YOFC_17022_WP

New Type of Optical Fibre Communication Device-Photonic Lantern

With the gradually improvement of social informalization degree, since 2000 the information data traffic has been increasing dramatically, the growth rate of 10 years is over 100 times, and the transmission capacity has nearly reached the non-linear Shannon limit of the current single-mode fibre communication system. In order to break this limit, multiple solutions have been put forward by home and abroad researchers, in which the mode-division multiplexing technology using spatial dimension is considered to be the most practical solution. The mode-division multiplexing technology uses the orthogonality between different modes of few-mode and multimode fibre to increase the number of information transmission channels to improve the information transmission capacity. Concrete manifestation of this technology is to load different signals of multiple channels on the different modes at the transmitting terminal and to divide the signals at the receiving terminals to realize the transmit-receive of information, and one of the key devices is the mode multiplexer and demultiplexer. Where since the low loss, small crosstalk and excellent electromagnetic interference resistance performance, the all-fibre photonic lantern has become the most popular mode multiplexer and demultiplexer.

1. The Principle of Photonic Lantern

The realization of photonic lantern is based on the mode multiplexing technology of few-mode fibre by using the mutually independent orthogonal mode of few-mode fibre as the independent communication channel to improve the communication capacity exponentially. The information transmission between different modes of few-mode fibre is shown in the Figure 1. Besides, compared with single-mode optical fibre, the mode area of few-mode fibre is larger, due to which the tolerance of non-linear effect has been improved accordingly. In that way, not only the transmission capacity but also the Shannon limit has been improved, which greatly increased the communication capacity of all optical fibre communication system.

YOFC reserves the right to the final interpretation of the above terms.

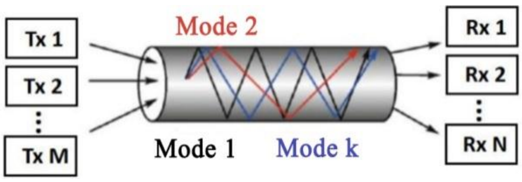

Figure 1 Schematic Diagram of Information Transmission between Different Modes of Few-mode Fibre

Take the tapered three-mode-selective photonic lantern as the example for the representation of mode multiplexing technology: three single-mode fibres has been closely and symmetrically distributed in the glass sleeve of which refractive index is slightly lower than optical fibre cladding by three-mode-selective photonic lantern, then the whole sleeve will be tapered. In the process of taper, the diameter of optical fibre core will gradually decrease, since that most parts of laser has leaked from the optical fibre core to the cladding and the optical fibre and the original cladding form an ineffective waveguide structure. Meanwhile, the original cladding of each optical fibre is fused with the original cladding of adjacent optical fibre, which gradually forms a new optical fibre guide light core. In the process of taper, the outer glass sleeve becomes the new cladding and the overall structure forms a new optical fire core/cladding waveguide. The connection of taper end of photonic lantern and few-mode fibre realizes the transformation of multiple fundamental modes into higher order mode to achieve the effect of mode multiplexing. Effective refractive index and mode elevation of three-mode-selective photonic lantern is shown in Figure 2.

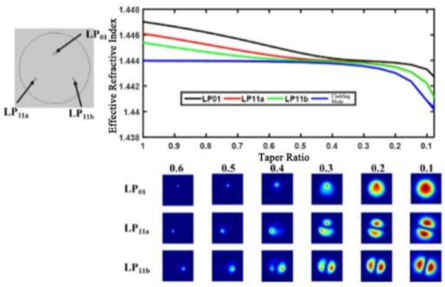

Figure 2 Schematic Diagram, Effective Refractive Index Curve and Mode Elevation Diagram of Three-mode-selective Photonic Lantern

2. The Fabrication of Photonic Lantern

Up to now, the photonic lanterns have been reported to include three major types of photonic lantern, such as the ultra-fast laser inscription photonic lantern, multi-core fibre photonic lantern and optical fibre cluster photonic lantern. The former two types of photonic lantern require the introduction of additional equipment or the addition of optical interface during the separate waveguide input or output and the connection with standard single-mode optical fibre, which is difficult in the technical level and may cause additional loss.

The basic structure of optical fibre cluster photonic lantern is by implanting single-mode optical fibre cluster into low refractive index capillary tube to perform fused biconical taper to form a waveguide structure which is similar to the few-mode fibre in the waist area. Theoretical and experimental studies show that for each photonic lantern, the number of optical fibre depends on the number of modes required, and the most ideal number and arrangement of single-mode fibre are unique and certain. The design purpose of lossless photonic lantern is that the finished size of single-mode fibre shall be closed to the size of few-mode fibre core to which single-mode fibre is spliced after the taper. When the optical core is isolated or weakly coupled, its supermode or the combination of supermode will be similar to the finished few-mode waveguide structure (coupled mode field distribution can be regarded as the superposition of isolated modes, which is also called supermode).

