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2D Recording of Image Data Using Simultaneous Ultra High-Speed Streak and Framing Cameras

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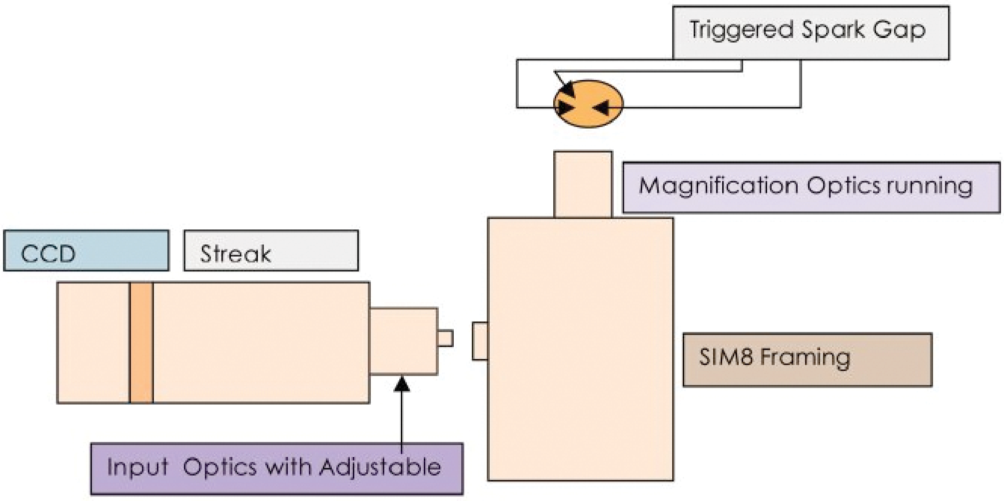

Fig. 1 *System layout.*

The ability to record simultaneous Framing Images and Streak Images has long been a requirement in the research fields of detonation, electrical discharge, bio-medical and many other applications. Early systems incorporating both framing and streak cameras used external beam splitting optics with light gathering limitations which required critical alignment of the external splitting optics. Later systems incorporated framing cameras and streak camera, built into one mainframe, using available beam splitters. This allowed for simultaneous framing and streak, however this type of beam splitter limited access to streak optics, and primarily limited the performance of the streak camera due to the smaller format streak tubes.

A new system recently configured for a proof of principle demonstration, incorporated a SIM8 Ultra Fast Framing Camera manufactured by Specialised Imaging, Ltd. of Tring, Hertfordshire, England and an Optoscope SC-10 Streak Camera manufactured by Optronis, GmbH of Kehl, Germany as a single package and attained performance levels never before achieved with a dual camera system.

An Ultra Fast Framing Camera built around a newly designed beam splitter optimized for spatial resolution with no geometric distortions and configured for up to 16 output ports was the primary imaging system. The system used for this test was configured with 9 ports. Eight of which were used for 8 channels of ICCDs for framing operation. The 9th optical port allowed a full sized Ultra Fast Streak Camera to be coupled to the system. Having the streak camera external to the framing camera allowed the use of a large format streak camera with a full sized 8-35 mm photocathode and a large 20-40 mm output screen ensuring long time windows. It also offered full access to the input streak optics. The adjustable slit and efficient lens coupling also allowing 88 filters and spectrographs to be inserted if needed. The beam splitter maintains an optical spatial resolution >70 lp/mm to ensure maximum image quality for both framing and streak modes.

This system was configured as a proof of principle in February 2007 at the Optronis GmbH laboratory in Kehl Germany. The two cameras were optically coupled as described above. As a virtual image plane is present 46 mm from the output port, setup and alignment was easily performed using the real time focus modes of both the framing camera and the streak camera with the same optical axis.

System Configurations

SIM8 Framing Camera. The Camera was fitted with 8 ICCDs and with 1360 x 1040 pixels and 12 bit digitization. This particular camera is programmable for framing speeds from 100 fps to 200 Million fps and exposure times are programmable from 10 msec to 5 nsec. Each frame has independently adjustable gain from unity to ~10,000X. Other options allow for multiple exposures in each frame if required.

The framing camera offers output pulses which are user programmable to allow for synchronization of other devices such as pulsed lasers or flash lamps. They can also be used to verify critical timing of the actual exposure with respect to other events of the experiment using oscilloscopes and time interval counters. The framing camera also has the ability to output an additional pulse prior to the framing sequence to pre-trigger devices that need to be synchronized such as flash lamps. This pre-pulse option was used to trigger the event.

