The Analysis Of Notch Filter With Wide Flattened Stopband By Using Asymmetric Grating Structure On Planar Waveguide

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Abstract: In this paper, the utilization of a resonant grating waveguide structure as photonic bandgap device with flattened spectral response was reported. The resonant leaky mode results from the interaction of interior diffraction orders that coupled from the external incident filed can be manipulated by altering the asymmetrical profile of grating. The phenomenon of flattened photonic bandgap according to the structure was theoretically explained and a bandstop filter with flattened stopband of 200 nm bandwidth was experimentally achieved

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1. Introduction
The resonance behaviour of diffraction grating have been observed and discussed for a while because of their remarkable phenomenon and attractive applications. [1] Guided-mode resonance (GMR) which belongs to one of the grating resonance has been studied intensively for their multiplicity and versatile potential applications in photonics. [2] Among these applications, the GMR devices could be afforded to substitute the optical filter composed of thin-film structure for their much simpler structure and excellent spectral properties. [5]

For an optical filter, the energy within the filtering region should be identical as possible for better efficiency. Several GMR filters with flattened passband have been proposed but with complex structure that was hard to realize. Recently, Magnusson and Ding have demonstrated that the degeneracy of the resonant modes will be break by altering the asymmetrical structure of grating profile. [2-4] The flattened passband can be achieved by controlling the nondegenerate resonant leaky modes with much simpler ways but the structure was rarely hard to realize. In this paper, we use a two-layer grating waveguide structure that differs from the one-layer grating structure. By altering the asymmetrical structure of grating profile, the wide stopband can also be achieved in a more realizable structure.

2. Designation
The proposed structure, as shown in fig.1, composed of a grating layer and a waveguide layer on substrate. The material of grating and waveguide layers are poly-Si with refractive index $n_{poly-Si}=3.48$. The substrate was assume to be quartz with refractive index $n_{Quartz}=1.46$. The structural parameters were as shown in fig.1. The rigorous-coupled wave analysis (RCWA) and finite differential time domain (FDTD) method were used to simulate the spectral response and analyze the field distribution, respectively. The ways to obtain the desired spectral response is also to adopt the asymmetry of grating profile. It was achieved by altering the filling factors of the grating under identical grating period. The normally incident plane wave was assumed to be TE polarized.

Fig.2 shows the simulated spectral response of the proposed structure under appropriate design by RCWA method. The asymmetry of grating profile aims to remove the degeneracy of the resonant leaky-mode at normal incidence. The RCWA method is used to analyze the resonance of the asymmetric grating with two different filling factor $f_1$ and $f_2$ under identical grating period. The results show that the diffracted angle in silicon substrate by asymmetric profile grating.

Fig.1 The structure of proposed resonant gratings filter include the grating with asymmetrical profile and the planar waveguide layer on substrate. The parameters are as shown in the plot.

Fig.2. Experimental and the corresponding fitted-simulation results for the transmitted efficiency as a function of wavelength for the fabricated GMR filter with grating period around 0.724 µm and depth near 0.4 µm under normally incident. The parameters for the fitted simulation are grating period of 0.7 µm, the relative filling factors correspond to the period are about 0.11 and 0.31, respectively, grating depth of 0.4µm, and waveguide thickness of 0.1 µm. The flat reflection band with a linewidth of ~200nm with central wavelength near $\lambda=1.2\mu m$. 

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We found the first diffracted angle $\theta_1$ is 29.1° and the second diffracted angle $\theta_2$ is 76.6° in the silicon. There are only two diffractive order exist in the silicon.

The RCWA results in Fig. 2 show that an extremely wide flattop with linewidth of 200nm. The energy is coupled to the high diffracted order instead of concentrating at the zero transmission order of symmetry profile grating. The diffraction efficiency at zero reflection order is only about 21% at resonance peak $\lambda$=1.2µm. However the effect of the grating can couple the energy to other high transmission order like $\pm1\Gamma$ and $\pm2\Gamma$ except the zero order. These effect of the grating can lead to the high reflection efficiency. The grating structure was fabricated by ebeam lithography and subsequent dry etching process. The measurement results were as shown in fig. 2. The stopband were found at resonance wavelength around 1.2µm with a bandwidth of 200nm and transmittance below -10dB.

3. Analysis results

Finite-differencetime-domain (FDTD) modeling is used to complement the RCWA by determining field strengths within the asymmetric grating region. The results from the analysis of the asymmetric grating using FDTD are shown in fig. 3. From the field distribution shows that the wave was coupled to high transmission order and then become guiding wave. Therefore the high reflection efficiency can be achieved by utilizing the grating coupling the energy from normal incidence wave to high diffracted transmission order. The diffraction angle makes the wave guiding and propagation in the x-direction. The wave can be coupled out again to the incident free space result from the effect of the grating and the high index difference between silicon and quartz.

Another important aspect is the cladding layer of quartz. For the high index difference of silicon and quartz contribute to the role of the cladding layer. The thickness of quartz can cause the Fabry-Perot effect and modulate the reflection efficiency. The Fabry-Perot effect is calculated by the RCWA as shown in fig. 4. We can design the proper thickness of quartz to raise the bandpass filter efficiency. These effect contribute to the high reflection and wide flattop.

4. Conclusions

In this paper, the utilization of a resonant grating waveguide structure as passband device with flattened spectral response was reported. The resonant leaky mode results from the interior diffraction orders that coupled from the external incident field with the asymmetrical profile of grating. The phenomenon of flattop according to the structure was theoretically analyzed and a bandstop filter with flattened stopband of 200nm bandwidth was achieved.

5. References