A Novel Integrated, Compact OSA and ASE Source for Increased Fiber Optic Sensing Capacity

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Abstract

Typical fiber Bragg sensing systems, in the 1500nm to 1600nm wavelength range, use gratings spaced approximately 5nm apart. This large spacing is preferred since optical power illuminating the gratings is limited and monitoring systems often have low performance and hence have difficulty in differentiating between closely spaced gratings.

In this paper, we present a high power ASE source in combination with an extremely high performance Optical Spectrum Analyzer (OSA), that allows sensing gratings to be closely spaced so many sensing elements can be monitored while maintaining very good wavelength and power detection. The integrated unit can be provided on a PCI card, in a box or as an OEM module to enable a robust, handheld unit.

The OSA is built around proprietary Compliant Micro Electro Mechanical (CMEMs) tunable filters, primarily developed for very densely populated Telecommunications applications. The OSA is wavelength calibrated and can be matched to the ASE source to compensate for any spectral power characteristic of the source. This integrated OSA and ASE source will allow the sensing industry to increase grating array sizes while maintaining low cost.

Introduction

Fiberoptic sensing based on Fiber Bragg Gratings (FBGs) is being applied to a plethora of applications including strain/pressure sensing on bridges, blades on wind generators, oil tankers, land fills, high rise buildings and other structures and temperature/pressure sensors in oil wells and reservoirs. Fiberoptic sensors are becoming more prevalent because of insensitivity to electrical interference, greater sensitivity to desired measured parameters and, more recently, to reduced costs.

A FBG sensing system, in its simplest form, consists of a light source to illuminate the FBGs, the FBG array connected by fiber, and a detector system. The detector system receives the output from FBGs and feeds the output that presumably changes as a result of environmental influences to an analysis system. Some of the art in designing these systems is to make sure the:

- signals are strong enough or the detector is sensitive enough to receive the signals;
- system is calibrated so that variations in signal are accurately and reliably determined to be due to the parameter (i.e. wavelength and/or power) one wants to measure and not environmental noise.
- number of sensors (FBGs) are sufficient to measure all points of interest
- the induced changes are detected to a sufficient degree of accuracy.
- cost of the system is within market requirements.

Often these considerations are at odds with one another. For example, the denser the array the more points can be measured but the higher the cost of getting enough power to illuminate all the gratings and accurately detecting the changes. FBGs are steadily coming down in price but the FBG interrogation system is still a bottle neck in bringing new denser fiber optic sensing arrays to the market in a cost effective manner. This paper presents a novel approach to providing the illuminating source and monitor for detection in a cost effective, compact, powerful integrated system that can hasten the time to market and enable more applications of fiberoptic sensing.

ASE Light Source

Fiberoptic sensing systems can use a variety of light sources including LEDs, Lasers, SLEDs and ASE sources. Many current sensor systems are relatively small arrays and often use the SLED as a light source because of its favorable pricing.

ASE (Amplified Spontaneous Emissions) sources are essentially an optical amplifier without an input signal. The ASE light source is broad and incoherent as compared to a laser which is narrow and coherent. While not typically as broad as say a SLED the ASE can cover the C and/or L band and even broader. One distinct advantage of the ASE is that it can deliver higher power, e.g. 16dBm and higher and thus can accommodate denser arrays. Another advantage of the ASE is the stability of the light source and the absence of periodic spectral ripple that can lead to false detected readings. ASE sources are now becoming very cost effective making them a superb candidate for future fiberoptic sensor systems.

Figure 1. The ASE Source. Package dimensions are 90 x 70 x 12 mm.

The disadvantage of the ASE, depending on the application, can be the tilt or spectral shape (i.e. the output power varies as a function of wavelength). Common solutions to this disadvantage is to add a GFF (Gain Flattening Filter) to flatten the spectral shape. A GFF adds cost to the system and/or design effort to the interrogation system. The proposed solution discussed in this paper offers a solution in the form of an integrated package.

