AN ANALYTICAL STUDY OF THE POWER DISTRIBUTION PATTERNS OF SILICA WAVEGUIDES WITH HIGH PARABOLIC CYLINDRICAL DEFORMATION

P. K. Choudhury[1] and Roger A. Lessard[2]
[1] Satellite Venture Business Laboratory
Faculty of Engineering
Gunma University
Kiryu 376-8515, Gunma, Japan
[2] Department of Physics
Faculty of Science and Engineering
Laval University
Quebec City G1K 7P4, Canada

Received 30 July 2001

ABSTRACT: *An attempt is made to determine the relative power distribution in a step-index parabolic cylindrical waveguide (PCW) with high deformation across the direction of propagation. The guide is assumed to be made of silica. The scalar field approximation is employed for the analysis under which a vanishing refractive-index (RI) difference in the waveguide materials is considered. Further, no approximation for fields is used in the analytical treatment. Due to the geometry of such waveguides, PCWs lose the well-defined modal discreteness, and a kind of mode bunching is observed instead, which becomes much more prominent in PCWs with high bends. However, with the increase in cross-sectional size, the mode-bunching tendency is slightly reduced. The general expressions for power in the guiding and nonguiding sections are obtained, and the fractional power patterns in all of the sections are presented for PCWs of various cross-sectional dimensions. It is observed that the confinement of power in the core section is increased for PCWs of larger cross-sectional size. Moreover, a fairly uniform distribution of power is seen over the modes having intermediate values of propagation constants.* © 2002 John Wiley & Sons, Inc. Microwave Opt Technol Lett 32: 127–133, 2002.

Key words: *optical waveguides; EM wave propagation*
DOI 10.1002 / mop.10110

1. INTRODUCTION

Lightwave propagation through various types of core cross-sectional waveguides constitutes an important area of investigation, and in this context, several forms of optical waveguides have appeared in the literature [1–10]. Guides with noncircular cross sections, like planar, rectangular, etc., form the basic building blocks of integrated-optics technology. Among these, parabolic cylindrical waveguides (PCWs) are those where the core section is embedded between two nonguiding claddings having parabolic cylindrical boundaries. Dielectric PCWs have been studied earlier by Choudhury et al. [11–13], and a kind mode-bunching property was indicated as one of the fundamental characteristics of such guides. They also presented the power attenuation characteristics of PCWs [14]. In their study, the guide was supposed to have a very small deformation, and under the circumstances, asymptotic representations for fields were employed. However, a rigorous study of such guides with high deformation [15] was also presented, and it was found that the mode-bunching property of PCWs becomes much more prominent in the latter case. Apart from dielectric PCWs, such guides having very small deformation, and filled up with chiral materials, were also presented by Singh et al. [16, 17], and the guide was classified as a parabolic cylindrical chirowaveguide.

In the present communication, we make an analytical estimation of the distribution of power in the different sections of a PCW with a large angle of deformation. For the analysis, no approximation for field representations is employed. However, power patterns of slightly deformed PCWs near cutoff were already presented earlier by Choudhury et al. [18, 19], and the studies were made by incorporating the asymptotic forms of field functions. In the present analytical approach, exact forms of fields are used for the determination of power distribution, and it is observed that, with the increase in waveguide thickness, the phenomenon of bunching of modes becomes less effective, and as a result, there occurs an appreciable difference in power transmitted by the different modes. For guides with lesser thickness, however, an almost equal amount of power is carried by the different azimuthal modes. This is mainly attributed to the fact that, with the increase in waveguide thickness, the sustained modes are less tightly bunched together, and therefore, different modes will carry different amounts of power; higher power is transmitted by lower azimuthal modes. Further, with the increase in average thickness of the guide, a greater amount of power gets confined in the core of the PCW. An analysis of the propagation of power in the guiding region of a highly bent PCW was presented earlier [20], where it was found that an almost equal amount of power is carried by the bunched modes in thinner PCWs, and this feature is affected for guides having higher thickness where the modes are less tightly bunched together. The present analysis is, however, more elaborate, and confirms the previous results on this issue. Further, in this study, the relative power patterns in all of the regions are taken into consideration. It is suggested that PCWs would be of immense use as waveguide directional couplers, which is because of the presence of a taper and a flare both in the core section, which are essentially required for easy launching of light signals.

2. THEORETICAL DEVELOPMENT

Figure 1 shows the parabolic cylindrical coordinate system and the transverse cross-sectional view of a PCW. For the analysis, we essentially use the parabolic cylindrical coordinate system (ξ, η, z), and the cross section of PCW assumes the area bounded by the deep solid lines in Figure 1. The core section of PCW has two parabolic cylindrical boundaries with $\sqrt{a}$ and $\sqrt{b}$ as their parametric coordinates, $2a$ and $2b$ being the latus recta of the respective parabolic sections. The waveguide bend is across the direction of lightwave propagation, which is along the direction of z, i.e., the wave propagates perpendicular to the plane of paper. Further, n_1 and n_2 $(< n_1)$ are the RI values of the core and the cladding give the limitation of high pump powers, all the devices present almost the same XL (around −1.5 dB).

For the soliton regime, in all the devices there is a decrease of XL for pump powers around 1 W, which is the energy of the fundamental soliton. For high pump powers, all devices present a second peak, and decreased XL is detected. For the *L*/10 device, the minimum (−3.7 dB) is around 8 W.

The increase of the pump power results in high-order solitons and pulse compression; in this situation the bandwidth of the pulse increases and we can extrapolate the bandwidth of the device as the XL increases.

Our study of the XL on the AOTF, operating with ultra-short optical solitons, provides possibilities for achieving high efficiency in ultrafast all-optical signal processing, especially for optical switches, filters, and optical transistors. The AOTF has attracted much attention in recent years, in part because it appears to be a suitable basis for multiwavelength optical cross-connects. It is probably the only known tunable filter capable of selecting several wavelengths simultaneously. This capability can be used to construct a multiwavelength router.

ACKNOWLEDGMENT

We thank Funcap, CNPq, CAPES, and FINEP (Brazilian Agencies) for their financial support.

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