Tracking wavy shock fronts
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2026 PDV workshop

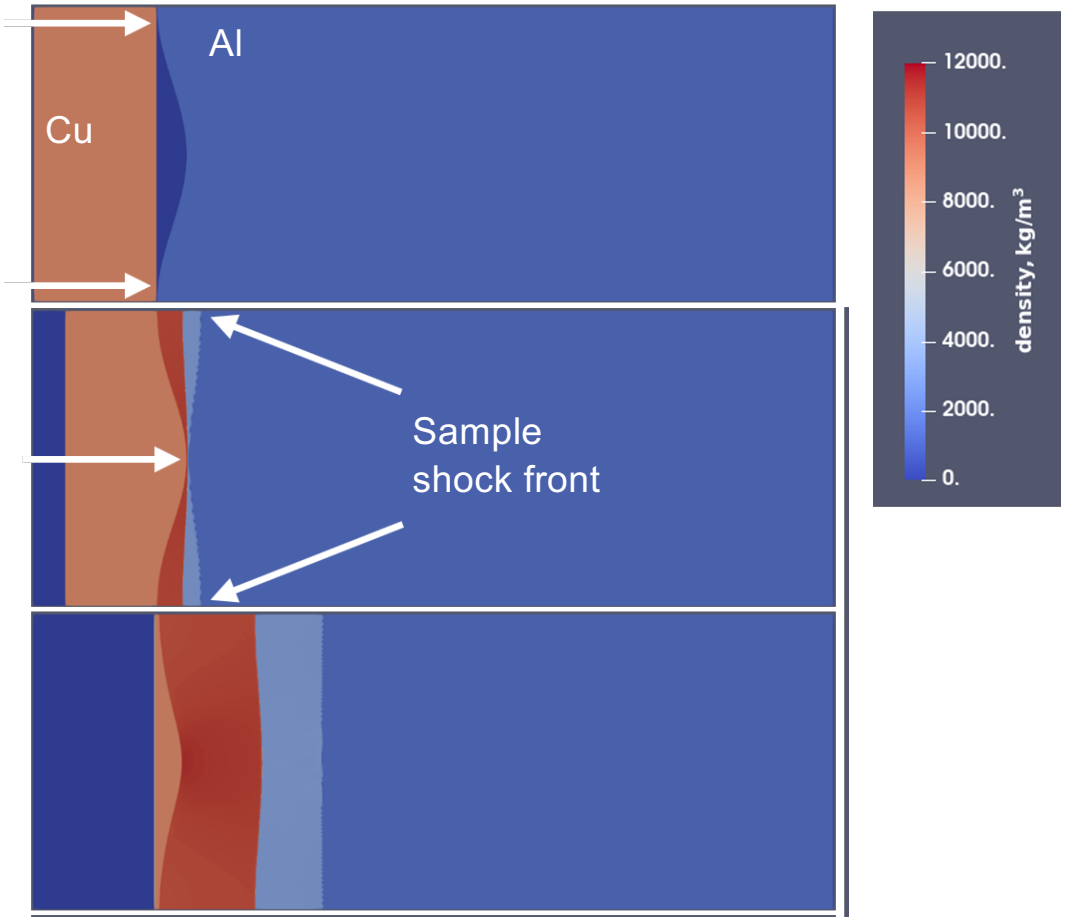
Overview

- PDV tracks different types of motion
  - Normally material velocity u_p
  - Can also *directly* measure Doppler shift from shock velocity U_s
    - Probe alignment
    - Substantial frequencies involved

- Can PDV monitor a wavy shock wave?
  - Could allow new types of HED measurement (viscosity)
  - Has all the standard problems, plus some new surprises

