Prompt Experimental Diagnostics

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This project leverages the efforts of subsystems already in place for 1) prompt transcoding of x rays to the optical domain using x-ray induced changes in the refractive index of III-V semiconductor resonant optical cavities; and 2) high-fidelity, single-shot recording of ultrafast optical waveforms implementing temporal imaging and optical deflection-based techniques. An integrated diagnostic combining these subsystems has the potential for recording x-ray transients with near picosecond resolution and high dynamic range.

Project Goals

There are numerous challenges associated with the integration of these subsystems. They include the spectral compatibility of the transcoder and recorders, high peak power probe sources that do not disturb the transcoder resonance; synchronization of probe and signal to recorder temporal windows; and maintaining signal throughput. The goal of this project is to address these issues and arrive at an architecture that can preserve near picosecond temporal resolution and dynamic range in excess of 8 bits.

Relevance to LLNL Mission

The experimental validation of codes used to model fusion burn is critical to stockpile stewardship at LLNL. Expected radiation signatures on NIF will exhibit picosecond-scale features that span many orders of magnitude. Conventional recording instruments such as streak cameras do not have sufficient dynamic range at these timescales. The system created by this project will deliver a unique, high-performance recording capability for upcoming NIF experiments.

FY2009 Accomplishments and Results

Over the past year we made continuing improvements to the speed of the transcoder response. Building on FY2008 work, we used ion implantation to create crystal defects that aid electron-hole pair recombination and achieved the fastest transcoder devices built to date.

In a GaAs device, a sub-ps 800-nm impulse was transcoded to 930 nm with a resolution of 1.1 ps (Fig. 1). In an InGaAsP device, the same impulse was transcoded to 1560 nm, with a resolution of 2.3 ps (Fig. 2). A secondary consequence of ion implanting is increased absorption that can spoil the resonance and reduce x-ray sensitivity. To mitigate this effect, we conducted a study of post-implant thermal annealing and found it to be effective at minimizing some of the induced absorption without compromising device speed. Historically,

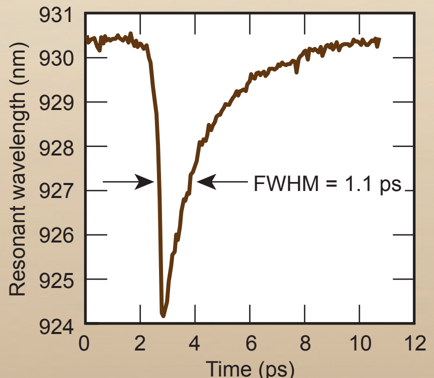

Figure 1. **Optical pump-probe data from a 930-nm GaAs transcoder showing a 1.1-ps response.**

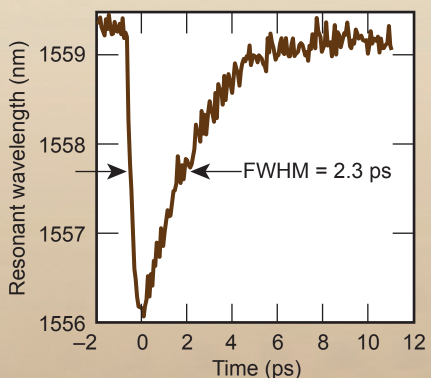

Figure 2. **Optical pump-probe data from a 1560-nm InGaAsP transcoder showing a 2.3-ps response.**

the epitaxial growth of the cavity layer has not been controlled with sufficient precision to guarantee resonances directly compatible with probe sources. Several effective means of resonance tuning were demonstrated this year including the addition of silicon trim layers, as well as angle and temperature adjustment.

The temporal imaging-based transient recording system has been reconfigured and rebuilt to increase the record length to 200 ps, increase the time magnification to 42 X, and improve the systems resolution and dynamic range. Figure 3 shows the response of the recorder to a single 776-fs input pulse (as measured using a frequency resolved optical grating (FROG)). Multiple single-shot output measurements recorded with a 30-GHz photoreceiver on a 20-GHz oscilloscope, after time magnification, are shown in blue, with the average width being 1.02 ps FWHM. This indicates a recording system resolution of 660 fs (Gaussian deconvolution approximation). In order to acquire recordable signals from the transcoder, we built a pulsed probe source with rectangular pulse width of 5 ns and peak power of 100 W, but only 1 mW of average power to avoid thermal activation of transcoder device.

