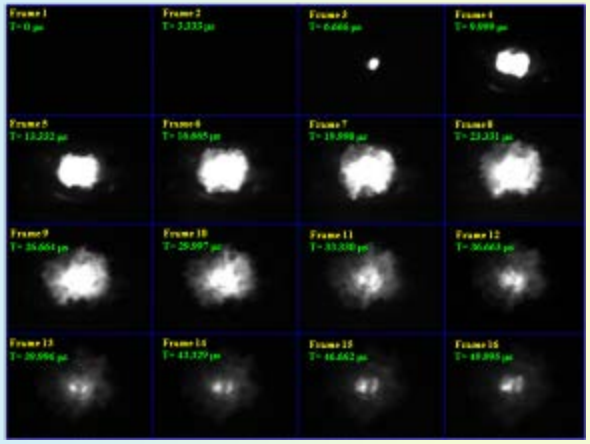
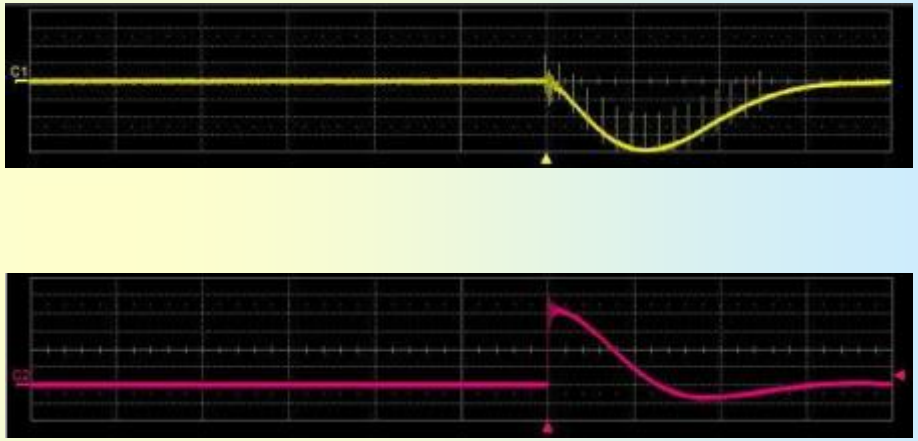
Nano second behavioral of Exploding Bridge Wire (EBW) using Ultra High Speed Imaging Technology





H. Muthurajan, Martin Yeo Kwee Liang, Low Chan Gee, Ang How Ghee

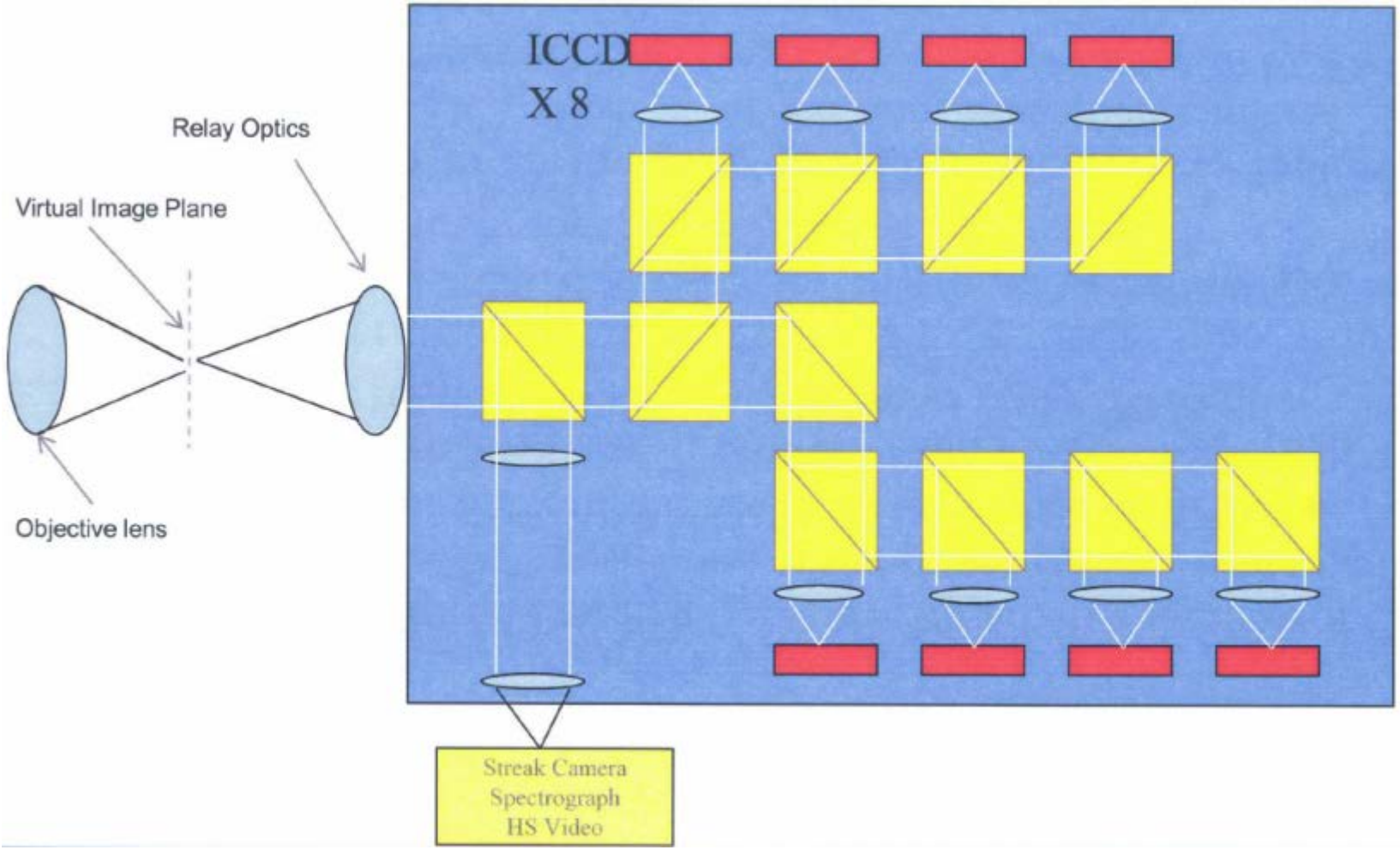
Energetic Materials Research Centre
Nanyang Technological University, Singapore

For 58th Annual Fuze Conference, Baltimore

Overview of Presentation

1. Introduction
    a) Framing Camera for detonics
    b) Streak Camera for detonics
    c) Simultaneous Streak and Framing Camera
2. Al based EBW
    a) Ultra high speed framing
    b) Streak Record
    c) Digital Storage Oscilloscope Analysis
3. Result and Discussion
4. Conclusion

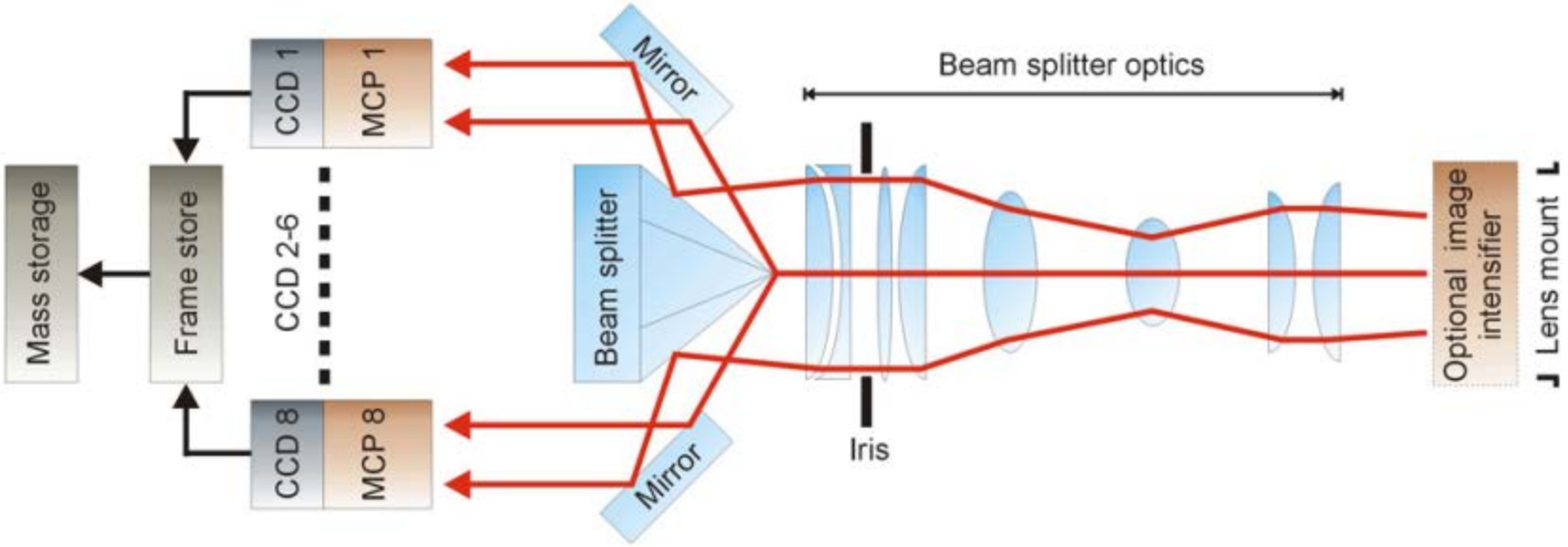
High Speed Framing Camera
Eight way beak splitter with additional optical port



