PDV development at the LANL Proton Radiography Facility: smaller, cheaper, lower bandwidth

The Los Alamos Proton Radiography Facility (pRad) employs a high-energy proton beam to image the properties and behavior of materials driven by high explosives. We will discuss features of pRad and describe some recent experiments, highlighting optical diagnostics for surface velocity measurements.

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Philip Rae, David Holtkamp

Physics Division, Los Alamos National Laboratory

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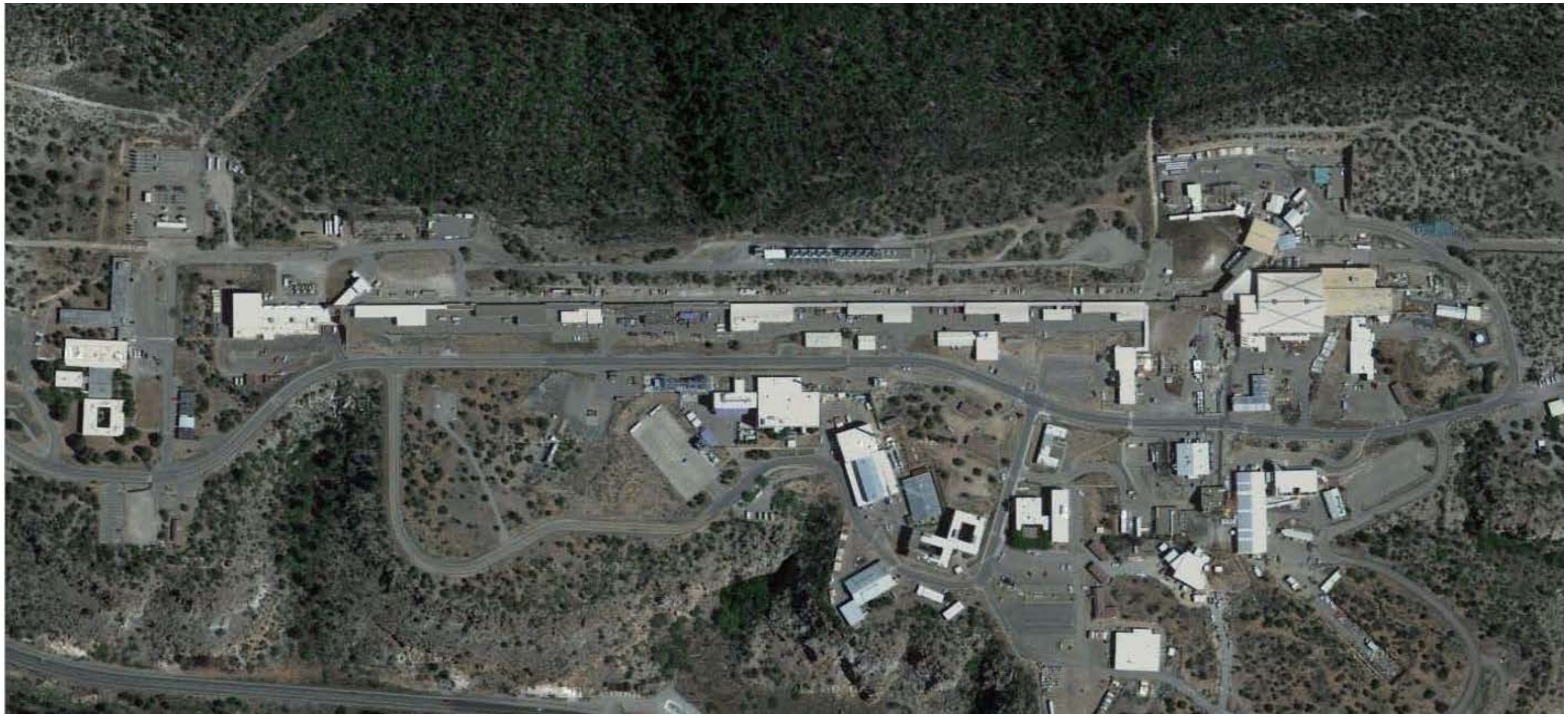
LANSCE:
Los Alamos Neutron Science
Center



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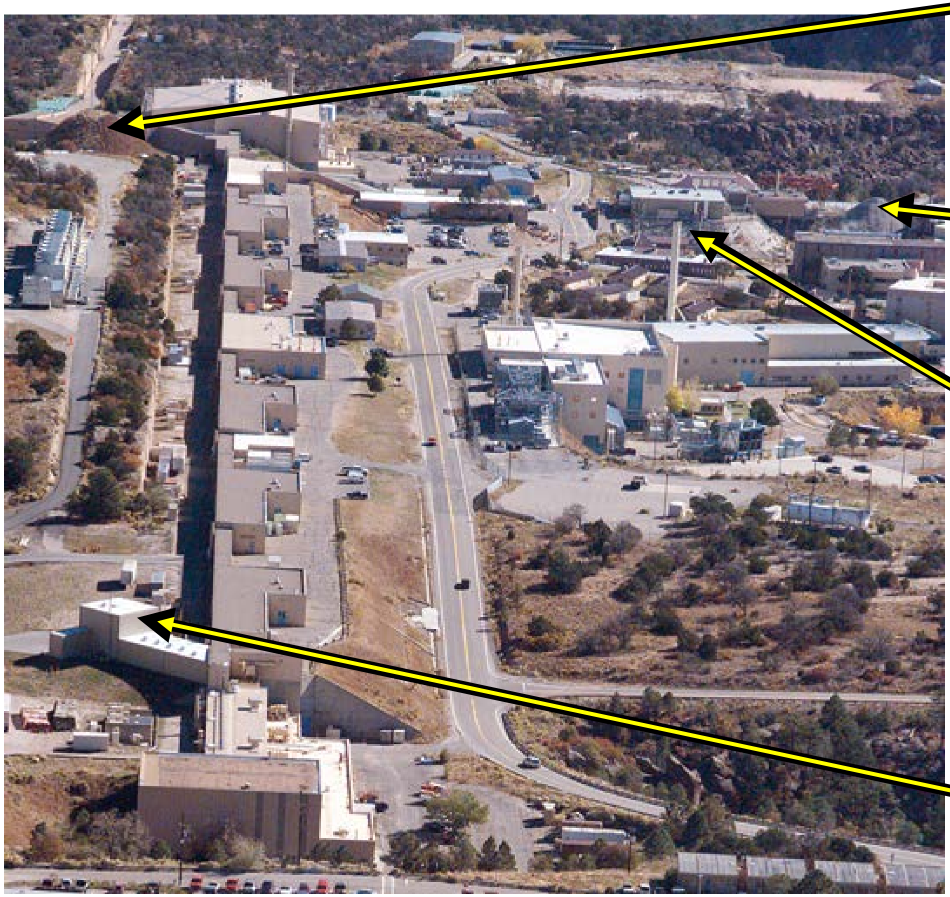

Proton Radiography

National security research
Dynamic Materials science
Hydrodynamics

WNR

National security research
Nuclear Physics
Neutron Irradiation

Lujan Center

National security research
Materials, bio-science, and nuclear physics
National user facility

Isotope Production Facility

Medical radioisotopes

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Incident
protons

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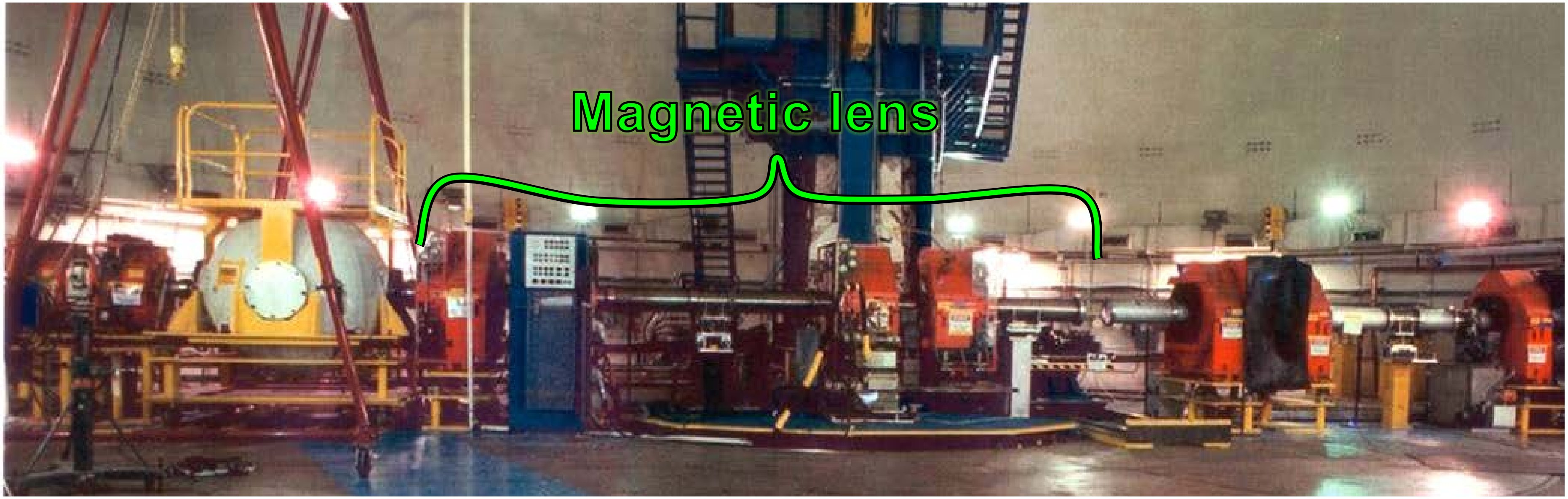
Pass through the sample

A magnetic lens re-images the sample

The most highly-scattered protons are removed



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Protons form a real image

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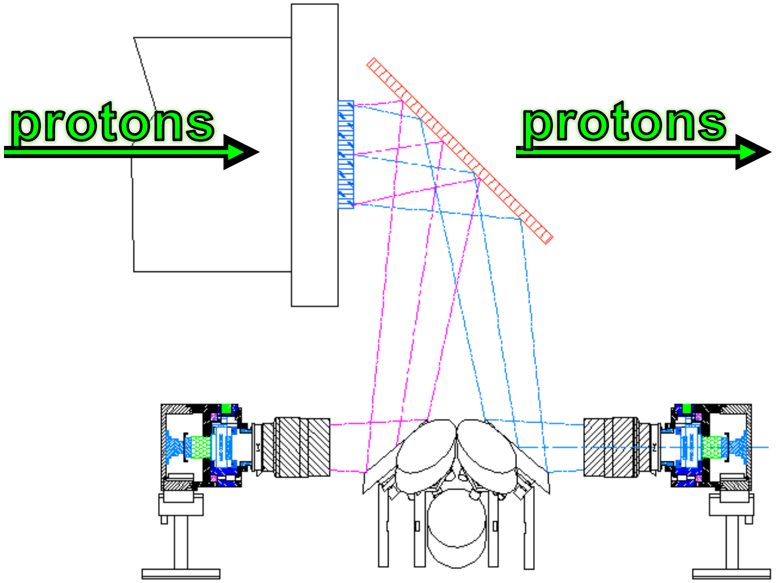
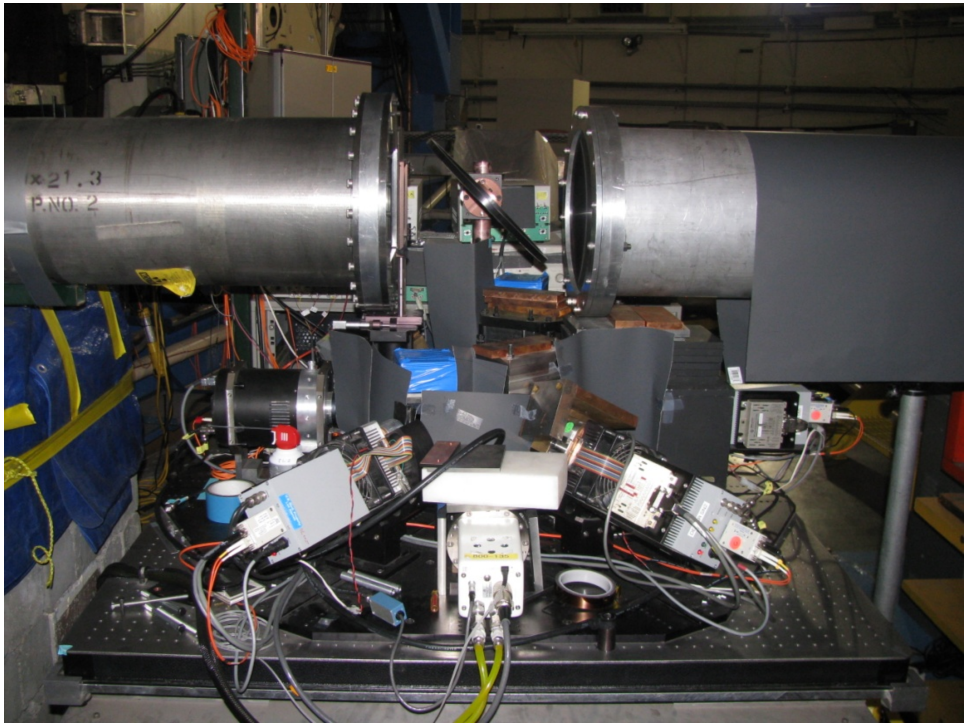
A visible image
is recorded





