Experimental Results at 1-2microns With Pyreos Line Array Sensors

Introduction and executive summary

This report contains the data collected using a Pyreos line array sensor in the near-infrared as a replacement for InGaAs based sensors. This test information can serve as a useful introduction for customers interested in using the low cost, uncooled & robust line sensor products of Pyreos in near IR and raman IR applications. The experimental was to a proof of principle demonstration that the Pyreos line sensor array could provide similar performance to InGaAs at much lower cost.

The data is split up into six experimental sections which are described below.

1. A general set-up test for the variable optical attenuator (VOA) and Pyreos sensor, using light from a test fibre. These results show that the set up generates a useful level of signal.

2. An examination of the impact of increasing the chopping frequency on the Pyreos line sensor output. This shows a distinct reduction in pixel cross talk but also a reduction in the signal output level.

3. Two experiments examining data collected from a fibre containing multiple channels spread across the sensor using a volume phase holographic grating. The first experiment collected 17 channels of data at 39Hz chopping frequency, shows clearly that spectral information is available, but that the cross talk is unacceptable for an optical channel monitoring application. The second experiment was collected with 34 channels each separated by 0.4nm. This was achieved by increasing the chopping frequency to 125Hz and refocusing the grating and shows a useful signal with clear channel separation. However there is a significant variation in signal response with light wavelength, but the proof-of-principle was proven and with optimisation it was believed to be possible to remove such variability.
4. Further examination of the varied spectral response noted in previous experiments is presented using a white light source (constant emissions over the whole frequency range). This shows a distinct and large variation in response over a small change in frequency, which is believed to be an etalon effect.
5. The etalon affect noted in the experiment above is further investigated using the tuneable laser to vary the light wavelength and shining the light directly on to the sensor from the fibre output. This shows that the etalon affect is significantly reduced when the fibre touches the surface of the AR coated silicon window, indicating that it is caused by interaction of the light with the SI and the AR coating.
6. Further work was conducted viewing data through the 1.1um to 2.2um volume phase grating. This shows that it is possible to get a good response from the Pyreos sensor and that spectral information is present. The set-up used for this experiment was not optimised;

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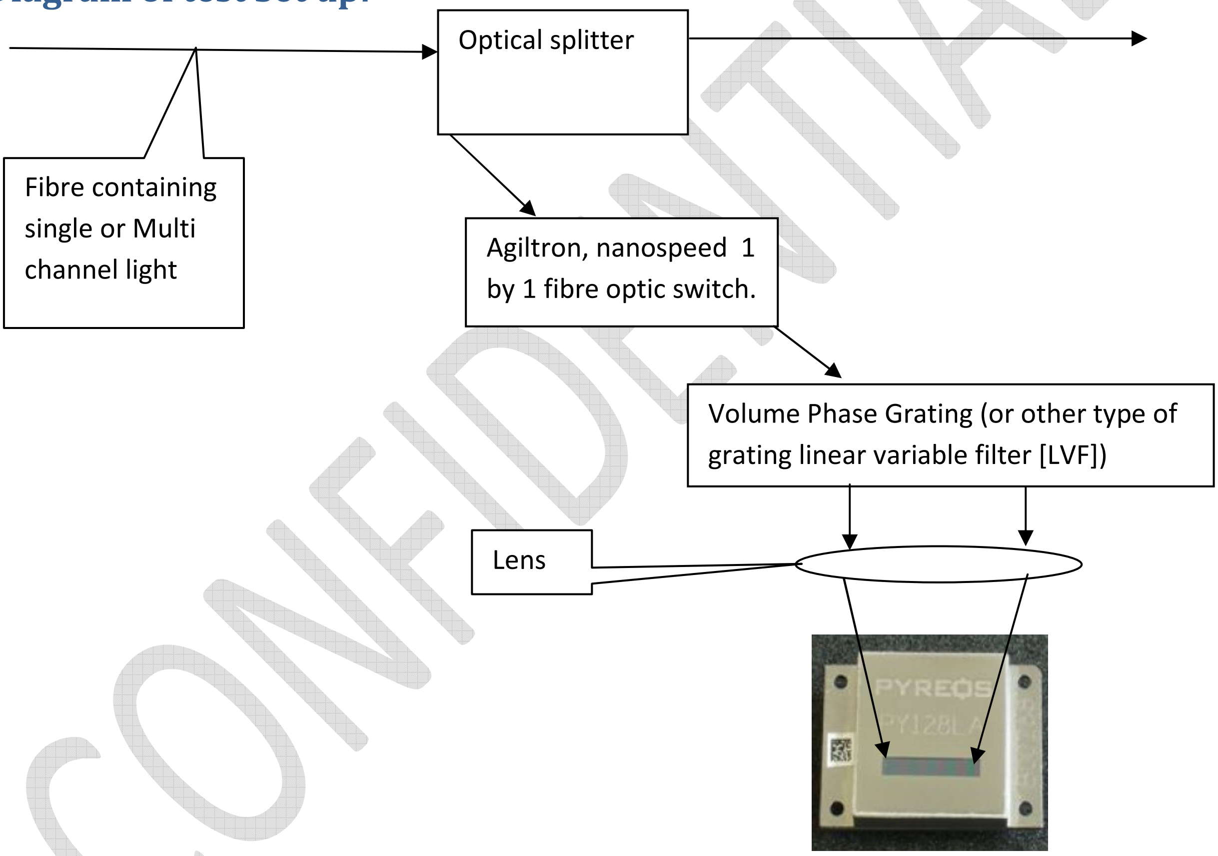
however the s/n ratio of InGas at the longer wavelengths is much lower than that offered by Pyreos.

