Spatial Light Wide-View of Field Reception Based on Fiber Mode Couplers

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***Abstract*—A fiber mode coupler is prepared by using the melt-drawn cone method, which is used in spatial light-fiber reception experiments achieve wide-view of field reception with higher lateral offset tolerance characteristics.**

Keywords—fiber mode coupler, coupling efficiency, lateral offset tolerance, spatial light-fiber reception

I. INTRODUCTION

The purpose of a spatial optical coupling system is to couple the signal light into the receiver optics as much as possible [1]. How to couple spatial light into the fiber to achieve efficient and stable coupling is a challenge [2]. Since spatial optical fiber generally adopts single mode transmission, coupling the beam into the single-mode fiber (SMF) with the core diameter of only 9μm leads to small displacement tolerance of the optical coupling efficiency of the system, which seriously affects the spatial fiber coupling efficiency and communication quality at the receiver [3,4]. Multi-mode fiber (MMF) can effectively improve the light receiving range of the fiber due to its large mode field diameter, but it is difficult to achieve long-distance transmission due to the presence of more mode dispersion, and there is also a matching problem with single-mode devices at the back end [5]. Therefore, it is of unique significance to combine MMF and SMF to achieve wide field-of-view spatial fiber reception.

In this letter, a fiber mode coupler (FMC) with conversion efficiency higher than 95% and loss less than 1dB is prepared. The FMC can convert the input large-area mode into fundamental mode transmission. Therefore, the FMC can be applied to the spatial light-fiber receiving system, which can effectively improve the transverse tolerance characteristics of the system. The coupling efficiency and lateral offset tolerance of SMF, MMF and FMC are analyzed experimentally.

II. SIMULATION AND PREPARATION OF FMC

Rsoft was used to build a lens-fiber based on the coupling model. The fiber types were defined as the SMF and taper. Fig. 1(a) is a lens-SMF coupler model when the dx=0 μm and its coupling efficiency is about 80%; Fig. 1(b) is a lens-taper coupler model when the dx=0 μm, it can be seen that the coupling efficiency is almost 60%.

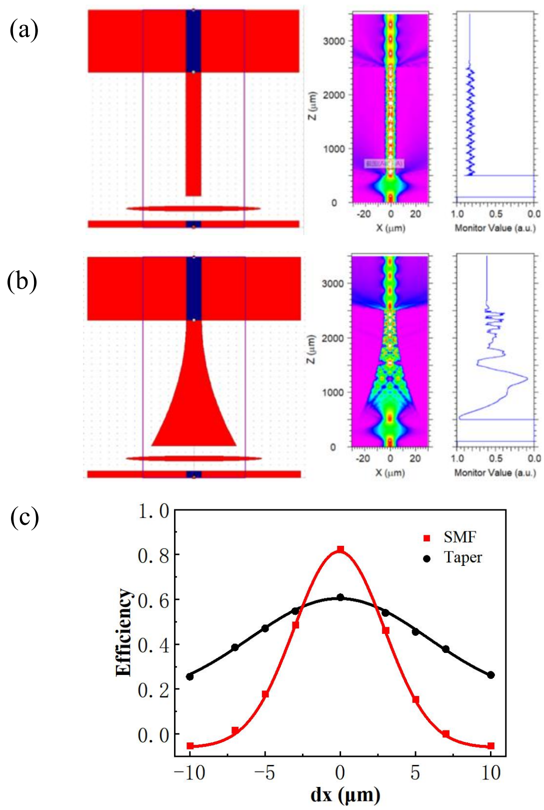

Fig. 1. (a) The lens-SMF coupler model when the dx=0 μm and its coupling efficiency; (b) The lens-taper coupler model when the dx=0 μm and its coupling efficiency; (c) Comparison of SMF and FMC spatial optical-fiber coupling efficiency simulation curves.

The parameters were set to change the position of the receiving fiber relative to the lens, thus plotting the transverse offset curves of the SMF and Taper. It can be seen from Fig. 1(c) that the maximum coupling efficiency of the Taper is less than that of the SMF, but the lateral offset tolerance is better than that of the SMF. The simulation proves that tapered fiber can realize wide-field receiving in space optical coupling.

Therefore, through the above simulation, the FMC was prepared by fusion pull-cone method. The laser is fed from the MMF input and passes through the cone region of the two fibers for energy coupling and mode conversion. The fundamental mode is output from the SMF, and the higher-order mode is output from the MMF.

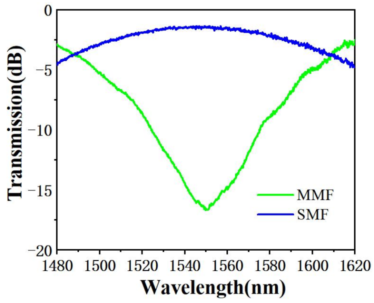

Fig. 2. The mode conversion efficiency of the FMC at 1550 nm.