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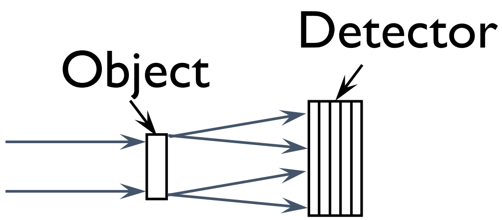
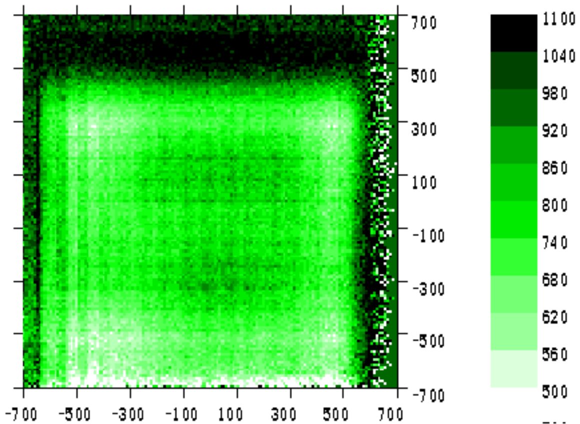
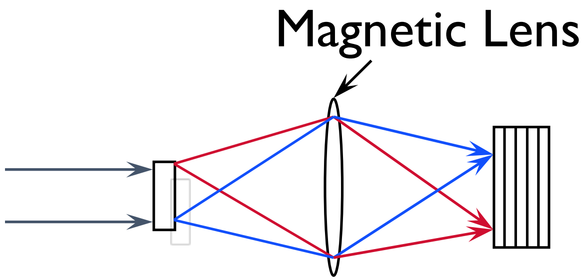
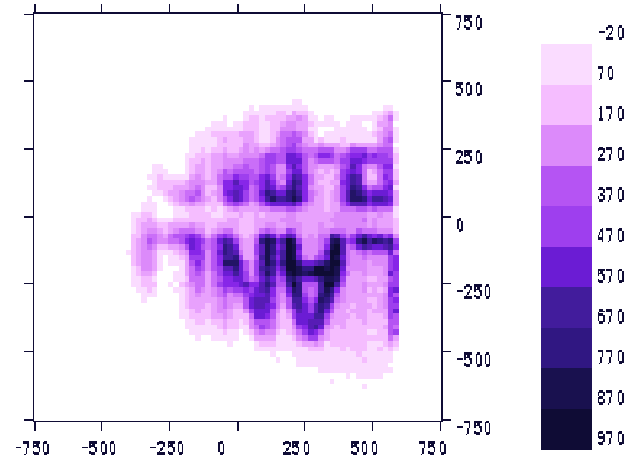




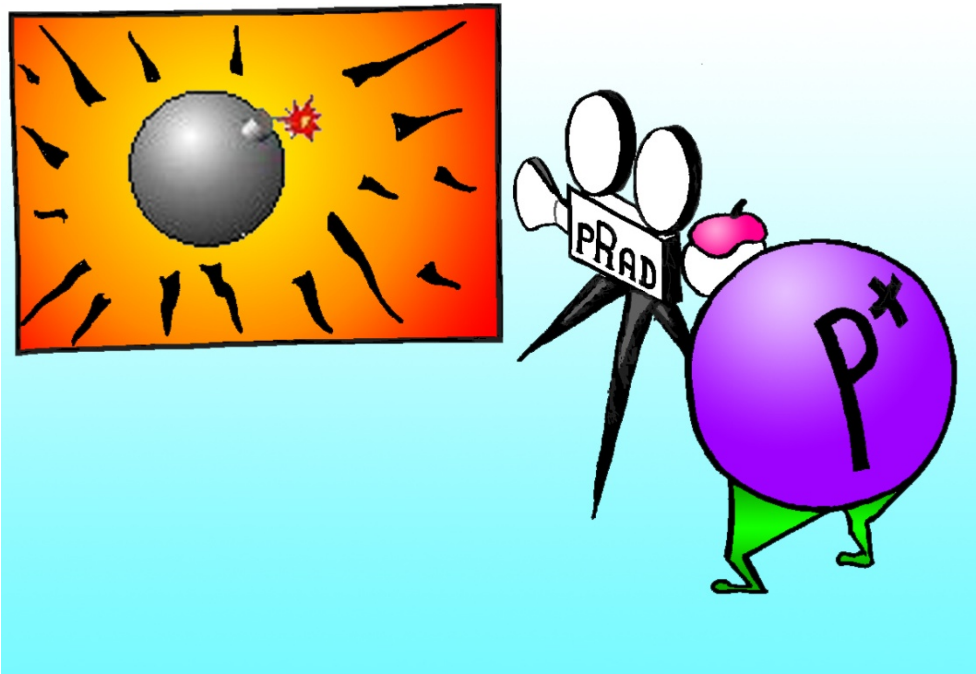


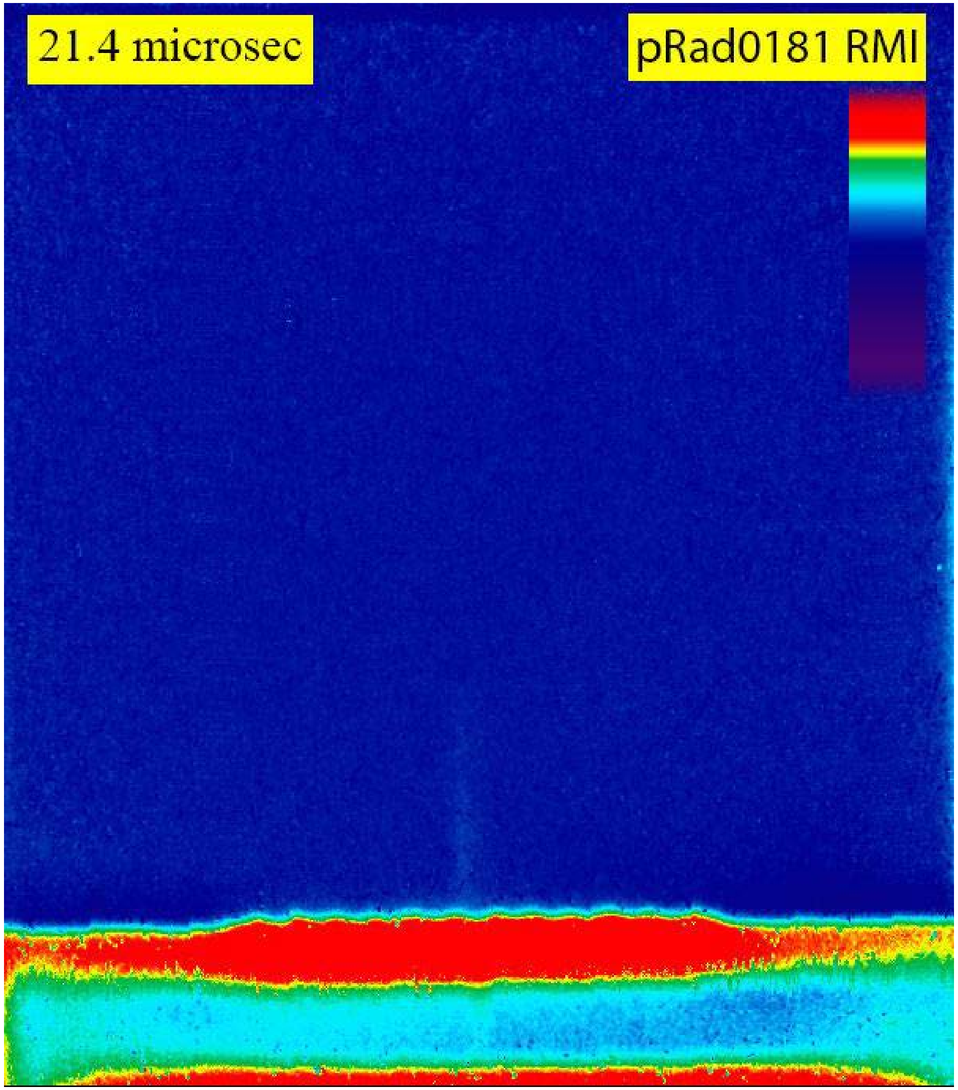


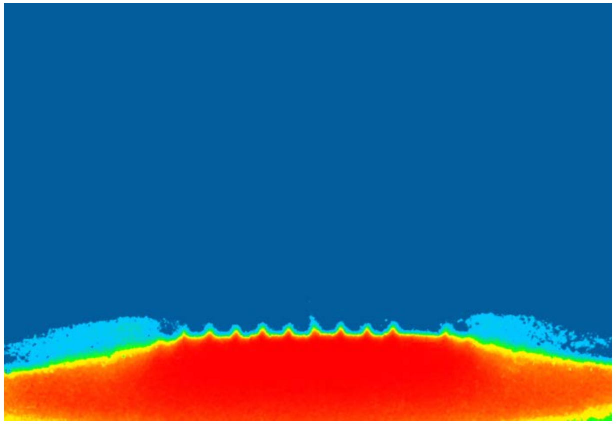
Simple "shadow" image – results are substantially blurred.

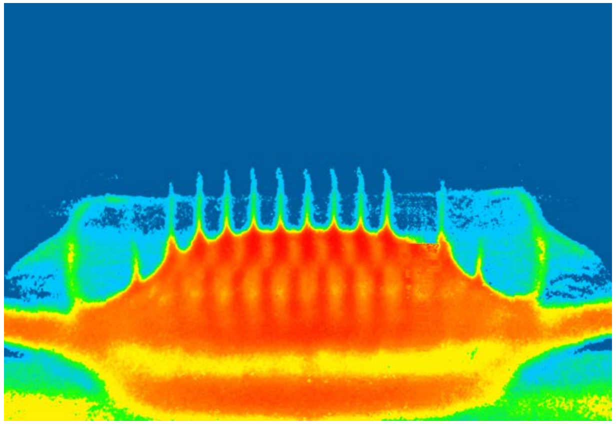
Magnetic imaging of the protons preserves high resolution. (Los Alamos 1995)

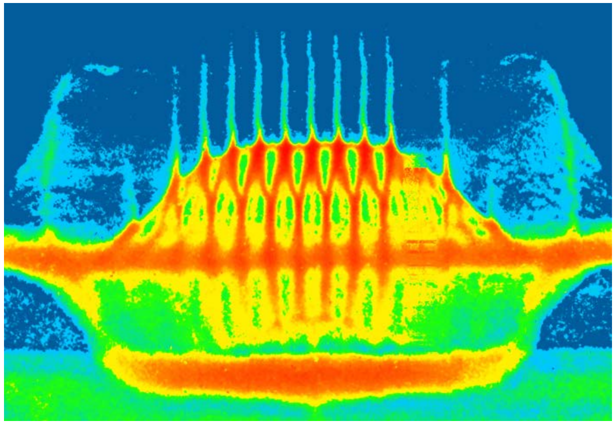
Proton pulse timing sequences can be specified by the experimenter → **High-speed radiographic movies!**











Experiment Principal Investigator: Billy Buttler

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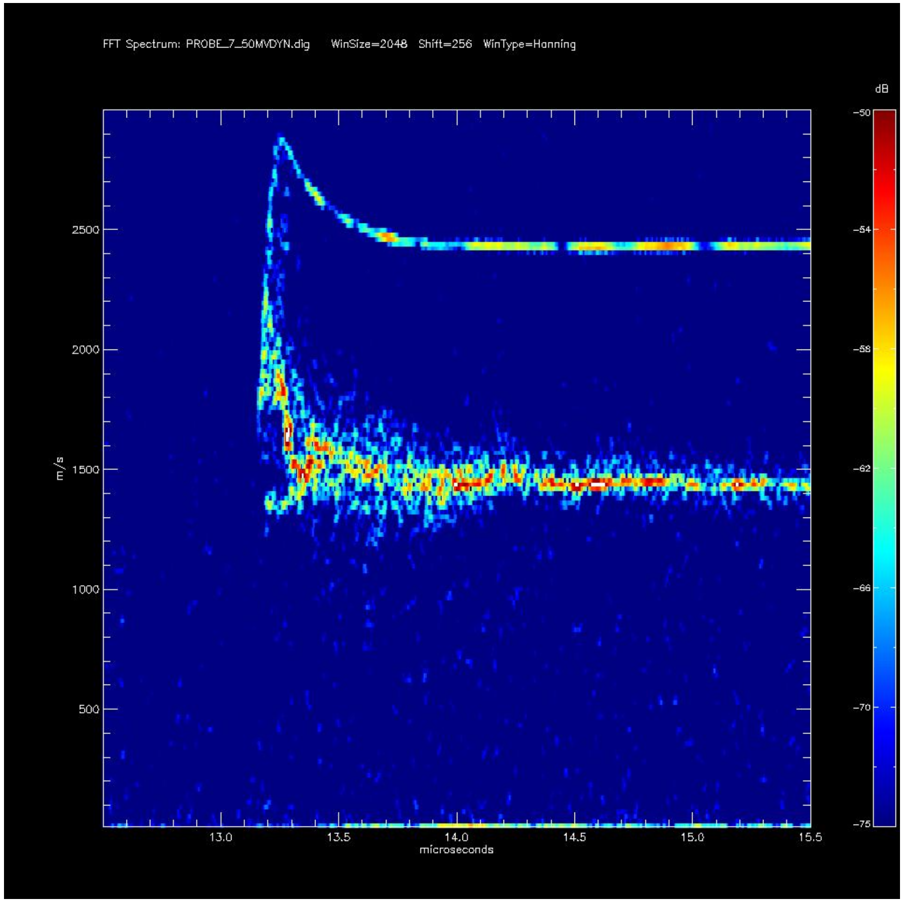

