

# 10. Quantum Optics and Electronics

## Academic and Research Staff

*Prof. M.M. Salour, Dr. G.W. Fehrenbach, Dr. A. Fuchs,  
Dr. P. Jaanimagi, Dr. H.P. Kayoun, Dr. P. Kumar,  
Dr. F.P. Leland, Dr. R. Welte, Dr. T.K. Yee,  
F.W. Barrows*

## Graduate Students

*N.S. Bergano, R.S. Bondurant, J.G. Fujimoto,  
B.C. Johnson, M. Maeda, G.W. Miller, R.S. Putnam,  
C.B. Roxlo, J. Yorsz*

## 10.1 Nonlinear Optical Interactions in Semiconductors

*U.S. Air Force - Office of Scientific Research (Contract F49620-79-C-0071)  
Michael M. Salour*

The aim of this program is to investigate a variety of novel, nonlinear optical interactions that accompany, or immediately follow, the creation of an electron-hole pair in semiconductors. These studies will combine theory and experiments on the basic physics of the interaction of intense picosecond pulses with semiconductor systems involving mobile carriers.

We have demonstrated tunable cw laser action of platelet semiconductors in both mode-locked and unmode-locked configurations. The gain media were platelets of CdS, CdSe, CdSSe, and InGaAsP, cooled to 85°K and longitudinally pumped by Ar<sup>+</sup> and Kr<sup>+</sup> lasers. Antireflection coating of the crystal face and external bandwidth restriction have been used to generate pulses as short as 4 ps in CdS. The pulses observed are chirped, with nontransform-limited time-bandwidth products of about 1.7. The energy conversion efficiency is 20% into the TEM<sub>00</sub> mode, with output powers of over 10 mW from CdS. Pulses as short as 7 ps tunable over a 26-nm range have been obtained in InGaAsP.

These compounds can potentially provide continuous tunability between 500 nm and 1.5 μm, a range which is not entirely available from dye lasers. Because of the lack of dye jet fluctuations, semiconductor lasers may provide narrower linewidths than dye lasers, and samples mounted adjacent to each other can be easily changed to provide tunability over a broad range. A very long shelf life and the lack of orientational bleaching may make these lasers more practical than F-centers for many applications. Optically pumped semiconductors should provide a useful tool for spectroscopy in both the time and frequency domains.

## 10.2 Picosecond Dye Laser Optics

*Joint Services Electronics Program (Contract DAAG29-80-C-0104)*

*U.S. Air Force - Office of Scientific Research (Contract F49620-79-C-0071)*

*Michael M. Salour*

We have observed photoelectric emission and thermally enhanced photoelectric emission from a zirconium metal surface using our intense UV laser pulses of two-picosecond durations. Our data show that the electron and lattice-temperature remain approximately equal, and the electron-phonon energy relaxation time is less than one picosecond.

In another series of experiments we have made detailed measurements of the luminescent spectra of CuCl as a function of pump power and temperature.

Excellent agreement was found with earlier values for exciton energy; however, a new broad background was found at high excitation. Evidence for free Cu in the luminescence spectra is found in all samples under very high excitation, even in the samples which had been carefully screened for free Cu by x ray and ESR. We have observed a broadening of the  $Z_3$  line, which we tentatively ascribe to phonon effects due to the modified "Cu", CuCl structure.

Finally, we have observed the time dependence of the bound luminescence of the CuCl by exciting single crystals of CuCl at 8°K with the low-intensity frequency-doubled output of an actively mode-locked R6-G dye laser. We have measured the time dependence of the bound exciton luminescence directly by a synchronously operating electron-optical streak camera accumulating data at the dye laser repetition rate of 82 MHz. We have determined (directly) that the observed bound exciton lifetime for the I line (3898 Å) is typically ~130 ps with a formation time of less than 10 ps.

## 10.3 Nonlinear Spectroscopy of Atoms and Molecules

*U.S. Navy - Office of Naval Research (Contract N00014-79-C-0694)*

*Michael M. Salour*

We have demonstrated a new method of "light-by-light switching" in a unidirectionally amplifying medium, based on the method of Doppler compensation by velocity-dependent light shifts. The time response of such a switch is limited by the fact that the bandwidth of the compensating pulse has to be small compared to the Doppler width of the atomic vapor. These widths are generally of the order of gigahertz, which means that the response time cannot be shorter than a few nanoseconds (i.e.,  $\sim 10^{-9}$  sec). The rise and fall times of the switching are determined by the rise and fall times of the superfluorescent pulse which, in this experiment, was of the order of one nanosecond (i.e.,  $10^{-9}$  sec).

A very exciting feature of this switching technique is its unidirectionality, which makes it a unique tool for applications in optical communications, ring lasers, Doppler-free directed superradiance, Doppler-free coherent transients, and so on.

