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Research on Mode Multiplexer / Demultiplexer by Using Optical Waveguides for MDM Transmission System

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Abstract: *This paper deals with the research proposal and evaluation of a novel optical mode multiplexer/ demultiplexer. It is based on angled-multimode interference (a-MMI) waveguide for realizing compact size, low loss and high integrated mode multiplexer/demultiplexer. Previously, the optical mode demultiplexer which was based on a-MMI waveguide showed the possibility of multiplexing the fundamental and first order modes. However, the mode-crosstalk between the fundamental and first order modes are not sufficient, that is due to the insufficient focal point shift between the fundamental and first order modes for the transmission system. The proposed approach is using another type which is based on Rowland circular geometry and it has been investigated comprehensively. The principle has also been confirmed for mode multiplexing/demultiplexing process for mode division multiplexing (MDM) transmission system.*

Keywords: Rowland circle; Multiplexer/Demultiplexer; MDM; BPM

1. INTRODUCTION

Today's communication infrastructure is not imaginable without the use of optical transmission systems. The goal is always to greatly enhance data transmission capacity and improve the quality of networks for data centers and consumers in order to meet the ever growing demand. Arrayed Waveguide Grating (AWG) devices have gained so much popularity in the field of optical waveguide technology and have been considered for the design of numerous communication systems and applications. They are found to be very attractive because of their growing reputation in providing high speed connection and secure connectivity in the access network [1]. They have been widely deployed and implemented in Mode Division Multiplexing (MDM) commercial applications especially for providing high speed fiber connectivity to homes, offices and other premises. Work has been done to realize a new AWG design based on Rowland circle geometry in TE mode. Arrayed Waveguide Gratings (AWGs) are essential for MDM systems and are commonly used as multiplexers and de-multiplexers in data optical networks [2]. The sensitivity of these devices to phase errors means that a rigorous design process and simulation tool is required. However, the size and complexity of an AWG make it very challenging for most simulation tools. Due to this, BPM simulation environment was implemented.

In order to increase the multiplicity of the spatial mode to more than 100 modes, it is necessary to have a device technology capable of collectively multiplexing and demultiplexing single mode multiple modes of 100 modes or more. As the number of modes increases, the number of strong coupling waveguides on the input side of the Rowland circle increases, and there is concern that the device size will increase [3]. Also, it is desirable that the insertion loss of the device due to collective demultiplexing in 100 modes or more and the crosstalk characteristic between modes be at least -20 dB or less so that they can be branched without depending on digital processing. In this research proposal, we examined the fundamental principle and mechanism of bulk multiplexing/demultiplexing by phase control using Rowland circle approach and established the basic design technology of an optical integrated device capable of collective mux/demux of 100 modes or more and verified the possibility of a practical application.

2. PRINCIPLE AND METHODS

2.1 Working Principle (Rowland Circle)

In this research, we propose a phase control type multiplexer/demultiplexer using Rowland circle which can multiplex/demultiplex single-dimensional spatial mode. As shown in Fig.1, in the single-dimensional ν-order mode in the N strong coupling waveguides, a phase difference of $\pm \nu / (N - 1)\, \pi$ occurs between the waveguides, and the equiphase wavefront of each mode [3]. Furthermore, in the Rowland circle, as shown in Fig.2, when the equiphase planes of the input light are different, the output light condensing positions have different characteristics. Utilizing this characteristic, the condensing position for each mode differs by controlling the equiphase plane of the input single-dimensional mode, and as a result, the multiplexed mode can be collectively combined and demultiplexed. The number of modes that can theoretically be collectively combined and demultiplexed is equal to the number of waveguides on the input side, and it can be considered that bulk multiplexing/demultiplexing of 100 modes or more is possible by proper design of the input side waveguide and Rowland circle.

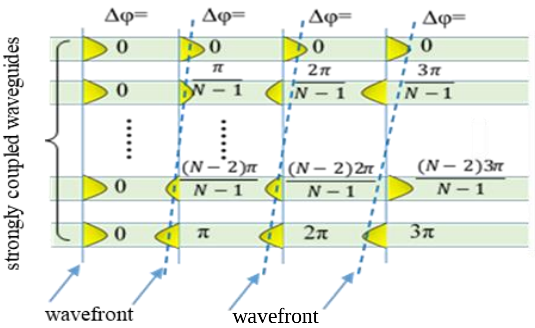

Fig.1. Field distribution characteristics of a single-dimensional mode in a strongly coupled waveguide.

2.2 BPM Simulation Environment

The beam propagation method (BPM) is an approximation technique created and developed for simulating the environment of propagation of light in a slowly varying optical waveguide. For the analysis and simulation purposes, this method was deployed in order to determine the field distributions and effective refractive index of the optical waveguide structure shown in Fig.3. First the input star coupler is simulated with BPM. For each of the array waveguides the power and phase are determined at a location where the waveguides are sufficiently decoupled. Subsequently the phase change in each array waveguide is calculated by taken into account the optical path length of waveguide. Finally, the start field for this simulation consist of the eigenmodes of each of the array waveguides, considering the proper power and phase.

