Photonic phase correctors based on grating coupler arrays

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Abstract

Integrated optical devices are replacing bulk optics in IR astronomical instrumentation thanks to the growing
field of astrophotonics, where miniaturization simplifies cryogenic control and enables multiplexability. Photonic
spectrographs, beam combiners, and OH suppression filters have been reported in the literature with many
undergoing on-sky testing and becoming facility instruments.
Turbulence-induced distortions in light waves propagating through Earth's atmosphere limit the ability to
couple them into single-mode fibers (SMFs) which is necessary for most photonic devices. These temporal and
spatial distortions can be corrected by an adaptive optics (AO) system where deformable mirrors (DMs) and
Shack-Hartmann wavefront sensors (WFSs) have been the preferred options to measure and apply the correction.
However, photonic WFSs have recently been suggested to detect blind modes and non-common path aberrations
(NCPAs), a limitation of pupil plane WFSs. Photonic wavefront correctors have also been used in experiments
for satellite-to-ground free-space optical (FSO) communication.

We propose a photonic integrated circuit (PIC) capable of coherently coupling the beamlets from the sub-
apertures of a telescope pupil into an SMF. The PIC consists of a square array of grating couplers used to inject
the light from free space into the plane of a single-mode waveguide in a chip. Resistive elements are used to
alter the refractive index of a coiled section of the waveguides and shift the phase of the propagating modes.
Consequently, the channels can be coherently combined, and the collected light can be delivered to an output
SMF. In an AO system, the phase corrector would act as a DM commanded by a controller that takes phase

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measurements from a WFS. Simulations and proof-of-concept lab results are presented for a device capable of correcting 2 × 2 subapertures.
Photonic phase correctors have smaller footprints and require less power than classical correctors. Depending on the design, they usually have larger strokes and can be driven faster than deformable mirrors. In very large telescopes (VLTs), and extremely large telescopes (ELTs), the multiplexability and flexibility of photonic phase correctors may be used in multi-object AO (MOAO) systems that feed multi-object spectrographs (MOSs).

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