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INTEGRATED OPTICS AT LAWRENCE LIVERMORE NATIONAL LABORATORY

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Abstract

We discuss lithium niobate and gallium arsenide integrated optical device work at Lawrence Livermore National Laboratory. Specifically, we focus on application of these devices to high speed diagnostic systems and fiber optic links.

Summary

Wide bandwidth, low drive voltage, small size and weight, and immunity from electromagnetic interference makes integrated optical devices key components in many optical fiber based systems. While the initial impetus behind much of the early integrated optical device work was the telecommunications industry, other applications have emerged, including optical fiber gyroscopes and optical signal processing systems. Our interest in integrated optical devices stems from a need to develop high speed, single shot, data acquistion systems for nuclear weapons tests. Indeed, integrated optics is the preferred technology for transmitting this information with high fidelity, bandwith, and density. While our application for these devices is relatively unusual within the technical community, the excellent device performance specifications which we demonstrate will hopefully hasten introduction of these devices into many other defense systems. Here, we describe the design, fabrication, and evaluation of high speed lithium niobate and gallium arsenide integrated optical devices.

In much of our early work, we have focused on lithium niobate Mach-Zehnder integrated optical modulators which operate at a wavelength of 800 nm. This wavelength is compatible with the spectral sensitivity of the streak camera based diagnostic systems which are frequently used in nuclear weapons tests (Fig. 1). In these diagnostic systems, the voltage output from a radiation detector is applied to an integrated optical modulator, thus externally encoding information from the experiment on a laser carrier. The signal is then transmitted over optical fibers, and the resulting intensity variations are recorded on a streak camera. Specifically, we have fabricated Mach-Zehnder integrated optical modulators for these diagnostic systems which have 22-GHz bandwidths, 10-volt switching voltages, and 4-dB optical insertion losses. In addition, we have fabricated 1300-nm Mach-Zehnders which have 18-GHz bandwidths, 7-volt switching voltages, and 4-dB optical insertion losses. While these 1300-nm devices are incompatible with the streak camera based system shown in Fig. 1, these devices can be used in single-shot instrumentation systems in which a high speed photodetector is coupled to an oscilloscope. Finally, the excellent performance characteristics of these devices makes them quite suitable for other wide bandwidth, low drive power applications, such as fiber optic links for aircraft.

In addition to our work in lithium niobate, we have investigated the response of gallium arsenide integrated optical devices to radiation from a Febetron. The Febetron produces 3-ns pulses of x-rays in the energy range 300-700 keV. We monitored the prompt radiation effects on a ridge optical waveguide ($Ga_{0.85}Al_{0.15}As$ / $Ga_{0.75}Al_{0.25}As$/ GaAs substrate) using a streak camera recording system. For example, we have examined radiation luminescence induced in the waveguide when the Febetron pulse impinges on the structure. The experimental setup is shown in Fig. 2. Fig. 3 shows the resulting streak camera trace, with an initial rapid increase in light intensity followed by a gradual decay. Although the band gap edge of the waveguide is 810 nm, the observed luminescence occurs at a wavelength of 750 nm, implying that a band-filling process is occurring within the semiconductor. We are presently conducting further experiments in order to understand the exact physical processes which are occurring.

In summary, we have discussed lithium niobate and gallium arsenide integrated optical device work at Lawrence Livermore National Laboratory. While our ultimate applications for these devices are relatively specialized, their excellent performance specifications should, nevertheless, make them quite useful for other types of defense systems.

Acknowledgments

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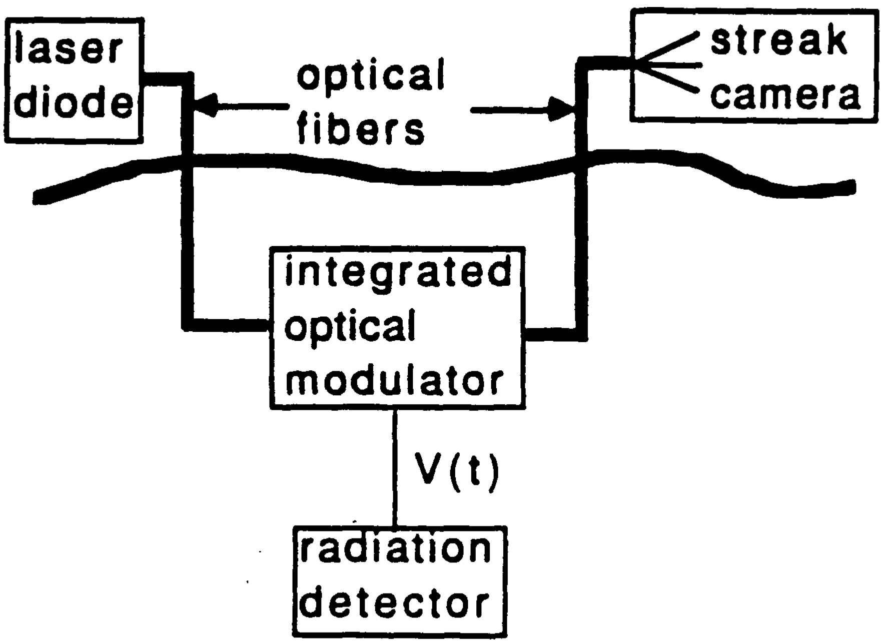
Figure Captions

