Extreme velocity: PDV in cylindrical compression experiments

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PDV workshop
October 22-23, 2012

National Nuclear Security Administration

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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

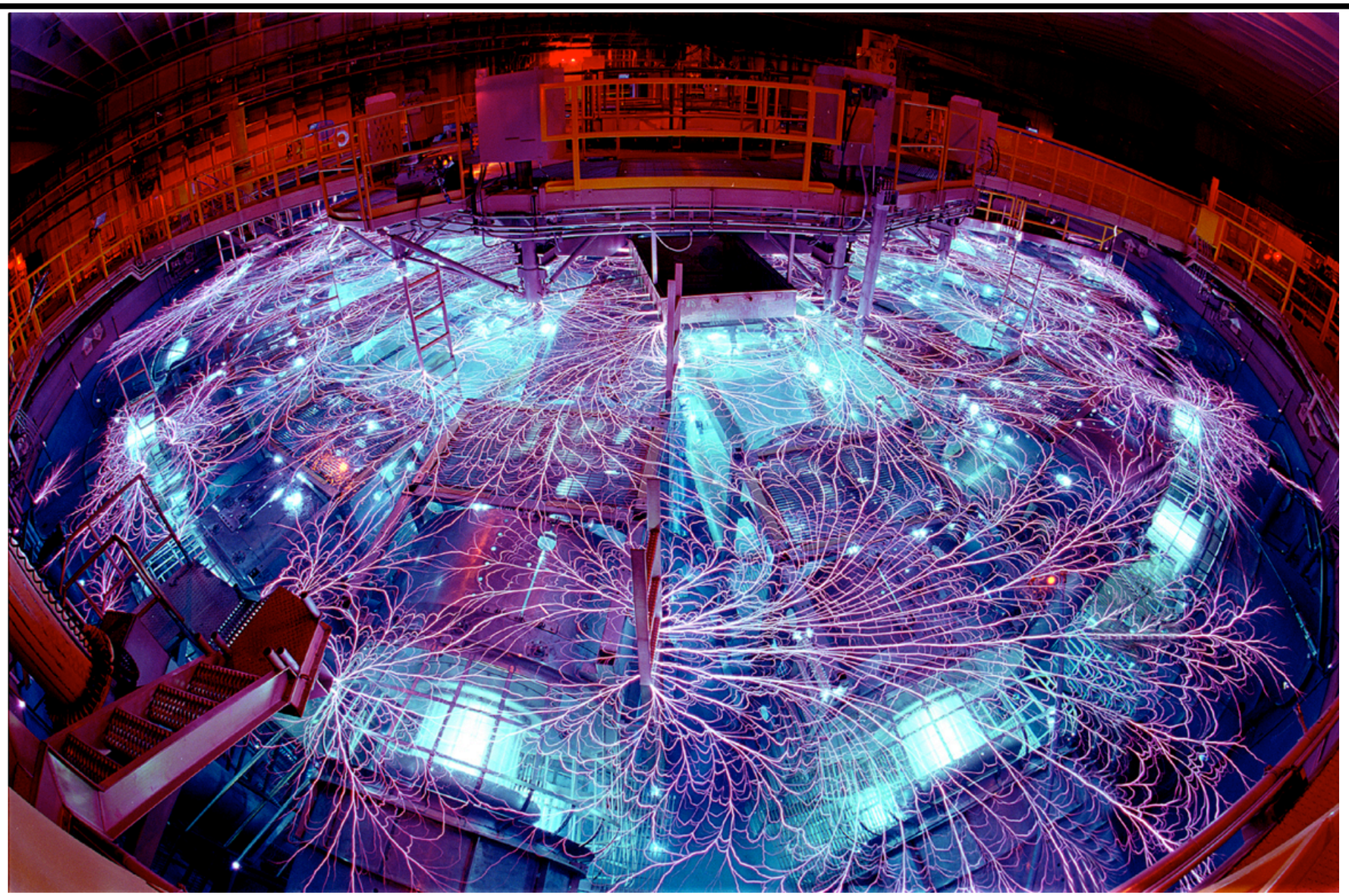
- Frequency shifting usually costs some bandwidth, so the actual velocity limit may be lower

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...

