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EXPERIMENTAL STUDY ON 100 KM FREE SPACE COHERENT OPTICAL COMMUNICATION

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ABSTRACT

An experiment of free space optical communication based on heterodyne detection in the 100km link from erlangjian to Quanji Township in Qinghai Lake is built. The experimental results show that the acquisition, pointing, tracking (APT) system with composite axis structure can achieve the beam alignment, the adaptive optical system based on the combination of fast steering mirror(FSM) and deformable mirror(DM) can correct the wave front distortion, and the multi-antenna transmission structure can effectively improve the coupling optical power and suppress the light intensity flicker.

***Keywords**: Free Space Coherent Optical Communication, Acquisition Pointing Tracking, Adaptive Optics.*

I. INTRODUCTION

Compared with intensity modulation, free space coherent optical communication has the characteristics of multi modulation modes and high detection sensitivity[1-2], which is more suitable for ultra long distance laser communication. Most of the laser communication schemes for super long distance adopt coherent detection such as satellite to satellite and satellite to ground[3], but there are few reports on laser communication for super long distance of near earth link[4]. The atmospheric turbulence intensity of the 100 km near earth link is stronger than that of the satellite earth link. The biggest bottleneck of laser communication is that the existence of strong turbulence makes the laser beam mode completely degenerate after transmission. In this paper, a 100km free space coherent optical communication experiment near the ground is carried out with Qinghai Lake as the field experiment site. The experimental contents and results are briefly introduced.

II. EXPERIMENTAL PROCEDURE

The experimental link of free space coherent optical communication based on heterodyne detection is located at the two ends of Qinghai Lake, the transmitting end is located in erlangjian , the receiving end is located in huquanji township, and the communication distance is 100km. The experimental time is August 20, 2019. Figure 1 is the experimental link diagram.

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Fig.1 100 km experimental link diagram

The transmitter consists of laser source, electro-optic modulator, optical fiber amplifier, transmitting antenna, coarse aiming platform and micro aiming platform. The laser seed source is a 1550nm narrow line width laser produced by NKT Potonics company. After the electric signal is modulated into the electro-optic phase modulator, the optical signal is amplified by the fiber amplifier, and the output optical power is up to 5W. The structure of transmitting antenna is Kepler transmission optical antenna. The transmission structure is a double transmission structure, that is, a seed laser source is used, after beam splitting and amplification respectively, two identical optical antennas are used to collimate the two output lasers. The coarse aiming platform, micro aiming platform and focal length adjusting system of optical antenna constitute a compound axis linked mechanical structure to realize the acquisition, pointing and tracking of the beam. Figure 2 is the field experiment of compound axis dual antenna structure.

Fig. 2 field experiment of compound axis dual antenna structure

The receiving end is mainly composed of receiving antenna, adaptive optical system and coherent detection system. The receiving antenna is Cassegrain reflective receiving antenna. The fast steering mirror, deformable mirror and wavefront (WFS) sensor constitute the adaptive optical system to correct the wavefront distortion. Among them, the type of FSM is PT2M60 piezoelectric fast steering mirror, the type of DM is Alpao DM69, and the WFS is haso4 NIR wavefront sensor produced by Imagine Optics company. After the wavefront correction, the laser enters the fiber mixer and the balance detector through the fiber coupling, and the electrical signal is recovered after mixing with the local oscillator laser. Figure 3 is the physical drawing of receiving end and the Figure 4 is the structure of optical antenna.

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Figure 3 physical drawing of receiving

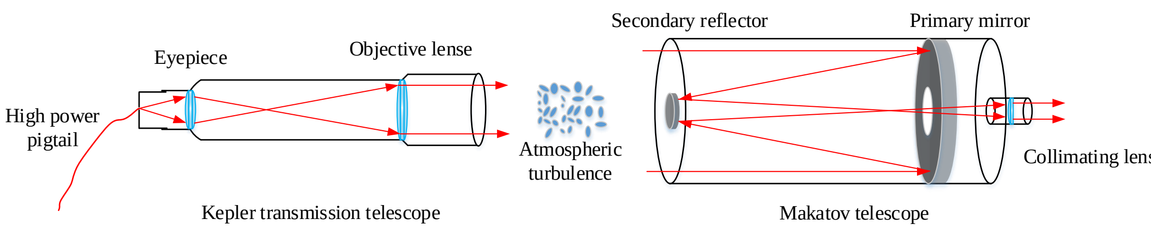

Figure 4 structure of optical antenna

III. RESULT & DISCUSSION

At the transmitting end, the coarse aiming platform adopts the rectangular scanning method, and in the receiving end, the infrared camera is used to capture the beam. The beam is fully aligned by adjusting the pitch and orientation and the antenna focal length. Figure 5 is the ATP structure diagram and Figure 6 shows the image of the spot taken by the infrared camera at the receiving end in the process of acquisition and pointing.

