Unclassified

Security Classification

**DOCUMENT CONTROL DATA - R & D**

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

1. ORIGINATING ACTIVITY (Corporate author)
Division of Engineering and Applied Physics
Harvard University
Cambridge, Massachusetts

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE

STIMULATED RAMAN AND CONCENTRATION SCATTERING

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final Technical Report

5. AUTHOR(S) (First name, middle initial, last name)

N. Bloembergen

| 6. REPORT DATE | 7a. TOTAL NO. OF PAGES | 7b. NO. OF REFS |
|---|---|---|
| July 1971 | | 6 |

| 8a. CONTRACT OR GRANT NO. | 9a. ORI 'S REPORT NUMBER(S) |
|---|---|
| DAHC04-68-C-0037 | nal Technical Report |
| b. PROJECT NO. | |
| c. | 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) |
| d. | |

10. DISTRIBUTION STATEMENT
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| 11. SUPPLEMENTARY NOTES | 12. SPONSORING MILITARY ACTIVITY |
|---|---|
| | Advanced Research Projects Agency of the Department of Defense and the U.S. Army Research Office-Durham. |

13. ABSTRACT

The activities on stimulated raman and concentration scattering during the duration of the contract June 1968 - Jun~ 1971 are summarized. A list of publications, technical reports and personnel is given.

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0101-807-6811

Unclassified

Security Classification

A-31409

| KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Stimulated Brillouin Scattering | | | | | | |
| Stimulated Concentration Rayleigh Scattering | | | | | | |
| Binary Gas Mixture | | | | | | |

Office of Army Research

Contract DAHC04-68-C-0037

Duration of Contract: June 1968 - June 1971
Amount of Contract: $195,000

# STIMULATED RAMAN AND CONCENTRATION SCATTERING

Final Technical Report

Contractor: President and Fellows of Harvard College

Principal Investigator: N. Bloembergen, 617/495-3336

Project Scientist: H. Lowdermilk, 617/495-4466

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by the U. S. Army Research Office-Durham, Box CM, Duke Station, Durham, North Carolina 27706 under Contract No. DAHC04-68-C-0037.

July 1971

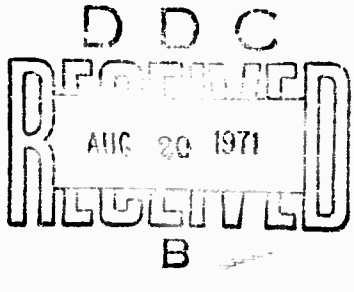


Division of Engineering and Applied Physics
Harvard University · Cambridge, Massachusetts

Sponsored by

Advanced Research Projects Agency

ARPA Order No. 675 Am 7
Program Code No. 9E20



# STIMULATED RAMAN AND CONCENTRATION SCATTERING

## A. Personnel:

During the period on this contract June 1968 - June 1971, the following scientific personnel has been associated with it,

Dr. N. Bloembergen, Gordon McKay Professor of Applied Physics,

Dr. C. S. Wang, Research Fellow,

Mr. W. H. Lowdermilk, Graduate Student.

Mr. Lowdermilk was granted the Ph.D. degree by Harvard University in June 1971. His Ph.D. thesis was based on the research supported by this contract.

## B. Statement of Problem Studied:

In the first year of this contract attention was mainly devoted to the stimulated raman scattering in heavy hydrogen gas $D_2$. The effect was observed and preliminary data were compared with previously published results on $H_2$. At the same time a theoretical study was made of transient raman scattering in collaboration with a project supported by the Joint Services Electronics Program. This theoretical investigation resulted in a publication in the Physical Review, listed below as reference 1.

Since stimulated raman gain in $D_2$ is considerable lower than in $H_2$ at the same pressure and temperature, considerable effort was spent on the construction of a cryostat, able to maintain a high-pressure $D_2$ cell at $77^{\circ}K$. At that time the focus of attention shifted to the

phenomenon of stimulated concentration scattering in gaseous mixtures. It was realized that the available equipment of a controlled ruby laser oscillator plus a ruby amplifier could be used advantageously to the concentration scattering problem. Since the atmosphere is a mixture of gases, a basic understanding of propagation characteristics of high power laser beams in gaseous mixtures was desirable.

The last two years of effort under this contract were therefore exclusively devoted to the study of stimulated concentration scattering. The theory of the effect was published in the Physical Review (reference 2) and was also incorporated as Appendix A in Technical Report No. 1, dated October 1970. What is believed to be the first unambiguous demonstration of stimulated concentration scattering was the change of frequency of the back scattered light in a mixture of $SF_6$ and He as a function of the partial He concentration. This result was published in Physical Review Letters (reference 3) and also appeared as Appendix B in Technical Report No. 1, dated October 1970.

During the final year of the contract detailed experimental results have been obtained in mixtures of He and $SF_6$ and mixtures of He and Xe. Furthermore a quantitative interpretation has been given in terms of machine computations based on theoretical formulae derived in reference 2. All the required thermodynamic quantities for the gases used are known and this research stimulated the investigation of spontaneous concentration scattering in binary gas mixtures under a separate program. The very good agreement between theory and experiment, as well as details of experimental techniques are fully described in Technical Report No. 2, dated June 1971, which also served as the Ph. D.

thesis, submitted by W. H. Lowdermilk. A condensed version of this Technical Report is now being prepared for publication in the Physical Review.

The main conclusion of the research performed under this contract is that good insight has been obtained in the hydrodynamic response of gas mixtures at high frequencies. On the basis of our results it is safe to conclude that concentration effects are not important for the propagation characteristics of high power laser beams in the atmosphere.

C. Publications:

1. R. L. Carman, F. Shimizu, C. S. Wang and N. Bloembergen, Phys. Rev. A2, 60 (1970). "Theory of Stokes Pulse Shapes in Transient Stimulated Raman Scattering".

2. N. Bloembergen, W. H. Lowdermilk and C. S. Wang, Phys. Rev. Letters 25, 1476 (1970). "Observation of Stimulated Concentration Scattering in a Mixture of $SF_6$ and He".

3. N. Bloembergen, W. H. Lowdermilk, M. Matsuoka and C. S. Wang, Phys. Rev. A3, 404 (1971), "Theory of Stimulated Concentration Scattering".

4. W. H. Lowdermilk and N. Bloembergen, Phys. Rev. (to be submitted). "Stimulated Concentration Scattering in Mixtures of Helium with $SF_6$ and Xe".

Technical Report No. 1. "Stimulated Raman and Concentration Scattering", October 1970.

Technical Report No. 2. "Stimulated Light Scattering in Binary Gas Mixtures", June 1971.