An additional data set was collected using a tuneable laser to move light across the array with a focused grating. These tests show that it should be possible to use the Pyreos sensor in a channel monitoring application but that the light must be modulated at a frequency >125Hz. There are still further work required to optimise signal response / wavelength, however the tests conducted in these experiments indicate that much of this complication is caused by the AR coated SI window. It is clear that the Pyreos sensor provides a significant benefit over InGas at longer wavelengths, whilst still being able to produce a useful signal at 1.5 microns and shorter wavelengths.

Diagram of test Set up:



TSimplified line drawing of the experimental set-up

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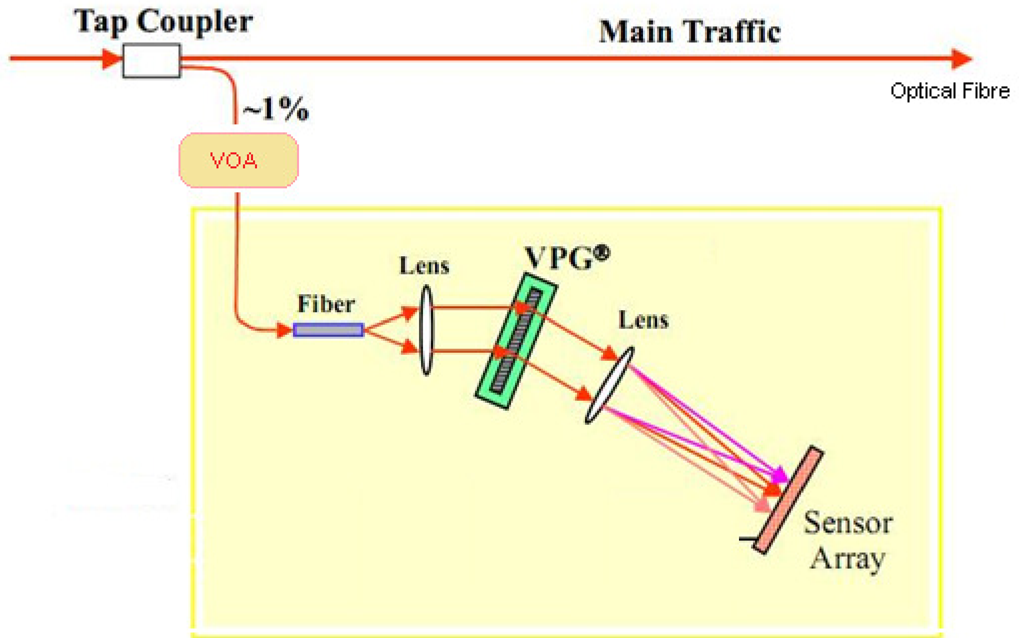
