



(U) Development and Testing of a New Commercially Produced Optical Receiver for PDV

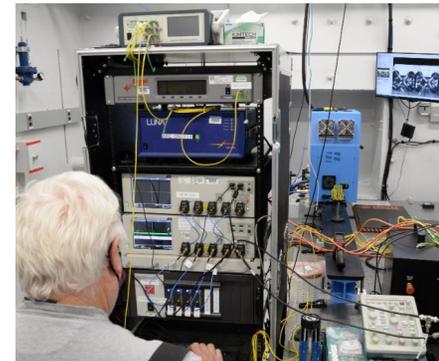
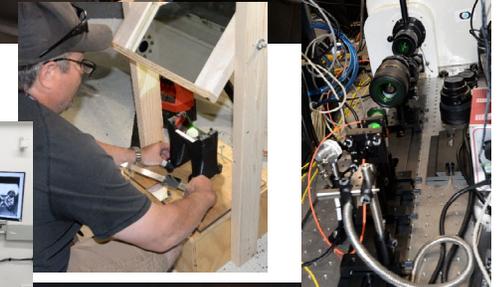
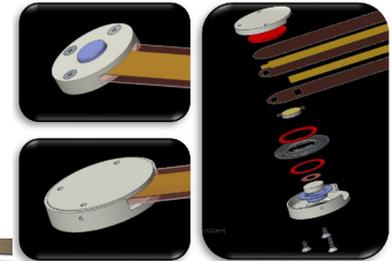
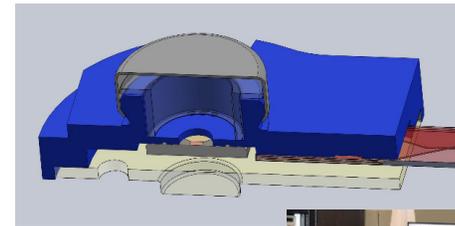
Rory Bigger, Alexis Mundt, Steve Clarke, Andrew Piegzik
Q-6 Detonation Science and Technology

PDV Workshop 2023
February 7, 2023
Santa Fe, NM

LA-UR-23-20710

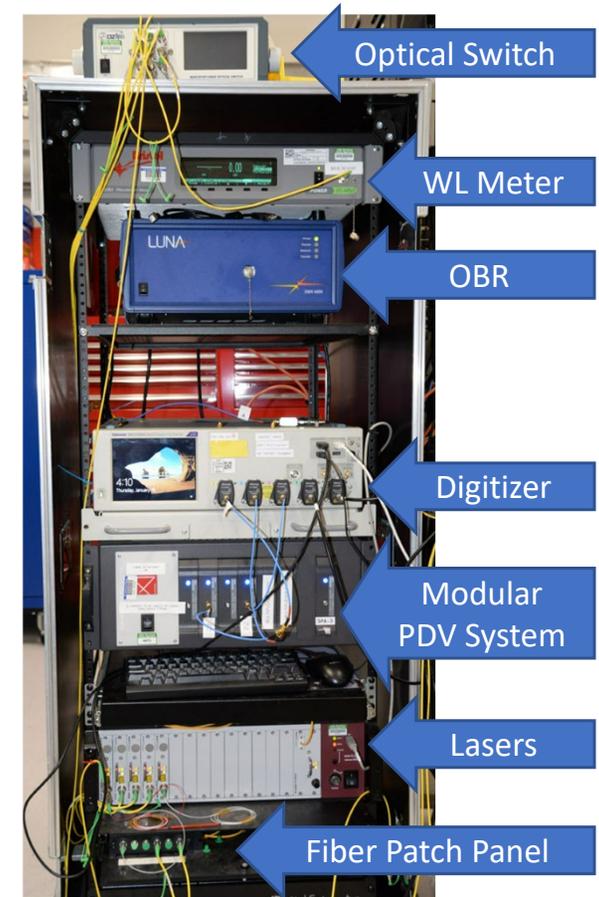
Introduction & Outline

- Q-6 Detonation Science and Technology
 - Design authority for LANL detonators from cradle to grave
 - Over 1000 detonators test fired annually at several Q-6 labs
 - PDV widely used by Q-6 as a test fire diagnostic
- Photodetectors used for Q-6 PDV hard to get right now
- Commercial alternative investigated in 2022
- Outline
 - Q-6 PDV system overview
 - Experimental setup and baseline results
 - New detector testing and results
 - Continued development



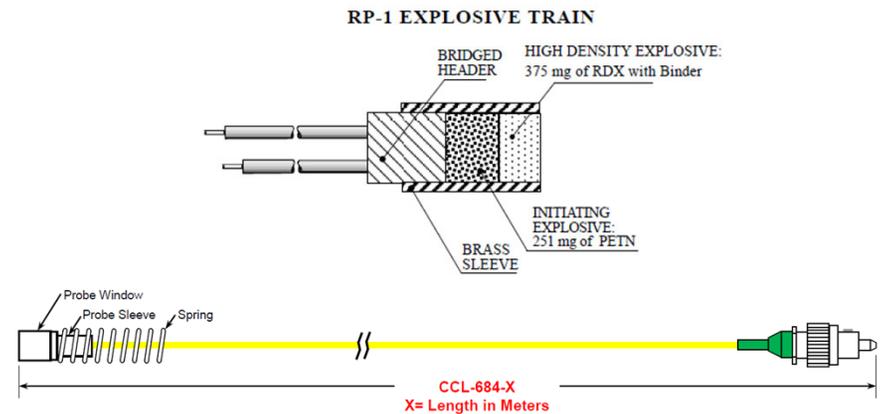
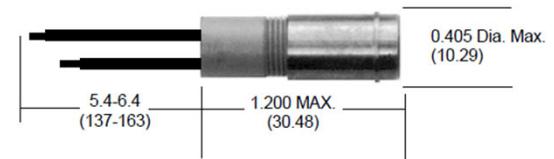
Q-6 PDV Systems

- Standardized rackmount modular heterodyne PDV system used across Q-6
 - NKT Photonics Acoustik chassis with Basik E15 tunable 1550 nm laser cards
 - Tektronix DPO72304SX digitizer (23 GHz BW)
 - TS&I modular PDV system with VOAs, power meters, circulators, combiners, and optical receivers (USB or Ethernet control)
- Bristol 228A wavelength meter with 99/1 splitters and optical switch on some racks (see LA-UR-21-27721)
- Miteq 20 GHz optical receivers (SCMR-100K20G-30-15-10)
 - Pulse injection has damaged receivers + need to build more racks
 - Lead times running over one year
 - Receivers also show DC offset upon large optical power changes



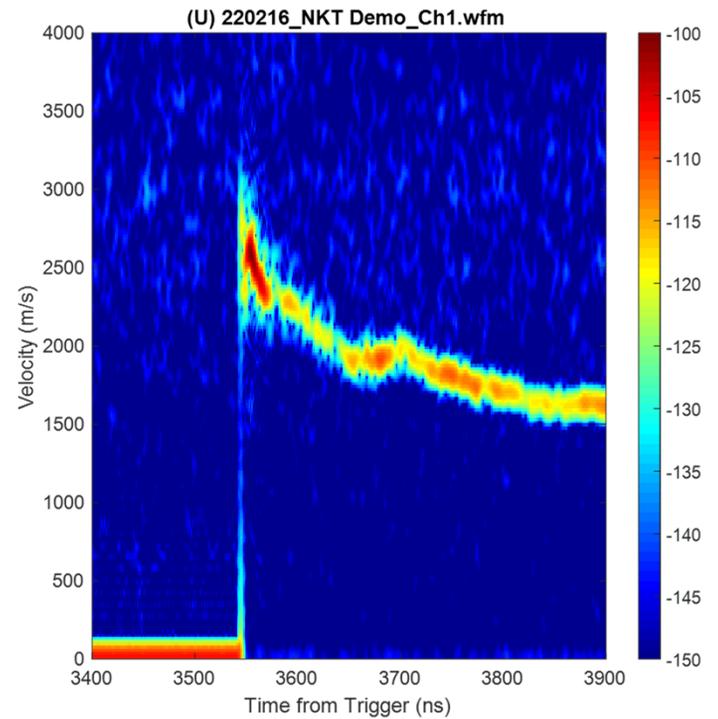
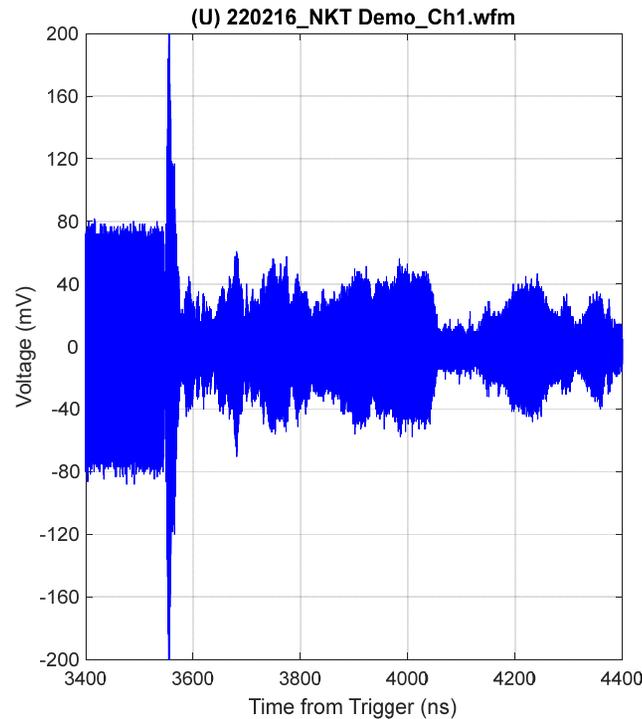
Experimental Setup

