

# Development and testing of a new multiplexed Heterodyne Velocimeter.

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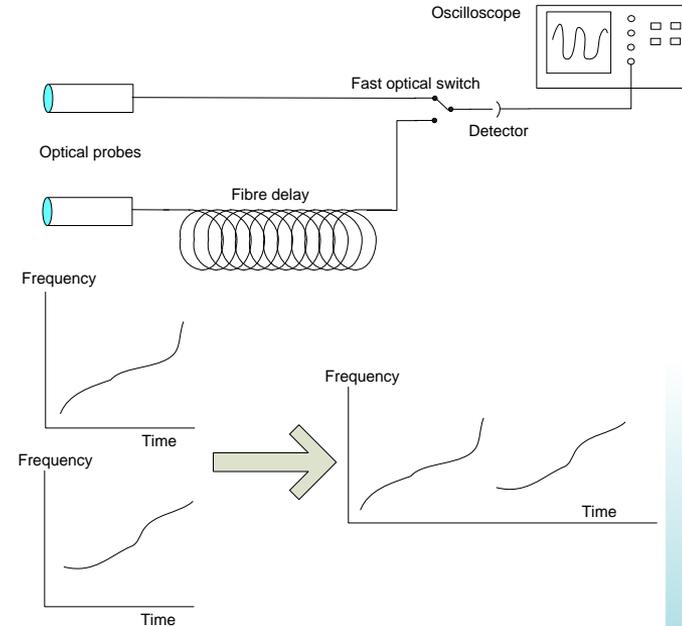


# Super Raptor concept 1

The Super Raptor will not use frequency multiplexing due to the reduction in effective bandwidth as the oscilloscope is recording two beat signals simultaneously.

Instead only temporal multiplexing will be used but this will be extended beyond the single stage used previously.

Temporal multiplexing involves delaying an optical signal for a period of time such that a preceding optical signal has been recorded in full. This can be achieved with a long coil of optical fibre and an optical switch.



## Super Raptor concept 2

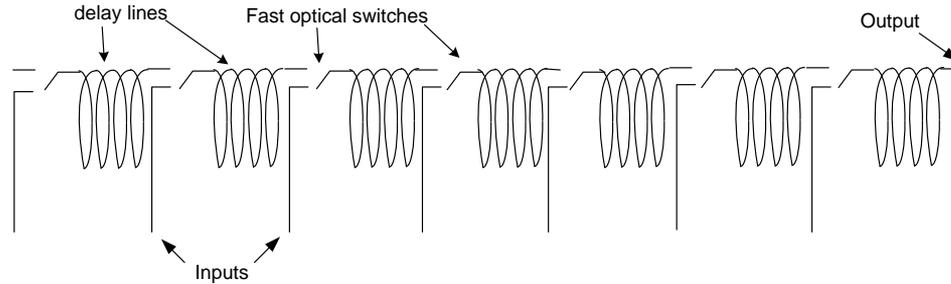


Light levels returned from a surface can be very low and can fluctuate over several orders of magnitude.

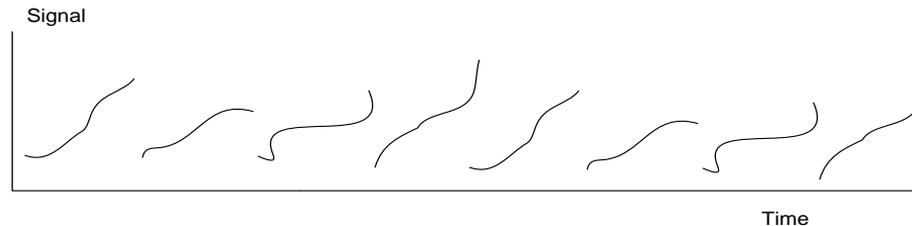
To maintain a good signal with little light return we have previously amplified the return signal but this can result in too much light.



A more efficient method for using multiple probes is to employ a network of fibre delays which utilises the coils for multiple signals.



In this scheme, different inputs traverse different numbers of delay lines with most of the delays used multiple times. The resultant output sees the individual signals recorded sequentially even though they occurred simultaneously.

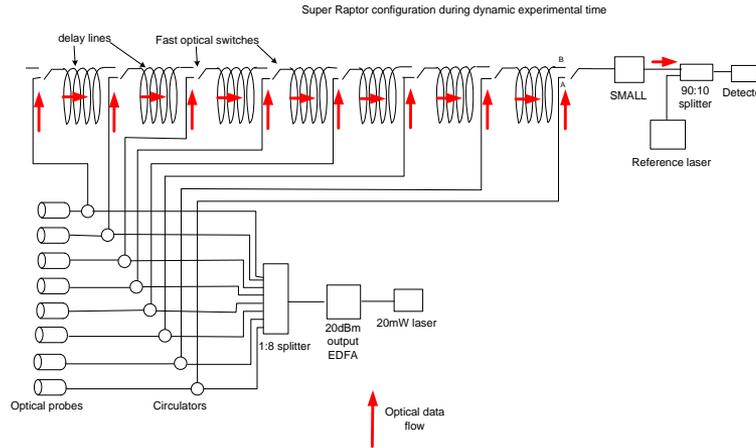


Multiplexing 8 optical data channels will increase the number of channels recorded by a factor of 2 over the MHetV whilst avoiding the bit depth issues associated with frequency multiplexing.

