MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1965 - J
Nonlinear Optical Phenomena in Solids

Mercury Cadmium Telluride, Gallium Arsenide/Gallium Arsenide Aluminum Arsenide, Superlattices, Bulk Crystals
The nonlinear optical properties of $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ for $x$ values between 0.20 and 0.23 have been evaluated experimentally under CO$_2$ laser excitation at 295$^\circ$K, 77$^\circ$K, and 12$^\circ$K. Optical phase conjugation arising from conduction band nonparabolicity and the photoexcited plasma mechanisms has been studied. Third order susceptibility values ranging from $1 \times 10^{-8}$ esu (conduction band nonparabolicity) to $3 \times 10^{-2}$ esu (photoexcited plasma) have been measured. A new effect in which the phase conjugate signal is erased or quenched by means of a separate CO$_2$ laser has been observed. The mechanism depends upon an enhanced Auger recombination rate due to two-photon absorption. Optical absorption data were obtained on eight samples of $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ over the interval from 10$\mu$m to 40$\mu$m and interpreted theoretically in terms of interband, intraband, impurity, and lattice absorption measurements. The temporal behavior of degenerate four-wave mixing and optical bistability was studied theoretically for a superlattice or quantum well for both absorptive (photoexcited plasma) and dispersive (conduction band nonparabolicity) mechanisms. The third order susceptibility due to both conduction band nonparabolicity and the photoexcited plasma mechanisms in both GaAs/Al$_x$Ga$_{1-x}$As and $\text{Hg}_{1-x}\text{Cd}_x\text{Te}/\text{Hg}_{1-y}\text{Cd}_y\text{Te}$ superlattices has been investigated theoretically. The optimized GaAs/Al$_x$Ga$_{1-x}$As superlattice has a third order susceptibility due to conduction band nonparabolicity which is about one hundred times that of bulk GaAs. The third order susceptibility due to conduction band nonparabolicity in the $\text{Hg}_{1-x}\text{Cd}_x\text{Te}/\text{Hg}_{1-y}\text{Cd}_y\text{Te}$ superlattice is approximately the same as in the bulk $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ alloy. The third order susceptibility in both superlattices due to the photoexcited plasma mechanism is substantially the same as in the corresponding bulk alloys. Including work done under the previous contract which was published during the present, there was a total of two chapters, fourteen written papers and fourteen spoken papers describing this work. One patent was issued and one application submitted.
1.0 RESEARCH OBJECTIVES

The objectives of the contract are listed below:

(1) Determine the dependence of the power reflection coefficient upon signal and pump intensities for optical phase conjugation by resonant four-wave mixing in mercury cadmium telluride crystals.

(2) Study optical phase conjugation by four-wave mixing in epitaxial layers of mercury cadmium telluride.

(3) Investigate noncollinear phase matched far infrared radiation in mercury cadmium telluride.

(4) Measure the spectral dependence of the optical absorption coefficient in mercury cadmium telluride from 10 to 50 micrometers and separate band edge absorption with possible exciton effects from intervalence band and free carrier absorption.

(5) Measure the spectral dependence of the quantum efficiency in small gap mercury cadmium telluride from 10 to 50 micrometers.

(6) Determine the relative contributions of the microscopic mechanisms, including conduction band nonparabolicity, photoexcited plasma, and saturable absorption, to optical phase conjugation in Hg$_{1-x}$Cd$_x$Te.

(7) Investigate the quality of the phase conjugate return in Hg$_{1-x}$Cd$_x$Te.

(8) Investigate optical bistability in Hg$_{1-x}$Cd$_x$Te arising from third order nonlinearities.
Investigate theoretically the response time of nonlinear optical interactions produced by the various microscopic mechanisms in semiconductors.

Investigate theoretically the nonlinear optical interaction mechanisms in semiconductor superlattices.

2.0 STATUS OF RESEARCH EFFORT AND FUTURE PLANS

The work carried out during the final period of the contract, 9 January 1985 - 15 June 1985, is described in this section.