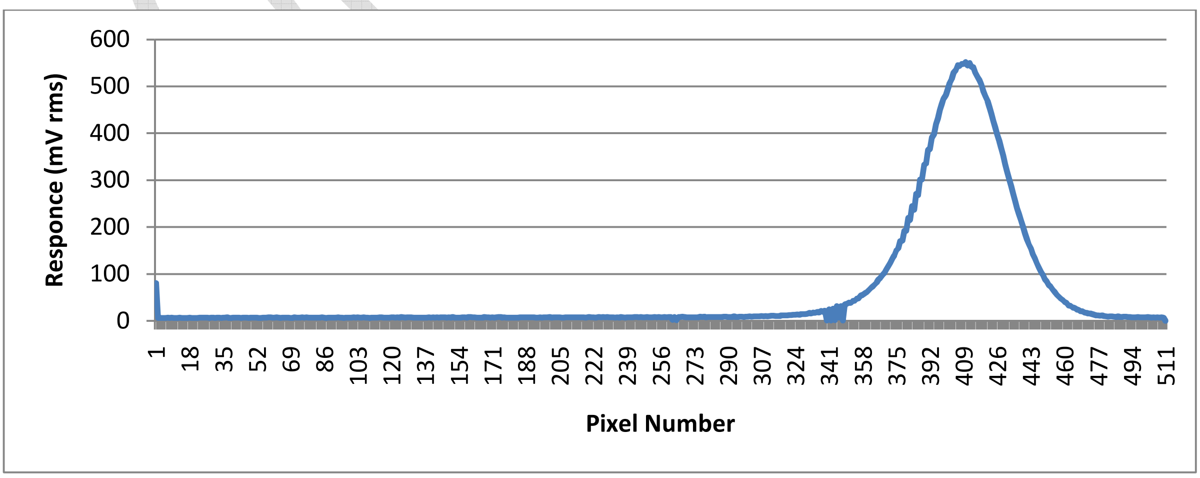


Experiment 1: Test of Pyreos sensor with 1500nm light from fibre through VOA

This was a preliminary test to validate that the line sensor could detect something at the wavelengths of interest.

Test conditions, 11Hz chopping (22 Hz sample), chopper driven by the Pyreos demo kit(PYDK-LAS), 1x 510 Pyreos line sensor device V, with IR absorber and AR coated SI window.

The test showed that even without particularly good alignment a strong signal was achieved, saturating several pixels. The light was attenuated using Agilent equipment and the following result was achieved:



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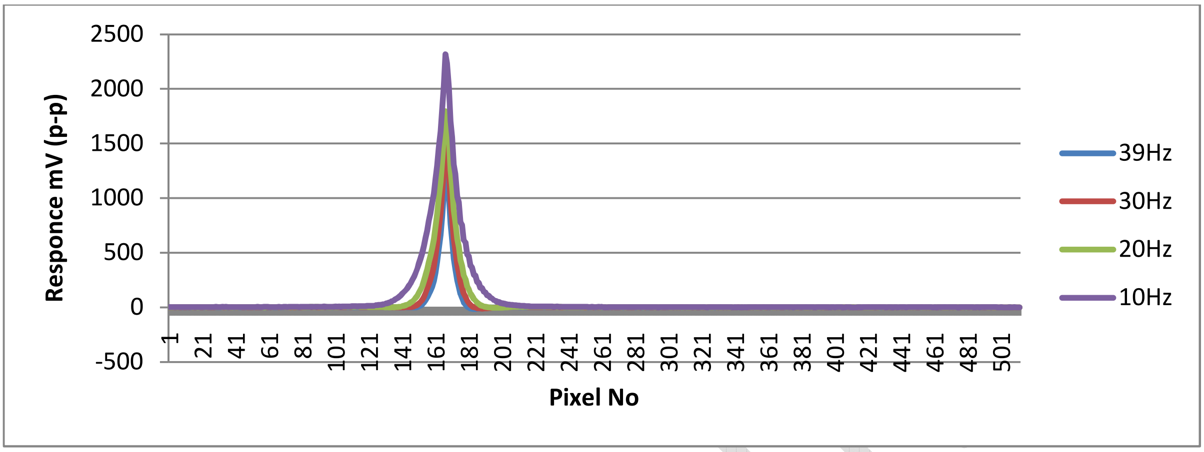
Experiment 2: Repeat of the above at a variety of different chopping frequencies