The Sandia Z machine

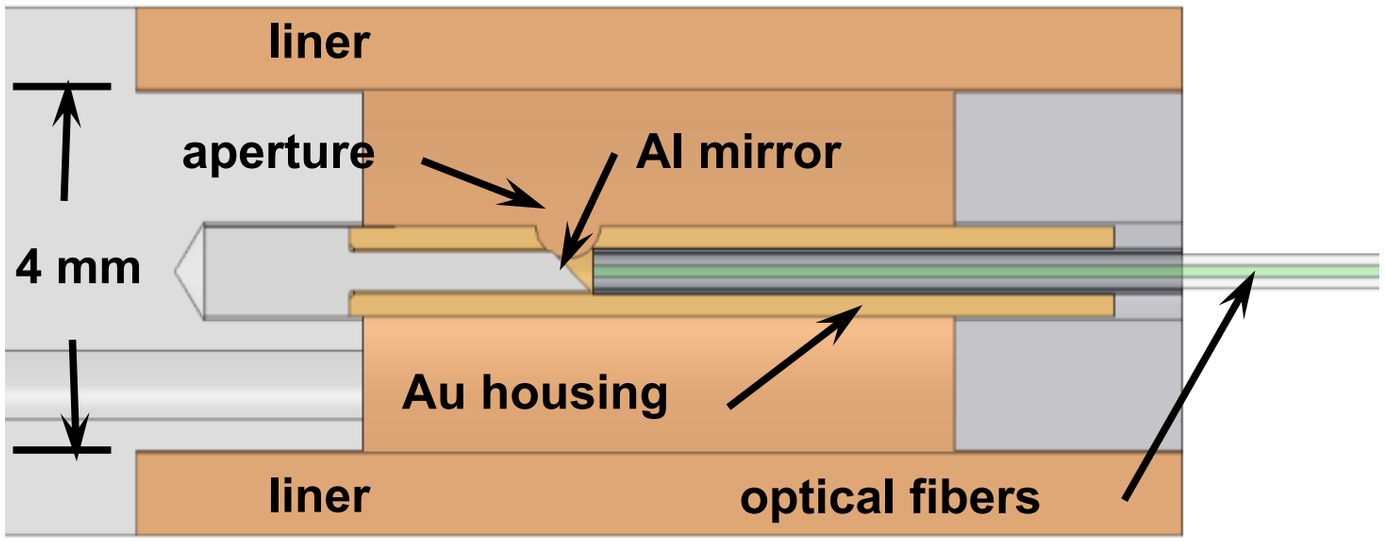


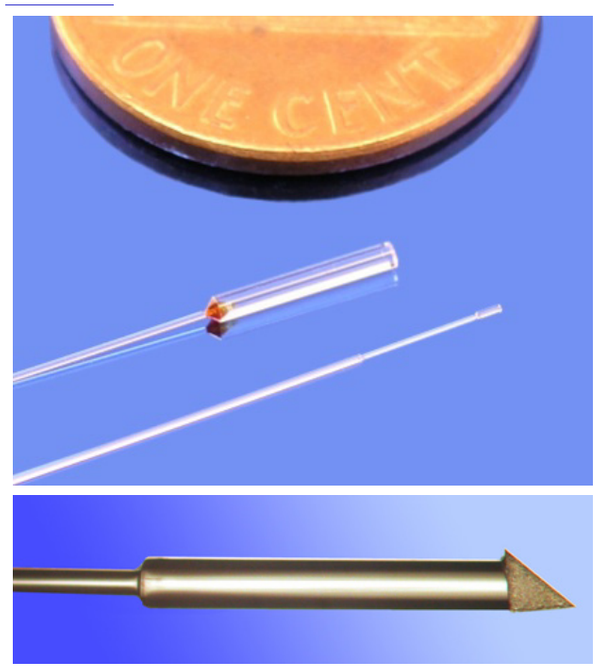
- Electromagnetic drive created by >20 MA pulsed current
  - Launch flyer plates up to 40 km/s (shocks)
  - Ramp wave compression (0 to >>10 km/s continuous)