- SE-1 detonator
 - EBW detonator produced by Mound Laboratory
 - Commercially available as Reynolds RP-1
 - SE-1/31 coax (C-cable) version used
- Coastal Connections PDV probe
 - PMMA machined body w/ aluminum foil reflector
 - OZ Optics pigtail fuser embedded in body
 - Coaxial spring for loading into detonator
- “Mousetrap” fixture
 - PDV probe inserted into fixture first
 - Detonator threaded into fixture against probe
 - 3D printed using Stratasys polyjet



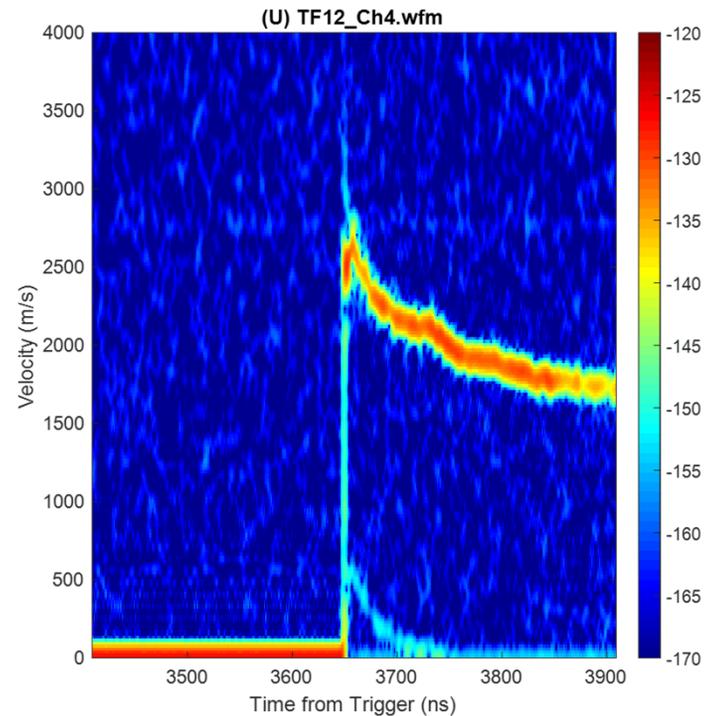
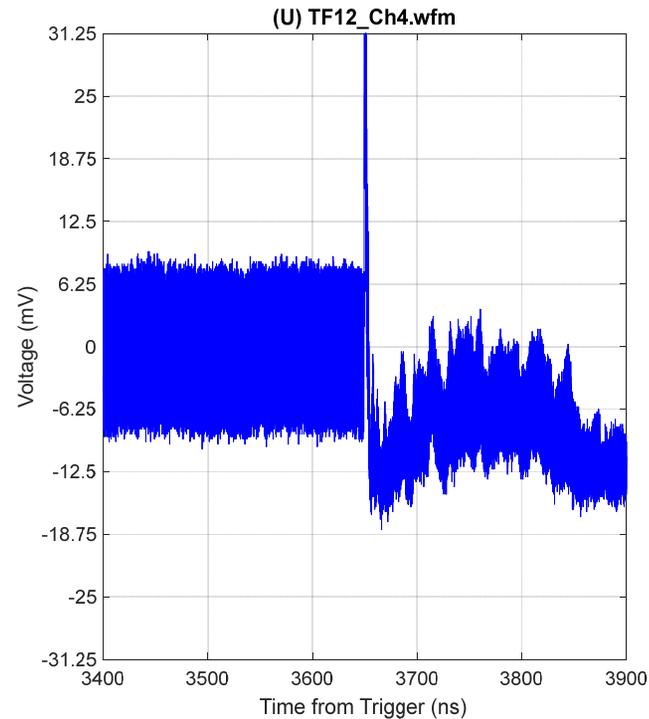
Baseline PDV Settings and Result

- Typical detonator shot for Q-6
 - Input power: +6.0 dBm
 - Ref power: +3.0 dBm
 - Return: -11.1 dBm
- Current “standardized” Miteq receiver
- Higher return can cause DC offset issues
- Heterodyne offset
 - Approx. 4000 m/s
 - Typ. 100 to 400 mVpp



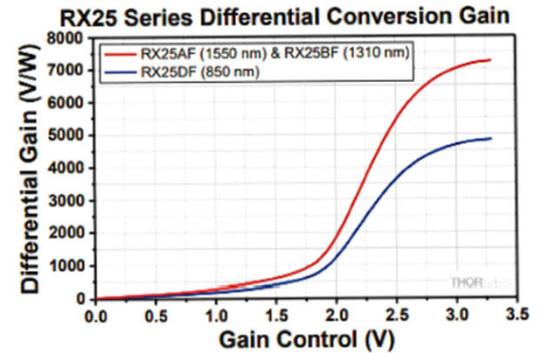
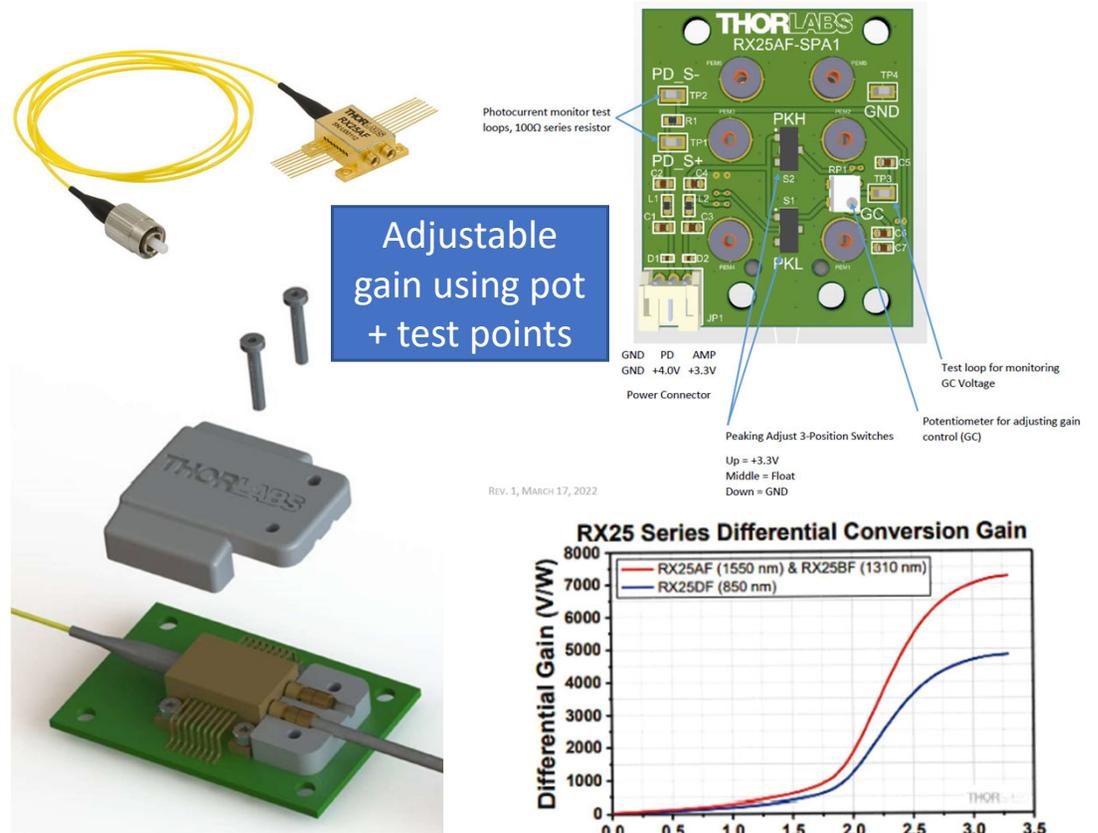
Initial Alternative Detector Attempt

- Thorlabs DX20AF
 - Direct drop-in replacement for Miteq in our TS&I modules
 - 20 GHz
 - 22.5 V/W gain w/o external amplification
- At voltage limit of oscilloscope (6.25 mV/div) while maxing out input power (+15.4 dBm in, -1.6 dBm return)
- But v vs. t looked good



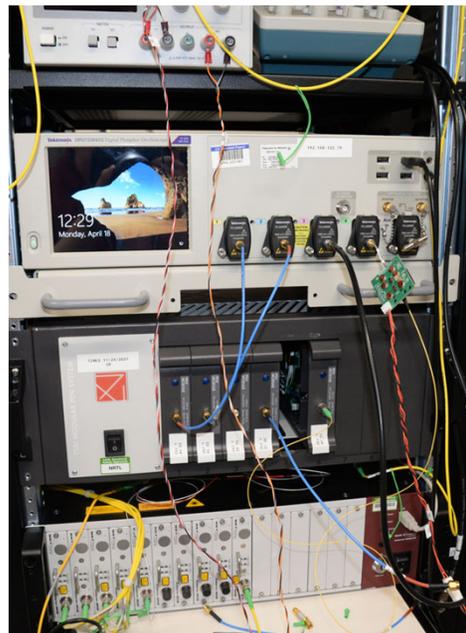
Next Attempt Using Amplified Detector Board