Disadvantages

Disadvantage of this technique is that **at each beam** splitter 50% light intensity is reduced (halve, i.e split in-to 50% and 50%) which is received by next subsequent beam splitter. Hence each ICCD receives different intensity of light

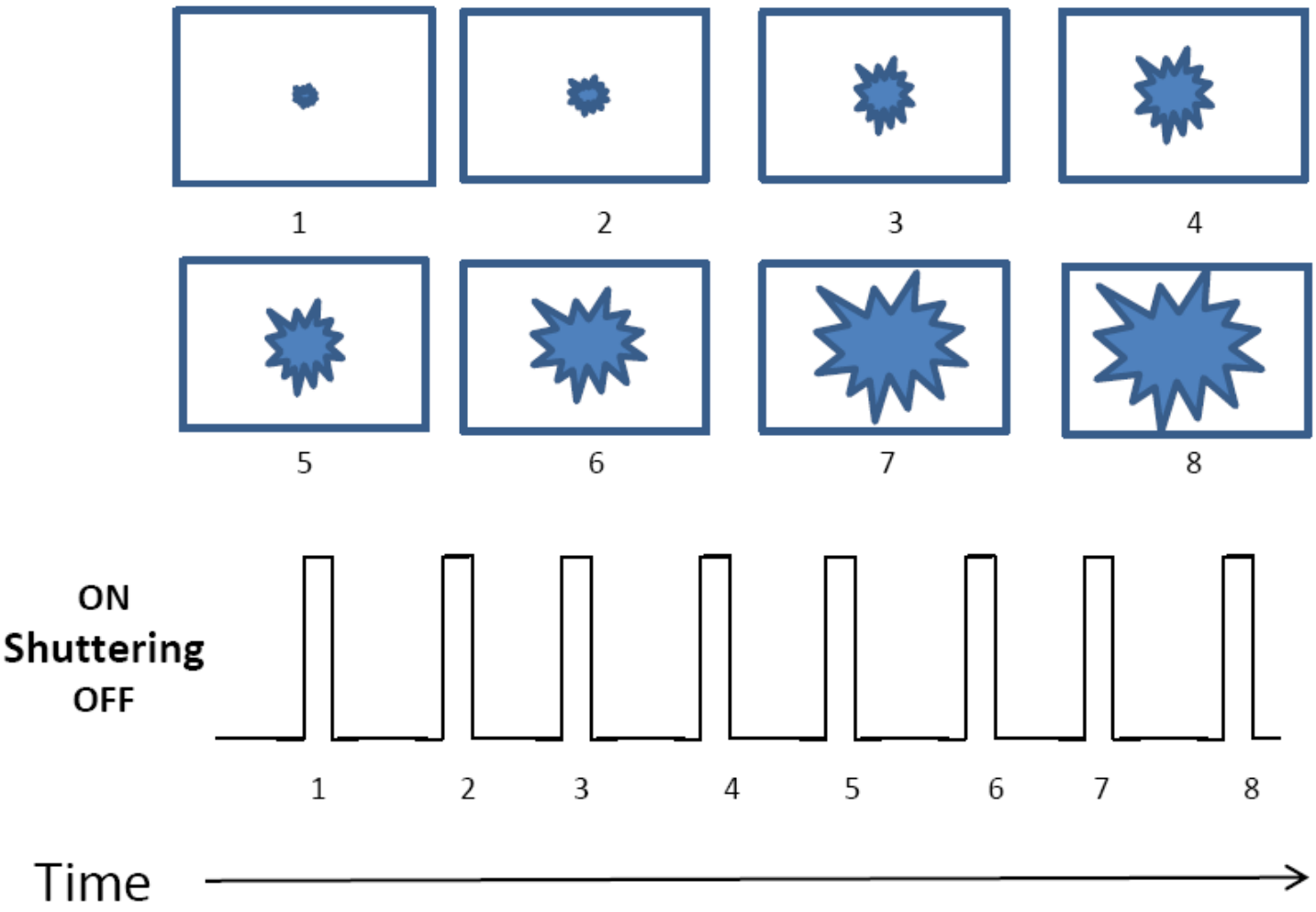
Framing Camera : Pyramid beam splitter



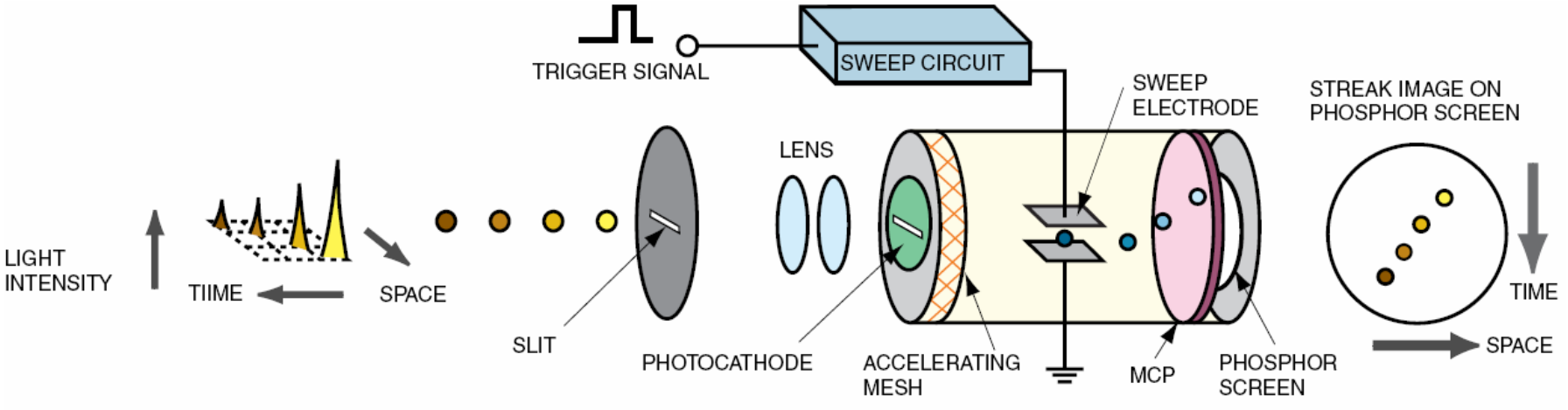
Each camera consists of eight individual CCD detectors. The signal is collected by a common optical system and is then split into eight identical copies that are relayed to the individual CCD detectors. The camera also has the option of double exposure for the CCDs thus giving 16 images.

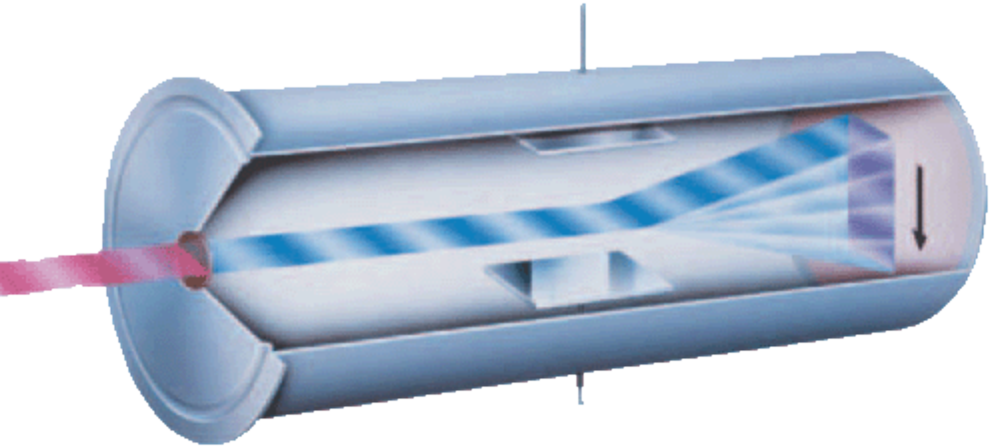
The **pyramid mirror** has eight plane facets reflecting eight images of the object on to the faces of **eight image intensifier devices** for respective image sensor devices. In each case the respective image is reflected via an intermediate mirror