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

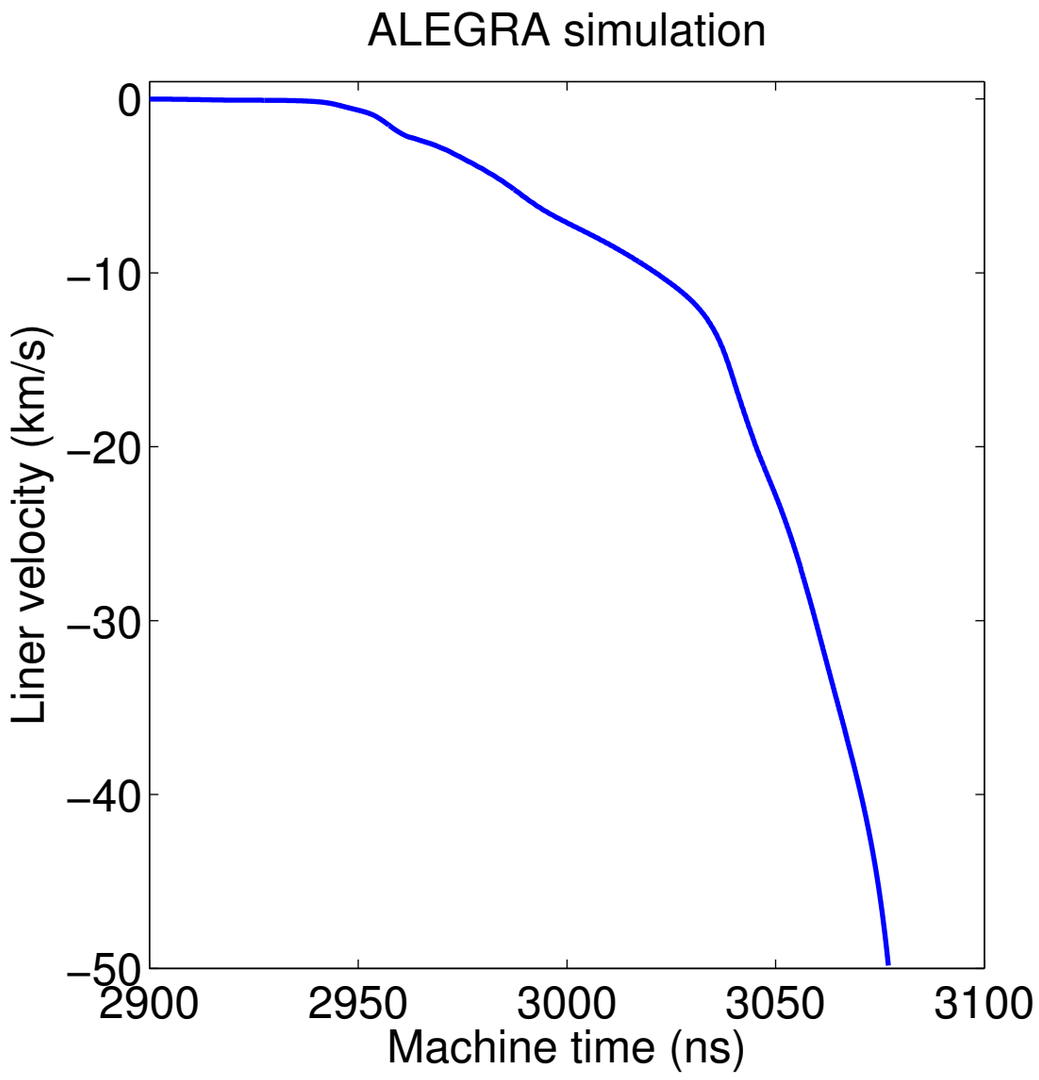
Liner Experiment with Radial PDV





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



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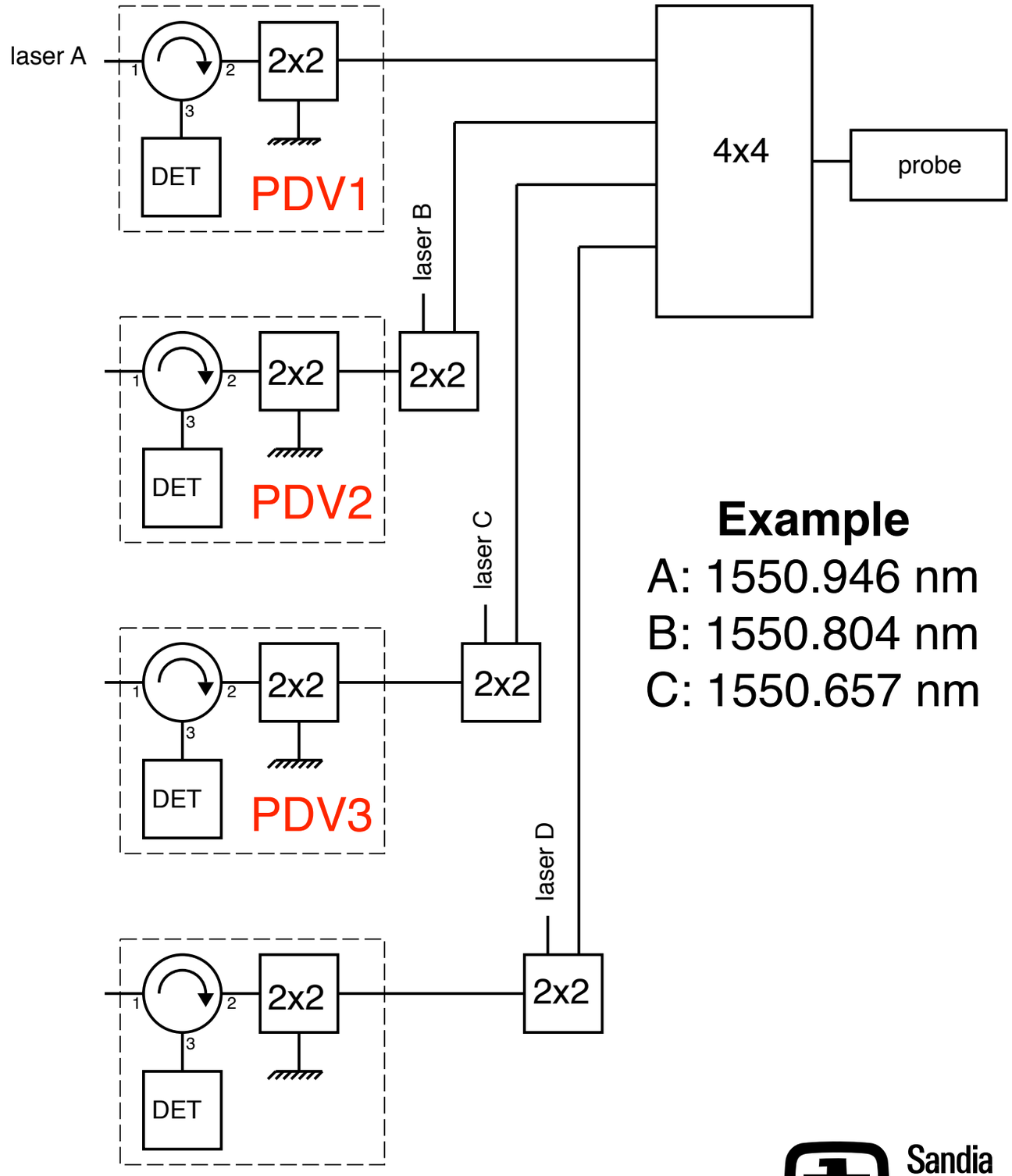
Leapfrog PDV