- Thorlabs sells a 25 GHz amplified detector in an OEM package (RX25AF) with adjustable gain to over 7000 V/W (200x DX20AF)
- Not a drop-in fit for our modules, needs EE work
- Turned out that Thorlabs was already making an RX25AF-SPA1 PCB assy. for another LANL Group
 - Powered from external DC supply using standard 3-pin connector
 - Q-6 asked for an “SPA2” with FC/PC swapped for FC/APC



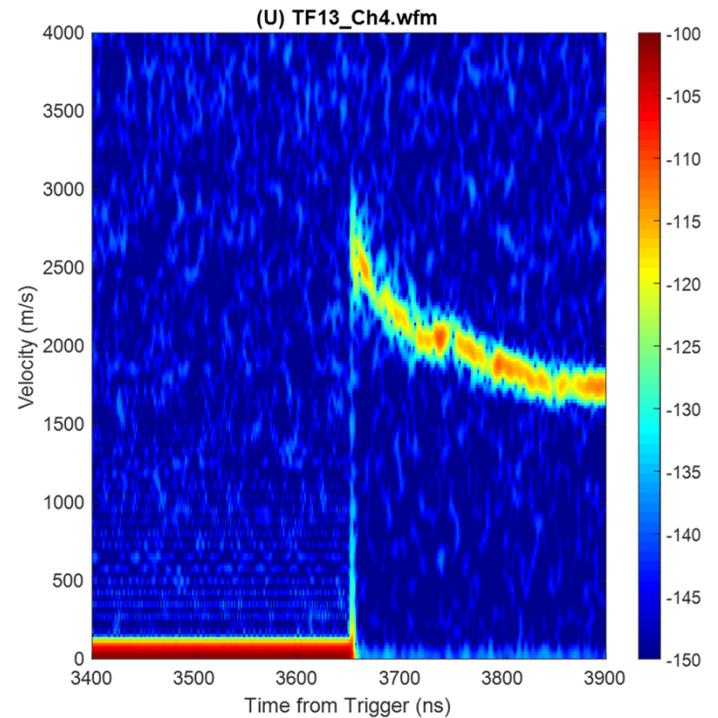
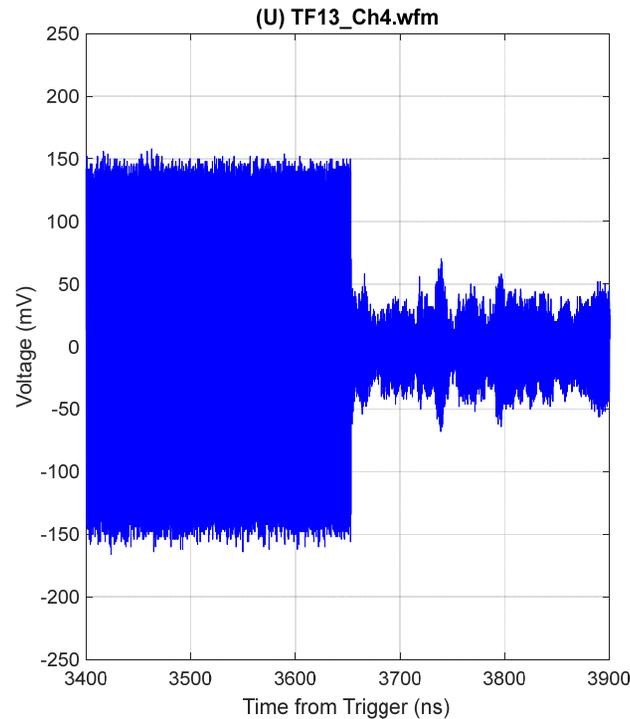
RX25AF-SPA2 Test Fire Setup

- TS&I module cover removed
- Miteq receiver disconnected from combiner output, Thorlabs receiver connected through what was used as RF output opening
- Thorlabs card connected to digitizer using short, semi-rigid RF cable
- Powered using a 2-channel benchtop adjustable DC power supply
- All TS&I control and monitoring remains available



RX25AF-SPA2 Initial Results

- “Just looking for a place to start”
- Input power 0 dBm
- Ref power 0 dBm
- Return -17.9 dBm
- Gain not tested or recorded
- Approx 350 mVpp
- Result looked promising to additional shakedown testing



Shakedown Testing Matrix

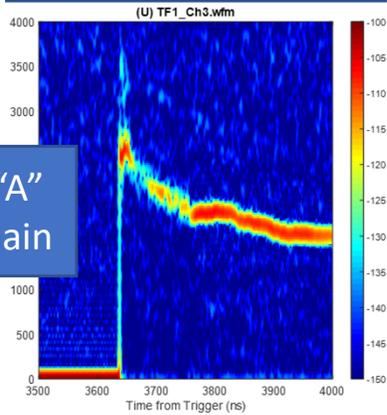
Shot	Receiver	Gain (V)	SIG IN (dBm)	REF IN (dBm)	Return (dBm)	Vpp	mV/div	Result	Comments
13	A	Unknown	0.0	0.0	-17.9	350	50	Yellow	First try with SPA2, gain not checked or recorded "TF13"
1	A	3.138	5.0	-6.0	-12.9	326	50	Green	Vpp measured post-test in MATLAB
2	A	3.138	8.6	0.3	-12.9	335	50	Green	Vpp measured on scope
3	A	3.318	7.0	-3.5	-12.9	219	30	Yellow	90/10 power match on return/ref laser
4	A	3.138	0.0	5.0	-23.1	125	20	Yellow	"Weak probe" simulation
5	A	3.138	15.0	0.0	-2.1	790	100	Red	High power, no PDV data, receiver went into safe mode
6	A	3.138	10.5	-3.5	-12.9	240	50	Green	Repeat of TF3 to make sure receiver is OK
7	A	3.138	15.0	-12.5	-2.4	510	70	Red	High signal, low reference - safe mode again
8	A	3.138*	-10.0	5.0	-29.5	170	30	Green	Very weak return (Miteq essentially gets no data here)
9	B	2.5672	8.5	-2.0	-12.7	365	50	Green	2nd SPA2, Gain set near mid-point on potentiometer
10	B	2.5672	7.3	-3.5	-12.9	220	30	Green	90/10 power match
11	B	3.133	6.3	-3.5	-12.9	260	50	Green	90/10 power match, gain set to match TF1-8
12	B	3.133	-10.3	5.0	-29.5	165	30	Yellow	"Weak probe" sim (TF8 repeat) with receiver "B"

*Not recorded, but inferred from notes

-  Good SNR, clear v vs. t separation from background in spectrogram
-  Poor SNR, but can put v vs. t from spectrogram
-  No v vs. t data recorded (detector protective shutdown, clipping, etc.)

