Recirculating Optical Probe for Encoding Radiation (ROPER)

Stephen P. Vernon
(925) 423-7826
vernon1@llnl.gov

LLNL is performing physics experiments on the NIF, OMEGA and Phoenix platforms, including those addressing DT burn physics, equations of state, and dynamic material properties. The dynamic range, spatial resolution, bandwidth and noise robustness required in these experiments are extremely challenging and surpass present capabilities. This project is undertaking engineering reduction-to-practice of a picosecond response time, radiation to optical down-converting detector that can address these requirements. The concept can be optimized for the detection of x rays, γ rays and neutrons.

The Recirculating Optical Probe for Encoding Radiation (ROPER) sensor is a resonant optical cavity consisting of high-reflectance mirrors that surround a direct band-gap semiconductor detection medium (Fig. 1). Radiation absorption within the detection medium induces a change in its optical refractive index. The index change produces phase modulation of an optical probe beam that transits the sensor medium. Interferometry is used to convert the phase modulation to amplitude modulation. In effect, the sensor down-converts the radiation signature to amplitude modulation of the optical probe beam.

Ultrafast, approximately picosecond response is achieved using a H^+ ion implant of the sensor medium to tailor the sensor temporal response. The H^+ implant produces a high volumetric density of recombination centers in the medium that increases the carrier recombination rate and, therefore, reduces the temporal duration of the transient index perturbation.

Project Goals

The ROPER project was re-scoped in FY2008. The new plan focused on incorporating the H^+ ion implant process in our engineering of the ROPER sensors to produce detectors with approximately picosecond response times. Sensors were built for integration and testing with prototype, next-generation, all-optical recording systems at LLNL. The recorders operate at 900 and 1535 nm, respectively; GaAs technology was used for the 900-nm sensors, and

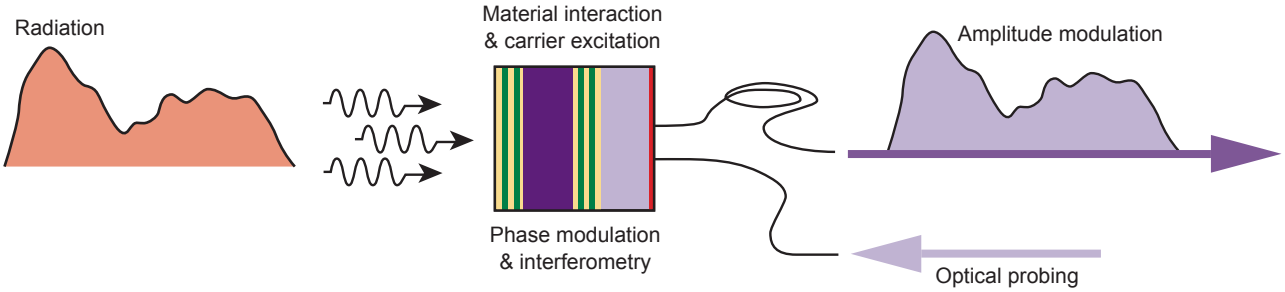

Figure 1. The ROPER system. Radiation absorption within the ROPER sensor modifies the sensor optical refractive index. Interferometric detection of the phase-modulated probe beam converts the radiation signature to an amplitude modulated optical signal.

