Making the Invisible Visible

Remote operation and self-calibration are important for today's streak camera applications.

by Michael Pavia, Sydor Instruments

Since the early part of the 20th century, streak cameras have offered the fastest way to capture an optical waveform consisting of both a time and an intensity profile. Early models consisted of a mechanical rotating drum and a large spool of photographic film to capture transient events in ballistics, energetics and detonics.

In the latter part of the 20th century, US and European governments embarked on large laser programs to simulate energetic events in a laboratory environment. Laser fusion facilities such as Omega at the University of Rochester in New York, the National Ignition Facility at Lawrence Livermore National Laboratory in California, Project Orion in Aldermaston, UK, the Laser Megajoule Project in Bordeaux, France, and other programs around the world all needed a new way to capture transient events on the order of tens of nanoseconds down to just a few picoseconds. Next-generation streak cameras began to incorporate CCD technology and image analysis software to capture and process these ultrafast images.

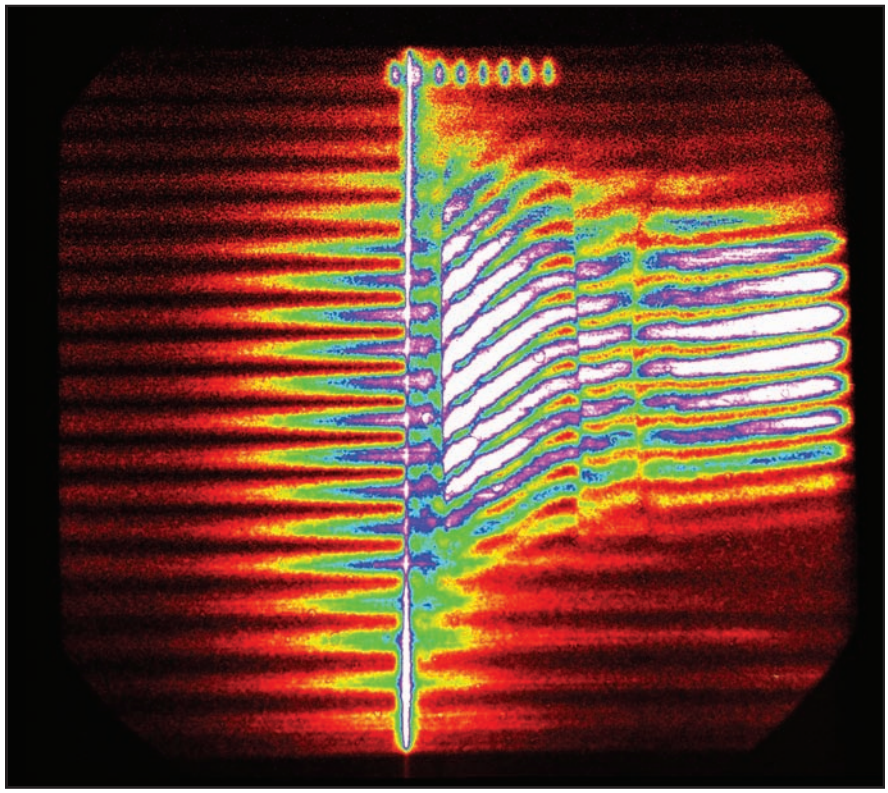

Figure 1. *In this streak image taken with a velocity interferometer and self-calibrating streak camera, fringe transitions show the breakout of a shock wave on ultrafast timescales. Note the timing reference signal at the top of the image.*

As the systems got larger and more complex, it became apparent that these cameras had to be operated remotely and calibrated in place. It simply wasn't practical to send instruments out for off-site calibration that could not be verified on the laser shot cycle, which is typically one hour or less.

Next-generation

Researchers at the University of Rochester Laboratory for Laser Energetics and at Lawrence Livermore National Laboratory embarked on a multi-year program to develop the next-generation streak camera that would offer remote operation and self-calibration with the better than 1 percent measurement accuracy required by next-generation fusion laser systems. The result was a fully self-contained optical calibration module, which Sydor Instruments of Rochester, N.Y., acquired through a technology transfer.