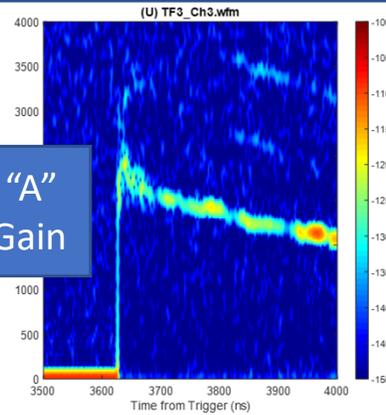
Example Results with RX25AF-SPA2

“Typical” Q-6 setup



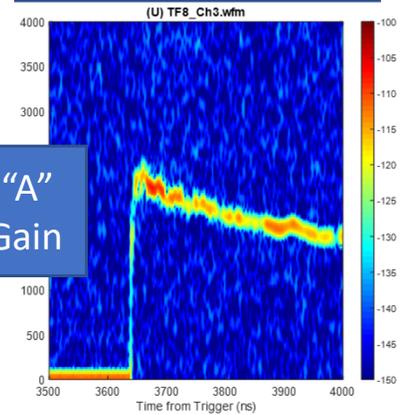
SPA2 “A”
High Gain

90/10 Return/Ref Split

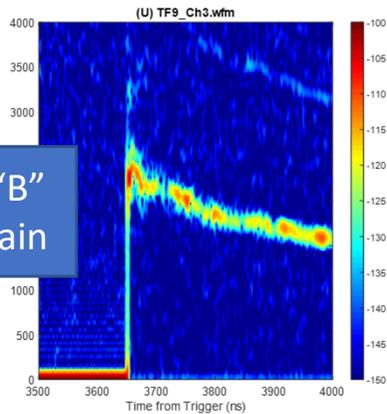


SPA2 “A”
High Gain

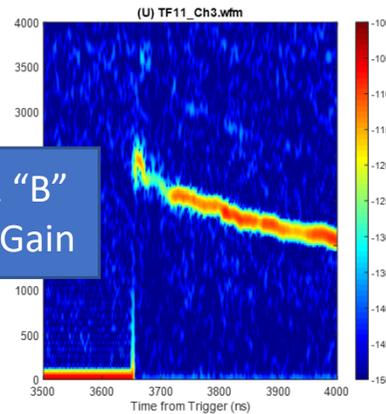
-29.5 dBm Return



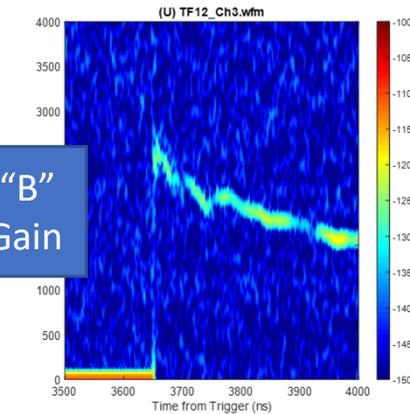
SPA2 “A”
High Gain



SPA2 “B”
Mid Gain



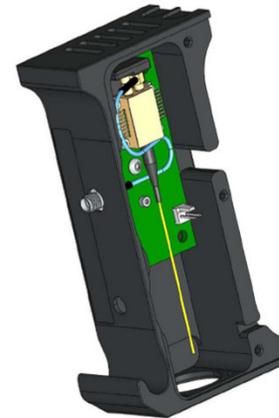
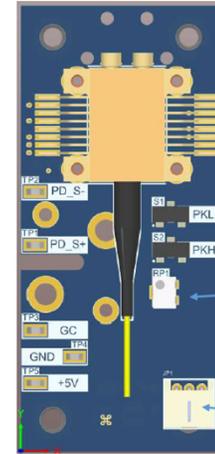
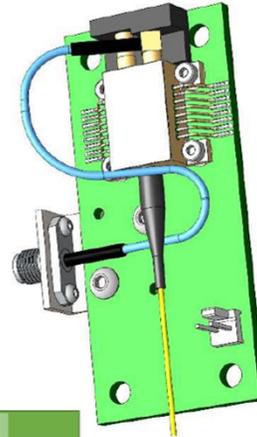
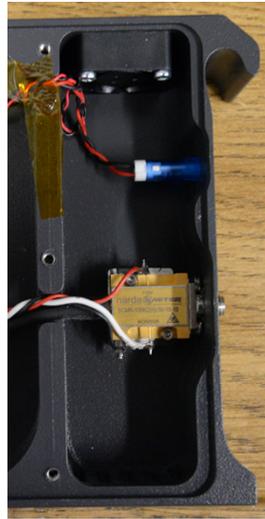
SPA2 “B”
High Gain



SPA2 “B”
High Gain

Further Development: RX25AF-“SPA3”

- Q-6 asked Throlabs if it would be possible to reconfigure the “SPA2” PCB to fit into the available space in the TS&I module
 - Initial contact March 2022
 - Rough sketches in one week
 - 3D models early May
 - Preliminary spec sheet mid-May (RX25AA-SPA3)
 - Purchase order June
 - First parts arrived July
- Fit and function OK, testing performance is underway

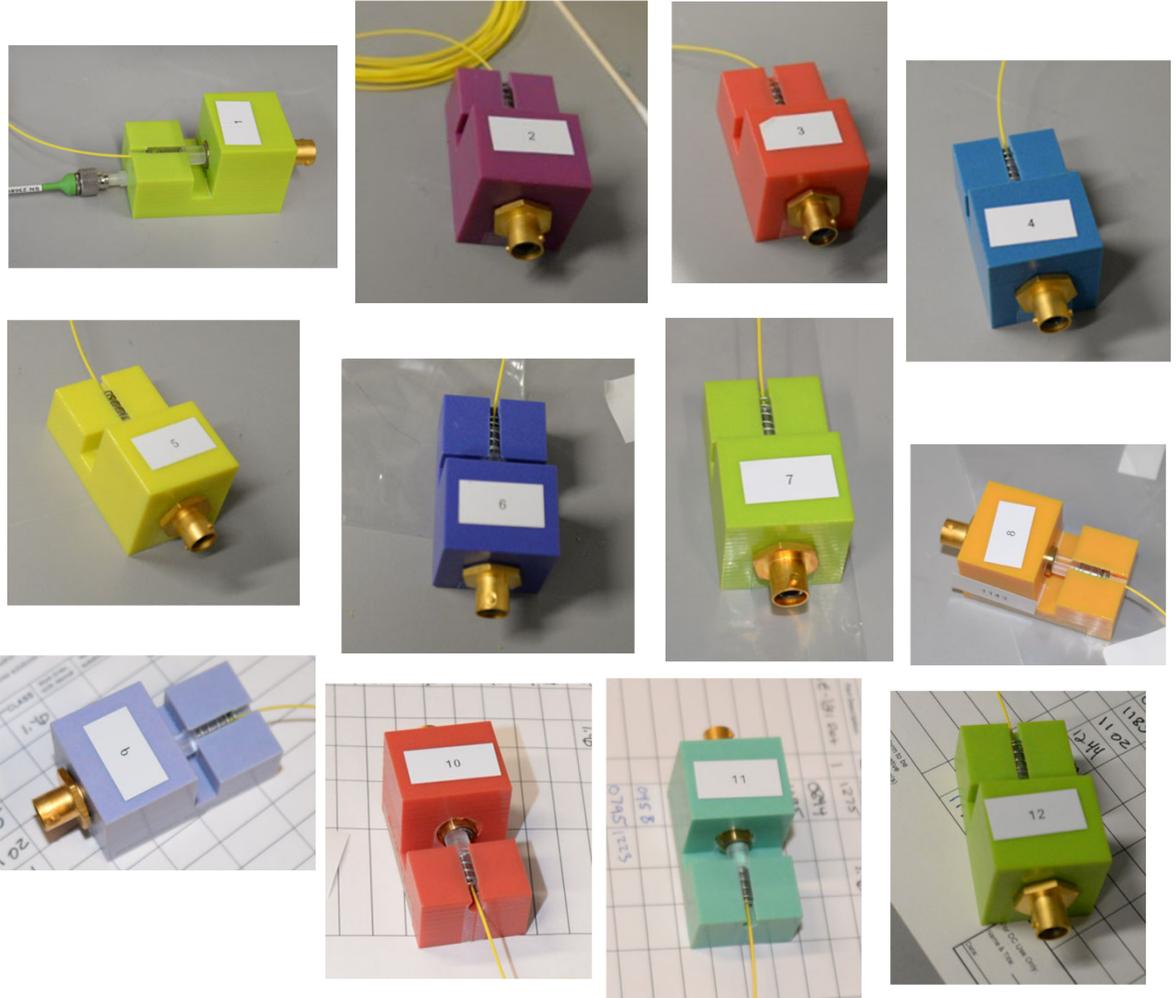


Lessons Learned and Concluding Remarks

- Commercial-off-the-shelf exist that can be used for heterodyne PDV in high-explosive applications, although they may not be quite “drop-in” (e.g. DX20AF)
- R&D sector has ability to respond rapidly to customization requests for special applications: Thorlabs developed and delivered RX25AA-SPA3 customized module using existing RX25AF OEM-style receiver in 5 months
- Supply from R&D focused companies is currently better than those with a more defense-biased business
- SPA2 overall performance is very good w/limitations, SPA3 testing ongoing
 - Low noise
 - Performs down to limits of our power meter (-30 dBm)
 - No DC offset behavior observed yet (more testing needed at higher return power)
 - Goes into protection mode ≈ 500 Vpp, need to know return, use VOA's & gain control

Questions?

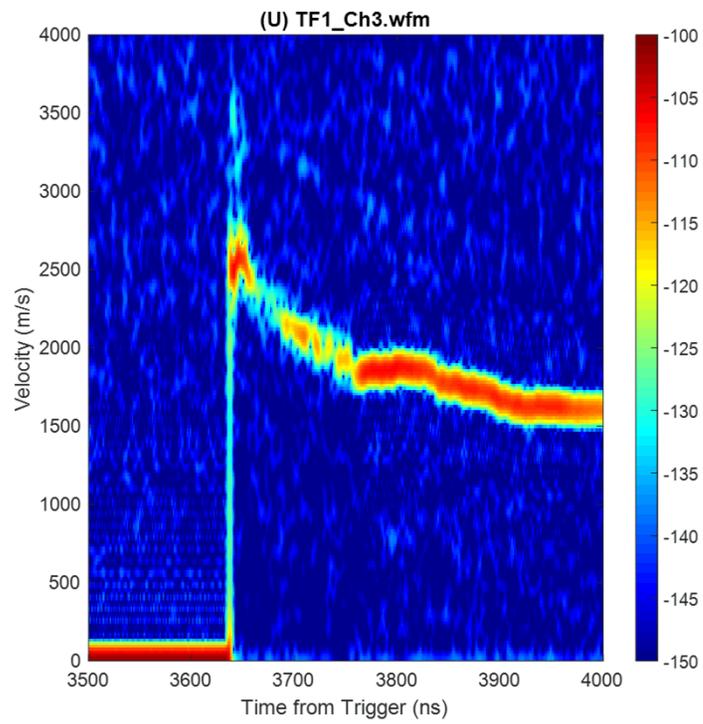
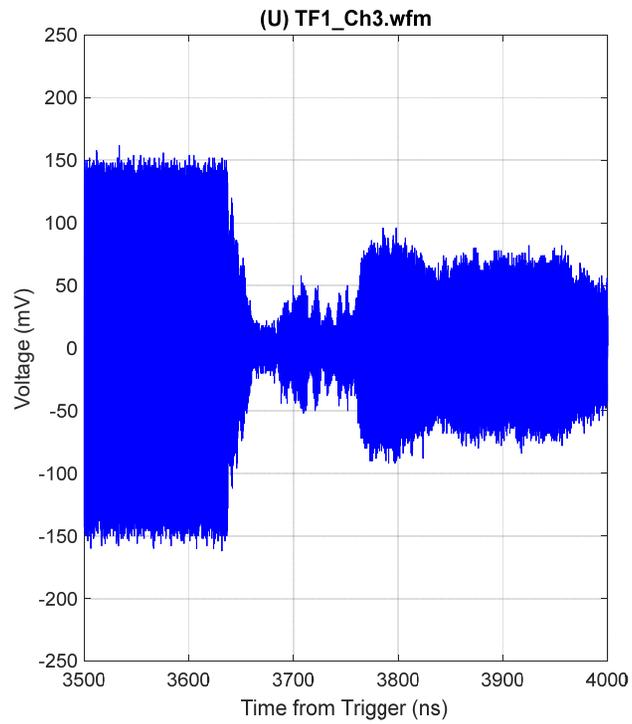
- Acknowledgments
 - Q-6 Engineering Technologist Bud Reed
 - Thorlabs' Adam Knapp and team
 - Brent Noel at TS&I
 - LANL W-11's Adam Kuiper who printed our test fixtures