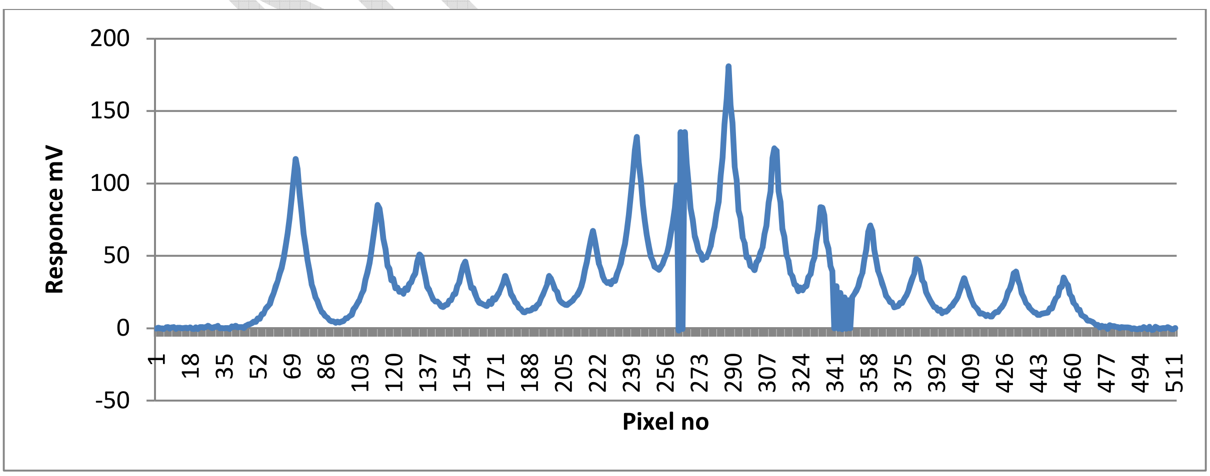
Test conditions: wavelength 1500nm, fibre placed approx 1cm above line senor, 10Db optical attenuation used, 510 line sensor device V, with IR absorber and AR coated SI window.



It is clear from these results that there is both a reduction in responsivity and thermal cross talk when the chopping frequency is increased. The frequencies mentioned are chopping frequencies (sample frequency is 2 times chopping frequency), and there are two samples per cycle: one for off and one for on.

Experiment 3: Viewing multichannel light through the grating

Test conditions: chopping frequency 39Hz (sample frequency 78Hz), grating focused and 17 channels of light incident on detector passed through 10Db of optical attenuation,1x 510 Pyreos line sensor device V, with IR absorber and AR coated SI window.



For telecom optical channel monitoring applications and for high performance spectroscopic applications it is desirable to have greater spectral(channel) resolution, which would be defined by

