Coherence-gated Shack-Hartmann wavefront sensor insensitive to stray reflections

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In the present paper we investigate the possibility of narrowing the depth range of a physical Shack – Hartmann (SH) wavefront sensor by using coherence gating (CG). Two methods of low coherence interferometry (LCI) set-ups are demonstrated capable of eliminating stray reflections.

1. Introduction

Due to the limited numerical aperture in the beams associated with each microlens in the lenslet array (LA), a Shack – Hartmann wavefront sensor (SH/WFS) has little sensitivity to the position in depth in the object where the signal comes from. This makes the SH/WFS insensitive to depth variations of aberrations. Consequently, stray reflections from the interface optics cannot be rejected and this is one of the main factors that renders SH/WFSs inefficient in microscopy.

2. Method

Elimination of stray reflections and operation as a depth resolved WFS can be achieved by incorporating principles of CG. We propose and demonstrate two LCI solutions based on using a physical LA array in opposition to a virtual LA proposed earlier [1]. We investigate how the multiple beamlets output by the LA are superposed on a reference beam provided by the same optical source. A time domain (TD) and a swept source (SS) coherence gated (CG)-SH/WFS are evaluated. For the TD method, a super luminescent diode is used and in the reference arm, the reference mirror is mounted on a piezo actuator, driven by a ramp generator. This is used to create four phase differences equal to $\pi/2$, where 4 images are collected during a $2\pi$ phase cycle. The interference pattern is discerned based on principles of phase shifting interferometry, light originating from outside the coherence gate is eliminated and the amplitude of interference from points within the coherence length is recovered. For the SS method, a broad sweeper is used. This method has better sensitivity, however the drawback that requires a supplementary step in comparison to the TD method, that of organizing the data in the form of an en-face image of spots.

3. Results

The SH spots due to stray reflections were totally eliminated and the only SH spots in the image were due to the object. An enhancement of the signal was obtained using both LCI methods. Both methods [2] proved that a CG-SH/WFS can work under large stray reflections in the interface optics. This research can lead to wavefront sensing assisted adaptive optics (AO) microscopy, reduction of the layout size of AO assisted imaging instruments and to an improvement in performance.