ALEGRA simulation of Cu hitting corrugated Al

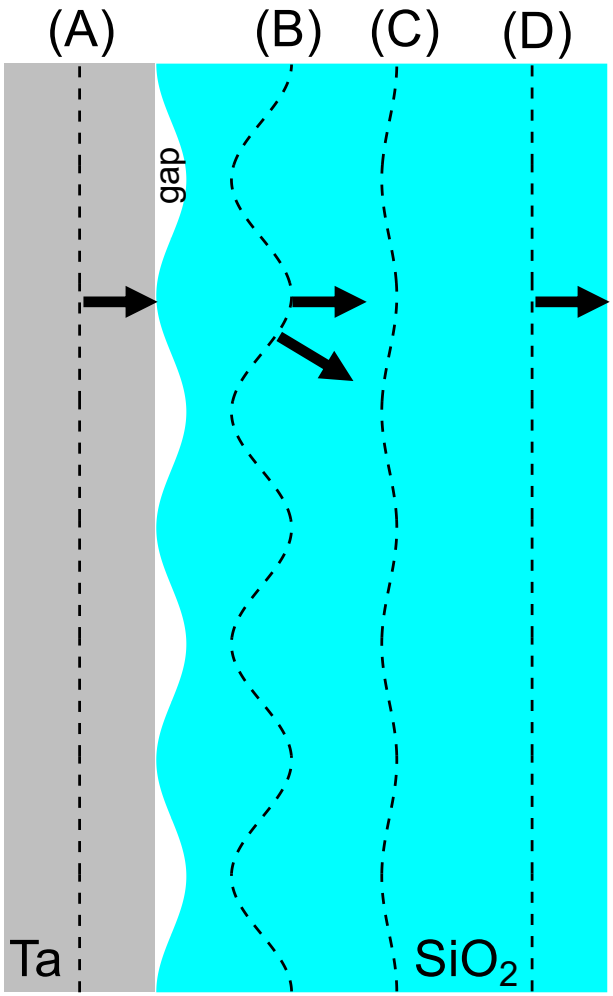
- Cu impacts wavy Al sample
  - Peaks hit first
  - Troughs closed later
  - Wavy shock front flattens with propagation
    - Geometry + viscous effects
- Shock fronts are hard to track in an opaque metal



shock.wsu.edu

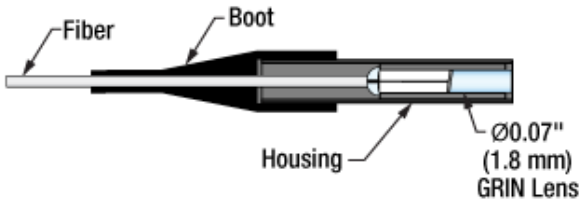
Generating a wavy shock front (not to scale!)

- Ta-Ta plate impact generates a uniform shock (A)
  - Two-stage gun, 6.7-6.9 km/s
- Corrugated fused silica surface creates wavy shock front (B)
  - Front shape inverted from corrugation
  - 110 GPa shock moves at ~10 km/s
  - Gaps filled with epoxy*
- Geometry and viscosity diminish waviness (C)
- Shock eventually coalesces to uniform front (D)
- Instabilities occur at the Ta-SiO_2 interface, but **these are obscured by the molten, opaque shock front**



Probing questions

- Collimating probes make a lot of sense...
  - Readily available and commonly used
  - Spot peaks/troughs sees peaks and troughs
- ...but are almost **useless** in tracking shocks
  - Uniform shocks are specular, requiring precision alignment
  - Front does not exist before impact, so how do you even make that alignment?
  - Several failed attempts at SNL and WSU



