1. Introduction

This document will introduce and characterize the performance of the Enhanced Visibility Option for the si255 Hyperion Interrogator. The goal is to inform the reader about circumstances where the EV model may be the appropriate instrumentation choice over the standard si255 Hyperion, application details for which are outlined extensively in TN1107.

2. Motivation

The si255 Hyperion Interrogator serves applications with features that have traditionally presented several mutually exclusive choices among the features of historically static and dynamic measurement technologies. The si255 offers a “no compromises” approach to optical sensing, supporting both full spectrum and peak detection data acquisition, high dynamic range with no required user settings, rapid acquisition speeds with NIST traceable wavelength accuracy and wide 160 nm wavelength ranges over as many as 16 simultaneous data acquisition channels.

That said, further optimizations of the si255’s measurement capabilities can extend the utility of the platform into additional application scenarios. This document will attempt to identify the types applications where such a variant of the si255 Hyperion, the si255 Enhanced Visibility Option, would be an appropriate choice.

3. How are the si255 and si255 EV Option are similar

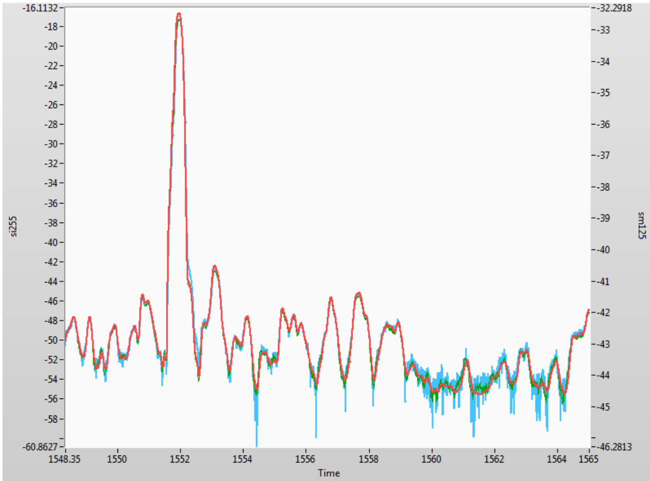
The si255 and si255 EV are similar in many respects. Both are built on the field-proven Micron Optics swept wavelength laser technology, and both are available in 120 and 160nm models. Both instruments share a common physical footprint, optical architecture, electrical architecture, firmware, API, and ENLIGHT software. Both instruments carry the same IEC, ATEX, and “green” certifications.

4. How do they differ?

The si255 and si255 EV Option hardware differ principally in the receiver electronics and extent of data conditioning performed, the EV Option having both optimized for greater visibility into a number of optical sensor applications. In the case of the si255, the receivers have been optimized to support both fast peak acquisitions with > 25 dB continuous dynamic range and full spectrum acquisitions with > 40dB dynamic range. Over a great many applications, this merging of static and dynamic, peak and full spectrum capabilities meet or exceed application requirements. However, there are certain circumstances were deployment of an alternate receiver technology enhances the visibility of certain types of sensors in certain applications. The si255 EV Option serves to facilitate compatibility for those applications.

4.1. Enhanced visibility into spectral nulls

The si255 Hyperion uses a novel optical detection and amplification architecture that facilitates both high-speed peak and deep dynamic range full spectrum measurements within a single measurement. The following image shows the high degree of correlation between the 1kHz dynamic si255 Hyperion interrogator (blue, green) with a traditional low speed (1-2Hz) static swept laser interrogator.

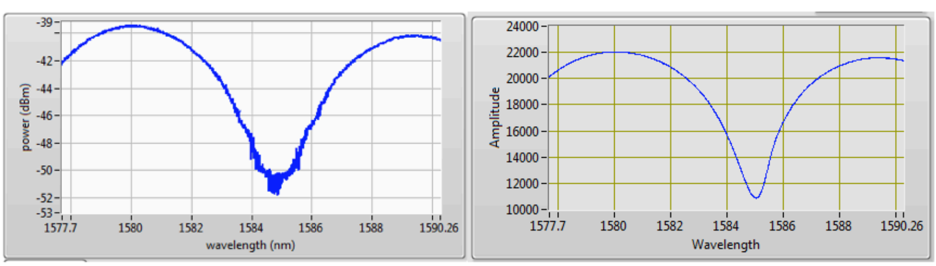


Comparison of si255 Hyperion full spectrum data (blue, green) to traditional static interrogator full spectrum (red)

It can be seen from the plot that for full spectrum data, there is a high degree of correlation between the red and the blue/green traces over a wide range of optical power. However, differences are seen at the lower registers of the range, particularly in the "nulls" of the optical spectrum. It is in these areas where the si255 EV Option offers a different dimension of capability as compared to the standard si255.

Consider the following trace of a Fabry-Perot spectrum. FP gages are used in a number of applications, and the data can be captured and processed in many ways. In several applications, the peak values of the FP gages are used in dynamic fashion measure high-speed accelerations, changes in pressure, etc. However, in other circumstances, it is either in the nulls of the spectrum or in the complete, continuous spectral traces from which the required degree of sensor accuracy must be derived. In these cases, the si255 EV Option offers enhanced visibility into the nulls of those signals, yielding better fits to calibration models, and ultimately more stable measurement results.

