Ultrafast photoconductive detector–laser-diode transmitter

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ABSTRACT

We report the results of an experiment in which we used an ultrafast, photoconductive, radiation detector to drive a fast laser-diode transmitter. When we irradiated the neutron-damaged Cr-doped GaAs detector with 17-MeV electron beams, the temporal response of was measured to be less than 30 ps. The pulses from this detector modulated a fast GaAlAs laser diode to transmit the laser output through 30- and 1100-m optical fibers. Preliminary results indicate that 50- and 80-ps time resolutions, respectively, are obtainable with these fibers. We are now working to integrate the photoconductive detector and the laser diode transmitter into a single chip.

1. INTRODUCTION

The purpose of our study is to develop an ultrafast detection system that can detect radiation and transport data in the form of an analog signal with high bandwidth to a recording system a significant distance away. We have explored the possibility of using a fast photoconductive detector to drive a high-bandwidth laser-diode transmitter. The detector, which we recently developed,[1] is a neutron-damaged, Cr-doped, GaAs semiconductor (GaAs:Cr:n) with a resolving time less than 30 ps. We irradiated the detector with electron beams from the 17-MeV linear accelerator (linac) at EG&G, Santa Barbara, CA. The pulses emanating from this detector modulated a fast GaAlAs laser diode, from which the laser output was transmitted, in separate experiments, through 30- and 1100-m optical fibers to a streak camera. Preliminary results indicate that 50 and 80-ps time resolutions, respectively, are obtainable with these fibers.

2. ELECTRON-BEAM PULSE AND PHOTOCONDUCTIVE DETECTOR

The pulse length of the linac beam is not precisely known, but in earlier experiments with a Cerenkov detector coupled to a streak camera, the linac staff estimated it to be greater than 30 ps. An example of the response of our GaAs:Cr:n detector to this electron beam is shown in Fig. 1. We measured the detector output with a sampling oscilloscope averaging 20 linac pulses. If one assumes the rise time of the sampling head to be 25 ps, then the pulse width of the detector output is 45 ps. Reference 1, which is printed elsewhere in these Proceedings, contains more details about this detector.

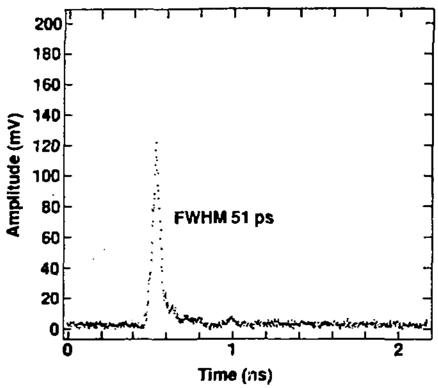

Figure 1. The response of a neutron-damaged, Cr-doped, GaAs detector to a 17-MeV electron beam.

3. LASER DIODE MODULATION AND OPTICAL-FIBER TRANSMISSION

We performed two experiments with different transmission distances. Both experiments used a signal similar to that of Fig. 1, except that the linac current and detector bias were increased such that the signal amplitudes were 2 to 3 V. In the first experiment, we used the detector signal to drive an 810-nm, 10-GHz GaAlAs laser diode through a 2-ft coaxial cable. We biased the laser diode beyond the lasing threshold and used a pigtail to connect the laser diode to a 30-m, graded-index fiber. With a lens, we focused the light emerging from the end of the 30-m fiber on the photocathode of a streak camera, and then we read and digitized the output phosphor with a silicon-intensified-target (SIT) camera.

Figure 2 shows an example of the trace from the streak camera. Note that a detector pulse rides on the lasing continuous-wave (CW) background. Figure 3 shows the digitized line-out of a similar event: the measured FWHM is 58 ps. If we take the linac pulse to be ≥ 30 ps, we estimate that the resolving time of the total detection system to be ≤ 50 ps. This includes the responses of the GaAs:Cr:n detector, the GaAlAs laser diode, and the streak camera (~ 20 ps). The material dispersion of the 30-m fiber is negligible.

Figure 2. A streak-camera trace showing the lasing CW background modulated by a detector pulse.

