FINAL REPORT

on

STUDIES IN QUANTUM AND SOLID STATE ELECTRONICS

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Sponsored by

Air Force Office of Scientific Research
Office of Aerospace Research
General Physics Division

Ultramicrowave Section
Electrical Engineering Research Laboratory
Engineering Experiment Station
University of Illinois
Urbana, Illinois

I. Personnel

The following people have received support from this grant:

Paul D. Coleman	Professor of Electrical Engineering
Robert J. Strain	Research Assistant in Electrical Eng'g.
Donald P. Akitt	" " " " "
Robert H. Swendsen	" " " " "
John F. Lowe	Instrument Maker
Thomas A. Newkirk	Senior Electronics Technician
Patricia Shafer	Clerk Typist II

Effective 1 September 1962 Professor Coleman took a one-year leave of absence to participate in the microwave and quantum work at the Hansen Laboratory of Stanford University. During this period, Professor M. D. Sirkis has assumed Professor Coleman's duties, but at no charge to AF-AFOSR-62-287. Mr. Strain continues to act as an associate principal investigator.

Of the personnel listed above, three are working toward advanced degrees with AFOSR support:

R. J. Strain

D. P. Akitt

R. H. Swendsen

II. Scientific Achievement

Portions of the work done under this grant have appeared as papers:

1. R. J. Strain, P. D. Coleman, "Millimeter Wave Cavity Coupling by Quarter Wave Transformer," I.R.E. Trans. Microwave Theory and Techniques, Vol. MTT-10, pp. 612-615, (November 1962).

2. R. J. Strain, P. D. Coleman, "Stimulated Emission in the Submillimeter Region," Millimeter and Submillimeter Conference, Orlando, Florida, (January 7-10, 1963).

The paper, "Stimulated Emission in the Submillimeter Region," has been submitted to the I.R.E. Transactions on Microwave Theory and Techniques for publication in the issue devoted to the Orlando Conference.

In addition a paper based upon work not supported by this grant was presented at the Orlando Conference, and it also was submitted to the I.R.E. Transactions on Microwave Theory and Techniques. The work grew from Mr. Strain's summer (1961) with the University of Colorado.

3. E. G. Wessel, R. J. Strain, "Millimeter Frequency Multiplication with an In-Line Harmonic Generator," Millimeter and Submillimeter Conference, Orlando, Florida, (January 7-10, 1963).

The reprints submitted to the sponsor in the course of the grant serve as reports of the work indicated above. Other work, not yet at a publishable state, will be summarized below.

1. Non-linear quantum mechanics.

Non-linear quantum effects have been pursued on both theoretical and experimental fronts. The experimental work has been involved with efforts to observe third harmonic output from HCN driven at 35 kMc. The millimeter wave nature of this experiment has necessitated a departure from conventional microwave cavity resonators. A confocal resonator has been chosen for this experiment because of its large volume and low dispersion. The fundamental power is coupled into the cavity by means of a high-power modification of the coupling system described in "Millimeter Wave Cavity Coupling by Quarter Wave Transformer." Harmonic coupling is accomplished by using an array of waveguides which are transmitting for the harmonic, but cutoff for the fundamental. The resonator is incorporated in a vacuum and HCN handling system, and the entire apparatus is within a specially designed fume hood for safety.

The tests to date have yielded no 105 kMc output, though a detailed theory of the generation process indicates that at least 100 microwatts should have been available. The current sensitivity of the video detection system is extremely low, low enough to explain the lack of observed harmonic output.

In addition to the detailed theoretical description of the harmonic generation experiment, the neo-classical Schroedinger radiation equation has been extended to a three dimensional form though under somewhat restricted conditions. This equation has not yet been applied to any cases.

2. Mixing of laser beams.

The goal of this effort is to generate microwave power in the submillimeter wave gap by extracting the difference frequency from two laser beams mixed in a non-linear dielectric. To accomplish this efficiently, two synchronization conditions must be satisfied within the dielectric. First, the beams must be colinear, and second the difference of the phase velocities of the two light beams must be the same as the phase velocity of the difference frequency. The attainment of these two conditions maximizes the volume of coherence for the generating process.

The first condition may be achieved by either mechanical orientation of two similar lasers at different temperatures, or by using the two different output frequencies of a single red ruby laser; the difference of these output frequencies is 1920 kMc, equivalent to a .156 mm wavelength. The second condition is met by using suitable polarization of the drive signals in an optically anisotropic crystal. Here the possibility of synchronization depends upon both the optical and microwave characteristics of the crystal. A number of bi-refringent crystals have been considered, and these show the characteristics necessary to achieve synchronism:

Potassium Dihydrogen Phosphate

Titanium Dioxide (Rutile)

Aluminum Oxide (Corundum)

Experimentally, work has been done to increase the pumping of a dark ruby laser, but the pumping is not yet efficient enough to cause lasing.