Digital Holographic Interferometry in the Long-Wave Infrared for the Testing of Large Aspheric Space Reflectors

Jean-François Vandenrijt[1], Cédric Thizy[1], Yvan Stockman[1], Patrick Queeckers[2], Frank Dubois[2], Dominic Doyle[3], and Marc Georges[1]

[1] Centre Spatial de Liège, Univ. de Liège, Av. du Pré Aily, B-4031, Angleur, Belgium
mgeorges@ulg.ac.be, jfvandenrijt@ulg.ac.be

[2] Institut für Technische Optik – Univ.Stuttgart, Pfaffenwaldring 9, 70569 Stuttgart, Germany

[3] Optrion, PIMW, Boulevard de Colonster 4, B-4000 Liège, Belgium

1 Introduction

Digital Holography (DH) in the Long-Wave InfraRed (LWIR) range shows an increased interest since its first demonstration in 2003 [1]. In particular it allows observing large objects due to the fact that at such wavelengths the ratio between the wavelength and the pixel size allows reconstructing objects 5 to 10 times larger than with DH in visible light [2,3]. We already presented various configurations of LWIR DH interferometry and electronic speckle pattern interferometry for deformation metrology and non destructive testing [3,4]. In this paper we present the application of LWIR DH in interferometric testing of large deformation of large aspheric mirrors in the frame of a European Space Agency project. Here the study focuses on the case of parabolas and ellipses which are usually tested through interferometric wavefront error measurements which require expensive null-lenses matching each of the reflectors considered. In the case of monitoring deformation a holographic technique can be considered where the wavefront is compared with itself at different instants. Therefore the optical set-up can be quite simple and easily reconfigurable from one reflector to another. The advantage of using long wavelength is that large deformations can be measured at once, in addition to being more immune against environmental perturbations. In this paper we review different optical configurations of DH interferometer that led to test a parabolic mirror under thermal-vacuum test [5], as well as an off-axis ellipse tested in laboratory conditions, which is a new result.

2 LWIR Digital Holographic Interferometer for Parabola Testing

There are basically two schemes for dealing with specular reflectors and that were discussed in [5], but only one was implemented then. Without loss of generally we

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will present both in the case of parabolic mirror which serves as a demonstration speciment (1.1 m diameter parabola, 1.58 m focal length). Fig.1. shows the two different configurations. The first one is called the specular configuration (Fig.1(a)) in which we use a point source generating a spherical wave which is reflected towards the parabola. Due to the astigmatic behaviour of the mirror, the rays are not refocused on a single point but instead on a spot (LCC - Least Circle of Confusion). This spot constitutes the object beam which has to be made interfering with the reference beam. This situation can become more complex if the parabola is more open or if we consider more exotic reflector shapes. However it is possible to compute the dimensions of the LCC in order to collect all rays for using them in an imaging configuration such as the one shown in Fig.1(a). An alternative configuration is shown in Fig.1(b) and consists in illuminating the parabola with an extended source constituted by a diffuser which is illuminated by the laser. This way it is possible to generate a large variety of rays which reach the detector, even in case of large object slopes. We presented this configuration in details in [5] and we call it the scattering configuration as it is roughly similar to the case of a truly scattering object which would be imaged by a usual optical system. In Fig.2 we show results obtained with the two configurations for a similar tilt applied to the parabola. In the specular case the fringes have a higher quality, similar to fringes obtained by pure interferometry. However the inter ferograms suffer from secondary interferences due to multiple reflections by optical elements in the object path. Also large tilts introduced lost of rays reflected by some parts of the mirror. This is not the case with the scattering configuration but the quality of the fringes is lower, as this is generally the case with techniques based on scattering objects with speckle effect.

