High Reflectance Multiple Step Metal Grating for Multichannel Reflector

Ramanpreet Kaur
Student
BGIET, Sangrur

Neetu Sharma
Assistant Professor
BGIET, Sangrur

Jaspreet Kaur
Assistant Professor
RIMT, Mandi Gobindgarh

ABSTRACT
The multiple step subwavelength metal grating with relief structure is designed and analyzed in which the profile of grating structure is having a relief structure with multiple steps. The optical presentation of traditional structure is evaluated and compared in terms of reflectivity over visible and ultra violet spectrum with the help of Opti-FDTD. It is shown that, near the ultra violet band multiple reflections can be found compared to traditional metal grating in the same parameters. With these characteristics, designed metal grating with multiple steps is expected to find applications in optical communication as multichannel reflector.

Keywords
Metal grating, FDTD, Multichannel reflector.

1. INTRODUCTION
As an vital optical element, gratings take part in the fundamental role in all types of optical systems. In view of the fact that Nevdakh et al. [1] had considered the polarization uniqueness of subwavelength grating has develop into the focus of researches in most recent years. Researchers have done work on gratings and they concluded that when grating period is near to or slightly smaller than the wavelength then it will be having good polarization characteristics. With this characteristic, we can fabricate a variety of polarizing devices, such as special wave plates [2], polarizing color filters [8, 9], and polarizing beam splitters [3–7]. But if wavelength and grating period are at large gap from each other then there will be weak polarization characteristics. On the supplementary hand, the fabrication has been very grown-up. As given in the grating equation, when light propagates onto the subwavelength grating surface, just the zeroth-order diffraction exists [6]. Traditional subwavelength metal grating reflectance is generally about 51% at only one wavelength point in the particular wavelength area.

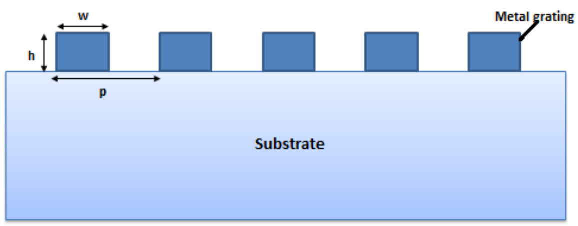


Figure 1: Traditional subwavelength metal grating with glass substrate and Si grating where grating period=1µm and grating width=0.5µm and height=0.25 µm

In this given structure of traditional metal grating, glass substrate is used having refractive index of 1.5 and grating used is of Silicon having refractive index of 3.48. Grating period is of 1µm and grating width of 0.5µm. We have examined the reflectivity power of this structure at input wavelength of 1.55µm and optimized by using Opti FDTD in the wavelength range of 400nm to 900nm and we get high reflectivity power only at one wavelength point, that is very poor reflectivity over this range. So, here we want to improve the reflectivity over visible and ultra violet region. Various structures have been implemented recently to use gratings as various optoelectronic devices. Included planar waveguide circuits are extensively used in optical telecommunication systems, with AWG (arrayed waveguide grating) multiplexers being one of the most composite of such circuits [4]. Presently, these viable waveguide devices are characteristically made from doped silica glass with a low refractive index distinction. The high-index contrast (HIC) SOI material system obtain the potential of a considerable size and cost diminution of integrated planar waveguide devices, as well as AWGs [5,11]. Additionally, new applications are raising for miniaturized SOI waveguide devices. Such as, we have lately demonstrated a dense high resolution micro spectrometer [12]. In our design we will show how a multistep grating can be used for multichannel reflections.

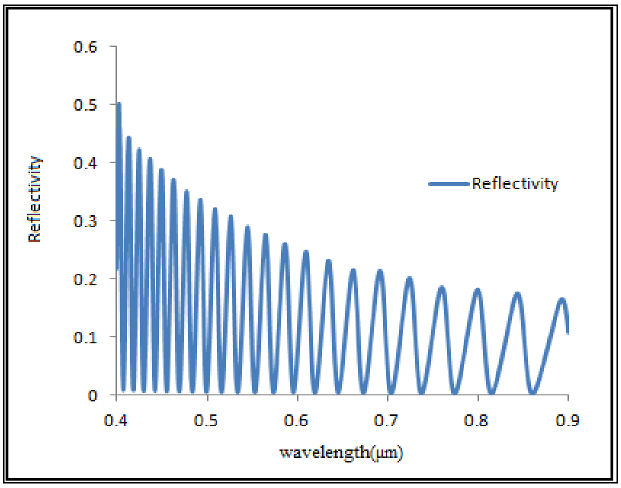
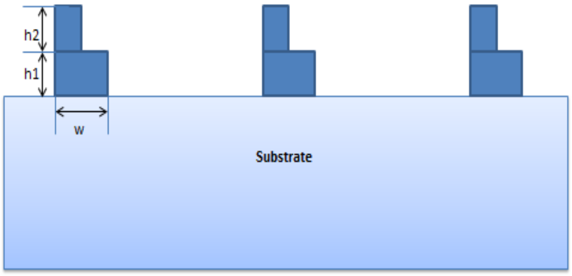


