XI. ELECTRODYNAMICS OF MEDIA[*]

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RESEARCH OBJECTIVES AND SUMMARY OF RESEARCH

The research on interaction of electromagnetic fields with media is pursued (a) to obtain self-consistent formulations of electrodynamics in the presence of moving and deforming media, (b) to make theoretical and experimental studies of nonlinear interactions of electromagnetic fields at optical frequencies, (c) to formulate wave propagation in bianisotropic media, and (d) to provide the theory for electromagnetic probing of layered media.

1. Formulation of Macroscopic Electrodynamics

The interface of macroscopic and microscopic electrodynamics of media will be studied to clarify the macroscopic model.

L. J. Chu, H. A. Haus

2. Nonlinear Interactions at Optical Frequencies

The purpose of the work on TEA gas lasers is to obtain short optical pulses and to use them in the study of nonlinear amplification phenomena. The short pulses of CO_2 radiation obtained by modelocking and cavity dumping will be utilized to measure the relaxation mechanisms in TEA CO_2 laser discharges. In particular, we will attempt to measure the vibrational relaxation time of the asymmetric stretching mode in CO_2. The study of nonlinear optical pulse amplification and pulse shaping will be continued. The simplified theory developed in the preceding year, describing both the electron distribution and population of the vibrational levels in a molecular gas discharge, will be applied to predict efficiency, gain in flowing gas mixtures, and other characteristics of interest.

Work on nonlinear amplification will be performed in high-frequency experiments. The superradiant gain transitions in TEA noble gas discharges will be studied.

H. A. Haus

3. Subsurface Probing with a Dipole Antenna

Radiation of a dipole antenna in a stratified medium has many applications. Examples are subsurface probing in geophysics and underground communication. We are

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particularly interested in radiofrequency interferometry depth-sounding technique which involves a dipole antenna as transmitter and a dipole antenna as receiver. The receiving antenna measures field intensities as a function of distance and yields an interference pattern. Using a stratified medium as a model, we are able to identify subsurface discontinuities and their electromagnetic properties.

J. A. Kong

4. Microwave Remote Sensing of the Earth

In order to understand microwave emission characteristics of terrestrial surfaces, theoretical models must be studied as a function of various parameters. Although modeling of complex structures such as vegetation or porous ice is at best approximate, we hope that it may be possible to develop mathematical models that are meaningful and computationally tractable. We begin with a simple stratified medium with planar boundaries, and will use appropriate dielectric constants for computations. The model will be elaborated to include the effects of scattering centers in the layers and roughness of the surface.

J. A. Kong, D. H. Staelin

5. Optics of Media and Optical Systems

Optical properties of anisotropic media have been extensively studied and applied to many optical systems. The merger of fiber optics and integrated optics offers promise for future communication systems. Conceptual design of a system and the system components will be of interest. We propose to study mode characteristics and wave behavior in anisotropic and bianisotropic media in the light of their potential applications in optics. The use of electro-optical and magneto-optical material to make modulators will also be considered.

J. A. Kong

A. EXPERIMENTS ON A ROOM-TEMPERATURE TEA CO LASER

Joint Services Electronics Programs (Contract DAAB07-71-C-0300)

T. Holcomb, H. A. Haus

We have reported observations on a room-temperature sealed-off TEA discharge in He, Xe, and CO. Superradiant gain was reported in the neighborhood of 5.065 μm. Experiments aimed at reproducing these results on a flowing He-Ar-CO mixture also showed a superradiant transition, which became stronger as the partial pressure of CO decreased (see Section XI-B). We found that this is an Ar transition, and therefore we reinvestigated the sealed-off system. We were able to identify the superradiant transition as not that of CO, but rather the transition at 2.026 μm of Xe, which passed in 5th order through the spectrometer. Similar behavior has been found with He-Kr and He-Ne mixtures. Details will be presented in a future report.

B. PRELIMINARY INVESTIGATION OF A "SUPERRADIANT" NEUTRAL ARGON LINE IN A TEA LASER

Joint Services Electronics Programs (Contract DAAB07-71-C-0300)

C. T. Ryan

It is well known that the noble gases possess several "superradiant" laser lines in the infrared when operated in a pulsed longitudinal laser system at fairly low pressures (10^{-2}-10 Torr) without any mixing gas.[1,2] Recently, we have been investigating a "superradiant" line in neutral argon which has been operated at 300 Torr total pressure, 16% argon and 84% helium, in a standard pin-resistor TEA configuration. This particular line is the $3d(1/2)_1^0 - 4p(3/2)_2$ transition in argon with a wavelength which was found to be 1.79 μm. This line has been noted in previous experiments for its high output power in the TEA configuration, but it has not, to our knowledge, been reported to be "superradiant" in this configuration, nor has the excitation mechanism been explained.[3] Our present investigation is geared to explaining the excitation mechanism for this transition.

Our experimental arrangement includes two .05 μF capacitors in series, charged to 16 kV and discharged through 170 pin-resistor gaps using 1-kΩ resistors and a gap of ~2.5 cm for the discharge length of the filaments. The system is triggered externally by a spark gap which gives a main current pulse, 1 μs long, and a peak value of 900 A. An overshoot with a peak value of 120 A and a duration of 1 μs is also produced. When the system is operated with one totally reflecting gold flat mirror, the laser pulse occurs when the main current pulse initially reaches ~400 A, at a time ~.15 μs after the onset of the current pulse. The laser pulse duration is ~.1 μs. The short duration of the laser pulse compared with the current pulse can be explained by the fact that the lower laser level (J=2) is not coupled to the $3p^6\,{}^1S_0$ (J=0) ground state of argon through a dipole interaction. Thus rapid buildup of the lower laser level population destroys the inversion.

Using these conditions and an estimate of the filament radii as 2 mm, we calculated $E/p = 8\ \text{V cm}^{-1}\ \text{Torr}^{-1}$ and pd = 1200 Torr mm. From this we obtained an electron density of $8 \times 10^{13}\ \text{cm}^{-3}$ during the laser pulse. We could not show positively whether the ionization mechanism is primarily Penning ionization of the argon by helium metastables or direct electron impact. Calculations seemed to indicate that the primary effect should be direct electron impact ionization of the argon to yield a calculated electron temperature of approximately 2 eV. This is inconsistent, however, with our measured output vs pressure data which, under "superradiant" conditions, call for a maximum argon percentage of 30%. With a second mirror, laser action can be sustained up to a maximum of 35% argon, although at much lower output. This would seem to suggest that the helium plays a vital role in determining either the discharge parameters or the excitation mechanism.

We are continuing the investigation using primarily the normal "nonsuperradiant" laser. In this configuration, laser action occurs immediately at the onset of the current pulse and has a duration of ~.4 μs. After this main laser pulse subsides, a small, sharp secondary spike in the lasing action appears at the onset of the overshoot. The secondary spike is approximately 3% of the peak output of the main laser pulse and the duration is only .1 μs. At the end of the overshoot, a third pulse of similar peak intensity is observed but decays with a time constant of 1 μs. This lasing action after the main pulse may give some more clues to the nature of the excitation mechanism.

References

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