Intelligent self-calibration tool for digital few-mode fiber multiplexers based on multiplane light conversion

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Development of fiber optical networks as the backbone of the global infrastructure has driven exponential growth in data demands.
Space division multiplexing (SDM) over few-mode fibers (FMF) spatial domain is proposed to enhance optical networks' capacity limits by orders of magnitude compared to state-of-the-art single mode fibers.
Based on multiplane light conversion (MPLC), multiple input beams are converted to the FMFs mode domain and launched into the fiber.
Inside the MPLC the beams are modulated by a phase-changing element within several passages and are shaped in amplitude and phase due to diffraction.
We use a spatial light modulator (SLM) for the implementation of the MPLC, whose programmability allows us to sample the MPLCs behavior and compensate on phase and polarization aberrations during operation.
Conventionally, phase masks are calculated in advance that carry out a spatial transformation between spatially distributed input spots and coaxial output modes.
After calculation, phase masks are either printed on dielectric mirrors or displayed on diffractive optics.
This process entails two-fold problems.
First, the phase masks are calculated offline and inserted into the experiment later on, where small deviations cause enormous performance reductions.
Second, phase mask printing can barely adapted after fabrication.
We propose a data-driven optimization of the displayed phase mask by using machine learning to overcome the hurdles of re-configurability and alignment.
We use neural networks (NNs) for digital calibration to ensure pixel-precise alignment.
Our implementation of the MPLC with a SLM is mimicked as a digital twin by a NN, the model-NN.
In a second step, the fixed model-NN is controlled by another neural network called actor-NN.
After the calibration, our Actor-Model scheme predicts phase patterns for the SLM based on the desired intensity distribution after the MPLC, i.e. the FMFs mode patterns.
By digitally sampling and control of the MPLCs behavior with NNs, we improved the SLMs beam-shaping quality without suffering from the SLMs refresh rate limitations, depending on the available filling factor and resolution.
The adaptability of the SLM as a digital optical device allows further re-calibration during operation.
Due to the all-optical implementation, transmission and multiplexing of delicate quantum states is proposed.