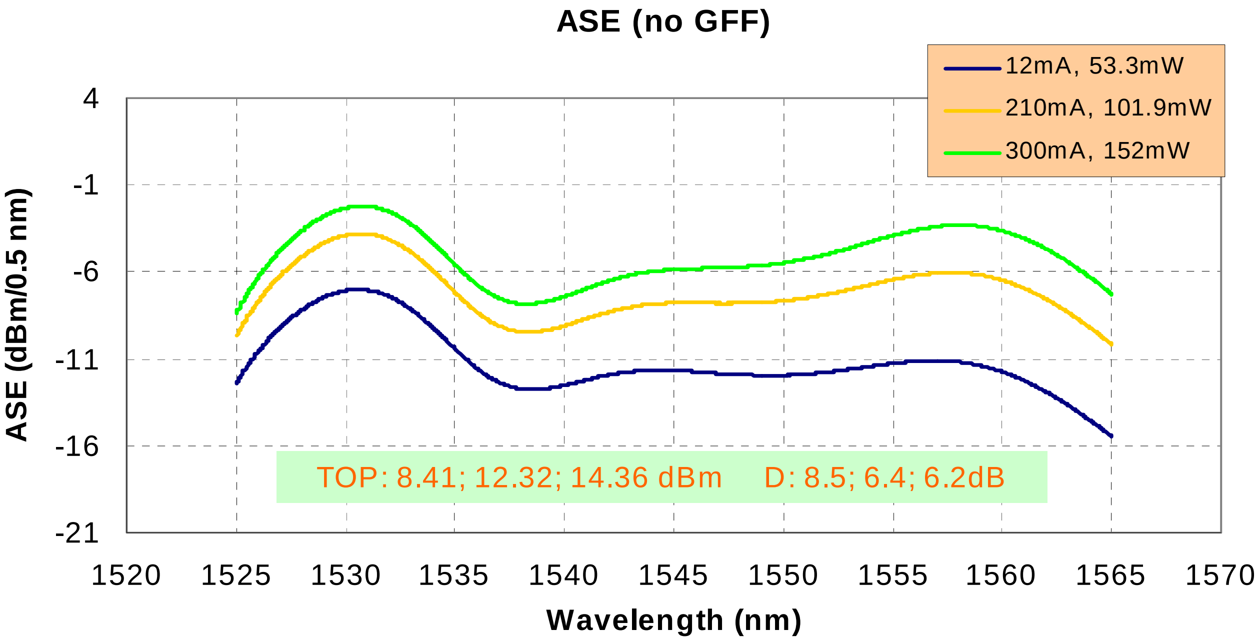

Figure 2. Typical ASE Source ouput for different current settings.

OSA FBG Interrogation System

Telecommunication based optical performance monitoring instruments work by drawing a percentage of signal power from a fiber-optic network, demultiplexing it into individual wavelengths and measuring for each channel optical power, spectral accuracy and signal-to-noise ratio (SNR). These instruments can be applied to the analysis of a fiberoptic sensor array.

The cost of these instruments is linked closely to the complexity of their demultiplexing components, which can rely either on diffraction gratings or Fabry-Perot interferometers. Most current instruments-those monitoring channels separated by 100 GHz or less - rely on a combined diffraction grating and photodetector array. But such devices become problematic as channel counts increase. For starters, they cannot easily demultiplex more finely spaced channels, because most detector arrays have resolutions limited to 512 pixels. Also, grating-based devices require a separate photodetector for each channel under test. This requires many detectors.

Another approach is to demultiplex signals using scanning Fabry-Perot interferometers[1], which require only a single-element photodetector to measure multiple channels separated by 25 GHz or less. To resolve these closely spaced channels requires the filters to have a resolution bandwidth corresponding to a finesse of around 2,500.

Different FP filters have different tuning methods. A versatile approach uses microelectromechanical-systems technology to alter the separation between a fixed and a movable resonator mirror. The mirror spacing establishes a single peak within a given wavelength band. Applying electrostatic forces to the movable mirror alters the spacing, allowing the filter to tune across its free spectral range. A change in mirror separation of 1 micron, for example, enables tuning of a single resonance peak across 100 nanometers or more-enough to cover signals in the C-band and L-band.

An alternative MEMs approach, which allows the use of flat mirrors, incorporates compliant elastomeric materials to support the movable mirror, hence the name C-MEMS[2, 3]. These elastomeric materials are as much as six orders of magnitude less stiff than silicon and can be deposited in a much broader range of layer thicknesses. Unlike carbon-based elastomers, the materials used in C-MEMS have a Si-O-Si backbone, giving them excellent mechanical, chemical and thermal stability. Compared with traditional silicon-based MEMS, elastomer-based C-MEMS have a far more rugged device structures that have long lifetimes, of more than 20 years[4]. Electrostatic force is enough to drive the mirrors and keep them parallel over the lifetime of the device, regardless of ambient vibrations, shocks or fluctuating temperatures.