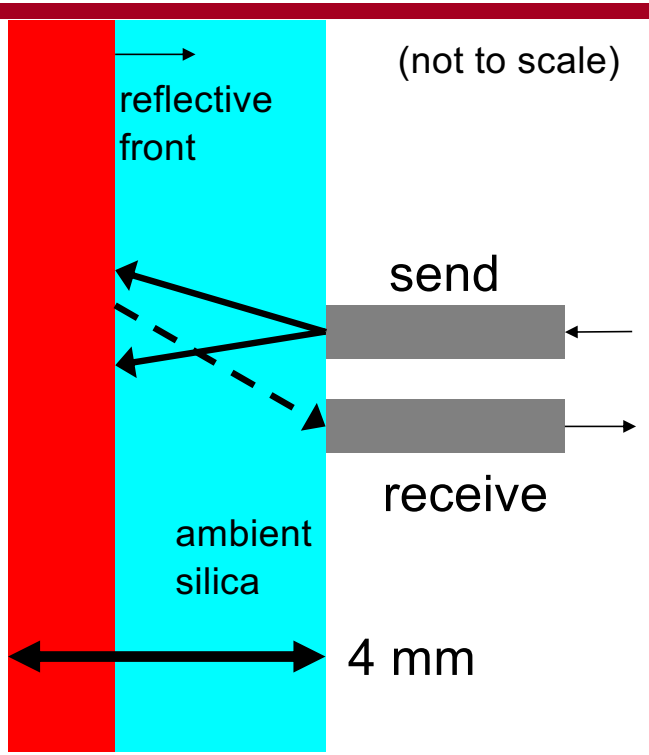
Thorlabs example:
~0.50 mm beam diameter
<0.25 deg acceptance

Bare fiber accepts ~ 5.5 deg

- Lesson: do not point a collimator at a mirror, *particularly one cannot see in advance*

Bare fiber probes do a better job in this case

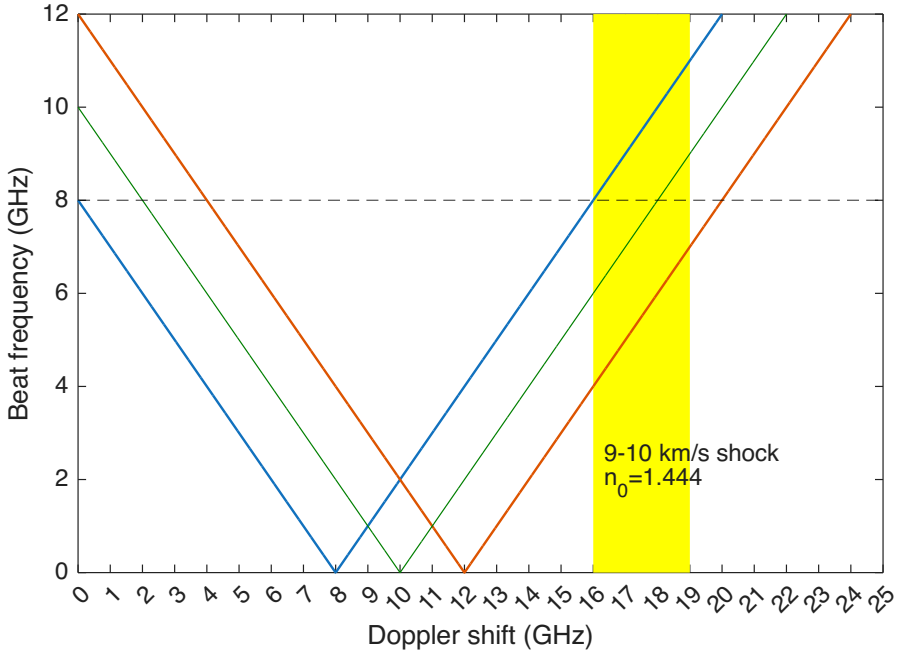
- Step 1: divert the target laser
  - Bypass the PDV circulator
  - Light goes to send fiber
- Step 2: connect receive fiber to PDV
  - This fiber passively collects reflected light
  - Be prepared for 40-50 dB **insertion** loss
  - You may need a different meter (or two meters) for unidirectional testing
- Step 3: send +20 dBm to the target
  - Collect -20 to -30 dBm on the receive fiber
  - Declare victory



Max angle:
5.48 degrees (vacuum)
3.80 degrees (fused silica)
Spot **starts** at 760 um OD

Substantial Doppler shift...