Yangtze Optical Fibre and Cable Joint Stock Limited Company (hereinafter referred to as YOFC) cooperates with the team of Professor Wu Jian (Institute of Information Photonics and Optical Communications, BUPT) to optimize the taper process on the own optical fibre processing platform and use the self-produced specialty optical fibre and low refractive index capillary tube to make the first domestic finished optical fibre cluster photonic lantern (Figure 3) by the adiabatic taper process. On the basis of the research, the National Natural Science Foundation of China (the theoretical and experimental study of all-fibre mode selective multiplexer/ demultiplexer for weakly coupled mode-division multiplexing communication systems) was successfully applied (project approval number: 61875019).

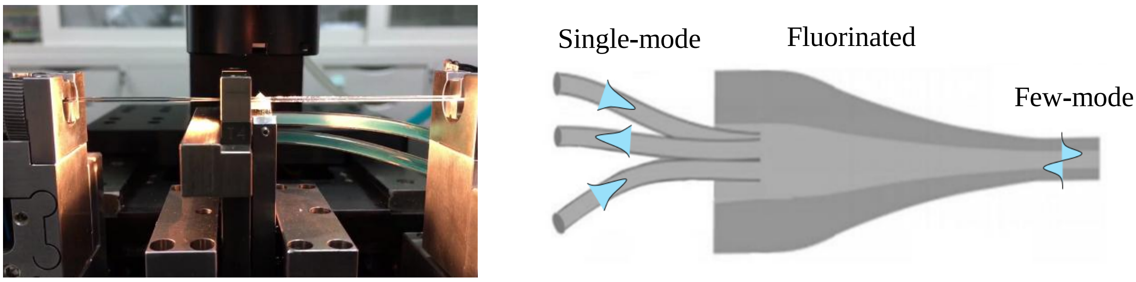

Figure 3 Schematic Diagram of Optical Fibre Processing Platform and Three-mode-selective Photonic Lantern Fabrication

Figure 4 shows the input and output mode of the three-mode-selective photonic lantern and the crosstalk conditions of different patterns. Figure 5 shows that all the insertion loss test results of the photonic lantern at 1530nm~1600nm are less than 5dB.

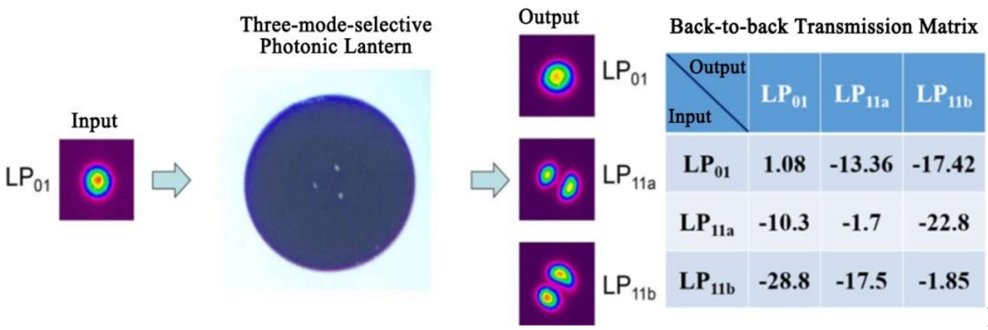

Figure 4 Schematic Diagram of the Mirco-end-face and the input and output of Three-mode-selective Photonic Lantern

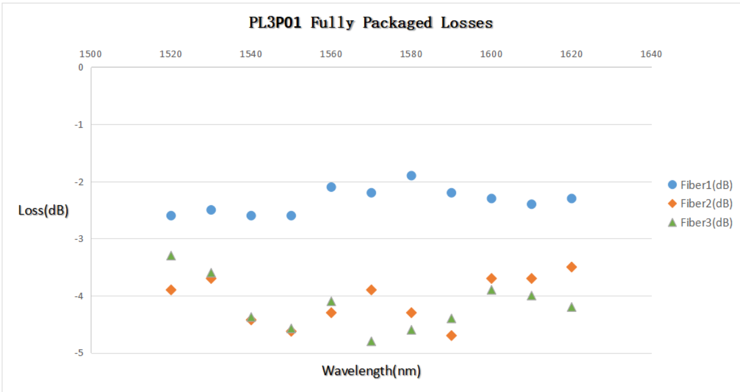

Figure 5 Loss of Three-mode-selective Photonic Lantern at 1530nm~1600nm

As a kind of all-fibre structure device, the optical fibre cluster developed by YOFC and BUPT has the advantages of low loss and low crosstalk between modes (Table 1 is the product technical indicators). This technology and its product are advanced international level, which has been successfully applied to space division multiplexing system. In the future, YOFC will rely on years of optical fibre fabrication technology and mature optical fibre processing platform to develop higher capacity and wider bandwidth device systems, which will provide strong support for the development of optical communication technology.

Table 1 Technical Indicators of Three-mode-selective Photonic Lantern

Parameter	Unit	Specifications
The number of optical fibre at input terminal	EA	3
Working wavelength	nm	1530~1600
The type of optical fibre at input terminal	/	YOFC PH 1010-A
The type of optical fibre at output terminal	/	YOFC Few-mode fibre

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Insertion Loss	dB	<5.0
Mode Dependent Loss	dB	<3.0
Polarization Dependent Loss	dB	<0.5

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