2.1 Nonlinear Optics Experimental Investigations

Semiannual Technical Reports 6-8 described an effect never previously reported in the literature in which a degenerate four-wave mixing signal was modulated using an "erase beam". The experimental configuration is shown in Figure 1. The arrangement utilizes degenerate four-wave mixing in which 10.6μm wavelength pump and probe beams come together at an angle θ on a Hg1-xCdxTe sample to form interference fringes. This modulation of the intensity in turn creates a diffraction grating in the sample. The sample used was Hg.77Cd.23Te cooled to 800K. The bandgap of this material at 800K is 0.141eV. The grating in turn diffracts the pump and probe, resulting in the signal. If either pump or probe is blocked, the signal disappears. A third beam, the erase beam, is employed to irradiate the back side of the sample. This results in the signal being quenched or erased. The effect of erasing the signal increases with increasing erase beam intensity until it saturates at some low value of signal, see Figure 2. The effect did not require the erase beam to be coherent with the pump and probe. Because the energy of the radiation (0.117eV) is less than the bandgap energy, two-photon absorption is responsible for the photoexcitation.
Beam From 10.6 μm CO₂
TEA Laser ~1 MW/cm²

BS
Polarization Rotator
Erase Beam

Pump & Probe

Sample Chamber Temp from 80K to 300K

Signal

Ge:Cu Detector 4K

Scope

FIGURE 1
Experimental Arrangement
FIGURE 2

Effect of Erase Beam on Signal

Hg$_{0.7}$Cd$_{0.3}$Te
T = 80 K
Back illumination; 4 ns delay
Pump intensity = 53 kW/cm$^2$
$\theta = 3.5^\circ$

Normalized Signal

Erase Beam Power (KW/cm$^2$)

0 200 400 600 800 1000 1200 1400 1600 1800 2000

0 0.25 0.5 0.75 1.0
During this reporting period, the effect of a time delay on the erase beam was examined. This was done by increasing the distance the erase beam had to travel before arriving at the sample. All of these experiments were done with a Hg$_{0.771}$Cd$_{0.229}$Te sample at $T=80^\circ$K and a pump/probe angular separation of $\Theta=3.5^\circ$ with pump intensities of about 50kW/cm$^2$. The results are shown in Figure 3. It was found that the erase beam had the greatest effect ("erased" most of the signal) for the shortest time delay (4ns). As the delay was increased the effect was reduced. However, there was an effect even at a 65ns delay; (the pulse width of the CO$_2$ TEA laser is about 50ns). The erase beam experiment was also done with the polarization of the erase beam 90$^\circ$ to the incident beam. The erase beam was equally effective in quenching the phase conjugate signal in this configuration, which shows that erasure is not an interference effect.

The effect of delaying the pump and probe beams relative to the erase beam was also studied, see Figure 4. This arrangement also showed a decrease in signal; however, the signal vs. erase beam intensity had a smaller slope than did that with the erase beam delayed with respect to the pump and probe beams. There was little difference between the 7ns pump and probe delay and the 24ns pump and probe delay.

The effect of the erase beam on the phase conjugate signal as a function of angle for $\Theta=2.39^\circ$, 3.04$^\circ$ and 6.42$^\circ$ was also studied, see Figure 5. This experiment showed no significant angular dependence of the effect. The signal intensity vs. erase beam intensity for $\Theta=2.39^\circ$ was very similar to that at $\Theta=6.42^\circ$. The effect of the erase beam as a function of temperature and incident power was also studied, see Figures 6 and 7. No significant dependence on either parameter was seen.
Figure 3
Effect of Erase Beam Time Delay

Pump: 50 KW/cm²
T = 80K
H₀.₇C₀.₃Te

Normalized Signal vs. Erase Beam Peak Power Density (KW/cm²)
FIGURE 4

Effect of Erase Beam
Prior to Pump and Probe Beams
T = 80K
Pump: 95 kW/cm²
EB polarization 90°
to Signal
Hg₇₇Cd₂₃Te

Erasure Beam Peak Power (KW/cm²)

Angular Dependence of Erase Beam Effect
FIGURE 7
Pump Intensity Dependence of Erase Beam Effect

Hg$_x$Cd$_{1-x}$Te
$T = 80^\circ$K
$\theta = 4.4^\circ$

Erase Beam Intensity (KW/cm$^2$)

Normalized Signal

Pump Intensity
21 KW/cm$^2$
134 KW/cm$^2$
63 KW/cm$^2$
Frontal irradiation of the sample was also shown to give rise to the effect, see Figure 8. However, the effect was not as great as that seen with backside irradiation.