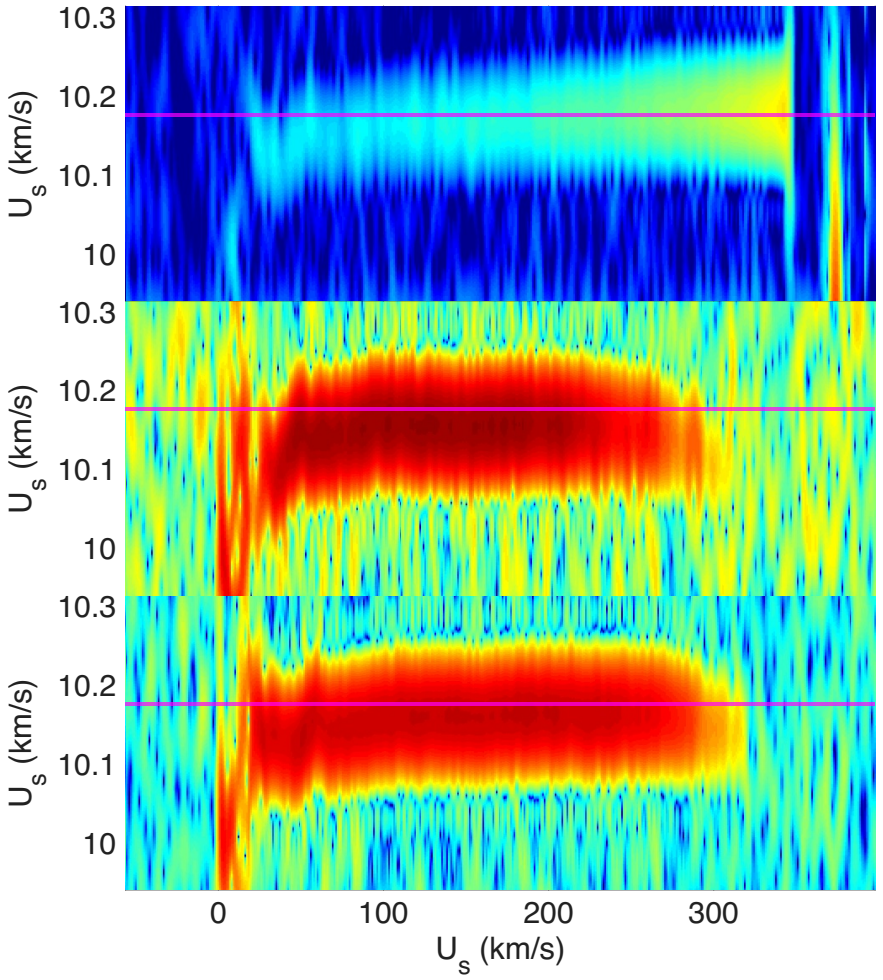
- 10 km/s is 12.9 GHz at 1550 nm, but...
  - Silica makes this look 1.44x faster
  - 14.4 km/s is 18.6 GHz
  - ~2 GHz upshift means 20+ GHz
- Our system limited to 8-13 GHz
- Leapfrog PDV saves the day
  - Reference wavelength shorter than the target laser (~80 pm)



- Initial beat near the top of the system bandwidth
- Shock measured at lower frequency than the initial beat
  - Right side of the "V" in the frequency-shift plot

