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Fourier Moire Wavefront Sensor

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Technology description

Background

Moiré deflectometry is used to perform the wavefront correction that is commonly required for many analytical laser measurements, such as adaptive optics to compensate for atmospheric turbulence or density variation, three-dimensional moiré shadow tomography for stress/strain analysis and high-resolution position sensing, non-invasive small tissue imaging, and time-resolved experiments using ultrashort pulses. Typical analyses of moiré deflectograms include fringe-determination, computer Fourier transformations and phase-shifting techniques, requiring multiple shots in order to get high resolution.

Technology Description

The present invention uses the Fourier transforming properties of a lens to optically compute the wavefront curvature of incident light, so computation takes place as fast and simply as possible, with greatly increased dynamic range and resolution.
When wavefront aberrations induce changes in the moiré deflectogram, they also change the deflectogram frequency information in a characteristic way at the Fourier plane. The broadening of particular frequency components is such that the angle of the fringes in the deflectogram is encoded as intensity information by the filter, downstream, in the image plane. Hence, wavefront curvature is encoded directly as intensity information. This image plane is then imaged in a single shot onto a detector array which can be directly connected with conventional electronics to an analog interpreter, and then to adaptive optic elements.

Advantages

The Fourier moiré sensor represents a huge advance over other moiré deflectometry techniques, which typically require computer Fourier-transform and phase-shifting algorithms. A vast array of computer routines has been written to "automatically" process data, all of which require the ability to resolve and determine where the fringes are – not a trivial task when fringes close into loops or branch. Because in the present invention optical Fourier processing is automatically performed within the optical device, information is available literally at the speed of light, the deflectogram does not have to be digitized, and the fringes do not have to be resolved by detection equipment. Hence resolution is determined by pixel size, not fringe spacing or algorithm matrix size.

There are also other advantages over currently used techniques. For example, the Schlieren technique gives the magnitude of wavefront distortion, but not the sense of curvature. The device known as the Shack-Hartmann sensor is vastly popular for wavefront correction, but suffers from trade-offs between diffractive effects and sensitivity. A Shack-Hartmann system can also cost upwards of $30,000. The Fourier moiré wavefront sensor overcomes the technical difficulties of previous techniques, at minimal cost – it can be constructed of items typically found in any teaching laboratory. The device could actually be housed much like camera-lenses are. This way, important parameters, such as relative grating angle and grating separation, can easily be adjusted and measured in order to vary sensitivity and dynamic range.

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