Simultaneous Photonic Doppler Velocimetry and Dual-axis Framing Technique

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Introduction

- Experiments on detonator components have historically been routinely limited to three metrics: current, voltage, flyer velocity (the “trifecta”)
- This was consummate with the modelling capability available
- Recent advances in magnetohydrodynamic modelling (ALEGRA, ALE-MHD) have driven an improvement in detonator experimental capability
- Current, voltage, flyer velocity and multi-axis high-speed imaging are now routine
Improvements in experimental capability

- AWE has implemented a significant uplift in capability, realised in the Microdetonics Laboratory
- Designed for EFI & EBW detonators and components
- Multi-year effort by several staff members
- Highly-diagnosed experimental capability with current, voltage, velocity (PDV), dual axis streak and framing (the “pentafecta”)
The “Pentafecta” capability

- High-speed imaging (parallel)
- High-speed imaging (perpendicular)
- Current
- Voltage
- Velocity
The Microdetonics Laboratory
Firing enclosure

- 135 mm internal bore
- Bayonet closure
- Castell interlock
- X, Y alignment
- 8 ports (plus lid)
- Optical ports are 2x 12mm polycarbonate (angled to reduce reflections)
- Tested to 6.5 g TNT
- Rated to 1.2 g TNT
Firing enclosure
Firing unit & interface

- Capacitor discharge firing unit
  - Designed by Pete Horn (AWE)
  - 50, 100, 165, 200, 350, 500, 830 nF
  - 20-4000 V
  - Thyristor switch >5000 shot switch life

- Firing unit interface
  - Prevent exposure to firing unit terminals
  - Seal enclosure against overpressure

- Teledyne Reynolds bullseye connector to interface box
- Copper C-clamp to join test cable
- Windows for inspection of joint
Current and voltage

- Differential voltage probe directly across bridge
  - Recorded on two oscilloscope channels
  - Comparable response to Agilent and Barth HV probes
  - Estimated 1 GHz bandwidth
- Pearson 2879 current monitor (20 MHz bandwidth)
MISSEX EFI cable

- Modular Instrumented Small Scale Explosive Experiment
- Low cost cable for flexible foil (and soon Chip) bridges
- Replaceable bridge
- Designed for dual-axis imaging and voltage measurement
Modular experimental fixture

- Modular design using Thorlabs 30 mm cage system
- Holds slapper cable, window, pellet, explosive flyer, etc
- 5 axis alignment
- Repeatable to 0.01 mm
Laser illumination

- CAVILUX Smart spoiled-coherence diode lasers
- 400 W peak power, 10 μs pulse duration
- 640 nm wavelength
- One laser per axis
- Frontlighting (Y axis) and backlighting (X axis)
Imaging

- Specialised Imaging SIM 8 cameras
  - 8 frames, 5 ns exposures
  - Typical interframe time 25 ns to 100 ns
- Optronis streak cameras coupled to framing cameras
Imaging challenges

- Variable, high magnification (20x, 1 mm field of view) required
- Long working distance (175 mm)
- Limited space for lenses
- X axis – double SLR lenses
  - Primary lens – 175 mm focal length
  - Secondary lens – 1000 mm focal length
PDV and Imaging

SIM 8 Framing Camera

600mm telephoto lens

Thorlabs CM1-BS013 50/50 beamsplitter

650 nm

1550 nm

150mm focal length PC lens

Thorlabs DMSP950R shortpass beamsplitter

12mm polycarbonate (x2) with AR coating (vis and IR)

Thorlabs RC08APC-P01 reflective collimator

30mm focal length PC lens
PDV and Imaging

- 300mm telephoto lens with teleconverter (600mm) focussed at infinity hence collimated
- PDV and illumination folded into beam path
- 150mm focal length lens to focus onto target
- Magnification 600/150 = 4x
- Very lossy – polycarbonate windows are absorbing
- NKT Photonics lasers with pulsed (100μs) EDFA (7 watts)
- Considering back-end EDFA also
PDV system

- 25 mW reference laser
- 25 mW seed laser, 5 W EDFA (100 μs pulse)
- 2-5 GHz offset
- Up to 4 channels
- Thorlabs reflective collimator coupled to Navitar 12x zoom lens
- 0.1 mm focused spot
LUNA data

- LUNA OBR4600 optical backscatter reflectometer probes all optical interfaces, from circulator output to target
- Identifies spurious returns and losses
- Ensure PDV “sees” target
Example PDV data

- Optical signal detected by Miteq 12 GHz receiver
- Electrical signal recorded by Tektronix DPO71604C 16 GHz oscilloscope at 100 GS.s⁻¹
- Can use two detectors to maximise contrast
Flyer velocity history from PDV

Example Velocity Trace

Flyer velocity at impact
Impact into window
Pressure pulse in window
Example Data

Data acquired in the AWE Microdynamics Laboratory

Shot 20151217-05, copper bridge, 634um x 635um
Flexible Foil, Kapton flyer, 50um, capacitor size 350nF, charge voltage 2790V
Example data

Shot SAND15, bridge size 380um, bridge thickness 5um copper
Flexible Foil, flyer 25um Kapton, capacitor size 350nF, charge voltage 3000V

Acquired in the AWE Microdetonics Laboratory
Example data
Example data
Conclusion

- AWE has significantly uplifted the capability for EFI and EBW experiments with the Microdetonics Laboratory
- Current, voltage, **PDV and dual-axis imaging** are standard
- Now able to investigate features such as bridge defects, flyer formation and break-up
- Aligns with high-fidelity magnetohydrodynamic simulations
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