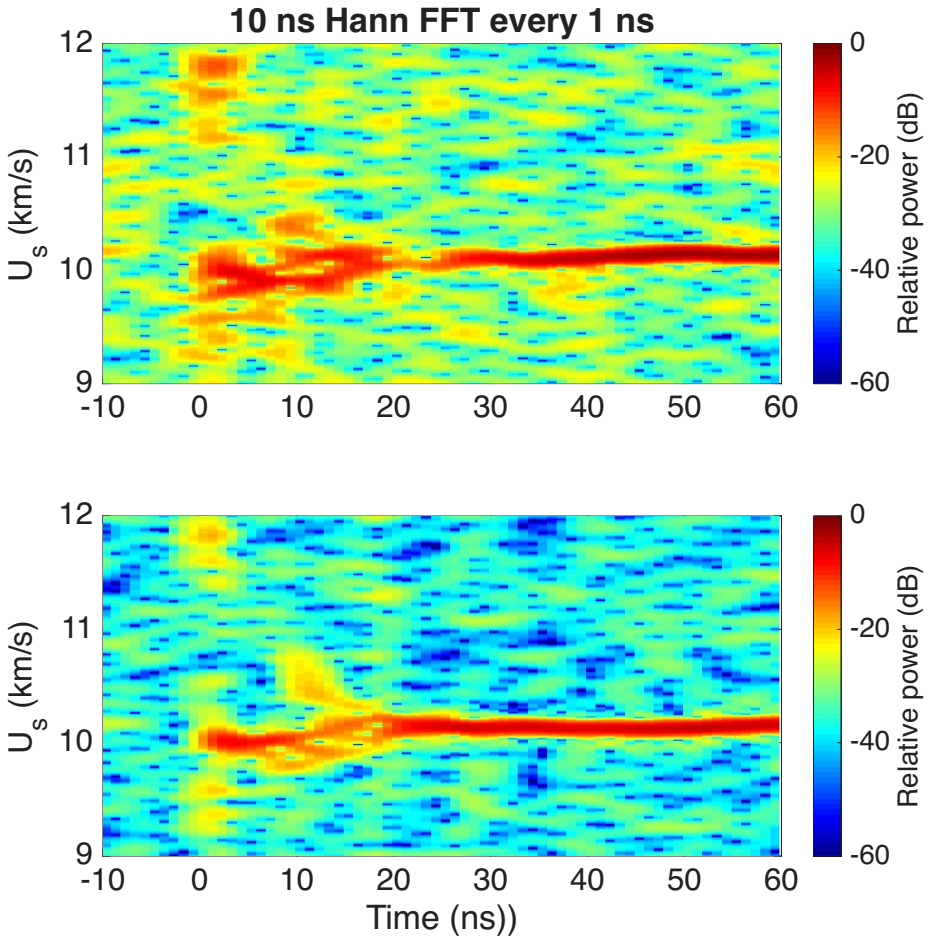
First success with a home-built fiber bundle

- Roadrunner 07
  - 100 um lateral period
  - 30 um peak-value depth
- Send fiber also used as probe
  - Bidirectional measurement
  - Strong reflection from flat polish
  - Shock visible as it gets closer
- General similar results on two unidirectional measurements
  - Reflection fades away when shock gets too close for bounce between fibers