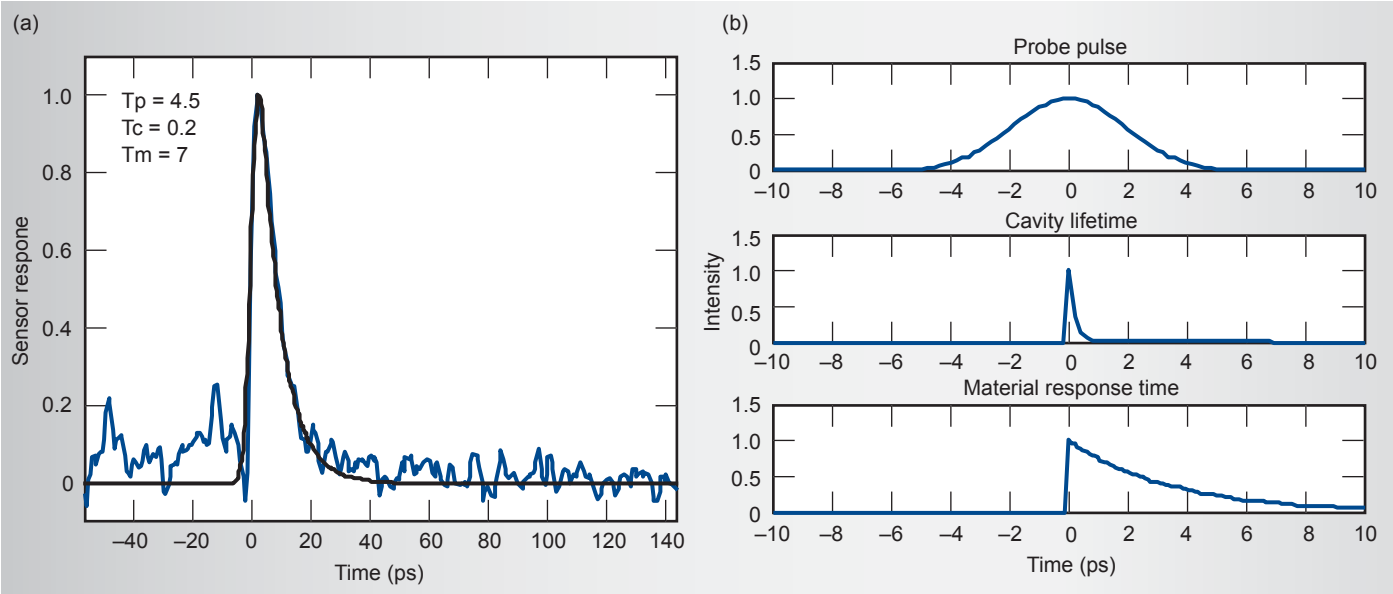

Figure 2. (a) Measured ROPER sensor response using pump-probe techniques and above-bandgap optical excitation of the sensor. The signal is the convolution of the probe pulse, cavity temporal response, and material temporal response (b). The analysis indicates a material response time of ~7 ps.

InGaAsP technology was used for the 1535-nm application.

Relevance to LLNL Mission

This project specifically addresses the instrumentation requirements of Weapons and Complex Integration (WCI). It is well aligned with institutional Science and Technology Plan thrust areas in Weapons Science ("Advanced Experimental Platforms Including Diagnostics") and Discovery Class Science ("Beyond-State-of-Art Instrumentation and Measurement Capabilities"). The project enhances LLNL's core competency in measurement science at extreme dimensions. In addition, we anticipate that, when available, ICF and HEDP experimental programs will identify applications for these detectors.

FY2008 Accomplishments and Results

In FY2008 we successfully combined the radoptic and ion-implant technologies in a reduction-to-practice effort yielding ROPER sensors with approximately picosecond temporal response. This was demonstrated experimentally in pump-probe measurements using above band-gap optical excitation of the sensor medium. The excitation pulse was ~200 fs from a mode-locked Ti:sapphire laser and regenerative amplifier operated at 780 nm. The probe pulse was generated using an optical parametric amplifier pumped by the same Ti sapphire oscillator. Figure 2a illustrates the measured sensor response of ~7ps. This is a convolution of the probe pulse, the material response time, and the sensor cavity lifetime, illustrated in Fig. 2b.

Related References

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Project Summary

H^+ ion implant techniques were used to fabricate radoptic ROPER radiation sensors with approximately picosecond temporal response. This represents a five-order-of-magnitude improvement in sensor response time. (ROPER sensors using undamaged material exhibit response times ~ 200 ns.) The spatial distribution and intensity of the ion dose can be selected to tune and optimize both the temporal response and the detection sensitivity of the ROPER sensor for specific radiation detection applications.