MEDUSA: An optically-switched multiplexed PDV system

2014 PDV Workshop

Mike Bowden, Will Neal & Sarah –Pantaleon Knowles

AWE Plc

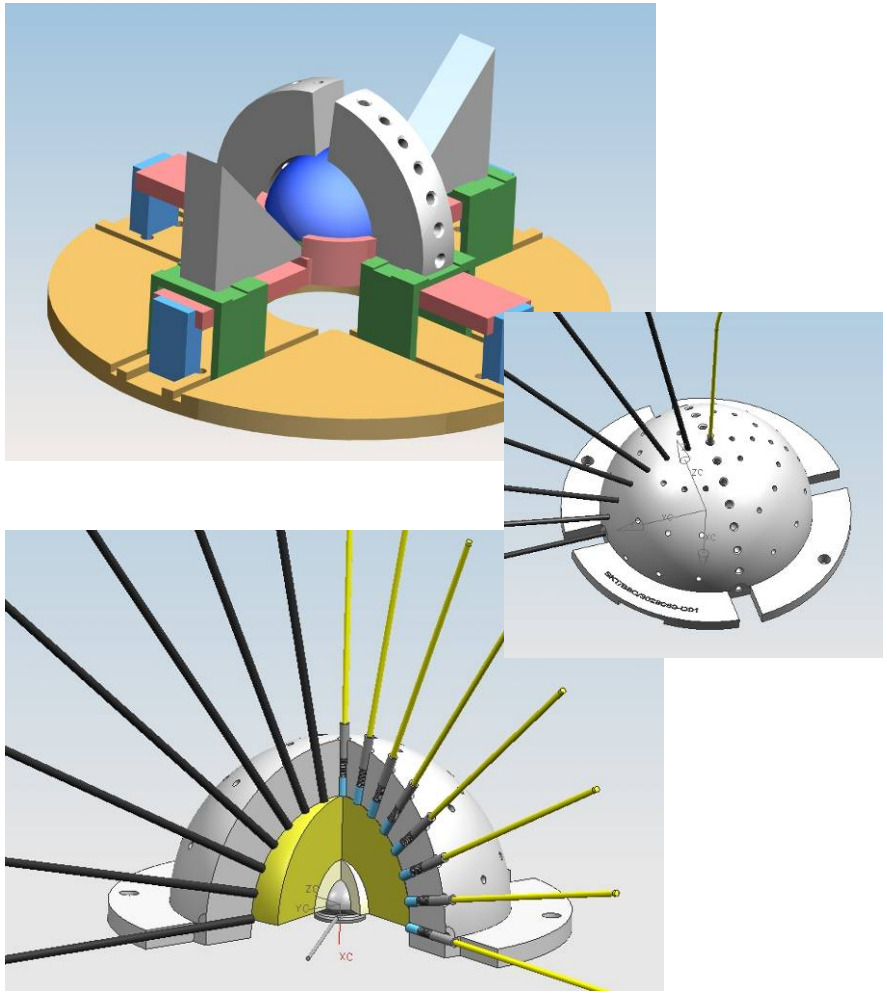
mike.bowden@awe.co.uk

Introduction

- MEDUSA (backronym - Multipoint Experimental Diagnostic for Ultrafast Shock Applications) presented to 2012 PDV workshop
- Further developments and improvements are presented and discussed
- But first, some background…

Customer requirement

- To develop a highly-multipoint PDV system for ITraC and half peach (snowball, onionskin, hairball, furball)
  - Minimum 8 channels
  - Goal >30 channels
  - Maximum velocity of 5 km/s
  - Time resolution of <1 ns
  - Transportable between sites



How do we get >30 channels?

- Simple answer: 8+ oscilloscopes at $100K each
- However, typical experiment is <10 μs duration, <8 GHz frequency range
- Oscilloscope has 16 GHz bandwidth, 100 μs record length
- Can only multiplex 2 channels in frequency domain
- Can multiplex many channels in time domain!