The physical mechanism underlying this erasure effect was described in Interim Technical Report 8. It is a result of the concentration dependent Auger lifetime of photoexcited carriers in Hgl-xCd_xTe. The phase conjugate signal arises from the probe beam being diffracted by the free carrier concentration grating generated by two-photon absorption and the interference of pump and probe beams. Those parts of the grating having high carrier concentrations are characterized by having an Auger lifetime \( \tau_A \) which is inversely proportional to the square of the carrier concentration, i.e.,

\[
\tau_A^g = \frac{1}{(n_0 + \Delta n)^2};
\]

where \( n_0 \) and \( \Delta n \) are the equilibrium and photoexcited carrier concentrations respectively. The areas of the grating with no photoexcited carriers have

\[
\tau_A = \frac{1}{n_0^2}.
\]

The "lifetime" of the diffraction grating then is approximately \( \tau_A \). If the erase beam is on, more carriers are photoexcited, not only at the concentration grating peaks but uniformly throughout the crystal. This uniform excitation results in the background carrier concentration being elevated above \( n_0 \), and \( \tau_A \) is reduced further. If the erase beam is very intense, the differences in lifetimes between the grating's peaks and valleys become effectively zero. Because the power in the diffracted beam depends upon the square of \( \chi^{(3)} \), the third order susceptibility, and \( \chi^{(3)} \) is proportional to \( \tau_A \), the effect of the
FIGURE 8

Erase Beam Effect with Frontal Irradiation
erase beam is to reduce the diffracted signal, almost eliminating it at high erase beam intensities. The effect of a time delay is to reduce the overlap between the pump/probe and erase pulses, thereby reducing the background photoexcited carrier concentration and the effect of the erase beam.

2.2 Nonlinear Optics Theoretical Investigations

As stated in Semiannual Technical Report 8, Honeywell entered into an agreement with Prof. Yia-Chung Chang of the Department of Physics, University of Illinois at Champaign-Urbana, to address research objectives (9) and (10). The results of his analysis leading to research objective number (10) were discussed in Semiannual Technical Report 8. During the period 9 January 1985 - 15 June 1985, Prof. Chang addressed objective (9), "Investigate theoretically the response time of nonlinear interactions produced by the various microscopic mechanisms in semiconductors." His analysis is contained in the manuscript "Transient Response of Nonlinear Optical Properties in Semiconductor Superlattices" which he has submitted for publication in the Journal of Applied Physics. His findings are summarized below.

The transient behaviors of optical bistability (OB) and degenerate four-wave mixing (DFWM) for a semiconductor superlattice (3-D case) or a quantum well (2-D case) were studied. It was determined that the up-switching time (tu) for dispersive OB or DFWM due to band-nonparabolicity is of the same order of magnitude as the round-trip transit time (2L/v) within the semiconductor cavity. For absorptive OB or DFWM due to a photoexcited plasma, tu is of the order of T1, the interband recombination time. The down-switching
time \((t_d)\), which is defined as the time required for the output signal to decay to a certain value, is found to be of the same order of magnitude as the cavity decay time (for OB) or the roundtrip transit time, irrespective of the mechanism. However, if the down-switching time \((t_d)\) is defined as the time required for the system to return to the original state, then \(t_d\) should be of the order of the \(T_1\) for absorptive OB or DFWM.

It was determined that in the direct saturation model, the semiconductor superlattice or quantum well medium does not yield the absorptive OB near the threshold optical frequency corresponding to the energy gap. In the Burstein-Moss model, only the semiconductor quantum well (or narrow-band semiconductor superlattice) can give rise to pronounced absorptive OB.