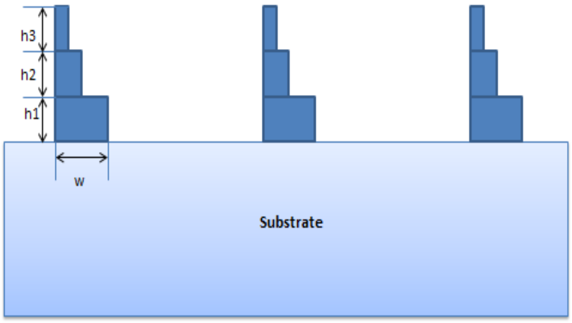
Figure 2: Reflectivity vs. wavelength characteristic for traditional grating structure at 1.55nm input wavelength

2. DESIGN AND STRUCTURE
Figure 1 shows schematic of traditional subwavelength metal grating here grating layer used is of Silica (refractive index, n=3.48). Here p is the grating period, w is the grating width and h is the grating height. So filling factor for this structure can be calculated as $f = w/p$[10]. This factor plays an significant responsibility in determining the optical properties of gratings. Owing to different materials with different reflection powers, thus choosing the right material is chief problem. In our proposed method we used layer of gratings. In order to improve reflectivity power of traditional subwavelength metal grating, subwavelength metal gratings with relief structures designed by using multiple steps are

shown in figure 3. First layer which we used is of tourmaline having refractive index 1.63, second layer we choose is of purpurite having refractive index 1.84 and third layer is lumicera having refractive index 2.08. Here we will discuss two step and three step gratings. Substrate used here is of refractive index 1.5. Heights of different layers are taken as h1, h2 and h3 respectively.



(a)



(b)

Figure 3: Representation of subwavelength metal grating with relief structure having multiple steps

3. RESULTS AND DISCUSSION

The subwavelength metal grating we used in our structure is having glass substrate and grating used is of different refractive indexes which vary layer by layer. Input wavelength used here in our design is of 1.55µm. We have calculated the results in wavelength range of 400nm to 900nm or we can say over visible and ultra violet region. We have evaluated results using Opti FDTD. Reflectivity when calculated for two step grating is about 80% but when calculated for three step grating it is about 99.9% which we can say is perfect result for reflectance. We can see that in our result we got multiple reflections. So, we can use our design as a multichannel reflector.

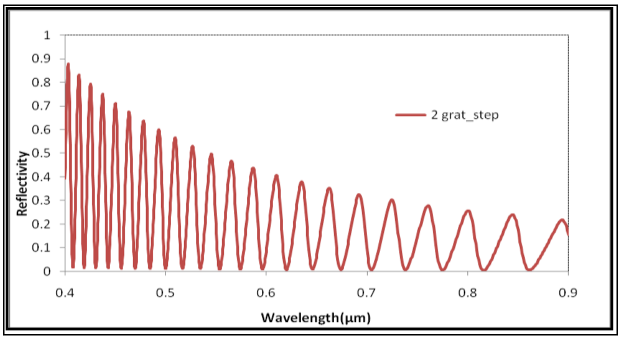


Figure 4: reflectivity vs. wavelength characteristics for 2 steps grating over visible and ultraviolet region

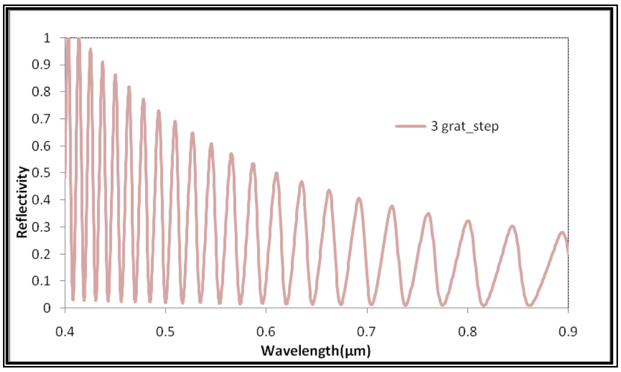


Figure 5: Reflectivity vs. wavelength characteristics for 3 steps grating over visible and ultraviolet region

