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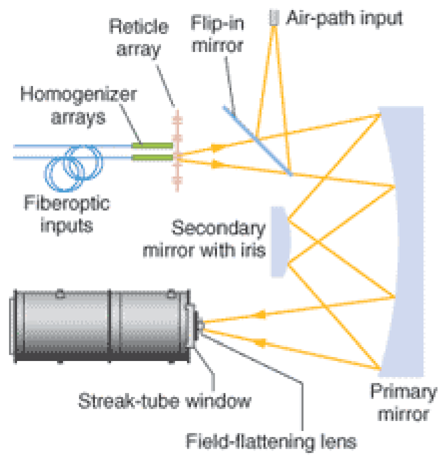
HIGH-SPEED IMAGING: Remotely operated streak camera is self-calibrating

Gail Overton

Researchers at the University of Rochester Laboratory for Laser Energetics (LLE; Rochester, NY) have developed a remotely operated stand-alone streak camera with comprehensive autofocus and self-calibration capabilities.[1] The camera was developed to satisfy a need for improved measurement of implosion and basic physics experiments in support of the National Inertial Confinement Fusion program. A prototype of the Rochester Optical Streak System (ROSS) camera has been tested by a team at the Lawrence Livermore National Laboratory (LLNL; Livermore, CA) and found to have a spatial resolution of 20 line pairs per millimeter (lp/mm), temporal resolution of 12 ps, and a dynamic range of 500 for a 2-ns window.[2]

The eight streak cameras in use at LLE for the past five years have served as a testbed for the ROSS camera. Two years ago the Rochester researchers embarked on a project to build a generic streak camera that could accept other streak tubes and could incorporate a list of subsystem upgrades that built on the experience gained in the acquisition of more than 500,000 streak records. The camera's performance is limited by the streak tube's electron optics. The input optics design is an achromatic Offner triplet mirror system with spherical aluminum-coated mirrors (see figure). A field-flattening lens can be added for use with streak tubes that have a curved photocathode plane. The design consists of two object planes; an air path for signals from external sources can be selected with a flip-in mirror, or the main path can be used for fiberoptic signals and internal calibration sources. Autofocus capability was added by building all components on motorized stages. Three independently timed shutters are used to control signal access to the photocathode. This optical setup provides the means to verify proper system focus and spatial or temporal optimization at a specific photocathode position.



Input optics for the ROSS camera are based on an Offner triplet system. An air path for signals from external sources can be selected with a flip-in mirror, or the homogenizer arrays for fiberoptic signals and internal calibration sources can be used.

A signal-to-noise-ratio goal of greater than 100 was the motivation for the repeatability and stability specification for the ROSS electronics. Housed in magnetically shielded boxes to enhance immunity to electromagnetic interference from external sources, the ROSS camera is powered from an external, well-filtered, and regulated power supply. Several 1-ms-resolution timer circuits are available for controlling shutters and CCD exposure timing. There are four remotely selectable sweep speeds; the fastest-sweep duration is 1 ns. The CCD camera used for recording is run from the camera's power supply, but the control and data link are via optical fiber and independent of the rest of the camera controls. With 2048 ×2048 pixels, each 13.5-µm square, the large-format CCD allows use of a 1:1 fiber stub to avoid losses associated with a fiber taper.

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Improved spatial resolution

The streak-camera gain was defined as the number of CCD electrons recorded per single-electron event hitting the ROSS streak tube phosphor. The Rochester researchers measured gains in the range of 108 to 150 CCD electrons per 15-keV streak-tube electron, with a noise factor of only 1.17. Analysis of a prototype ROSS camera with a Photonis (Brive, France) streak tube by scientists at LLNL confirmed the data, citing a system gain of 101 CCD electrons per photoelectron. While the ROSS system exhibits magnification, temporal resolution, and sweep linearity comparable to other industry streak cameras, its spatial resolution-measured by the LLNL team to have a 40-µm (full width at half maximum) line-spread function and greater than 20-lp/mm contrast transfer function-represents a factor of two improvement when compared to existing technology.

A unique attribute of the ROSS camera is its built-in calibration capability. “Quantitative analysis hasn’t been offered by other manufacturers because it’s very difficult to do,” says senior scientist Paul Jaanimagi at the LLE. Unlike other streak systems that may require hours or even a full day for calibration, as well as a host of external illumination sources and optical equipment, the ROSS camera can be calibrated *in situ* with its internal light-emitting diodes and slow-sweep electronic ramp signals in approximately 30 minutes. The internal light sources, as well as a selection of reticles to produce the desired spatial profile, are built into the system and allow quantitative data analysis and calibration through knowledge of the system’s flat-field response, geometric distortions, sweep speed, as well as the point-, line-, and edge-spread functions at all locations in the image.

The University of Rochester researchers have licensed the technology to Sydor Instruments (Henrietta, NY). Sydor President Michael Pavia estimates that 100 units will be sold in the next four to seven years. - *Gail Overton*

REFERENCES

1. P. A. Jaanimagi et al., *Intl. Congress on High Speed Photography and Photonics*, Alexandria, VA (September 2004). To be published in *SPIE 5580*.
2. R. A. Lerche et al., *Review of Scientific Instruments 75*, 4042 (2004).

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