Physical Insight into Dispersionless FBG Designs

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Abstract: We provide physical insight into the role different sections play in inverse-scattering-designed dispersionless FBGs. Using this knowledge we design and fabricate strong (>30dB) bidirectional dispersionless filters.

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1. Introduction

Inverse scattering (IS) has been established as the main design algorithm for advanced grating-based components [1],[2]. Starting from the required transfer function and applying causality, the required refractive-index modulation and chirp profile are obtained. The freedom to choose arbitrarily the response though comes at the expense of device complexity. IS usually results in intricate designs that depart considerably from established intuitive and straightforward approaches. A typical example is the square, dispersionless grating that enables dense WDM and large number of concatenated add-drop functions without substantial penalty [3]. However, such gratings are uni-directional and cannot be used from both sides, which severely compromises their use as add *AND* drop multiplexers.

So far no attempt has been made to physically understand how these mathematically rigorous designs really work. In this paper, we demonstrate that dispersionless square filters are actually *dispersion compensated* devices and we physically identify the spatially separate *main (dispersive) reflector* and *dispersion compensator* sections. We then use this knowledge to design strong bidirectional gratings with dispersionless response from both sides.

2. Dispersionless FBGs

Figure 1(a) shows the refractive index (RI) modulation profile for a square 50GHz dispersionless FBG filter with R=99.9%. The profile is highly asymmetric and it consists of a main lobe (II) preceded and followed by secondary lobe series I & III of different height and periodicity. Figure 1(b) shows the reflectivity and transmissivity spectra, while Figure 1(c) shows the reflection group delay from left and right. It clearly shows that the filter is dispersionless only when light enters from the left. The reflection from the opposite side, on the other hand, is highly dispersive. This is known to severely compromises the simultaneous add *and* drop function of the same FBG.

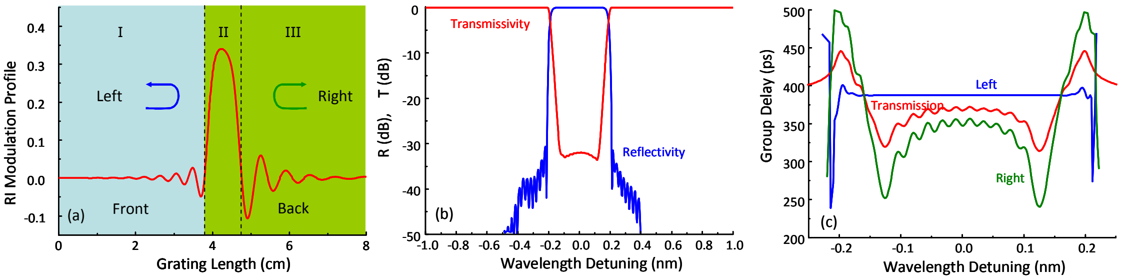

Figure 1: (a) RI Modulation profile (b) Reflectivity & Transmissivity and (c) Group Delays

The RI modulation profile can be divided into to distinct sections, denoted as front and back parts in Figure 1(a). The front part comprises only the preceding lobe series (section I). The back part on the other hand comprises the main lobe (section II) and the following lobe series (section III). Three different gratings (front-part, back part and whole FBG) were written using a modified “step-and-write” technique [4] and measured separately. Figure 2(a) shows the reflectivity and reflection group delay of the back part alone. This part provides the reflection and it is highly dispersive. Figure 2(b) shows the reflectivity and group delay of the front part alone. The front part provides negligible reflection and it is again highly dispersive with dispersion, however, of opposite sign to the front part. Figure 2(c) finally shows the reflectivity and group delay of the whole dispersionless FBG. Its reflectivity is largely the same with the one of the front part while its group delay is substantially flattened. The residual ripple is of small enough magnitude and period to incur any substantial penalty to high bit-rate data [6].