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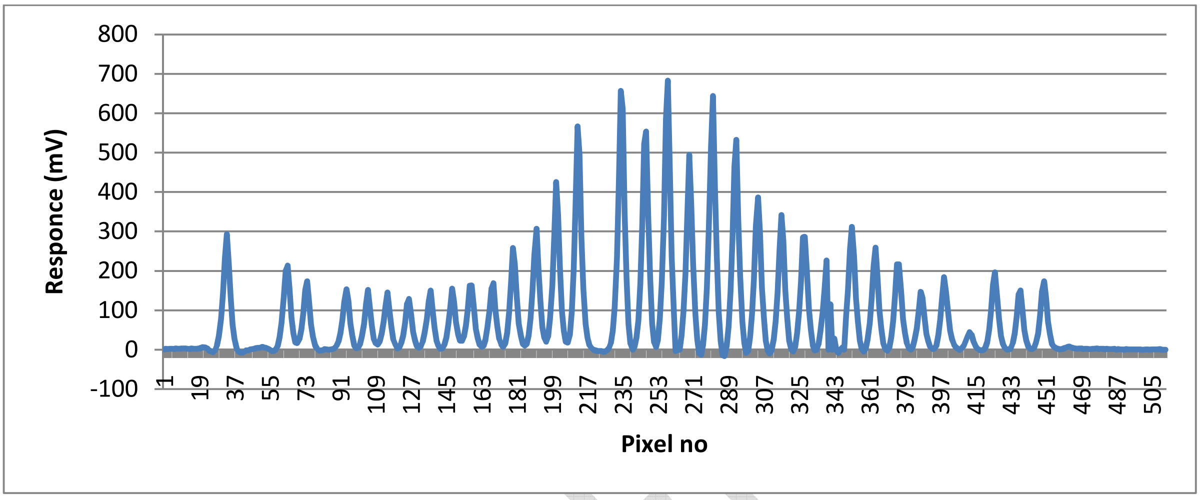
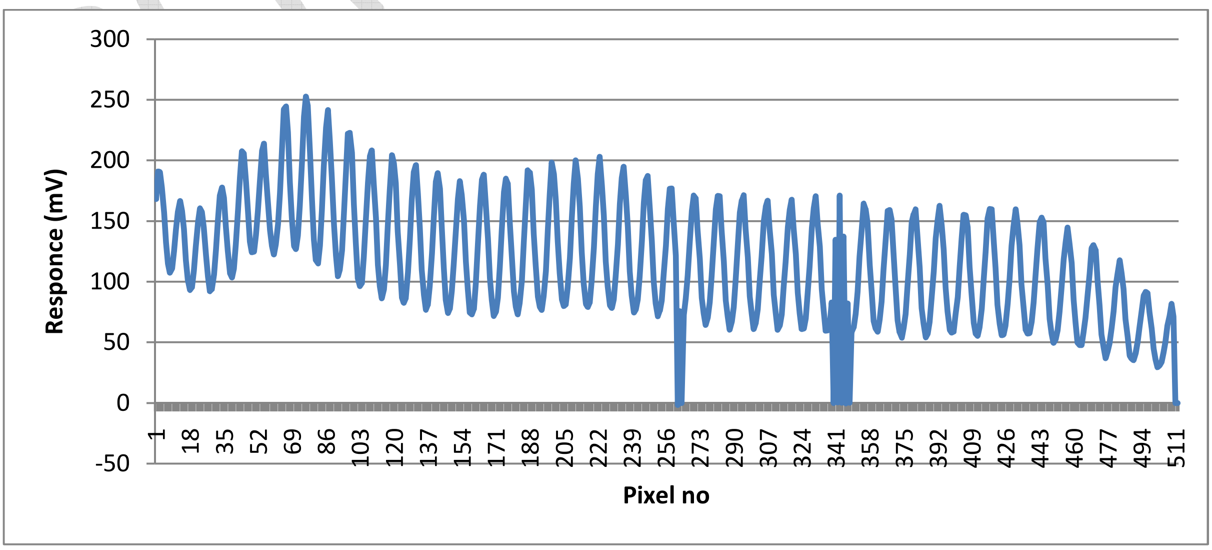
sharper responses and and less variation in response with wavelengths. To improve resolution, the number of channels was increased to 34, and the grating re-focused. The chopping frequency was increased until the signals became sharp and focused on more specific pixels of the Pyreos line sensor array. Further increase in chopping frequency would provide even better resolution, but the purpose of this short set of experiments was a proof-of-principle only.