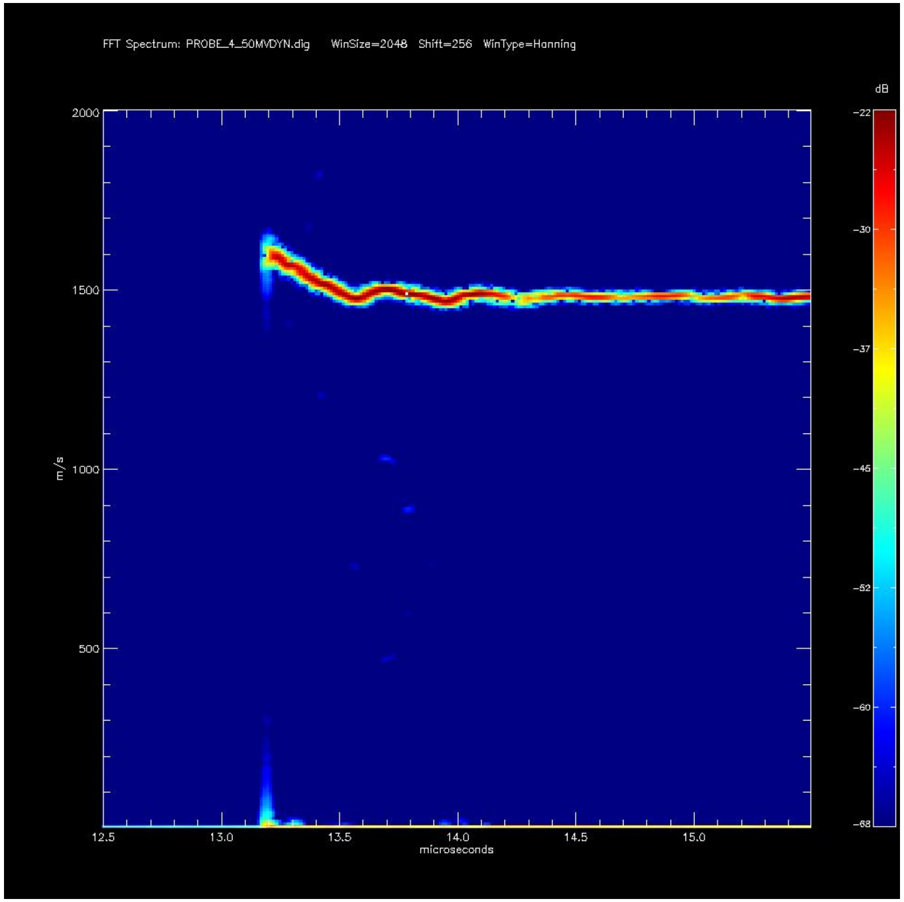

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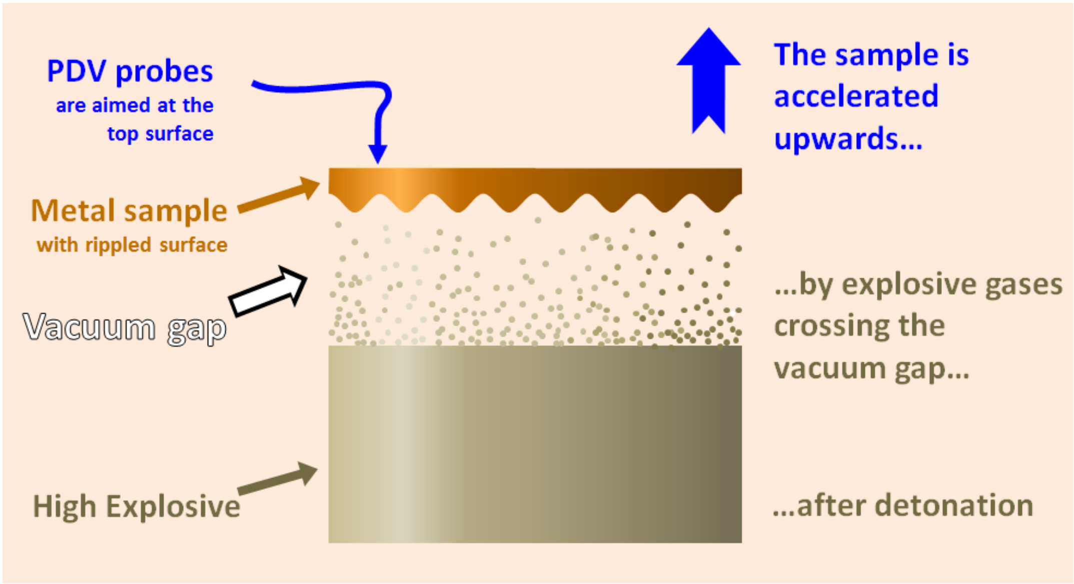
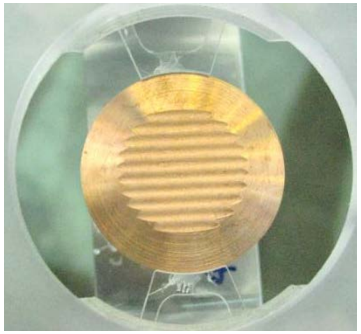
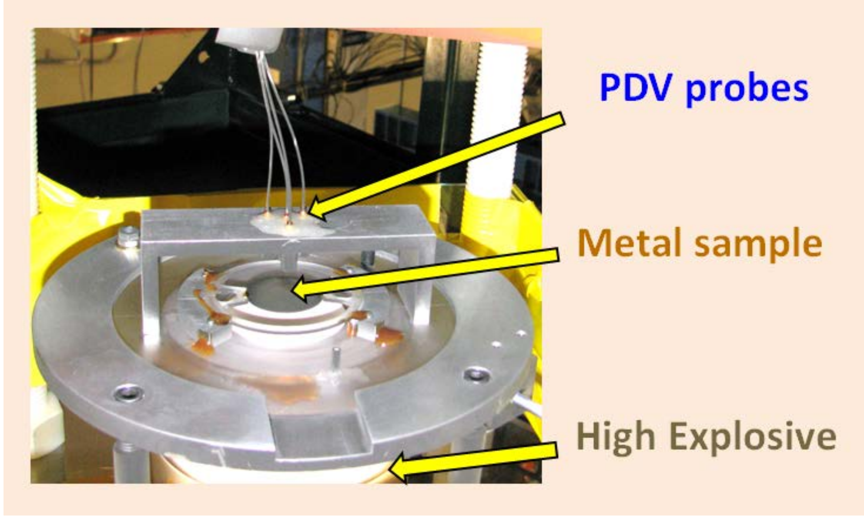
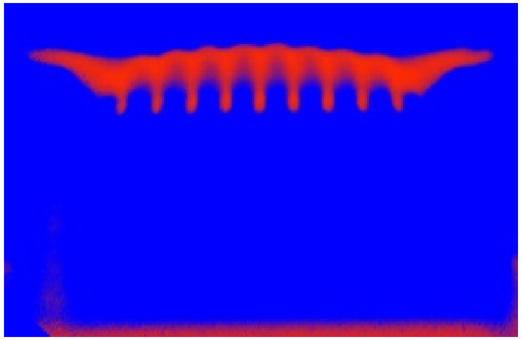
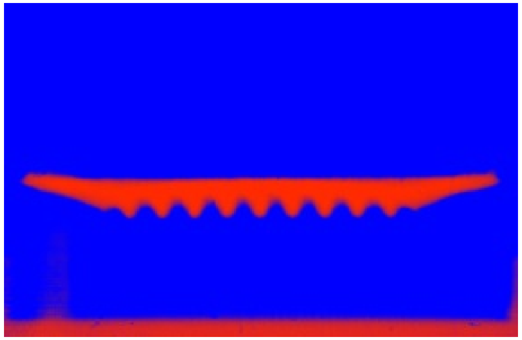
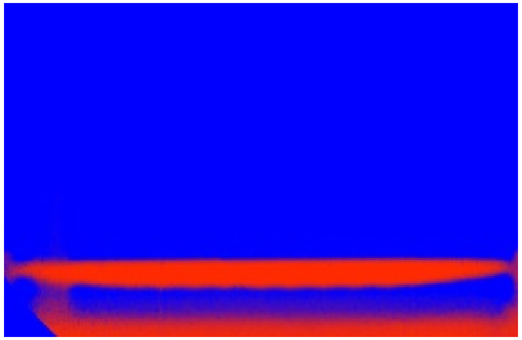






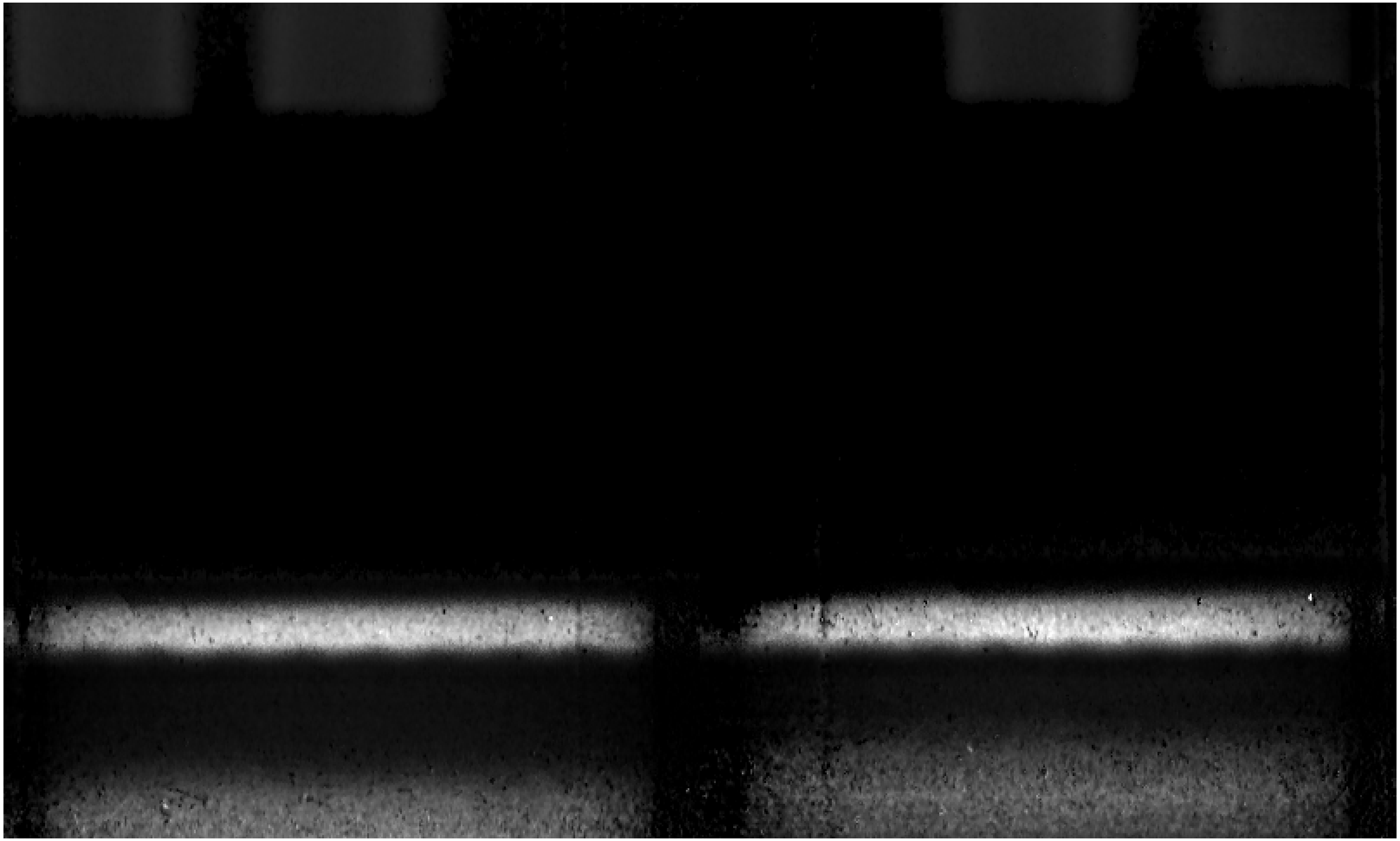






Experiment Principal Investigator: Russ Olson

movie



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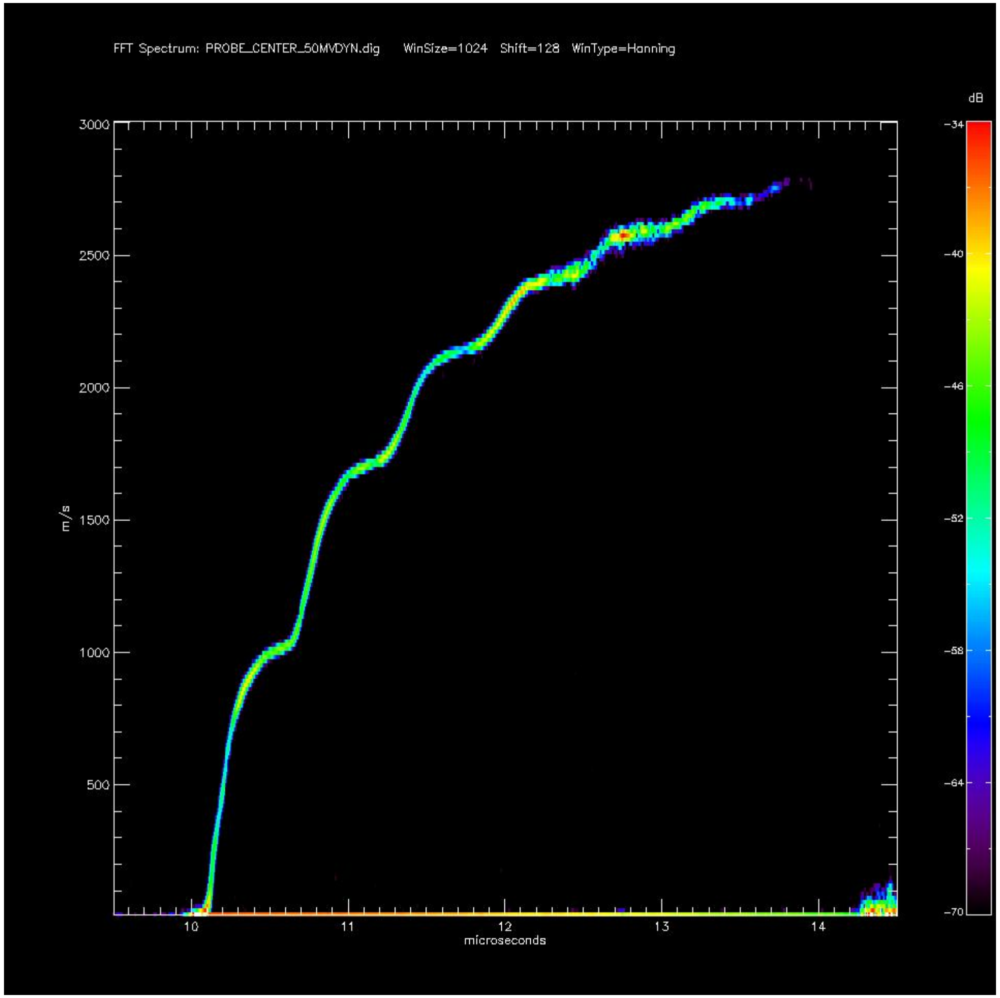

