High Reliability Fan-in / Fan-out Device with Isolator for Multi-core fibre Based on Free Space Optics

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Abstract We developed a fan-in / fan-out (FIFO) device with an isolator with high reliability. We clarify the manufacturing accuracy to obtain high reliability in actual manufacturing. We conducted high-power optical input test using this device as practical reliability indicators and obtained good results.

Introduction

In recent years, the demand for network services such as web conferencing and video distribution has expanded communication traffic rapidly, and various researches on space division multiplexing (SDM) have been conducted to address them[1]. Practical research on systems using multi-core fibres (MCF) in SDM has become active as the next target[2]. There is a field of optical amplifiers as a practical research example using these MCFs[3], and this time I would like to propose a more effective device specialized for optical amplifier applications. As is generally known, an isolator is indispensable for an optical amplifier, and the same applies to a system using an MCF. In the past reported cases, there were cases where the light of each core of the MCF was separated by a FIFO device and an isolator was installed in each[4], and cases where an isolator was manufactured by MCF without using a FIFO device[5]. In this way, the isolator is indispensable for the optical amplifier, and the FIFO device is also indispensable for the MCF transmission systems. Furthermore, in devices using multi-core fibres, there have been no cases of examining the reliability for input optical power for optical amplifiers.

In order to solve this problem, we verified the structure of a device using MCF that can withstand high optical input power, and based on this result, we developed a device that combines the functions of FIFO and isolator. In this report, we clarify the manufacturing accuracy to obtain high reliability for devices using multi-core fibres and report the evaluation results of actually manufactured devices.

Structure proposal

Figure 1 shows a schematic view of FIFO device with isolator. As shown in this figure, it consists of bundle fiber, two same aspherical lenses, isolator, and MCF. The feature of this device is that a 4f imaging system with 1x magnification with less lens aberration and an isolator are installed between these two lenses. The merit of this configuration is that it functions by simply inserting a functional element between the two lenses and that it can follow the design of conventional optical devices. As a benefit of this, All of the optical elements actually used are commercially available products that are generally used for optical communication.

For example, the lens used has a focal length of 1.8 mm, and the isolator core has an effective diameter of φ0.9 mm, both of which are standard. The key element of this configuration is to adopt a bundle structure with the same core pitch for the fan-in part. The bundled optical fiber is a standard Single-mode fiber with an MFD of 8.6 μm (1310 nm) that complies with the ITU-T G.652.B standard and has been reduced in diameter by etching. The diameter of the etched part is reduced to 40 μm, which is the same as the core pitch of MCF. We used uncoupled 4-core MCF with a φ125μm cladding diameter which is a recent trend.

Consideration of loss and high power optical input in optical devices

Optical devices generally used in optical amplifiers are required to have high reliability for optical input power. It has been pointed out that the upper limit of the optical input power to the

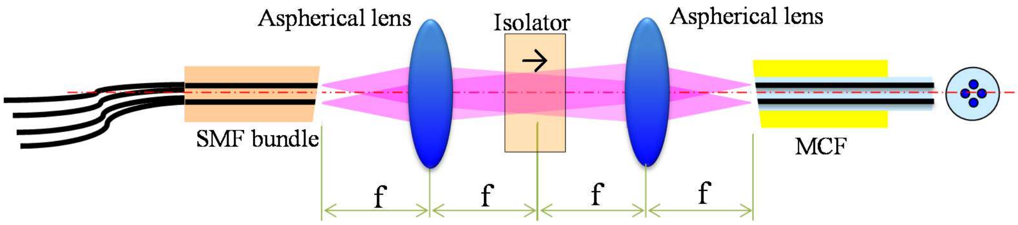

Fig. 1. Schematic view of FIFO device with isolator function

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optical fiber is related to the fiber fuse, and it is reported that it is induced by the heat generation of the fiber and is generated at about 1.4 W[6]. This means that optical devices are also required to withstand this optical input power. In the case of a device using a MCF, the number of cores is added, so consideration for optical input power becomes even more important.

