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Calculating Reflectivity of Fiber Bragg Grating for Different Apodization Techniques

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Abstract

In this paper reflectivity spectra of fiber Bragg grating structure for different appodization techniques are computed and plotted as a function of operating wavelength with 1.55nm central value. Computation is made using coupled mode approach and variation of index change is considered as the turning parameter along with grating length. Result is compared with that obtained in absence of appodization thus variation of bandwidth due to deformation in wave shape is investigated. Simulated results are critically important for calculating reflectivity for practical application.

Key words

Apodization, gaussian, raised-cosine, hyperbolic-tangent, reflectivity, fiber bragg grating.

1. Introduction

In the 21st century, due to the rapid growth of information industry, communication network with higher speed and capacity of data is one of the major requirements [1]. Performance of this systems is critically depended on the time domain broadening of the transmission pulses; i.e., on dispersion. Generation of higher side lobe in the reflectivity profile causes major problem in WDM multiplexing as it produces cross-talk [2]. This purpose can effectively be counter balanced through the use of appodization techniques is to reduction of side lobe without major ditoriation in the fundamental wave shape. Literature is already available with appodized grating as effective solution for compensating chromatic dispersion in higher capacity optical communication system [3].Thus analysis of apodized waveform in reflectivity profile of Bragg grating structure is required.

Ugale [4] calculated the FWHM for different apodized Bragg grating and corresponding reflectance profile, through constant FWHM is obtained for a longer period of grating length and is also independent of index variation. Khan et.al [5] showed that sink profile fits based for reduction of chromatic dispersion as a function of grating length but comparison with idealistic profile is not obtained. The experimental setup for measuring the Gaussian apodizatio effect is described by Singh et.al.[6] for switching application the result is carried out using software package, but analytical calculation is missing for verification. Effect of side lobe outside the desired region is measured by Ashry et.al [7] for sensing application though magnitude of side lobe is quite high. Wideband chirped fibre Bragg grating for dispersion compensation is investigated by William et.al [8]. Gumsta [9] calculated spectra response for apodized grating structure.

Kim [10] calculated coupling loss for optical communication with reflective mirror. Studies are also carried out on network and switching technologies [11-12] using fiber Bragg grating. Interferometric [13] and sensor performances [14-15] are also analyzed in recent past. In the present paper reflectivity of grating structure is calculated for different standard apodization technique and is compared with ideal reflectivity profile results are very important for study of bandwidth variation and side lobe reduction.

2. Mathematical Modeling

We consider the forward and backward propagating waves inside a 1D photonic crystal respectively as-

$$B(z,t) = b(z)\exp\left[-j\left(\beta_b z - \omega t\right)\right] \tag{1.1}$$

$$A(z,t) = a(z)\exp\left[j\left(\beta_a z - \omega t\right)\right] \tag{1.2}$$

We further assume that *a(z)* and *b(z)* are exactly in same modes, i.e.,

$$\beta_a = \beta_b \tag{2}$$

Thus we can write-

$$\frac{db}{dz} = \kappa a(z)\exp\left[2j(\Delta\beta)z\right] \tag{2.1}$$

$$\frac{da}{dz} = \kappa b(z)\exp\left[-2j(\Delta\beta)z\right] \tag{2.2}$$

Coupling between these wave intensities are computed referencing Bragg wavelength (λ_B). Solution of weakly coupled wave equations with appropriate boundary conditions give

$$a(z) = b_0 \sinh[\alpha(z-L)] \times \frac{\bar{\kappa}\exp[-j\Delta\beta z]}{[\Delta\beta\sinh\alpha L - j\alpha\cosh\alpha L]} \tag{3}$$

$$b(z) = b_0 \frac{\bar{\kappa}\exp[j\Delta\beta z]}{[-\Delta\beta\sinh\alpha L + j\alpha\cosh\alpha L]} \times \left[\Delta\beta\sinh\left\{\alpha\left(z-L\right)\right\} + j\alpha\cosh\left\{\alpha\left(z-L\right)\right\}\right] \tag{4}$$

where

$$\alpha = \sqrt{\kappa^2 - (\Delta\beta)^2} \tag{5}$$

Thus, total reflectivity my be obtained as

$$R = \frac{\kappa^2\sinh^2(\alpha L)}{[(\Delta\beta)\sinh(\alpha L) - j\alpha\cosh(\alpha L)]^2} \tag{6}$$