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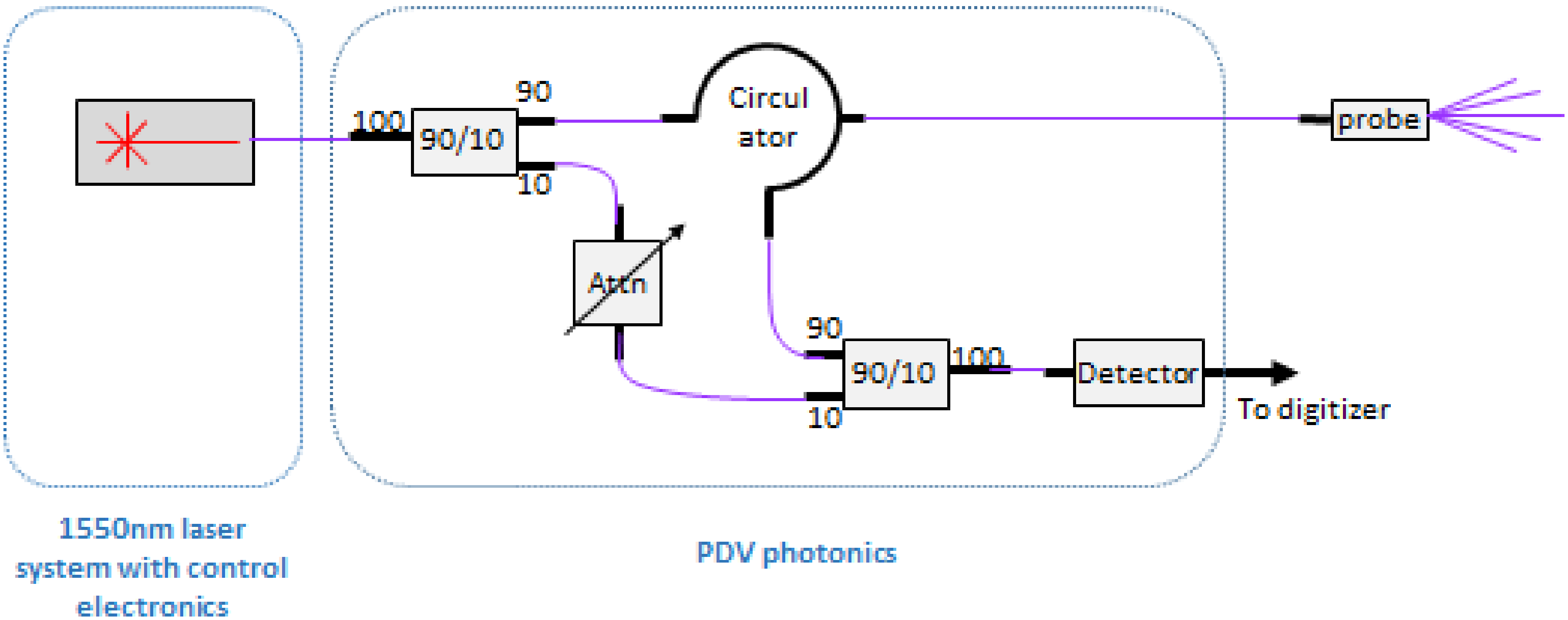
PDV: Photon Doppler Velocimetry



New hardware implementations towards several goals:

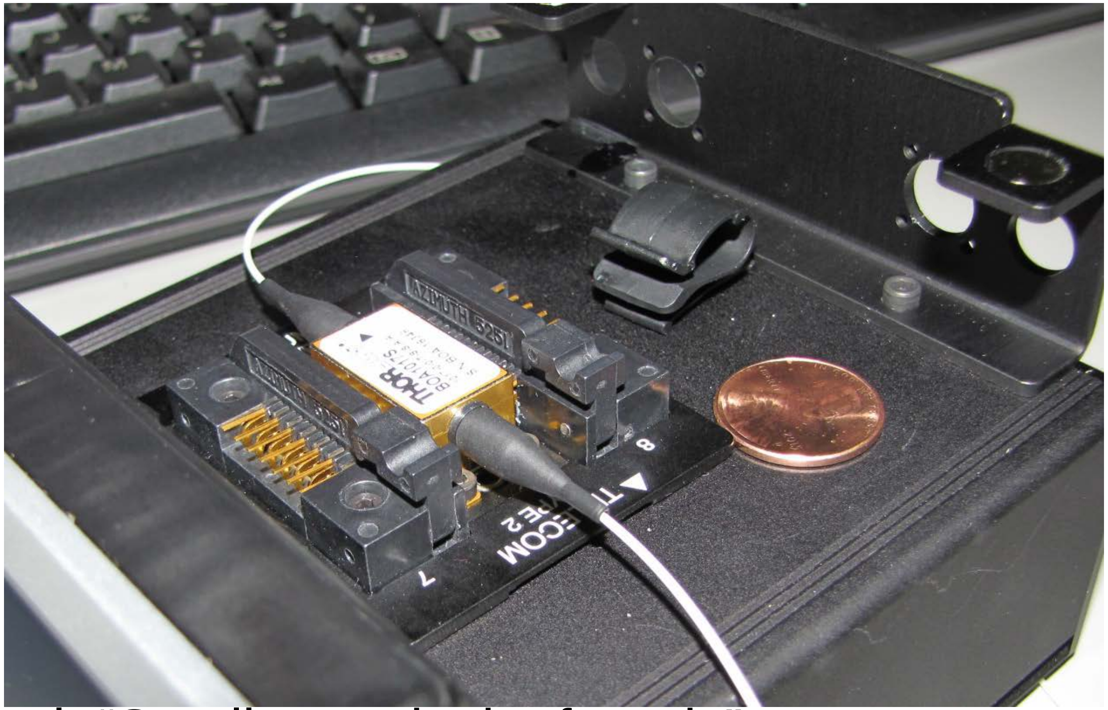
(1) Miniaturize PDV hardware

(2) Reduce total cost per channel

(3) Reduce digitizer bandwidth requirements

(1) Miniaturize PDV hardware

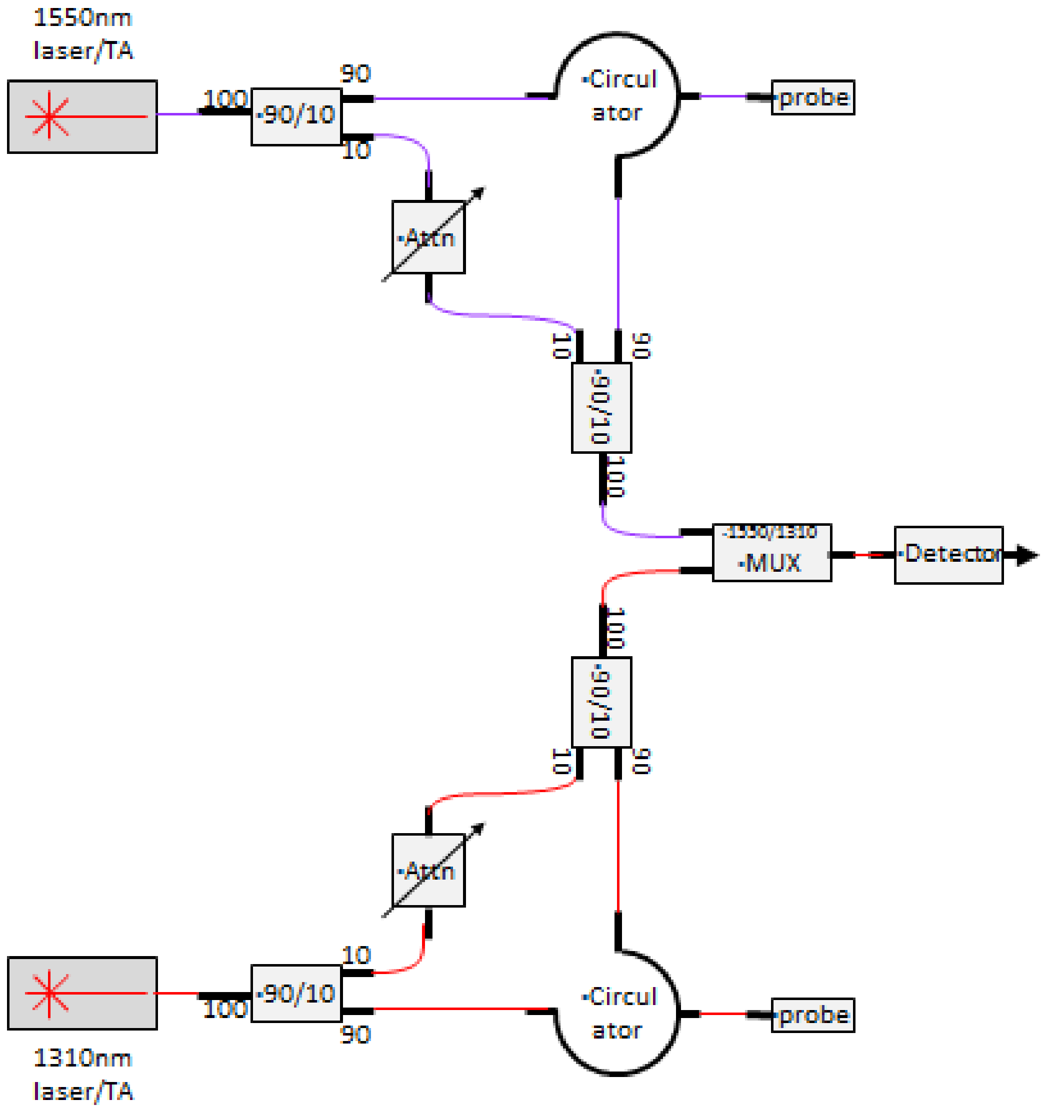
Replace rack-mounted EDFA lasers with single frequency laser diodes and tapered amplifiers.



Goal: “Small as a deck of cards”

(2) Reduce total cost per channel

Add a 1310nm-based PDV; overlay signal with 1550nm PDV



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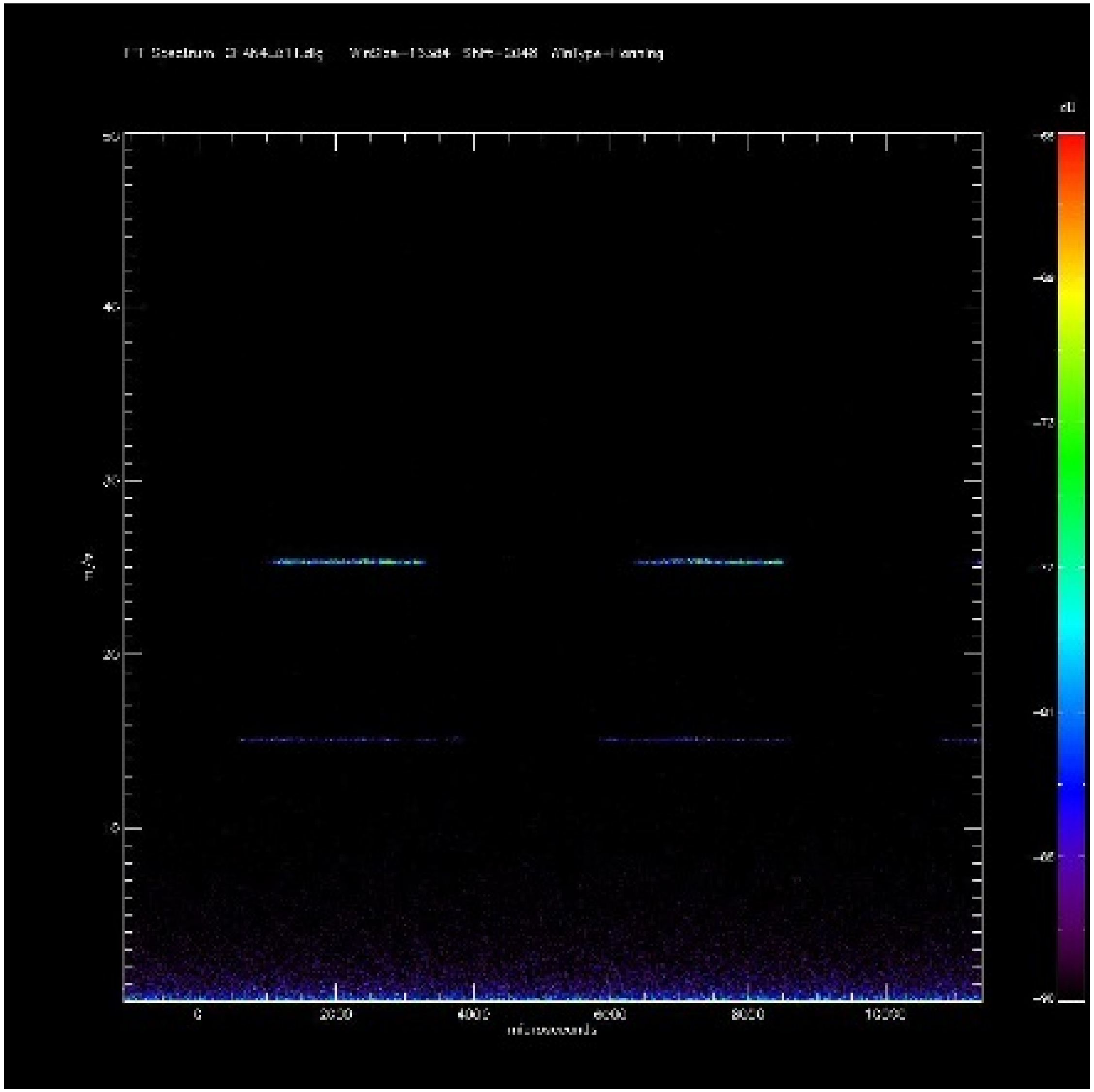
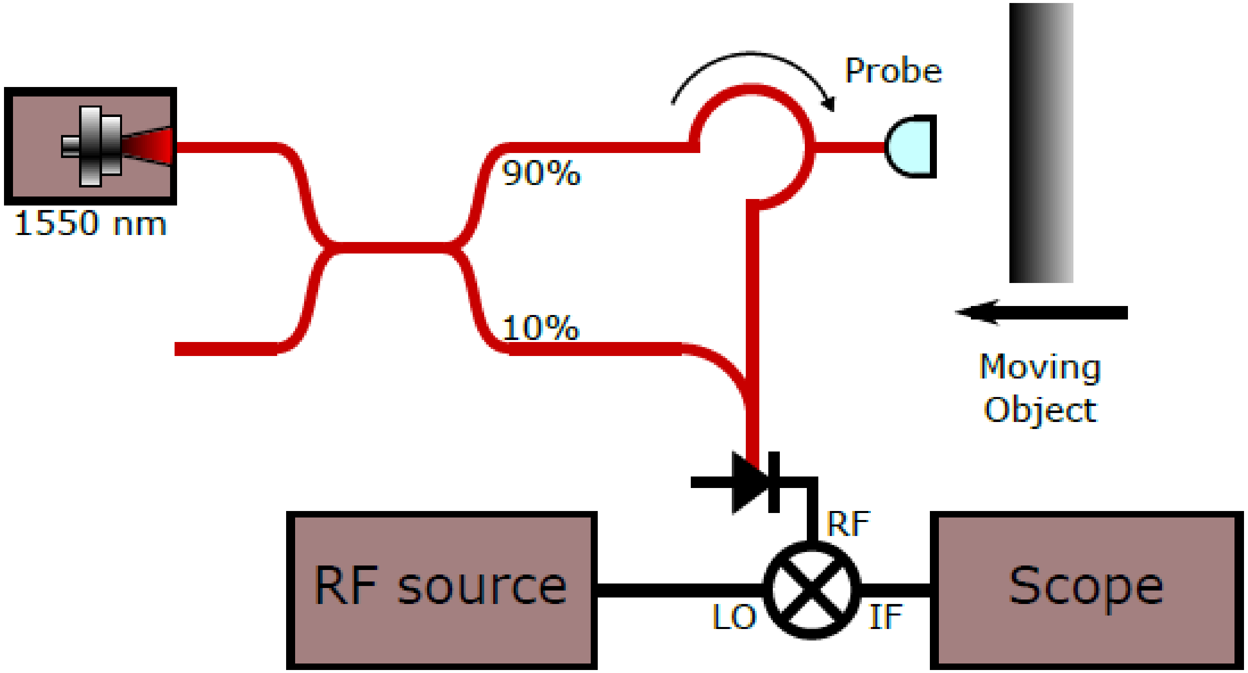
Demonstration that dual-wavelengths and tapered amplifier technologies work for PDV application



(3) Reduce digitizer bandwidth requirements.