The module is part of a complete camera package that can perform optical analysis in situ. It enables researchers to characterize geometrical distortion, perform flat fielding of images and conduct time-base calibration. The module at the heart of the package consists of a vertical-cavity surface-emitting laser, the LED illuminator and more. A user-selectable reticule pattern enables spatial resolution and contrast measurement of the camera. Multiple channels can be analyzed simultaneously via both fiber optic and free-space input. Light is delivered to the photocathode via all-reflective fully achromatic imaging optics. Autofocus and autoalignment software scripts run motorized operation of all camera functions. The camera has multiple imaging configurations that enable x-ray, ultraviolet, visible and near-infrared operation.

It can measure timescales from a few picoseconds to several microseconds. Remote operation from up to 100 m away from the main computer server is possible via a fiber optic link to an onboard control system. A user can access all software features and functions remotely from any computer on the network by logging onto an individual camera and performing calibrations and image analysis.

Applications

Streak cameras are used in many applications for both laser and target diagnostics such as power balance, pulse shaping and beam synchronization. A key application used in target diagnostics of high-energy density physics experiments is velocity interferometry to study shock waves of various materials. By combining temporal and spatial information in the form of fringes, researchers can detect velocity and burn history information with a combination of interferometry and streaked optical pyrometry. X-ray streak cameras also are used to study x-ray emission from various target geometries. In all of these measurements, the fidelity of the data must be ensured on the shot cycle.

Although laser fusion is the main application for these cameras, others are emerging in the life sciences. Researchers are using streak cameras for fluorescence lifetime imaging and Förster resonance energy transfer. These techniques enable high-content screening to accelerate the drug discovery process. Others are using the single-photon-detection capabilities of these cameras in conjunction with spectrometers for bioluminescence studies. For example, studying the time, intensity and wavelength signature of plant material can provide insight into disease-resistant crops.

Many applications that require high signal-to-noise, high dynamic range and single photoelectron detection are well suited for streak imaging. Many of them are "needle in the haystack" problems that require detection of very low level transient signals with high-fidelity data recording. For example, detecting a transient red signal in a blood sample using intensity and wavelength is extremely difficult, but by adding the time domain and gating the camera to carve out the temporal signal of interest, that parameter can be discriminated above the background.

