Extreme velocity: PDV in cylindrical compression experiments

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Overview

• In PDV, bandwidth is life!
  • Every km/s of velocity requires 1.29 GHz of bandwidth
  • Every GHz of bandwidth supports 775 m/s of velocity

• Common velocity limits
  • 6 GHz : 4.65 km/s
  • 12 GHz : 9.30 km/s
  • 20 GHz : 15.5 km/s

• Frequency shifting usually costs some bandwidth, so the actual velocity limit may be lower
What is the problem?

• Electrical bandwidth has two limits
  • Digitizers (>30 GHz)
  • Amplified detectors (~20 GHz)
• At present, digitizers are winning
  • Faster detectors available without amplification, but greater sensitivity is needed

• Does this matter to anyone?
  • Commercial bandwidths cover standard gun, explosive, and pulsed power experiments
  • However, there are exceptions...
• Electromagnetic drive created by >20 MA pulsed current
• Launch flyer plates up to 40 km/s (shocks)
• Ramp wave compression (0 to >>10 km/s continuous)
Why bother with PDV?

- For planar loads, VISAR works fine
- PDV has some advantages
- VISAR tricky in cylindrical compression
  - Probe and all optics must fit inside 1 mm gold rod
- Agiltron carries OCT probes that work quite nicely
  - Collimating
Can PDV work?

• Good news
  • Pulse designed to avoid shock formation

• Bad news
  • Start at rest...
  • Move to 50 km/s (64.5 GHz)
  • in 100-150 ns!

• More bad news
  • Curved reflector
  • No surface finish control
  • Nasty things going on
    • Machine produces harsh EM environment
    • Radiography x-rays may pass through the probe
Leapfrog PDV

• Mix Doppler shifted light with lasers of progressively shorter wavelength

• Each mixing produces measurable beat frequencies over a particular velocity range

• Interleave the ranges in some intelligent fashion
  • At least one measurable beat frequency is needed for all conceivable velocities
    • Not at DC or bandwidth limit

• Two beat frequencies resolve ambiguities
  • Similar to fringe jumps in VISAR
Laser A illuminates the probe
- IPG with a RIO seed

Lasers B and C are used as local references
- NKT AdjustiK lasers

Doppler shifted light split between three systems
- PDV1 is conventional
- PDV2/PDV3 are frequency shifted
- PDV4 not initially used for lack of a fourth laser

Example
A: 1550.946 nm
B: 1550.804 nm
C: 1550.657 nm
Initial results promising (Z2370)

Shifted light combined with original laser light

\[ \lambda = 1550.9479 \text{ nm} \]

Optical harmonic believed to be a double reflection

Shifted light combined with 1550.8276 nm light

Z2370 Al liner velocity simulated & measured (PDV)
Followup experiment (Z2408)

- 18 GHz PDV separation
- 39.5 km/s maximum measured velocity
Third time is a charm

- Be liner
- Z2424 (10/18/2012)
Work in progress

• Multiple PDV channels need to be spliced into a common velocity history
  • Tedious...

• Dropouts are a problem (dynamic speckle)
  • Multiple probes may not be an option

• Fourth PDV laser now available
  • Could theoretically cover 4x18+20=92 GHz (71.3 km/s)
  • Assuming some Doppler shifted light can be collected

• Time-domain multiplexing seems like an obvious next step
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