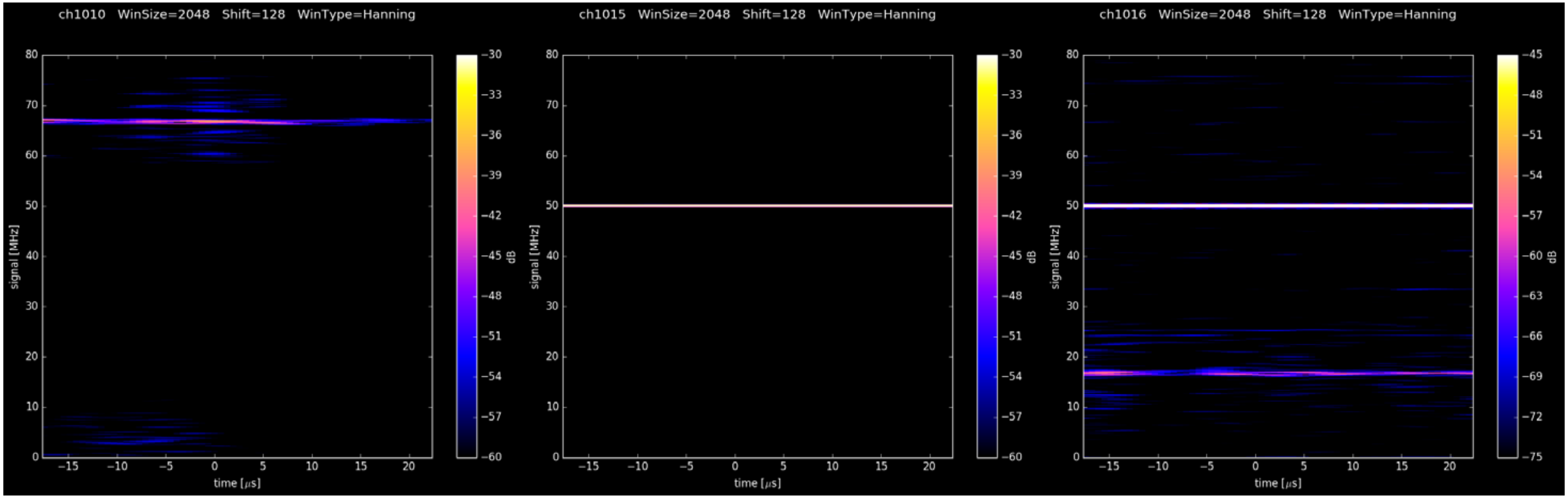
For 1550 nm, PDV signal is 1.3 GHz per km/s speed

Electrical heterodyning produces signal at $f_{LO} \pm f_{sig}$



(3) Reduce digitizer bandwidth requirements:

Electrical heterodyning produces signal at $f_{LO} \pm f_{sig}$



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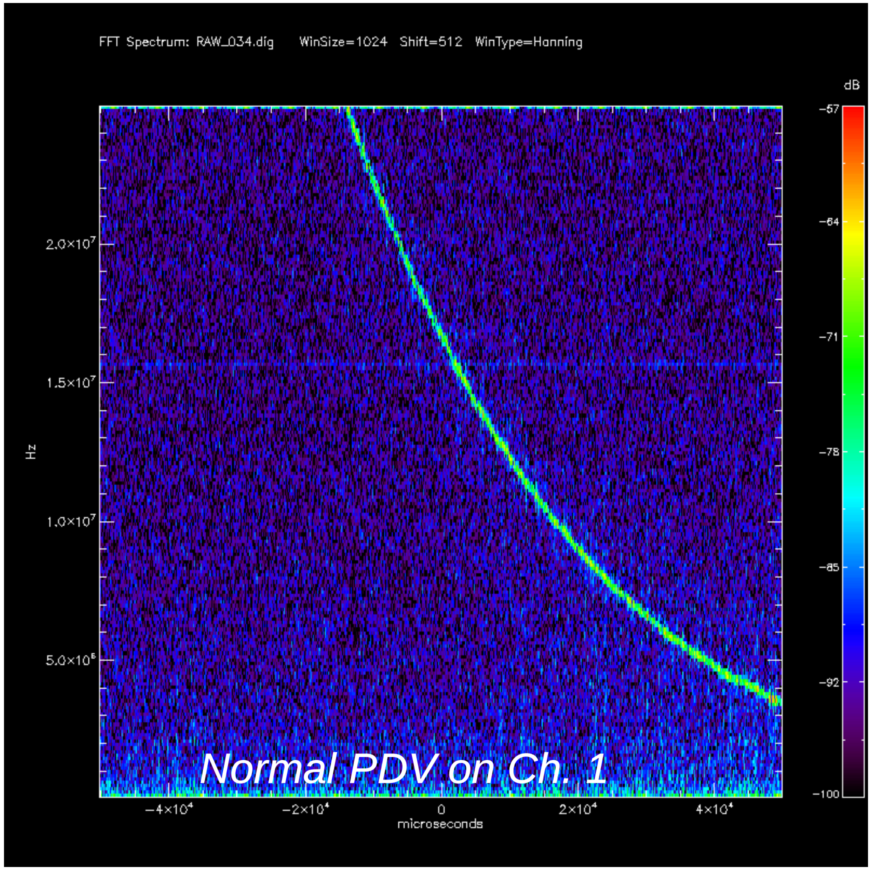
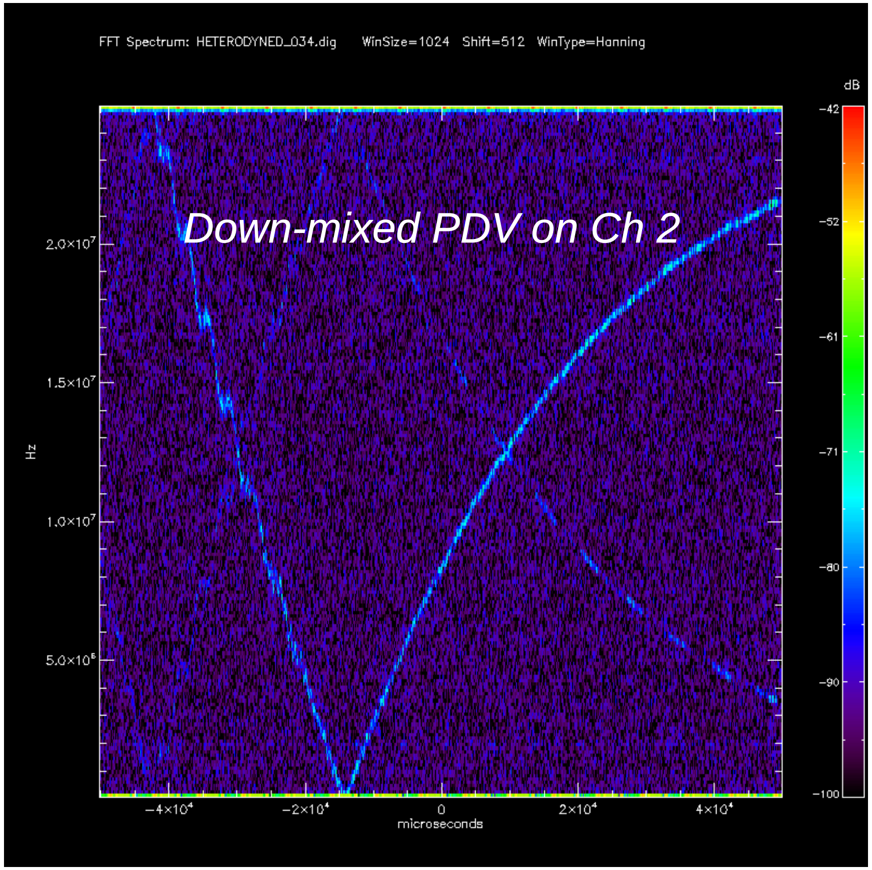
(3) Reduce digitizer bandwidth requirements:

Electrical heterodyning produces signal at $f_{LO} \pm f_{sig}$



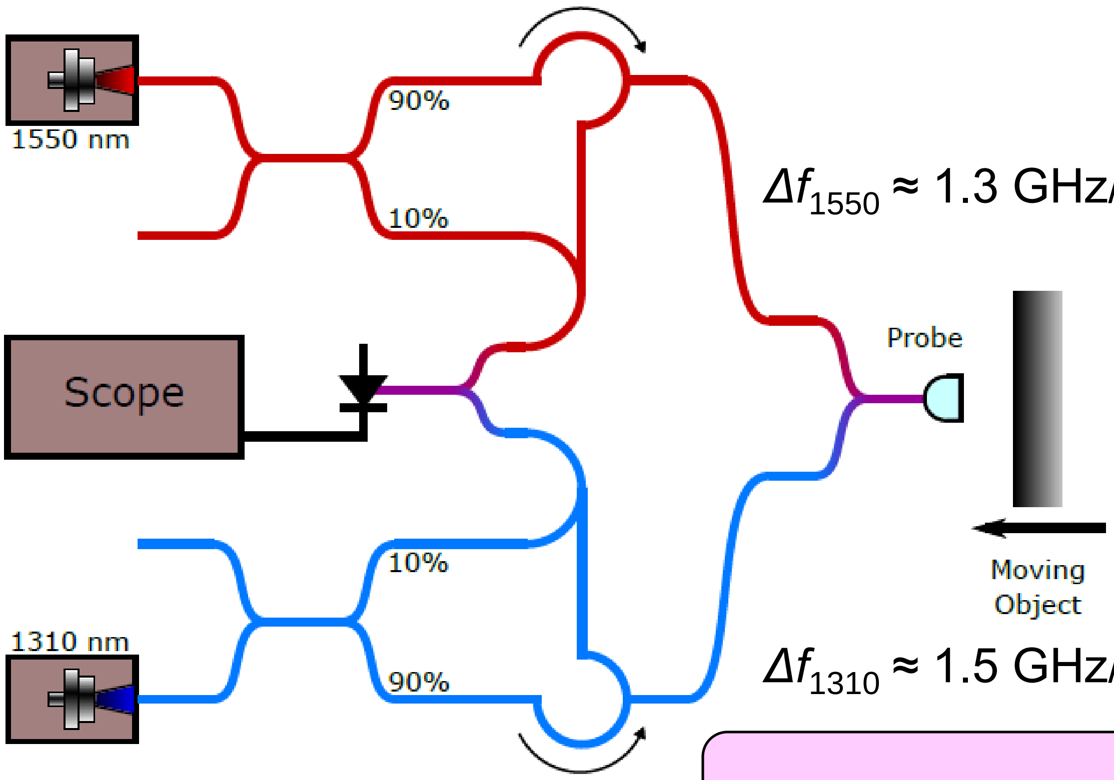


(3) Reduce digitizer bandwidth requirements:

Electrical heterodyning requires recording multiple bands of frequency offset.

Alternative approach: reduce constant for velocity/GHz

(3) Reduce digitizer bandwidth requirements: Reduce signal frequency per given speed

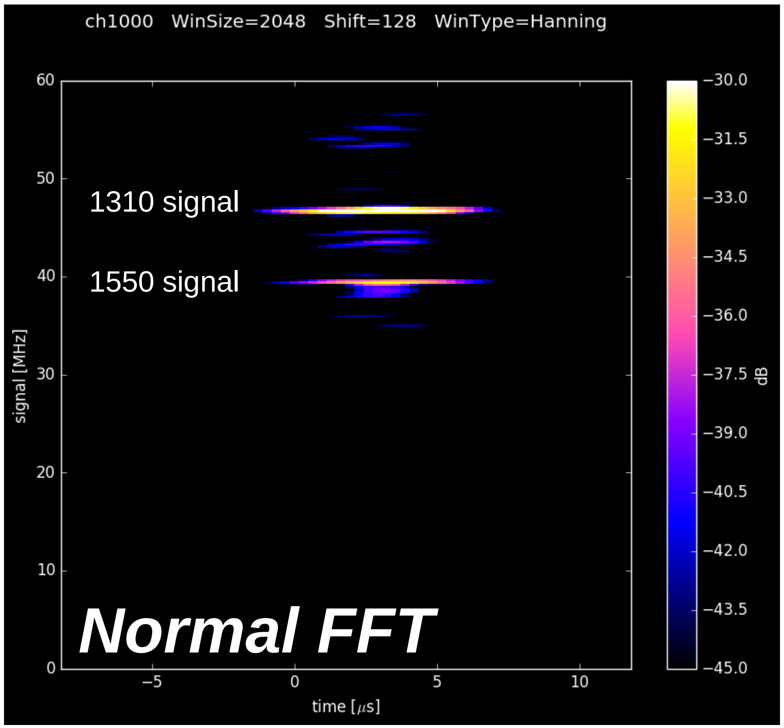


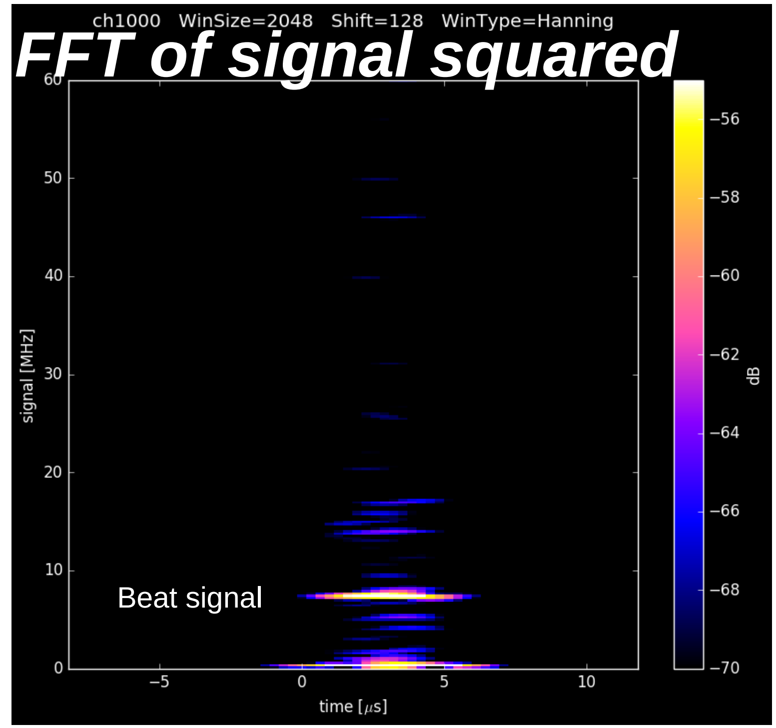
$\Delta f_{1550} \approx$ 1.3 GHz/km/s

$\Delta f_{1310} \approx$ 1.5 GHz/km/s

$(\Delta f_{1310} - \Delta f_{1550}) \approx$ 237 MHz/km/s

(3) Reduce digitizer bandwidth requirements:
Reduce signal frequency per given speed