For this test the Ultra Fast Framing Camera was programmed to frame at 50 Million fps, with 20 ns interframe time (leading edge to leading edge), and 10 ns exposure times. This gave a total recording time of 170 ns from the start of the first frame to the end of the last frame.

Optoscope SC-10 Streak Camera. The streak camera was built around the SC-10 main unit with 8mm photocathode and 15x20 active screen area. The main unit can be used for streak systems which provide down to 2 psec temporal resolution. The camera was fitted with the Slow Sweep Unit with programmable sweep speeds from 330 ps/mm to 5 ms/mm. The camera was also fitted with a removable 25 mm MCP intensifier which in this case was run at minimum gain due to the brightness of the event. If needed it could have been removed. The system also included a fiber optic coupled CCD camera to capture and digitize the streak image with 1360 x 1024 pixels digitized to 12 bits.

The Ultra Fast Streak Camera was programmed to streak at 100 ns/mm giving a 2 usec time window and using a 100 um slit, giving a time resolution of 10 ns, which matched the exposure time of the framing camera. The 2:1 de-magnification of the streak camera input optics allowed the use of a 16mm slit on the image plane of the 9th optical port of the Framing Camera.

To prove the operation of this Dual Camera System a triggered spark gap with a 2 mm main gap was imaged. The main gap was imaged into the primary image plane of the framing camera using a Nikon lens set of 50 mm (f1.4) and 105 mm (f2.5) lenses configured front to front to give ~2X magnification. Having access to the input optics of the streak camera the alignment of the images into the framing camera and streak camera was easily achieved using the real time focus modes of both cameras. See Fig 1. system layout.

Both cameras were programmed for the appropriate operating parameters such that the framing camera pre-triggered the spark gap. Knowing the trigger delay of the triggered spark gap, a time delay of about 1.52 usec was programmed into both the framing camera and streak camera so that the breakdown would coincide with the recording time window of both cameras.

Several tests shots were taken to ensure the jitter of the triggered spark gap in air would repeatedly occur during our recording time window. Trigger jitter of the air spark gap was typically 100 to 250 nsec.

Test Results

Framing results below show two dimensional images of the initial break down of the trigger gap which occurred sometime between frames F2 and F3, followed slightly later by the main gap break down. In the framing data we see the breakdowns occur but, as there is dead time between frame recording times, data is lost during that dead time. Programming the framing camera with no dead time between frames will minimize lost data but the total recording time window will be reduce proportionally.

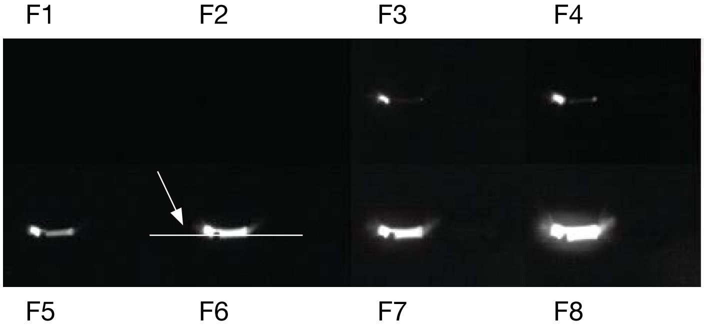

Fig. 2 *Framing Sequence at 50 Million fps, 10 ns exposures.*

The streak image, with time measurements made from the data, shows that the initial trigger breakdown (lower earlier portion of the streak) takes place about 50 ns prior to the main breakdown. The Streak Data also shows continuous recorded data as the main breakdown grows in magnitude with a rise time of about 400 ns, with no dead time in the recording data. In the intensity profile trace below, you can easily see the initial trigger pulse breakdown ahead of the main gap break-down.

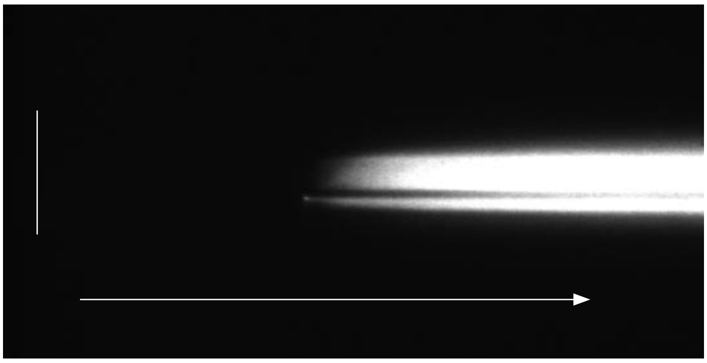

Fig. 3 *Streak Record, 100 ns/mm writing speed, ~ 2 usec total time window.*

System configuration for tests showing the Streak Camera looking into the optical port of the framing camera viewing the event through the same optical axis.

