Next-Generation Fiber Grating-Based Components Fulfill the Requirements of Future Optical Networks

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Introduction

With the development of innovative manufacturing techniques, next-generation fiber Bragg grating (FBG) components can now be produced with the level of performances and reliability that allow mass deployment of these devices for high-end applications. Gain flattening filters (GFF) with low-error function, low-dispersion WDM filters suitable for operation at 40 Gb/s and low group delay ripples multichannel chromatic dispersion compensators are among these high-end applications. Moreover, since FBG is an all-fiber technology, tunability can be easily implemented opening the door for applications such as tunable chromatic dispersion compensator.

In this paper, we will present an overview of those high-end applications and show that FBG technology is well suited to overcome the challenges imposed by future optical networks.

Gain Flattening Filters

Improved recording technique for FBG-based components now allows GFF to be obtained with error function below +/-0.1 dB while reducing polarization dependence such as PDL and PMD. Figure 1 presents a comparison between FBG-based GFF obtained with a standard and an improved recording technique. The improved recording technique clearly minimizes the amplitude ripples that have a direct impact on the achievable error function. Moreover, amplitude ripples reduction introduces low group delay ripples making GFF fabricated with this technology an ideal candidate for long-haul application at 40 Gb/s.

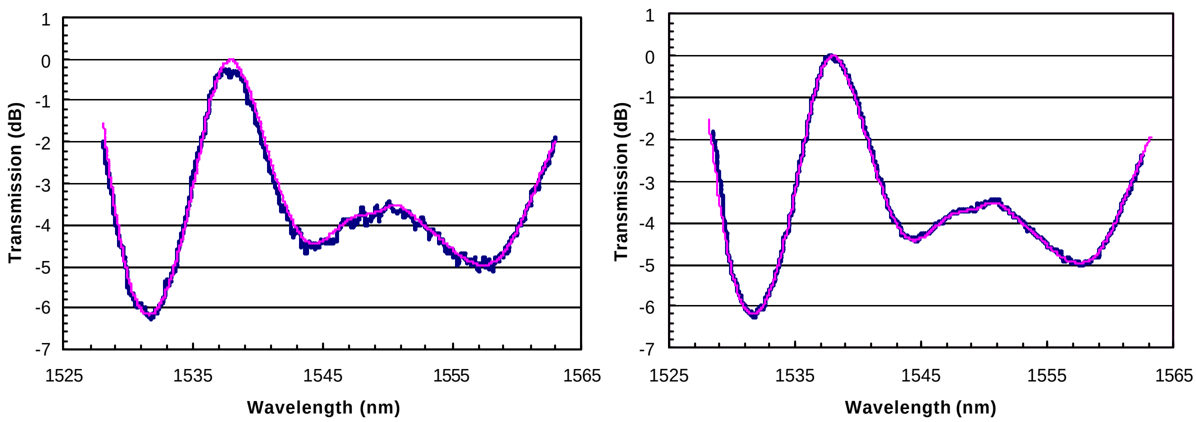

Figure 1: GFF with standard (left) and improved (right) recording technique.

Low-Dispersion WDM Filters

Narrow channel spacing WDM filters with high bandwidth efficiency (square filter) based on FBG have long suffered fom high level of dispersion in the passband making them unsuitable for operation at 10 Gb/s and higher. With new numerical design techniques along with the possibility to accurately transfer the required complex apodization profile in the core of the optical fiber (see figure 2), WDM filter with very narrow channel spacing (<25 GHz) and low level of dispersion can now be produced. Figure 3 demonstrates the advantage of using a low-dispersion design compared to a standard design for a

50 GHz WDM filter; passband efficiency is increased by a factor >2 for a bit error rate of 10^{-9} when those WDM filters are tested at 10 Gb/s.

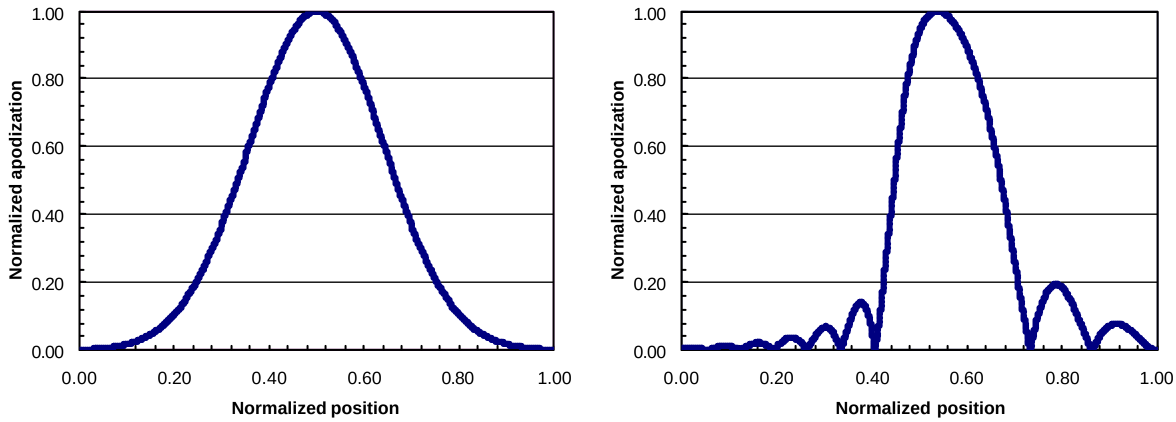

Figure 2: Apodization profile of standard (left) and low-dispersion (right) WDM filter.