The two plots below show the same FP gage as measured by a standard si255 (left) and an si255 EV Option (right). If one assumes that the full accuracy of the FP gage will be derived from the fit of the measured traces to a theoretical model, it is clear that the measurement from the si255 EV Option offers an advantage.



4.2. Enhanced visibility of peak wavelength measurements (extreme temperatures) at extreme losses

The si255 Hyperion supports >25 dB of continuous loss budget for sensors using the on-board peak detection algorithms at dynamic speeds. At 1kHz laser scan rate, the internal peak detection algorithm acts on a single 1ms spectral acquisition and is robust to loss sensor levels up to 20 dB. At 100 Hz laser scan rate, the internal peak detection algorithm acts on a 10ms spectral acquisition and is robust to loss levels up to 25 dB. Beyond those levels, signal to noise ratio is such that on-board sensor peak detections degrade in repeatability to a significant degree or drop out altogether.

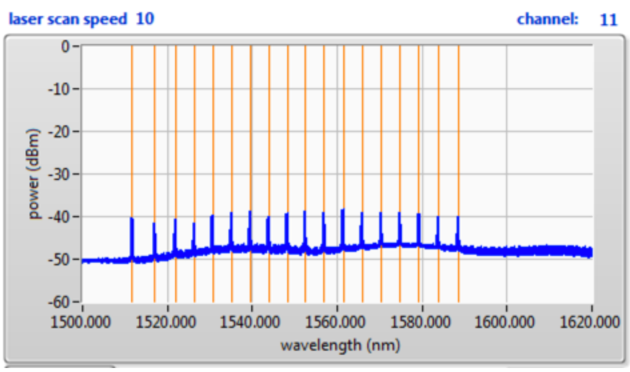
Beyond 25 dB of sensor loss, the full spectrum data from the si255 can be used in conjunction with external peak detection algorithms to accommodate even greater. The exact level of loss that can be accommodated is function of the shape/frequency content of the sensor, the fidelity of the peak detection algorithm, and the broad-spectrum interference of optical back-reflection in the system. The si255 Hyperion is specified to have a full spectrum dynamic range of 40dB (defined as laser launch power minus detection noise floor), and that is the range over which external data processing can add benefit.

Below those levels, however, the si255 Hyperion ceases to track additional losses. The electronics noise of the system serves as the floor of measurements, and sensors with greater losses are simply not seen by the system.

The si255 EV Option uses an alternate receiver technology that minimizes the contribution of electronic noise to the system and will continue to grant the user visibility into signals at greater losses than the standard si255 Hyperion. That is not to say that there are no degradations to sensor measurements at losses higher than 25 dB with the si255 EV Option. Rather, it is to say that the effects of high sensor loss manifest differently, and in doing so, support continued visibility of the sensors and the ability to extend measurements in different ways than that of the standard si255.

In short, the si255 EV Option can continue to "see" and track sensor peak values, even using the convenient on-board peak detection algorithms, to loss levels higher than that of the standard si255. Unlike the si255, at losses of 20 or 25 dB, the peak measurements will not degrade in repeatability or drop out. The si255 EV Option can continue to track those peaks through an additional 10 to 15 dB of loss, although the measurements will the be subject to a level-dependent wavelength offset.

The following images show measurements of a lossy FBG array using an si255 EV Option. This particular system has a laser launch power of ~-18dBm, and shows a sensor with the weakest detected power of ~ -42 dBm…a loss of ~24 dB. While a standard si255 interrogator could detect these sensors, they would represent the very minimum possible signal, and any additional losses on the system would very likely result in loss of detection of one or more of the peaks.



Sensor array with 24 dB of insertion/reflection loss

However, by deploying the si255 EV Option for these sensors, an additional 10dB of loss or more can be accommodated with continued visibility into those peaks. (It should be noted that the floor at -50 dB is here caused by an optical back-reflection and scales with the insertion loss of the fiber. The electronic/system noise is well below -60 to -70dBm).

Again, it should be noted that for low sensor amplitudes, below -45 dBm or so, there would be a level-dependent shift in the wavelength readings. The effect of this shift should be weighed against the benefit of continued visibility of the sensors at very low levels. In many applications (particularly high or wide range temperature measurements in harsh environments), the ability to track the sensors and still make good quality relative temperature measurements is itself very enabling. The user should consider the details of the application requirements to make the best instrument selection.

4.3. Enhanced visibility at extreme distances

The si255 EV option offers the greatest reach for measurements of optical sensors at distances of many km. For designs of optical sensor networks spanning distances of 5km, 10km or more, the si255 EV Option may be worth exploring.

5. The tradeoff

The principal tradeoff for selecting the si255 EV Option is straightforward. Unlike the standard si255 Hyperion, which offers simultaneous static and dynamic measurements features and strengths, the si255 EV Option is limited exclusively to a 10 Hz swept laser scan.

6. Conclusions

for most optical sensor applications where dual static and dynamic features offer maximum benefit, the standard si255 Hyperion is the go-to choice for instrumentation. For the types of circumstances outlined in this note, the si255 EV Option can enhance the visibility of the of Hyperion instrument and its benefits even further.

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