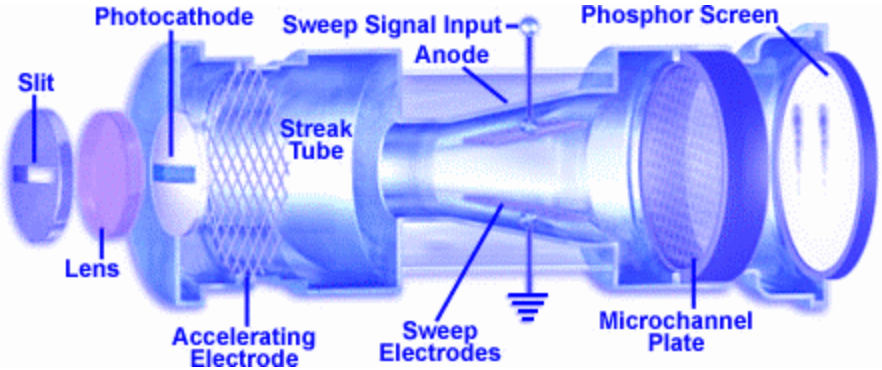
Framing Sequence



Operating Principle of Streak Camera for Detonics



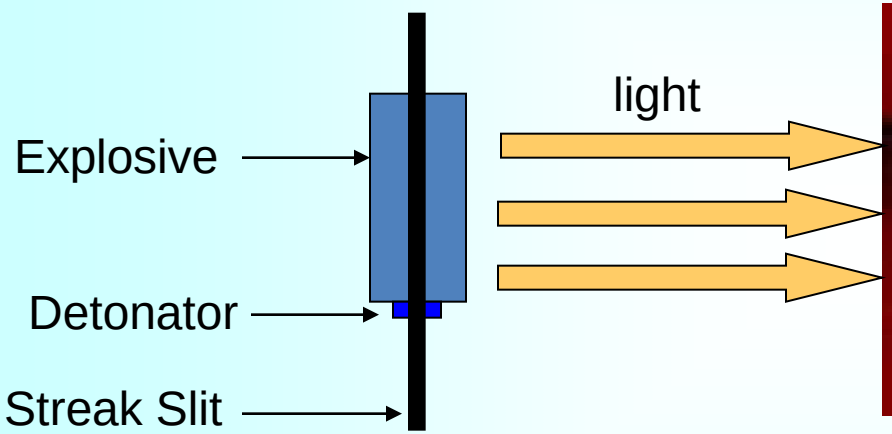




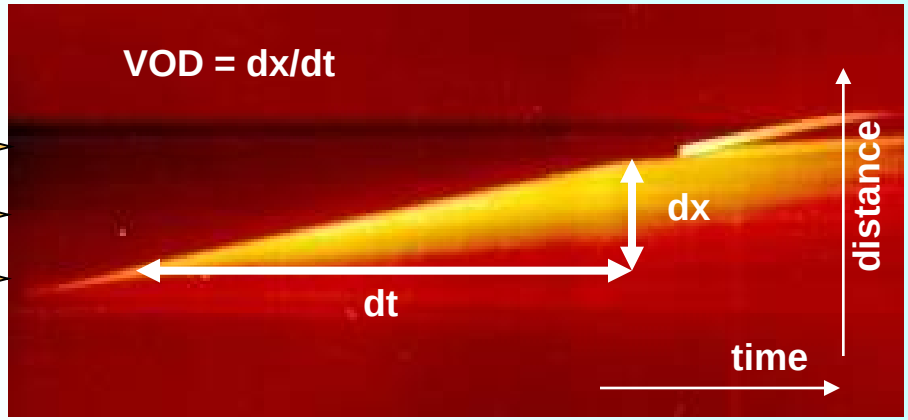
Streak Tube

Streak record for VOD determination

- Use to derive velocity of detonation (VOD)
- Event parallel to slit, perpendicular to optical axis



Setup



Typical streak image

$$\text{Slope} = \text{m} = \tan\theta = \frac{y_2 - y_1}{x_2 - x_1} \Rightarrow \theta = \tan^{-1}\left(\frac{y_2 - y_1}{x_2 - x_1}\right)$$

$$VOD = \frac{d_x}{d_y} * \frac{SF}{WR}$$

$$C_J = \frac{1}{4}\rho D^2$$

Why *nano* seconds exposure for detonics?

“Freezing” Image Motion

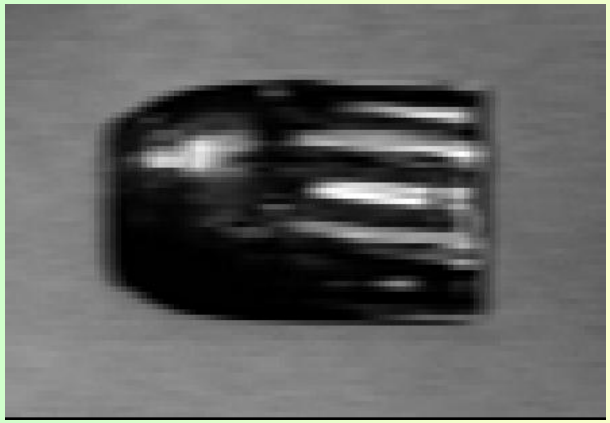
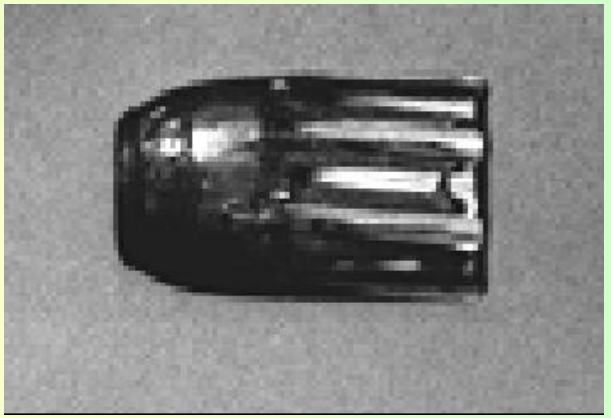
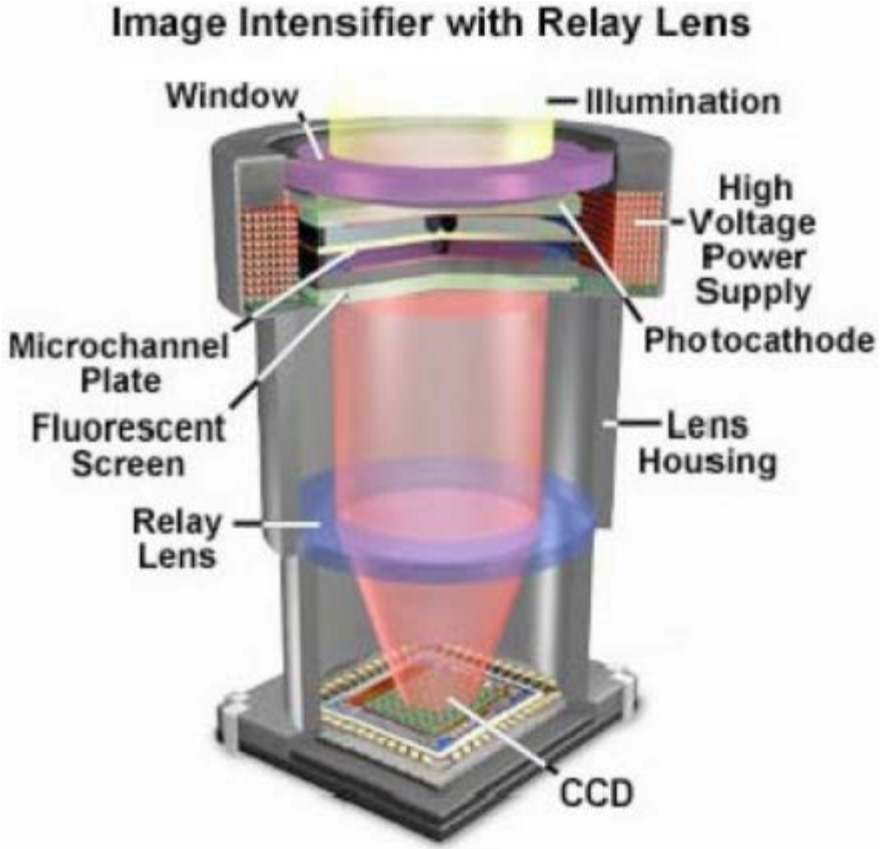


Image blur on the camera sensor.