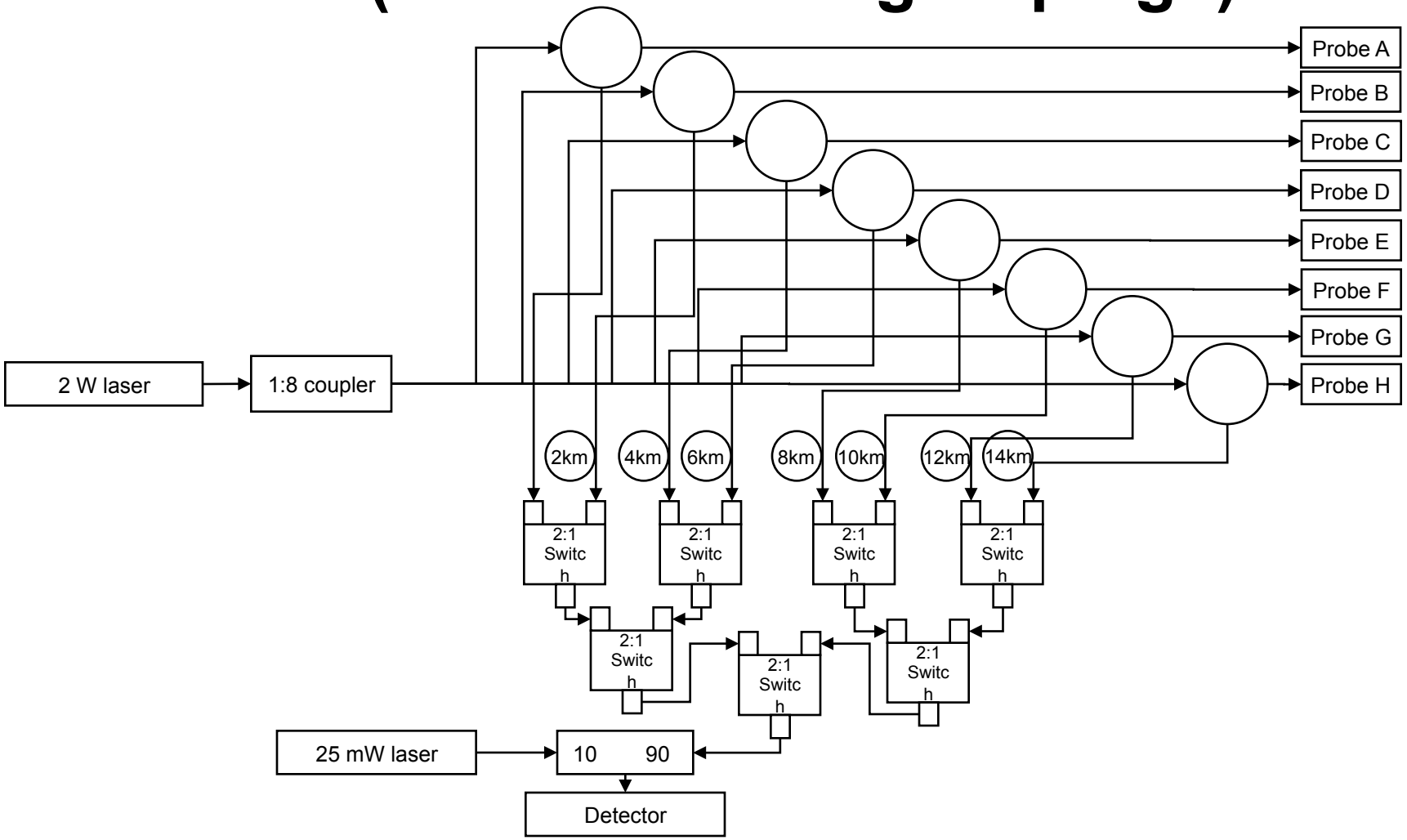
Time domain multiplexing

- Use delay legs to delay signals relative to each other
- 2 km = 10 μs spacing
- Oscilloscope record length 10 MPts = 100 μs
  - Maximum 10 channels per oscilloscope channel
- 8 channels per oscilloscope channel
  - 32 channels, room for expansion
- Twin laser (optical upshifting) to improve signal to noise
  - Aim for 2 GHz upshift

Combination options

- 8 to 1 combiner
  - Cheap
  - Very high insertion loss (>10 dB)
  - Cross talk between channels
- Fast fibre switch
  - Expensive
  - Fast switching time (300 ns)
  - Low insertion loss (2 dB)
  - Reduces cross talk between channels
- Fibre switch selected

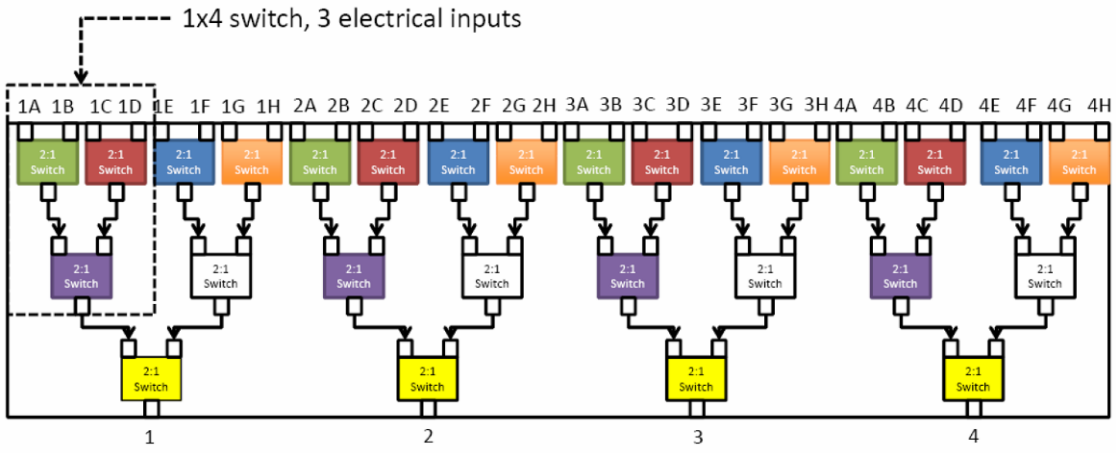
Schematic (1 of 4 channel groupings)