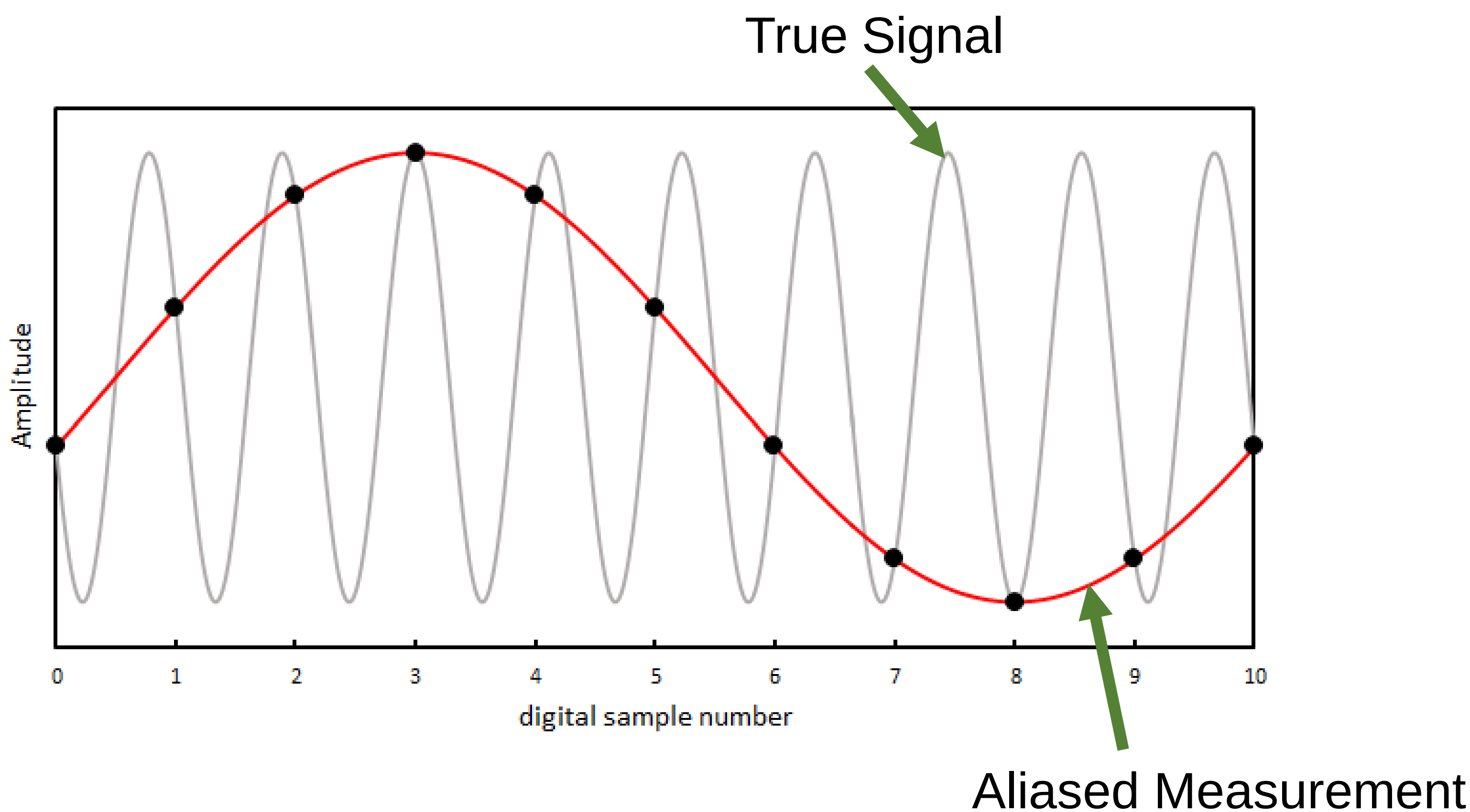




$(\Delta f_{1310} - \Delta f_{1550}) \approx$ **237 MHz/km/s**

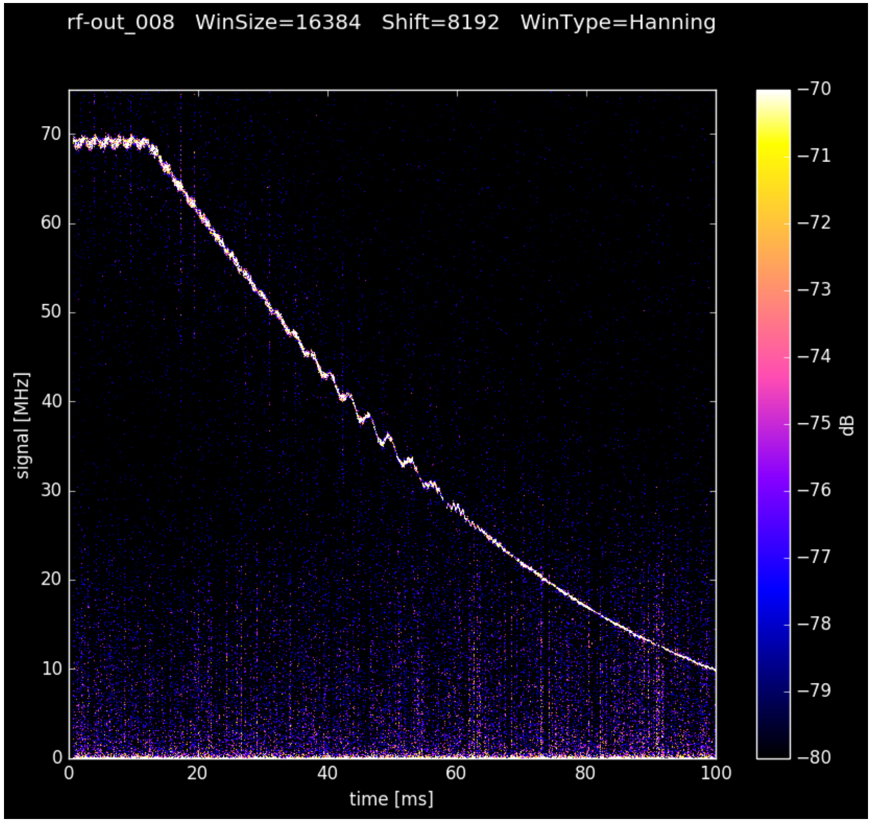
(3) Reduce digitizer bandwidth requirements: Decode digitizer "alias" with two laser frequencies

Undersampling a periodic function produces aliasing

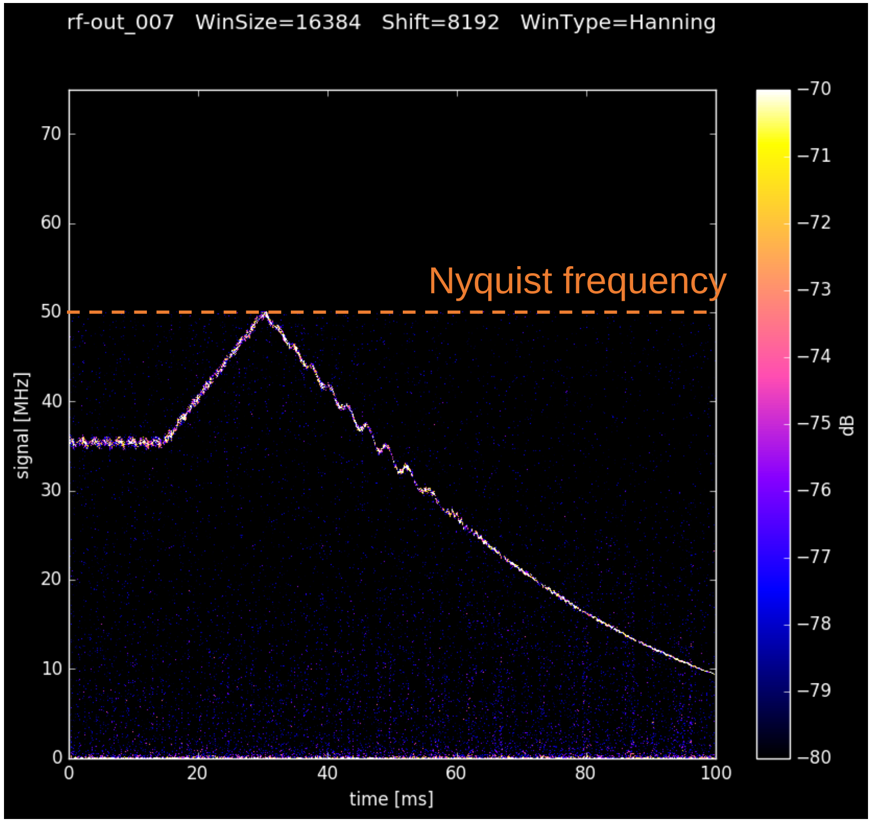


(3) Reduce digitizer bandwidth requirements:
Decode digitizer "alias" with two laser frequencies

Sampled at 312 MS/s



Sampled at 100 MS/s



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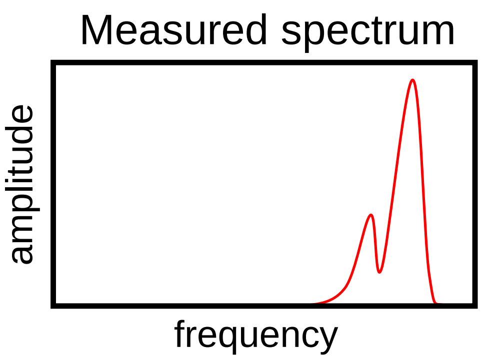
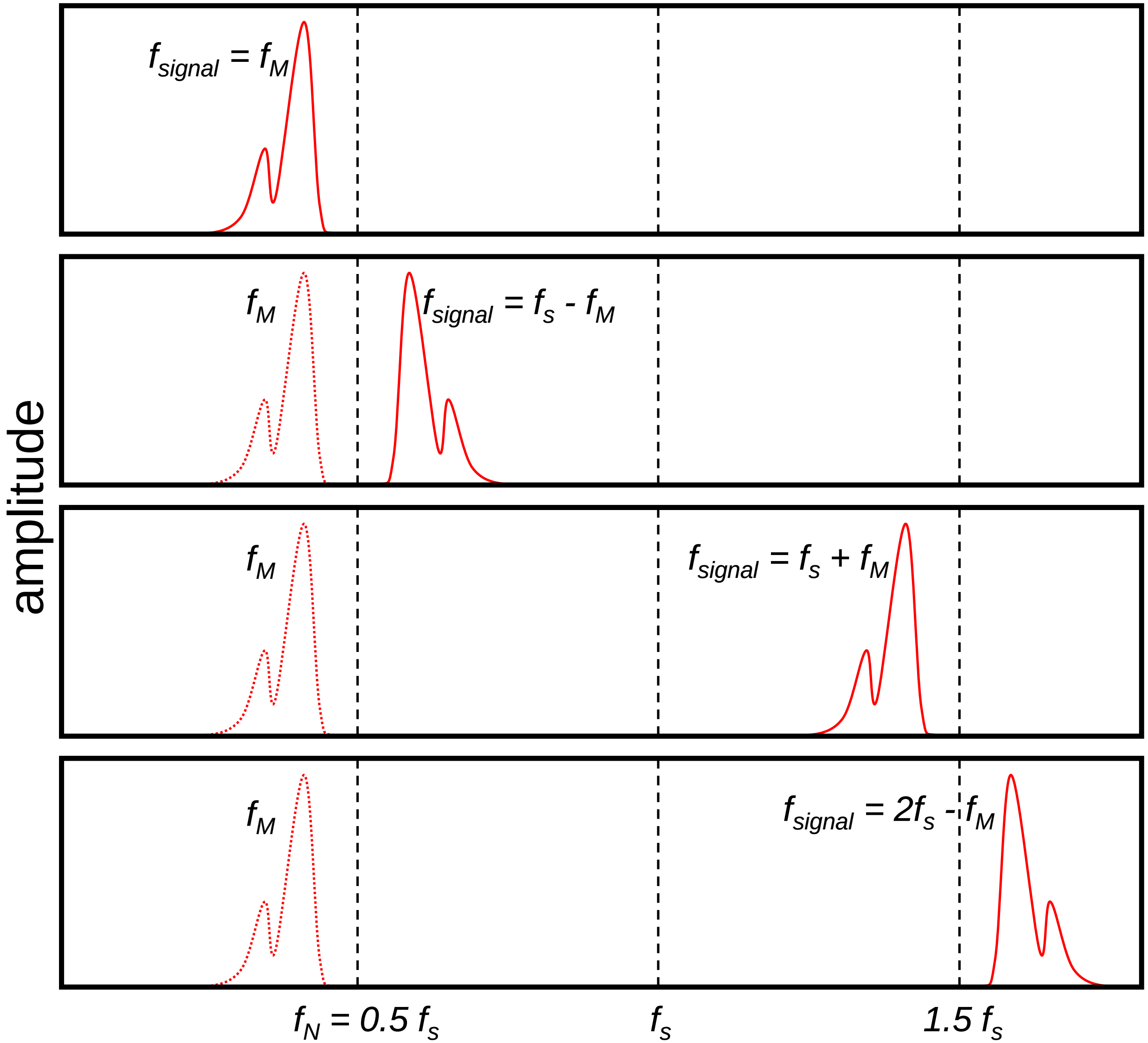
Multiple spectra can result in a single measured spectrum



