Application note

No. 15

Triggering for microsecond accuracy

Accurate and consistent triggering of Framing and Streak cameras is an aspect of their use which can be challenging when considering their use for the first time. Applications where events are a few microseconds in duration require single digit microsecond accuracy to make full use of the number of images available. Energetic material testing is one application where microsecond accuracy is required. Depending on the triggering method employed this application can also be subject to significant triggering jitter, so careful preparation for successful image capture is required.

The image shows a SIMX8 framing with an Optronis SC10 streak camera attached to the SIM auxiliary port. Attaching the Streak camera to the SIM allows both cameras to have the same perspective using, in this case a 105mm objective lens. Both cameras were bolted to adjustable translation stages fixed to a rigid breadboard. The event was a detonator (8mm diameter x 40mm long), fitted vertically into a wooden block. The cameras were to capture images for radial case expansion and tip velocity study. The initial tests explained here were over a 30ms time window, but later test capture windows were between 5µs and 12µs. Illumination was provided by an SI-AD500 flash lamp placed behind the detonator to provide a shadowgraph image through a diffuser. Flash lamp duration was 2ms with a rise time 80µs. Both cameras and flash lamp were protected using 5mm thick Perspex.

Triggering:

To simplify this aspect, a single common "master" trigger was used to trigger all test components. This was a delay generator that output two separate signals - T-Cam for the cameras and T-Det for the detonator. The detonator itself possessed a significant potential delay of between 15µs - 20µs following receipt of T-Det. To assist calculating the different delays for all components in this test, a timeline diagram is a useful tool to visualise the triggering relationships.

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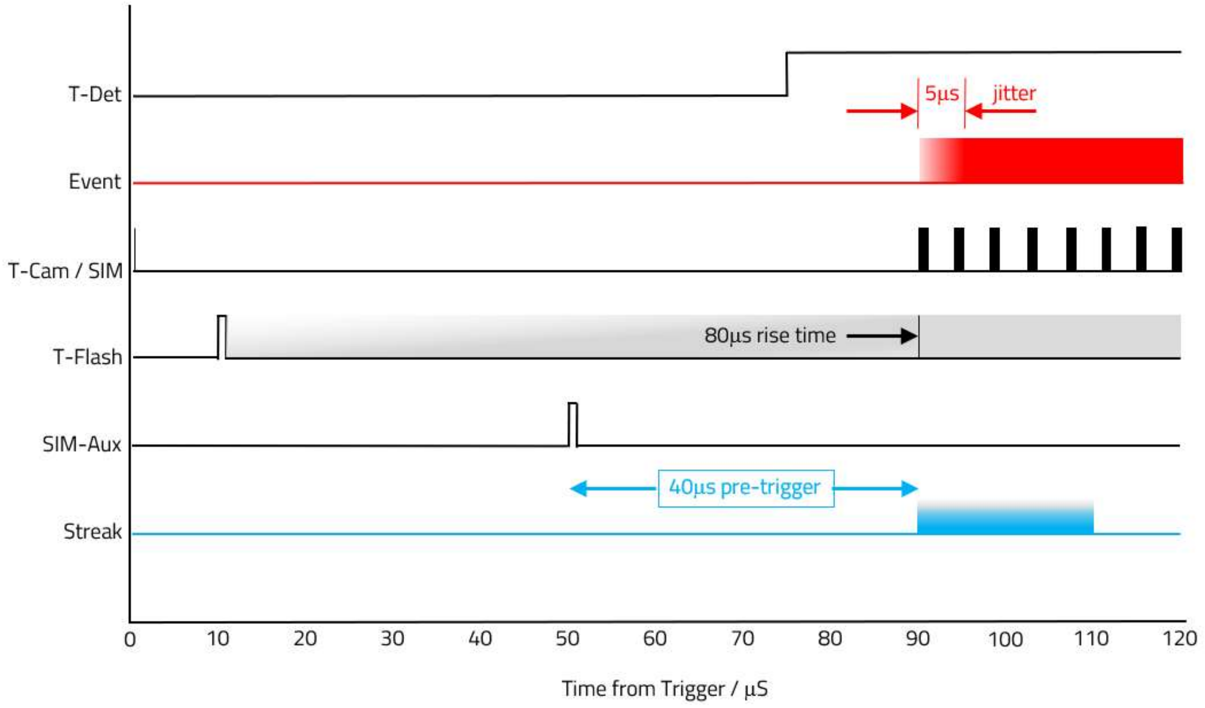