This plot is much closer to what is measured using InGas arrays in the same set-up, although there is some difference in response from different channels, in some applications it would be feasible to compensate for this by calibration ot to further optimise the set-up..

Experiment 4: Viewing white light through the grating

Test conditions: 125Hz chopping, white light through the volume phase grating, 1x510 Pyreos line sensor device V, with IR absorber and AR coated SI window.



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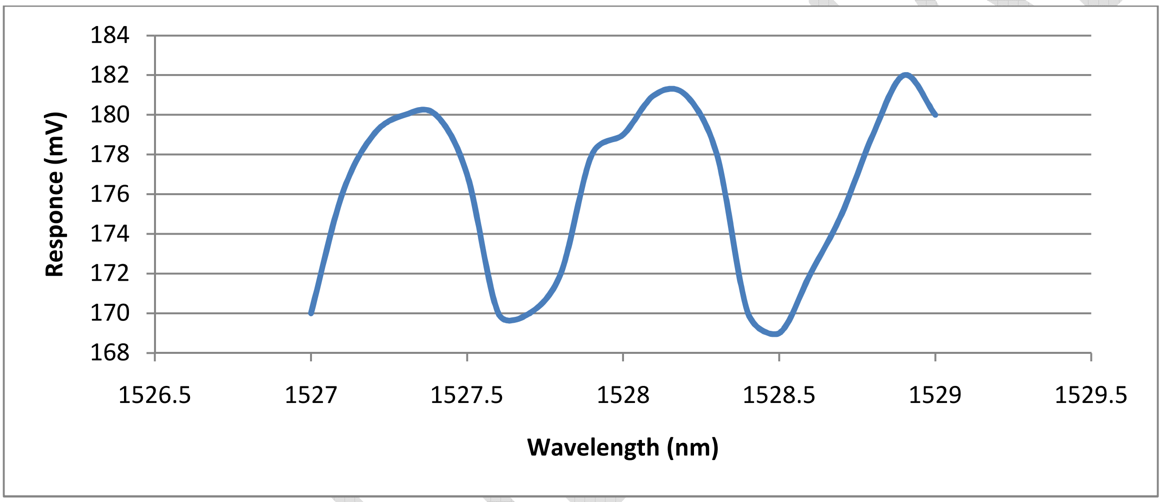
This result shows a marked variation(etalon) in response across the wavelengths with a distinct harmonic at approx 1.1nm (10 pixel) intervals. It was not initially understood what was causing this effect.

Experiment 5: Viewing absorption data from a single pixel

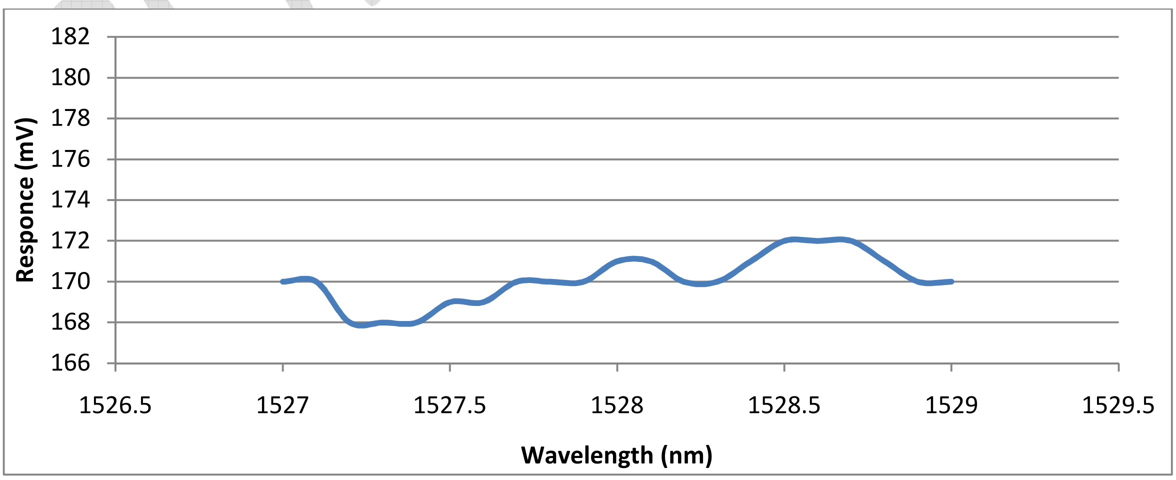
To try to establish the cause of the etalon effect observed in experiments 4 further experiments, were conducted using the tuneable light source and are described below.