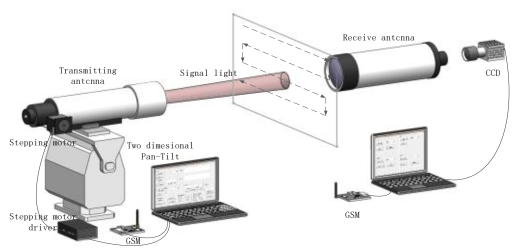

Fig.5 ATP structure diagram

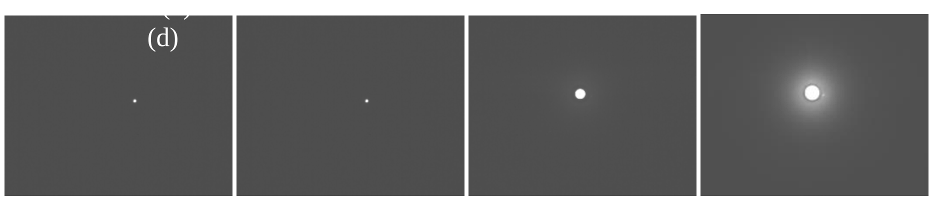

Fig.6 capture graph

After the beam is fully pointed, the wavefront of the laser after 100km transmission is measured by WFS at the receiving end, and the distorted wavefront is corrected by the FSM and DM at the same time. The measurement optical path and the corrected optical path are shown in the Figure 7.

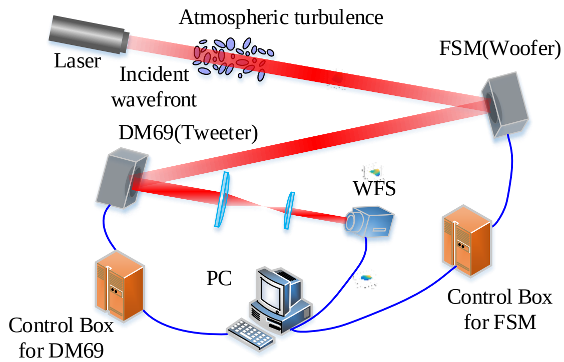

Fig.7 measuring optical path

Figure 8 is the comparison of wavefront peak to valley (PV) curve at different distances. Figure 8 shows that the wavefront distortion of 100km is much larger than that of other wavefront aberrations. The reason for the discontinuity in the measurement of 100 km wavefront PV value is that the scintillation of light intensity caused by strong turbulence makes the acquisition of wavefront sensor slope fail and wavefront reconstruction difficult.

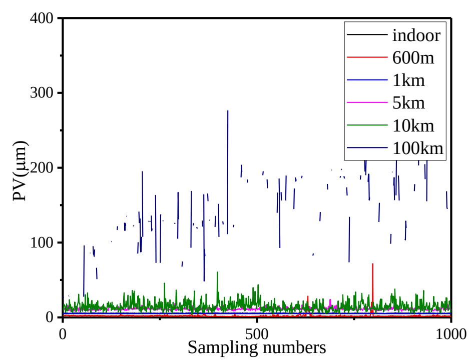

Fig.8 wavefront PV measurement curve at different distances

For the distorted wavefront, the tilt components of the wavefront are corrected by the FSM, and the other higher-order components of the wavefront are corrected by the DM. The correction curve is shown in the Figure 9.

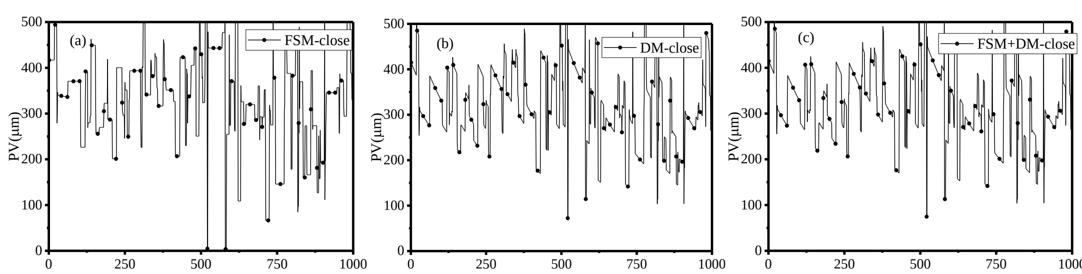

Fig.9 FSM correction DM correction FSM and DM correction at the same time

The PV value of wavefront decreases from 450 μm to 300 μm only after the FSM is closed-loop; Only when the DM is closed-loop, the PV value of wavefront decreases from 450 μm to 300 μm; When the FSM and the DM are closed at the same time, the PV value of the wave front decreases from 450 μm to 200 μm. The results show that the effect of simultaneous correction of FSM and DM is better than that of single correction.

Under different conditions of fiber amplifier output power, the optical power coupled into the optical fiber is measured after 100km transmission. The average and variance of the power under different conditions are calculated as follows.

Table 1 coupling power of receiving system under different output power of multiple transmitting system

	1W Mean	1W Var	2W Mean	2W Var	3W Mean	3W Var	4W Mean	4W Var
Single(dBm)	-40.33	6.78	-44.53	6.01	-39.18	7.63	-36.63	4.07
Double(dBm^2)	-40.12	4.65	-33.47	3.79	-34.73	3.16	-34.22	3.25

It can be seen from the Table1 that, with the increase of fiber amplifier output power, the power of coupling into the optical fiber increases, and the power of double emission coupling is higher than that of single emission. At the same time, the variance value of coupling power in the case of double emission is lower than that single emission. The results show that the structure of multi beam emission can effectively suppress the flicker of light intensity and the fluctuation of coupling light power caused by atmospheric turbulence.

IV. CONCLUSION

In this paper, 100 km free space coherent optical communication experiments are summarized. The experimental results show that the laser beam can be acquisition and pointed by using the composite axis structure; The wavefront can be modified by the adaptive optics system which consists of the FSM and the DM; The multi emission system can effectively improve the optical fiber coupling power and suppress the light intensity flicker.

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