Multi-Grating Sections of Dielectric Waveguides

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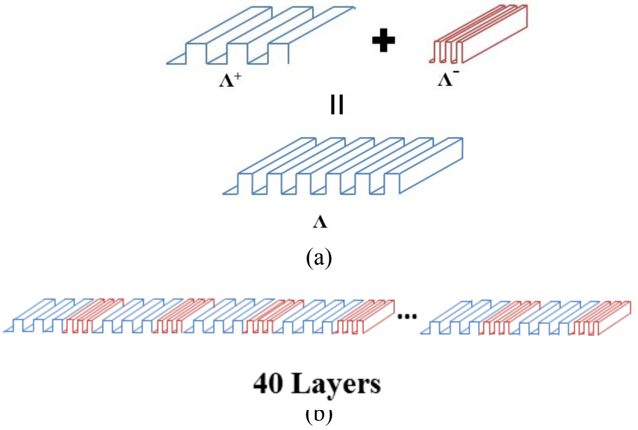
***Abstract-* The reflectivity of forty-grating sections consisting of two grating periods is simulated. Close difference of two gratings periods causes similarity of the reflectivity of forty-gratings and single gratings except for the phase shift phenomenon.**

I. Introduction

The structure of a periodic dielectric waveguide in distributed Bragg reflector (DBR) lasers or distributed feedback (DFB) lasers consists of a grating region and two uniform dielectric waveguides. The requirement that a grating period $\Lambda = m\cdot\lambda/(neff\cdot 2)$ (where Λ is the grating period, m is an integer, λ is the free space wavelength, and neff is the effective index of the waveguide) for feedback or outcoupling may not be able to be exactly achieved by electron beam writing due to equipment limitations that do not allow a continuous variation in the grating period.

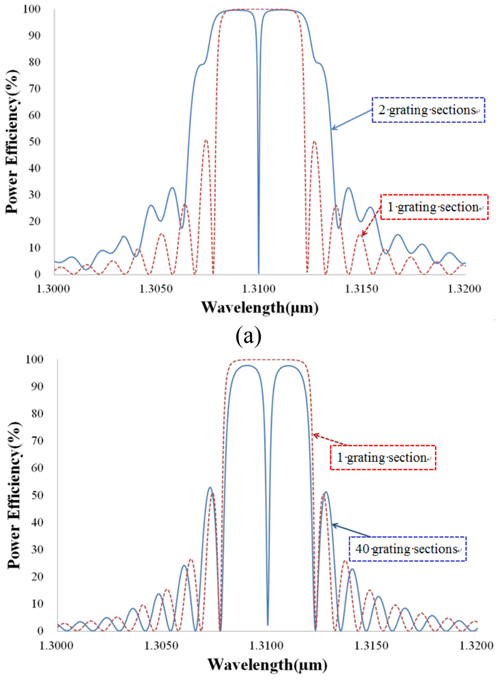


(a)

(b)

Fig. 1 (a) The diagram of using a longer grating period (Λ+) and a shorter grating period (Λ-) to replace the original grating period (Λ). (b)The geometry of a surface corrugation dielectric waveguide with 40 grating sections.

A solution to this problem is to use groups of two grating periods, which are denoted by a longer grating period (Λ+) and a shorter grating period (Λ-), to provide an average grating period equal to the required grating period Λ. Figure 1(a) shows the concept of achieving an average "exact" grating period with two grating periods. Figure 1(b) illustrates the geometry of a surface corrugation dielectric waveguide with 40-grating sections, where the longer grating period section (Λ+) and the shorter grating period section (Λ-) are alternately aligned. In this paper, we demonstrate the reflection characteristics of the periodic waveguide structure with multi-grating sections. The Floquet- Bloch theory [1] and the Mahmoud-Beal's method [2] are applied to calculate the reflection spectra of the multi-period grating structures.



(a)

(b)

Fig. 2 The reflection spectra of the periodical waveguide with (a) one grating section and two grating sections and (b) forty grating sections. The grating period of one grating region is 0.20286985 μm with grating length of 200 μm. The grating periods of multi-grating sections consist of two grating periods of 0.20276985 μm and 0.20296985 μm. The total length of each grating section is 100 μm.