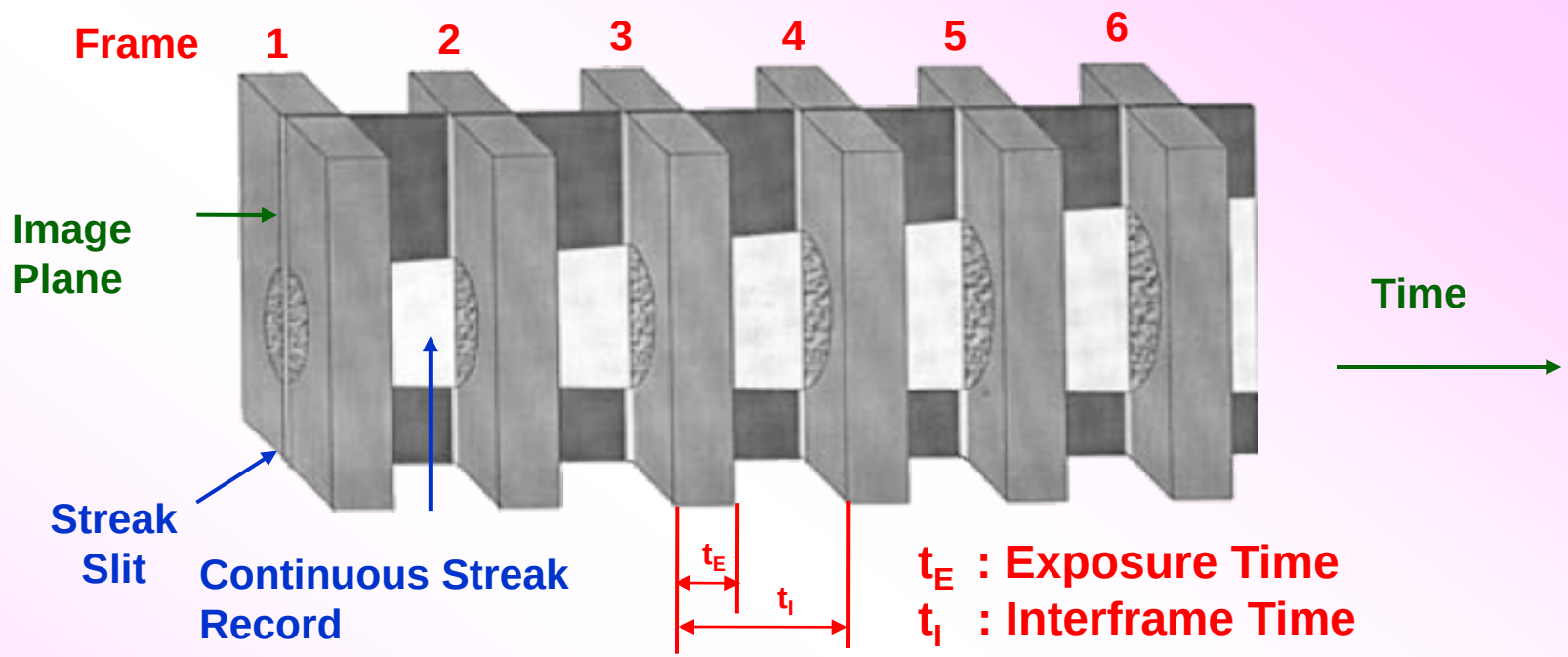
Using a very short exposure time reduces blur.

ICCD (Intensified CCD) for Framing and Streak Camera



- **Photocathode:** Generation of photoelectrons
- **Microchannel plate (MCP):** Multiplication of electrons
- **Phosphor Screen:** Conversion of electrons back into highly increase ($x10^4$ - 10^6) number of photons
- High numerical aperture lens-coupling for superior distortion free image quality
- **CCD:** Conversion of the very high number of photons to charge, readout and digitization

Simultaneous Streak-Framing Record



Streak : Continuous imaging, difficult to interpret

Framing : "what you see is what you get", but only at certain time-intervals

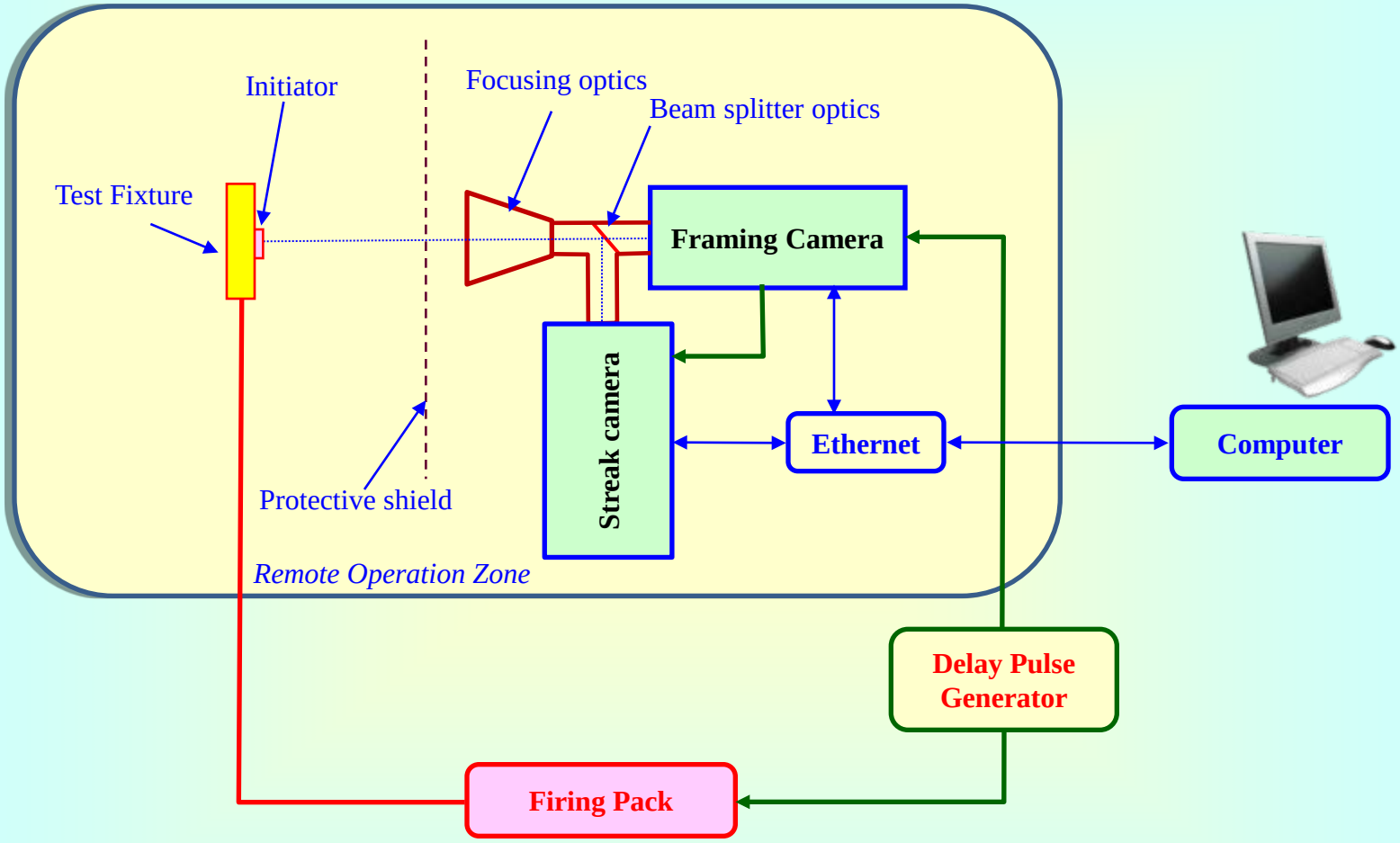
Simultaneous Streak and Framing

- Allows recording of entire phenomena (with streak) + easier interpretation (with framing)
- Prevent misinterpretation of images

Advantages of Simultaneous Streak and Framing Records

Parameter	Frames	Streak
Spatial picture	+	–
Space resolution	–	+ (but only in 1 plane)
Time resolution	–	+
Full-time observation	–	+
Interpretation	→	←
Velocities	→	←