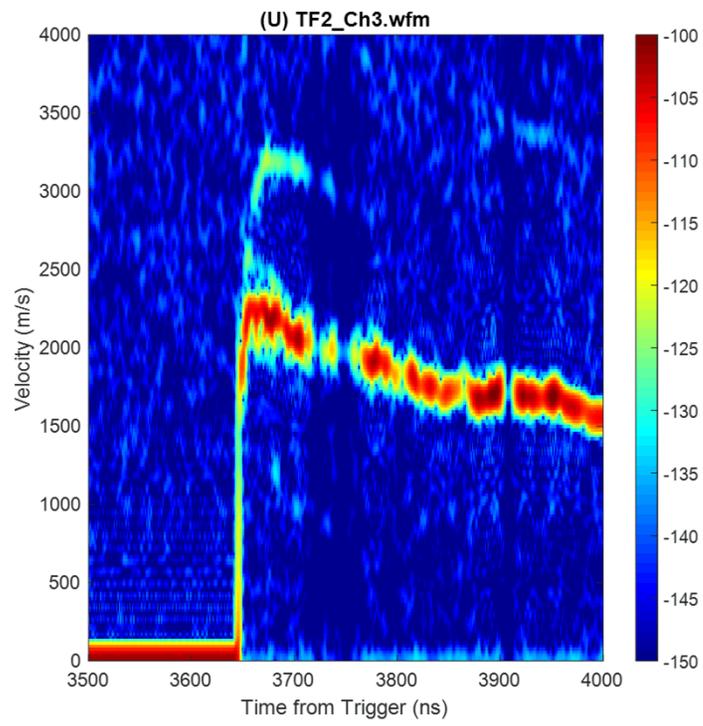
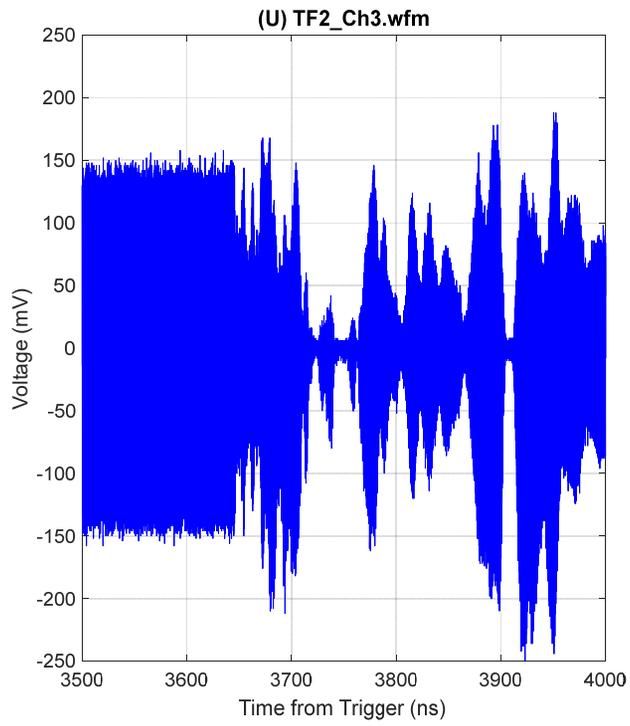
Backup Slides

- All Shakedown Test Results
- Miteq “DC Shift” Example

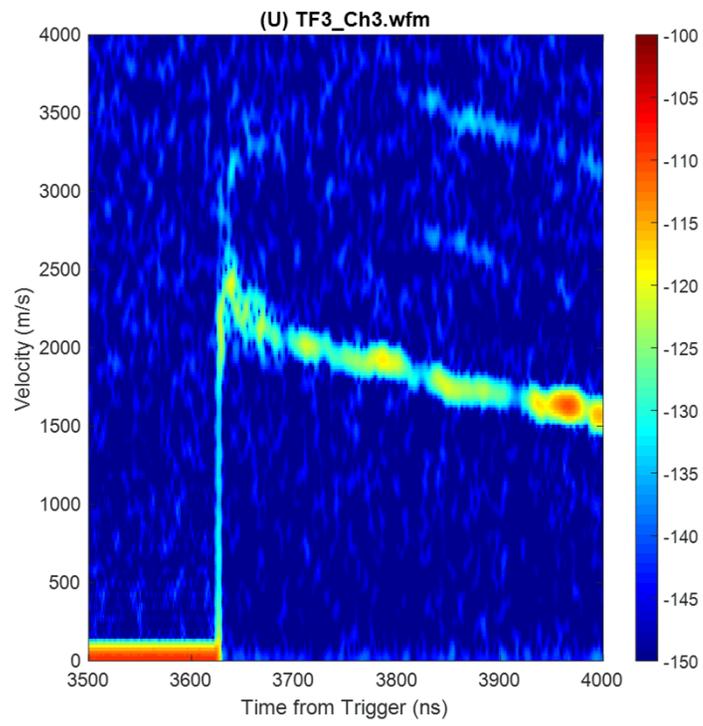
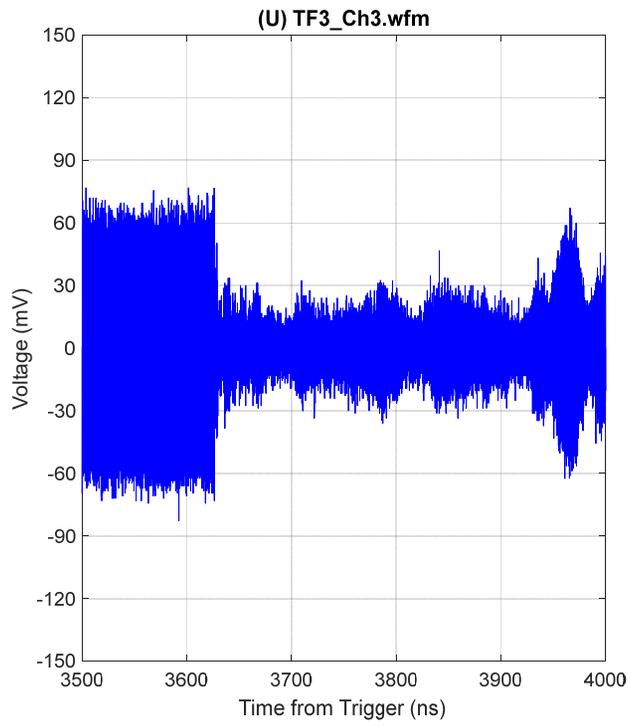
TF1