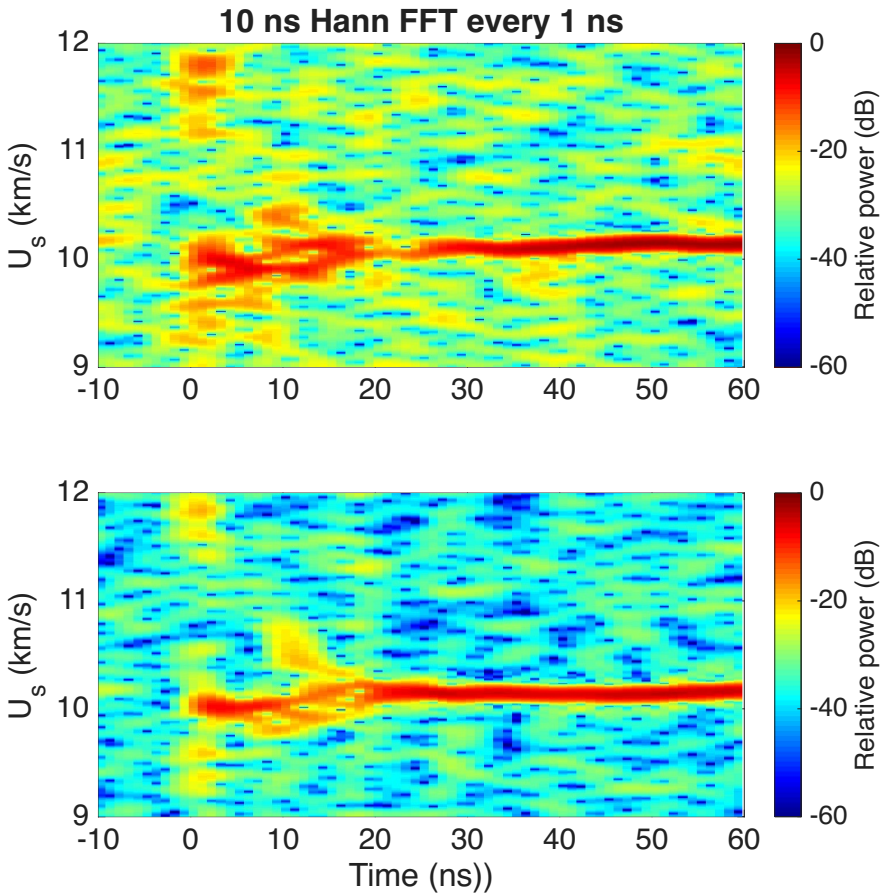
Trends in Roadrunner 07

- Brief high-velocity burst (< 5 ns)
- Medium term (5-20 ns) velocities below/above steady state
  - ~1 km/s full spread
  - Multiple converging streams
- Long term (20-100+ ns) coalescence towards steady state
  - Periodic variation on top of an upward trend

