Research progress of fiber laser coherent combining

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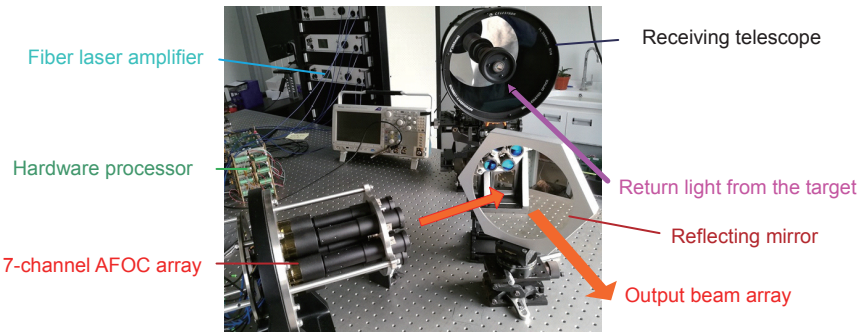

The photo of laser beam transmitter and receiver in the 7-channel laser-array transmission and TIL control experiment

Overview: To build an optical phased array (OPA) based on multi-channel fiber lasers, each channel equipped with a fiber optical collimator, is crucial and effective for the long-range laser transmission application, where the atmospheric turbulence will weaken the beam quality and power intensity on the target. Aberrations in such transmission systems include turbulence-induced dynamic aberrations located at the path from the fiber laser based OPA to the target, besides the inherent phase errors like phase noises and tip/tilt errors. With the help of the OPA structure, the monolithic optical wavefront is replaced by multi-subwavefronts emitting from the subapertures, where each subaperture is provided with the abilities of correcting the piston and tip/tilt type phase aberrations. So, the OPA structure can deal with atmospheric turbulence aberrations and inherent system aberrations to achieve the coherent beam combining, and even the conformal emission. Effective control bandwidth for eliminating such aberrations is limited by the optical transmission time delay and the increment of the array scale in the OPA system. Existing techniques, e.g., target-in-the-loop (TIL) and delayed stochastic parallel gradient descent (SPGD), are difficult to deal with the fast-changing turbulence-induced tip/tilt aberrations. In recent years, the fiber laser coherent beam combining technique was deeply studied in the Key Laboratory on Adaptive Optics, Chinese Academy of Sciences. The new-style fiber-based aberration correctors, e.g., adaptive fiber-optics collimator (AFOC) and piezoelectric fiber phase corrector (PZT-PC) were developed for the tip/tilt and piston phase error compensation. The indoor coherent beam combination of a three-element fiber array based on TIL technique was achieved. With the help of 500 W AFOC, the 2 kW incoherent beam combining of four fiber lasers was demonstrated. The coherent beam combining with tip-tilt control of seven-channel AFOC array was achieved by using the divergence cost-function in SPGD algorithm. In the front of this paper, research progress of multi-aperture laser transceiving control for coherent combining applications was presented, where the outdoor demonstration of TIL technique with seven-channel AFOC array was realized under 200 m horizontal atmosphere distance. The coherent beam combining technique for laser transmission in atmosphere has been widely investigated, while the study of this technique's application in space optical communications is few. In fact, the structure of multi-aperture receiving antenna based on coherent beam combining could be employed to correct the atmospheric turbulence effect and to enhance the performance of the space optical communication system. In most part of this paper, the research progress of fiber-based coherent beam combining in multi-aperture receiving space optical communication system is reported in detail, including the coherent combining based on 3 dB fiber coupler and the coherent polarization combining based on fiber polarization beam combiner, which might have great potential in space optical communication system.

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