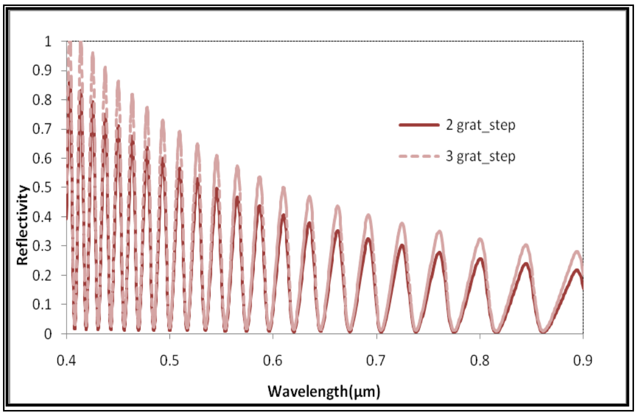


Figure 6: Comparison of reflectivity for 2 step and 3 step grating structure

As shown from our reflectivity curves, reflectivity for traditional metal grating is of about 51% but by using our design we can get reflectivity of about 99.9% by using multiple step structure.

4. CONCLUSION

In our design and analysis of subwavelength metal grating with relief structure using multiple steps we get the result of about 99.9% multiple wavelength reflectivity for 3 steps grating and 80% of multiple wavelengthreflectivity for 2 steps of grating by using Opti FDTD.

SWG with relief structure gives more exciting results than traditional subwavelength metal grating with input wavelength of 1.55µm over the visible and ultraviolet region(400 nm to 900 nm). By further tuning the filling factor, grating period, grating material or sizes, we can use our design for more purposes like multichannel wavelength filter.

5. REFERENCES

[1] V. V. Nevdakh, N. S. Leshenyuk, and L. N. Orlov, "Experimental investigation of the polarization properties of reflective diffraction gratings for CO2 lasers," *Journal of Applied Spectroscopy*, vol. 39, no. 5, pp. 1249–1254, 1983.

[2] D.-E. Yi, Y.-B. Yan, Q.-F. Tan, H.-T. Liu, and G.-F. Jin, "Study on broadband achromatic quarter-wave plate by subwavelength gratings," *Chinese Journal of Lasers*, vol. 30, no. 5, pp. 405–408, 2003.

[3] V. V. Nevdakh, N. S. Leshenyuk, and L. N. Orlov, "Experimental investigation of the polarization properties of reflective diffraction gratings for CO2

lasers," Journal of Applied Spectroscopy, vol. 39, no. 5, pp. 1249–1254, 1983.

[4] D.-E. Yi, Y.-B. Yan, Q.-F. Tan, H.-T. Liu, and G.-F. Jin, "Study on broadband achromatic quarter-wave plate by subwavelength gratings," *Chinese Journal of Lasers*, vol. 30, no. 5, pp. 405–408, 2003.

[5] L. Zhou and W. Liu, "Broadband polarizing beam splitter with an embedded metal-wire nanograting," *Optics Letters*, vol. 30, no. 12, pp. 1434–1436, 2005.

[6] S. Janz, P. Cheben, A. Delˆage, et al., "Silicon-based integrated optics: waveguide technology to microphotonics," in *Proceedings of the Materials Research Society Symposium (MRS '04)*, vol. 832, pp. 3–14, Boston, Mass, USA, November-December 2004, F1.1.

[7] N. V. Tabiryan, S. R. Nersisyan, T. J. White, T. J. Bunning, D.M. Steeves, and B. R. Kimball, "Transparent thin film polarizing and optical control systems," *AIP Advances*, vol. 1, no. 2,Article ID 022153, 2011.

[8] Y. Ye, Y. Zhou, H. Zhang, S. Shen, and L. S. Chen, "Plorizing color filter based on a submicron metal grating," *Acta Optics Sinica*, vol. 31, no. 4, Article ID 0405003, 2011.

[9] P. Cheben, "Wavelength dispersive planar waveguide devices: echelle and arrayed waveguide gratings," in *Optical Waveguides: From Theory to Applied Technologies*, M. L. Calvo and V. Lakshminarayanan, Eds., chapter 5, CRC Press, London, UK, 2007.

[10] N. Nguyen-Huu, Y.-L. Lo, Y.-B. Chen, and T.-Y. Yang, "Realization of integrated polarizer and color filters based on subwavelength metallic gratings using a hybrid numerical scheme,"

[11] P. Cheben, D.-X. Xu, S. Janz, and A. Delˆage, "Scaling down photonic waveguide devices on the SOI platform," in *VLSI Circuits and Systems*, vol. 5117 of *Proceedings of SPIE*, pp. 147– 156, Maspalomas, Spain, May 2003.