The band-nonparabolicity mechanism in semiconductor quantum wells was found to be quite promising for applications involving dispersive OB because of its fast switching time \((-2L/v)\) and low switching power \((10-100 \text{ kW/cm}^2)\).

The transient behavior of DFWM in semiconductor superlattices is found to be similar to that in bulk semiconductors, although the semiconductor superlattice in the narrow-band limit (2-D case) tends to give a stronger saturation.

3.0 Summary of Significant Accomplishments

Listed below are the significant accomplishments achieved during the period 9 January 1981 - 15 June 1985, organized according to research objectives:
(1) **Objective:** Determine the dependence of the power reflection coefficient upon signal and pump intensities for optical phase conjugation by resonant four-wave mixing in mercury cadmium telluride crystals.

**Accomplishment:** Optical phase conjugation by bandgap resonant four-wave mixing in Hg$_{1-x}$Cd$_x$Te was studied at 770K. The power reflection coefficient was experimentally determined as a function of CO$_2$ laser pump and probe intensities. From these data, values of $\chi^{(3)}$ of $3 \times 10^{-2}$ esu were measured. Close agreement was found with theory$^{(1)}$. These experiments were described in the following publication:

- M.A. Khan, R.L.H. Bennett, and P.W. Kruse, "Bandgap Resonant Optical Phase Conjugation in N-Type Hg$_{1-x}$Cd$_x$Te at 10.6 $\mu$m," Optics Lett. 6, 650(1981).

(2) **Objective:** Study optical phase conjugation by four-wave mixing in epitaxial layers of mercury cadmium telluride.

**Accomplishment:** A computer-controlled (hp-9825) laser scanner and data acquisition system was assembled to obtain phase conjugation data from (Hg,Cd)Te epitaxial layers. One sample was evaluated. It consisted of a CdTe substrate on which was grown a 20 $\mu$m thick epitaxial layer of n-type Hg$_0.79$Cd$_{0.21}$Te having a free electron concentration of $1 \times 10^{15}$cm$^{-3}$. Over this was grown a 10 $\mu$m thick epitaxial layer of n-type Hg$_{0.65}$Cd$_{0.35}$Te. A weak phase conjugate signal ($S/N = 5$) was detected at 770K in response to 10.6 $\mu$m radiation from a CO$_2$ laser. The limitation in signal was due to the layer being too thin to absorb radiation efficiently. This was the first report of optical phase conjugation from epitaxial layers of Hg$_{1-x}$Cd$_x$Te,

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and possibly from epitaxial layers of any material. This work was reported in two publications:


(3) **Objective:** Investigate noncollinear phase matched far infrared radiation in mercury cadmium telluride.

**Accomplishment:** Experiments of this type were initiated under the previous contract in collaboration with investigators at MIT. They met with only slight success; the generation of far infrared radiation is a very inefficient process. After consultation with AFOSR, it was decided that it would be more productive to work on the other research tasks.

(4) **Objective:** Measure the spectral dependence of the optical absorption coefficient in mercury cadmium telluride from 10 to 50 micrometers and separate band edge absorption with possible exciton effects from intervalence band and free carrier absorption.

**Accomplishment:** Optical absorption measurements from 10 $\mu$m to 40 $\mu$m were carried out on eight bulk Hg$_{1-x}$Cd$_x$Te samples (3 p-type and 5 n-type) with compositions (x-values) ranging from 0.19 to 0.40. Data were also taken on epitaxial layers of Hg$_{1-x}$Cd$_x$Te. A computer program was developed which permitted calculation of the contribution to the optical absorption cross-
section from all the major absorption mechanisms including interband, intraband, lattice, and impurity absorption. The data for both bulk and epitaxial samples were compared with theory. The results were presented in the spoken paper:

- "An Investigation of the Far Infrared Optical Properties of Hg\(_{1-x}\)Cd\(_x\)Te" by T. N. Casselman and G. Hansen, 1983 Mercury Cadmium Telluride Workshop, Dallas, 8-10 February 1983.