# Practical Operation

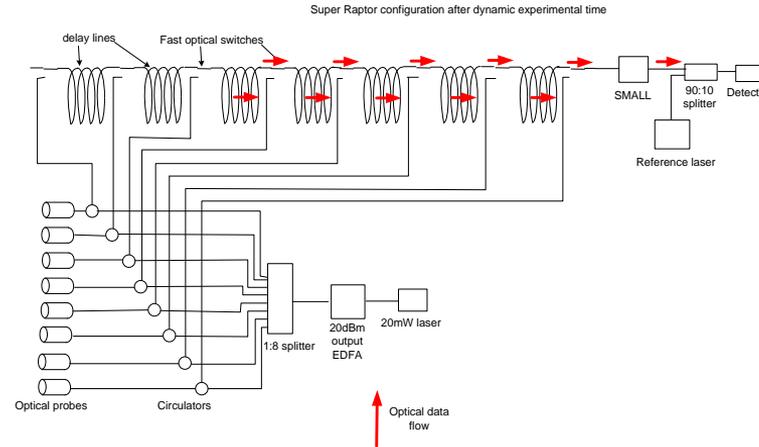
At the beginning of a dynamic experiment, the optical switches are in the “A” position and the probe is connected to its respective delay coil.

The delay acts as optical memory, storing the light returned from the surface of the experiment.



At the end of the dynamic experiment, the switches are all simultaneously moved to position “B” which connects all of the delay coils together and connects them to the detector section.

The stored signals then drain through the network sequentially.

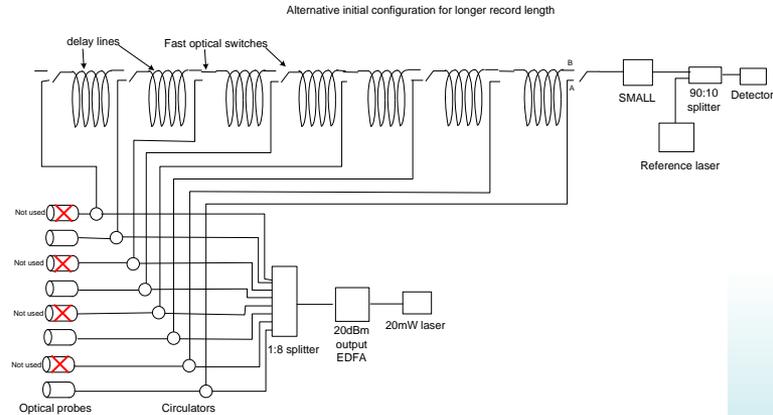


## Alternative modes of operation

The delay lines have a limited storage capacity determined by their length.

In the case where longer recording times are required, the delay generator which operates the switches can be programmed in an alternative configuration.

In this case, each optical probe can use two delay coils as storage, doubling the recording time for the channel at the expense of losing half of the available channels.



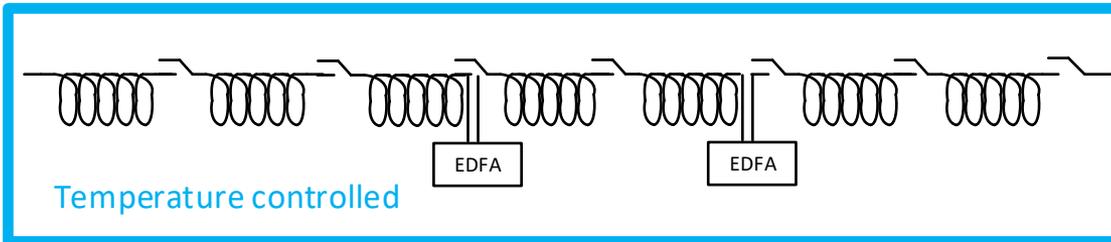
# Time delays in the Super Raptor system



For the Super Raptor system, we need enough time delay to record the full experiment and thus the delay coils must be specified accordingly. We use 15.4 km lengths giving over 70  $\mu\text{s}$  of delay for each channel.

Due to attenuation in such long fibres, two EDFAs are used in the network in order to boost the signals.

The delay coils are built into a temperature controlled enclosure in order to minimise timing errors. We also include a fiducial marker to prove out the timing.