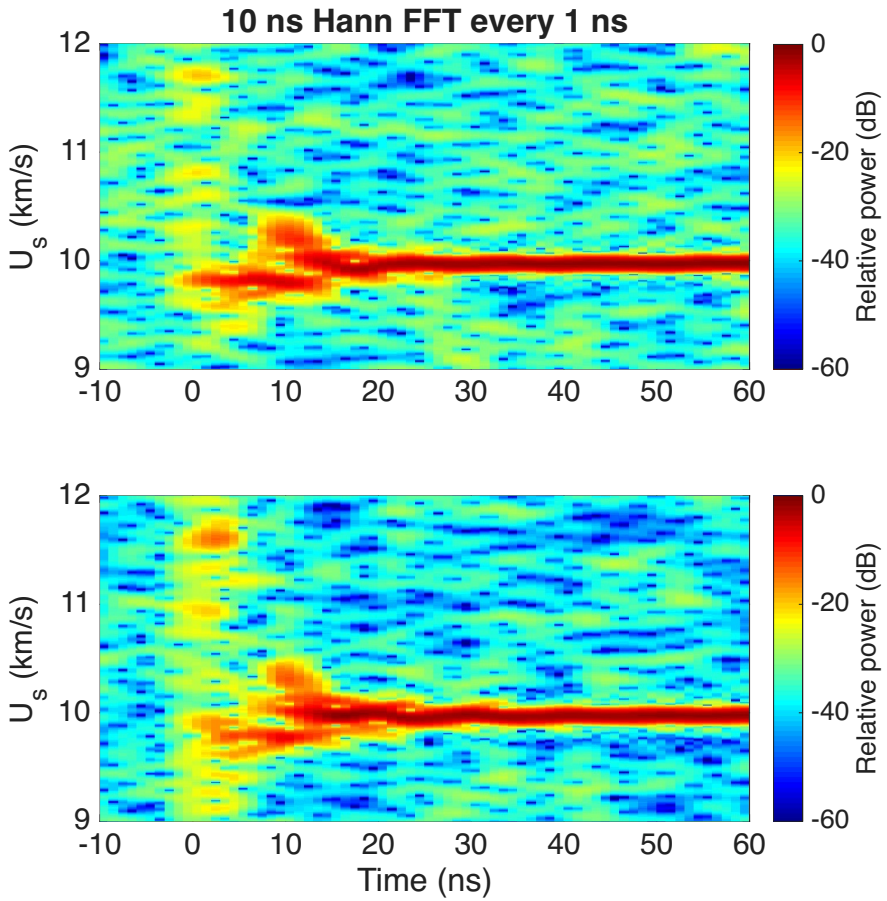


Reproducibility at 100/30 corrugation

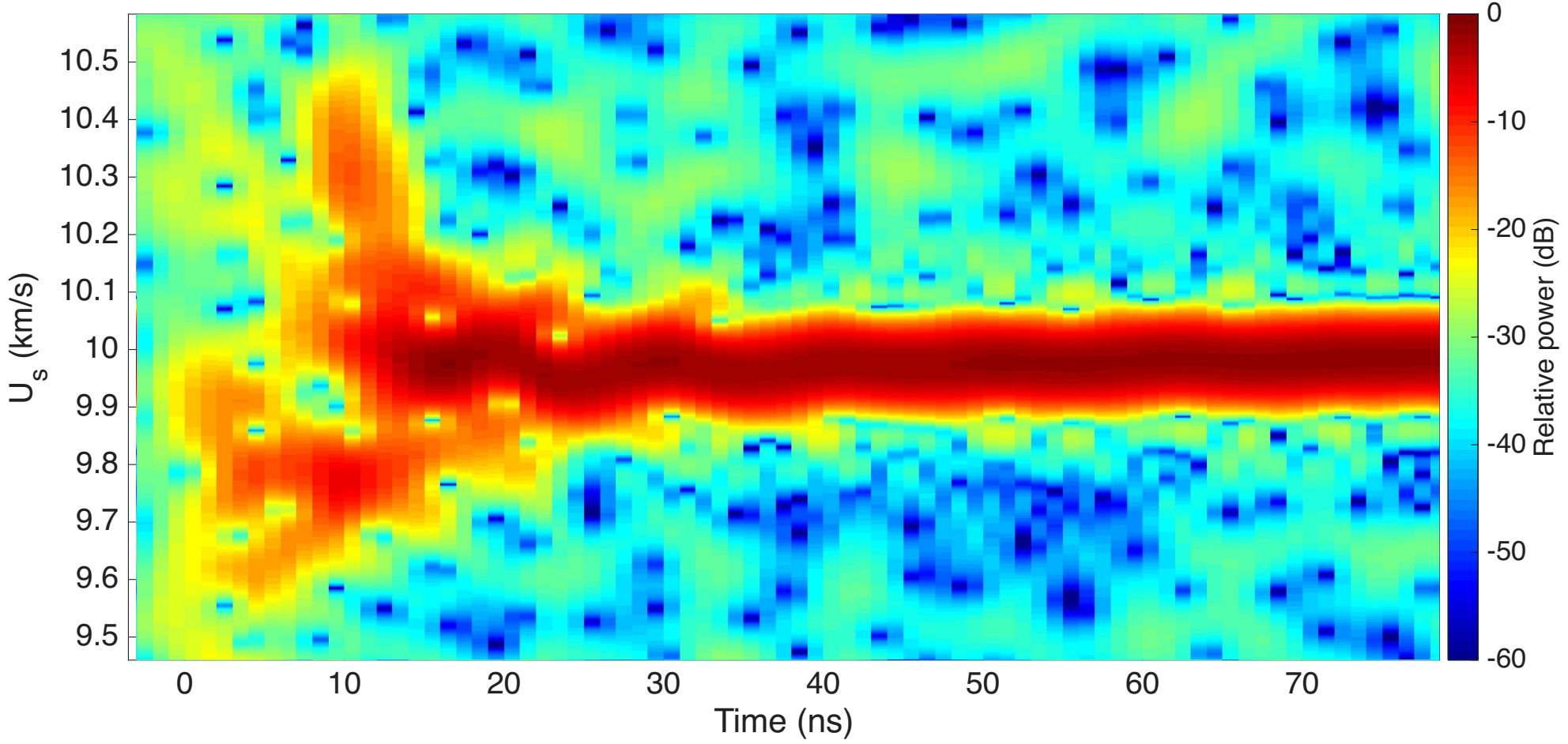
Roadrunner 07



Roadrunner 22

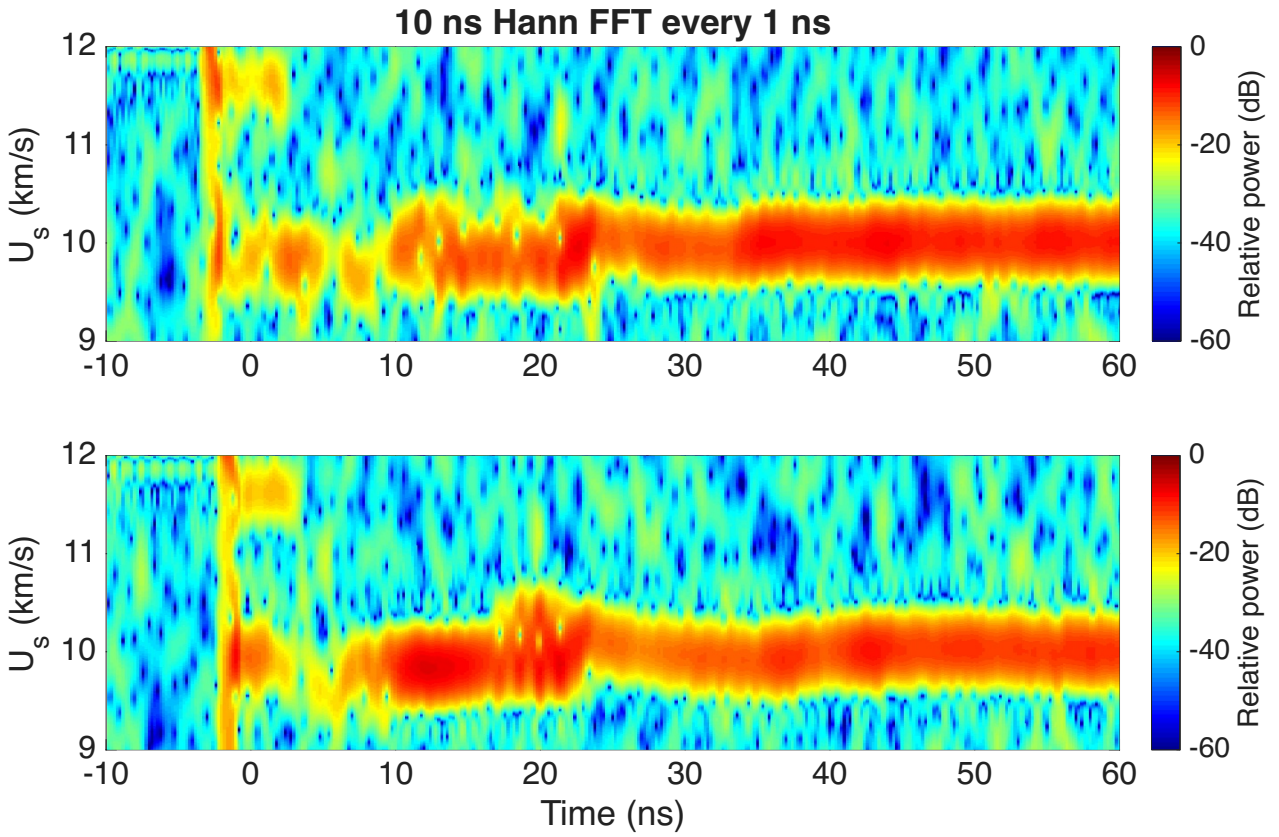


Finer details of Roadrunner 23 (100/30)



Changing the waviness (Roadrunner 23)

- 200 um period, 60 um peak-valley
  - Same aspect ratio
- Consistent results between probes
  - Some familiar features
- Different than 100/30 experiment
  - Quantification still in progress...



Summary

- PDV can track a wavy shock front
  - This turned out to be more challenging than expected
  - Bare fiber probes work to some degree

- There is lots of room for improvement
  - Gaps should probably be left unfilled (simulations usually omit this)
  - PDV refinements
    - More channels would help
    - Ultra-high NA fiber might pick up more lateral variation
    - Improve alignment between fiber pairs and sample corrugation

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