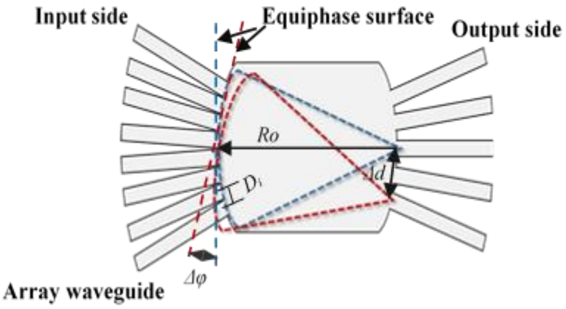

Fig. 2. Schematic view of the principle of Rowland circle in an AWG device.

Design Parameter	Value
Number of arrayed waveguides	16
Center operating wavelength	1.55μm
Arrays index of refraction	1.44
Number of input ports	9
Number of output ports	9
Wavelength channels	8
Channel spacing	16μm
AWG size L x W (mm)	12 x 1.5
Core layer material	SiO_2

Fig. 3. Star coupler design parameters in BPM.

3. RESULTS AND DISCUSSION

3.1 Design and analysis of optical waveguide device

The shape of the input star coupler is derived from Rowland circle. It is defined by the region bounded by the inner and outer circles for the coupler. In order to achieve constant light propagation and low insertion losses, the design specifications were made using SiO_2 material having a refractive index of 1.44 at a wavelength of 1.55μm and the coupler having 9 input ports and 16 output ports.

Data was acquired regarding the focus of the output power when checking for the phase variations at the array side. The maximum that was achieved was approximately 83% of focus output power was observed after the simulation was done and as low as 45% was also observed. This showed good potential and was up to expectation as the desired output power is close to 90%. This was due to the design parameters that was chosen for the device design such as the focal length of the star coupler, the length between two input ports and the length between two array ports. We examined and showed good potential for getting low crosstalk value as low as -10 dB when the arrays were strongly coupled.

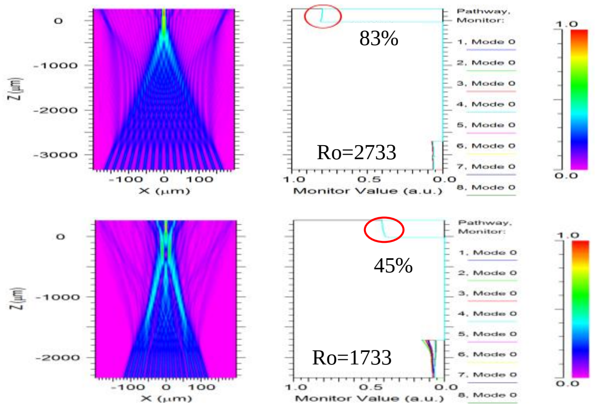

Fig.4. Propagation of light focus and output power at different Ro values.

3.2 Phase variation of different modes

The phase values and their variations were checked and confirmed for the first four modes (0^{th} to 3^{rd}). The propagation was along the z direction in order to get the correct phase values.

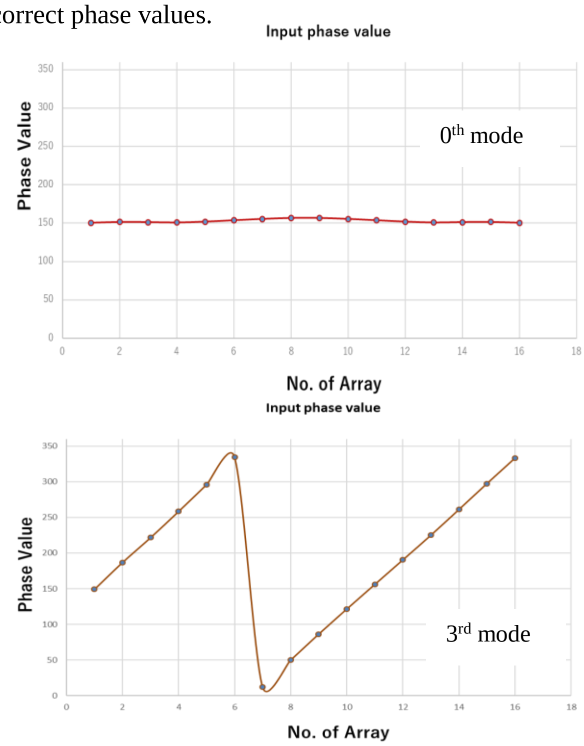

Fig. 5. Phase variations for fundamental and 3^{rd} modes

4. CONCLUSION

This work has proposed and evaluated a novel optical mode multiplexer/demultiplexer based on Rowland circular approach in order to achieve compact size, low power and insertion losses and highly integrated mode multiplexer/demultiplexer optical waveguide device. The concept and simulation results showed that it is possible to achieve higher order modes that can be realized of up to 100 modes or more and are applicable for mode division multiplexing transmission system.

5. REFERENCES

[1] Smit, Meint K., and Cor Van Dam. PHASAR-based WDM-devices: Principles, design and applications. IEEE Journal in quantum electronics 2, no. 2 (1996) 236-250.

[2] Y. Kokubun, M. Koshiba, Novel multi-core fibers for mode division multiplexing: proposal and design principle, IEICE, Volume 6, Issue 8, (2009) 522-528.

[3] Kokubun, Yasuo. Input/output channel coupling devices for SDM and MDM. In OptoElectronics and Communications Conference (OECC), IEEE, (2016) 1-3.