UNIVERSITI PUTRA MALAYSIA

DESIGN AND DEVELOPMENT OF VARIABLE FIBER OPTIC COUPLER

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By

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

DESIGN AND DEVELOPMENT OF VARIABLE FIBER OPTIC COUPLER

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Chairman: Associate Professor Mohd Khazani Abdullah, PhD

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This thesis presents the research works on design, development and analysis of variable fiber optic coupler.

The fiber couplers are devices that distribute light from a main fiber into one or more branches of fibers which can be used as a power divider, wavelength-division multiplexer (WDM) and optical switches. These couplers are important in all fiber optic networks as they are used in long haul, metro, distribution and access fiber networks. With the widely increasing deployment of metropolitan area network, fiber-to-the-home (FTTH) and cable TV networks, the market potential for the fiber couplers is becoming larger.

However, most of the fiber couplers can only provide a fixed optical coupling ratio which is unable to provide flexibility, reliability and scalability. The evolution of the telecommunications networks has created an increasing demand for the variable fiber

couplers, but there are some limitations of the existing variable fiber couplers such as unstable, small tuning range of coupling ratio, high in loss and costly. Hence, this gives rise to the need for searching new design of developing better performance variable fiber couplers. The new design utilize a fix coupling ratio Fused Biconical Tapered (FBT) coupler that is involved low loss coupling process and low in cost. This coupler is known as a Variable Fiber Optic Coupler (VFOC).

There are two approaches used in this thesis that are simulation and experimentation. The simulation is important in designing the VFOCs, as through the simulation process, the characteristic of the design VFOCs can be determined. The successful simulation is then realized through the experimentation, which is included the fabrication of the VFOCs. However, the results obtained from the experiments are slightly different from the simulation results. These are due to the losses in the experiments and the ideal environment in the simulation.

In the experiment, the variable coupling ratio is achieved by applying deflection to the fabricated FBT couplers. The dependency of the variable coupling ratio on the deflection is elaborated. It is found that in the range of 0.8 mm deflection, the coupling ratio can be varied from 11% to 92% with the excess loss less than 0.1 dB.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

REKABENTUK PENGGANDING GENTIAN OPTIK BOLEH UBAH

Oleh

MARSYITA HANAFI

Januari 2006

Pengerusi: **Profesor Madya Mohd Khazani Abdullah, PhD**

Fakulti: **Kejuruteraan**

Tesis ini mempamerkan penyelidikan pada rekabentuk dan analisis bagi pengganding gentian optik boleh ubah.

Pengganding gentian adalah peranti yang mengagihkan cahaya daripada gentian utama kepada satu atau lebih cabang gentian yang boleh digunakan sebagai pembahagi kuasa, pemultipleks pembahagian gelombang (WDM) dan suis optik. Pengganding adalah penting dalam semua rangkaian gentian optik kerana mereka digunakan di dalam rangkaian gentian berlanjutan, metro, pengagihan dan capaian. Dengan peningkatan penggunaan rangkaian kawasan metropolitan, gentian ke rumah (FTTH) dan rangkaian kabel TV, potensi pasaran untuk pengganding gentian semakin berkembang.

Sungguhpun begitu, kebanyakkan pengganding gentian hanya boleh memberikan gandingan nisbah optik yang tetap, yang tidak berupaya memberikan kebolehlenturan,

kebolehpercayaan dan kebolehskalaan. Evolusi rangkaian telekomunikasi telah mewujudkan peningkatan dalam permintaan terhadap pengganding gentian pemboleh ubah, tetapi terdapat beberapa kelemahan pada pengganding gentian pemboleh ubah yang sedia ada seperti tidak stabil, julat penalaan gandingan nisbah yang kecil, kehilangan yang tinggi dan mahal. Oleh yang demikian, ini meningkatkan keinginan untuk mencari reka bentuk baru bagi penghasilan pengganding gentian pemboleh ubah yang berprestasi lebih baik. Rekabentuk baru menggunakan pengganding FBT dengan nisbah gandingan tetap yang melibatkan proses gandingan kehilangan rendah dan murah. Pengganding ini dikenali sebagai pengganding gentian optik boleh ubah (VFOC).

Terdapat dua pendekatan yang digunakan di dalam tesis ini iaitu simulasi dan pengujikajian. Simulasi adalah opsyen mutlak dalam merekabentuk semua VFOC, di mana melalui proses simulasi, ciri-ciri bagi rekabentuk semua VFOC boleh ditentukan. Kejayaan simulasi boleh direalisasikan melalui pengujikajian, iaitu termasuk pembikinan semua VFOC. Sungguhpun begitu, keputusan yang diperolehi daripada pengujikajian adalah berbeza sedikit daripada keputusan simulasi. Ini adalah disebabkan kewujudan kehilangan dalam pengujikajian, dan persekitaran unggul di dalam simulasi.