Required delays, pre-triggers & jitter:

- Flash unit pre-trigger: 80µs
- Streak camera pre-trigger: 40µs
- Event delay: 15µs - 20µs (5µs jitter)

The T-Det delay was adjusted by the "master" trigger delay generator. However, no delay was applied to T-Cam before reaching the SIM. To provide simple adjustment and maintain synchronisation between all imaging elements, the SIM internal delay generator was used to control the Streak camera and flash unit delays. This allowed independent adjustment of the SIM, Streak camera and flash unit delays using the SIM control software.

The longest required delay (pre-trigger) was 80µs for the Flash unit, so the SIM "Flash trig output" with a pre-trigger of 80µs was used. A delay from T0 of 90µs between the SIM receiving T-Cam and the first image was chosen, to allow for the 80µs flash pre-trigger. The SIM interframe time was 4.27µs (frame rate of 234,000 fps), so the total record duration was 30µs. The SIM shutter was set to 100ns.

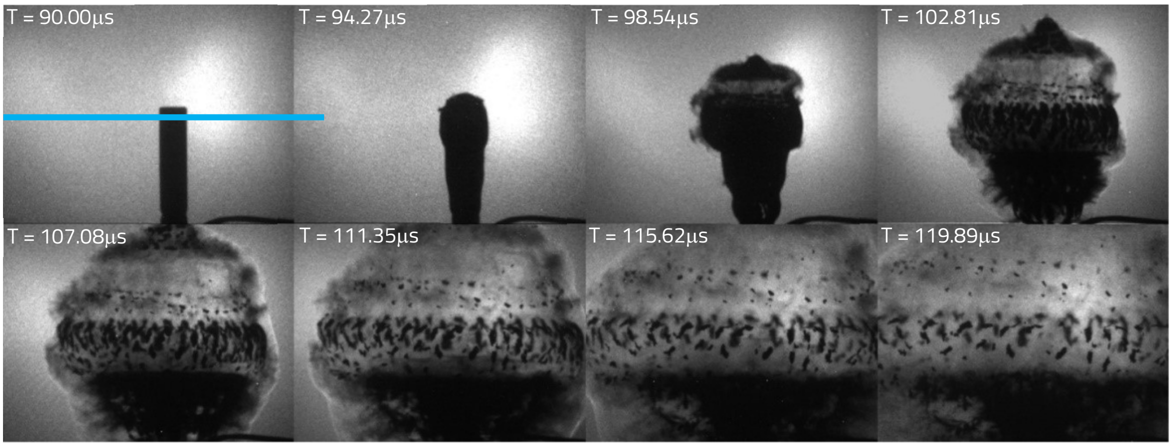
A T-Det delay of 75µs was chosen because the additional delay once the trigger was received by the detonator itself was between15µs - 20µs. The case expansion would then start between 90µs - 95µs from T0.

The Streak camera sweep rate was 1µs/mm which provided a record duration of 20µs. This camera also required a pre-trigger time of 40µs. This trigger was provided by the SIM camera Aux output.