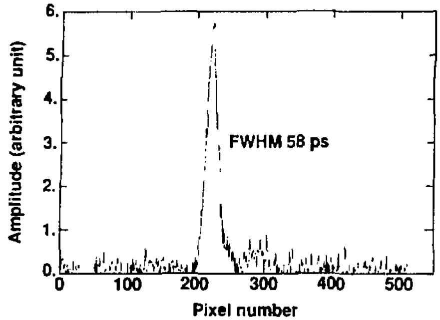

Figure 3. Digitized line-out of an event similar to the one in Fig. 2, recorded by our 30-m detection system.

We calibrated the streak and SIT cameras by two methods. In the first, we used the unbunched beam of the linac, in which the successive pulses are known to be separated by 770 ps. Figure 4 shows two such pulses recorded by our detection system. In the second, we used a comb generator, and the result was in excellent agreement with the first method.

In the second experiment, we used the GaAs:Cr:n detector to modulate an 810-nm, 6 GHz, single-longitudinal-mode, GaAlAs laser. We fused a single-mode pigtail from the laser diode to an 1100-m single-mode fiber to eliminate reflecion at the joint. Single-mode operation is crucial if we are to preserve high bandwidth through such a distance. Figure 5 shows the measured single pulse of the linac beam: the FWHM is 88 ps. Again, if we take the linac pulse to be greater than 30 ps, we estimate that the resolving time of the total detection system to be less than 80 ps. This includes not only the responses of the GaAs:Cr:n detector, the GaAlAs laser, and the streak camera, but also the dispersion of the 1100-m fiber. Clearly, an excellent time resolution can be obtained with such a detection system.

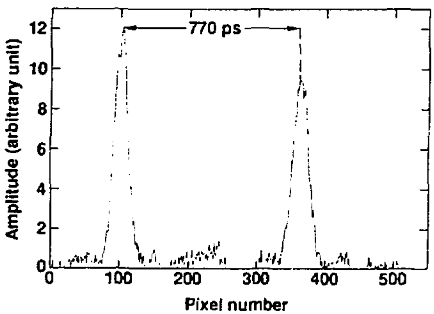

Figure 4. Two successive pulses in the unbunched linac beam used to calibrate the streak camera and the SIT camera.

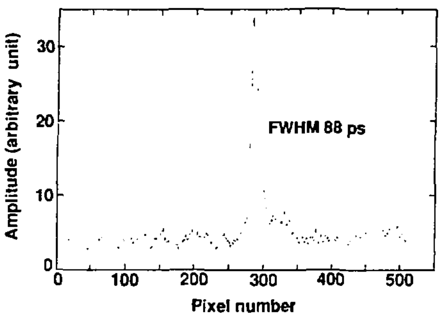

Figure 5. A linac electron pulse recorded by our 1100-m detection system.

4. POTENTIAL APPLICATION AND DISCUSSION

Aside from the obvious applications of our detection system for electrons, x rays, and gamma rays, a very interesting potential application exists for measurement of the laser fusion burn width. In this application, a plastic converter may be placed on the GaAs detector to enhance the efficiency of the system for detecting 14-MeV neutrons. This should provide a neutron-detection resolution of less than 50 ps, and the detector would be much simpler and smaller and could be placed closer to the fusion target than with previous schemes using a neutron streak camera[2] or a gated-transmission-line neutron diode.[3]

The 30-m detection system is relatively simple and straightforward and is expected to have a useful dynamic range. For the 1100-m system, even though our preliminary data indicate that 80-ps resolution can be obtained, much more work needs to be done to determine if there is chirping in the laser or pulse compression in the long fiber. Also, although each component of the detection system has a reasonable linear region, the dynamic range of the whole system has yet to be determined.

Cr-doped GaAs is a fast radiation detector and has been used as the substrate of the GaAlAs laser diode. It is a natural next step to integrate the radiation detector and the laser transmitter into a single chip and mass-produce an array of such devices for x-ray spectroscopy or x-ray and gamma-ray imaging. We are well under way toward obtaining such an integrated detector-transmitter.

5. ACKNOWLEDGMENTS

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6. REFERENCES

1. C. L. Wang, M. D. Pocha, J. D. Morse, M. S. Singh, and B. A. Davis, "Ultrafast photoconductor radiation detectors," in these Proceedings.

2. C. L. Wang, R. A. Lerche, H. Medecke, G. E. Phillips, and M. S. Singh, Rev. Sci. Instrum. 57, 1749 (1986).

3. C. L. Wang et al., Rev. Sci. Instrum. 56, 1096 (1985).