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Adaptive-Filter Based Bragg Grating Demodulator

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Abstract: We describe a demodulator for Bragg grating based sensors which utilizes an adaptive/ programmable filter. The technique can be used to provide simple discriminator or wavelength-tracking filter demodulation.

Introduction: Fiber optic Bragg grating sensors have shown promise for a very broad range of applications from distributed strain and temperature measurements in structural monitoring (1,2) to pressure transducers and accelerometers in industrial applications (3,4). The technology lends itself to a wide range of simple 'demodulation' methods, and many approaches have been reported based on simple 'discriminator filter' techniques (5-7). One of the issues with using such approaches is the fixed nature of the filter, and the difficulty with multiplexing sensors based on this approach. In this paper we describe a new tool for permitting the wavelength demodulation of Bragg gratings using an adaptive/programmable filter that provides a unique degree of flexibility in the 'discriminator' filter function, and accommodates the ability to multiplex several sensors.

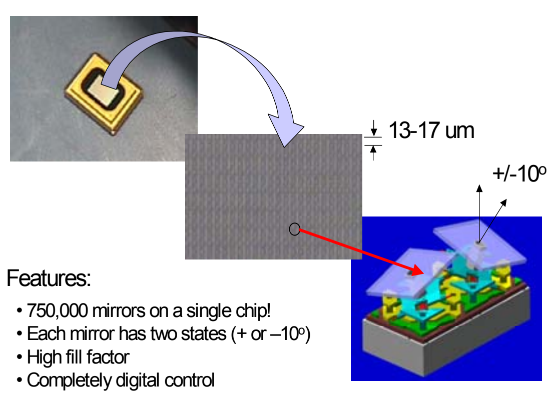

Figure 1: The TI DLP™ w/~800,000 micromirrors

Adaptive Filter Demodulator: The adaptive/programmable filter used was a Programmable Spectral Processor - PSP (Newport Corp. OSP 9100), which is based on a platform originally developed by CiDRA Corp. for adaptive spectrally-dependant dynamic gain control in optical amplifiers. The platform utilizes TI Digital Light Processing™ technology, illustrated in Figure 1, at the heart of the device (8). In operation, broadband light from a source is used to illuminate a Bragg grating array. The light reflected from the gratings is input to the DLP™-based demodulator, the optic concept of which is shown in Figure 2. Internal to this unit, light is dispersed off a diffraction grating onto the

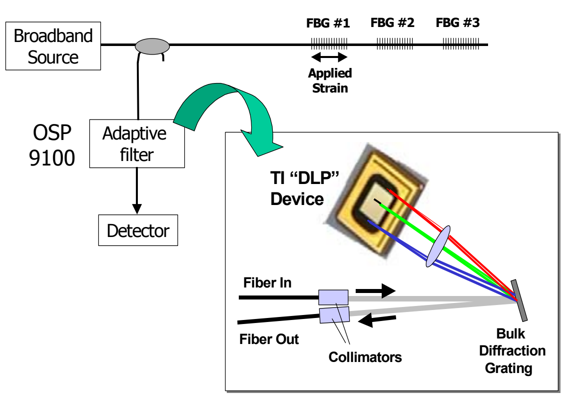

Figure 2: Optical configuration of the adaptive/programmable filter

surface of a DLP™ chip. Light reflected off the DLP™ chip is directed to a second fiber output port and onto a photodiode/power meter. The DLP™ device comprises approximately 800,000 micro-mirrors, each of which is individually addressable. By creating spatial patterns on the micro-mirror array, arbitrary degrees of attenuation can be provided at any given wavelength. The device can thus be used to create discriminator filters (e.g. ramp functions) in the wavelength vicinity of the grating signal from the array. In the approach we propose here, each grating in the system is sequentially addressed by moving the ramp function to each grating in turn, while strongly (> 30 dB) attenuating the other grating signals. This concept could also be extended to one in which the different ramps created in the PSP spectrum are modulated at different frequency (e.g. flipped on and off) to provide a carrier form of demodulation. In this mode, each grating signal would be transposed into the AM sidebands of a particular carrier frequency.

Experimental: In the demonstration of this concept, we took an array of 3 Bragg gratings, two of which were kept at this nominal wavelength, and the third of which was attached to a simple cantilever beam and strained. Figure 3 shows the spectrum of this grating over a range of 0 to approximately 1000 μstrain. The OSP 9100 was set to induce a linear filter edge from 1535 to 1538 nm with a relative transmission of 0.001 to 1.0 over the range. The spectrum indicates the variation in transmittance w/strain, and thus the simple adaptive filter discriminator concept proposed here.