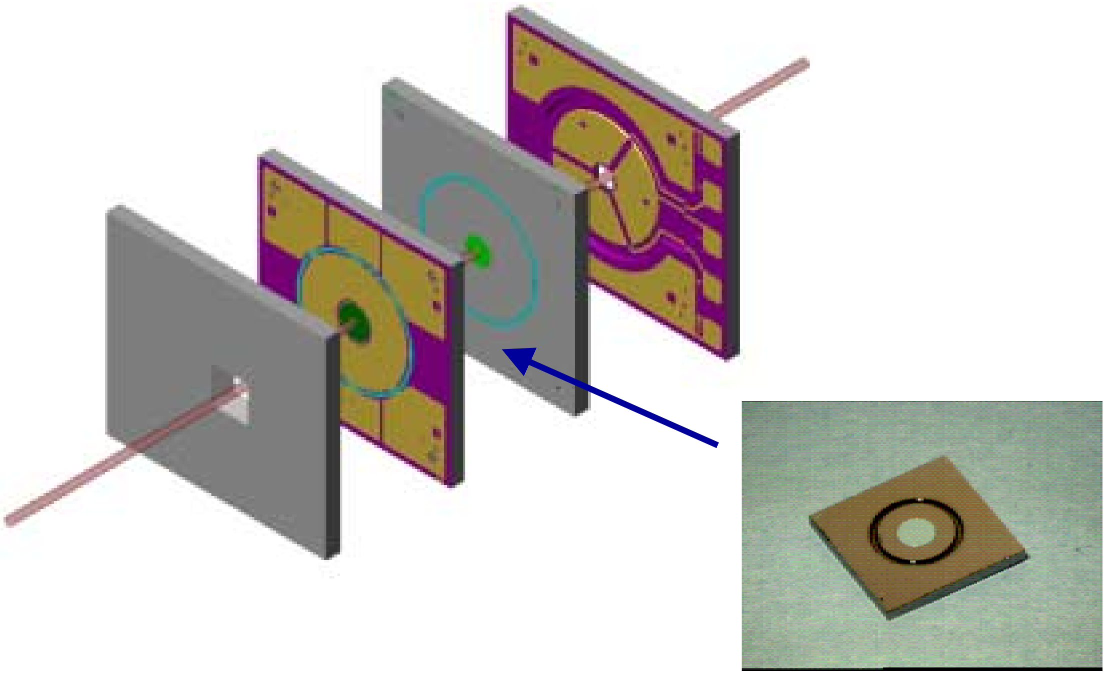

Figure 3. Device structure of a CMEMs Tunable Filter.

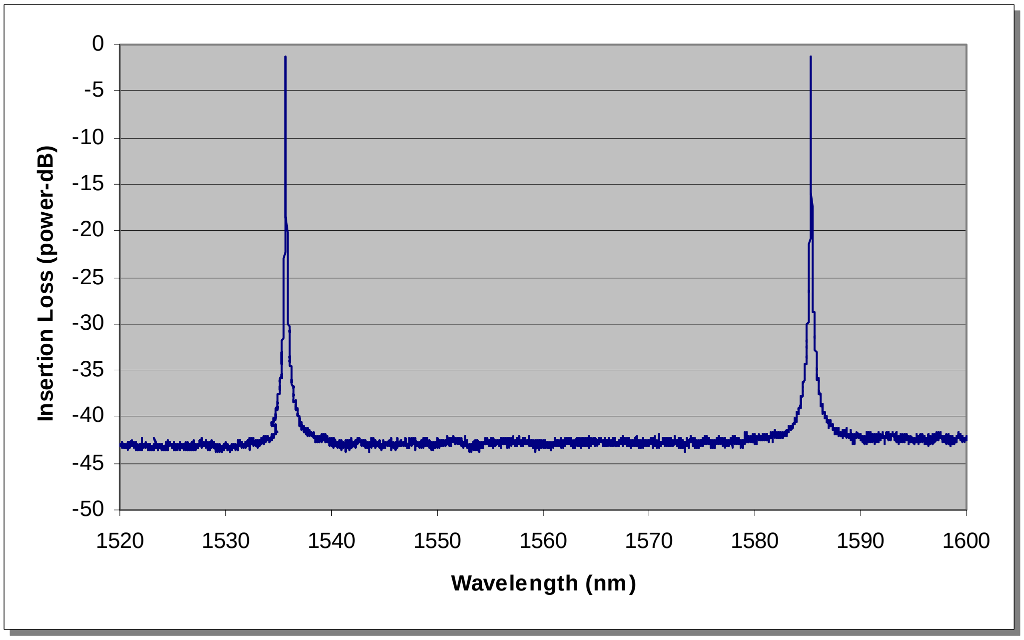

Figure 4. Typical transmission of a C-band CMEMs Fabry-Perot filter.