The results were also published in the following written publication:


(5) **Objective:** Measure the spectral dependence of the quantum efficiency in small gap mercury cadmium telluride from 10 to 50 micrometers.

**Accomplishment:** Due to the departure of T. N. Casselman, this work was redirected. However, preliminary results were reported in two publications:


(6) **Objective:** Determine the relative contributions of the microscopic mechanisms, including conduction band
nonparabolicity, photoexcited plasma, and saturable absorption, to optical phase conjugation in Hg$_{1-x}$Cd$_x$Te.

**Accomplishment:** To determine the relative contributions of the microscopic mechanisms, a series of optical phase conjugation experiments was carried out on four n-type samples of Hg$_{1-x}$Cd$_x$Te at 295$^\circ$K, 77$^\circ$K, and 120$^\circ$K. The sample x-values were 0.232, 0.231, 0.225, and 0.216. The pump and probe beams were provided by four CO$_2$ lasers, the choice depending upon the experiment. For studying nonresonant behavior a pulsed CO$_2$ TEA laser was employed. For studying bandgap resonant behavior a CW CO$_2$ laser was employed. For studying spin resonant behavior, two Q-switched CO$_2$ lasers were employed. Both forward mode and reflective mode signals were obtained. The microscopic mechanisms were identified. Values of $\chi^{(3)}$ were determined and compared with theory. In general $\chi^{(3)}$ was of the order of $1\times10^{-8}$ esu for conduction band nonparabolicity, $1\times10^{-4}$ esu for spin resonance, and $3\times10^{-2}$ esu for photoexcited plasma. These experiments were described in the following spoken papers:


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- P.W. Kruse and M.A. Khan, "Nonresonant and Bandgap Resonant Optical Phase Conjugation in Hg_{0.784}Cd_{0.216}Te", Conference on Lasers and Electro-Optics (CLEO), Phoenix, 14-16 April 1982.


These experiments also were described in the following written publications:


(7) **Objective:** Investigate the quality of the phase conjugate return in Hg_{1-x}Cd_{x}Te.

**Accomplishment:** A new effect was discovered, in which the phase conjugate signal could be quenched or erased by a CO_2 laser beam incident upon the same region of the sample in which the pump and probe beams were incident. The mechanism was found to include Auger recombination whose rate is enhanced by photo-excited carriers obtained
by two-photon absorption, see Section 2 of this report. An invention disclosure has been submitted to Honeywell's legal department as a candidate for filing with the U.S. Patent Office:

- M.A. Khan and J. Lehman, "Device for Modulating 10.6μm Radiation".

These experiments were described in two spoken presentations:


- David K. Arch, M. Asif Khan, John Lehman, and Paul W. Kruse, "Erasure of Phase Conjugate Signals in Hg0.77Cd0.23Te", 1985 Annual Meeting of the Optical Society of America, Washington, D.C., 14-18 October 1985.

(8) Objective: Investigate optical bistability in Hg1-xCd1xTe arising from third order nonlinearities.

Accomplishment: Optical bistability experiments were carried out on two Fabry-Perot Hg1-xCd1xTe cavities (x = 0.217 and 0.227) at 770K. Some indications of bistable operation were observed; the transmitted intensity vs incident intensity exhibited discontinuities, but no hysteresis loops were seen. Due to inhomogeneities in composition or nonuniform thickness, the transmitted intensity varied with position on the faces of the samples. A novel method of measuring the value of the nonlinear contribution to the refractive index (n2) was developed based upon a Mach-Zender interferometer. Measurements of n2 were compared to
values calculated from the third order susceptibility $\chi^{(3)}$ and excellent agreement was found. This work was reported in the spoken paper:


(9) **Objective:** Investigate theoretically the response time of nonlinear optical interactions produced by the various microscopic mechanisms in semiconductors.

**Accomplishments:** The temporal behavior of degenerate four-wave mixing and optical bistability was studied for a superlattice or quantum well. Upswitching and downswitching times were analyzed for both absorptive (photoexcited plasma) and dispersive (band nonparabolicity) mechanisms. This work is described in a paper which has been submitted for publication:


(10) **Objective:** Investigate theoretically the nonlinear optical interaction mechanisms in semiconductor superlattices.