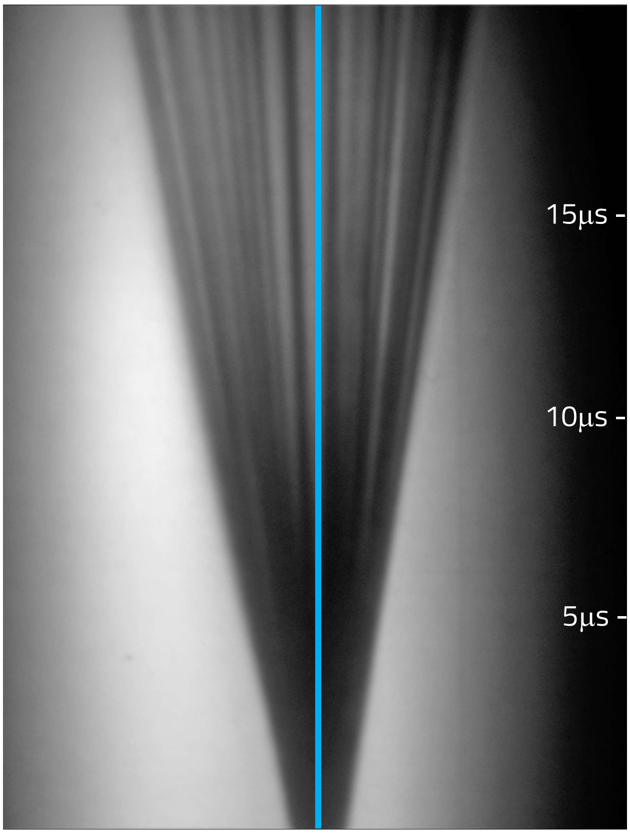
By connecting all imaging elements to the SIM camera and using the same control software to orchestrate the respective trigger delays, any necessary adjustment for different tests or changes in master trigger e.g. switching to a contact probe at the detonator surface, was greatly simplified.

Images:

The 8 SIM camera images below show the detonator case expanding, rupturing, and fragmenting over a timescale of 30µs. The expansion can be seen as not axis-symmetric.



The streak image shows the rate of case expansion, rupture and fragmentation over a shorter 20µs timescale but with much higher temporal resolution. The slit was placed just below the top of the detonator as shown blue line on SIM images above. The start of the streak sweep coincided with the first image of the SIM sequence. The streak image confirms the detonator expansion as non-axisymmetric but the rate of expansion to be linear over the first 20µs. The fragmentation stage begins when the tips of the pale streaks in the image start to appear approx. 7µs from the start of the sweep. Knowing the sweep duration and diameter of the detonator, allows the image to be calibrated.



From this the case diameter expansion velocity was calculated to be approx. 2,200m/s.

