

Design of Novel Photonic Antenna for Optical Wireless Communication by Analyzing Non Linear Filtering Effects using Advanced Optical Signal Processing Method

L.R.D.Suresh and Dr.S.Sundaravadivelu

Abstract— Many structures for photonic antenna were suggested after analyzing its ability and suitability to optical wireless communication using classical transmission line analogy. But we are using novel idea that is analyzing the non linear filtering effects of triangular grating structure with metal strips (non linear structure) and then designing the photonic antenna. We are using recent advanced optical signal processing technique namely the Beam Propagation Method for our analysis and design. The results show that the radiation efficiency and spectral width are very much improved by this structure and it is suitable for long distance optical wireless communication.

Keywords— Beam Propagation Method, nonlinear filtering, photonic antenna, optical wireless communication

I. INTRODUCTION

THE optical wireless communication is the only solution to the transmission of images due to some of the key advantages over the existing RF wireless systems; (1)large information bandwidth (THz-range), (2) low transmitted power (mW-range), (3)high directionality (beamwidth-mrad.), (4)high speed data transmission(Gb/s), (5)high signal security, (6)free from electromagnetic interference, (7)very less Bit Error Rate(10^{-12}), (8)very small size and weight of the optical components etc[1]. The optical components and devices can be developed using Integrated Optics technology in the nm range for optical signal generation, transmission and processing having considerable interest in the optical wireless communication[2]. Because of this extremely high band width and bit rates, optical wireless system is suitable particularly for image transmission and reproduction without distortion and blurring. Using recent advances in the optical technology, the Photonic Antenna structure can be integrated with other components, so that miniaturized size of the optical system can be obtained.

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Here we introduce our novel idea by means of metallic strip at the center of the triangular grating structure to improve the radiation efficiency. Among many structures the triangular grating structure with metal strip is one of the best. The triangular grating profiles are used to perform wide variety of applications like non linear filtering, coupling, polarization splitting etc[3]-[4]. The major application is the light is extracted from the surface of waveguide by the insertion of metal strip. These waveguide structures will scatter light into many directions, but the efficiency is considered to have the scattered light in particular direction only[5]. Many structures have been proposed to increase the radiation[6], but the most efficient structure is obtained by introducing non linearity by means of metal strip in the structure.

This paper intends to study the optical characteristics of a photonic antenna structure with metallic strip that can be adjustable with the wavelengths for nm-wave applications. Most of the theoretical analyses of rectangular waveguide gratings are based on equivalent transmission line analogy. Though these results achieved are quite accurate, these methods are not giving directional characteristics of structure. For this reason, it is useful to reformulate the problem using Beam Propagation Method[7] in the design with the inclusion of triangular waveguide grating profile with metal strip.

The Beam Propagation Method (BPM) is an advanced technique originally developed to calculate radiation / scattering losses due to refractive index variations in a planar waveguide and also used for bend waveguide as well as more complicated waveguide structures. The photonic antenna structure analyzed here is a triangular grating profile in association with metal strips present at the centre of gratings, using Beam Propagation Method, which is suitable for optical frequency range. With a particular attention directed towards the radiation characteristics of such structures[8] act as photonic antenna. These dielectric triangular grating profiles with metal strips are referred as photonic antennas through this paper.

From various literature survey, it is concluded that the effect of insertion of metal strip solves the diffraction of optical waves propagating into free space rather than waveguide. This paper presents a novel integrated photonic

$$\text{where, } k_x = \frac{2\pi}{\lambda} + \frac{2\pi N}{\sqrt[3]{d_1 d_2 d / 2}} + j\alpha \quad (8)$$

d_2 is width of the metal strip. The triangular index profile with metal strip is given by,

$$\begin{aligned} n(z) &= n_f + z(d-z)\Delta, & 0 \leq z \leq d_1 \text{ \& } d_2 \leq z \leq d \\ &= n_m, & d_1 \leq z \leq d_2 \end{aligned} \quad (9)$$

where n_m is the refractive index of the metal strip. The average refractive index is given by,

$$\bar{n} = (1/2) \left[\sum_{x=0}^{1.4\mu m} (n_{f_x} + \Delta) / T + (n_m) \right] \quad (10)$$

The amplitude is Gaussian mode profile and is expressed by equation(5). The input power at $z=0$ is specified by equation(6) and the power flow along z -direction is calculated using the equation(7). With the insertion of metal strips, \bar{n} is changed and the corresponding β and k_x are also changed.

III. RESULTS

This paper focused on developing the design criteria that maximize the radiation beam leaked out towards cover region and then to free space, so that these structures acts as photonic antenna. To achieve this objective, the typical photonic antenna configurations of triangular grating profile with metal strips are analyzed using BPM.

The triangular grating profile structure with and without metal strips are analyzed using BPM. The structure has film thickness(t_f) $20\mu m$, substrate thickness(t_s) $200\mu m$, grating thickness(t_g) $1.5\mu m$, the total numbers of gratings(N) are 50, non guiding layers attenuation of 1500/m, film refractive index (n_f) is 1.696, substrate refractive index (n_s) is 1.690, the triangular grating refractive index is increasing linearly from film refractive index 1.696 to 1.700, the refractive index of metal strips are taken as(n_m) 1.418 and 1.986 respectively, the values of d_1 , d_2 & d are taken as $1.5\mu m$, $0.2\mu m$ & $3\mu m$ respectively, aperture size is 40cm and the operating wavelength is 1500nm which is suitable for optical wireless communication. The input signal is launched at the centre of the film layer with normalized power. The power distributions along z -direction are calculated for every (Δz) $40\mu m$ distance with the total length of $500\mu m$.