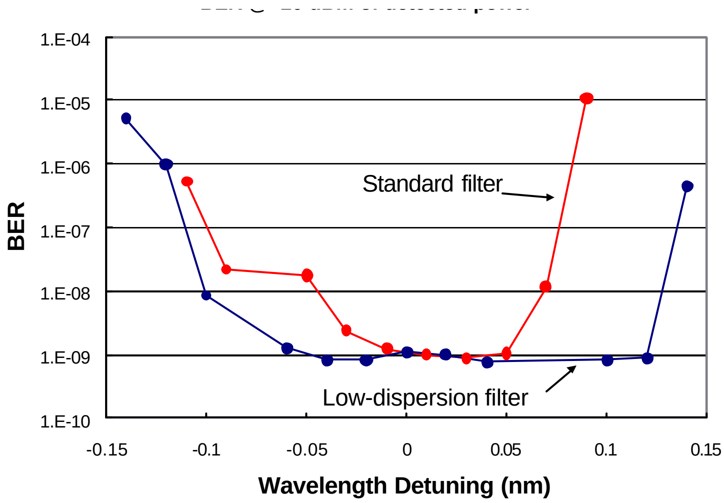

Figure 3: Bit Error Rate measurement at 10 Gb/s for 50 GHz standard and low-dispersion FBG-based WDM filter.

Multichannel Chromatic Dispersion Compensators

Earlier FBG-based dispersion compensators were limited to single channel operation and large group delay ripples. These two drawbacks were directly related to the process used to fabricate the gratings. With the improvement of holographically-made phase masks and the possibility to compensate multiple channels simultaneously using a single grating, efficient broadband compensation (dispersion and dispersion slope) on a per-channel basis can now be achieved with the level of performances required by system designers. Figure 4 presents a 12-channel 200 GHz spacing dispersion slope compensator where the dispersion slope is adjusted on a per-channel basis. As an example, this type of component could be used at the receiver to compensate for the residual slope accumulated by multiple spans of dispersion compensating fiber (DCF) modules.

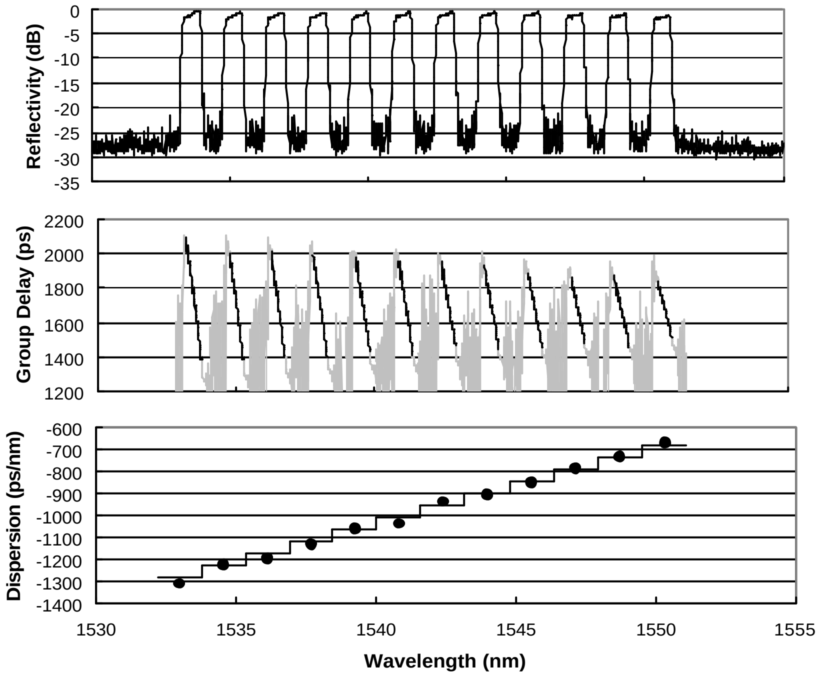

Figure 4: Reflectivity and group delay spectra of a 12-channel dispersion slope compensation grating (upper two graphs). The dots in the bottom graph gives the dispersion values obtained from a curve fit of the group delay while the solid line represents the target value.

Tunable Chromatic Dispersion Compensators

Tunable chromatic dispersion compensation on a per-channel basis will be a key element for next-generation WDM systems. At 40 Gb/s, dispersion compensation must match exactly the fiber link chromatic dispersion in order to insure transmission with a high level of quality. Since chromatic dispersion can fluctuate along the fiber link due to temperature variations and components aging, it is critical to be able to compensate the dispersion on a per-channel basis at the receiver. Chirped fiber grating along with an appropriate tuning platform is well suited to fulfill this application. As presented in figure 5, small footprint FBG-based tunable dispersion compensator with low-power consumption can now be realized with the level of optical performances required by next-generation WDM systems.

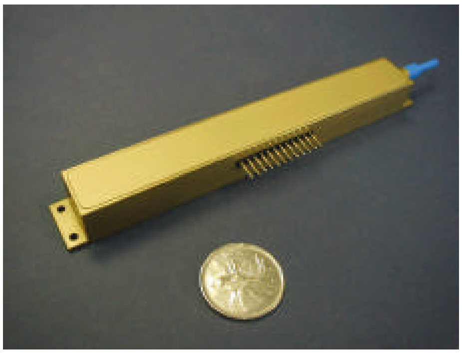

Figure 5: Tunable FBG-based chromatic dispersion compensator.