- 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

Z leapfrog schematic

- 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

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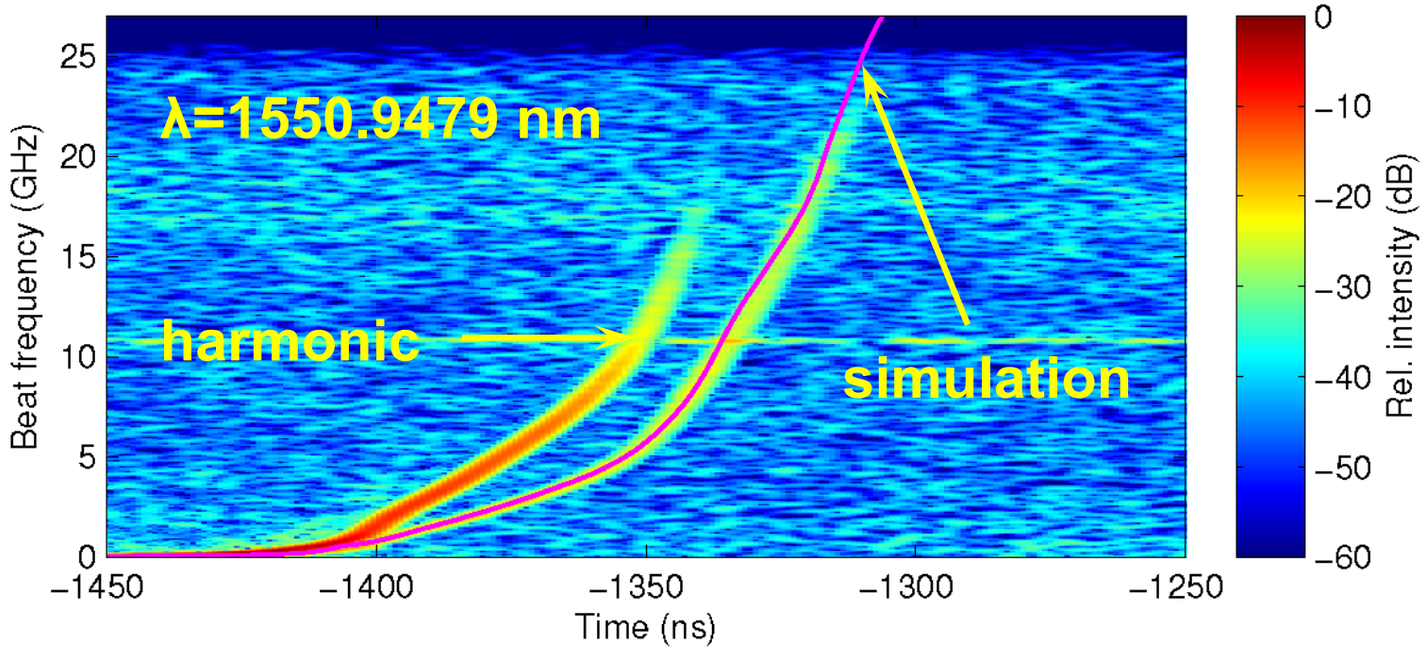
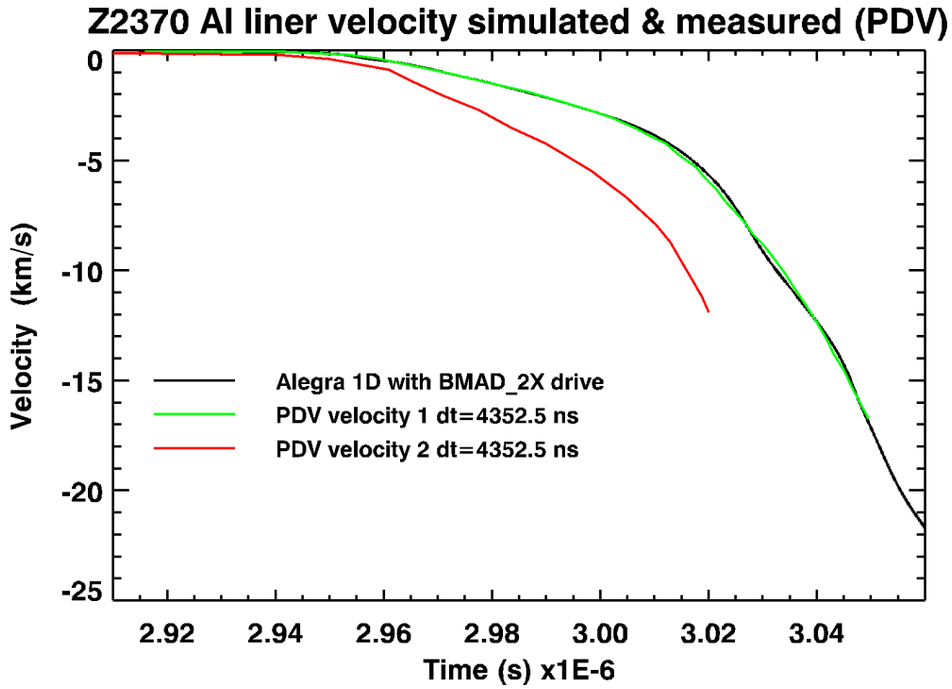
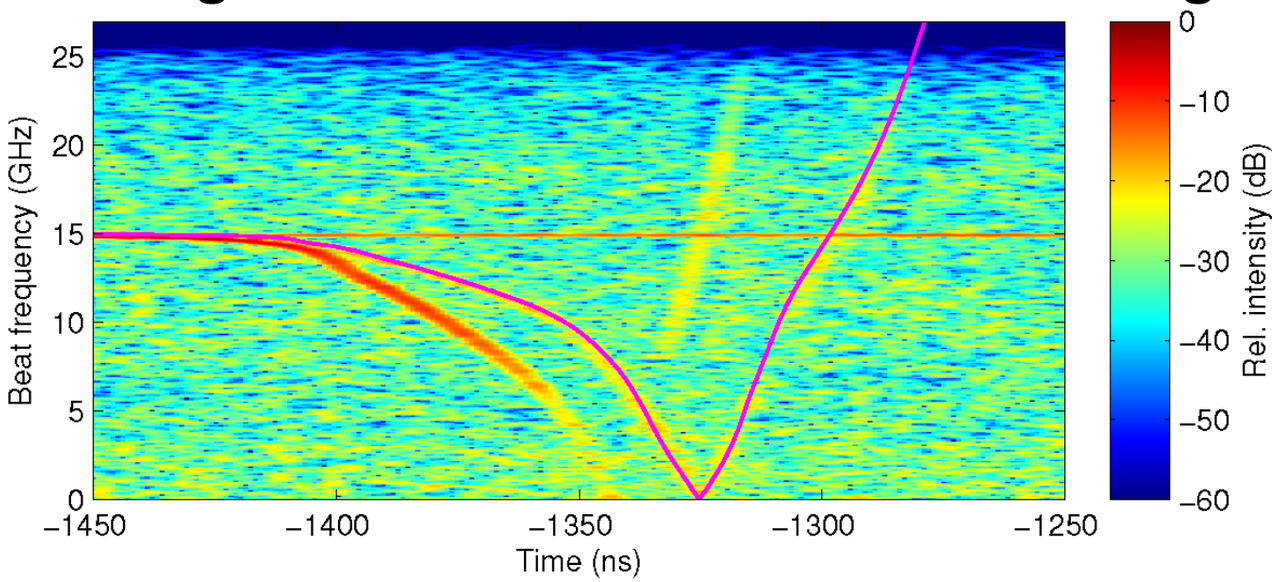
Initial results promising (Z2370)