For maximum reflectivity,

$$R_{\max} = \tanh^2(\kappa L) \tag{7}$$

Correponding maximum wavelength is given by

$$\lambda_{\max} = \left(1 + \frac{\langle \delta n_{eff} \rangle}{n_{eff}}\right)\lambda_D \tag{8}$$

For uniform Bragg grating, spectrum is given by

$$\Delta\lambda_0 = v\,\frac{\langle \delta n_{eff} \rangle}{n_{eff}}\sqrt{1 + \left(\frac{\lambda_D}{v\langle \delta n_{eff} \rangle L}\right)^2}\,\lambda_D \tag{9}$$

The apodization functions are given by

$$v_{Gaussian}(z) = \exp\left[-\left(\frac{z-(L/2)}{6L}\right)^2\right] \tag{10}$$

$$v_{Raised-Cosine}(z) = \frac{1}{2}\left(1 + \cos\left(\frac{2\pi(z-(L/2))}{L}\right)\right) \tag{11}$$

$$v_{Hyper-Tangent}(z) = 1 - \tanh^2\left[\frac{z-(L/2)}{0.16L}\right] \tag{12}$$

3. Results and Discussion

Using Equn (10), (11), (12) and (6), reflectivity profiles are computed and plotted for specific refractive index for the chirped fiber Bragg grating. Results are plotted in Fig 1, Fig 2 and Fig 3 individually.

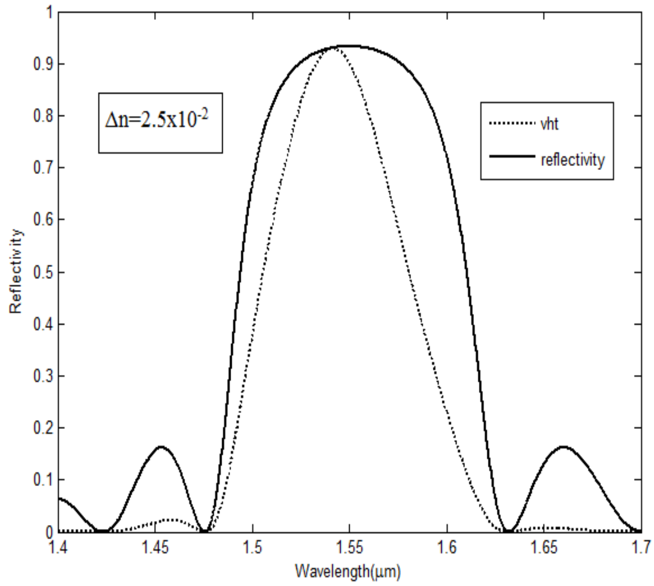

Fig.1. Reflectivity Profile with Wavelength for Hyperbolic-tangent Apodized Function, and Compared with Ideal Relfective Profile