Fig. 1. High speed integrated optical diagnostic system.

Fig. 2. Experimental set-up for measurement of prompt radiation effects on gallium arsenide integrated optical waveguide.

Fig. 3. Streak camera trace showing radiation induced luminescence in optical waveguide.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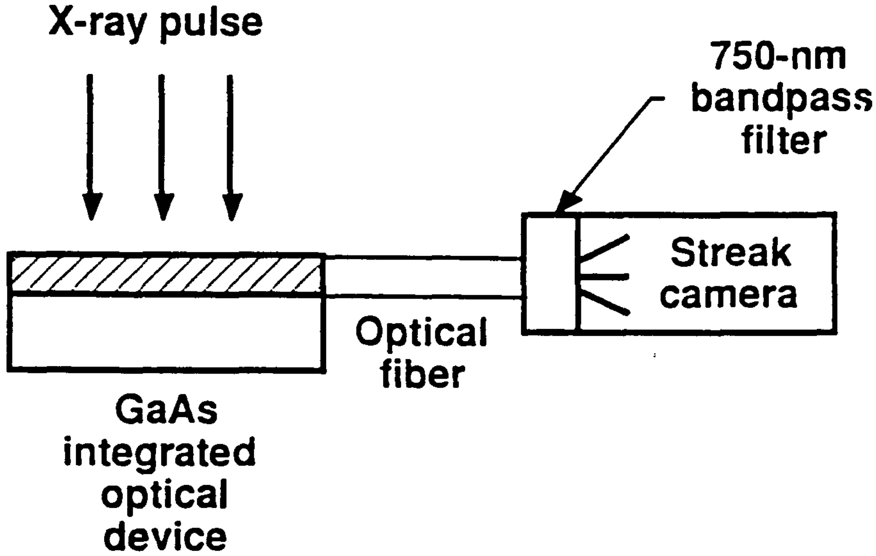
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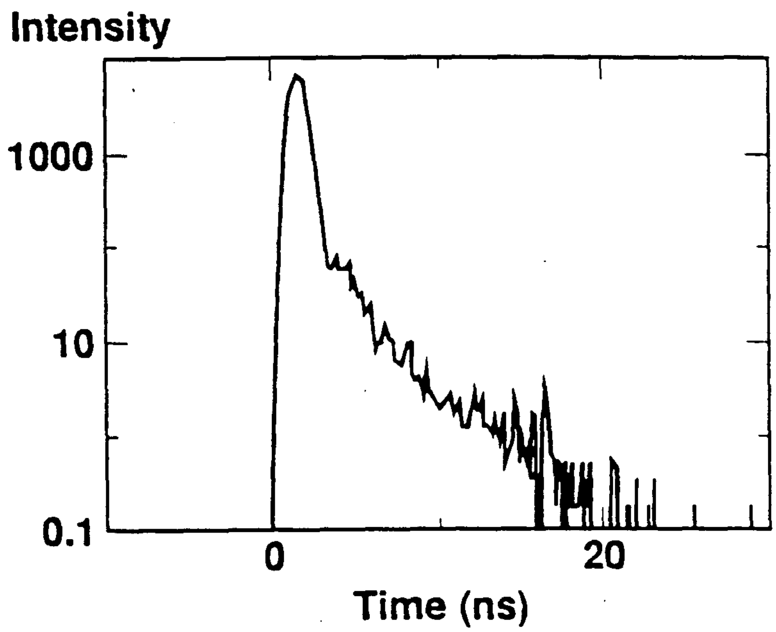
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