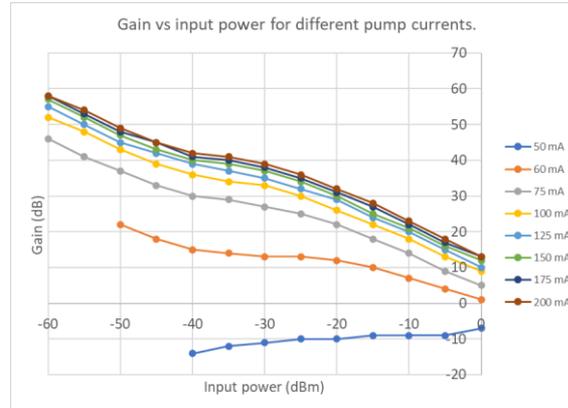
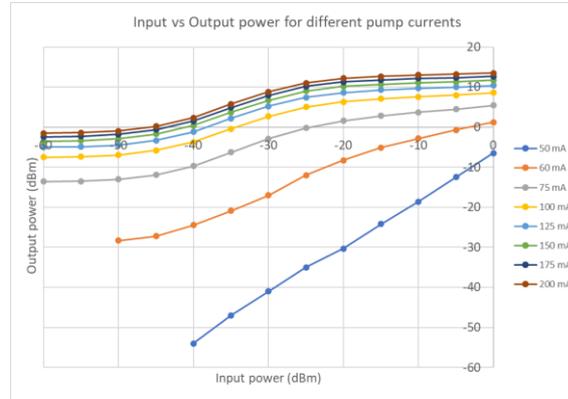
# SMALL

## Saturated Moderated Amplification of Laser Light

We use high gain, low power output EDFA amplifiers to condition the return light from the surface. This can be very low intensity light but it varies.

The heterodyne process works very effectively at moderating the beat signal amplitude but to cover large changes in light return levels, previous systems record on 2 oscilloscope channels with different sensitivities.

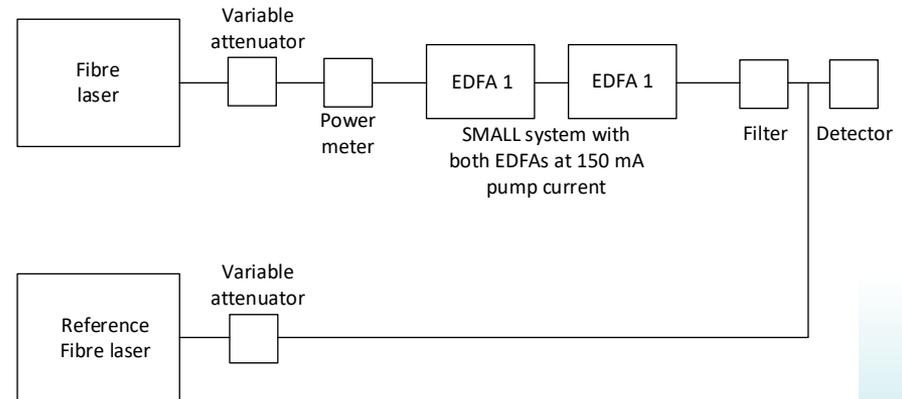
SMALL acts to further moderate this output such that only a single oscilloscope channel is required.



In order to maximise the moderation of the signal amplitude, the EDFAs are used in a 2 stage arrangement (the Routley configuration). This ensures that the amplitude of the return signal is further moderated and should remain relatively constant regardless of the return light from the surface.

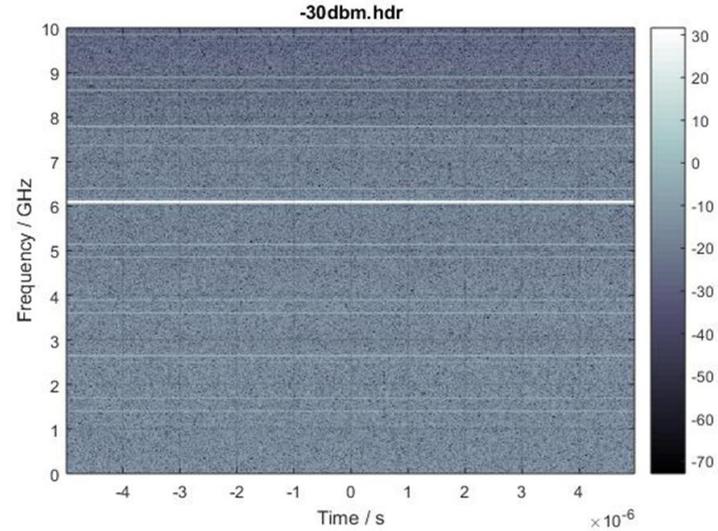
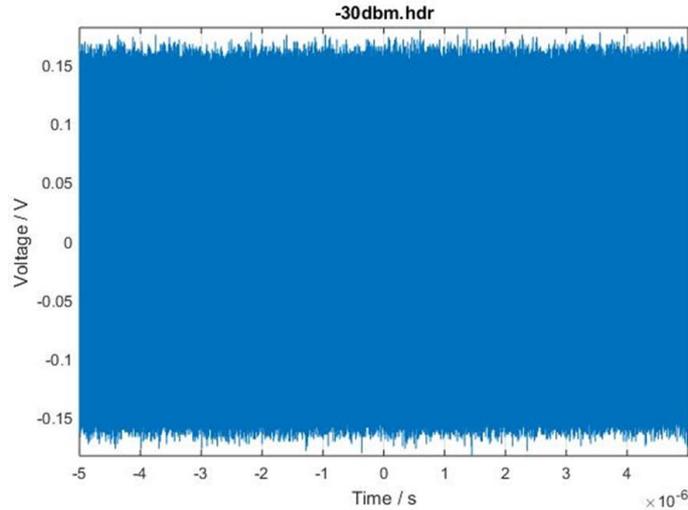
To test this a simple system was put together to assess the concept.