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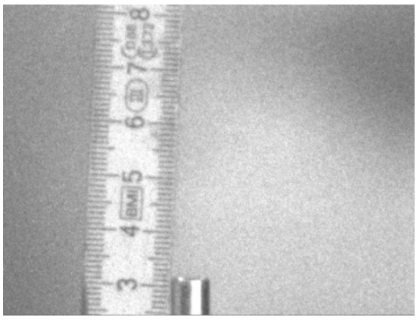
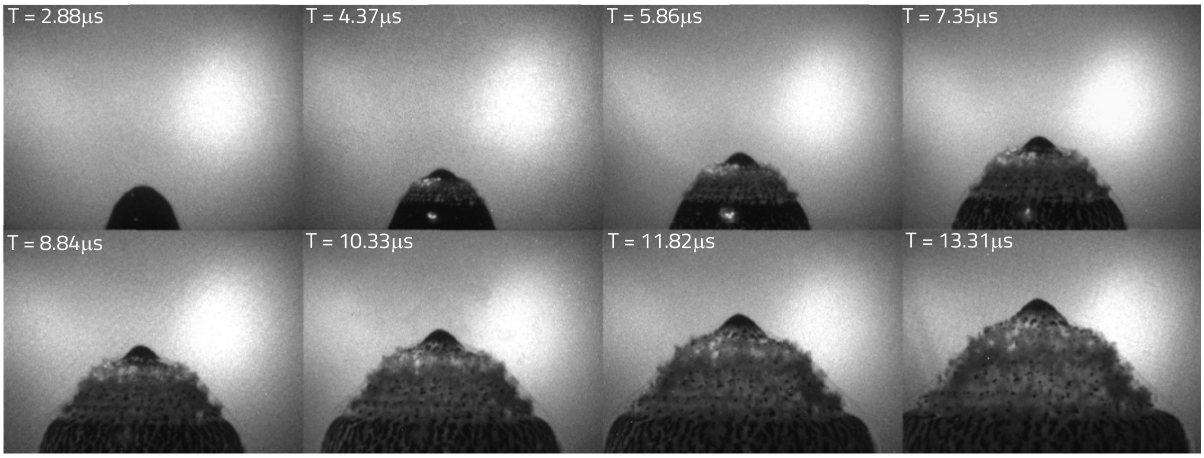
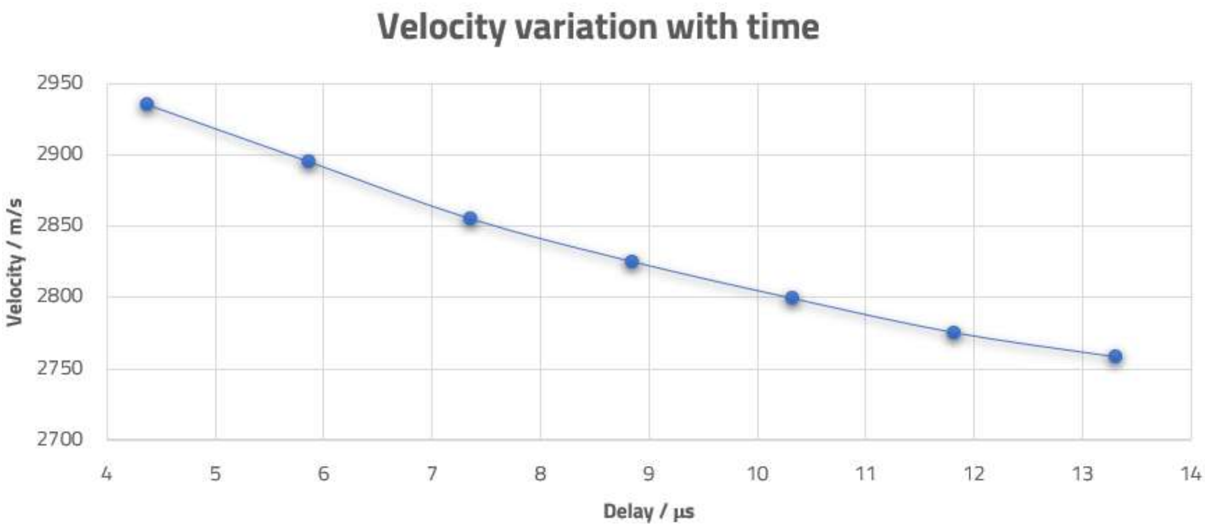
For one test the camera view and image delays were adjusted to capture data for tip velocity and deceleration measurement. The “master” trigger for this test was a “make” probe placed a short distance from the case.



The sequence below shows the tip rising over the full 8 images. Prior to the test, a set of static calibration images were taken for accurate measurements.



Using the static image to calibrate the dynamic sequence the tip velocities in images 2 – 8 could be measured using the SIM software measurement function.



With interframe times down to 1ns and exposure times as short as 3ns the SIM camera can accommodate even shorter duration events such as High voltage discharge. For all these applications, using the SIM camera for imaging, and as a delay generator to streamline the triggering of additional instrumentation, such events with microsecond or shorter timescales can be captured by multiple forms of instrumentation, and adjustments made easily to meet changing test requirements. In addition, measurements can be made minutes following a test using the SIM camera software.

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