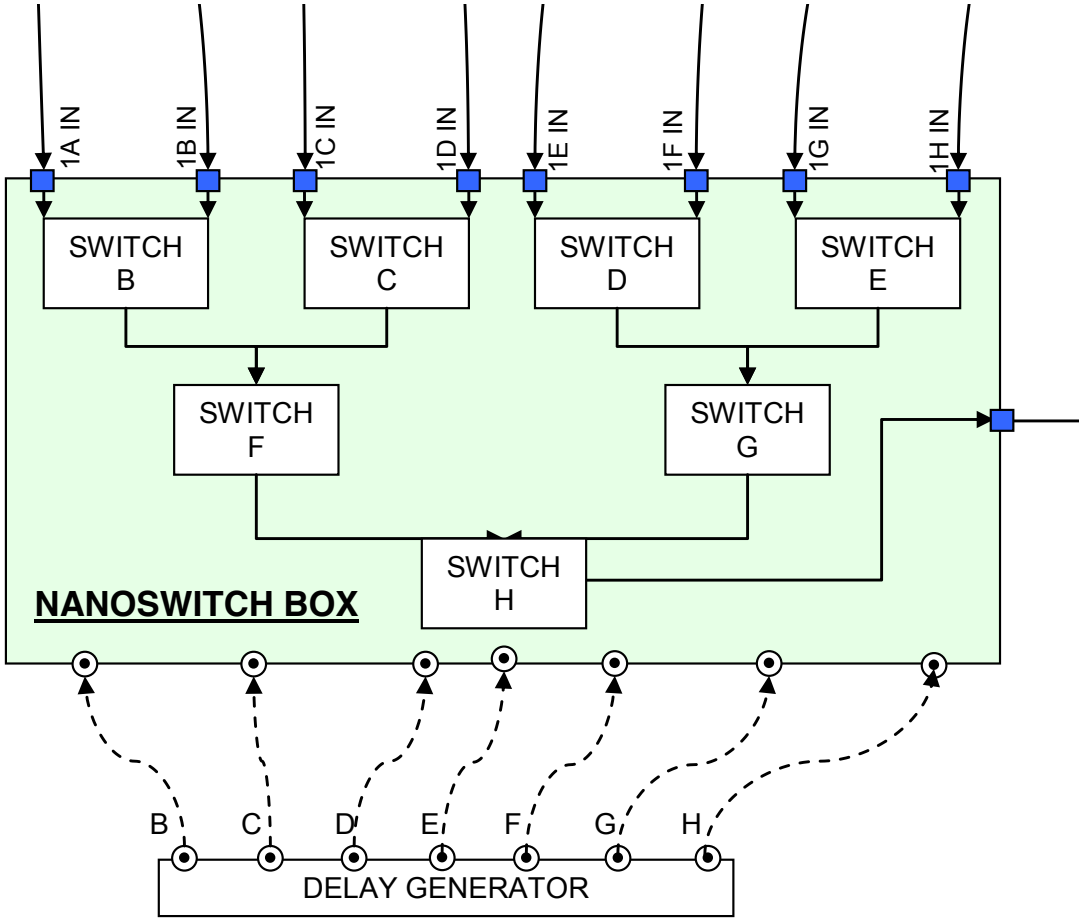
Fibre switch

- Agiltron custom build to AWE specification
- SMA electrical inputs on front, each controls 4 switches (as per colour code)
- LC/UPC inputs/ outputs on rear

Specs	Min	Typical	Max	Unit
Rise Time (Tr)[1]		85	100	ns
Fall Time (Tf)[2]		85	100	ns
Switch Speed (Rise) (Sr)[3]		315	350	ns
Switch Speed (Fall) (Sf)[4]		315	350	ns
Repetition Rate	DC		100	KHz
Pulse Width[5]	1.0		⩾1.0	us
Control Input (TTL pulse)	0		5	V
Power Consumption[6]	1		12	W
Power Current[6]	0.08		1	A
Power Supply		12		V
Operating Temperature	-5		70	°C
Storage Temperature	-40		80	°C
Electrical Connector	SMA			