This allows us to change the “return light level” over a large range and check the sort of system performance we should achieve.

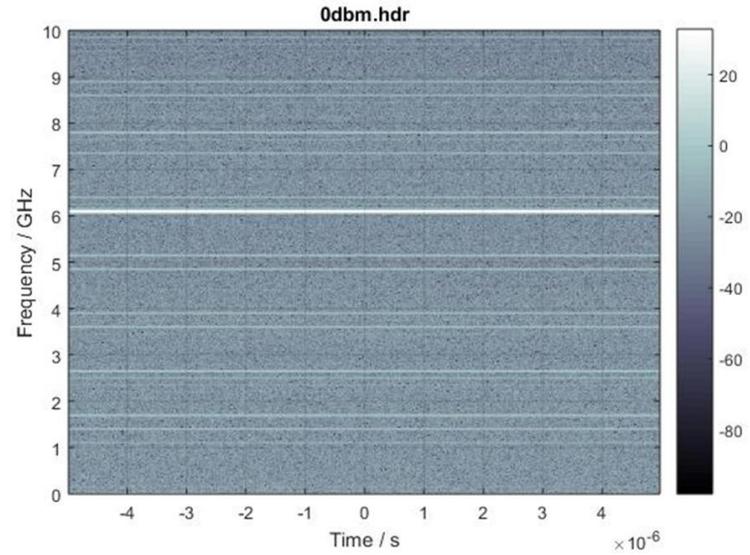
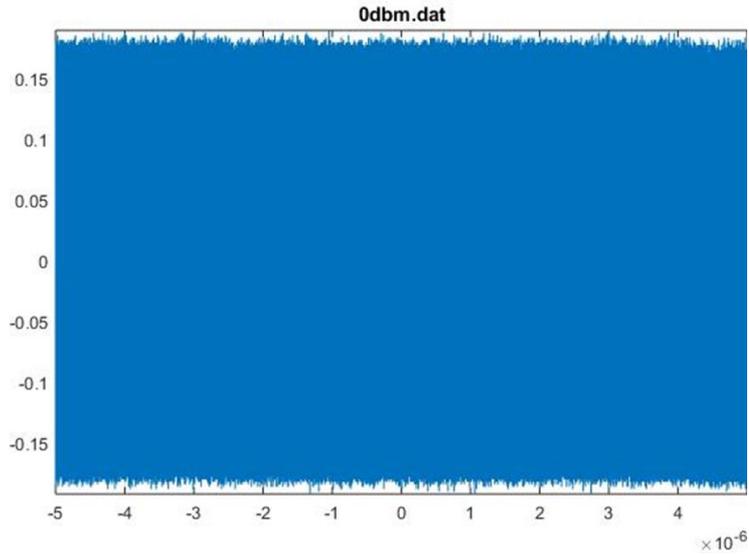


## -30 dBm signal return

Fairly typical signal return from a surface with -40 dB backreflectance and 10 mW light output

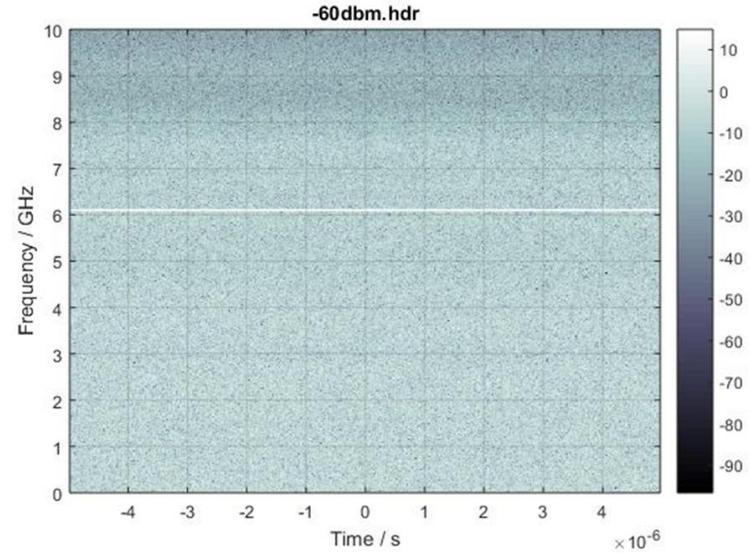
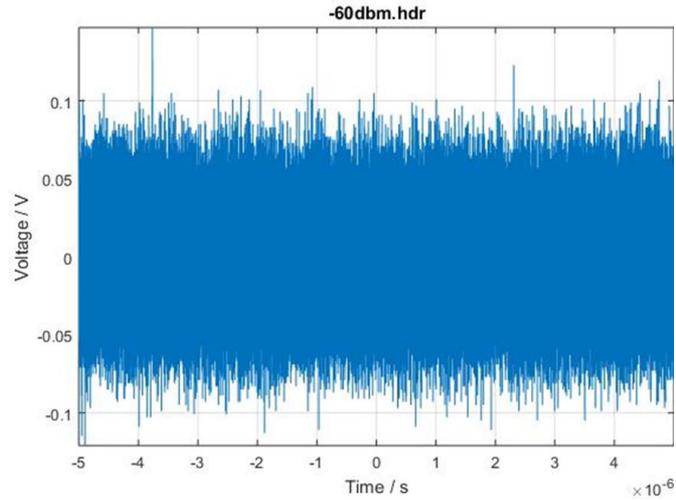