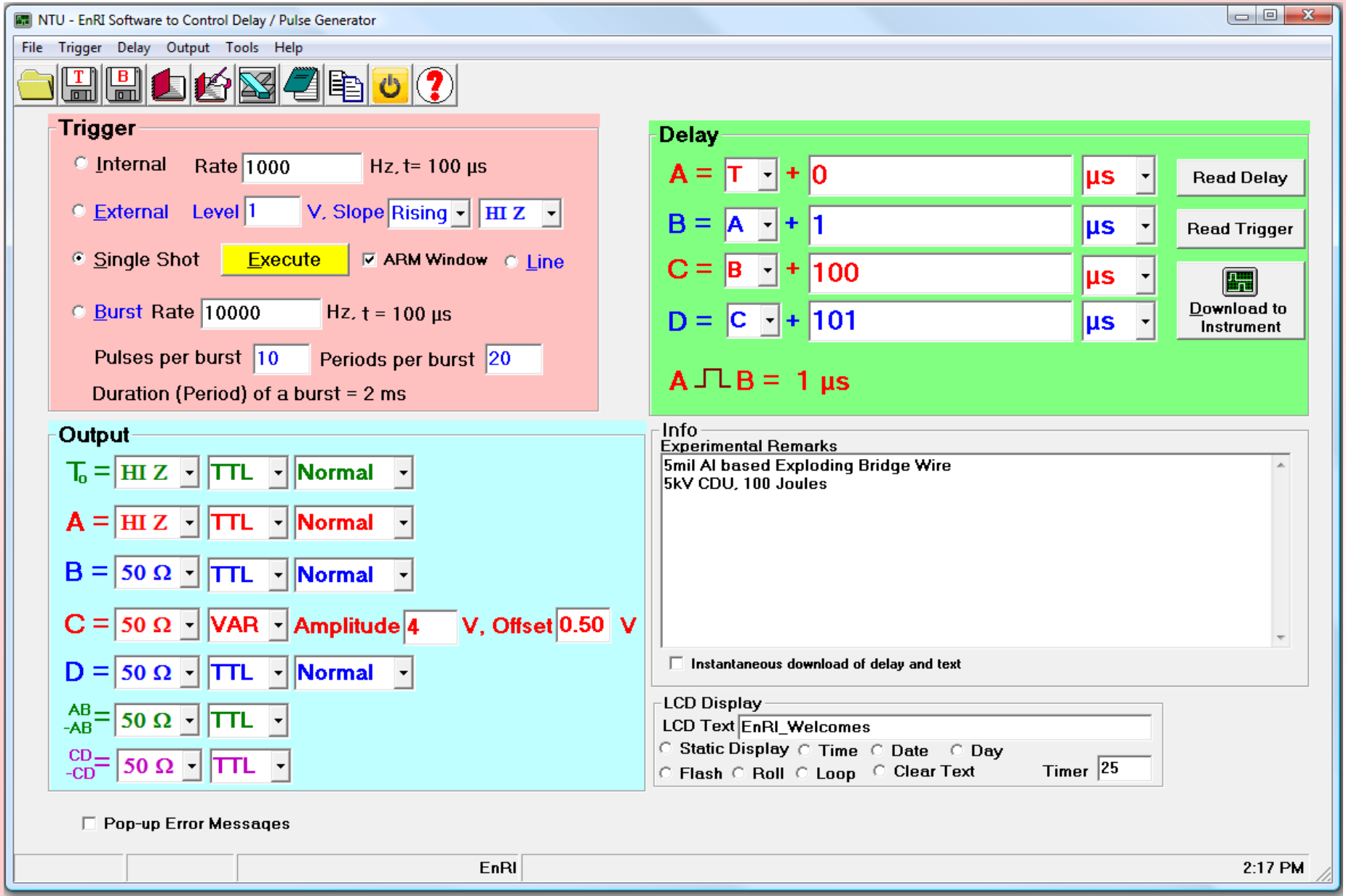
Experimental setup of Simultaneous Streak and Framing Imaging



Experimental setup of Simultaneous Streak and Framing Imaging for performance evaluation of Al based EBW

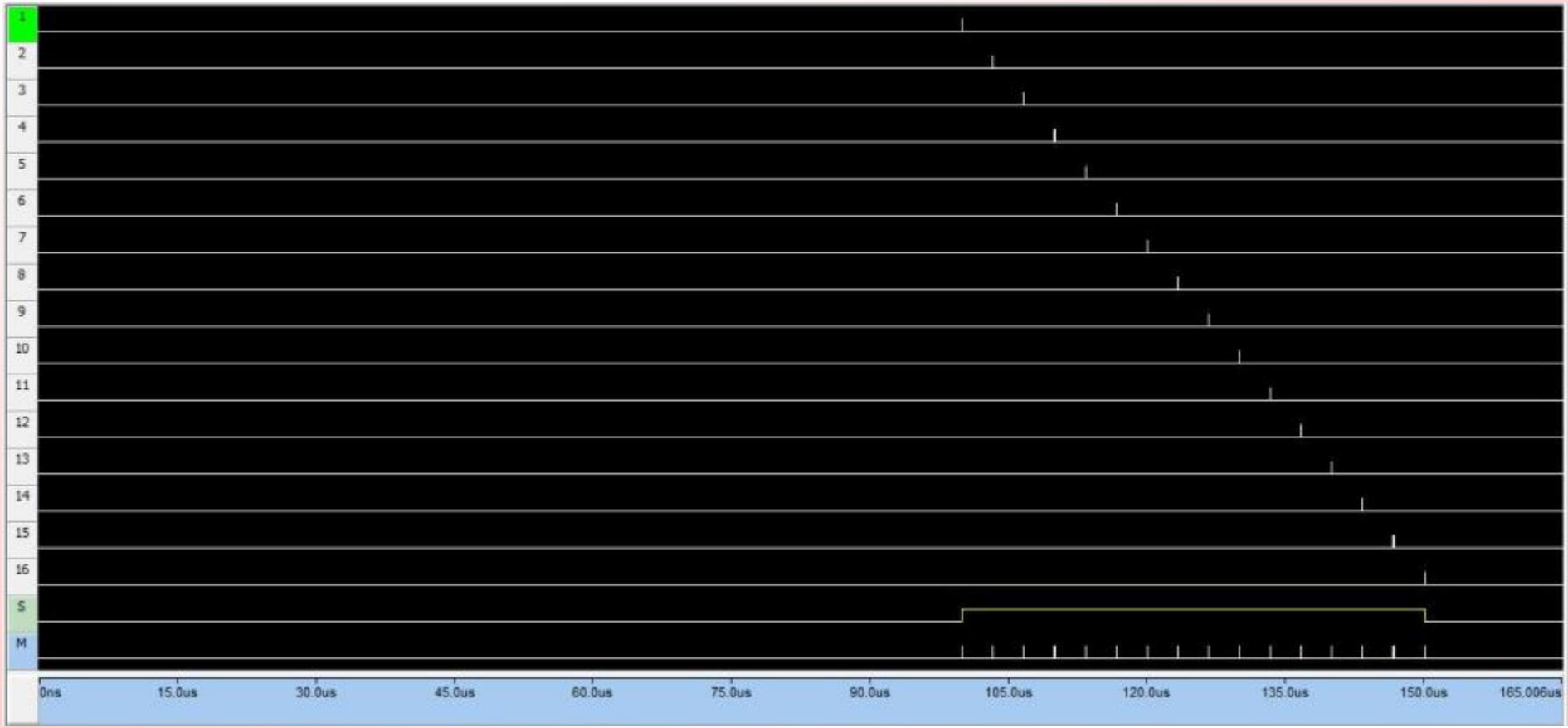
Simultaneous Framing and Streak Imaging of Al - EBW

