction of finite beams by thick gratings," Journal of the Optical Society of America, vol. 70, pp. 300-304, March 1980.

Moharam, M. G., Gaylord, T. K., and Magnusson, R., "Diffraction characteristics of three-dimensional crossed-beam volume gratings," Journal of the Optical Society of America, vol. 70, pp. 437-442, April 1980.

An evaluation of practical pages of binary data to be recorded and processed in optical storage and processing systems has lead us to an analysis of these data pages as stored volume holographically and then reconstructed. This analysis applies to arbitrarily-oriented (both in and out of the plane of incidence) reference beams. This work showed clearly for the first time that multi-port memories and multi-port data processing systems (using many reference beams) are possible. These results were reported in:

Gallagher, H. J., Gaylord, T. K., Moharam, M. G., and Guest, C. C., "Reconstruction of binary-data-page holograms for an arbitrarily-oriented reference beam," Applied Optics, vol. 20. pp. 300-306, January 15, 1981.

A new concept in two-dimensional signal and data processing was introduced during this time period. Combining digital processing and optical parallel processing, a potentially powerful processing structure was published. This system uses the content-addressable aspect of a holographic system to perform truth-table look-up computations in parallel. A highly efficient system is shown to result when the numerical operations are performed using a binary-coded residue number system. These results are reported in:

Guest, C. C. and Gaylord, T. K., "Truth-table look-up processors using binary and residue arithmetic," Applied Optics, vol. 19, pp. 1201-1207, April 1, 1980.

For the first time, a state variables approach from linear systems theory has been applied by us to solve the grating diffraction problem. This has been done rigorously and has resulted in a method of solution without approximations! With this very powerful and exact method of analysis, previously used approximations (neglect of second derivatives, neglect of higher-order waves, and neglect of boundary diffraction) have been evaluated for the first time! The resulting publications are anticipated to be cited by many future workers. The papers are:

Moharam, M. G. and Gaylord, T. K., "Rigorous coupled-wave analysis of planar grating diffraction," Journal of the Optical Society of America, vol. 71, pp. 811-818, July 1981.

Moharam, M. G. and Gaylord, T. K., "Coupled-wave analysis of reflection gratings," Applied Optics, vol. 20, pp. 240-244, January 15, 1981.

As a peripheral result of our research I have generated a graduate-level course in "Integrated Optics." Because of substantial student interest, this course is offered twice a year. Information about the course is contained in:

Gaylord, T. K., "A course in integrated optics," IEEE Transactions on Education, vol. E-23, pp. 62-65, May 1980.

We are continuing investigating the photorefractive effect and electro-optic volume gratings for applications to beam deflection, guidance, modulation, coupling, filtering, wavefront reconstruction, and distributed feedback in the fields of acousto-optics, integrated optics, holography, and spectrum analysis.

If additional information is needed, please contact us and we will supply it to you. Your support is deeply appreciated. Thank you.

Sincerely,

Thomas K. Gaylord
Professor

TKG/pm

Enclosures: Two copies each of all above cited papers.

GEORGIA INSTITUTE OF TECHNOLOGY
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ATLANTA, GEORGIA 30332

TELEPHONE: (404) 894- 2961

Febraury 16, 1983

National Science Foundation
Division of Grants and Contracts
Post-Award Projects Branch
1800 G Street, N. W.
Washington, D. C. 20550

Ref: NSF Award No. ECS-7919592, Final Project Report (98A)

Dear Sirs:

Attached is the Final Project Report by Dr. Thomas K. Gaylord, Principal Investigator, for the project entitled, "Photorefractive Effect and Volume Grating Diffraction in Electro-Optic Crystals."

If there are any questions, please contact us.

Thank you.

Sincerely,

Marsha Segraves
Admin. Asst.

cc: T. K. Gaylord

/ms

NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

FINAL PROJECT REPORT
NSF FORM 98A

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I–PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. NSF Program	3. NSF Award Number
Georgia Institute of Technology Atlanta, Georgia	Electrical & Optical Communications	ECS-7919592
	4. Award Period From 1 Mar 80 To 31 Aug 82	5. Cumulative Award Amount $50,000

6. Project Title
Photorefractive Effect and Volume Grating Diffraction in Electro-Optic Crystals

PART II–SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

The primary objective of this project was to be able to understand and to describe the diffraction of laser light by holographic gratings recorded in electro-optic crystals such as lithium niobate. As part of this project, a new and powerful method of grating analysis--rigorous coupled wave analysis--was originated and developed.

The rigorous coupled-wave theory allows the diffraction by gratings to be analyzed without approximations. This work has allowed, for the first time, simple and accurate grating diffraction calculations to be performed. These grating structures are widely used in laser beam deflection, guidance, modulation, coupling, filtering, wavefront reconstruction, and distributed feedback in the fields of acousto-optics, integrated optics, holography, quantum electronics, signal processing, and spectrum analysis. This theory has already been widely cited and used by other universities (University of Southern California, Telaviv University, Oxford University, etc.) and by industry (I.B.M., Bausch & Lomb, Perkin-Elmer, Bell Laboratories, etc.).

PART III–TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
				Check (✓)	Approx. Date
a. Abstracts of Theses	X				
b. Publication Citations		X			
c. Data on Scientific Collaborators			X		
d. Information on Inventions	X				
e. Technical Description of Project and Results			X		
f. Other *(specify)*					

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
Thomas K. Gaylord		14 Feb 83

NSF PUBLICATIONS (ECS-7919592)

Moharam, M. G., Gaylord, T. K., and Magnusson, R., "Bragg diffraction of finite beams by thick gratings," Journal of the Optical Society of America, vol. 70, pp. 300-304, March 1980.

Moharam, M. G., Gaylord, T. K., and Magnusson, R., "Diffraction characteristics of three-dimensional crossed-beam volume gratings," Journal of the Optical Society of America, vol. 70, pp. 437-442, April 1980.

Gallagher, H. J., Gaylord, T. K., Moharam, M. G., and Guest, C. C., "Reconstruction of binary-data-page holograms for an arbitrarily-oriented reference beam," Applied Optics, vol. 20, pp. 300-306, January 15, 1981.

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Moharam, M. G. and Gaylord, T. K., "Coupled-wave analysis of reflection gratings, Applied Optics, vol. 20, pp. 240-244, January 15, 1981.

Weaver, J. E. and Gaylord, T. K., "Evaluation experiments on holographic storage of binary data in electro-optic crystals," Optical Engineering, vol. 20, pp. 404-411, May/June 1981.

Gaylord, T. K. and Moharam, M. G., "Thin and thick gratings: terminology clarification," Applied Optics, vol. 20, pp. 3271-3273, October 1, 1981.

Gaylord, T. K. and Moharam, M. G., "Planar dielectric grating diffraction theories," Applied Physics B, vol. 28, pp. 1-14, 1982. (invited)

Moharam, M. G. and Gaylord, T. K., "Chain matrix analysis of arbitrary-thickness dielectric reflection gratings," Journal of the Optical Society of America, vol. 72, pp. 187-190, February 1982.