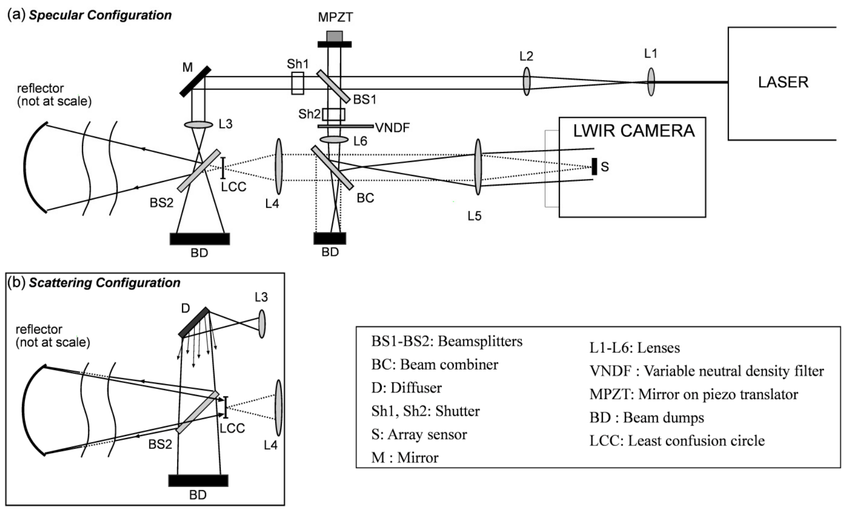

Fig. 1 Scheme of the mobile LWIR DH interferometer with CO2 laser and microbolometer array camera. (a) Specular configuration, (b) scattering configuration.

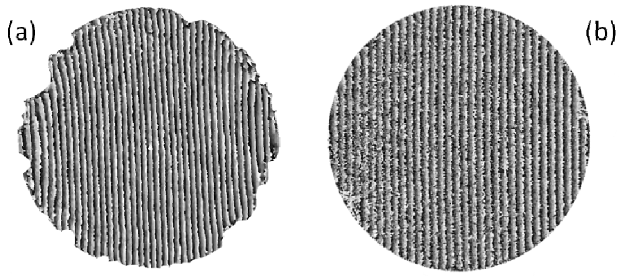

Fig. 2 Tilt observed by the two configurations (a) specular, (b) scattering

3 Testing of Off-Axis Elliptic Reflector

We have applied the scattering configuration to the observation of an off-axis elliptic reflector (60 cm wide). The set-up is depicted in Fig.3: after a beamsplitter (BS), the object beam (OB) illuminates the diffuser D which is placed close to one of the focus point (F1). The illumination lens IL and the diffuser D are chosen such that rays from D reach the entire reflector. Therefore all rays emitted close to the F1 travel towards to the other focus (F2) and are collected by a lens (CL). This

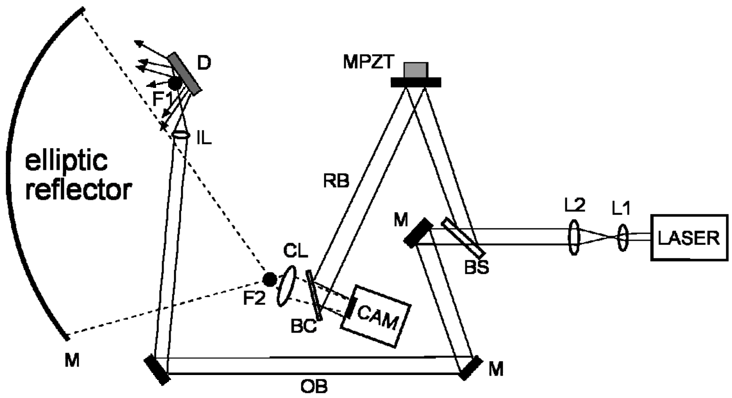

Fig. 3 DH interferometer for testing an off-axis ellipse with the scattering configuration

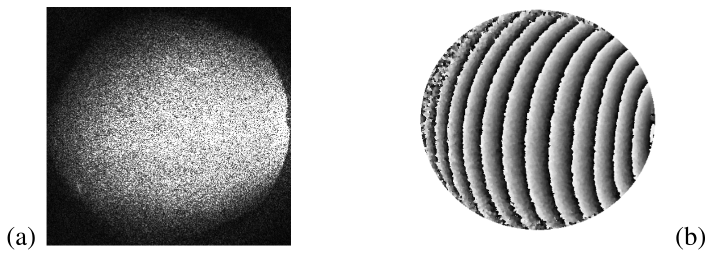

Fig. 4 (a) Amplitude of the reconstructed ellipse, phase difference by DHI due to tilt

forms the object beam which interferes with the reference beam (RB) on the detector, after combination by a beam combiner (BC). Fig. 4(a) shows the amplitude of the reconstructed image, whereas Fig. 4(b) shows the phase difference obtained after tilting the reflector.

4 Conclusions

We have shown that DHI in LWIR can be used to monitor displacement fields of large specular space aspherics. Two illumination configurations can be used but the one which makes use of a diffuser allows a simple set-up with high tolerance to misalignments and able to work with various aspheric shapes (parabola, ellipse).

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