Parameters of Experiment – Synchronization CDU and Imaging System



Simultaneous Framing and Streak Imaging of Al - EBW

Parameters of Experiment – Imaging Systems



Exposure Time : **10 ns**

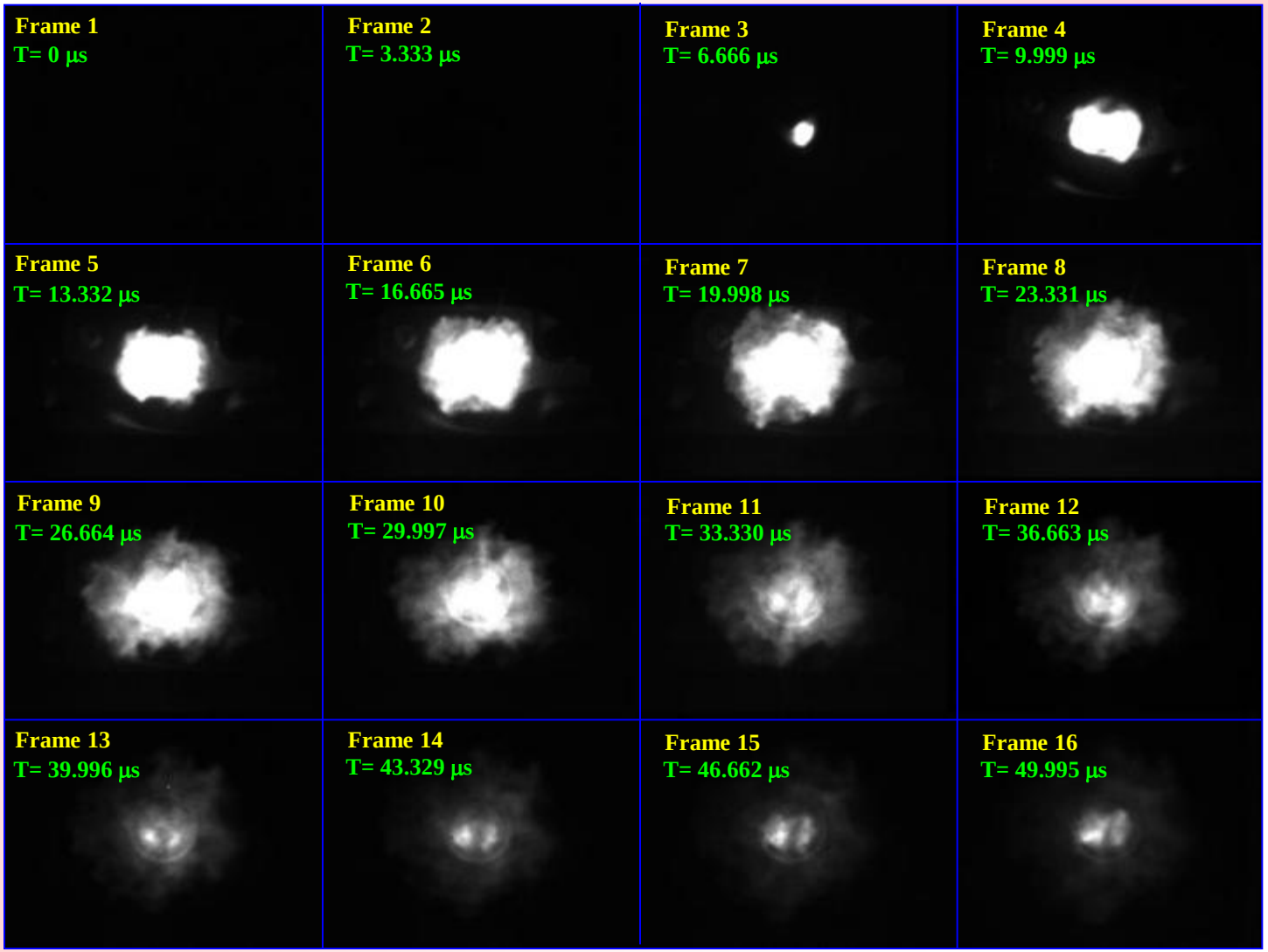
Inter-frame Time: 3.323 μs

Iris: f2.8

Gain: 1

Total Recording Length: 50.005 μs

Ultrahigh Speed Framing Imaging of Al - EBW



Observed Function Time : 6.666 µs

Exposure Time : **10 ns**

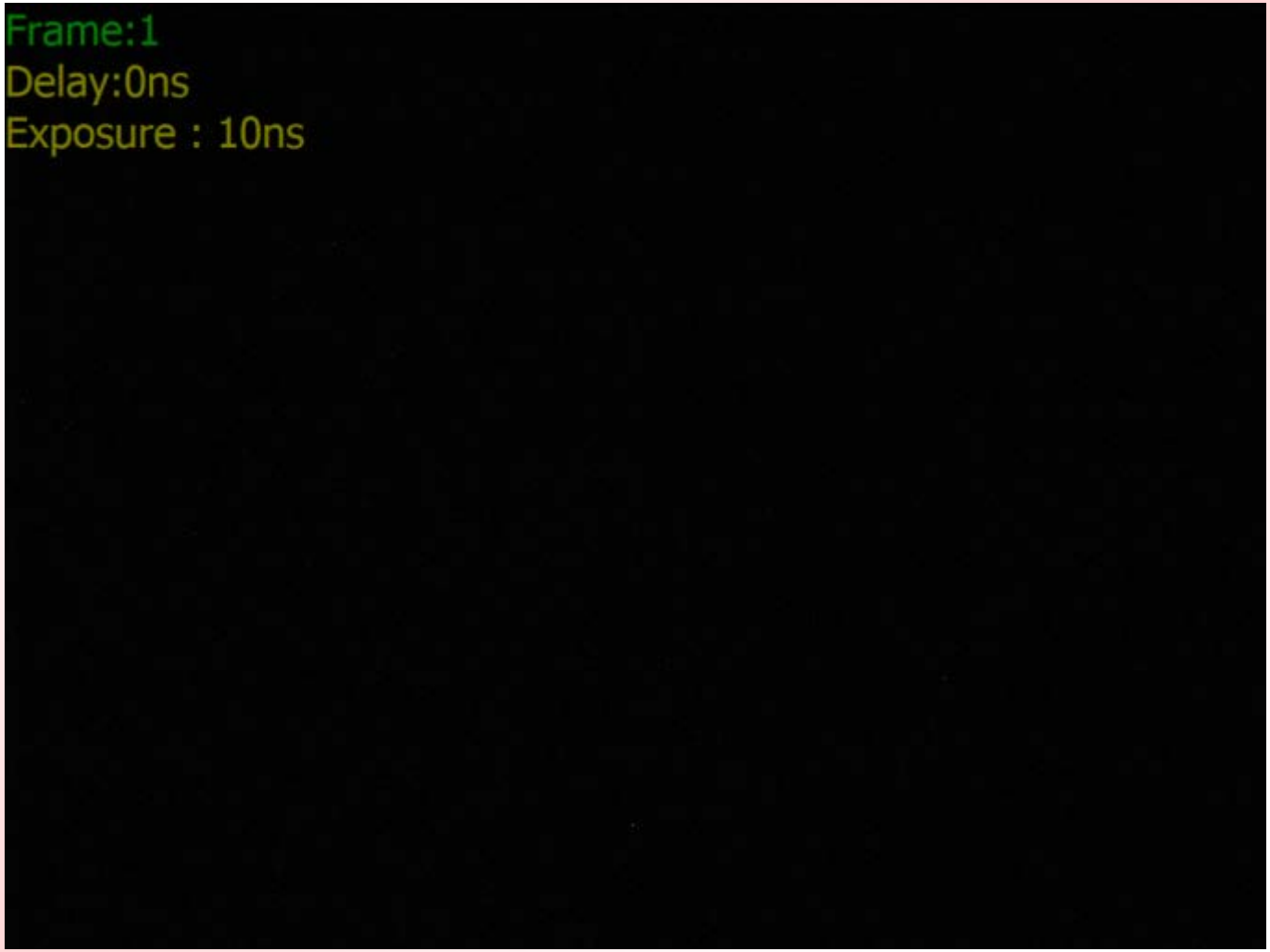
Inter-frame Time: 3.323 µs

Iris: f2.8

Gain: 1

Total Recording Length: 50.005 µs

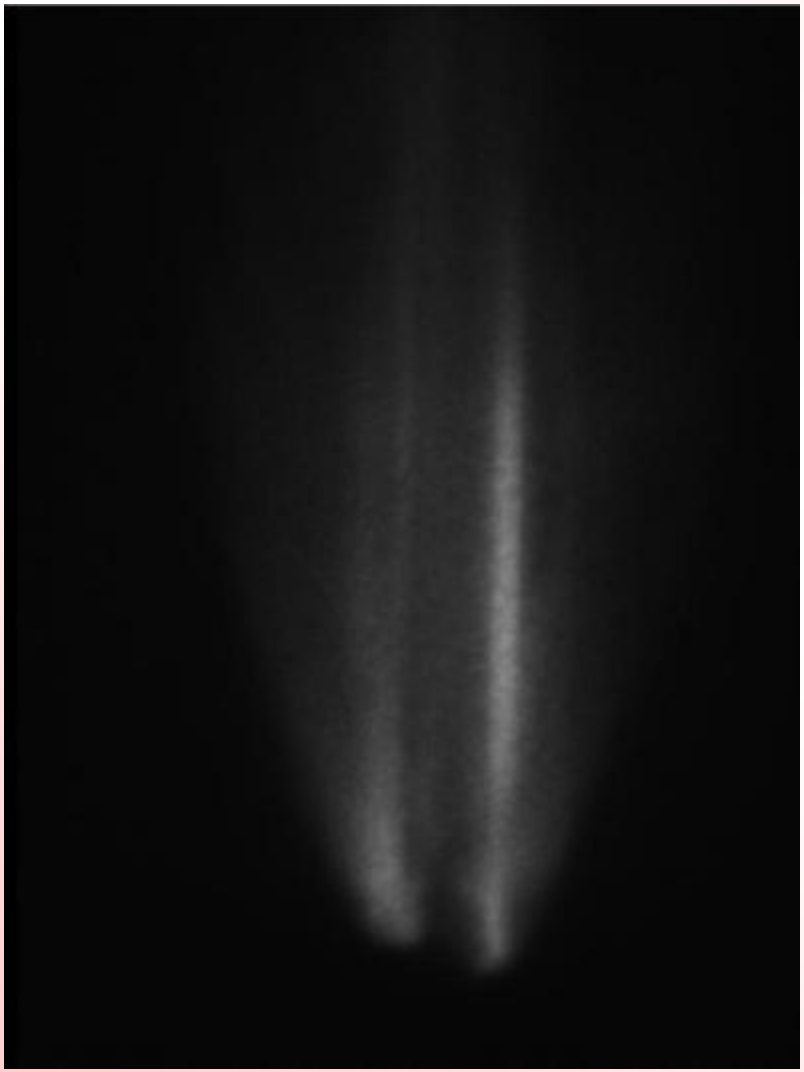
Ultrahigh Speed Framing Imaging (Video) of Al - EBW



Observed Function Time : 6.666 μs
Exposure Time : 10 ns
Inter-frame Time: 3.323 μs