Fibre Switch



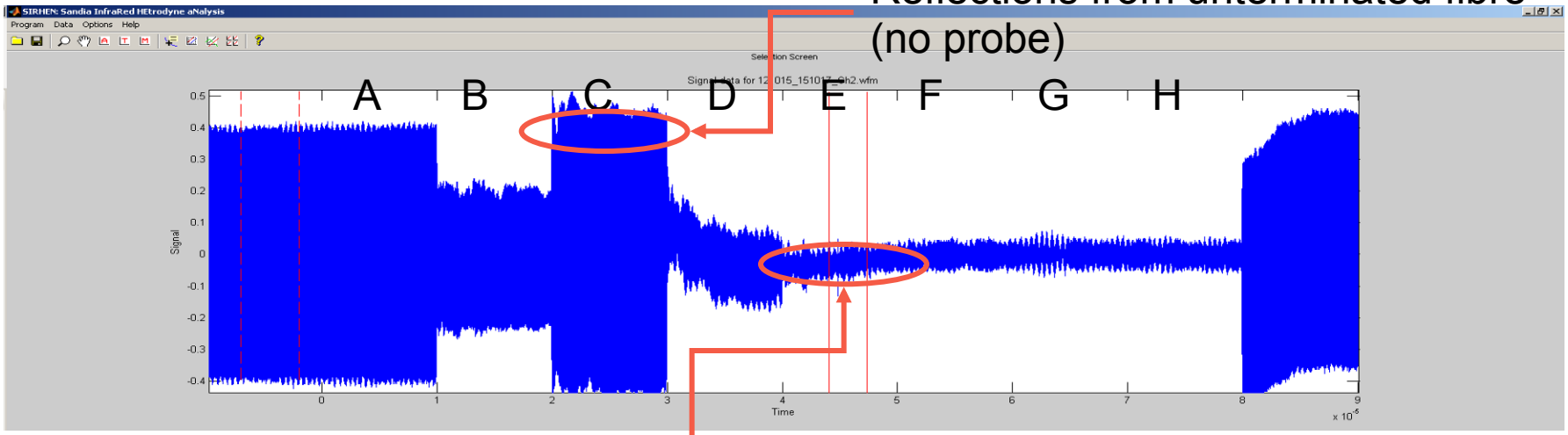
Triggering

	Fibre Channel Input										
Switch	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**		**s**	***µs***
B									Delay	= 0.00001	10
									Width	= 0.00001	10
C									Delay	= 0.00003	30
									Width	= 0.00001	10
D									Delay	= 0.00005	50
									Width	= 0.00001	10
E									Delay	= 0.00007	70
									Width	= 0.00001	10
F									Delay	= 0.00002	20
									Width	= 0.00002	20
G									Delay	= 0.00006	60
									Width	= 0.00002	20
H									Delay	= 0.00004	40
									Width	= 0.00004	40

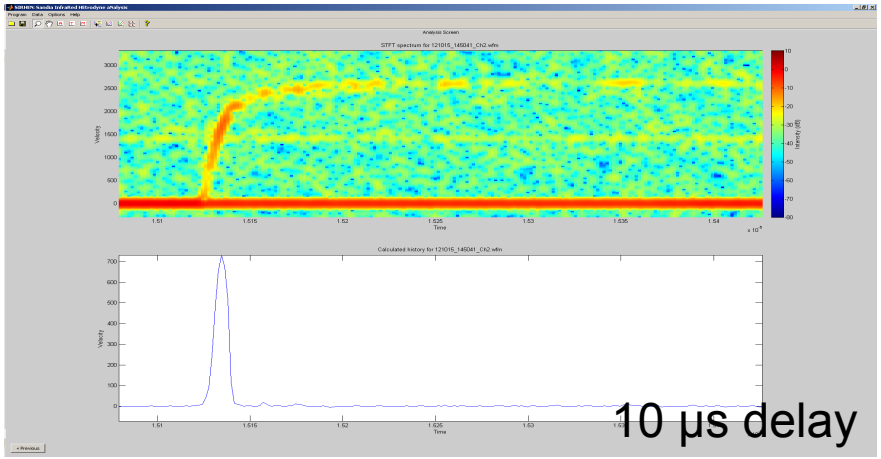
Switch Active (5V TTL)