The cause of failure at high optical inputs in optical devices is the generation of heat from losses. Therefore, we considered subdividing and analyzing the loss factors. Optical device loss factors include transmission loss, reflection loss, and misalignment loss. Since transmission loss and reflection loss can be dealt with by selecting appropriate materials and applying antireflection coating, the main cause of loss is misalignment. Furthermore, the classification of loss due to misalignment loss includes misaligned position, misaligned angle, and misaligned focus. We conducted an experiment to see if there was a difference between these misalignment types and the device temperature.

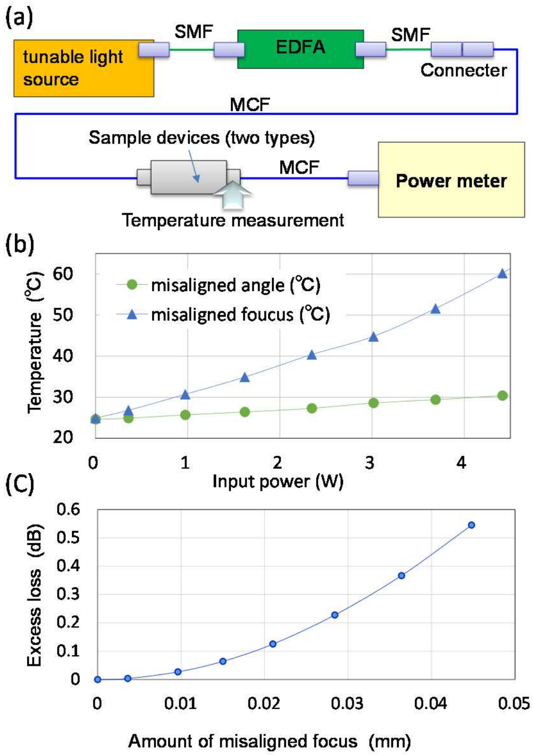

Fig. 2: (a) Experimental setup for measuring input power and temperature of two loss types, (b) The relationship input power and temperature of two loss types, (c) The relationship amount of misaligned focus and excess loss

Figure 2 (a) shows this experimental setup. We prepared two types of optical devices for using MCF that generated a loss of 0.5 dB due to misaligned angle and misaligned focus, and investigated the relationship between light input power and temperature. Figure 2 (b) shows the experimental results. As can be seen from the graph, it was found that the misaligned focus significantly increases the temperature of the device even though the two factor types have the same amount of loss. Comparing the amount of temperature change between the misaligned angle and the misaligned focus, there was a difference of about 5 times. From this result, assuming that the temperature rise and the loss amount are in a proportional relationship, it is necessary to suppress the loss due to misaligned focus to about 1/5. Figure 2 (c) shows the relationship between the amount of misaligned focus and excess loss. As mentioned above, 0.1 dB is a guideline for the loss amount of 1/5. From this graph, in order to suppress the loss due to misaligned focus to 0.1 dB, it is necessary to suppress the amount of misaligned focus within 0.02 mm from the target value. This is important to ensure reliability for high optical input power in optical devices. The FIFO device with isolator manufactured this time was manufactured in consideration of this.

Characteristics of FIFO with isolator

In this report, we report on the characteristics of the five manufactured device. Figure 3 (a) shows an external photograph of the FIFO device with isolator. Figures 3 (b) and (c) show insertion loss and isolation at a measurement wavelength of 1550 nm. The device size is 5.8 mm in outer