Figs.(3),(4)&(5) are plotted in 3-dimensional axis, with waveguide width, propagation distance and normalized power distribution. The graphs show that the power distribution decreases to zero after certain Δz for these structures.

The graph is plotted (fig.6) for these optical triangular grating waveguide structures about their normalized power distribution along z -direction (propagation direction).The results show that, the power is dwindle to zero, after $200\mu m$ for triangular grating profile without metal strip, after $280\mu m$ for triangular grating profile with metal strip of refractive

index 1.418, after $160\mu m$ for triangular index profile with metal strip of refractive index 1.986 respectively. This indicates that the incident power is radiated into free space, swiftly by 1.986 refractive index value metal strip, progressively by without metal strip, leisurely by 1.418 refractive index value metal strip structures respectively.

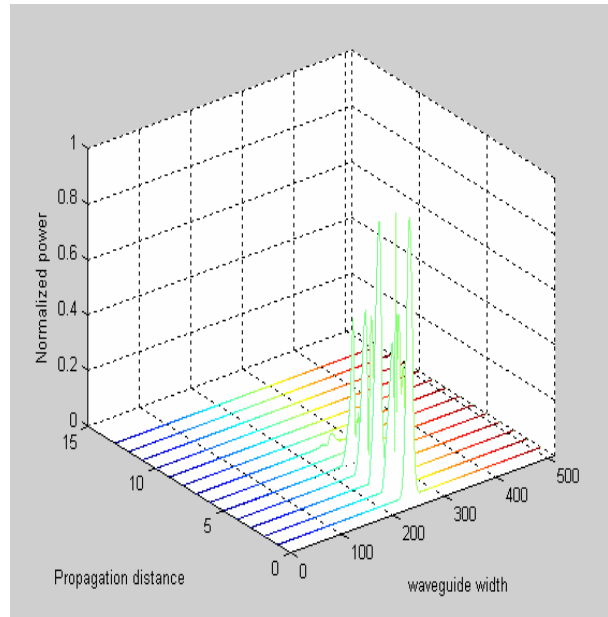


Fig.3. Power distribution of triangular grating waveguide structure with metal strip ($n_m=1.986$)

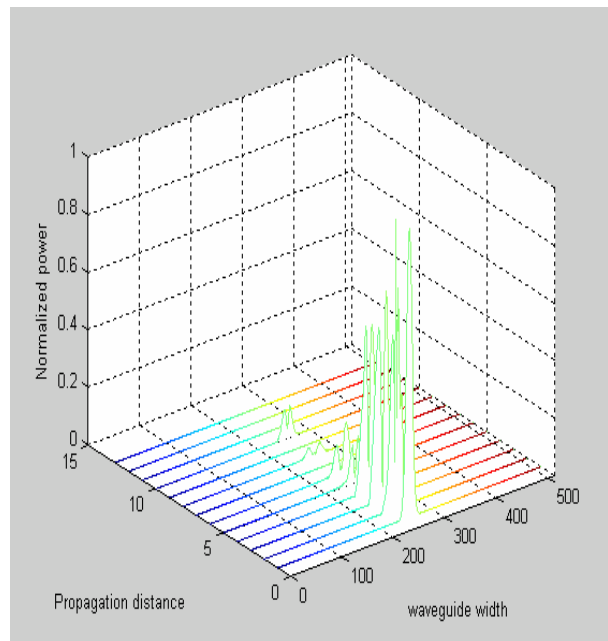


Fig.4. Power distribution of triangular grating waveguide structure with metal strip($n_m=1.418$)

Finally the graph (fig.8) is plotted flanked by power distribution inside the waveguides and the number of gratings. The consequences show that the power levels are declining exponentially along z-direction when the numbers of gratings(N) are increased for all structures. The power levels condensed to zero, at N=80 for triangular grating profile without metal strip, at N<60 for metal strip(nm=1.986), at N>80 for metal strip(nm=1.418) respectively.

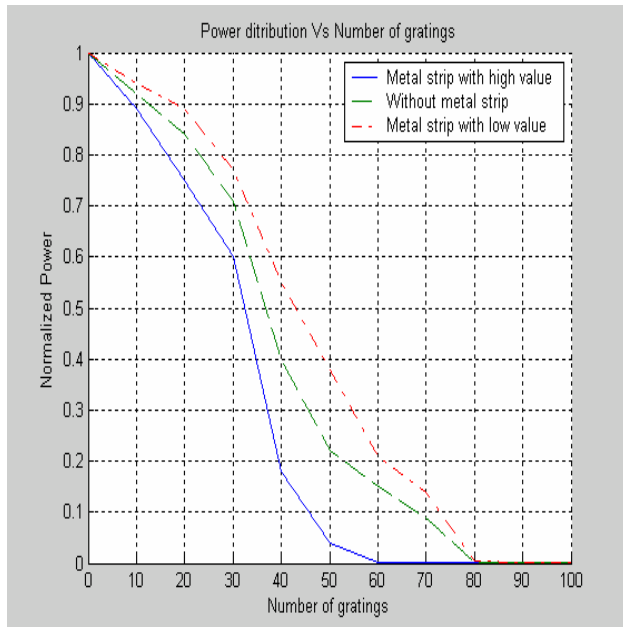


Fig.8. Power distribution of triangular grating profiles with respect to Number of gratings

IV. CONCLUSION

The triangular grating profiles with and without metal strip are analyzed using BPM. From the results, we have found out that this non linear structure act as non linear filter and directs the optical signal into free space. Hence, this structure performs an efficient photonic antenna. Due to high radiation efficiency this photonic antenna can be used for long distance optical wireless communications.

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