Speckle level suppression using an unbalanced nulling interferometer in a high-contrast imaging system

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High-contrast imaging systems with a stellar halo suppression level of 10^{-10} are required for direct detection of Earth-like extra-solar planets. Here $\lambda/10000$ rms wavefront quality is required for the optics to suppress the speckle level, and a coronagraph will be used to reduce the diffracted light of a parent star.

We investigated a novel high-contrast imaging system with an unbalanced nulling interferometer (UNI) followed by phase and amplitude correction (PAC) adaptive optics (AO), which not only can reduce starlight but also can suppress the speckle level by a virtual wavefront correction beyond the limit of the AO performance[1].

The present system consists of four stages, i.e., a first AO, the UNI, the PAC AO, and a final coronagraph (Fig. 1). In the experiments the UNI adopted a modified lateral shearing Mach-Zehnder interferometer which we call PINC (Polarization Interferometric Nulling Colonagraph[2]. We did not use the first AO here. We confirmed that the aberrations of the input wavefront were sufficiently magnified by the UNI, cf., $\lambda/100$ rms to $\lambda/16$ rms, thanks to the amplitude difference between the two wavefronts which were split and combined in the UNI.

Next at the PAC AO system, the magnified aberrations were effectively corrected in amplitude and phase with two deformable mirrors (Boston Micromachines Corp.) to the initial aberration level of $\lambda/100$ rms (Fig. 2). Here the electric field distribution was suppressed to $\lambda/550$ rms virtually by the product with the reduced mean amplitude after the UNI, although the observed aberration level was identical to the initial wavefront (AO performance). According to the pupil plane field, the suppression level of the speckle pattern at the focus of the final coronagraph (3D Sagnac nulling interferometer) was 7.0×10^{-4}, which was 0.073 times reduction from the initial (AO-limited) level of 9.5×10^{-3}.

Thus we demonstrated that the wavefront correction after the aberration magnification by the UNI can reduce the wavefront aberrations and the speckle level beyond the limit of the AO performance, and the UNIPAC would be an effective wavefront correction method in high-contrast imaging systems.

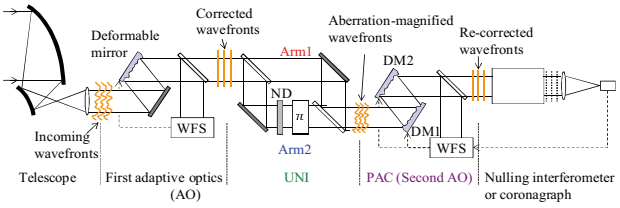

Figure 1: Schematic of coronagraph optics with UNI (unbalanced nulling interferometer).

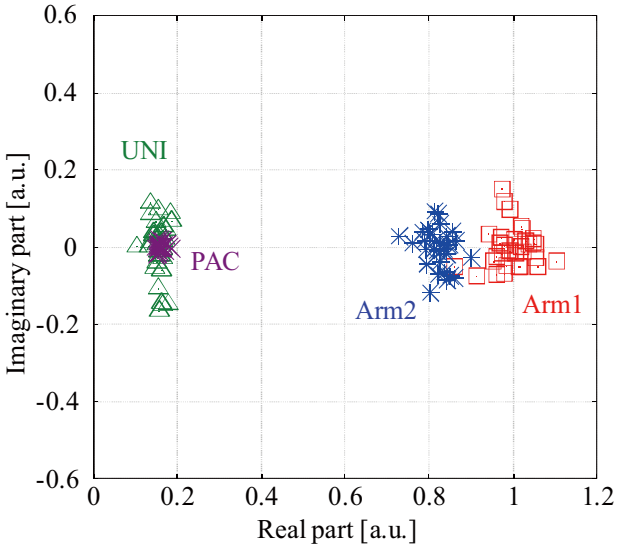

Figure 2: Electric field changes with the UNI (unbalanced nulling interferometer) and PAC (phase amplitude correction) processes.

References

[1] Yokochi, K., et al.: 2011, *Opt. Express*, **19**, 4957.
[2] Murakami, N., et al.: 2010, *Appl. Opt.*, **49**, D106.