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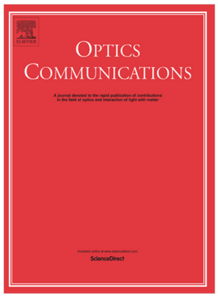

Highly sensitive fiber coupling for free-space optical communications based on an adaptive coherent fiber coupler

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Highly sensitive fiber coupling for free-space optical communications based on an adaptive coherent fiber coupler

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***Abstract*—In this paper, we present the result that the performances of the highly sensitive adaptive coherent fiber coupling (ACFC) technology, which consists of a movable fiber tip and a coherent detector. The ACFC technology is applied for the free-space coherent optical communication systems especially with a long distance link such as the satellite to ground, and it is used for compensating the tiny random angular jitter caused by the vibration of the receiver and the residual jitter error of the adaptive optics unit which is used for alleviating the effect of turbulence. Compared with the traditional fiber coupling using direct detection, the advantages of ACFC technology has been verified by analyzing the SNR value. The result shows that the receiver sensitivity can be enhanced by up to 20 dB. The residual jitter error of a free-space optical receiver with a 357-element AO unit is acquainted, and it is used for verifying the performance of the ACFC technology. The result shows that the average coupling efficiency is 73.2% with a mean square error (MSE) 1.12%, increasing significantly compared with the average coupling efficiency 50.1% and a MSE 7.43% without ACFC correction.**

***Index Terms*—Adaptive optics, Coherent fiber coupling, Free-space optical communication, SPGD algorithm**

I. INTRODUCTION

FREE space coherent optical communications, with high data rate and high confidentiality, have a potential application to become the main method for the long-range satellite to satellite, satellite to ground and deep-space communication links in future [1]. A free space coherent optical communication system with fiber optics components, such as optical fiber amplifiers, receivers and transmission facilities, the signal beam must be coupled into fibers before being detected. The highly efficient fiber coupling technique has become one of the key technologies for high-speed free-space coherent optical communications. However, the signal beam propagating through turbulence experiences random amplitude and phase fluctuations, which can severely degrade the spatial coherence of the signal beam and limits the fiber coupling efficiency [2-4]. An effective way to alleviate the effect of atmospheric turbulence on optical communications is using adaptive optics (AO) in the system that can overcome the effect of the optical random disturbance, and it has been applied in many fields [5]. Until now, it has been verified that AO technology can significantly improve the performance of the atmospheric optical coherent communications [6-9]. Some researchers also present the performance of AO technology to improve the single-mode fiber (SMF) coupling in coherent optical communication systems [10, 11].

However, there continue to be some problems in such systems. First, the AO system needs to be calibrated before correcting the wavefront distortion. Unfortunately, there might be a deviation between the calibrating original position of the signal beam in the focusing plane and the position of the fiber end-face. This will lead to a fixed error for coupling systems. Secondly, the fiber coupling system, which consists of fiber end-face and coupling lens, can produce tiny jitter errors because of the vibration of the platform. Those jitter errors cannot be compensated by the AO system..

In recent years, Geng et al. developed the adaptive fiber-optics collimator (AFOC) for tip/tilt control in beam combining applications [12]. Inspired by the principle of optical reversibility, the AFOC can be utilized to compensate the residual jitter errors and deviation errors of the fiber coupling system. Up to now, the application of AFOC for fiber coupling is using direct-detection (DD), which converts the incident signal beam to the digital signal directly in the electrical domain. However, in a long-distance optical link, the received signal light is extremely weak. In consideration of influence of shot noise and thermal noise, it's difficult to achieve a high signal to noise ratio (SNR) in a DD system.

In this paper, we present an adaptive coherent fiber coupling (ACFC) system which comprises of a movable fiber tip and a coherent detector. Coherent receiver sensitivity is analyzed and compared with DD system by analyzing the SNR value. Besides, the coupling efficiency performance of the ACFC using SPGD algorithm when facing the residual jitter error of a 357-element AO unit is examined.

II. DETECTION SENSITIVITY ANALYSIS

The schematic diagram of ACFC technology is illustrated in

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