Serrated Light Illumination for Deflection Encoded Recording (SLIDER)

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Conventional streak cameras are capable of sweeping electron beams at picosecond timescales. Unfortunately, space-charge effects lead to blurring at high signal levels, forcing an unforgiving tradeoff between resolution and dynamic range. Due to their absence of electrical charge, deflecting optical beams do not suffer from this limitation. A streak camera based on a deflecting optical beam thus has the promise of preserving high dynamic range at a timescale limited by the sweep rate of the deflection mechanism.

Project Goals

Deflecting a beam of light at a sweep rate required to achieve picosecond resolution has never been accomplished. We set out to demonstrate a novel deflection mechanism that can sweep an optical beam through multiple resolvable spots at near picosecond intervals. Implementing this deflection mechanism as a recorder, we set a goal of achieving near picosecond resolution with a 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. X-ray to optical transcoders are capable of imprinting x-ray signals on an optical carrier for transmission on a high bandwidth optical link. At a suitable standoff distance, the all-optical streak camera demonstrated in this project can record the imprinted signals with high fidelity and picosecond resolution on a single-shot basis.

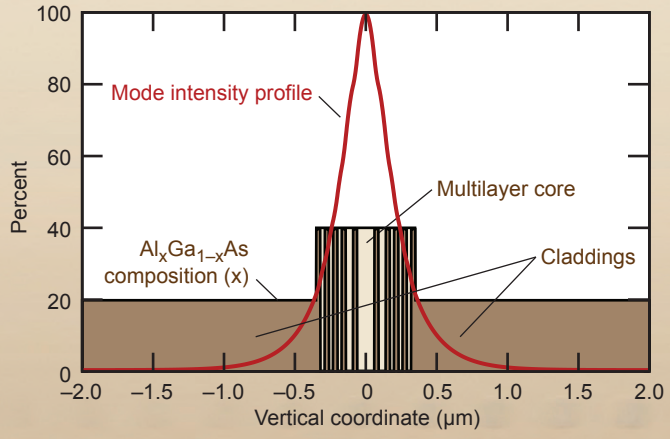

Figure 1. Multilayered waveguiding structure designed to limit the effective saturation fluence to 250 μJoules/cm². Also shown is the mode profile for the guided mode.

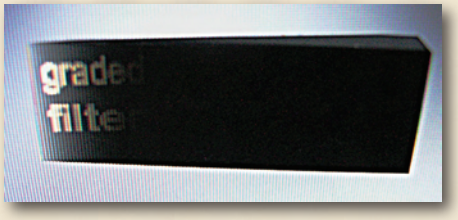

Figure 2. Graded filter used to compensate for the free-carrier absorption-induced falloff in transmission that increases with deflection.

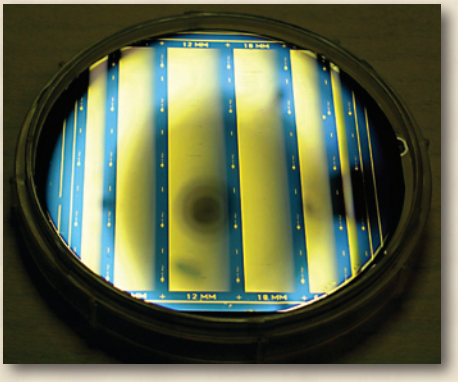

Figure 3. Array of SLIDER samples with varying gold prism patterns. The prisms are too fine to resolve and show up as a gradient. Wider patterns require more pump energy, are more likely to have end-facet defects, but can support multiple angularly multiplexed channels. Narrower patterns require less energy and result in higher device yield after cleaving, but limit the record over which the deflecting beam remains contained within the prism pattern.

FY2009 Accomplishments and Results

In the first two years of this project, we demonstrated a novel, ultrafast, optical beam deflection technique based on an array of transient, optically-induced prisms within a GaAs/AlGaAs planar waveguide. This year, we investigated the use of multilayered vs. step-index waveguides to provide extra degrees of freedom in controlling the saturation of the generated refractive index profile (Fig. 1). While it is not possible to mitigate free-carrier absorption while retaining free-carrier induced refractive index changes, we were able to demonstrate that the saturated effective index change can be limited to only the amount required for our desired resolution. This has the practical advantage of 1) stabilizing the shot-to-shot fluctuations in pump energy, and 2) flattening the effect of the nonuniformities in the pump beam creating the prisms, thereby reducing the wavefront error induced breakup of the deflecting focused spot. Free-carrier absorption limits the useful dynamic range to approximately 50 resolvable spots that can be allocated for high resolution or long record. To mitigate this, we investigated the use of transmission flattening by use of attenuation gradients inserted just before the recording plane of the camera.

To test this concept, we fabricated a custom graded filter from absorbing glass with a wedge angle designed to compensate for the reduction in transmission as a function of deflection (Fig. 2). We also varied the width of the serrated prism patterns to optimize the deflection per unit pump fluence (Fig 3). Using an optimized 8-mm-wide sample, we recorded several ring-down patterns (Fig. 4) and achieved a temporal resolution of 1.1 ps.

Related References

1. Heebner, J. E., and C. H. Sarantos, "All Optical Streak Camera, " *Conference on Lasers and Electro-Optics*, 2008.
2. Heebner, J. E., and C. H. Sarantos, "Ultrafast Optical Beam Deflection in a GaAs Planar Waveguide by a Transient, Optically-Induced Prism Array," *Integrated Photonics and Nanophotonics Research and Applications*, 2008.
3. Heebner, J. E. and C. H. Sarantos, "Progress towards the All-Optical Streak Camera," *Conference on Lasers and Electro-Optics*, 2009.
4. Bennett, B. R., R. A. Soref, and J. A. del Alamo, "Carrier-Induced Change in Refractive Index of InP, GaAs, and InGaAsP," *IEEE Journal of Quantum Electronics*, **26**, p. 113, 1990.

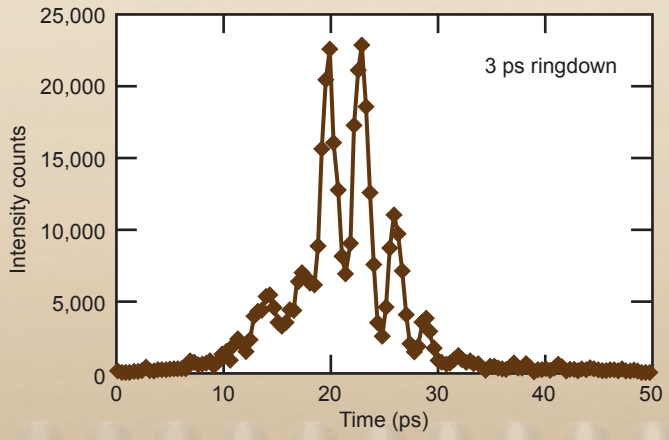

Figure 4. Recorded ring-down pattern from a Gires-Tournois cavity with 3-ps round trip spacing. Four pulses are clearly resolved within 10 ps. The resolution is 1.1 ps. Most of the background pedestal results from scattering at defects present at the waveguide facets.