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Programmable Broadband Light Source for Fiber Sensor Applications

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Abstract: We describe a programmable light source suitable for a range of fiber sensor applications, including low-coherence interferometry, gyroscopes, optical coherence tomography and Bragg gratings.

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Introduction:

A very large number of sensors and sensor mechanisms have been reported over the past two decades of fiber sensor R&D. These range from relatively simple intensity-based colorimetric techniques (1), low-coherence interferometry (2,3), optical coherence tomographic solutions (4), and wavelength-encoded sensors such as Bragg gratings (5,6). In each case, the sensing mechanism places certain demands on the choice of light source for the system. In this paper we describe a novel programmable light source and discuss its use in several different applications.

Programmable Light Source:

The programmable light source[1] utilizes TI's Digital Light Processing™ technology to select wavelength components from a spectrally dispersed light source. In operation, broadband light from an Erbium ASE source is dispersed by a diffraction grating and directed onto the surface of a Digital Micromirror Device (DMD). Light reflected off the DMD is then directed to a fiber output port. The DMD comprises approximately 800,000 digitally controlled micro-mirrors, each of which is individually addressable (7). By creating spatial patterns on the micro-mirror array, arbitrary degrees of attenuation can be provided at any given wavelength. An output spectrum can thus be synthesized to take any form, within the ~400pm resolution constraints of the optical design. This resolution allows for the synthesis of a very broad range of source spectra, with considerable fine detail. Attenuation of out-of-band power is > 30 dB.

Low-Coherence Interferometry:

To illustrate the capability of this device we simulated a range of source profiles, including a Gaussian profile, a Lorentzian profile and a 'flat-top' profile for a source 10 nm FWHM. Figure 1 shows the spectra recorded. These

[1] The programmable broadband source is available from Newport Corporation under the name of OSP9500.

source profiles can be important in the development of sensor techniques such as low-coherence interferometry (3) and optical coherence tomography (4). Indeed, in the case of low-coherence interferometry, the structure of the interference pattern generated (the interferogram) depends strongly on the power spectral density of the source, and much can be gained from

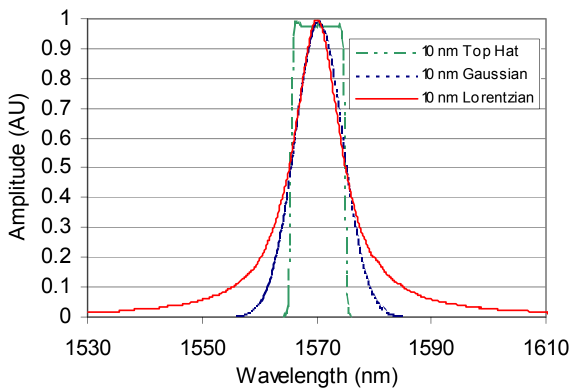

Figure 1. Three different programmable source spectra useful in low coherence intereferometry

tailoring the coherence characteristics to produce, for example, low side-lobe interferograms (8). In other circumstances, strong side-lobes may prove advantageous, or a double-peaked source profile would yield modulated interferograms, the beat frequency of which is dependent on the difference in the wavelength of the two peaks (this is a form of dual wavelength interferometry).

Colorimetric sensors:

Colorimetric devices comprise another sensing approach that can benefit from the type of programmable source described in this paper. Here, the source can be programmed to sequentially send into the system two different source profiles centered around different center wavelengths. Depending on the exact nature of the colorimetric sensing mechanism chosen, the source wavelengths can be selected to optimize the performance.

Bragg Grating Sensors:

Bragg grating based sensors have been the topic of considerable attention over the past 10 years (5,6). Much of this interest is directed towards the development of effective wavelength demodulation schemes. The programmable source concept described here provides a novel means for testing out such techniques. The simulation of an array of grating signals can be accomplished using a series of narrow peaks (as seen in Figure 2).

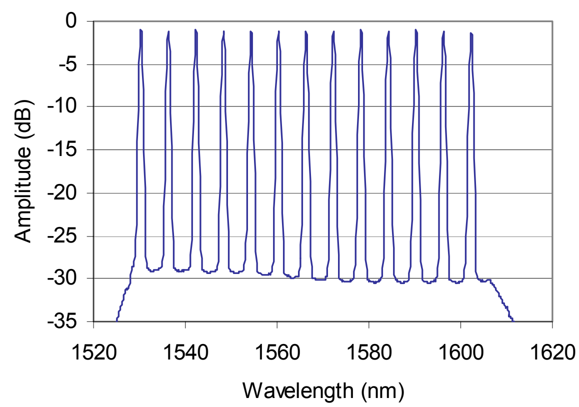

Figure 2. Programmable broadband source simulating an array of Bragg grating sensors.

It should be noted that the DMD-based concept provides for the ability to independently tune the center wavelength and effective reflectivity of each of the peaks in the spectrum. The center wavelength tunability can also be used to produce narrow band (~400pm FWHM) tunable sources useful in making absolute OPD measurements for small OPD interferometric sensors.

Gyroscope applications:

Yet another area where this device could provide additional flexibility and control is in fiber gyroscopes. In a fiber gyroscope, the system scale factor is dependent on many conditions, including the temperature of the fiber coil (9). One way to compensate for this is to change the center wavelength of the source. This in turn induces a scale factor shift that, through calibration, can be used to balance the temperature-induced error. The programmable source described here allows the weighted center wavelength to be controlled to ~ +/- 1 pm, providing ~ +/- 1 ppm scale factor tuning capability for a 1.5 um source wavelength. Figure 3 provides an example of the fine control over the ASE power spectral density made possible by the programmable broadband source. This figure provides the original unfiltered source spectrum (which is passively flattened to +/-3dB over a ~75nm band), as well as two slightly different spectra created by removing ~8dB of power in two spectral regions separated by ~50nm.

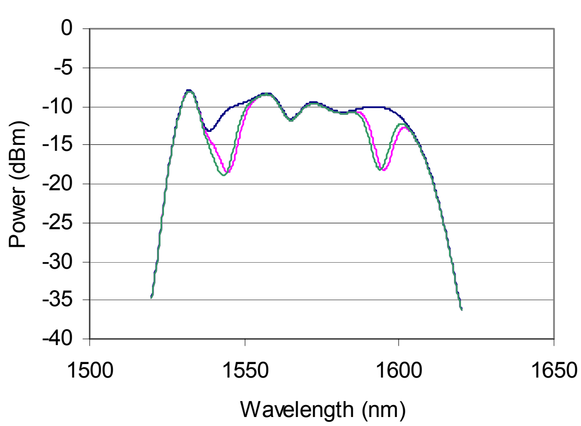

Figure 3. Example of a spectrally tailored superfluorescent source.

Discussion:

This paper has described an optical source with a completely programmable power spectral density, and has highlighted some possible uses in fiber optic sensing. The programmability enabled by the DLP™ technology makes this platform useful not only in the development of specific fiber optic sensor technologies, such as low coherence interferometry, but also in supporting the development and characterization of Bragg grating instrumentation solutions. Complete control over the power spectral density (to within +/-0.15dB in closed loop) makes the technology ideal for fundamental characterization of fiber sensor systems.

Digital Light Processor and DLP are trademarks of Texas Instruments.

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