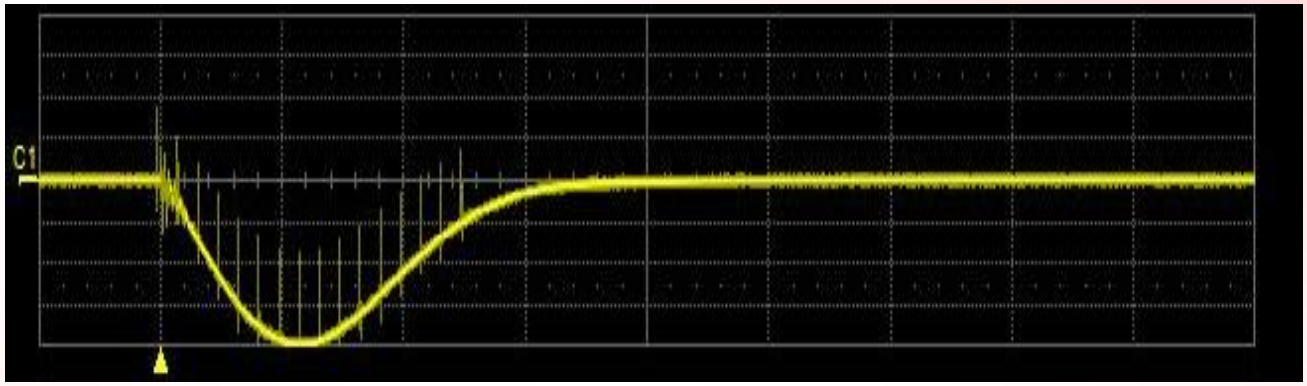
Iris: f2.8
Gain: 1
Total Recording Length: 50.005 μs

Streak Imaging of Al - EBW



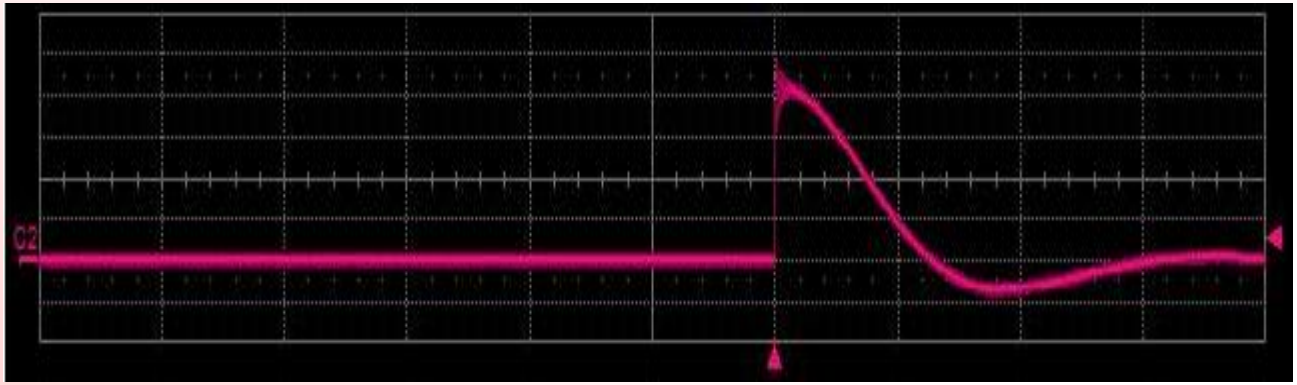
Sweep Speed : 2.5 μs/mm
Sweep Duration : 50 μs
Slit Size : 50 μm
Gain : 608 Volt
Iris : f2.8