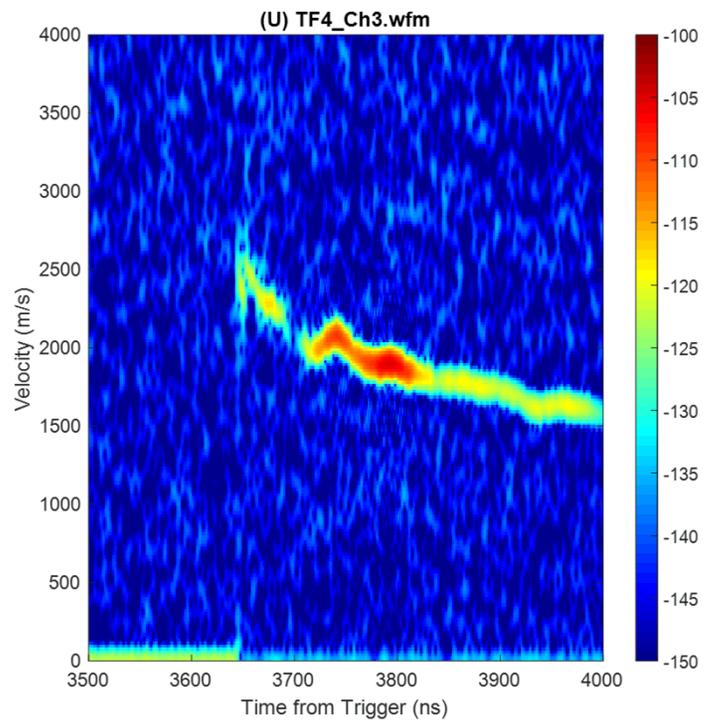
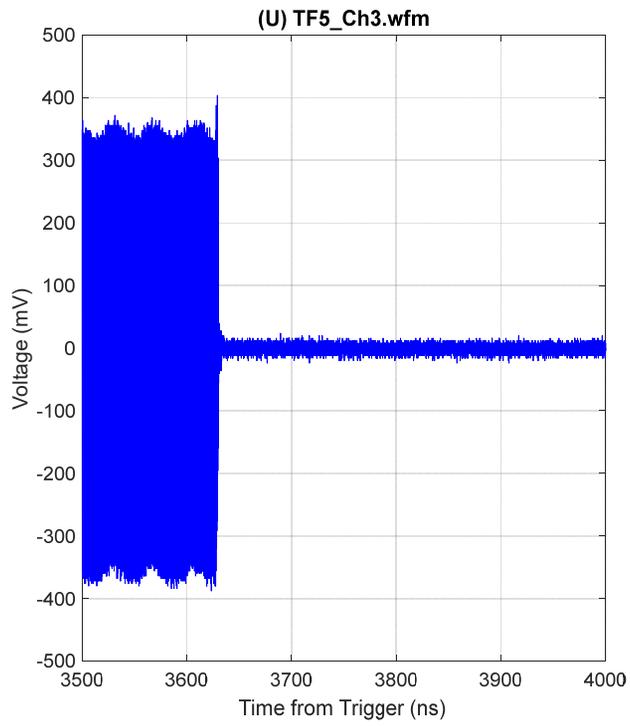
TF2



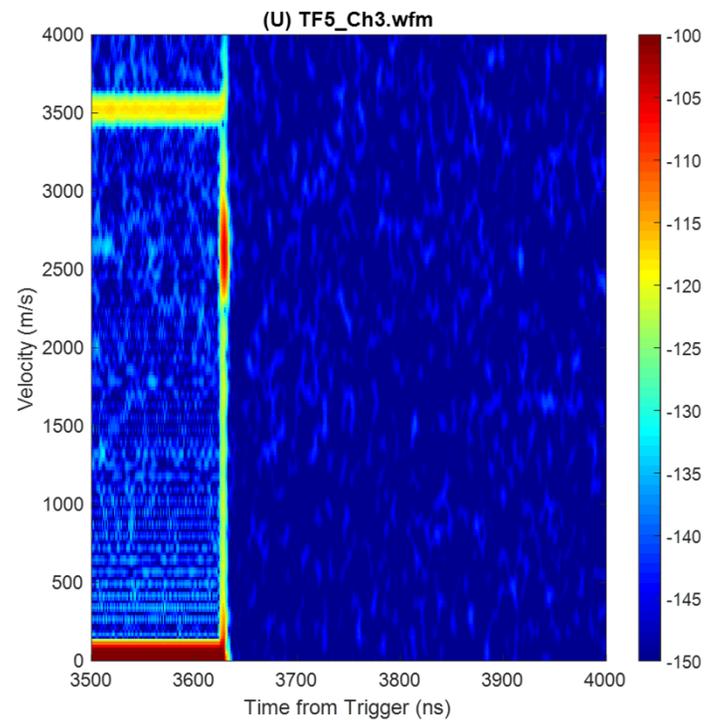
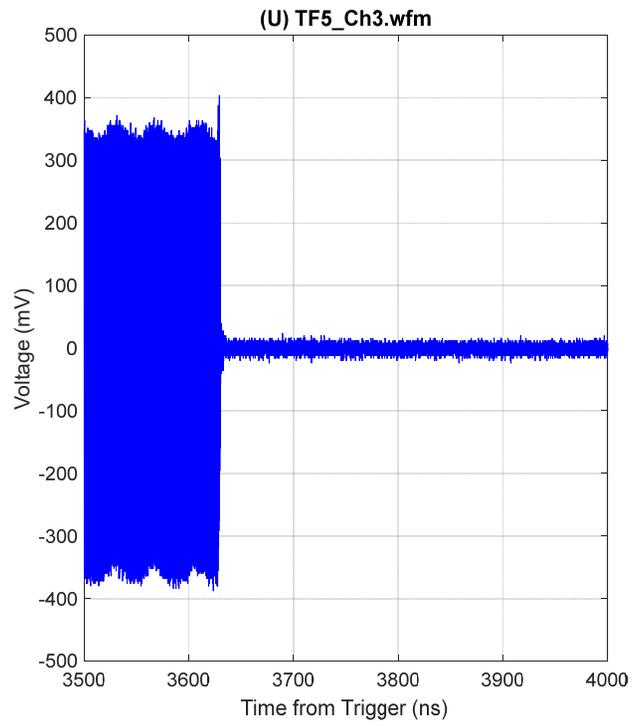
TF3



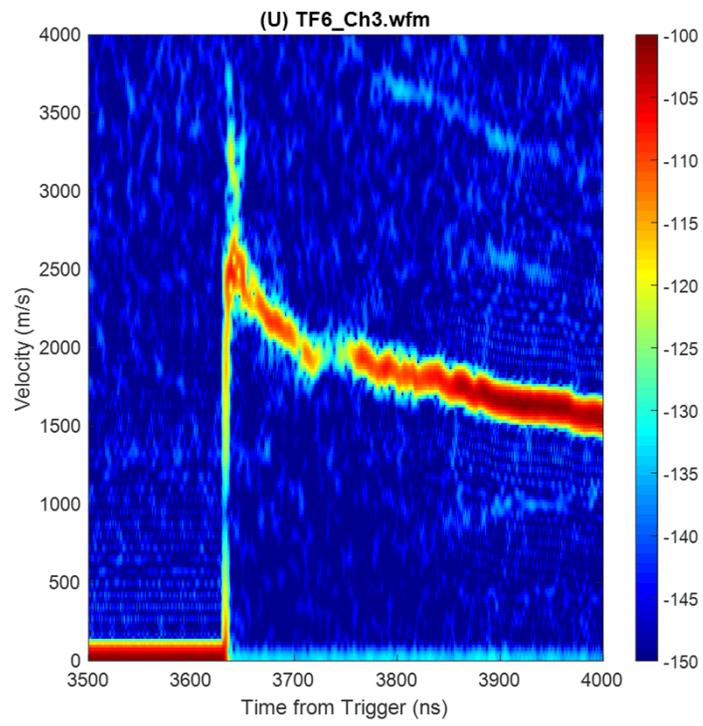
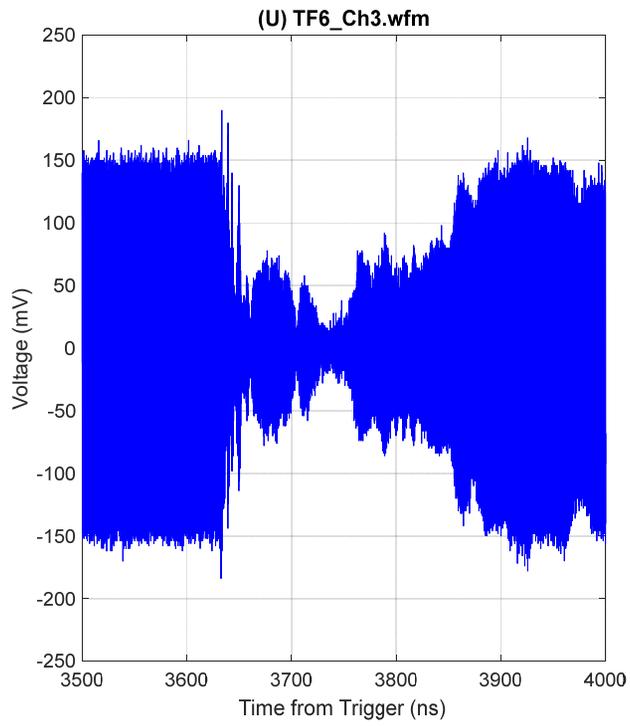
TF4