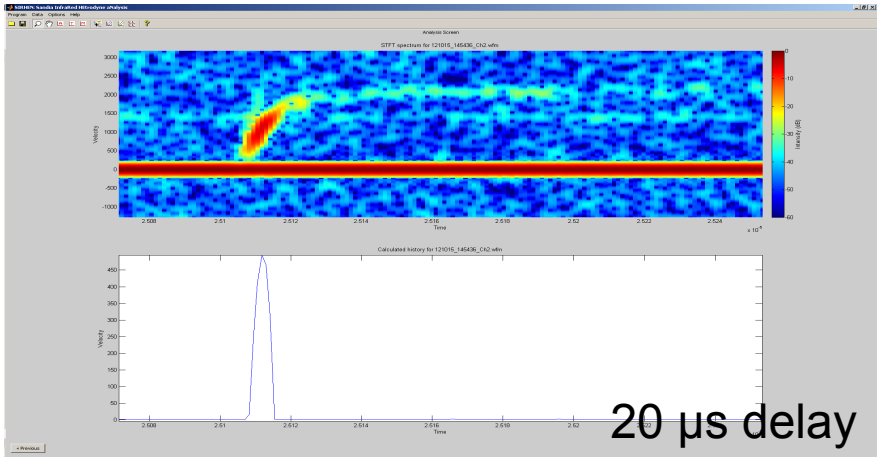
Initial system verification

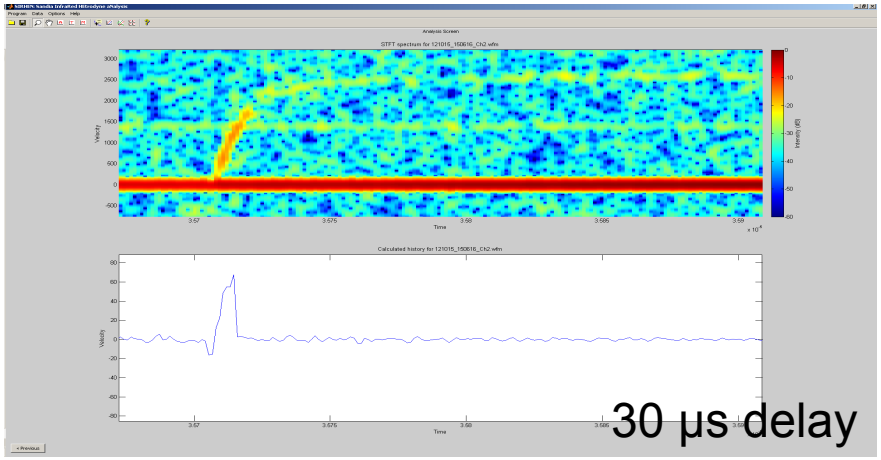
- Could not test all channels simultaneously due to time constraints
- 10 mW per probe (faulty shutter = lower laser power)
- Laser-driven flyers used to test each channel (5 km/s, 5 ns rise time)