[12] Jing Nie,Hu-Quan Li and Wen Liu,,"Perfect Anomalous Absorption of TM Polarized Light in metallic grating situated in asymmetric surroundings," IEEE photonic journal,vol. 6,number 6,December 2014.

[13] A. Densmore, D.-X. Xu, P. Waldron, et al., "A silicon-oninsulator photonic wire based evanescent field sensor," *IEEE Photonics Technology Letters*, vol. 18, no. 23, pp. 2520–2522, 2006.

[14] P. Cheben, J. H. Schmid, A. Delˆage, et al., "A high-resolution silicon-on-insulator arrayed waveguide grating microspectrometer with sub-micrometer aperture waveguides," *Optics Express*, vol. 15, no. 5, pp. 2299–2306, 2007.

[15] A. Densmore, D.-X. Xu, S. Janz, et al., "Spiral-path highsensitivity silicon photonic wire molecular sensor with temperature-independent response," *Optics Letters*, vol. 33, no. 6, pp. 596–598, 2008.

[16] Zhongfei Wang, Dawei Zhang, Qi Wang, Banglian Xu, Qingyong Tang, Yuanshen Huang, and Songlin Zhuang, "High-Transmittance Subwavelength Metal Grating with Relief Structure Composed of Multiple Steps," the scientific world journal,volume 2014,18 february 2014.

[17] L. Zhou and W. Liu, "Broadband polarizing beam splitter with an embedded metal-wire nanograting," *Optics Letters*, vol. 30, no. 12, pp. 1434–1436, 2005.

[18] S. Janz, P. Cheben, A. Delˆage, et al., "Silicon-based integrated optics: waveguide technology to microphotonics," in *Proceedings of the Materials Research Society Symposium (MRS '04)*, vol. 832, pp. 3–14, Boston, Mass, USA, November-December 2004, F1.1.

[19] N. V. Tabiryan, S. R. Nersisyan, T. J. White, T. J. Bunning, D.M. Steeves, and B. R. Kimball, "Transparent thin film polarizing and optical control systems," *AIP Advances*, vol. 1, no. 2,Article ID 022153, 2011.

[20] Y. Ye, Y. Zhou, H. Zhang, S. Shen, and L. S. Chen, "Plorizing color filter based on a submicron metal grating," *Acta Optics Sinica*, vol. 31, no. 4, Article ID 0405003, 2011.

[21] P. Cheben, "Wavelength dispersive planar waveguide devices: echelle and arrayed waveguide gratings," in *Optical Waveguides: From Theory to Applied Technologies*, M. L. Calvo and V. Lakshminarayanan, Eds., chapter 5, CRC Press, London, UK, 2007.

[22] N. Nguyen-Huu, Y.-L. Lo, Y.-B. Chen, and T.-Y. Yang, "Realization of integrated polarizer and color filters based on subwavelength metallic gratings using a hybrid numerical scheme,"

[23] P. Cheben, D.-X. Xu, S. Janz, and A. Delˆage, "Scaling down photonic waveguide devices on the SOI platform," in *VLSI Circuits and Systems*, vol. 5117 of *Proceedings of SPIE*, pp. 147– 156, Maspalomas, Spain, May 2003.

[24] Jing Nie,Hu-Quan Li and Wen Liu,,"Perfect Anomalous Absorption of TM Polarized Light in metallic grating situated in asymmetric surroundings," IEEE photonic journal,vol. 6,number 6,December 2014.

[25] A. Densmore, D.-X. Xu, P. Waldron, et al., "A silicon-oninsulator photonic wire based evanescent field sensor," *IEEE Photonics Technology Letters*, vol. 18, no. 23, pp. 2520–2522, 2006.

[26] P. Cheben, J. H. Schmid, A. Delˆage, et al., "A high-resolution silicon-on-insulator arrayed waveguide grating microspectrometer with sub-micrometer aperture waveguides," *Optics Express*, vol. 15, no. 5, pp. 2299–2306, 2007.

[27] A. Densmore, D.-X. Xu, S. Janz, et al., "Spiral-path highsensitivity silicon photonic wire molecular sensor with temperature-independent response," *Optics Letters*, vol. 33, no. 6, pp. 596–598, 2008.

[28] Zhongfei Wang, Dawei Zhang, Qi Wang, Banglian Xu, Qingyong Tang, Yuanshen Huang, and Songlin Zhuang, "High-Transmittance Subwavelength Metal Grating with Relief Structure Composed of Multiple Steps," the scientific world journal,volume 2014,18 february 2014.