$$f_{signal} = Nf_s \pm f_M$$

$$N = ???$$

f_M = Measured spectrum
f_S = Scope bandwidth
f_N = Nyquist frequency



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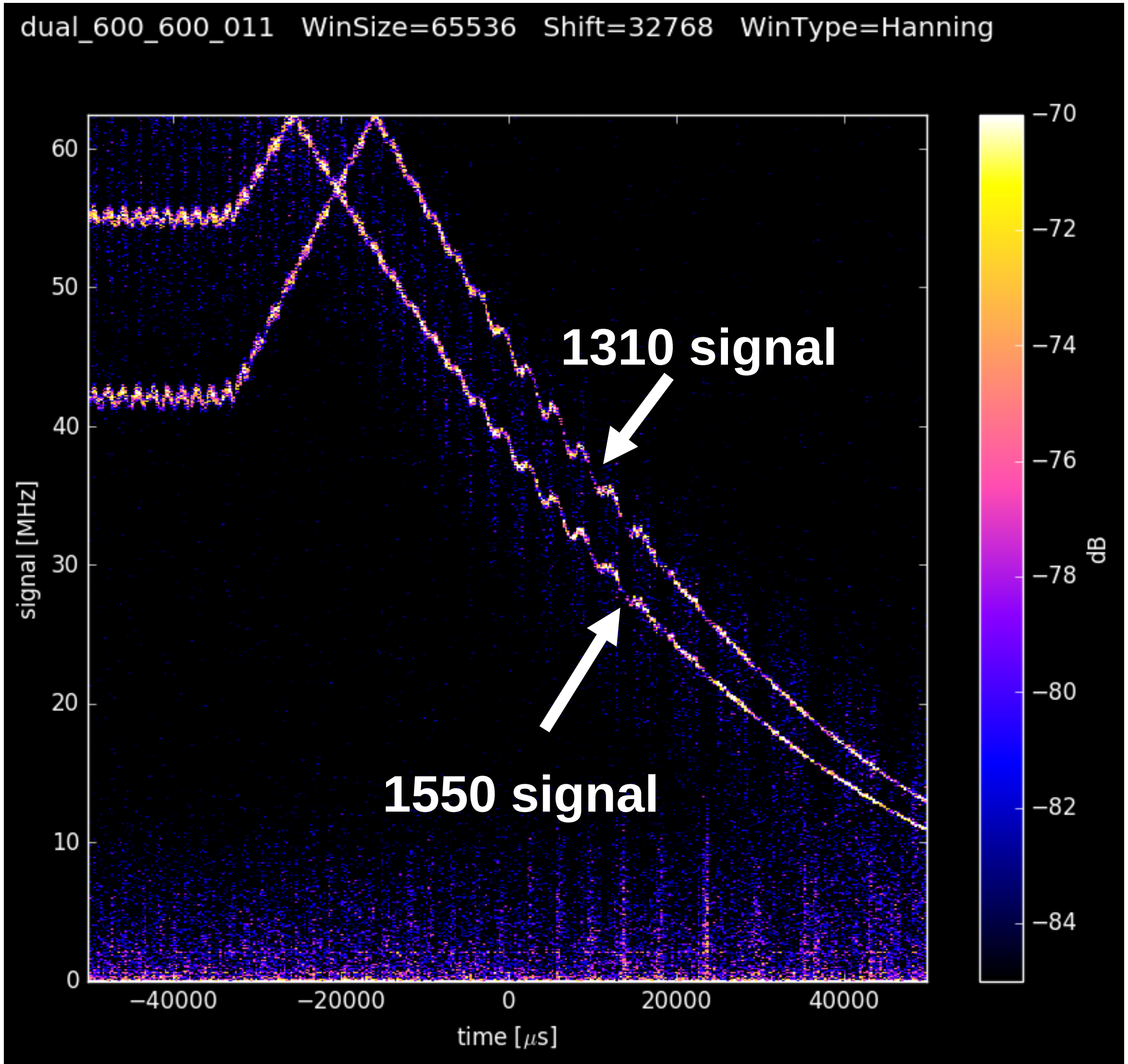

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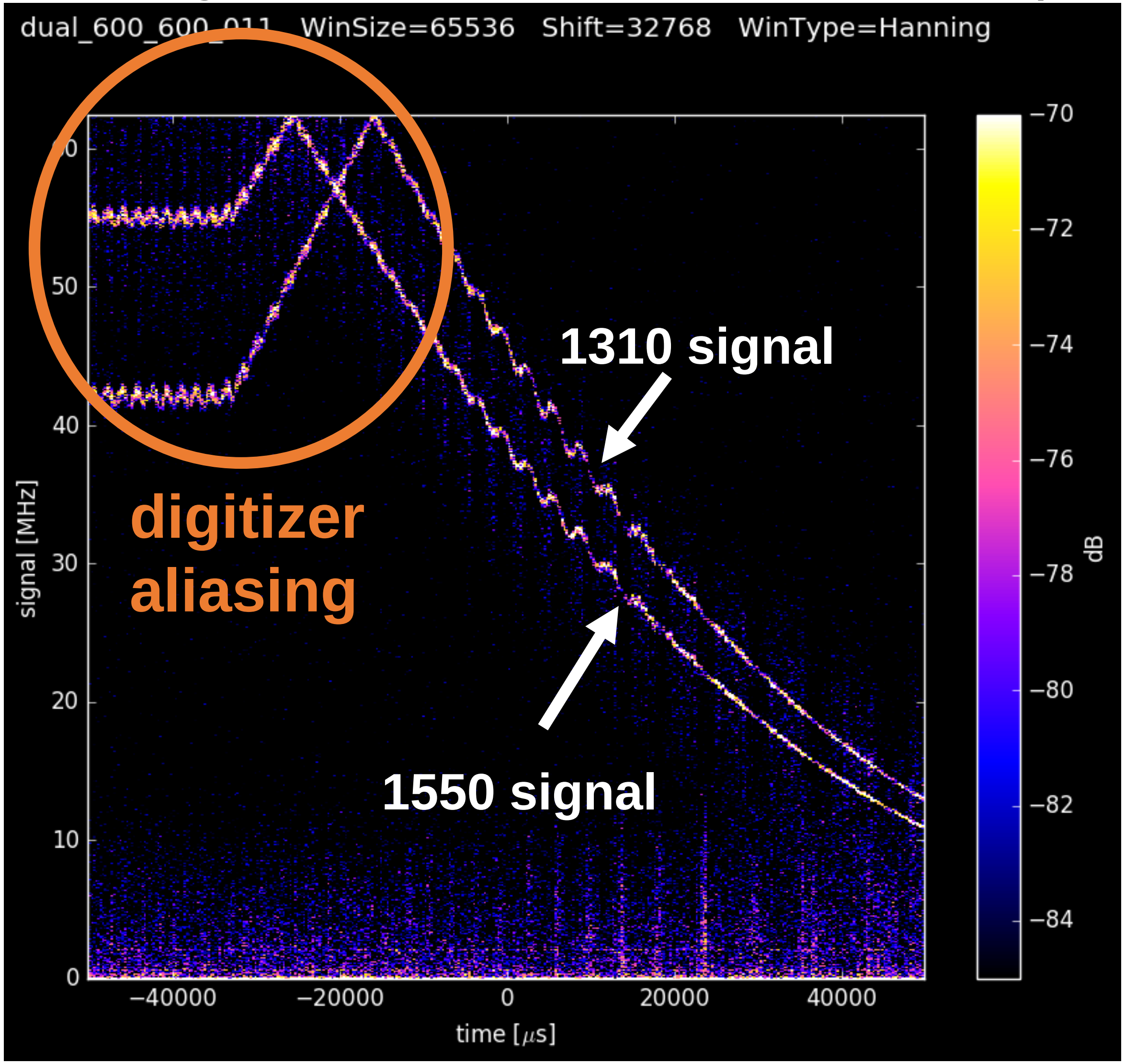

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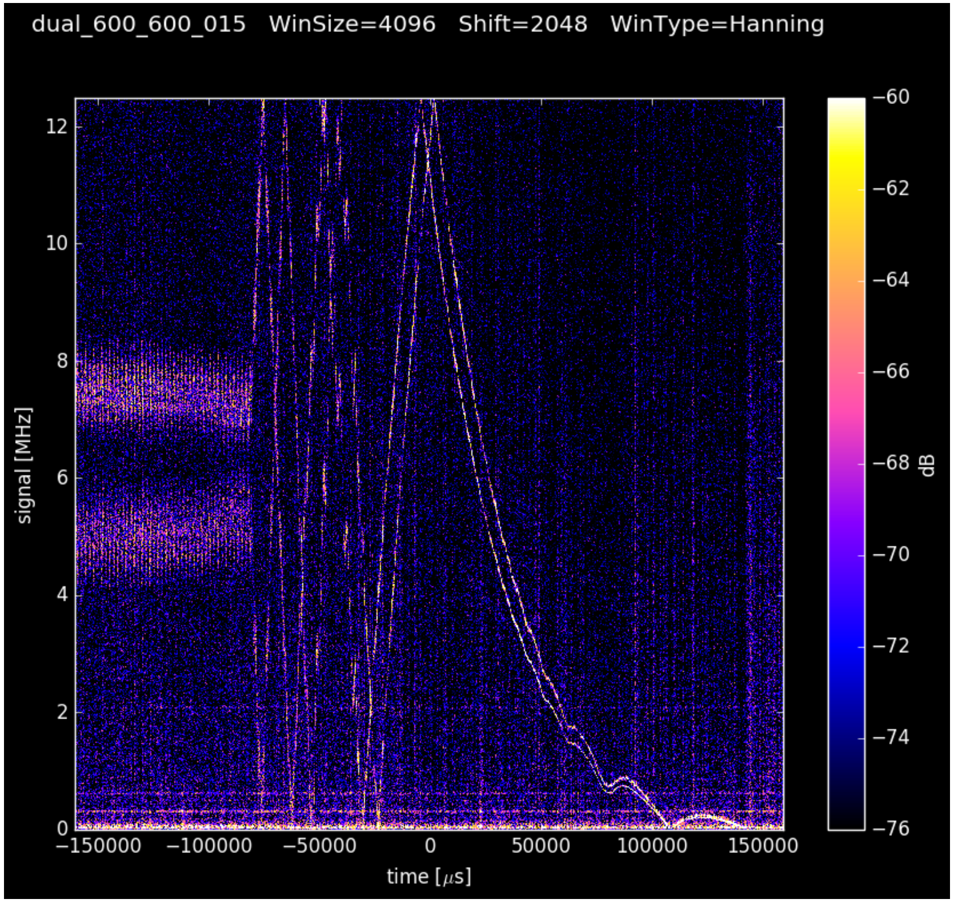

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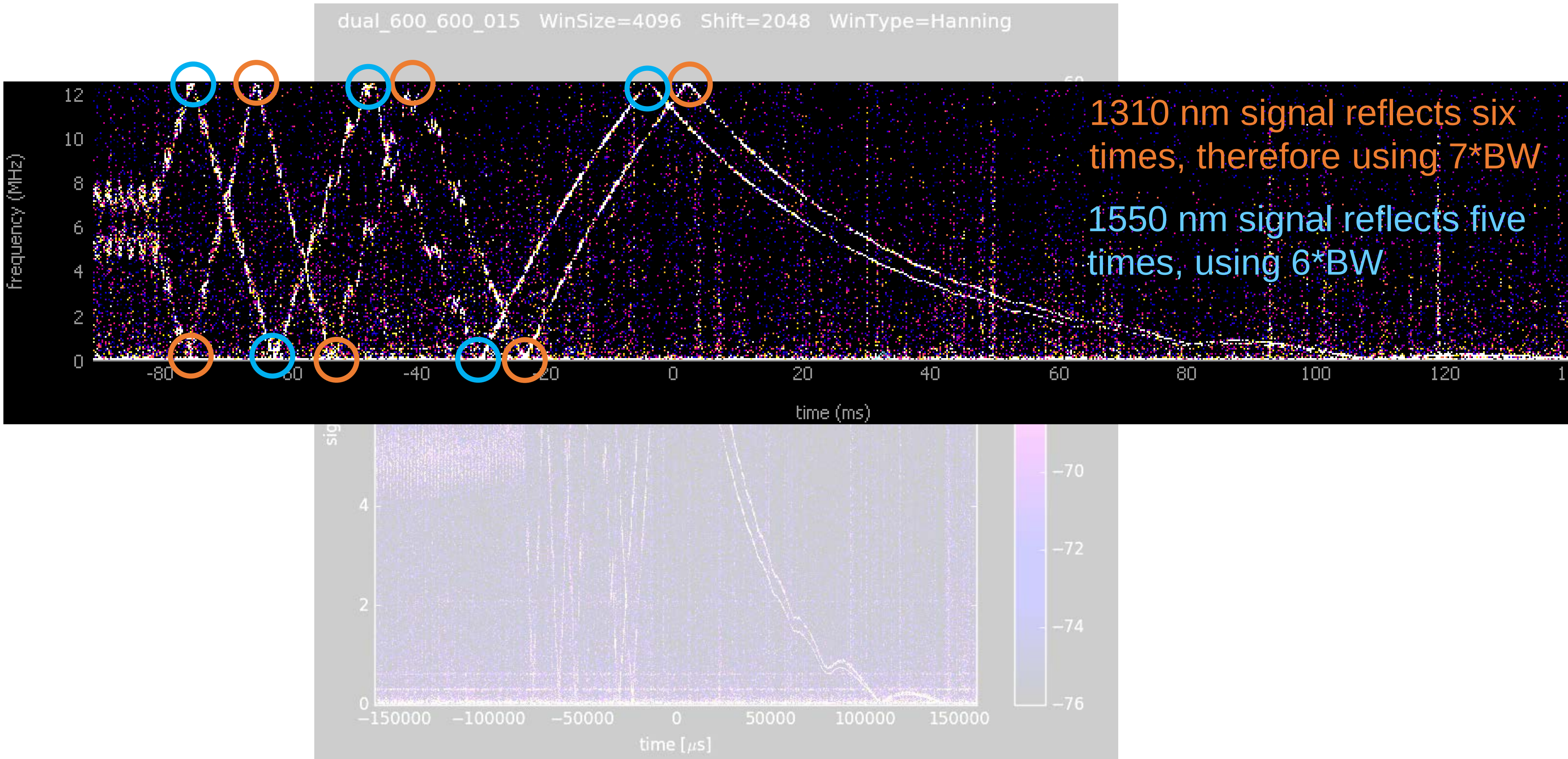
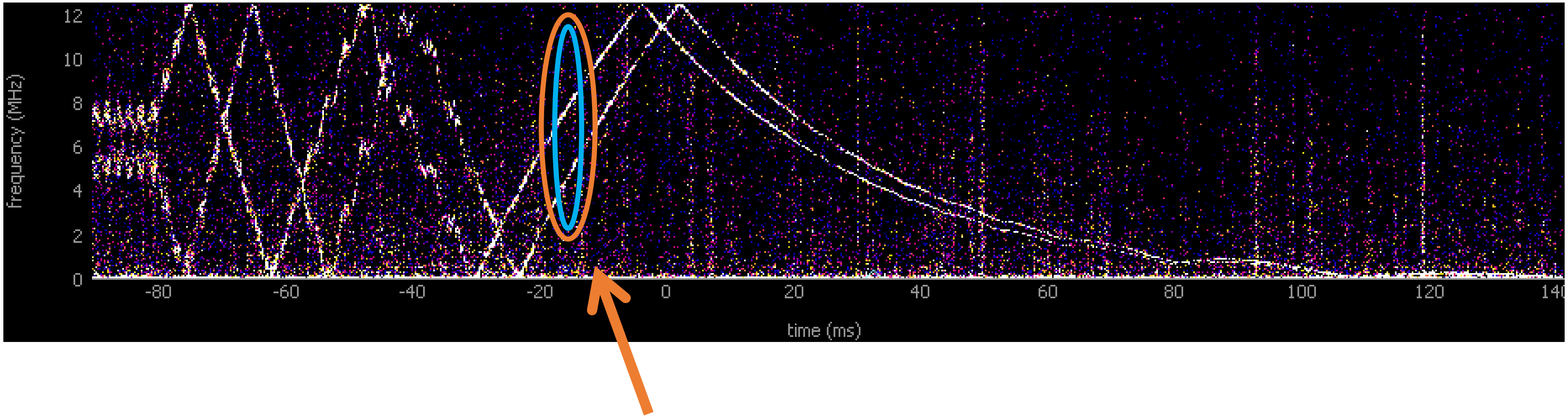