Test 1: Chopping frequency 125Hz, no volume phase grating present, light directed from fibre to line sensor with fibre touching line sensor filter, line sensor with IR absorber (please note a 1x 128 channel line sensor device was used), and response noted from a single pixel.



This data shows that a small harmonic variation exists in absorption approx +-3%.

Test 2: Chopping frequency 125Hz, no grating present, light directed from fibre to line sensor with fibre touching line sensor filter, line sensor without IR absorber (128 channel device), and response noted from a single pixel.



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This shows a much reduced harmonic effect.

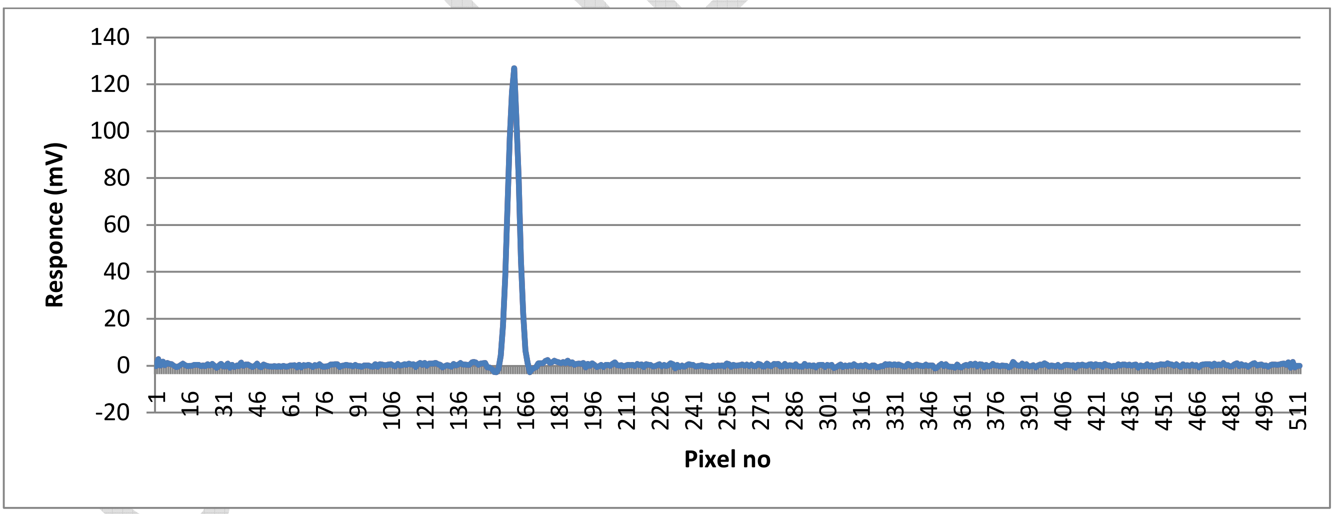
These experiments were then repeated with the 1x510 channel line sensor with IR absorber and the response increased markedly (by a factor of approx 10) and the harmonic was present with similar magnitude to that found in Test 1 above, although only general observations are available (not plots due to measurement constraints).

The fibre was then lifted above the line array filter window (window is made of AR coated Si) and the experiment repeated. The result showed that the response magnitude varied by a factor of ~2 from trough to the peek as the wavelength increased. This is consistent with the data collected during experiment 4 showing the etalon effect. It was also noted that the magnitude of response increased significantly over the tests where the fibre touched the Filter material.