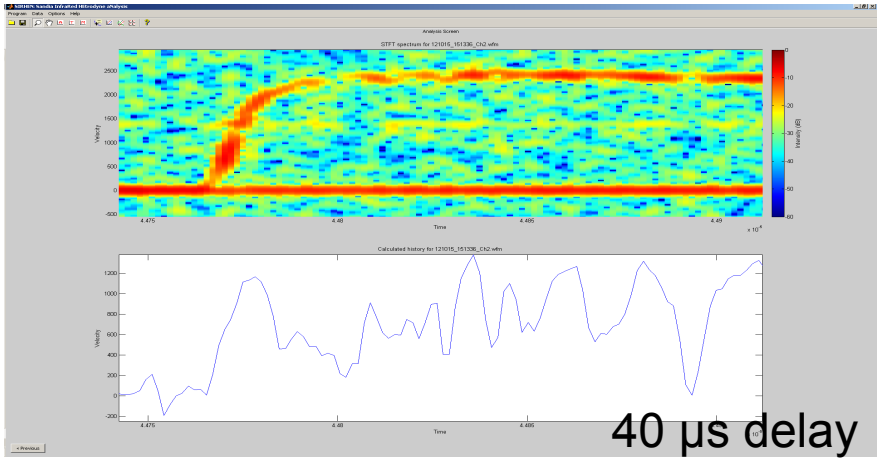


Example data







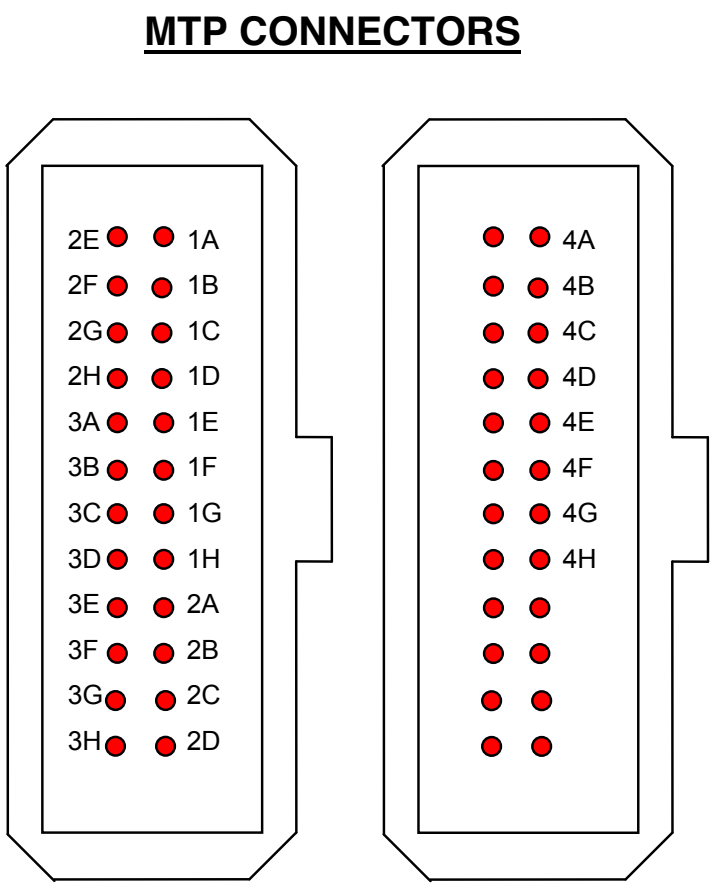


Improvements

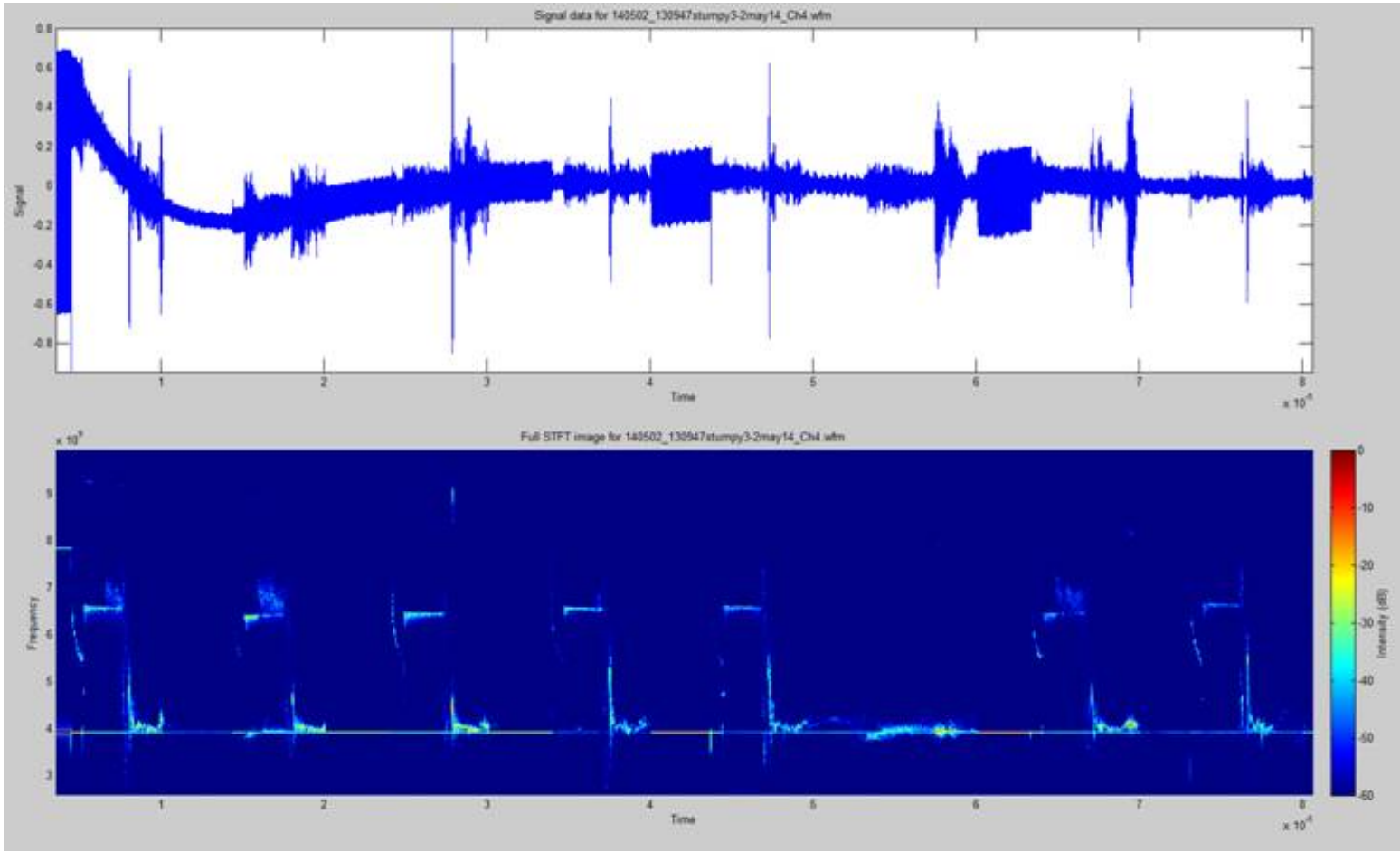
- Initial testing used 2 watts probe laser
- Replaced with 10 watt EDFA (Manlight)
- 25 mW NP Photonics seed laser
- Fibre-coupled interlocked shutter (100 ms) on EDFA output to minimise experimental heating
- EDFA ramped from 1 watt simmer to 10 watt for 100 µs