By setting the appropriate parameters through the software of the taper puller, couplers with high coupling efficiency and low loss can be obtained. The mode conversion efficiency of the FMC at 1550 nm as shown in Fig. 2, indicates that the mode conversion efficiency exceeds 15 dB (~96.8%) over a wide wavelength range (~20 nm).

III. Experiment and Results

The schematic diagram of the FMC-based receiver experimental system is shown in Fig. 3(a).

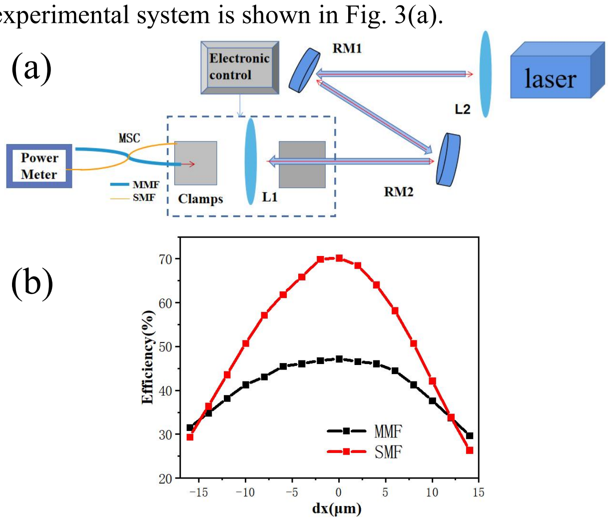

Fig. 3. (a) Diagram of the spatial light-FMC experimental setup. L1, L2: Lens; RM1, RM2: Reflective Mirror; (b) SMF and MMF spatial light-fiber coupling efficiency diagram.

The laser at 1550 nm is focused by the lens and reflected into the fiber to realize the spatial light coupling with the MMF. Visible light is input from the fiber end to achieve calibration with the optical path, while the fiber platform is then fine-tuned by observing the power at the fiber end, and the electric control platform is subsequently adjusted to record the output power after the lateral offset.

Firstly, two direct coupling methods between free-pace and the fibers are compared as shown in Fig. 3(b). The direct coupling into the SMF with a maximum coupling efficiency of SMF is about 70%, which is a little lower than the simulation result due to the small core diameter of the SMF. The coupling to the MMF connected with a SMF is used as the receiver with the maximum coupling efficiency of MMF is 47.2% due to the mode mismatch, but the lateral offset characteristic is better than SMF fiber, because the MMF holds larger core diameter and can receive more beams, which is consistent with the theory.

In order to improve the coupling efficiency when using the MMF, the home-made FMC is used and the coupling efficiency greater than 95% and loss less than 1dB for space light-fiber acceptance experiments. The coupling efficiency of the FMC and SMF was compared, as shown in Fig. 4. The maximum coupling efficiency of this FMC is 55.7%, 10% higher than MMF reception and consistent with simulation results.

Finally, the lateral offset characteristics of FMC and SMF are compared, the comparison results are shown in Fig. 4 (b). As can be seen that the FMC has better transverse tolerance than that of the SMF.

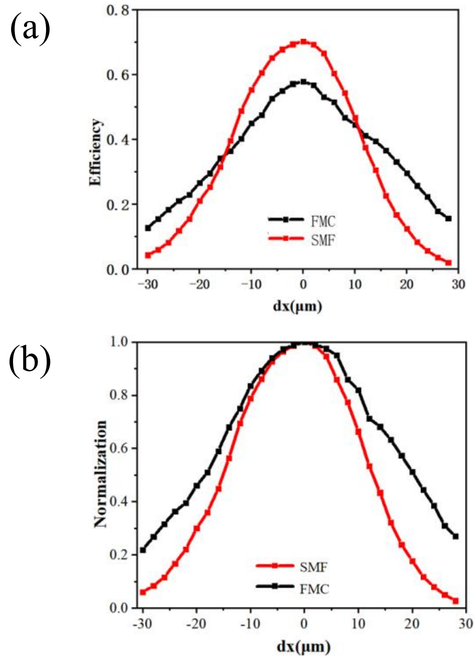

Fig. 4. (a) Comparison of coupling efficiency for FMC and SMF receiver; (b) normalized coupling efficiency.

IV. Conclusion

In summary, we prepared a FMC with coupling efficiency greater than 95% and loss less than 1dB. Then, applied the FMC to the space fiber receiving system. Compared with MMF spatial light-fiber coupling, the maximum coupling efficiency is increased by almost 10%. Comparison with SMF shows that FMC has better lateral bias tolerance and is more favorable for optical coupling. Therefore, the FMC prepared in the experiment can obtain high coupling efficiency and wide field of view spatial light reception.

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