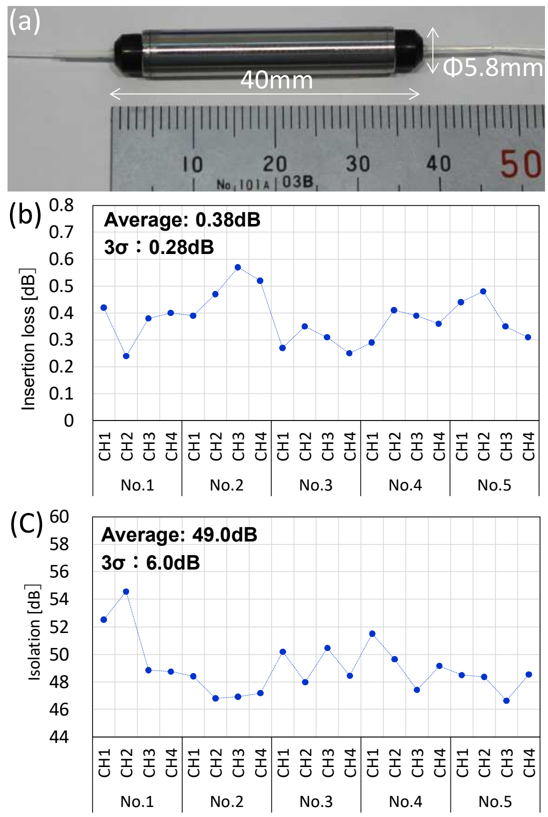

Fig. 3: (a) Photograph of the fabricated FIFO with isolator, (b) Insertion loss for FIFO with isolator, (c) Isolation for FIFO with isolator

diameter and 40 mm in length. The average value of insertion loss was 0.38 dB, and the 3σ value was 0.28 dB. The average isolation was 49dB and the 3σ value was 6.0 dB. In this way, good characteristics were obtained.

High-power optical input test for FIFO with isolator

This high-power optical input test was conducted using one of the five manufactured devices this time. The device used for this test was No. 2. This device's average loss is the highest. This reason is that, a device with a large loss is that the light could not be coupled to the core that stays in the device and has a high probability of failure when high power light is inputted.

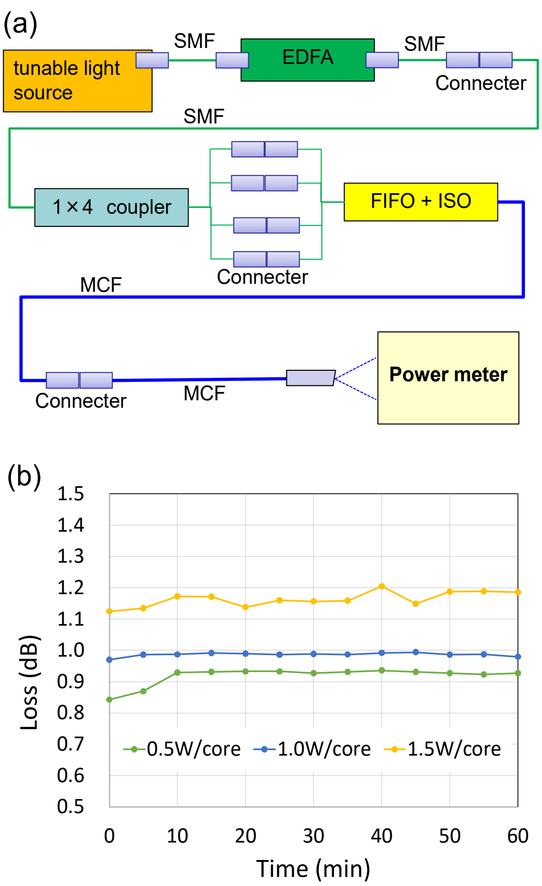

Fig. 4: (a) Experimental setup for high-power optical input test, (b) result of high-power optical input test

Figure 4 (a) shows the Experimental setup for this test. The light from the tunable light source is amplified by an optical amplifier and input each core of the device with a 1x4 optical coupler, and the light output from all the cores is passed through a fiber with a connector manufactured by MCF. Finally It is received this light by a power meter. The conditions of the input optical power are set to three levels of 0.5W, 1.0W, and 1.5W for each core, and all of them are continuously incident for 1 hour. Figure 4 (b) shows the result of this test. This result shows the one-hour loss variation in the loss of the measurement system. From the results, the loss tended to increase at the beginning of the measurement, but it was stable after that. On the other hand, the loss increased as the input power increased, after this test, it was found that this device's loss has not been fluctuated and the loss of the 1x4 optical coupler has been increased. Thus, it was found that there is no problem in the characteristics of this device when the high-power optical is inputted under this condition.

Conclusions

We developed a FIFO device with an isolator. In the manufacture of this device, we clarified the loss factor and the manufacturing accuracy that suppresses the temperature rise of the device when inputting high-power light to a device using MCF. In the high-power optical input test conducted as a reliability test using the actually manufactured device, the loss did not increase even if 1.5 W / core was continuously input for 1 hour. In this way, it was confirmed that this new device sufficiently meets the performance required for optical amplifiers. We believe that the new device shown in this work is an indispensable device for realizing the SDM optical network in the future.

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