Improvements 2

- 24-way fibre assemblies with MTP connectors used to route fibres into firing chamber
- Greatly simplifies connection and reduces clutter



Improved example data



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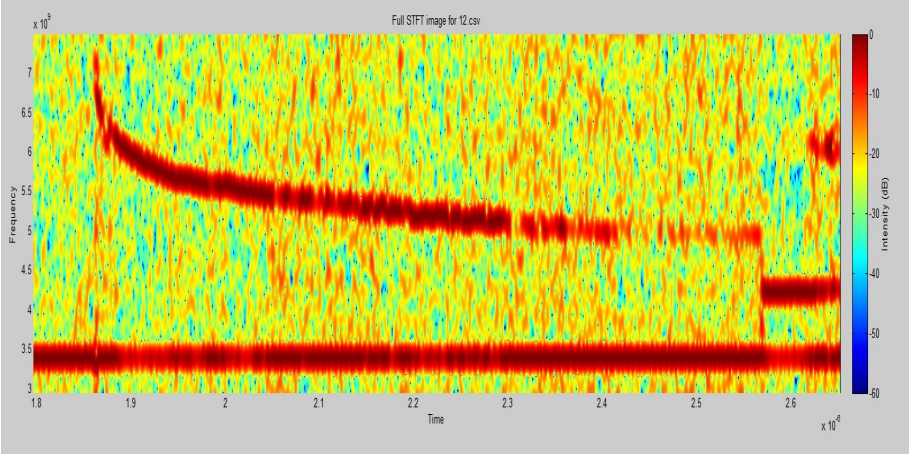