The SLIDER all-optical streak camera recording system was upgraded with a single-box 800-nm Ti:Sapphire pump source capable of lock-to-clock operation. This will later enable relocation of the system from a tabletop to an experimental HEDP facility, and synchronization of the optically-induced deflection to the incoming signal. In order to probe the GaAs transcoders, we constructed a grating-based stretcher that generates pulse widths up to 500 ps with only 1 nm of bandwidth so as to maintain compatibility with the transcoder cavity resonance line width. Because the 930-nm probe pulses are generated with a compact optical parametric amplifier that uses a portion of the 800-nm pump source, they are inherently synchronized. As an early test of an integrated transcoder-recorder system, a transcoded optical impulse was recorded using SLIDER (Fig. 4).

Related References

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2. Bennett, C. V., B. D. Moran, C. Langrock, M. M. Fejer, and M. Ibsen, "640 GHz Real-Time Recording Using Temporal Imaging," *OSA Conference on Lasers and Electro-Optics*, San Jose, California, May 2008.
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4. Sarantos, C. H., and J. E. Heebner, "Ultrafast Optical Beam Deflection in a GaAs Planar Waveguide by a Transient, Optically-Induced Prism Array," *Integrated Photonics and Nanophotonics Research and Applications*, 2008.
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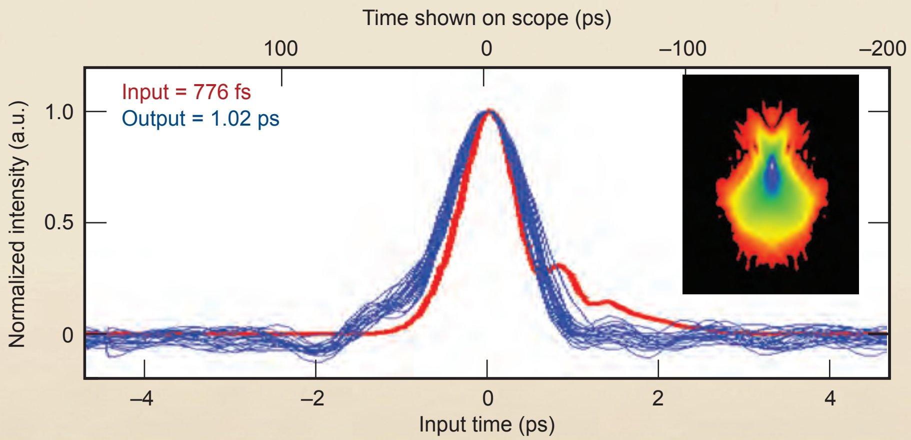

Figure 3. Temporal imaging of a 776-fs impulse with inset FROG measurement.

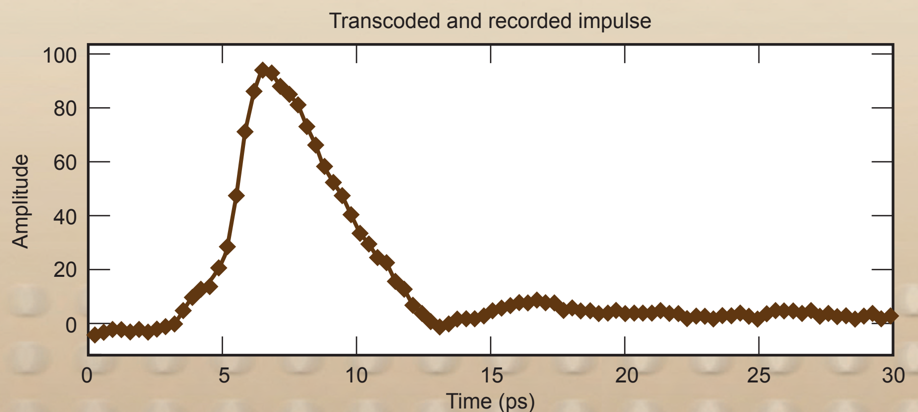

Figure 4. Pulse converted from an 800-nm above-bandgap x-ray surrogate beam using a GaAs transcoder and recorded using SLIDER. The system resolution is 3.9 ps.