EPJ Web of Conferences **287**, 09007 (2023) https://doi.org/10.1051/epjconf/202328709007
EOSAM 2023

Give your optical metrology a LIFT

Rafael Porcar[1,*], *Xavier* Levecq[2]

[1]Imagine Optic, 18, rue Charles de Gaulle, 91400 Orsay, France

Abstract. Shack Hartmann (SH) Wavefront Sensing (WFS) brings many advantages that has made it a standard in optical metrology, but it has long been limited by its resolution compared to other solutions, such as interferometry.
We will present a new approach to the linearized focal plane technique (LIFT), formerly developed by ONERA, which is based on the combination of standard SH technology with phase retrieval algorithms. Applied on all the spots of the SH wavefront sensor microlens array, it provides information on high spatial frequencies, allows to reconstruct more modes for each microlens and results in a 16-fold improvement (4x in each transverse direction) of the sensor spatial resolution!
We will present how we have optimized and validated the LIFT technology for optical metrology. We will share some measurements performed on extremely complex wavefronts. Finally, we will propose an implementation for industrial applications such as manufacturing and will describe some use cases.

Benefiting from the same advantages as SH WFS -such as robustness to vibrations and atmospheric turbulence, or the ability to easily work at any wavelength- the LIFT technology presents very promising perspectives for optical and freeform metrology and can advantageously replace, at lower cost and better usability, Fizeau interferometry.

1 Introduction

Shack-Hartmann (SH) technology has become the reference technology for wavefront measurement thanks to its unequalled performance in terms of dynamic range, measurement accuracy, achromaticity, insensitivity to vibrations, its ability to measure tilts in an absolute way, and its robustness mainly due to its simplicity of design. This technology suffered from one drawback only: its limited spatial resolution. Indeed, a large number of detector pixels are required to calculate the centroid of the spots formed by each microlens to determine the local slopes of the incident wavefront: In 2010 ONERA researchers opened the door to the possibility of improving the spatial resolution of Shack Hartmann wavefront sensors by analyzing of the distortion of each spot to determine the shape of the wavefront in front of each microlens [1]. They called this technology: LIFT (Linearized focal-plane technique). These researchers proposed an algorithm that determines the local curvature and astigmatisms in front of each microlens, which leads to an improvement by a factor of 4 (2x2) of the spatial resolution of a Shack Hartmann sensor. We are now proposing a new approach of this LIFT technology which results in an improvement of a factor of 16 (4x4) of the spatial resolution. The approach adopted for these new wavefront sensors is based on the combination of standard SH technology with a very fast phase retrieval algorithm, applied to each spot generated by the microlenses, that provides information on high spatial frequencies of the wavefront (Fig.1). This approach combines all the advantages of the Shack Hartmann technology, in particular its huge dynamic range and its excellent accuracy with the high resolution provided by the LIFT technique.

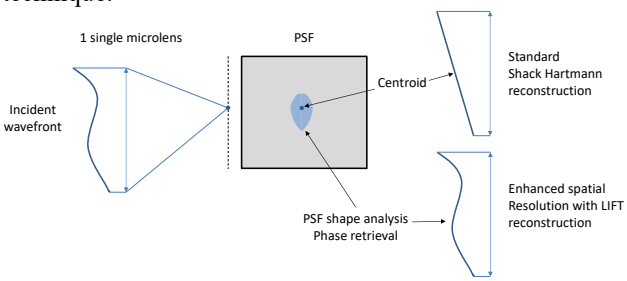

Fig. 1. Figure captions are indented 5 spaces and justified. If you are familiar with Word styles, you can insert a field code called Seq figure which automatically numbers your figures.

2 Concept and demonstration

The LIFT algorithms that have been developed are based on a phase retrieval approach requiring one image only as proposed by Meimon and al. [1] and Gonsalves [2]. As our microlens have a square geometry, we have taken Legendre polynomials instead of using Zernike polynomials. In order to solve undetermination problem for even modes the LIFT sensor use a phase offset as

* Corresponding author: rporcar@imagine-optic.com

proposed by Tokovinin and al. [3]. This offset consists in a combination of 4th order Legendre polynomials with an amplitude of 200 nm.

We have developed a specific bench including a Spatial Light Modulator (SLM) that can generate controlled phase patterns in order to test and validate this new high resolution wavefront sensor. A frequency transfer function has been measured by applying sinusoidal phase hologram with different spatial frequencies.

3 Implementation

Imagine Optic deployed the technique to its catalogue of sensors and optical metrology solutions, as it combines all of the advantages of classic WFS such as dynamic range, measurement accuracy, achromaticity, insensitivity to vibrations, ability to measure tilts in an absolute way, and robustness with a high resolution, that was once a privilege of interferometers.

We will showcase different integrations such as the HASO LIFT 680, with 680 x 500 phase points in the pupil, or the HASO SWIR LIFT 160 for testing in the SWIR spectral range (1050nm-1700nm). We will illustrate the results obtained on real optical components: below is reported in Fig. 2 the testing of a phase plate performed at SWIR wavelengths.

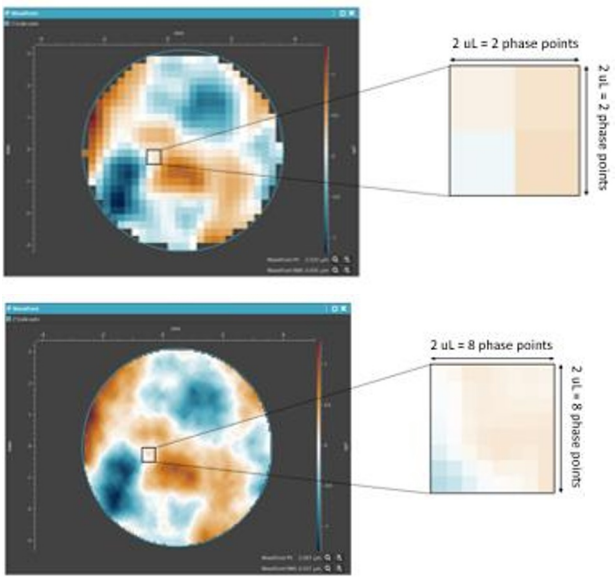

Fig. 2. Wavefront maps of a phase plate acquired with standard SH-WFS (left) and with LIFT (right).

References

1. R. Gonsalves, “Small-phase solution to the phase-retrieval problem”, Opt. Lett., Vol. 26, No 10, pp. 684-685 (2001)
2. S Meimon, “LIFT: a focal-plane wavefront sensor for real-time low-order sensing on faint sources”, Opt. Lett., Vol. 35, No 18 (2010)
3. A. Tokovin and al., “Donut: Measuring optical aberrations from single extrafocal image” Pub. Astron. Soc. Pacific 118, 1165 (2006)