Transient Sampling

For more information contact **Craig S. Halvorson**
(925) 422-6580, halvorson1@llnl.gov

Many physical phenomena studied at LLNL exhibit complex dynamics that require picosecond or faster temporal resolution. The fastest available commercial oscilloscopes have a resolution on the order of 35 ps. One way to achieve faster resolution is to use the optical portion of the electromagnetic spectrum, which has an inherent bandwidth several orders of magnitude greater than microwave electronics.

The transient sampling data recorder works by converting an electrical signal into an optical signal, which is injected into a recirculating fiber loop. Each time the signal circulates in the loop, some of the signal is picked off and recorded using a sampling oscilloscope. Sampling oscilloscopes have much greater bandwidth than storage oscilloscopes, but require repetitive signals. After being sampled, the signal is regenerated using an erbium-doped fiber amplifier (EDFA), and injected back into the loop. The process is repeated a few thousand times, and the sampling oscilloscope builds a detailed record of the transient signal. The apparatus is shown in Fig. 1.

Project Goals

The goals of the project are to build a high-bandwidth transient sampling data recorder, characterize it, and obtain a quantitative understanding of the technology.

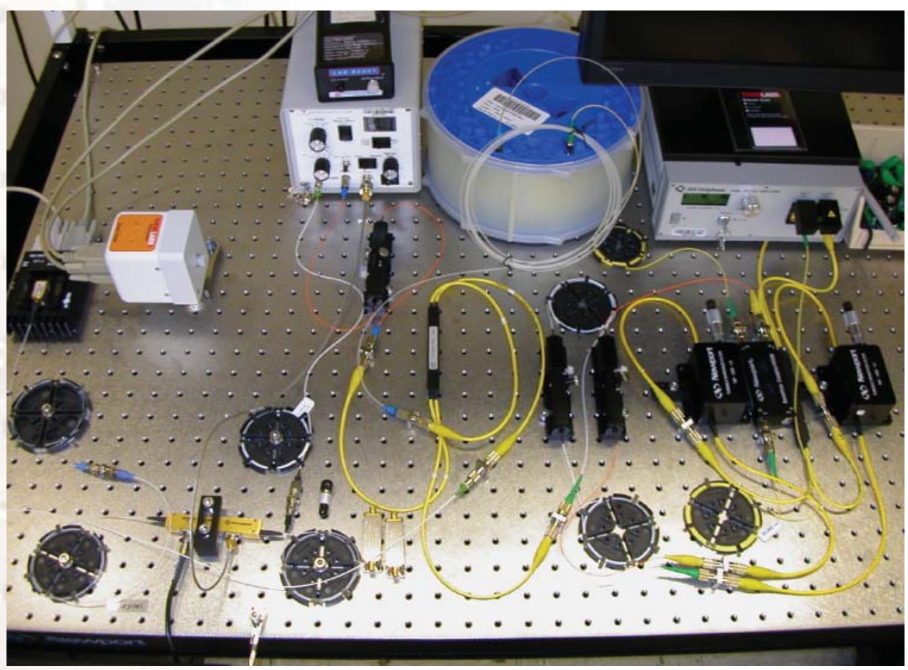

Figure 1. Transient sampling apparatus.

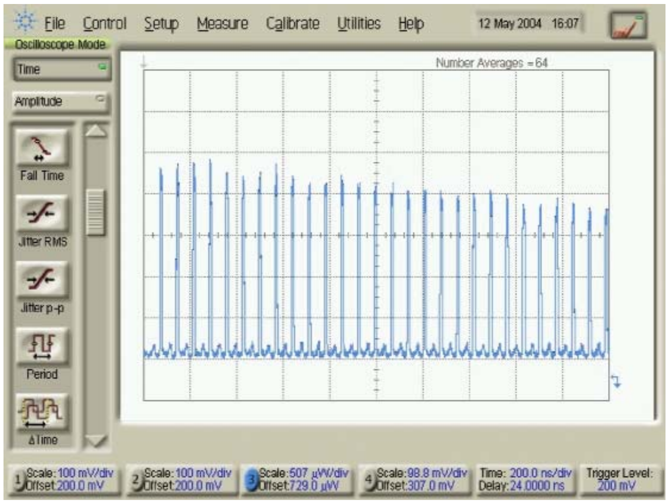

Figure 2. Gain clamping results in multiple signal replicas.