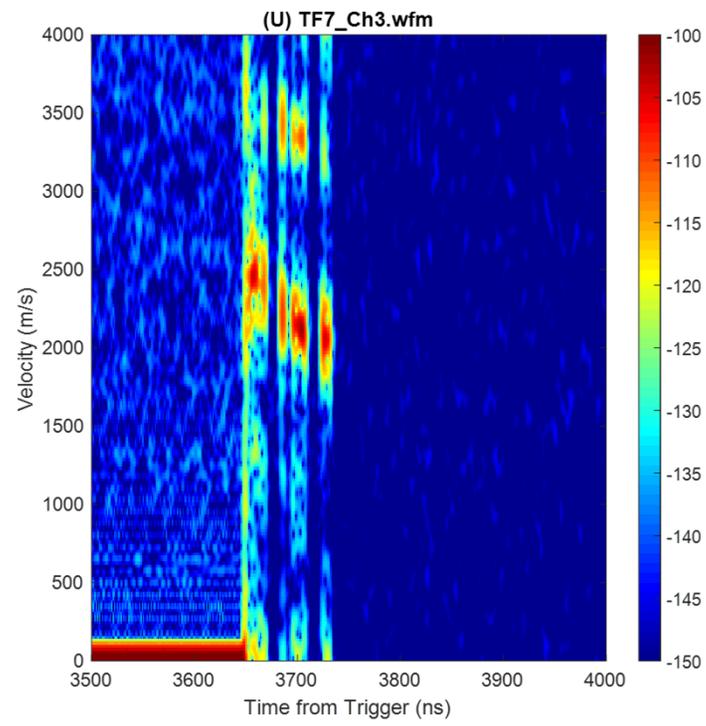
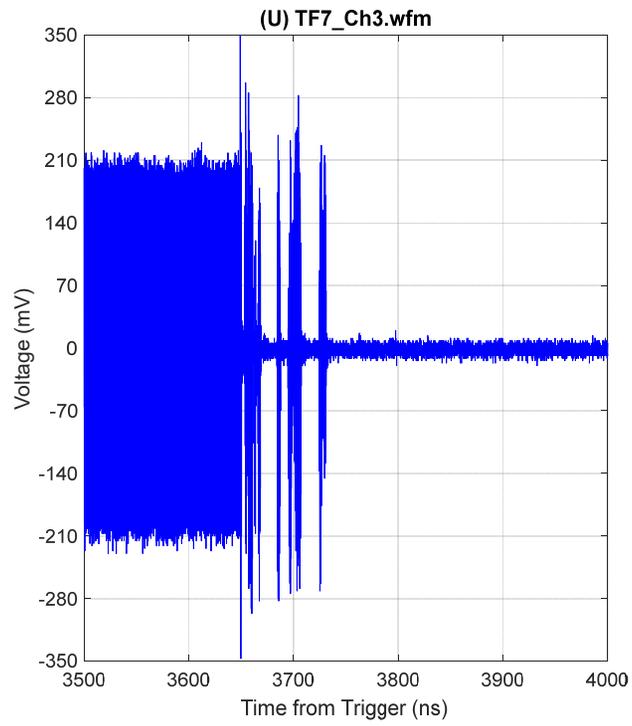
TF5



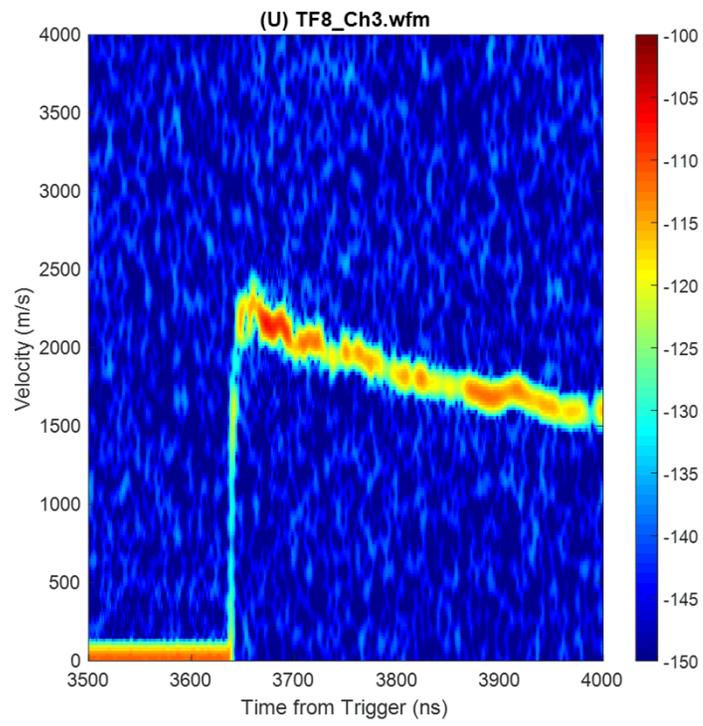
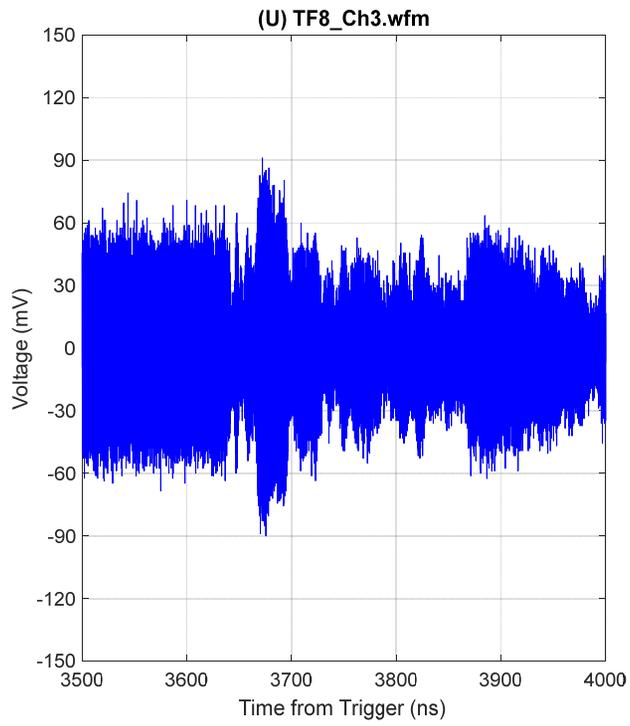
TF6



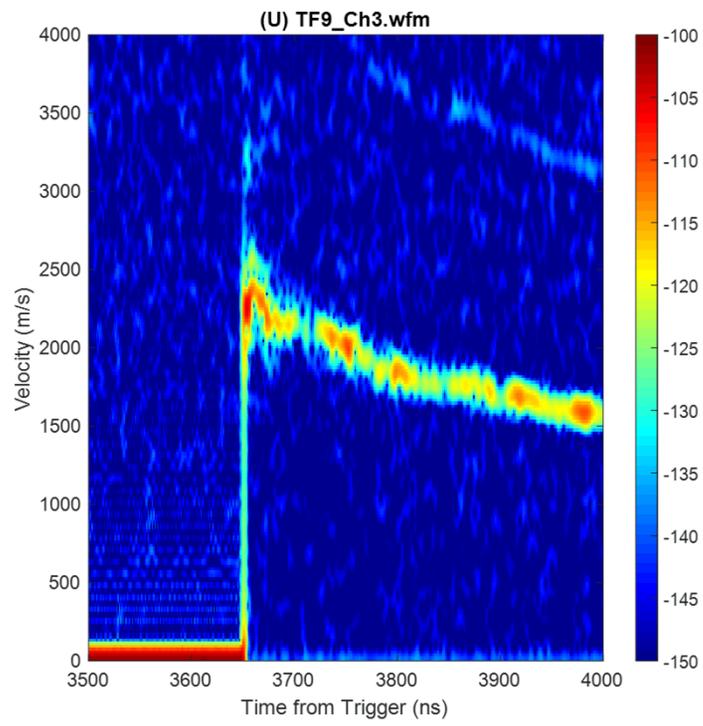
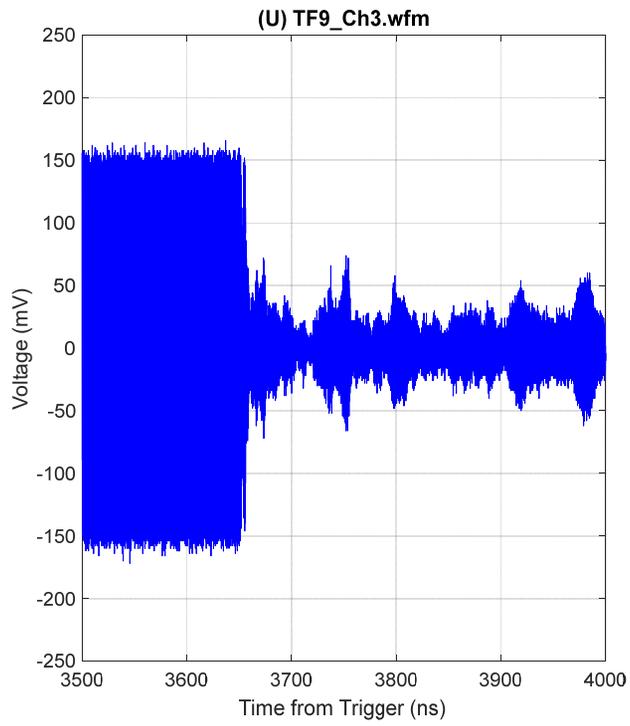
TF7