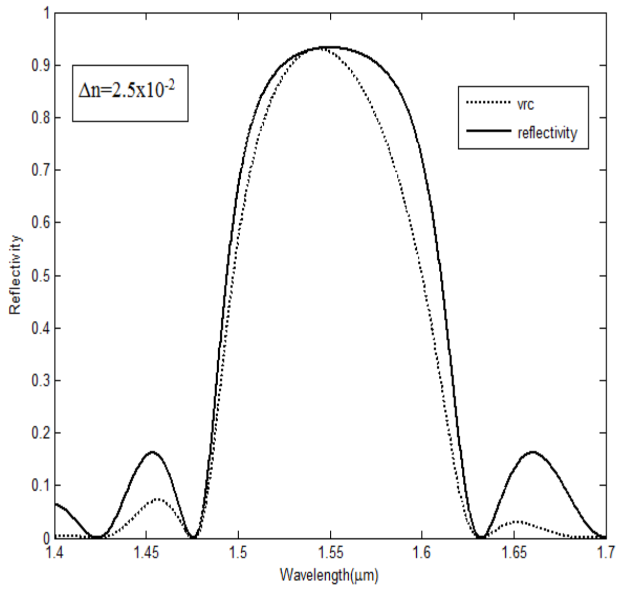

Fig.2. Reflectivity Profile with Wavelength for Raised-Cosine Apodized Function, and Compared with Ideal Relfective Profile

In Fig 1, plot is made for hyperbolic-tangent profile, and compared with ideal one. Here ideal means absence of apodization function. From the plot, it is seen that the incorporation of hyperbolic-tangent function makes the profile asymmetric, and peak appears at the lower side of central wavelength. Hence the difference with ideal profile is significant at the higher side of the spectrum, Again, one imporant point may be noticed that the magnitude of sidelobe is very negligible when apodized function is present.

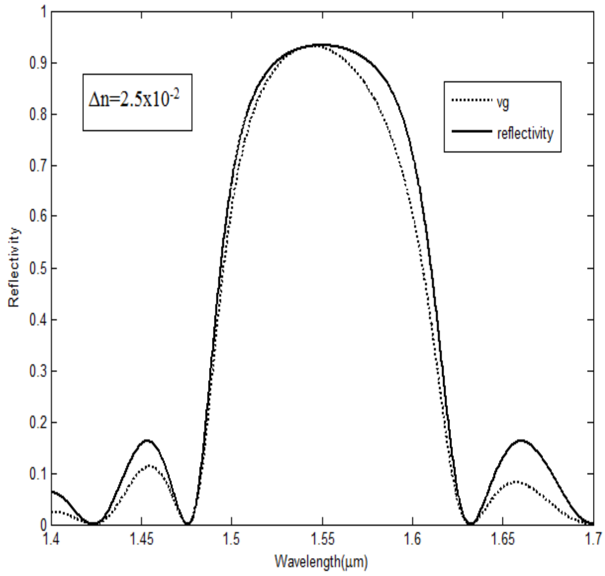

Fig.3. Reflectivity Profile with Wavelength for Gaussian Apodized Function, and Compared with Ideal Relfective Profile

Fig 2 shows the difference between raised-cosine apodization fucntion with ideal one. The similarity is observed with Fig 1 except the difference is that the gap between the spectra at higher wavelength is reduced. the gap is further reduced for Gaussian apodization fucntion (Fig 3), and hence it can be used for practical application.

Fig 4 shows the comparative study for the index difference for hyperbolic-tangent function. It is observed that the peak makes a blueshift with increase of index difference. This gives the indication that the peak position can be tailored externally which is required for grating application for different user-specified purpose.

The similar observation is made for Fig 5 and Fig 6 also. the significancelies in the fact that the difference of refractive index is more pronounced for gaussain distribution. Hence it is more desirable apodization than the other two.