### Publications

- Miller, D.E., "Microprocessor Controlled Passive Area Navigation System for Light Aircraft," S.B. Thesis, Department of Electrical Engineering and Computer Science, M.I.T., June 1978.
- Rotman, S.R., C.B. Roxlo, D. Beelaar, and M.M. Salour, "Pulsewidth Stabilization of a Synchronously Pumped Mode-Locked Dye Laser," *Appl. Phys. Lett.* **36**, 886 (1980).
- Petite, G., B.C. Johnson, W.K.H. Lange, and M.M. Salour, "Observation of Unidirectional Amplified Spontaneous Emission induced by Velocity Dependent Light Shifts," *Phys. Rev. Lett.* **45**, 1242 (1980).
- Heinrichs, R.M., "Efficient Conversion of XeF Radiation to the Blue-Green through Stimulated Raman Scattering," S.M. Thesis, Department of Electrical Engineering and Computer Science, M.I.T., June 1980.
- Messinger, B.J., "Angular Distribution of Electrically Scattered Light from Cylindrical Glass Fiber," S.B. Thesis, Department of Electrical Engineering and Computer Science, M.I.T., June 1980.
- Rotman, S.R., "Active Feedback Stabilization of Ultrashort Pulses in a Synchronously Mode-Locked Dye Laser," S.M. Thesis, Department of Electrical Engineering and Computer Science, M.I.T., June 1980.
- Rotman, S.R., C.B. Roxlo, D. Beelaar, and M.M. Salour, "Pulsewidth Stabilization of a Synchronously Pumped Dye Laser," *Proc. of the Picosecond Phenomena Conference*, North Falmouth, MA, July 18-20, 1980.
- Roxlo, C.B., D. Beelaar, and M.M. Salour, "Tunable CW Bulk Semiconductor Platelet Laser," *Appl. Phys. Lett.* **38**, 507 (1981).
- Roxlo, C.B., and M.M. Salour, "Synchronously Pumped Mode-Locked CdS Platelet Laser," *Appl. Phys. Lett.* **38**, 738 (1981).
- Fujimoto, J.G., T.K. Yee, and M.M. Salour, "Picosecond Spectroscopy of Bound Excitons in CuCl Using a Synchronously Operating Streak Camera," *Appl. Phys. Lett.* **39**, 12 (1981).
- Johnson, B.C., G. Petite, W.K.H. Lange, and M.M. Salour, "Observation of Unidirectional Amplified Spontaneous Emission Induced by Velocity Dependent Light Shifts," *Bull. Am. Phys. Soc.* **26**, 57 (1981).
- Fujimoto, J.G., T.K. Yee, and M.M. Salour, "Measurement of Low Intensity Bound Exciton Luminescence of CuCl Using a Synchronously Operating Streak Camera," presented at the International Conference on Excited States and Multiresonant Nonlinear Optical Processes in Solids, Aussois, France, March 18-20, 1981.
- Fujimoto, J.G., "Direct Determination of Excitonic Lifetime in CuCl Using a Picosecond Synchroscan Streak Camera," S.M. Thesis, Department of Electrical Engineering and Computer Science, M.I.T., June 1981.
- Johnson, B.C., "Unidirectional Amplified Spontaneous Emission through Doppler Compensation," S.M. Thesis, Department of Electrical Engineering and Computer Science, M.I.T., June 1981.
- Fujimoto, J.G., T.K. Yee, and M.M. Salour, Paper WR2: "Application of a Synchronously Operating Streak Camera to the Measurement of Bound Exciton Luminescence in CuCl," presented at the Conference on Lasers and Electro-optics (CLEO '81), Washington, D.C., June 10-12, 1981.
- Roxlo, C.B., and M.M. Salour, Paper WR4: "Generation of Picosecond Pulses from a Synchronously Pumped CdS Platelet Laser," presented at the Conference on Lasers and Electro-optics (CLEO'81), Washington, D.C., June 10-12, 1981.
- Salour, M.M., "Optically Pumped Semiconductor Platelet Lasers," presented at the Fifth International Conference on Laser Spectroscopy, Jasper Park, Canada, June 29-July 3, 1981.

- Salour, M.M. and G. Petite, "Light-Induced Unidirectional Light Switching. presented at the Fifth International Conference on Laser Spectroscopy, Jasper Park, Canada, June 29-July 3, 1981.
- Petite, G., B.C. Johnson, W.K.H. Lange, and M.M. Salour, "Observation of Unidirectional Gain Induced by Velocity Dependent Light Shifts," Proc. of the 7th International Conference on Atomic Physics, Boston, MA, August 4-8, 1981.
- Roxlo, C.B., "Optically Pumped Synchronously Mode-Locked Semiconductor," PhD. Thesis, Department of Electrical Engineering and Computer Science, M.I.T., September 1981.
- Salour, M.M., and G. Petite, "Light Induced Unidirectional Light Switching," *Opt. Lett.*, to appear December 1981.
- Roxlo, C.B., R.S. Putnam, and M.M. Salour, "Optically Pumped Semiconductor Platelet Lasers," *IEEE J. Quantum Electron.*, to appear March 1982.
- Roxlo, C.B. and M.M. Salour, "Dewar Design for Optically Pumped Semiconductor Lasers," to appear in *Rev. Sci. Instrum.*
- Lefkowitz, I., T.K. Yee, J.G. Fujimoto, M.M. Salour, and M. Combescot, "Evidence for New Features in the Luminescent Spectra in CuCl," submitted to *Phys. Rev. Lett.*, 1981.