Shifted light combined with original laser light



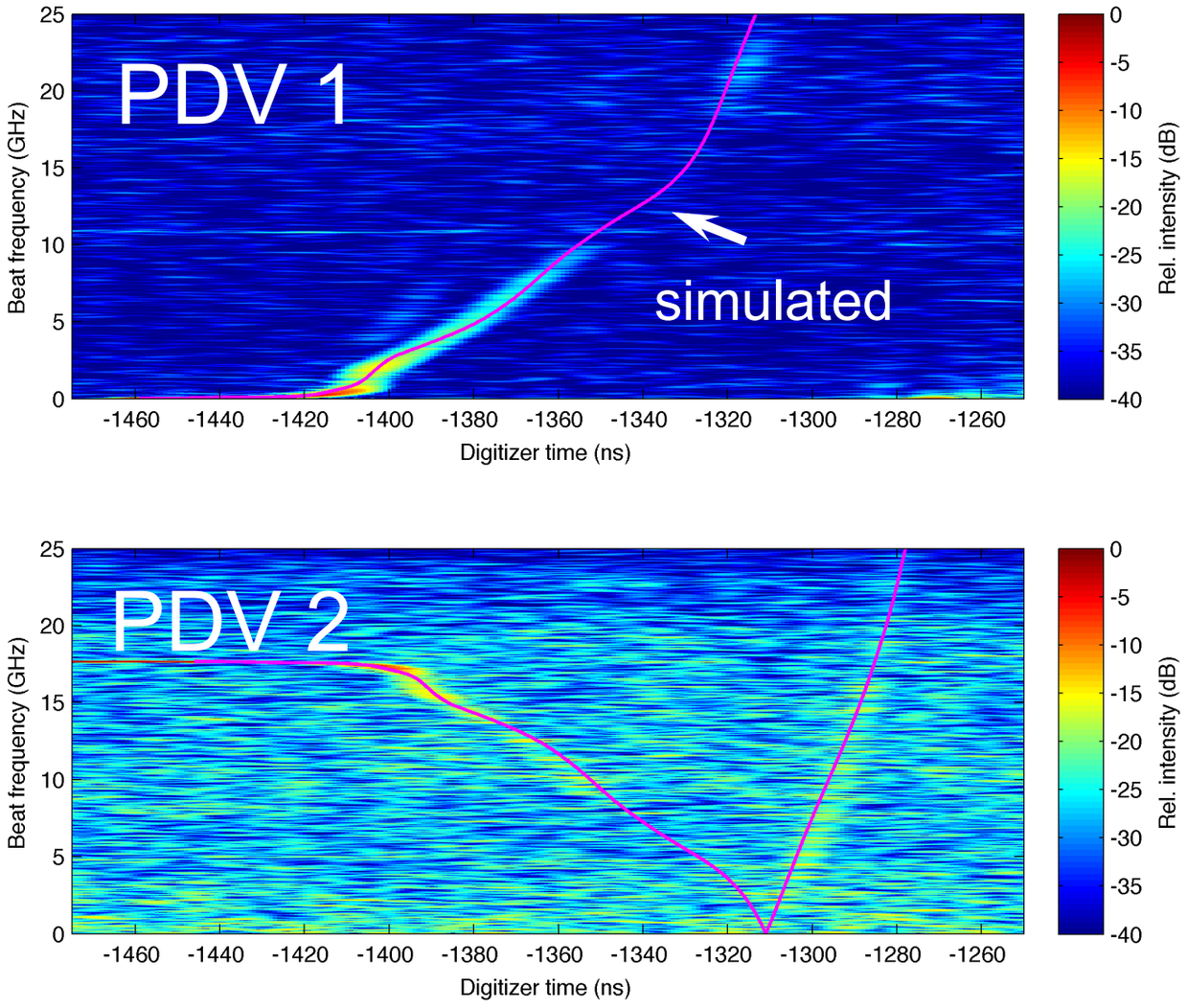


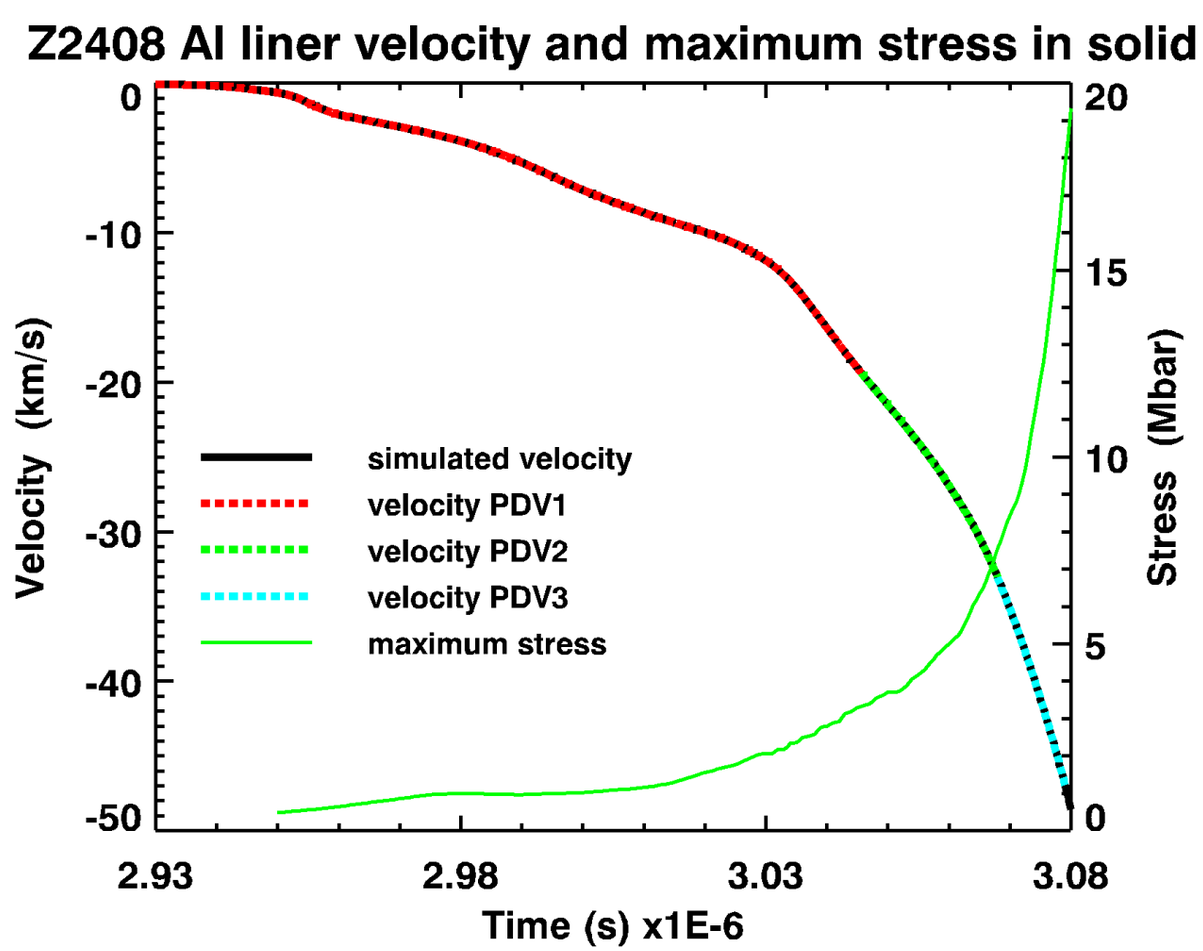
Shifted light combined with 1550.8276 nm light