(3) Reduce digitizer bandwidth requirements: Decode digitizer "alias" with two laser frequencies



Knowing that both signals represent the same velocity yields one unique solution for any given time

PDV development at the
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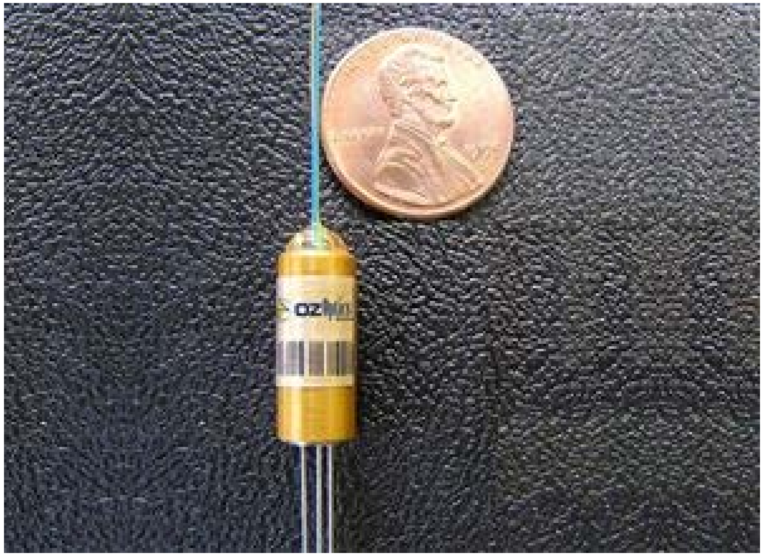
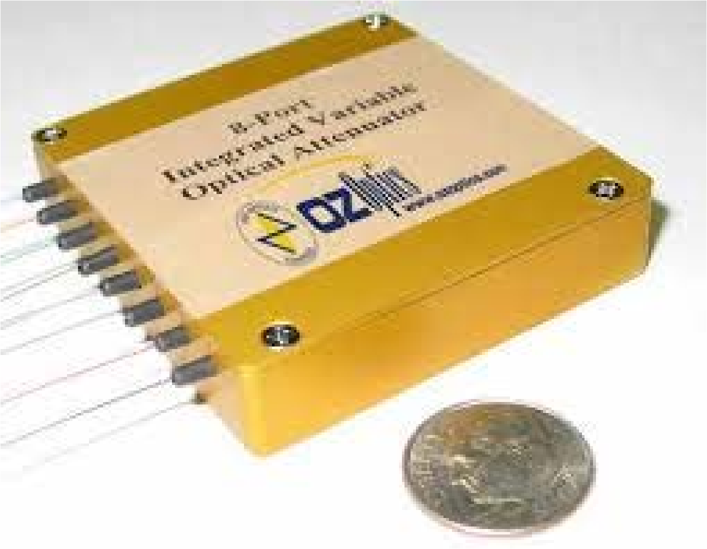
OZ Optics MEMS-based voltage controlled attenuators

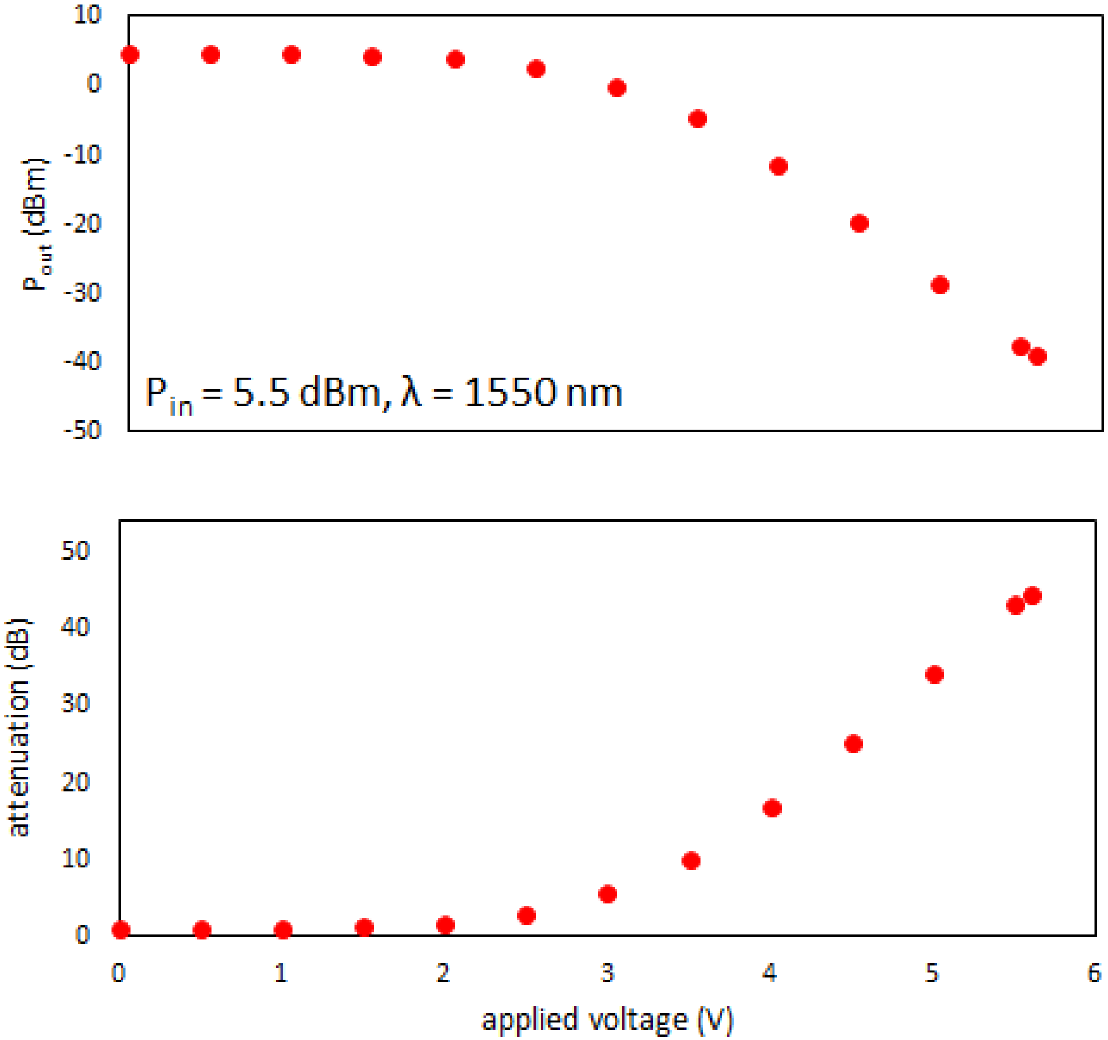
Single-channel



Eight-channel



OZ Optics MEMS-based voltage controlled attenuators



→ Low voltage, 0-6V

→ Low power electrical power consumption (<10 mW)

→ High optical power handling, up to 500 mW

→ Repeatable (negligible hysteresis)

→ Available with built in power monitoring

→ No new optical noise

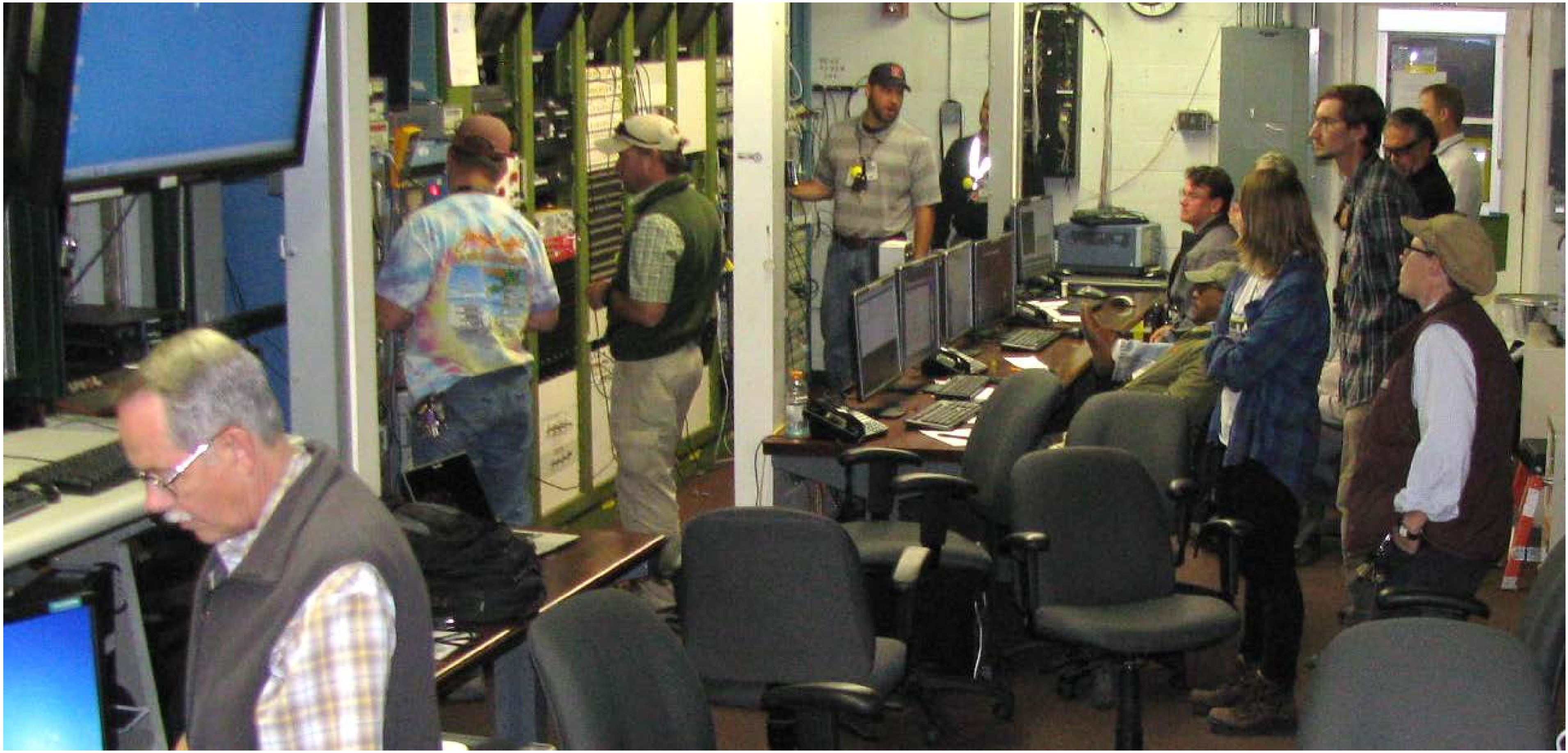
Conclusions:

There is ongoing development on PDV at the LANL Proton Radiography facility to make the diagnostic:

(1) Smaller

(2) Lower cost, for opto/electronics

(3) Available at digitizer bandwidths attainable on a university budget



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Velocimetry contributions:

Dale Tupa, Amy Tainter, Levi Neukirch

Philip Rae, David Holtkamp, Brian Glover, Jake Gunderson

Proton Radiography team:

M. Freeman, B. J. Hollander, J. D. Lopez, F. G. Mariam, M. J. Martinez, J. J. Medina, P. V. Medina, D. Morley, C. L. Morris, M. M. Murray, L. Neukirch, A. Saunders, T. Schurman, T. Sisneros, A. Tainter, F. Trouw, D. Tupa, A. Vera, J. Goett, F. E. Merrill, P. Nedrow, R. Simpson, J. Tybo, C. J. Wilde, J. C. Allison, W. V. McNeil, P. D. Scott, C. R. Valdez, S. W. Vincent, J. Strotman, C. R. Lopez

Experiment P.I.s:

B. Buttler, R. Olson