II. SIMULATION RESULTS

We consider the waveguide structure described in [3]. We

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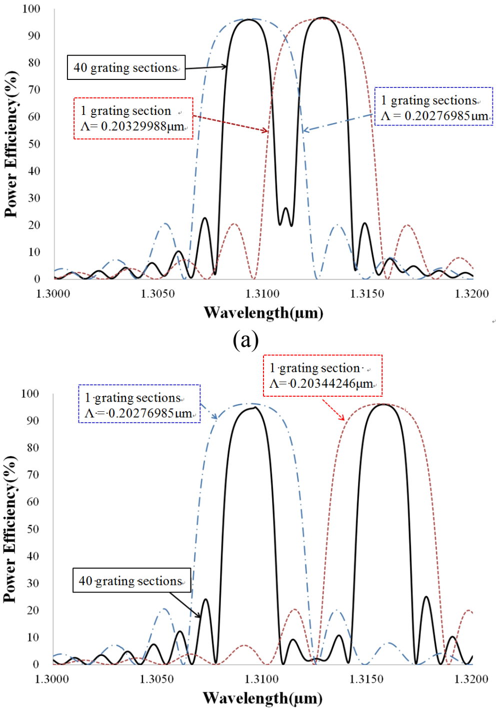
assume that there is no material loss in the layers, the grating depth is 0.1 microns, and that the duty cycle of the grating is 50%.

Figure 2(a) shows reflection spectra of the periodic waveguide with a single uniform grating and another periodic waveguide consisting of two different grating periods. For the uniform periodic waveguide, the grating period (Λ) is 0.20286985 µm and the grating length is 200 µm. As shown in Fig. (a), the center resonant wavelength of the structure is 1.31 µm. The 3dB resonant wavelengths ranges from 1.3095 µm to 1.3115 µm with a bandwidth of 0.0043 µm. The reflection spectrum of a two-grating period section is also shown in Fig. 2(a), where the two grating periods are 0.20276985 µm and 0.20296985 µm. The total length of the grating region is 200 µm, and the length of each grating region is 100 µm. The reflection spectrum of the two-grating section is similar to that of the uniform grating section, but with a wider 3dB bandwidth of 0.007 µm. The major difference between the two spectra is due to a phase shift at the center resonant wavelength of 1.31 µm. For the two-grating section structure, the reflectivity at resonance drops to 0.49%.



(a)

(b)

Fig. 2 The reflection spectra of a forty-grating section periodic waveguide compared to a uniform grating periodic waveguide. The two grating periods are 0.20276985 µm (Λ-) and 0. 0.20344246 µm (Λ+) for the composite waveguide.

Figure 2(b) displays the reflectivity of a single uniform grating waveguide and a grating waveguide consisting of forty-grating sections consisting of a series of short and long period grating sections that are each 5 µm long. The total length of the both the uniform and composite (two-period) grating waveguides is 200 µm. The composite grating waveguide consists of gratings with two grating periods: Λ-=0.20276985 µm and Λ+=0.20296985 µm. As shown in Fig. 1(b), the two gratings are alternately aligned over the complete grating region. Note that the average of the two grating periods is the same as the grating period of the uniform grating waveguide. From Fig. 2(b), we see that at the resonant region, the reflectivity of the multi-gratings dips sharply due to a phase shift resulting in low reflectivity of 2.32%. The 3dB bandwith of the forty-grating section waveguide is 0.004 µm.

Figure 2(b) shows that a forty-grating structure includes a phase-shift resulting in a low reflectivity at resonance. On the other hand, except near the resonance wavelength, the reflection spectrum of a forty section periodic grating is similar to that of a uniform grating of the same length. For the periodic waveguide shown in Fig. 2, the difference in grating periods (ΔΛ) is only 0.0002 µm. Figures 3(a) and 3(b) show the effects of increasing ΔΛ on the reflection spectra for periodic waveguides consisting of forty-grating sections for two combinations of two grating periods. The two grating periods are 0.20276985 µm (Λ-) and 0.20329988µm (Λ+) for Fig. 3(a), and 0.20276985 µm (Λ-) and 0.20344246 µm (Λ+) for Fig. 3(b). Note that we keep Λ- constant, and increase (Λ+). The differences of two grating periods (ΔΛ) are 0.00053003 µm and 0.001 µm for Fig. 3(a) and Fig. 3(b), respectively. The reflection spectra of uniform gratings with an average grating period of (Λ- + Λ+)/2 are also displayed in Figs. 3(a) and 3(b). The grating length of the uniform grating is 100 µm.

The spectrum of the forty-grating section periodic waveguide is sensitive to the value of ΔΛ. For larger values of ΔΛ, the reflectivity of the forty-grating section periodic waveguide has the properties of the combination of the two separate grating periods making up the composite grating. Therefore, the reflectivity spectrum of the forty-grating section periodic waveguide appearing in Figs. 3(a) and 3(b), are essentially the sum of the reflectivity spectra of the two grating periods that make up the composite grating.

IV. CONCLUSION

According to this study, if the difference of grating periods is greater than 0.0005 µm, multi-grating sections present the property of two connected single gratings. On the other hand, when the difference of grating periods is less than 0.0002 µm (~0.1%), the reflectivity of forty-gratings is similar to that of single gratings, except when the phasee shift phenomenon occurred in the center resonant wavelength. This work was supported by the National Science Council of the Republic of China under Grant MOST 104-2221-E-214-040.

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