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13. ABSTRACT (Maximum 200 words)

Extensive experimental and theoretical results obtained in the two research areas supported by this grant are summarized. These diverse areas include the statistical properties of light produced via stimulated Raman scattering and the operational and technical properties of the time-domain frequency-selective approach to optical data storage.

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## STATEMENT OF PROBLEM STUDIED

The work of M.G. Raymer's group during this period has been directed toward--

- Spatial and temporal properties of light generated by amplification of quantum noise in gain-guiding amplifiers.
- Optical phase memory in coherently excited optical amplifiers.

We have used stimulated Raman scattering as a prototypical and important instance of gain-guided optical amplifier. Several successful experiments have been accomplished, along with the necessary theoretical modelling. Optical parametric amplifiers have also been studied theoretically.

T.W. Mossberg's group has concentrated on the elucidation of new approaches to time-domain frequency-selective optical data storage and material problems associated therewith.

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## **SUMMARY OF RESULTS**

**1. Spatial Interference of Light from Independent SRS Sources --** We have demonstrated that the creation of spatial fringes occurs when two beams of Raman-generated light are superposed. Because the beams are generated from independent groups of molecules, they are statistically independent, and have random, uncorrelated phases and amplitudes. Thus the locations and depth of modulation of the fringes vary on each shot of laser. We have verified that the statistics of the light is identical to thermal radiation with an effective temperature as high as  $10^{12}$  Kelvin.

**2. Excess Spontaneous Noise in Gain-Guided Amplifiers --** Much has been made recently about an unusual and subtle effect that occurs in gain-guided semiconductor lasers. The modes of the structure are non-orthogonal and this leads to correlations between mode amplitudes, and so-called excess noise. We have discovered that this effect is also present in gain-guided amplifiers without resonators, such as Raman or X-ray amplifiers. By measuring the shot-to-shot jitter of the direction of propagation of the generated beam, we have been able to show that the non-orthogonality of the gain-guided modes plays an important role in the spatial structure of the light.

We carried out experiments and developed theoretical models to understand the quantum mechanical origin of the directional instability of the Stokes beam generated by SRS in a molecular gas such as hydrogen. For interaction Fresnel numbers greater than about five, we demonstrated for the first time that the Stokes beam direction fluctuates on the order of the diffraction-limited divergence angle. We measured the beam-angle standard deviation versus Fresnel number by employing a new interferometric technique in which two Stokes beams generated in different media are made to interfere spatially. The fringe spacing is a measure of the relative pointing angle.

The theory that we have developed to successfully fit the measurements is based on a transverse mode expansion of the Stokes field that naturally accounts for the gain guiding of the field by the laser-pumped Raman medium. So-called excess spontaneous-emission noise is incorporated in this model and is important for correctly describing the field statistics.

**3. Near-Quantum Limited Phase Memory in a Raman Amplifier --** We developed a new technique for measuring very small amounts of vibrational coherence in a high-density gas of molecules. By spatially interfering two Stokes pulses, produced in sequence in the same sample of molecules, we were able to detect on the order of 20 coherently vibrating molecules, in the presence of about  $10^{16}$  incoherently vibrating molecules. This approaches the quantum limit on the amount of detectable vibration in a gas.

**4. Squeezing in Wide-band Parametric Amplification --** We have developed a theoretical model for predicting the properties of light generated by wide-band, travelling-wave parametric amplification in nonlinear optical crystals. In particular, we analyzed the effects of group-velocity dispersion on the amount of phase-quadrature squeezing (reduction of quantum noise) that can be achieved in such amplifiers.

**5. Excitation-induced Frequency Shifts in Inhomogeneously Broadened Absorbers--** We have discovered a new property of solid-state optical absorbers. When such materials are exposed to resonant optical radiation and thereby promoted to excited atomic states, their optical transition frequencies are shifted. This effect must be taken into account in many experiments designed to study optical dephasing in solids. The effect must also be considered in the design of time-domain optical memories.

**6. Phase-noise and Time-domain Frequency-selective Optical Data Storage --** It was demonstrated that new classes of optical pulses are effective in the storage of time-domain optical data. These pulses are imbued with pseudo-random phase noise. It turns out that information stored with such pulses cannot be recalled without knowledge of the pseudo-random phase noise used in the storage process. As a result, a new means of secure data storage is provided.

**7. Swept-Carrier Time Domain Optical Memory --** An entirely new scheme of time-domain optical memory was proposed. In this scheme, long cotemporal, frequency-swept excitation pulses are employed. The new approach facilitates the use of full material bandwidth without requiring the use of extreme data modulation rates. Many more materials should be useable with the now swept-carrier approach.

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9. "Limits to wide-band, pulsed squeezing in a traveling-wave, parametric amplifier

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## **PERSONNEL**

1. Michael G. Raymer -- PI, Professor of Physics
2. Shih-Jong Kuo, obtained PhD degree in April, 1991.
3. Daniel T. Smithey, PhD student, planned graduation date--7/92
4. Shuangbo Yang, PhD student
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6. Dr. Jin Huang
7. Jiamin Zhang
8. Dr. Daniel Gauthier
9. Prof. Thomas W. Mossberg

## **INVENTIONS**

**Swept-carrier time-domain optical memory, T. W. Mossberg (patent applied for).**