Digital Storage Oscilloscope (DSO) Data on Al EBW



Y axis : 1 Volt/div
X axis : 20μs/div
Offset : 0 mV

Pulses from Framing camera corresponding to the frames acquired

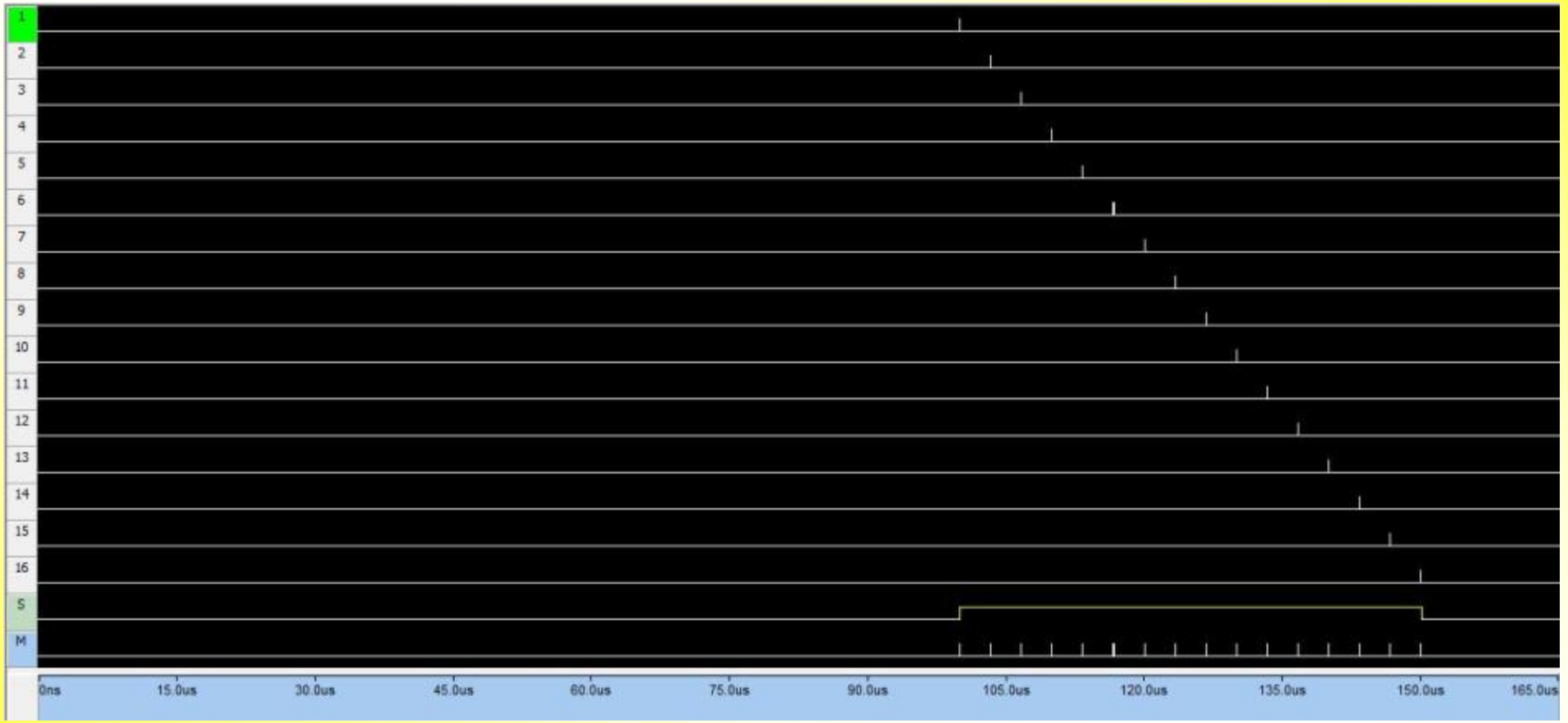


Y axis : 1.0 kV/div
X axis : 20μs/div
Offset : -2.0 kV

Voltage across the Al based EBW

Simultaneous Framing and Streak Imaging of Al - EBW

Parameters of Experiment



Observed Function Time : 6.656 μs

Exposure Time : **5 ns**

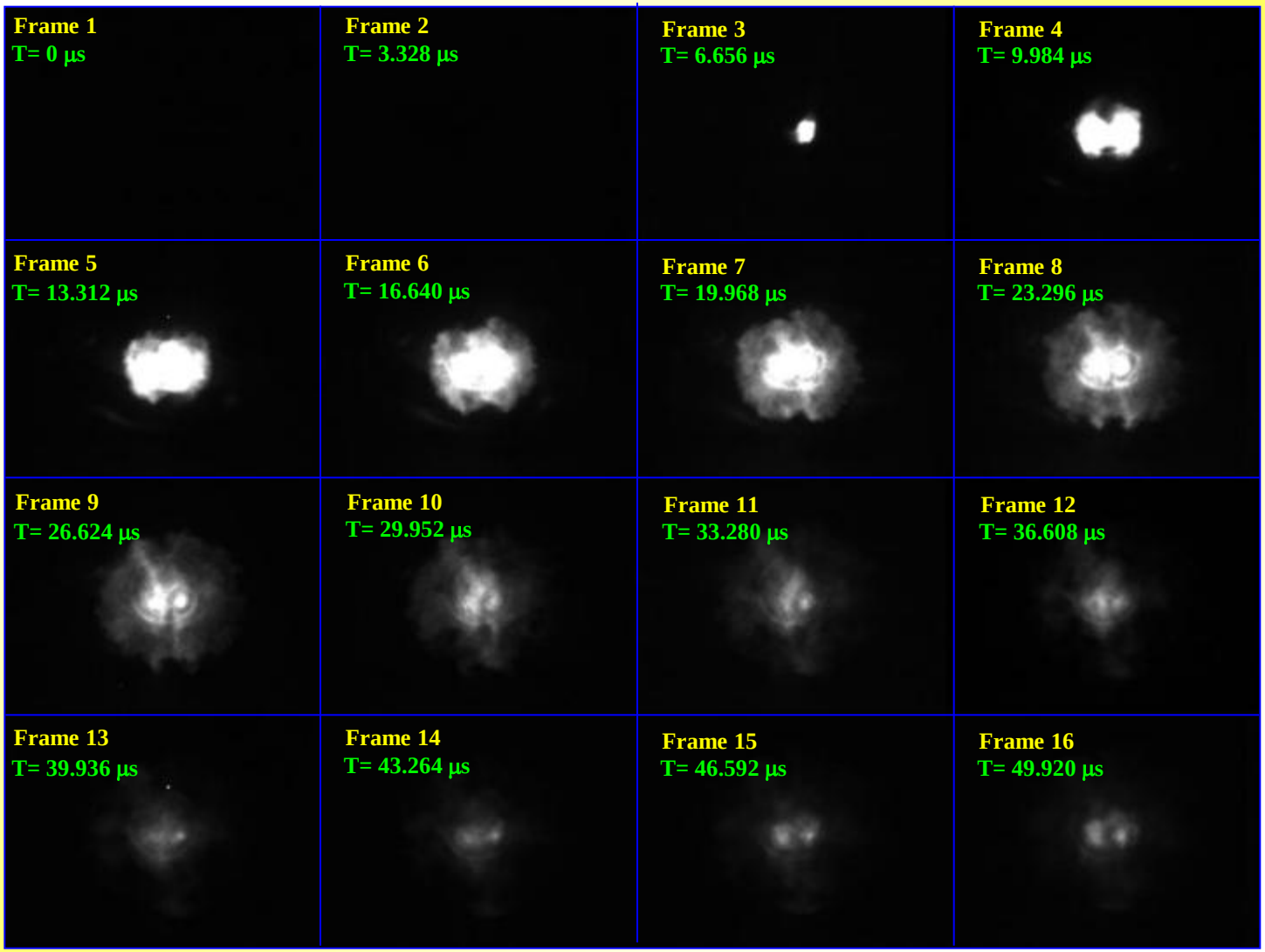
Inter-frame Time: 3.323 μs

Iris: f2.8

Gain: 1

Total Recording Length: 49.925 μs

Ultrahigh Speed Framing Imaging of Al - EBW



Observed Function Time : 6.656 µs

Exposure Time : **5 ns**

Inter-frame Time: 3.323 µs

Iris: f2.8

Gain: 1

Total Recording Length: 49.925 µs

Ultrahigh Speed Framing Imaging (video) of Al - EBW

Observed Function Time : 6.656 μs

Exposure Time : **5 ns**

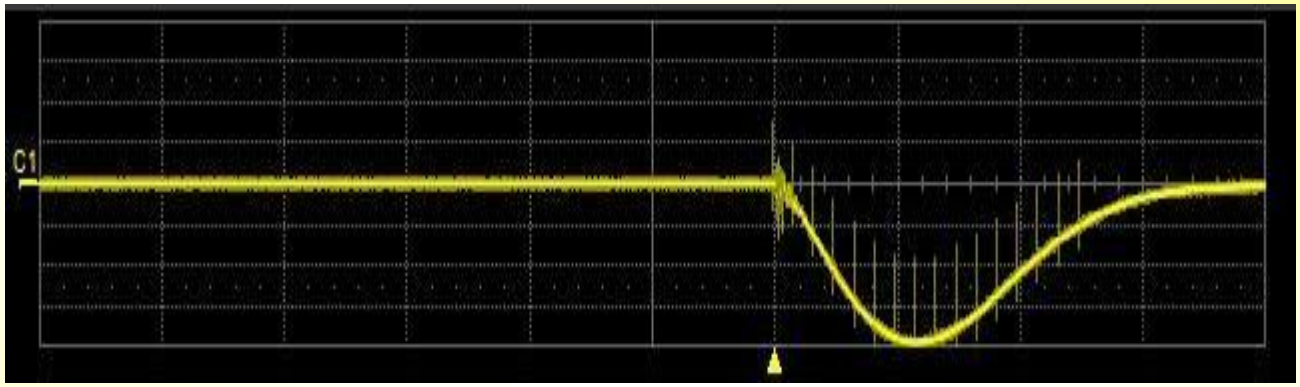
Inter-frame Time: 3.323 μs

Iris: f2.8

Gain: 1

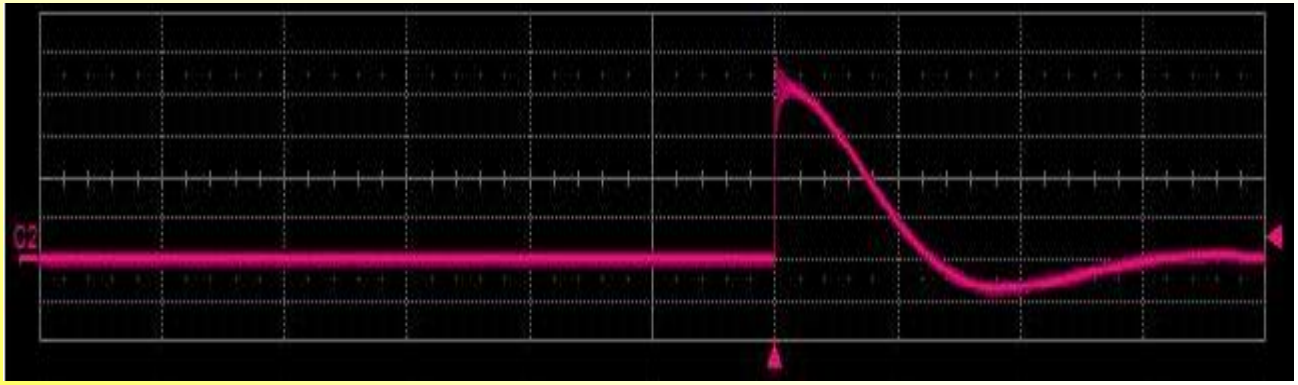
Total Recording Length: 49.925 μs

Digital Storage Oscilloscope (DSO) Data on Al EBW



Y axis : 1 Volt/div
X axis : 20μs/div
Offset : 0 mV

Pulses from Framing camera corresponding to the frames acquired



Y axis : 1.0 kV/div
X axis : 20μs/div
Offset : -2.0 kV

Voltage across the Al based EBW

CONCLUSION

a) Simultaneous streak and framing camera technique synergizes the advantages of the two methods and at the same time indicates whether the streak record had actually been taken in the expected or predetermined planes of observation.

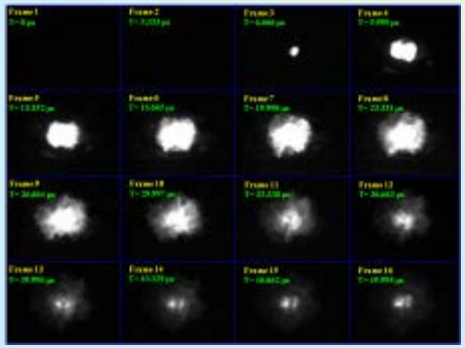
In this manner, faulty analysis and wrong interpretation, which were frequent problems in the early days of streak recording, can be eliminated completely.

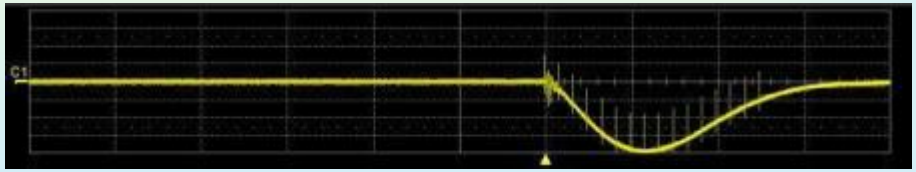
b) Due to simultaneous streak and ultra high speed framing camera we are able to evaluate the performance of Al based EBW

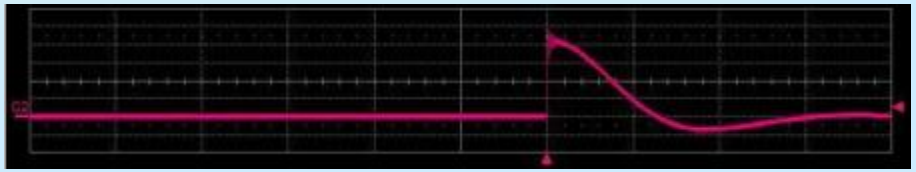
(1) The observed Function time Al - EBW is 6.66 μs for 5kV / 16μF CDU

(2) Ten or Five nano second exposure is sufficient for ICCD based ultra high speed framing camera to capture Al-EBW events

c) Demonstrated the repeatability of Al-EBW







EnRI
ENERGETICS RESEARCH INSTITUTE

THANK YOU

from

Energetics Research Institute

Nanyang Technological University

Singapore

Name : Harries Muthurajan
Phone : +65-6513 8172
Company:
Energetics Research Institute
Nanyang Technological University, Singapore - 639 798
Email: mharries@ntu.edu.sg
Abstract Reference number: 13745