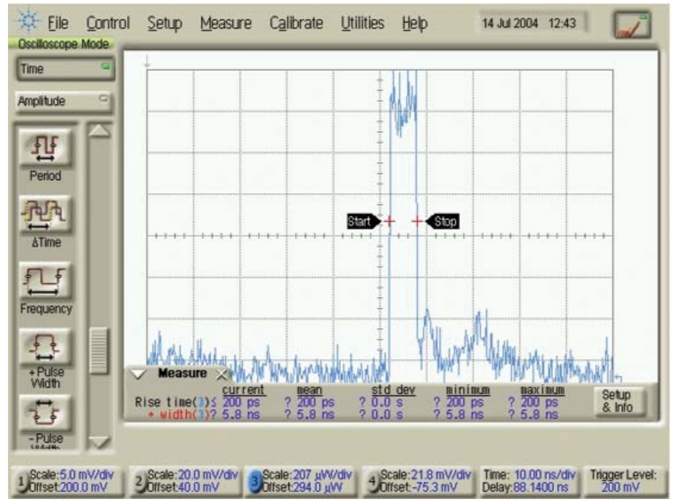

Figure 3. Transient square pulse recorded using the gain clamped apparatus, with 499 pulse replicas. The post-pulse noise is due to timing inaccuracies.

Relevance to LLNL Mission

High-bandwidth transient data recorders have several applications at LLNL. The high bandwidth could reveal previously unresolvable structure in the reaction history of exploding nuclear devices. Advanced diagnostics for NIF require ps resolution to follow the evolution of complex processes driven by ns and ps laser pulses.

FY2004 Accomplishments and Results

Several transient sampling data recorders were built and tested, beginning with simple proof-of-concept configurations. The injection of a transient signal was found to alter the gain dynamics of the amplifier, and this led to a rapid reduction of pulse replica amplitude. The addition of a gain clamp resulted in constant pulse amplitudes. Gain clamping an EDFA involves lasing (from noise) at one wavelength, while amplifying on another wavelength. When a transient signal is amplified, photons are removed from the lasing channel, and the amplifier gain remains constant. Gain clamping has allowed several thousand accurate pulse replicas to be created from one signal pulse (Fig. 2).

The transient sampling data recorder was tested using a one-shot square pulse. The data is shown in Fig. 3.

Related References

1. Kringlebotn, J., P. Morkel, *et al*., "Amplified Fibre Delay Line with 27000 Recirculations," *Electron. Lett*., **28**, (201), 1992.

2. Zirngibl, A., "Gain Control in Erbium-Doped Fibre Amplifiers," *Electron. Lett*., **27**, (560), 1991.

3. Sun, Y., J. L. Zyskind, *et al*., "Average Inversion Level, Modeling, and Physics of Erbium-Doped Fiber Amplifiers," *IEEE Jour. Sel. Topics Quant. Electr*., **3,** (991), 1997.

FY2005 Proposed Work

In FY2005, we will study the capabilities of transient-sampling technology. Any instrument adds distortion to signals, and this is especially true of high-bandwidth instruments. Chromatic dispersion, polarization mode dispersion, and component response times can all add distortions to signals recorded using transient sampling. By measuring these sources of distortion, an optimized data recorder can be created. Perhaps more importantly, the fundamental advantages and limitations of transient-sampling technology can be understood.

Ultimately, noise will limit the number of usable pulse replicas that may be generated, and that in turn will limit either the record length or the temporal resolution. It is not clear how many usable pulse replicas can be produced. If the number of replicas could be increased by another order of magnitude, the performance advantage of this type of data recorder could become compelling in many applications.