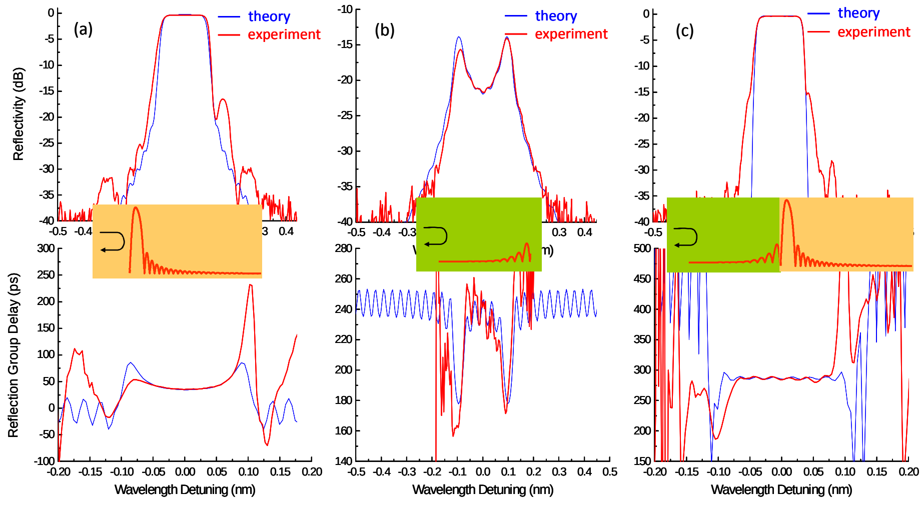

Figure 2: Inverse scattering dispersionless FBGs; (a) main reflector, (b) dispersion compensator and (c) entire grating

3. Bidirectional Dispersionless FBG Designs

This physical insight has enabled us to design and fabricate for the first time high reflectivity (>30dB) bidirectional, dispersionless FBGs by modifying exact IS profiles. To achieve this we simply replace section III on the back side with dispersion-compensating section I and symmetrize main lobe I. The symmetric profile is shown in Figure 3(a). It should be stressed that these IS-inspired symmetric profiles are considerably different to sinc profiles, which are are known to provide bidirectional dispersionless response only at low reflectivities (<~10%).

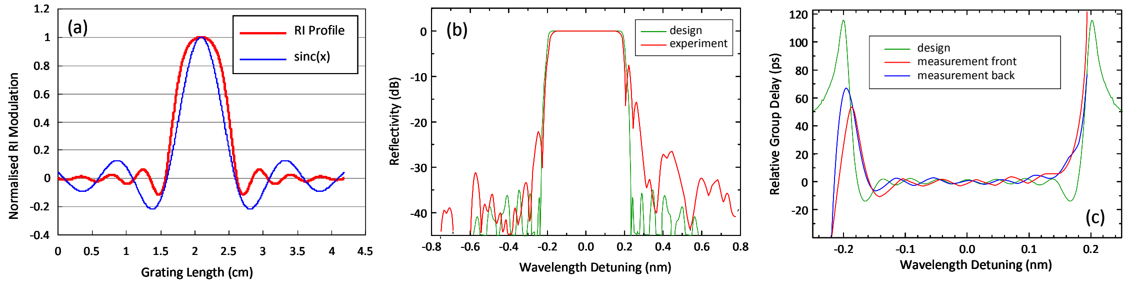

Figure 3: Symmetric low dispersion bidirectional FBG filter (a) RI modulation profile (b) reflectivity and time delay from left and right.

Figure 3(b) and (c) show the corresponding design and experimentally obtained reflectivities and the group delays. It is shown that our symmetric design gives almost identical dispersionless response from both sides, in excellent agreement with theory. More data will be presented at the conference.

4. Conclusions

We have shown that IS designed dispersionless square filters are actually *dispersion compensated* devices and identified the spatially distinct *main (dispersive) reflector* and *dispersion compensator* sections. We have used this knowledge to design and fabricate for the first time strong (>30dB) bidirectional gratings with dispersionless response from both sides, suitable for simultaneous add AND drop functions out of the same device.

5. References

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