Optical harmonic believed to be a double reflection

Followup experiment (Z2408)





- 18 GHz PDV separation
- 39.5 km/s maximum measured velocity

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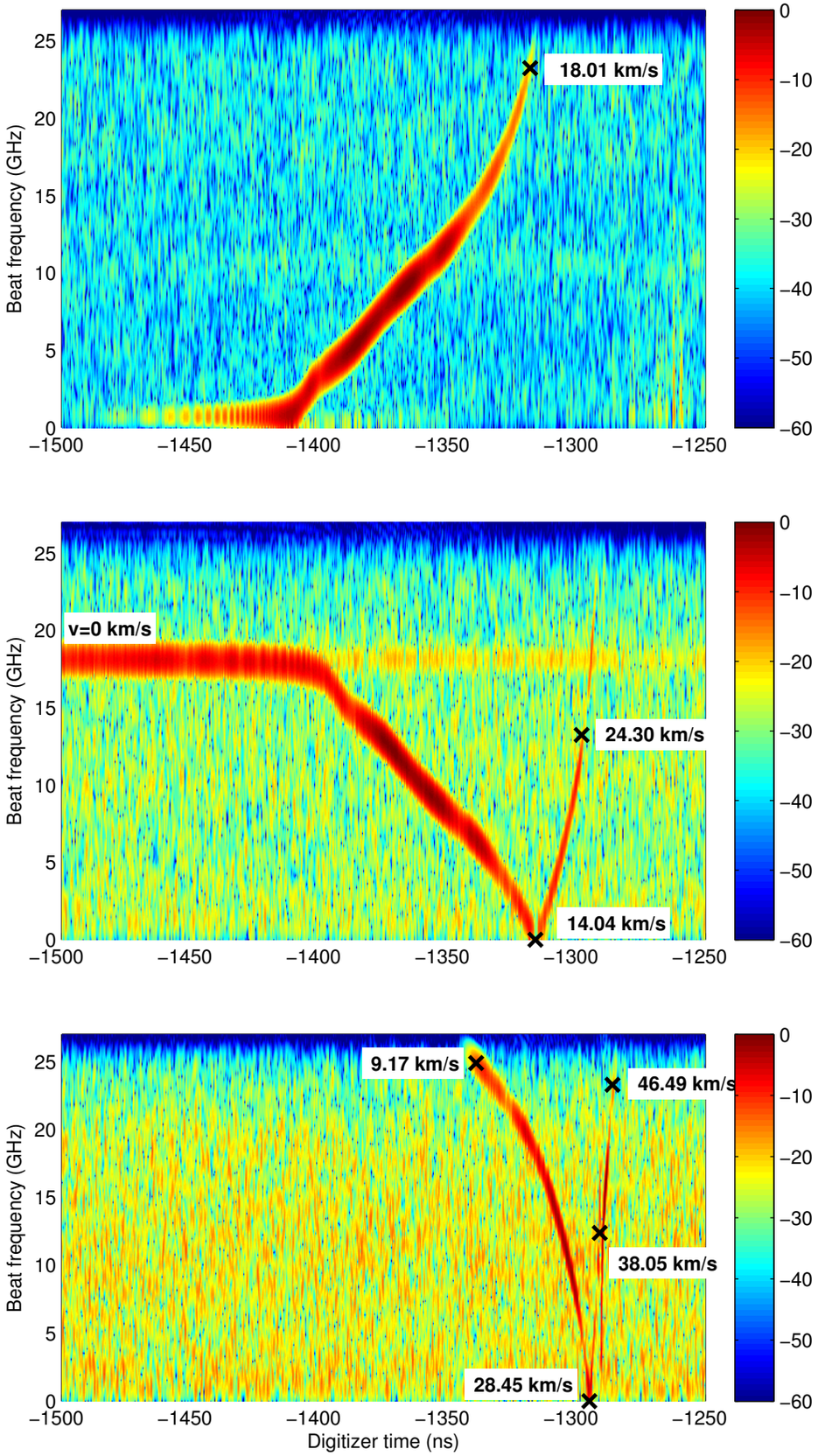
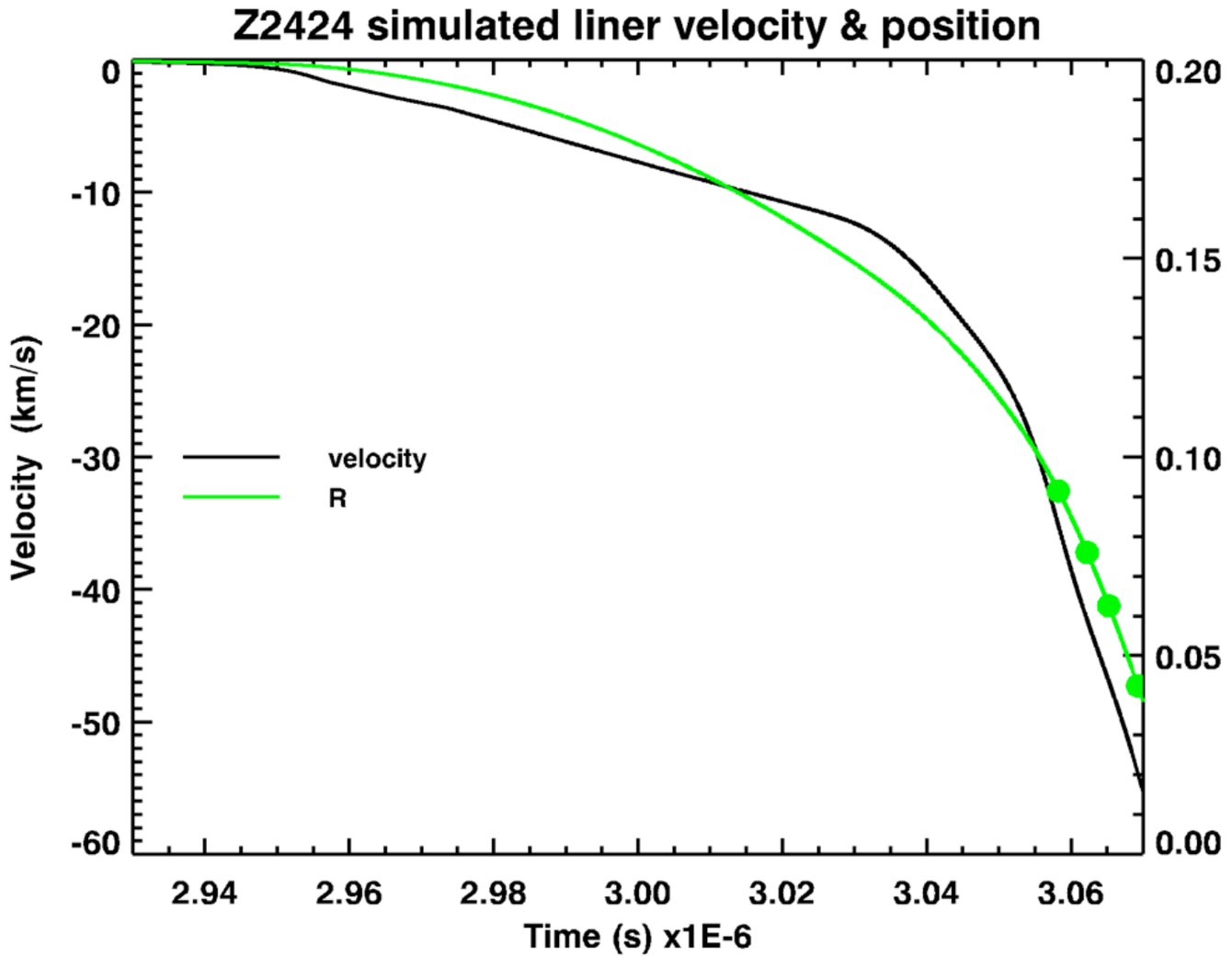
Third time is a charm



- Be liner
  - Z2424 (10/18/2012)



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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

Acknowledgements

- NSTec
  - High-speed conventional PDV built by LAO
  - Scott Walker (AO) built the system that ties four conventional channels into a leapfrog measurement

- ALEGRA simulations performed by Ray Lemke

- Z shots directed by Ryan McBride

- Probe installation, testing, and diagnostic support provided by Devon Dalton