**Accomplishments:** The third order susceptibility $\chi^{(3)}$ due to both the conduction band nonparabolicity and the photoexcited plasma mechanisms in both GaAs/Al$_x$Ga$_{1-x}$As and Hg$_{1-x}$Cd$_x$Te/Hg$_{1-y}$Cd$_y$Te superlattices was analyzed theoretically. The analysis showed that the optimized GaAs/Al$_x$Ga$_{1-x}$As superlattice has a value of $\chi^{(3)}$ due to conduction band nonparabolicity about two orders of
magnitude larger than that of bulk GaAs. For a small bandgap \( \text{Hg}_{1-x}\text{Cd}_x\text{Te}/\text{Hg}_{1-y}\text{Cd}_y\text{Te} \) superlattice, \( \chi^{(3)} \) due to conduction band nonparabolicity is approximately the same as that of bulk \( \text{Hg}_{1-x}\text{Cd}_x\text{Te} \). It was also determined that the value of \( \chi^{(3)} \) in a \( \text{GaAs/Al}_x\text{Ga}_{1-x}\text{As} \) superlattice arising from the photoexcited plasma mechanism is substantially the same as that of the \( \text{Al}_x\text{Ga}_{1-x}\text{As} \) alloy. The value of \( \chi^{(3)} \) in a \( \text{Hg}_{1-x}\text{Cd}_x\text{Te}/\text{Hg}_{1-y}\text{Cd}_y\text{Te} \) superlattice due to the photoexcited plasma mechanism can be at most three times greater than in the \( \text{Hg}_{1-x}\text{Cd}_x\text{Te} \) alloy. These results were published in the paper:


4.0 WRITTEN PUBLICATIONS IN TECHNICAL JOURNALS

The following publications representing work done under the prior Contract F49620-77-C-0028 (1 January 1977 - 31 December 1980) were published during the period of the present contract F49620-81-C-0034 (9 January 1981 - 15 June 1985).

Chapters


Scientific Papers


The following publications representing work carried out under both contracts F49620-77-C-0028 and F49620-81-C-0034 were published during the period of the present contract.


The following publications representing work done under contract F49620-81-C-0034 were published during this period.

- M.A. Khan, R.L.H. Bennett, and P.W. Kruse, "Bandgap Resonant Optical Phase Conjugation in N-Type Hg\(_{1-x}\)Cd\(_x\)Te at 10.6 \(\mu\)m", Optics Lett. 6, 650 (1981).


The following publication representing work done under Contract F49620-81-C-0034 has been submitted for publication.


5.0 PROFESSIONAL PERSONNEL ASSOCIATED WITH RESEARCH EFFORT

The following personnel with B.S. or higher degrees participated in the research effort during the period of the contract.

Dr. Paul W. Kruse, Chief Research Fellow
Dr. Muhammad Asif Khan, Senior Principal Research Scientist
Dr. David K. Arch, Principal Research Scientist
Dr. Darryl L. Smith, Senior Principal Research Scientist
Dr. R. Andrew Wood, Senior Principal Research Scientist
Mr. Thomas N. Casselman, Senior Principal Research Scientist
Mr. Joseph L. Schmit, Senior Principal Research Scientist
Mr. Paul R. Haugen, Principal Research Scientist
Mr. S. M. LaCroix, Graduate Assistant
Mr. John A. Lehman, Student Aide
Mr. Gary Hansen, Student Aide
Prof. Y-C Chang, Assistant Professor, University of Illinois

6.0 INTERACTIONS

6.1 Spoken Papers Presented at Scientific Meetings

The following spoken papers representing work done under the prior contract F49620-77-C-0028 (1 January 1977 - 31 December 1980) were presented during the period of the present contract F49620-81-C-0034 (9 January 1981 - 15 June 1985).