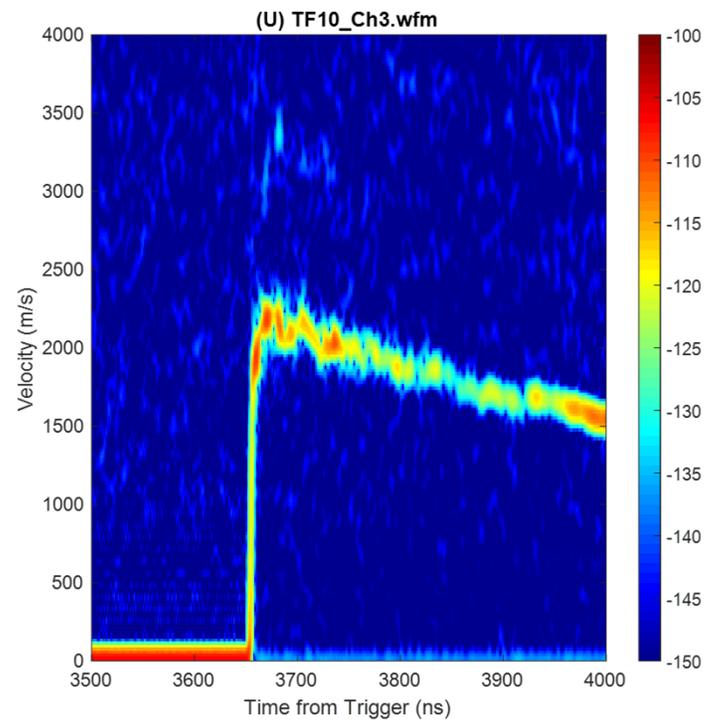
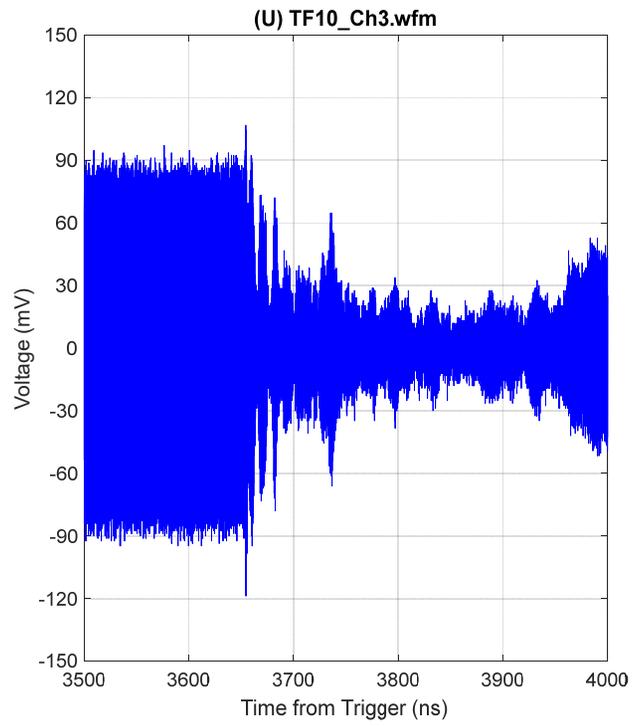
TF8



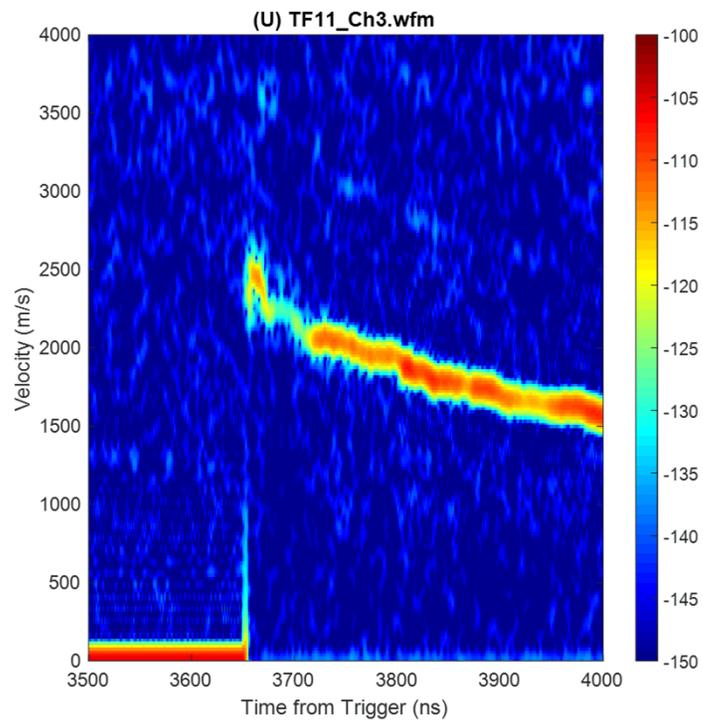
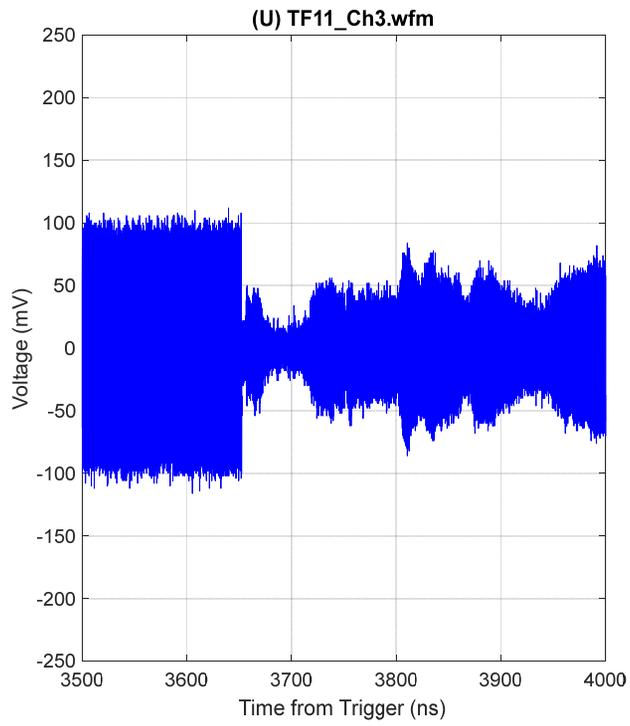
TF9



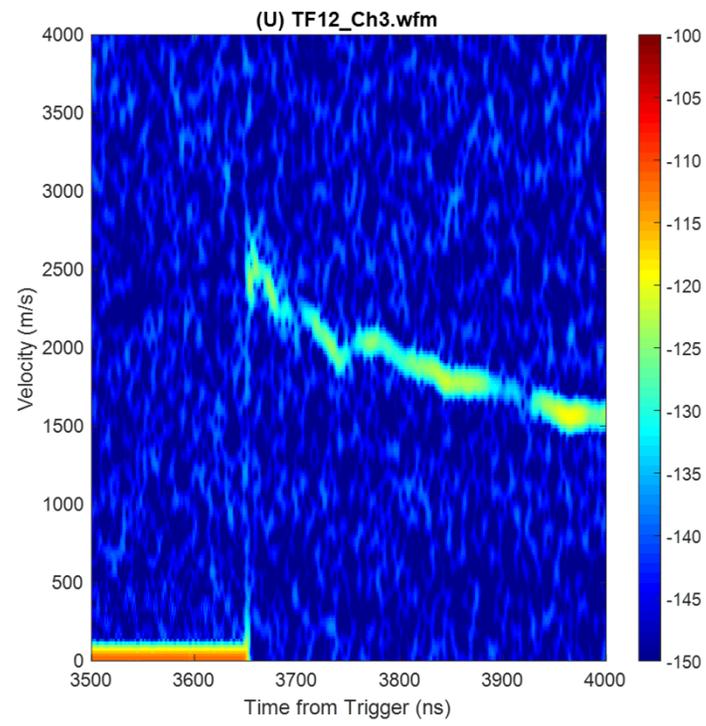
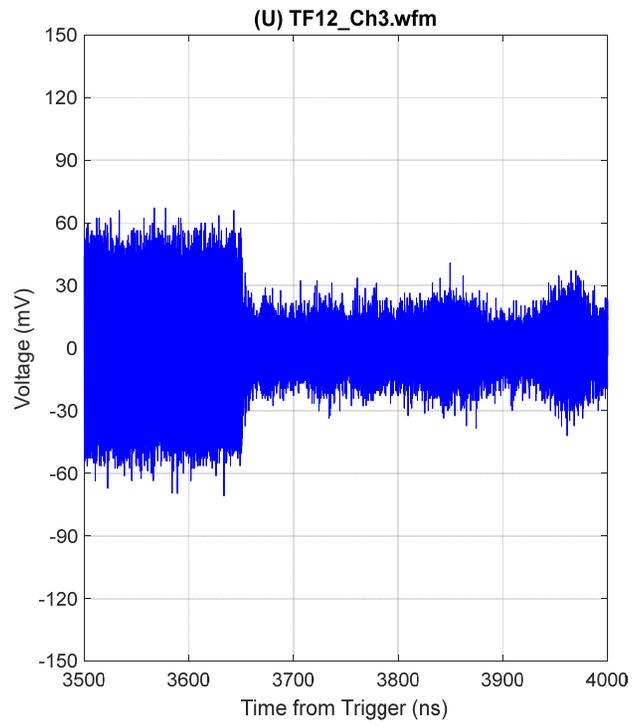
TF10



TF11



TF12



Miteq “DC Shift” Example (Flyer Plate Test, -10.9 dBm Return)

Probe return -10.9 dBm
Starts to show up at -12 dBm and
gets worse as return goes up