# 0 dBm light return



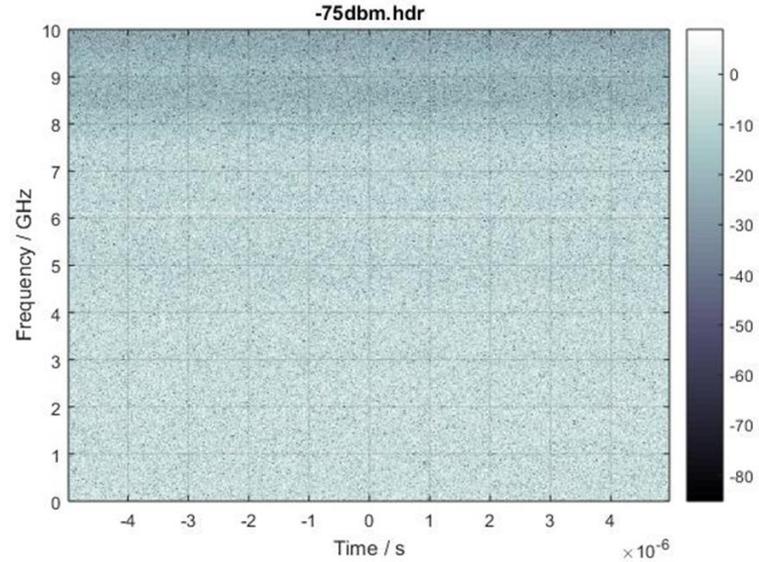
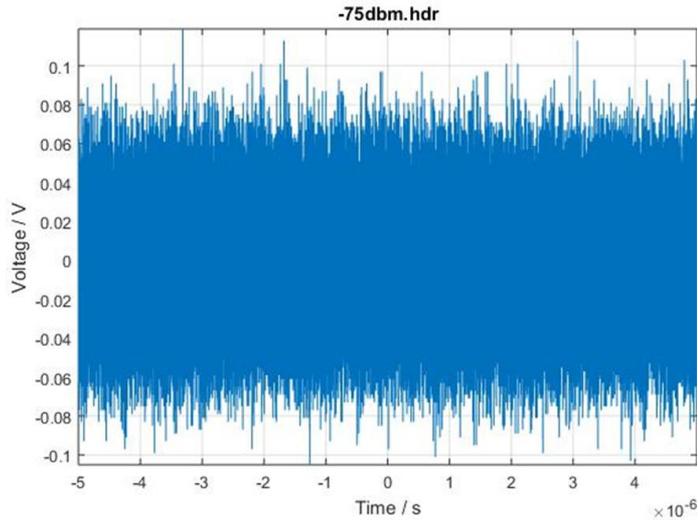
# -60 dBm light return