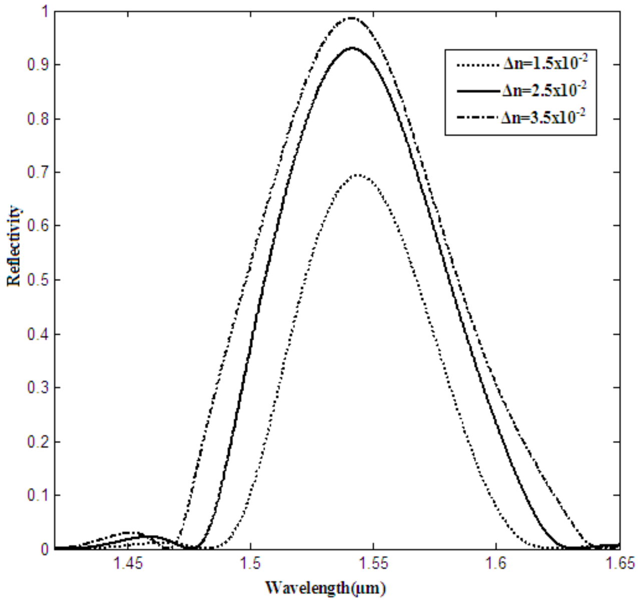

Fig.4. Comparative Study of Reflectivity Profile for Hyperbolic-tangent Apodization Function for Different Refractive Indices

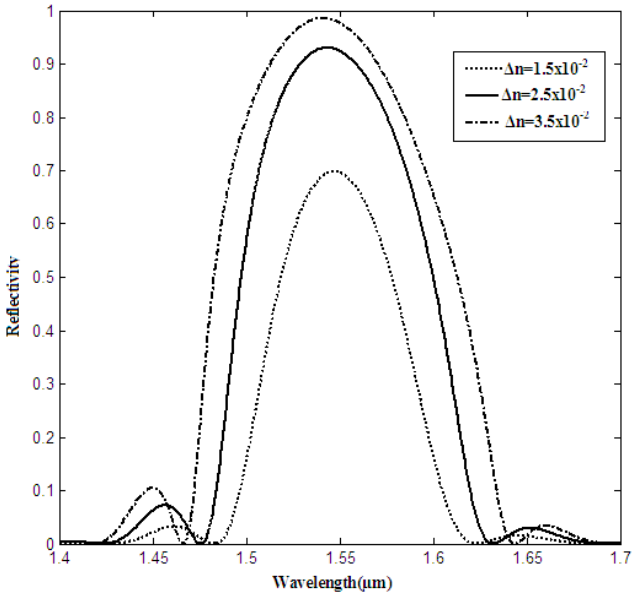

Fig.5. Comparative Study of Reflectivity Profile for Gaussian Apodization Function for Different Refractive Indices

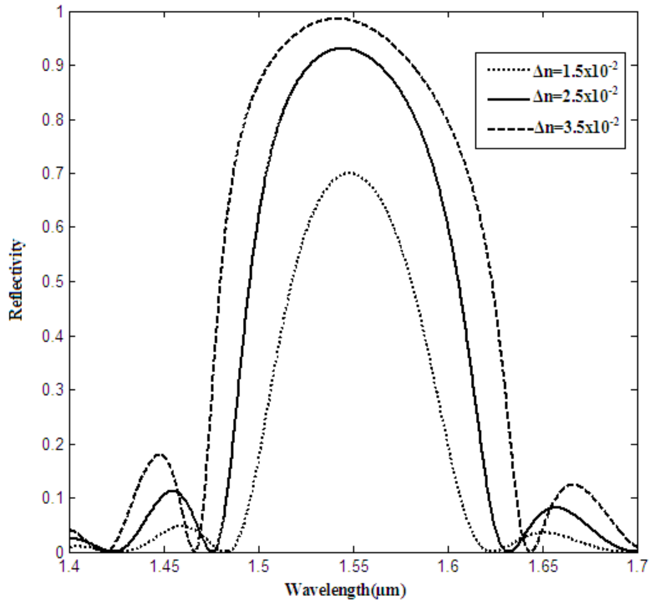

Fig.6. Comparative Study of Reflectivity Profile for Rised-Cosine Apodization Function for Different Refractive Indices

Conclusions

Reflectivity of apodized fibre Bragg grating is analytically calculated at central wavelength 1.55μm for different apodization functions comparative study with ideal response shows that variation of reflectance at major lobe, and the different is dependent on index difference also simulated findings will show that key aspect of grating design for desirable bandwidth. It is found that the Gaussian apodization is more suitable for practical application.

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