It should be noted, that the filter function of

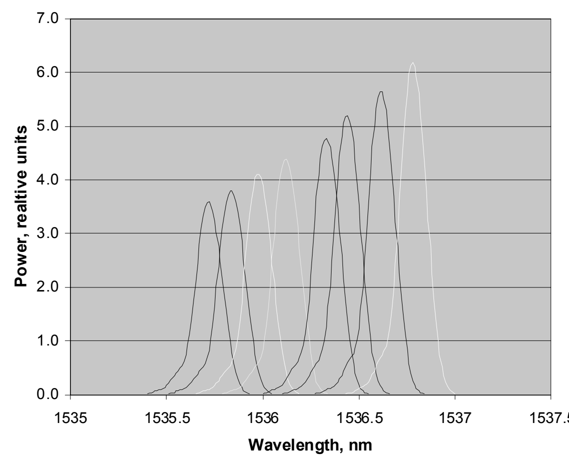

Figure 3: Grating profile following the PSF for various strain levels

the OSP 9100 can be changed rapidly, allowing different filter slopes, or the ability to reverse the sign of the slope (Note: this could be used to normalize the measurement, by taking a difference over sum ratio for a positive & negative filter slope).

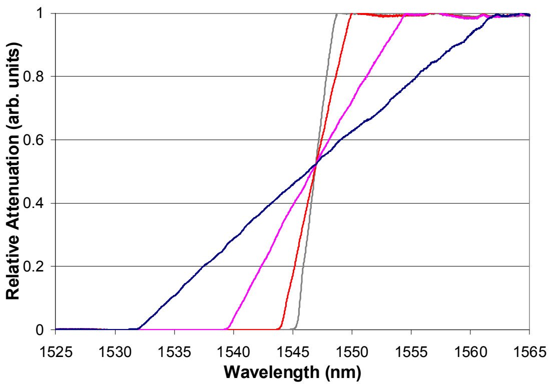

Figure 4: OSP 9100 ramp filter functions w/different slopes :0-100% over 3, 6, 15 & 30 nm

Figure 4 illustrates the capability of the OSP 9100 in generating various filter functions on command. The device can be switched rapidly (in milisecs) from one filter function to the next. The filter function itself can be of any arbitrary function across the operational window. The examples in Figure 4 show several 'discriminator' functions (e.g. ramp functions), with 0 to 100% transmission ranging over 10 nm down to 1 nm.

In the simple proof of concept demonstration discussed here, a single filter function was

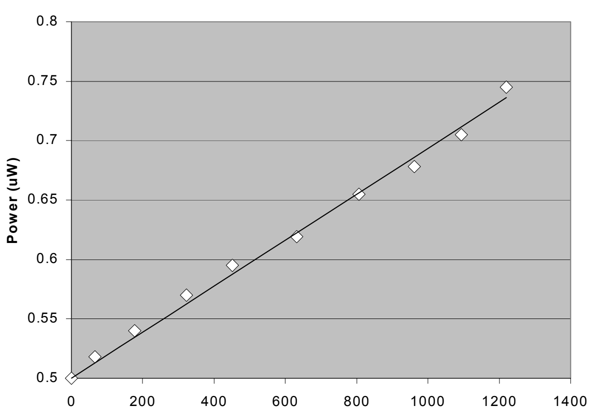

Figure 5: Change in transmitted power through the PSP filter w/grating strain

used. Figure 5 shows the change in transmitted power w/strain for the test grating over a range of approximately 0 to 1200 μstrain. As can be seen, a linear variation in power occurs w/strain.

Discussion: As discussed above, the unique feature of this approach is that the sensitivity of the detection system can be tailored for the application in mind: a small attenuation slope yields a wide range, but low sensitivity, whereas a high slope provide a narrower range, but high sensitivity to small strains. Whereas with fixed filters these attributes also apply, with the adaptive filter described here, the system can be switch between these two modes at will.

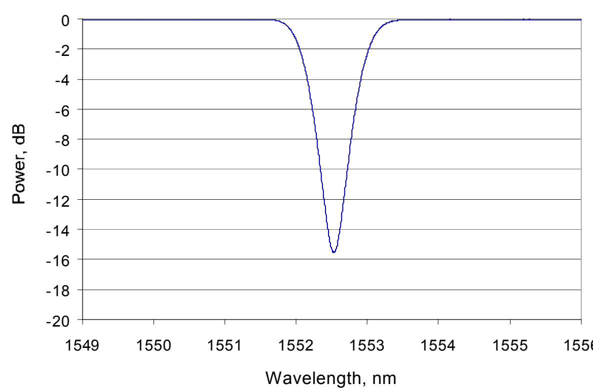

Figure 6: Example of a 'grating like' profile generated using the PSF 9100

In an alternative mode of operation, the PSP can be commanded to simulate a grating-like profile which can be wavelength-locked to that of a sensor grating signal using simple closed loop control of the PSP. In this mode, a better DC tracking capability is obtained, whereas the previous discriminator approach is more suited to detecting AC strains.

Summary: In summary we have described an approach for the demodulation of Bragg grating based sensors which utilizes an adaptive/programmable filter. The filter is based on the TI DLP™ micro-mirror chip. The technique can be used to provide simple discriminator or wavelength filter tracking demodulation.

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