A very dim light return

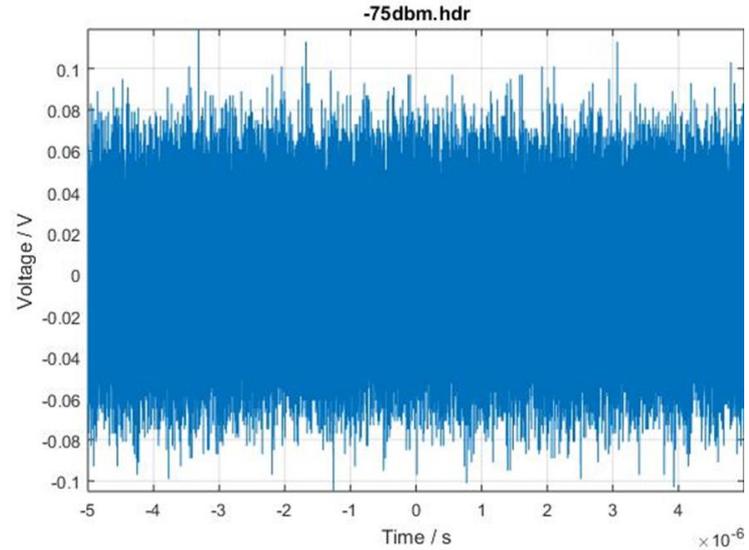
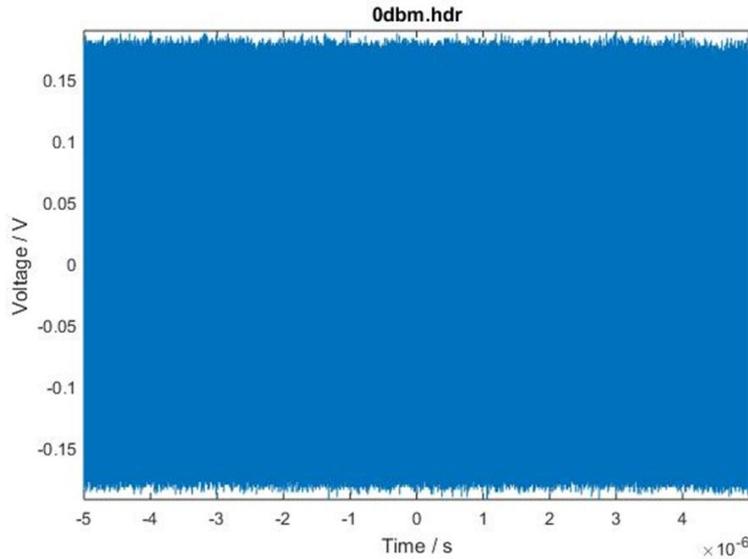


# -75 dBm light return

That is just 30 pW of power



# Comparison of signal strength at 0 dBm and -75 dBm light return

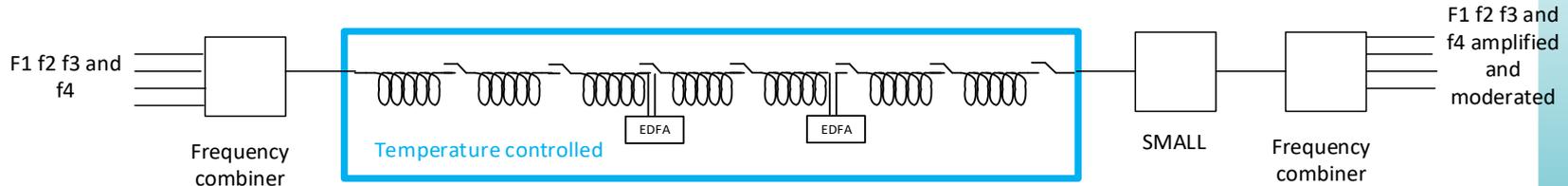


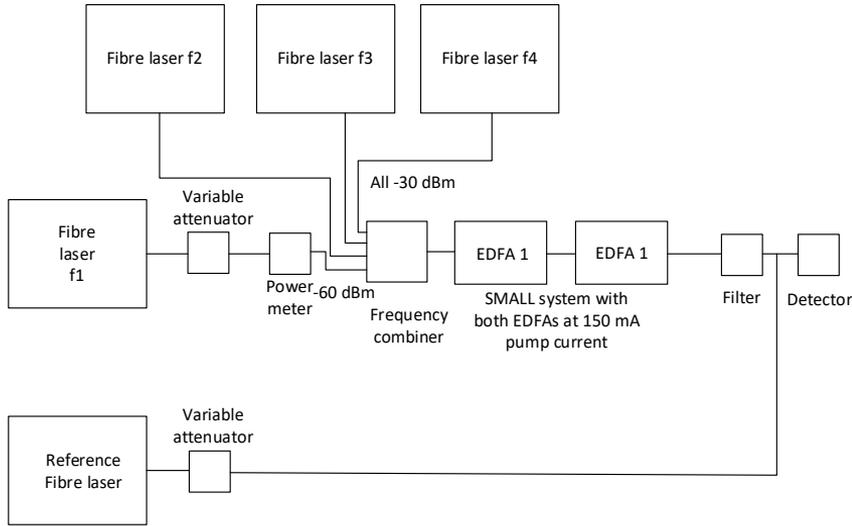
Nearly 8 orders of magnitude change in light intensity results in just a 50% drop in output signal.