Experiment 6: Viewing sources through a 1.1 to 2.2um grating

During discussions it was considered that the Pyreos line array significantly out- performs InGas at longer wavelengths. Two tests were performed using the 1.1um-2.2um grating again at 125Hz chopping frequency. The grating was not optimally focused on the line sensor due to mounting constraints.

Test 1, light source- 1550nm laser, 1x510 line sensor device V, with IR absorber and AR coated SI window.



Test 2, light source- wide band light source with centre at 1550nm, 1x510 line sensor device V, with IR absorber and AR coated SI window.

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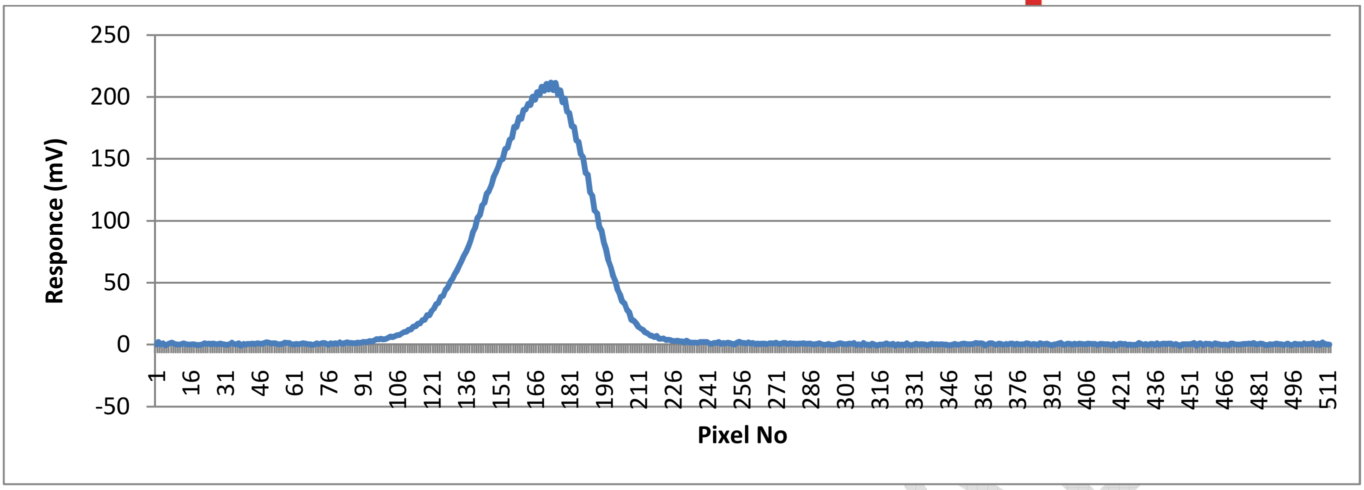

The data in both these plots show that there is a significant response to the signal, and that the Pyreos line sensor is well suited to a 1.1 to 2.2um application.

Additional Data

Data is collected using the tuneable laser to shine light through thevolume phase grating onto the line sensor, moving the light from 1525nm to 1565nm at 1nm intervals. It is available in the form of a CSV time series in the file ".csv" data, and it is therefore possible to plot this data. Close examination clearly shows the peak signal moving across the array at intervals of 6 to 7 pixels and confirms that there is a notable variation in the signal absorption with wavelength.

The raw data is available in the file "wStart1525wstop1565_1nInt.csv"

Summary

The Pyreos line sensor is a possible candidate telecom optical channel monitoring applications and raman and NIR spectroscopic applications. Further work is required to develop particular design of products.

It will be important for customers to consider and compensate for any wavelength-signal response variation across the wavelength range of interest to them. It is likely that significant chopping frequency will lead to optimised resolution.

All of the parts used in this proof-of-principle experiments have long life-times and should be suitable for customer applications. Most components can be sourced from a variety of suppliers.

The Pyreos line array sensors can perform better than InGaAs at wavelengths above 1.6um, as measured by comparing S/N. The Pyreos line array sensors can perform well between 1.1 and 1.6um when operating at frequencies of 125Hz and above.

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