Figure 4 shows the transmission of the CMEMs Fabry Perot filter. The low insertion loss and high Finesse ensure excellent peak detection capability. Figure 5 shows how consistent the transmission function is across all the wavelengths within the scanning range, this is essential for consistent accuracy across the full band of wavelengths.

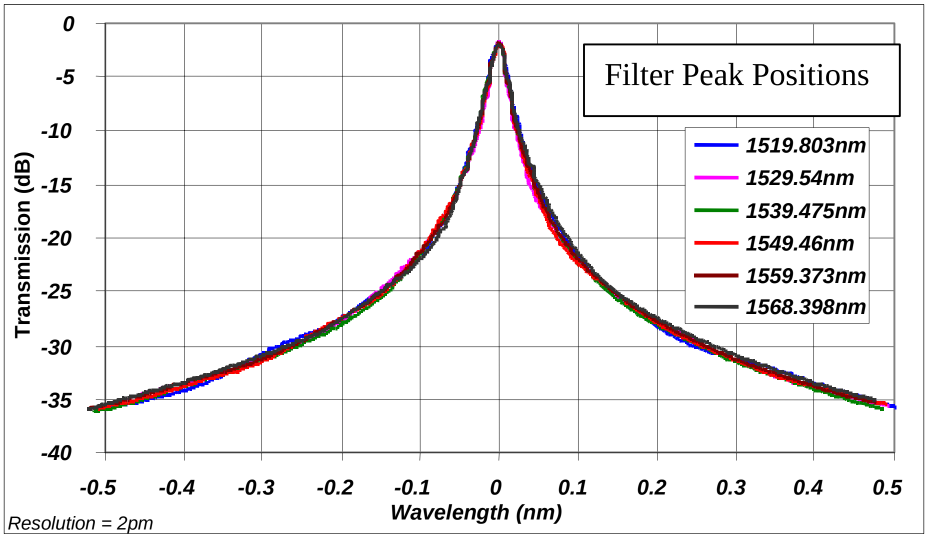

Figure 5. The CMEMs filter shape as a function of wavelength.

This CMEMs tunable filter provides the basis for the OSA system that can be applied as the FBG interrogation system by scanning the entire free spectral range, from 1520 nm to 1620 nm many times a second to monitor any changes in wave length or power from each of the FBGs in the array.

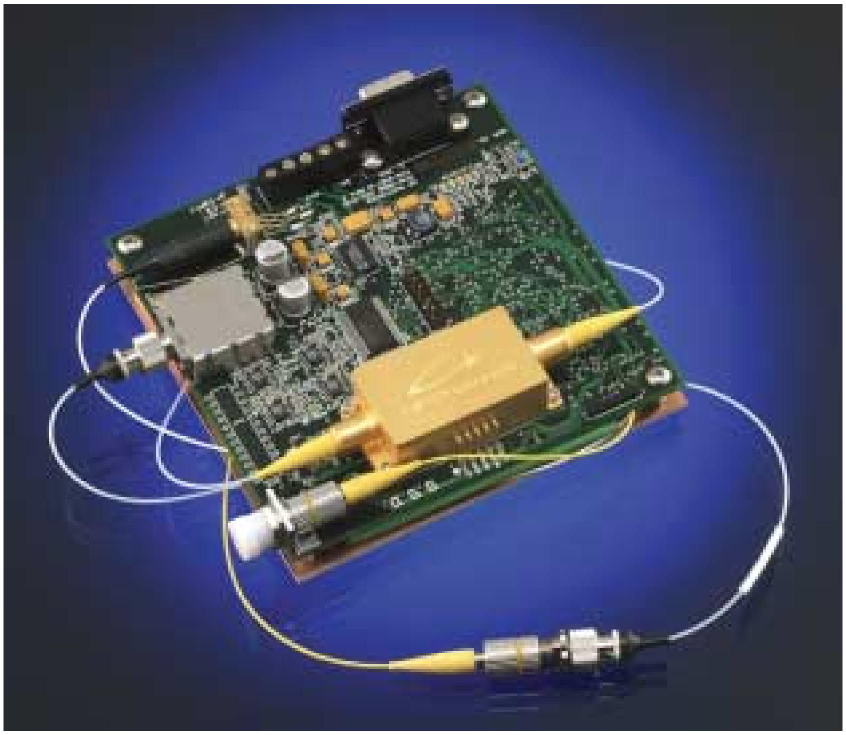

Figure 6. The OSA engine. Dimensions are 110 x 110 x 18.5mm.

The OSA has a resolution of 1 pm and provides the capability of handling very dense sensor arrays. This coupled with a high power, stable ASE source provides unprecedented capability in an integrated package to handle very long and dense FBG sensor arrays.