The commercial version of this system is now available with both the framing camera and streak camera rigidly attached to a single mounting plate with adjustable critical alignments for x-y-z positions and with 90° turning optics

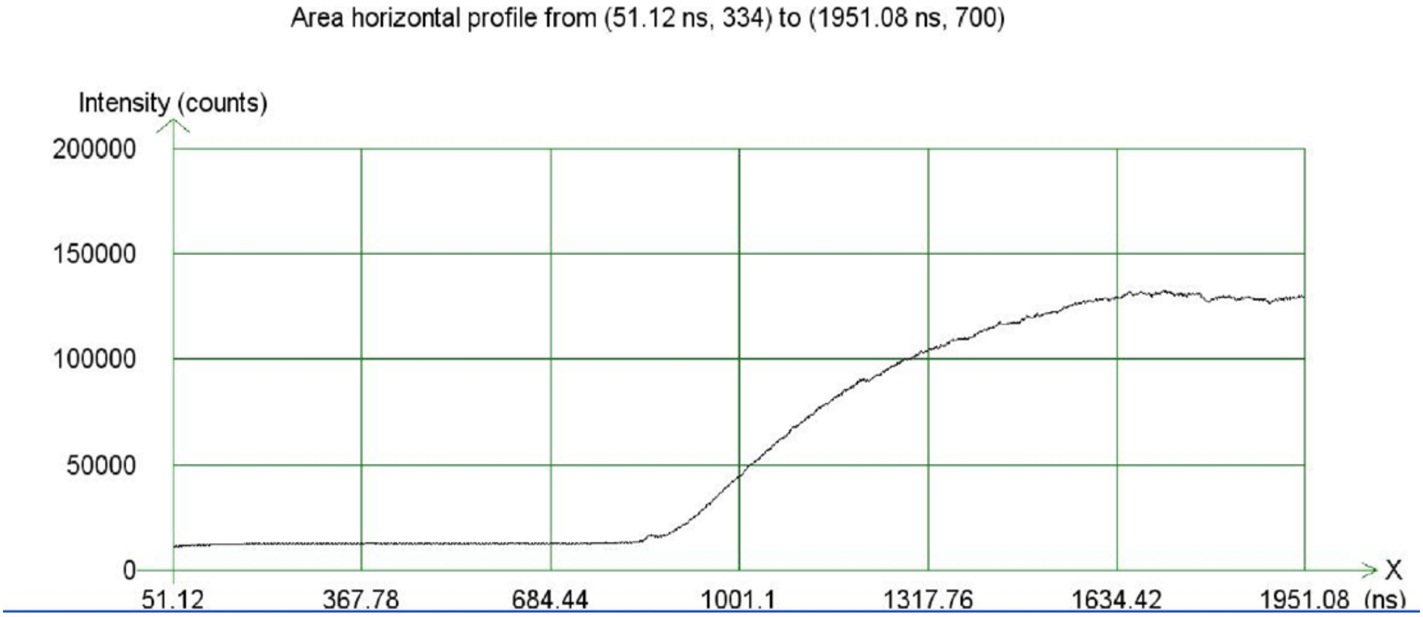

Figure 4. *Intensity Profile of Streak Image integrated over 200 horizontal lines.*

so that both cameras sit in the same orientation. The footprint is about 800 mm long and 500 mm wide allowing both horizontal and vertical mounting of the system for microscopy applications. Both cameras can be run independently if needed or combined and controlled from one computer. Both systems are controlled via Ethernet communications allowing both wire and fiber optics for long distance or high noise environments applications.

Figure 5. *Framing Camera and Streak Camera layout for test.*

Conclusion

A commercially available Ultra Fast Framing and Streak Camera configuration can easily be set up and operated with extreme accuracy in data acquisition. Data also shows that framing camera offers the advantage of two dimensional recording of image data over a large field of view. Conversely the streak camera data shows continuous recording of spatial, intensity and temporal data in the single dimension of the slit width. The framing camera could have been programmed for a minimum or for no dead time between frames but this would have limited the total record window. The streak speed could have been increased by orders of magnitude to see greater detail in the first 50 to 200 ns of the initial breakdown, but this would have shortened the total record time.

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