Berdasarkan keputusan pengujikajian, keboleh lenturan nisbah gandingan bagi semua VFOC terbikin telah ditunjukkan. Nisbah gandingan pemboleh ubah diperolehi dengan menggenakan pesongan kepada pengganding FBT terbikin. Kebergantungan

nisbah gandingan pemboleh ubah ke atas pesongan dihuraikan. Didapati bahawa di dalam julat pesongan 0.8 mm, nisbah gandingan boleh diubah daipada 11% kepada 92% bersama kehilangan lebihan kurang dari 0.1 dB.

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I certify that an Examination Committee met on 27th January 2006 to conduct the final examination of Marsyita Binti Hanafi on her Master of Science thesis entitled "Design and Development of Variable Fiber Optic Coupler" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

MARSYITA HANAFI

Date: 21 MAR 2006

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background

The development of fiber optic communication technology has increased tremendously with numerous applications. The applications are widespread involving voice, data and video transmissions and sensor application. As the world becomes more reliant on information technology, the need for a wider bandwidth data transmission has increased dramatically. The introduction of internet, video conferencing, Cable Television (CATV), Fiber-To-The-Home (FTTH) and Fiber-To-The-Office (FTTO) have also boosted more research on providing a larger information capacity (Yohji, 1990), (Kashima, 1995).

Concurrent with these, a lot of research and development have been done in several fields of optical fiber. These include the optical fiber networking system, characterization of single mode and multimode fiber and optical fiber devices such as polarization controller, modulators, power divider, passive filters, fiber amplifier and optical fiber coupler. Among all of the devices, optical fiber coupler is one of the important components in an optical fiber communication system.

The optical fiber coupler is a device that distributes light from a main fiber into one or more branches of fibers. This device split (demultiplex) or combine (multiplex) the optical signals passively (Mynbaev, 2001). Optical fiber couplers are important devices in fiber application such as high-speed data link systems, wavelength multiplexer-demultiplexer systems, coherent system, fiber sensors and fiber optic measurement systems. As the dynamic networks become more popular, such as the widely increasing deployment of metropolitan area network, fiber-to-the-home (FTTH) and cable TV networks, the demand for the fiber couplers has increased (Liu et al., 2005).

However, most of the fiber couplers can only provide a fixed optical coupling ratio which is unable to provide flexibility, reliability and scalability. Hence, the evolution of the telecommunications networks has created an increasing demand for the variable fiber couplers that are able to provide flexibility for optical network to maintain power equilibrium and maintain the quality of the network transmission (Liu et al., 2005), but there are some limitations on the existing variable fiber couplers such as unstable, small tuning range of coupling ratio, high in loss and costly. Hence, the need for a new designs of developing better performance variable fiber couplers. This coupler is known as a Variable Fiber Optic Coupler (VFOC). This project focuses on the design and development of the VFOC.

1.2 Problem Statement

The fabrication methods for the existence variable fiber couplers are mainly classified into two types, which are mechanical-polishing method (Digonnet et al., 1982) and Fused Biconically Tapered (FBT) method (Murphy et al. 1991). In mechanical-polishing method, couplers are fabricated by polishing each of two fibers and placing the two polishing faces in contact. Disadvantages of this method are that the polishing technique needs to be extremely accurate; the coupler characteristics are unstable and high in cost (Noda et al., 1987).

In the FBT method, the variable fiber couplers are fabricated by thermally fusing two fibers and elongating them (Murakami et al., 1981). The tuning of the coupling ratio were produced by a slight lateral shift of the unpackaged coupler (Hill et al., 1981) or by varying the depth of insertion of the screw gauge within the package which lead to a bending of the coupler (Murphy et al. 1991) and or by moving one of the elongations stages along a circular arc centered directly at the bare coupler (Birks et al. 1992). Although the coupling ratio can be tuned for that devices, there are some problems such as difficulty in producing coupler with a high tuning resolution, high in loss and the possible changes in the coupling ratio due to packaging conditions. For example, when coupling ratio is tuned from 0% until 60%, the obtained excess loss is quite high, which is 0.55 dB (Hill et al., 1981). Birks et al. have improved the values, at 80% of tuning range of the coupling ratio, the excess loss can be reduced until 0.3 dB. However, the coupler can easily break as the bending is directly on the bare coupler.

For this reason, it is desirable to improve the performance of the variable fiber couplers

1.3 Objectives

The objective of this research is to produce VFOC with a dynamic coupling ratio at a minimum loss and therefore, in the thesis, a design and development of the Variable Fiber Optic Coupler (VFOC) that consist of a fix Fused Biconically Tapered (FBT) coupler, which is fabricated from the FBT method is reported.

1.4 Scope of Work

There are two approaches taken in conducting this study, which are the software simulation and hardware implementations. The early stage of designing the VFOC utilizes the software. The selection of the software is based on the features that can help the simulation process of the device, and in this case the software used is BPM_CAD. The aim of this simulation is to identify the device that can produce an optimum performance, and then to be implemented on the hardware, which are fabricated using the FBT method.

In the simulation, the parameter under study is design parameters such as bending angle, coupling length, core diameter and operating wavelength. The design parameters are important as they will affect the VFOC's performance. For example,