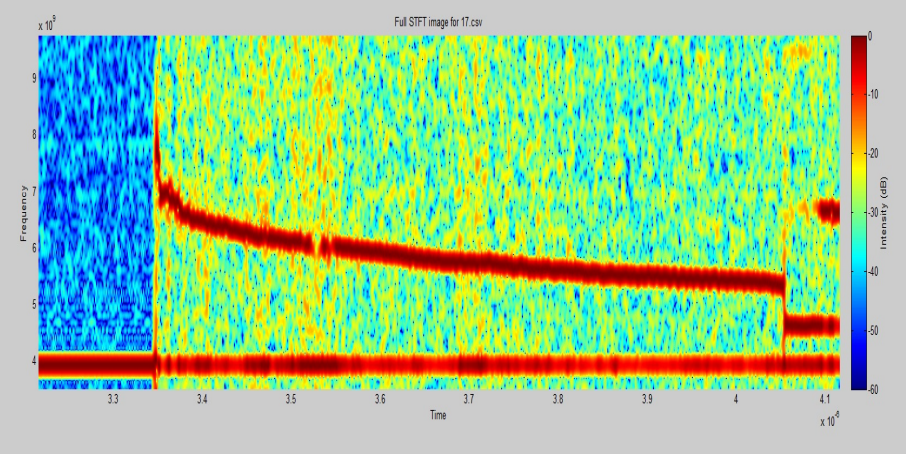

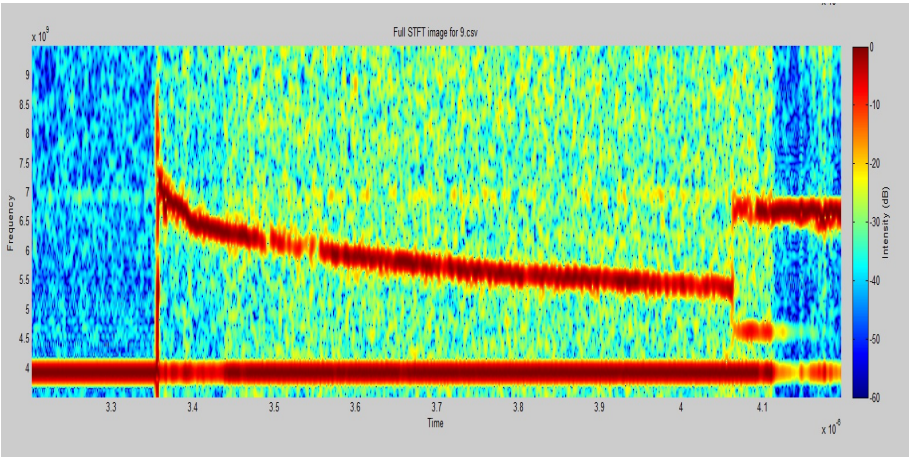

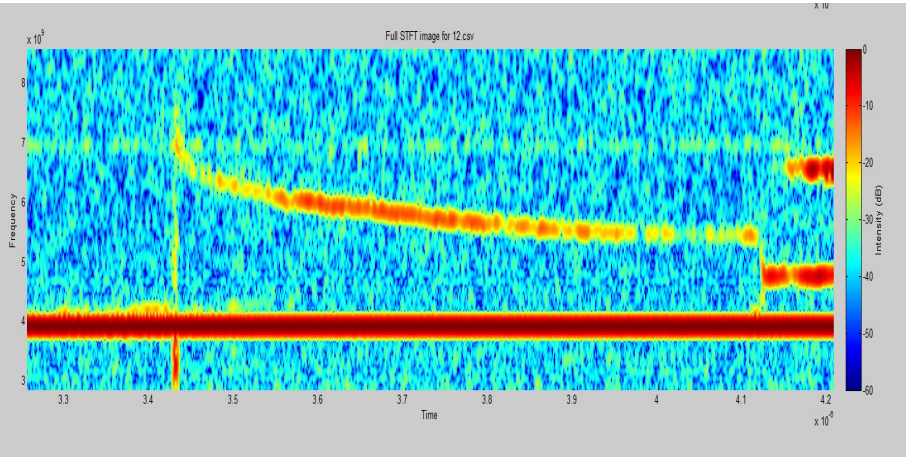

MEDUSA (top to bottom)

- NP Photonics reference laser
- Tektronix DPO71604
- Miteq 4 channel receiver
- Quantum Composer 9530 8 channel delay generator
- Agiltron fibre switch
- NP Photonics seed laser
- Manlight EDFA
- MEDUSA chassis
- Delay legs (2-14 km)

Insertion losses, laser to probes @ 7.5 W

Channel	Insertion loss, dB	Power, mW	Channel	Insertion loss, dB	Power, mW
1A	-16.17	181	3A	-16.95	151
1B	-15.98	189	3B	-16.3	176
1C	-16.16	182	3C	-16.22	179
1D	-16.03	187	3D	-16.31	175
1E	-16	188	3E	-16.49	168
1F	-16.25	178	3F	-16.45	170
1G	-16.26	177	3G	-16.41	171
1H	-16.03	187	3H	-16.4	172
2A	-16.13	183	4A	-16.01	188
2B	-16.23	179	4B	-16.41	171
2C	-16.38	173	4C	-16.19	180
2D	-16.17	181	4D	-16.32	175
2E	-16.23	179	4E	-16.17	181
2F	-16.71	160	4F	-16.08	185
2G	-16.23	179	4G	-16.49	168
2H	-16.15	182	4H	-16.95	151

Insertion loss, probe to receiver

Channel	Insertion Loss (dB)	Insertion Loss (%)	Channel	Insertion Loss (dB)	Insertion Loss (%)
1A	-3.66	56.9	3A	-4.2	62
1B	-3.9	59.3	3B	-5.02	68.5
1C	-6.05	75.2	3C	-4.92	67.8
1D	-5.97	74.7	3D	-5.46	71.6
1E	-5	68.4	3E	-6.51	77.7
1F	-5.74	73.3	3F	-7.52	82.3
1G	-6.5	77.6	3G	-7.51	82.3
1H	-6.35	76.8	3H	-8.04	84.3
2A	-4.57	65.1	4A	-2.79	47.4
2B	-5.16	69.5	4B	-3.98	60
2C	-6.17	75.8	4C	-3.72	57.5
2D	-5.8	73.7	4D	-5.08	69
2E	-6.88	79.5	4E	-4.97	68.2
2F	-8.59	86.2	4F	-5.75	73.4
2G	-7.46	82.1	4G	-6.55	77.9
2H	-7.78	83.3	4H	-8.05	84.3

Delays, microseconds

Channel	Delay	Channel	Delay	Channel	Delay	Channel	Delay	Average	S.D.
1A	0.07	2A	0.07	3A	0.07	4A	0.06	0.07	0.005
1B	9.89	2B	9.89	3B	9.89	4B	9.88	9.89	0.005
1C	19.68	2C	19.69	3C	19.68	4C	19.68	19.68	0.005
1D	29.50	2D	29.51	3D	29.50	4D	29.49	29.50	0.008
1E	39.29	2E	39.29	3E	39.29	4E	39.28	39.29	0.005
1F	49.09	2F	49.09	3F	49.08	4F	49.09	49.09	0.005
1G	58.90	2G	58.90	3G	58.95	4G	58.90	58.91	0.025
1H	68.69	2H	68.70	3H	68.71	4H	68.72	68.71	0.013

Lessons learnt

- Consistent switch failures (switch D)
  - Under investigation, limits MEDUSA to 28 channels
- Random switch failures
  - Gold plating flaking off brass SMA trigger connecting resulting in shorts
- Complex triggering
  - Shutter, delay generator, switch, EDFA, oscilloscope

Conclusion

- The MEDUSA optically-switched PDV system has been designed, constructed and commissioned
- It offers up to 32 channels, each with 10 μs record length using optical switching to reduce insertion losses and cross-talk between channels
- Multiple explosive shots with maximum probe count fired (see Will Neal's talk earlier this week)