Integrated OSA and ASE

Integrating a light source and monitoring system is useful in terms of saving costs by sharing packaging and electronics. Also a compact size is achieved from this integration. These factors may be motivation enough for combing these two functions but they are not the primary reasons. There is an additional benefit from integration of an ASE and OSA. The OSA can be calibrated to the ASE in such a way that includes virtually shaping the ASE source spectrum to the ideal form required for optimum analysis. The OSA can effectively do a normalization computation to subtract out the ASE spectral dependancey. This approach also saves costs by eliminating the need for a gain flattening filter and ensures accurate relative power changes, that are due to the sensors and are not source dependant.

The integrated OSA/ASE can be mounted on a PCI card, housed in a box or provided as an OEM module. The PCI arrangement was demonstrated at OFC 2003 in Atlanta in March. The figure below illustrates the demonstration set up.

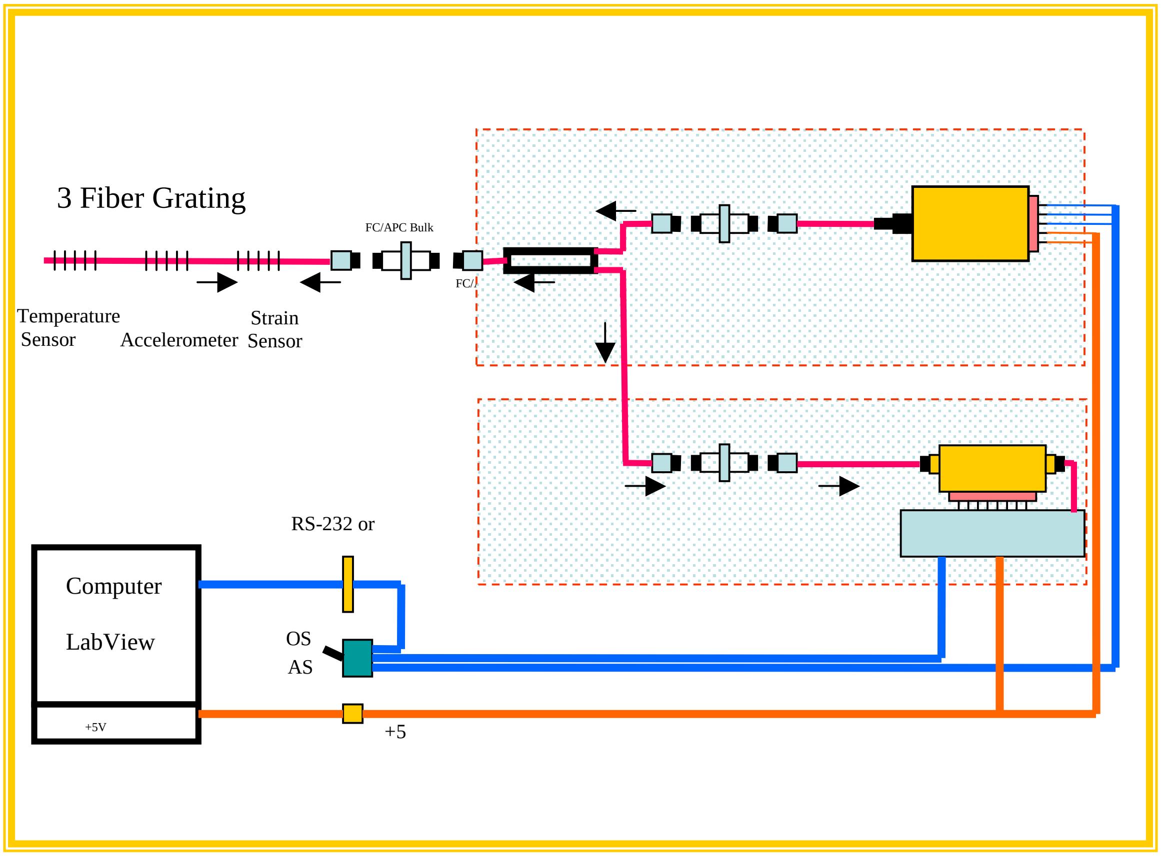

Figure 7. Illustration of an ASE/OSA interrogation system.

Conclusion

The integrated ASE/OSA provides a cost effective way to enable and interrogate a dense FBG sensor array. The calibrated ASE source provides an extraordinarily stable, high power source to do the illumination. An OSA based on a CMEMs tunable filter provides the accuracy with resolution down to 1 pm. The OSA combined with the ASE source provides a complete system that further enables a very dense FBG sensor array.

References

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