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Modified Artificial Fish School Algorithm for Free Space Optical Communication with Sensor-Less Adaptive Optics System

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The performance of free space optical (FSO) communication system is limited by atmospheric turbulent extremely. Adaptive optics (AO) is the significant method to overcome the atmosphere disturbance. Especially, for the strong scintillation effect, the sensor-less AO system plays a major role for compensation. In this paper, a modified artificial fish school (MAFS) algorithm is proposed to compensate the aberrations in the sensor-less AO system. Both the static and dynamic aberrations compensations are analyzed and the performance of FSO communication before and after aberrations compensations is compared. In addition, MAFS algorithm is compared with artificial fish school (AFS) algorithm, stochastic parallel gradient descent (SPGD) algorithm and simulated annealing (SA) algorithm. It is shown that the MAFS algorithm has a higher convergence speed than SPGD algorithm and SA algorithm, and reaches the better convergence value than AFS algorithm, SPGD algorithm and SA algorithm. The sensor-less AO system with MAFS algorithm effectively increases the coupling efficiency at the receiving terminal with fewer numbers of iterations. In conclusion, the MAFS algorithm has great significance for sensor-less AO system to compensate atmospheric turbulence in FSO communication system.

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I. INTRODUCTION

Free space optical (FSO) communication system with some advantages over traditional microwave communications and radio frequency (RF), has been considered as the most potential communication. Increasing data throughput, relieving from spectrum planning, and enhancing link security [1], it is widely applied to airborne communication, interstellar communication, ground-to-ground laser communication and other fields [2,3]. However, laser signal propagation through atmosphere channel is worse affected by atmospheric turbulence. It causes laser signal amplitude scintillation, phase distortion, beam wandering and broadening, power deep fade at the receiver [4–6].

A closed-loop Adaptive optics (AO) system applies an effectively method to reduce the effects of atmospheric turbulence by correcting the wavefront aberrations in real time [7, 8]. AO system consists of wavefront sensor, wavefront controller and wavefront corrector. Wavefront sensor measures wavefront aberrations, feeds back the results to wavefront controller. Wavefront controller controls the wavefront corrector to correct phase aberrations real-time [9]. Wavefront sensor is one of important unit in AO system, its measurement precision di-

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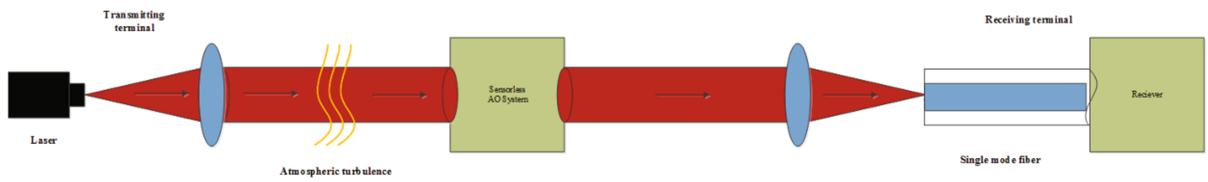

Fig. 1. (Color online) Functional block diagram of FSO communication system.

