Low Aspect Ratio Polarizer using Sub-wavelength Grating

Introduction

Polarization based devices are used in applications like communication and projector displays. Sub-wavelength gratings (SWG), which are polarization dependent and compact, are used in these devices. Rigorous modal theory yields high aspect ratio gratings. However, there is a unique observation of the behaviour of transverse magnetic (TM) polarization that there exist several combinations of fill factor and period of the grating, in which the TM polarization waves are all in phase, regardless of the height of the grating [1]. Hence the 0th order maxima will have most of the TM power and it would suffice to constrain only the TE power to go into the -1st order. This feature leads to a simpler albeit less efficient model, for designing sub-wavelength gratings, than rigorous modal theory. In this work, we have used the simplified modal method for design at 633 nm and fabricated it using e-beam lithography.

Principle

When a sub-wavelength grating is excited by a linearly polarized plane wave discrete modes in the grating get excited as predicted by the modal theory. If the polarization makes 45° with respect to the grating lines, there will be an equal power distribution between TE and TM components. The sub-wavelength structure separates the TE and TM modes and couples them out into different diffraction orders. The polarization separation or extinction ratio is highest when the angle of incidence θ_i is equal to the Bragg angle θ_B for the one dimensional grating shown in Fig. 1.

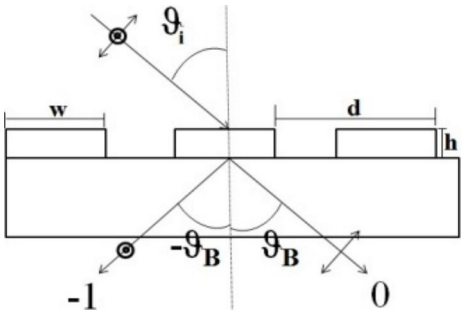

Figure 1. Polarization separation at Bragg angle

Fabrication

The grating was fabricated on poly methyl methacrylate (PMMA) using RAITH 150^{TWO} electron beam lithography system. An Indium Tin Oxide (ITO) coated glass plate was used as the substrate so as to overcome the accumulation of charge during electron beam exposure. In order to optimize parameters, writing was done for various apertures, beam currents, doses and voltages. A scanning electron microscopy (SEM) and surface profiler were used for the analysis of the surface morphology of the gratings. The grating was fabricated using an optimized exposure dose of $125\,\mu C/cm^2$ (acceleration voltage - 20 kV, aperture - 20 μm , write field - 100 μm, FBMS (fixed beam moving stage) mode).

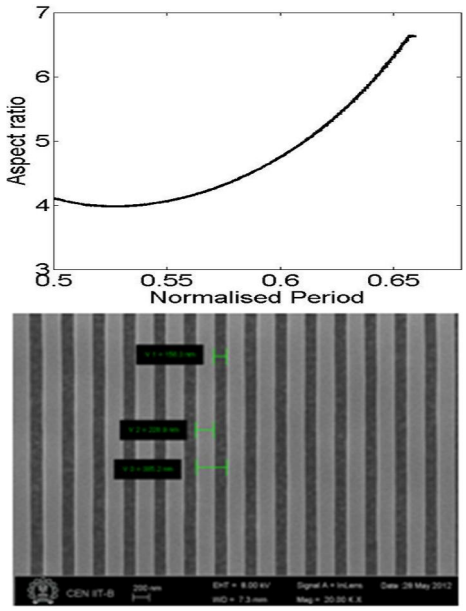

Figure 2. Top: Grating parameters that give maximum TE efficiency in -1st order. Bottom: SEM image of fabricated SWG

Conclusions

In the case of lower aspect ratio gratings, there will be coupling of evanescent modes in the diffraction orders which leads to a lower extinction ratio. Nevertheless, this can be overcome by adjusting the polarization angle of the incident light such that efficiency of TM in -1^{st} order goes to a minimum.

Publication

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Photonics Group
Department of Electrical Engineering, IIT Madras
http://optics.iitm.ac.in

G. Sridharan, V. Pramitha
S. Bhattacharya