LASER PHYSICS AND LASER TECHNIQUES

Final Technical Report
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A. INTRODUCTION

The general objectives of this program have been to develop new technologies for exploiting the ultrafast measurement and data transmission capabilities of lasers, and especially ultrashort laser pulses, and to apply these new capabilities to significant current scientific problems in physics, chemistry, and ultrafast electronics. Accomplishments that have been made under this contract support in different areas of this program are outlined below.

B. SEMICONDUCTOR LIFETIME AND SURFACE DAMAGE MECHANISMS

During this contract we extended and completed the program of work done in our group by Dr. Philippe Fauchet, first as a student and then as an IBM postdoctoral fellow, on picosecond measurements of semiconductor lifetimes and laser surface damage (see references 1 to 3 below). Dr. Fauchet has now become an Assistant Professor of Electrical Engineering at Princeton.

During the course of this work we observed, more or less accidentally, and were led to study further the very interesting spontaneous surface ripples that can be generated on almost any surface by a single laser beam, even in a single picosecond laser shot. Because of their similarity in many basic respects to the well-known Wood's anomalies in diffraction gratings, we now refer to these spontaneously occurring ripples as "Stimulated Wood's Anomalies." Because they can be formed on almost any surface, using almost any laser beam, and because they can change drastically the absorption properties of the surface, an understanding of these spontaneous ripples is important both for surface physics measurements and for surface and target damage studies. We have summarized the properties of these ripples in an invited review paper which will be appearing very shortly (cf. reference 4 below).


C. TIME-RESOLVED LUMINESCENCE IN QUANTUM WELL STRUCTURES

Quantum well structures have become extremely important for their applications to both ultrafast optical and electronic devices; and careful measurements of the basic properties of these structures are therefore of both scientific and technical importance. Under this contract Dr. Julie Fouquet carried out a series of ultrafast measurements of the lifetimes of the basic quantum-well transitions in both MBE and MOCVD-grown quantum well structures, using a mode-locked laser and time-resolved single photon counting, as reported in references 5 to 9 below, and in her Ph.D. dissertation (reference 10). Dr. Fouquet is now continuing essentially this same work at the Hewlett-Packard Research Laboratories in Palo Alto.

5. J.E. Fouquet and A.E. Siegman, “Room temperature photoluminescence times in a GaAs-Al\textsubscript{x}Ga\textsubscript{1-x}As multiple quantum well structures,” in Proceedings of the 17th International Conference on the Physics of Semiconductors (Springer-Verlag, August 1984).


D. TUNABLE TRANSIENT GRATING MEASUREMENTS

One of our major objectives over the past several years has been the development of a novel tunable laser-induced grating spectroscopy system for making ultrafast physical
measurements in the frequency domain, without the need for ultrashort optical pulses. During the period of this contract this system has been completed and put into operation, and measurements have been made on several chemical systems, notably on the femtosecond time response of the optical Kerr effect in the standard optical Kerr material CS$_2$. These latter measurements have partially confirmed earlier measurements, and partially demonstrated new and unexpected phenomena which we are still interpreting. Some of the results obtained with this system are reported in references 11 through 13 below, as well as in a lengthy invited review paper in a Special Issue on Laser-Induced Gratings of the IEEE Journal of Quantum Electronics (reference 14).


E. DYE LASER AND OPTICAL RESONATOR DESIGN RESULTS

As side developments from our efforts on picosecond measurement techniques and measurements, we have derived and published two analyses having to do with the optimum design of prism beam expanders for pulsed dye lasers, and also two analyses having to do with aspects of laser resonator design, namely:


F. GENERAL REVIEWS

Finally, two invited review papers were prepared and presented, one a review of picosecond spectroscopy techniques for a NATO Conference on Chemical Applications of Picosecond Pulses, and one a general overview of lasers for an anniversary symposium held by the National Academy of Engineering:


G. ADVANCED DEGREES AND OTHER ACTIVITIES

During this period Dr. Julie Fouquet received the Ph.D. degree in Applied Physics, with a Ph.D. dissertation listed as reference 10 above.

The principal investigator Professor A.E. Siegman received a Senior Scientist Award from the Alexander von Humboldt Foundation and spent a portion of the period 1984-1985 in research at the Max Planck Institute for Quantum Electronics in Germany (at no direct cost to the contract). He was also selected as co-chairman of the next OSA Topical Meeting on Ultrafast Phenomena, which will be held in Colorado in June 1986.
The objective of this program has been to develop new technologies for exploiting the ultrafast data transmission and measurement capabilities of lasers and to apply these new techniques to current scientific problems in physics, chemistry, and ultrafast electronics. Under this support we have developed several new techniques for making ultrafast measurements with lasers, both using ultrashort light pulses in combination with novel detection mechanisms to make ultrafast measurements in the time domain, and also using a novel "tunable-laser-induced grating method" for making ultrafast measurements without pulses, working in the frequency domain. Using the latter approach, we have made femtosecond resolution frequency-domain lifetime measurements on chemical systems, including the important optical Kerr material Cs₂. We have also demonstrated the first picosecond-pulse time-domain measurements using photoacoustic detection as a sensitive and flexible bulk and surface detection mechanism in liquids and solids. We are now working to extend this approach to use photothermal detection as a sensitive
flexible, noncontacting method for making picosecond and femtosecond measurements on a very wide variety of surfaces. We have also made a number of lifetime and damage studies on semiconductor surfaces, and explored the formation of spontaneous surface ripples or "stimulated Wood's anomalies," using picosecond laser pulses.

In addition, we have invented an entirely new ultrafast photodetector concept, based on ultrafast diffusion-driven charge transport, and are actively pursuing its experimental demonstration at the minute.
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