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Utilizing speckle decorrelation for tomographic wavefront sensing (with one wavefront sensor)

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Abstract content
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Generation of speckle using scattering that is spatially incoherent is a common, and often annoying, phenomenon but has not been as yet utilized in adaptive optics for wavefront sensing. This paper describes a method whereby light is scattered from a surface (which may be a plane within a sample being imaged) and then an image is obtained of the speckle created at two defocused planes at some equal but opposite distance from that pupil. Due to the correlation of speckle with propagation, a cross correlation of detected intensity (or amplitude, via interferometric detection) can be used to measure the wavefront gradient. The key advantages of this technique include the ability to alter the sensitivity of the wavefront gradient signal vs. the spatial sampling of the wavefront gradient. A further extension demonstrates how multiple but distinct regions of scattering can be utilized to produce overlapping but mutually uncorrelated speckle. The individual speckle cross-correlation can then be extracted to result in a set of wavefront gradients that, in astronomy, would be described as star-oriented. Astronomical data-reduction approaches can then be used to produce a tomographic or 3D wavefront solution. In this case, the wavefront sensor hardware is no different to the single-scattering source case and the angular source selection is done by computation rather than multiple devices; thus costs and complexity are minimized at the expense of detection and computational time.

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