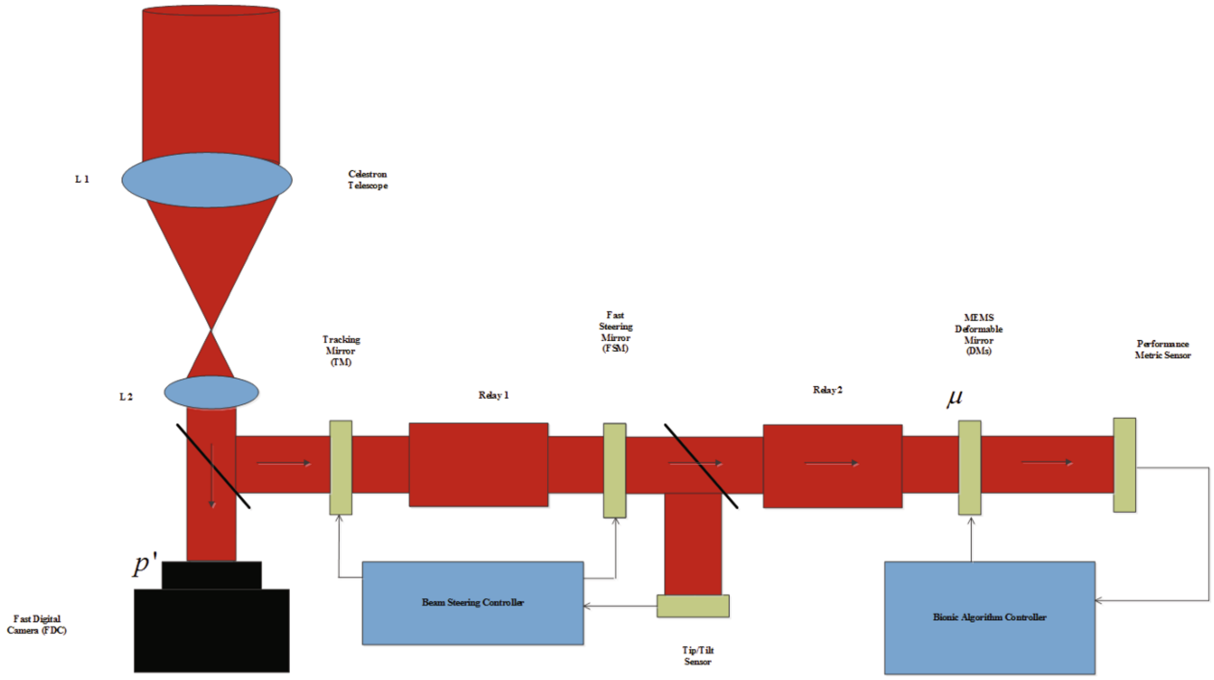

Fig. 2. (Color online) Schematic of sensor-less AO system.

rectly influences the performance of AO system. Shack-Hartmann wavefront sensor (SH-WFS) is one type of widely used sensors [10–12]. In [13] and [14], we have proposed two new wavefront sensors to measure the phase aberrations effectively. However, for strong scintillation of laser, some researchers point out sensor-less AO systems based on optimization algorithms are more suitable for FSO communication system. In sensors-less AO systems, wavefront information, as feedback, controls the parameters of the correction element, and optimization algorithm is used to obtain the optimal control parameters [15–18].

The sensor-less AO systems have many advantages of low cost, simple structure and implementation. It uses blind optimization method, converges to a certain performance index to optimum through repeated iterations. Common optimization algorithms include stochastic parallel gradient descent (SPGD) algorithm, simulated annealing (SA) algorithm, genetic algorithm, particle swarm optimization (PSO) algorithm, fish school algorithm and so on [19–22]. The SPGD algorithm is widely used for fast operating and simple realizing. However, SPGD algorithm is seldom used in FSO communication system since its slow convergence speed and poor convergence stability. Artificial fish school (AFS) Algorithm, as an effective optimization algorithm, can be used in sensor-less AO system. Unfortunately, AFS algorithm converges slowly when search process is in a higher-dimensional space [23, 24]. So on basis of traditional AFS algorithm, we propose modified artificial fish school (MAFS) algorithm with higher convergence speed, which is more suitable for FSO communication system. We introduce the velocity-displacement model of the PSO algorithm into traditional AFS algorithm to improve the optimum value of convergence [25]. The novel MAFS algorithm, combines the advantages of AFS algorithm and PSO algorithm. In this paper, both the static and dynamic aberrations correction is analyzed in theory and numerical simulation validate the capability of aberrations measurement and correction. We compare MAFS algorithm with AFS algorithm, SPGD algorithm and SA algorithm. The results show that MAFS offers better performance both in compensating speed (about 30 - 35 iterations) and level of compensating re-