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REPORT DOCUMENTATION PAGE

AD-A227 372

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1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED
Final Report 01 Dec 88 - 31 Dec 89

4. TITLE AND SUBTITLE
Picosecond Laser System for High Speed Characterization of Monolithic Devices

5. FUNDING NUMBERS
2305/C1 & 3842 A3

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER
AFOSR-TR- 90 1046

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NE
Bldg 410
Bolling AFB DC 20332-6448

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFOSR-89-0209

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

EQUIPMENT WAS PURCHASED

14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED

Final Technical Report The University of Texas at Austin

AFOSR-89-0209: Picosecond Laser System for High-Speed Characterization of Monolithic Devices

PI: Professor M. C. Downer
Co-PI's: Professors T. Itoh and D. P. Neikirk

A. Summary

Accurate characterization of high-speed electronic circuitry requires the introduction of optical sampling as a method for generating and measuring large electrical bandwidths. The optical sampling techniques that can be employed for measuring the electrical response of a circuit consist of electro-optic sampling[1,2] and photoconductive switching[3,4]. In electro-optic sampling, the fields of a propagating electrical pulse induce a transient birefringence in an electro-optic crystal which, in turn, rotates the polarization of an optical probe pulse transmitted through the crystal. The time evolution of the polarization rotation is an indirect measurement of the time evolution of the propagating pulse as it passes the crystal. In addition, the crystal can be "dipped"[5] into the fringing fields of the propagating electrical pulse above the circuit substrate, allowing for high spatial resolution while remaining noncontacting. In photoconductive switching, a small gap between two biased, transmission-line conductors laid down on a semiconducting substrate can be electrically closed by an optical pulse focused onto the gap. This results in the generation of an electrical pulse whose shape and duration are determined by the laser pulsewidth, the circuit characteristics of the gap and transmission line and the photo-excited carrier lifetime of the substrate. Also, the same technique can be used to measure the time evolution of an electrical pulse at a point along the transmission line. Specifically, an optical pulse closes the gap to charge a capacitor and the electrical pulse shape is inferred by measuring the charge collected versus the time delay between the optical and electrical pulses. In both electro-optic sampling and photoconductive switching, the effect of the optical pulse on the measurement of the electrical pulse is made negligible by chosing the optical pulsewidth much less than the electrical pulsewidth. To meet this requirement, an optical pulsewidth of a few picoseconds is desired and a sub-picosecond pulsewidth is ideal. In photoconductive switching, the optical pulse needs to be less than the relaxation time of the photoexecited carriers in the gap. This relaxation time can range from approximately one nanosecond for undamaged silicon-on-sapphire[6] to less than one picosecond for ion-implanted silicon-on-sapphire[7]. A laser system that optimally serves the requirements of both sub-nanosecond and sub-picosecond optical pulses for optical sampling consists of a mode-locked YAG laser (100 ps pulses) that synchronously pumps an ultrafast dye laser (100 fs pulses).

The complete measurement system that we have acquired for making optical sampling measurements on high-speed electrical circuits consists of a mode-locked Nd:YAG laser, synchronously-pumped dye laser, optical table and probe station.

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(AFOSR-89-0209: Picosecond Laser System...)

B. Equipment Purchased

A Coherent Antares mode-locked, Nd:YAG laser was purchased as the basic optical source for the measurement system and mounted on a vibration-isolated optical table purchased from Technical Manufacturing, Inc. The laser produces two separate outputs: 100 ps pulses at 1.064 μm and 70 ps at 532 nm, both at a repetition rate of 76 MHz. Sub-picosecond pulses will be obtained from a dye laser[8], synchronously pumped by part of the 532 nm beam from the Coherent Antares, that is under construction with commercially purchased components. The dye laser will be tunable, initially operating at a center wavelength of wavelength of 800 nm, and produce 100 fs pulses. Although probe stations are commercially available for mounting electrical substrates and making electrical connections, there were none available with options for coupling light to substrates nor could those available be altered to accomodate optical inputs. Therefore, a probe station was constructed from commercially available components in order to mount monolithic high-frequency electrical devices and couple optical pulses to the substrate and in and out of electro-optic crystals.

C. Research Progress

Our current research with the picosecond measurement system is divided into two areas. The first area is the characterization of substrates, for electrical device fabrication, in terms of the response time of photo-excited carriers. This characterization is important since this screens substrates that will exhibit photoconductivity on a picosecond timescale. The response time is determined from a time-resolved, pump-probe reflectivity measurement on the substrate. Two materials are being investigated: ion-implanted silicon-on-sapphire and low temperature, molecular beam epitaxy grown InAlAs. The former has been shown to exhibit picosecond response times while the latter is a promising new material with potential sub-picosecond response times[9]. The other area of research is associated with the fabrication and testing of high-speed electronic circuits using both the picosecond and sub-picosecond optical sources in conjunction with the probe station. One part of this research involves the investigation of pulse dispersion resulting from passage through planar transmission-line discontinuities for which time domain computations are currently in progress. The most important of these discontinuities are corners and T-junctions. Picosecond pulses are generated via the photoconductive effect while the measurement of the pulsewidth is made via electro-optic sampling.

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