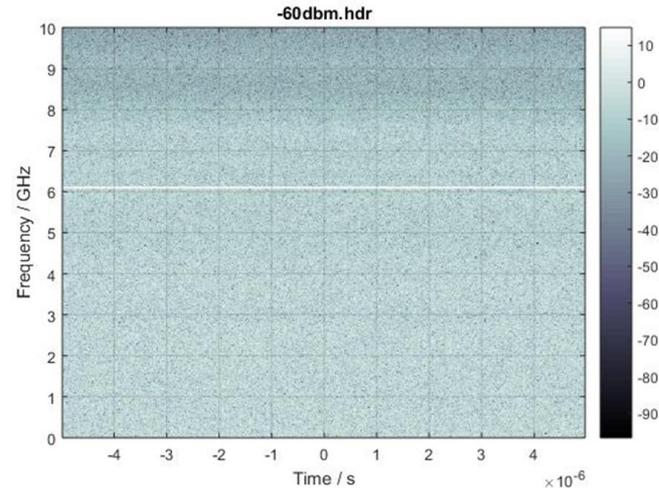
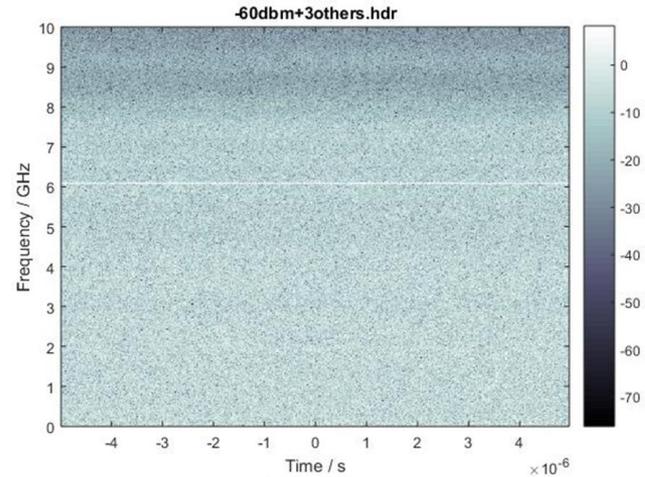
Delay lines are large so ideally we would like to use them to carry multiple signals at multiple ITU frequencies.

We were concerned at how the SMALL system would perform in such a configuration so we put together a lab test to check correct operation.





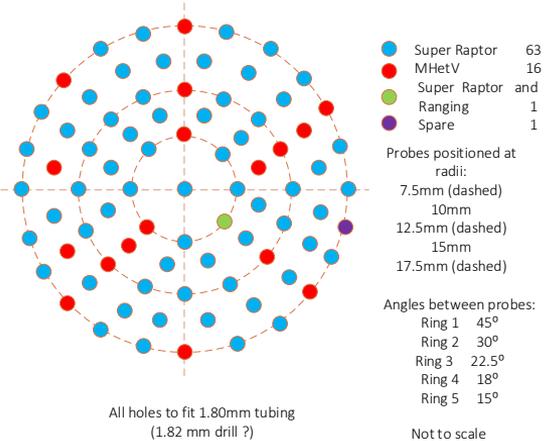
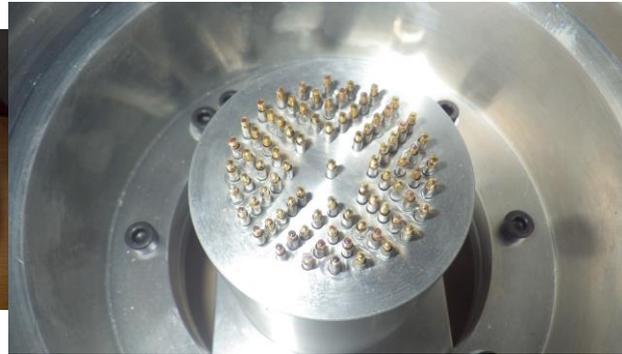
There is a little more noise in the resulting spectrogram but still very clear at very low power levels.





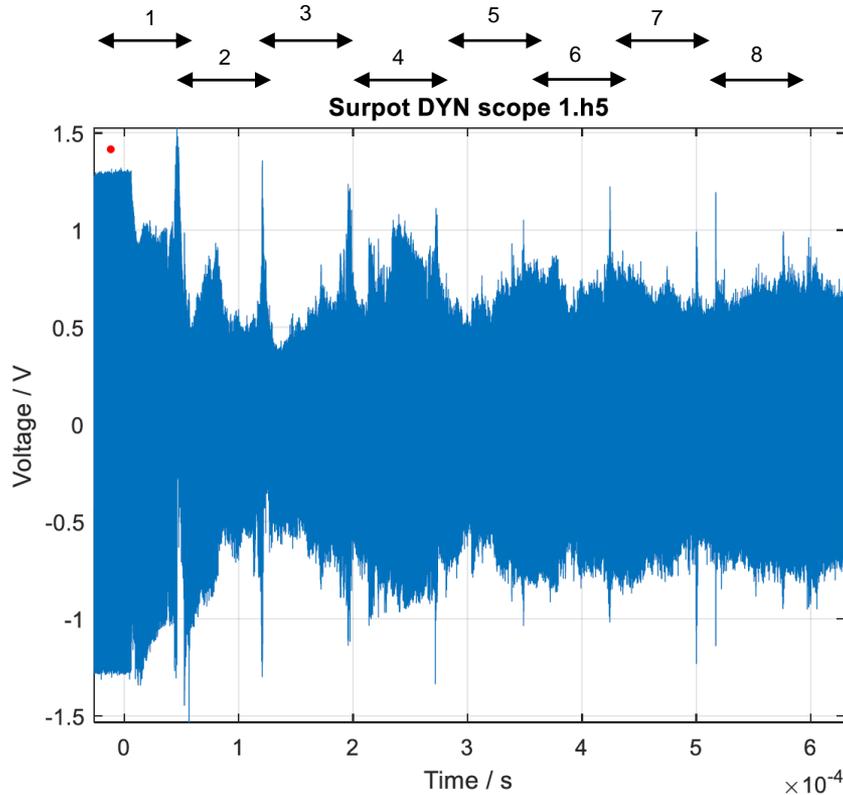
Final assembly of the Super Raptor system was completed in November.