Today, false-positive or false-negative test results are problematic in

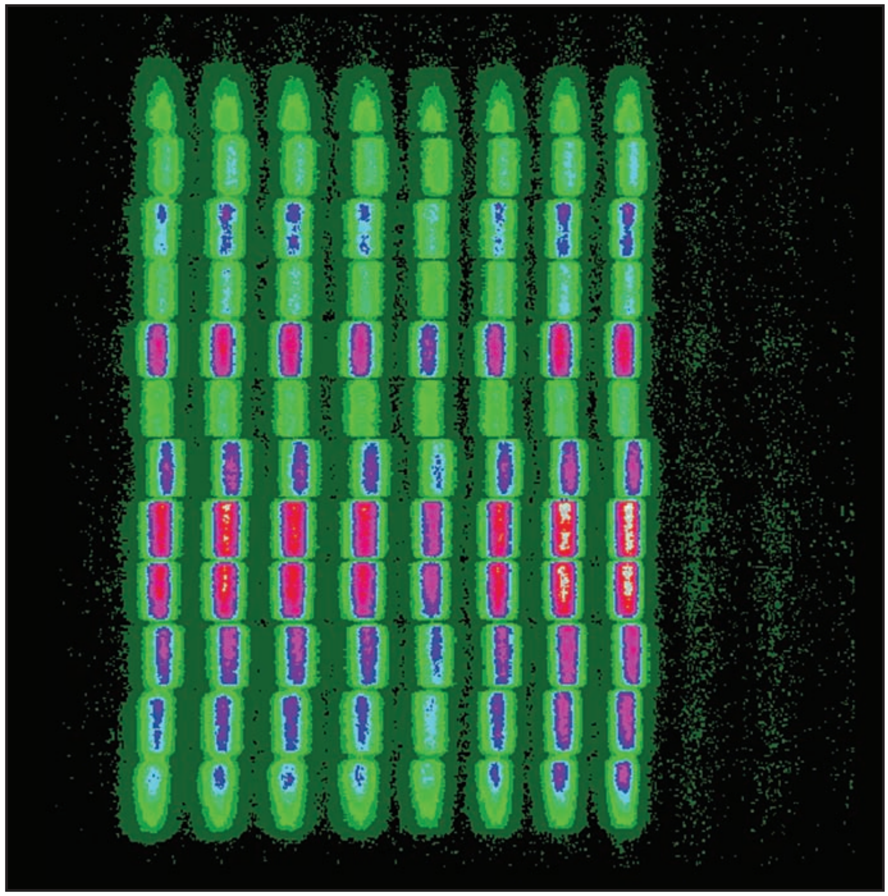

Figure 2. *This streak calibration image was taken using a slow ramp technique. Spatial information is taken at several points in the image and then processed to characterize the geometrical distortion and flat fielding profile.*

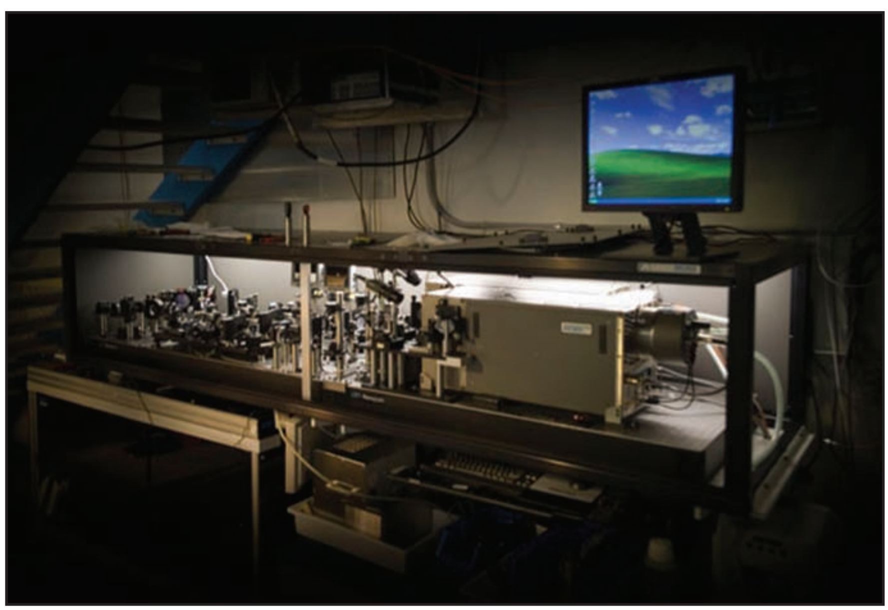

Figure 3. *An active shock breakout diagnostic is shown on the Omega laser at the University of Rochester Laboratory for Laser Energetics. Sydor built the system, which consists of a pair of streak cameras and velocity interferometers to image laser-driven shock waves for inertial confinement fusion research.*

cancer detection using blood samples. Incorrect diagnosis and failure to detect disease have huge implications. Intensity and wavelength (spectroscopic) techniques are still of insufficient accuracy to perform these critical diagnostic measurements. Yet, by incorporating the time domain, researchers can dramatically reduce the false readings in their data sets. In many applications, the time signal is found to be the most stable and reliable signal.

Streak cameras are unique imaging modalities that enable recording of intensity, wavelength and temporal information all in a single multichannel data set. As scan rates increase, this technology has the potential to revolutionize drug discovery and pathology. □

Meet the author

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Running head: Cameras at Work