- T.N. Casselman, "Calculations of the Auger Lifetime in Degenerate n-type (Hg, Cd)Te", 4th International Conference on the Physics of Narrow Band Semiconductors, Linz, Austria, September, 1981.
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- T.N. Casselman, "On the Problem of Determining the Lifetime Limiting Mechanisms in (Hg,Cd)Te from Lifetime Measurements", U. S. Workshop on the Physics and Chemistry of (Hg,Cd)Te, Minneapolis, 26-30 October 1981.

The following spoken papers representing work done under both the prior contract F49620-77-C-0028 (1 January 1977 - 31 December 1980) and the present contract F49620-81-C-0034 (9 January 1981 - 15 June 1985) were presented during the period of the present contract.

- Paul W. Kruse, Muhammad A. Khan, and John F. Ready, "Reflective and Forward Mode Optical Phase Conjugation in Hg\(_{1-x}\)Cd\(_x\)Te," International Conference on Excited States and Multiresonant Nonlinear Optical Processes in Solids, Aussois, France, 18-20 March, 1981.


The following spoken papers representing work done under the present Contract F49620-81-C-0034 (9 January 1981 - 15 June 1985) were presented during the period of the present contract.

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- P.W. Kruse and M.A. Khan, "Nonresonant and Bandgap Resonant Optical Phase Conjugation in Hg_{0.78}Cd_{0.216}Te", Conference on Lasers and Electro-Optics (CLEO), Phoenix, 14-16 April 1982.


The following spoken paper representing work done under the present Contract F49620-81-C-0034 (9 January 1981 - 15 June 1985) will be presented at a later date.

- David K. Arch, M. Asif Khan, John Lehman, and Paul W. Kruse, "Erasure of Phase Conjugate Signals in Hg_{0.77}Cd_{0.23}Te", 1985 Annual Meeting of the Optical Society of America, Washington, D.C., 14-18 October 1985.
6.2 Consultative and Advisory Functions

- Paul W. Kruse presented a seminar on optical phase conjugation at AFOSR on 21 June 1982.

6.3 Other Interactions

- During the first half of 1981, T.N. Casselman discussed models for free electron absorption with Prof. B. Jensen of Boston University.

- T.N. Casselman was the cochairman of the U.S. Workshop on the Physics and Chemistry of (Hg,Cd)Te, held in Minneapolis October 26-30, 1981. P.W. Kruse and M.A. Khan attended. Numerous conversations were held with the participants regarding far infrared photoeffects and optical phase conjugation in (Hg,Cd)Te.

- T.N. Casselman discussed the warping of the heavy hole band and the measurement of the warping factors in (Hg,Cd)Te with Prof. M. Weiler of M.I.T. during the last half of 1981.

- Dr. Brian S. Wherrett, Center for Applied Quantum Electronics, North Texas State University, on leave from Heriot-Watt University, Edinburgh, Scotland visited Honeywell's Corporate Technology Center on 6 August 1982. He presented a talk "Resonant Nonlinear Optical Processes in Semiconductors" to Honeywell scientists. The rest of the day was spent discussing his research and Honeywell's research in nonlinear optical effects.

- During the first half of 1983, Darryl Smith was on sabbatical at the California Institute of Technology. While there he worked closely with Professor T. C. McGill and his research group. Some of the work on the formal development of superlattice electronic structure theory
was done in collaboration with Mr. Christian Mailhiot, a graduate student in Professor McGill's group.

- Two samples of Hg$_{1-x}$Cd$_x$Te were provided to Prof. Jacek Furdyna, Purdue University, on 23 July 1985 to be used in to his investigations of dilute magnetic semiconductors.

7.0 NEW DISCOVERIES, INVENTIONS, OR PATENT DISCLOSURES

The following patent representing work done under the prior contract F49620-77-C-0028 (1 January 1977-31 December 1980) was issued during the period of the present contract F49620-81-C-0034 (9 January 1981 - 15 June 1985).


The following disclosure representing work done under the present contract F49620-81-C-0034 (8 January 1981 - 15 June 1985) has been submitted to Honeywell's legal department as a candidate for filing with the U.S. Patent Office.

- M.A. Khan and J. Lehman, "Device for Modulating 10.6\mu m Radiation".