Dynamic trials to prove out the instrument have been undertaken and analysis is underway.



All holes to fit 1.80mm tubing  
(1.82 mm drill ?)

## Preliminary results from Surpot

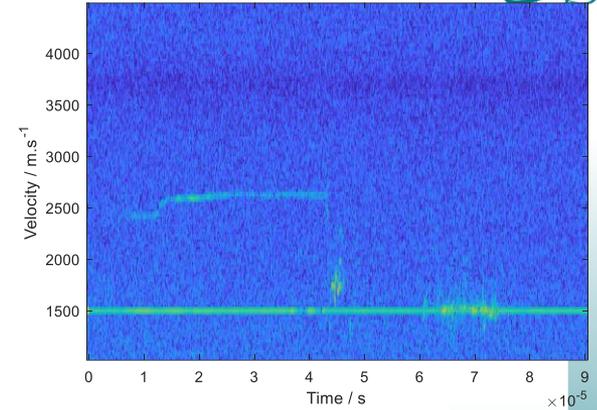
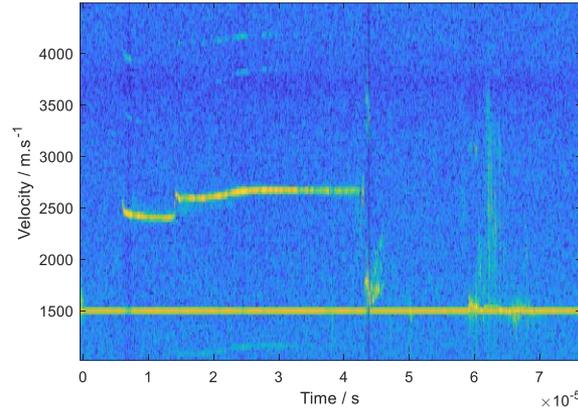
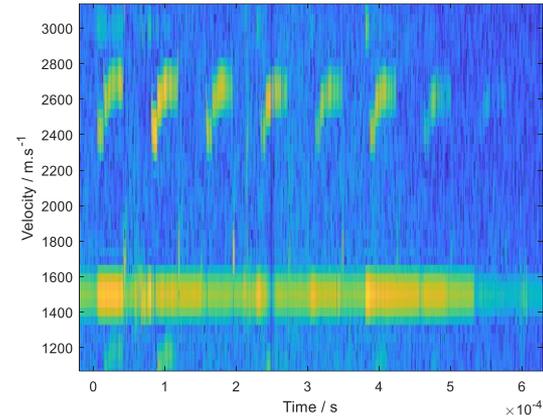


SMALL appears to be keeping the amplitude of the signal quite constant.

The first channel which does not go through any fibre delay is somewhat larger amplitude.

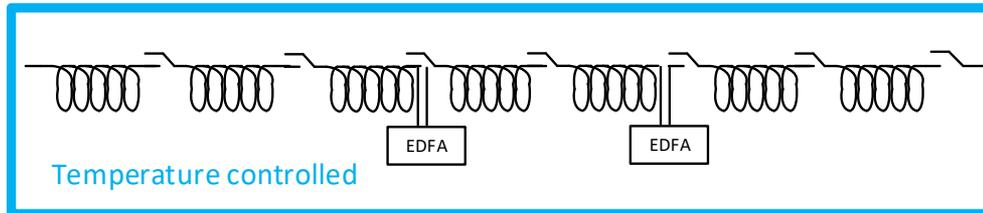
Also there is a spike when the switch is activated, most likely because of significant amplitude differences.

So SMALL operation is not instantaneous but looks very helpful in setting up the system.



Spectrograms of the data show that we have poorer signal quality towards the latter channels, particularly channel 8.

This is likely due to the amount of fibre the latter channels go through along with the limited numbers of boost amplifiers. Potentially this could also be due to the coherence length of the laser.



## Conclusions

The delay line configuration provides a simple and effective way of multiplexing multiple optical signals.

The boosting of signals within the delay network needs to be optimised to ensure no signal loss.

The SMALL amplifier configuration provides significant improvement in maintaining predictable and recordable signal level with a time multiplexed instrument.

Initial setup of such a system is difficult to optimise due to the number of variables but this should only need to be done once.

Further investigation of how rapidly SMALL can respond to large changes in signal intensity need to be investigated.

Further investigation of EDFAs used in SMALL may prove very beneficial

- lower gain?

- 3 or more stages?

Thank You.  
Any questions?