

# Probing liquid-mirror surface quality using the CCD triangulation technique

**Francois Finet**

University of Liège

Belgium

E-mail: finet@astro.ulg.ac.be

**Jean Surdej**

University of Liège

Belgium

E-mail: surdej@astro.ulg.ac.be

**Abstract.** In the framework of the 4-m International Liquid Mirror Telescope project, we have developed an innovative technique to assess the optical quality of liquid mirrors, whose optical quality may be affected by the propagation of wavelets over the mercury layer. In this paper, we present a method based upon the reflection of a laser beam over the surface, and present the mathematical modelling as well as preliminary results obtained from laboratory measurements. © 2013 Society of Photo-Optical Instrumentation Engineers DOI: 10.0000/000.000

Subject terms:

Paper 000000R compiled October 18, 2013.

## 1 Introduction

The surface of a liquid rotating around the vertical axis, sets into a paraboloidal shape, thanks to the combined action of the centrifugal force and the local gravity. Consequently, a rotating dish containing a reflective liquid (such as mercury) allows to form cheap large parabolic mirrors that can be used as the primary mirror of a zenith pointing telescope.<sup>1,3,4</sup> This technology has been used for the construction of a 4 meter class telescope, the International Liquid Mirror Telescope (ILMT), in the framework of which the present research has been conducted.

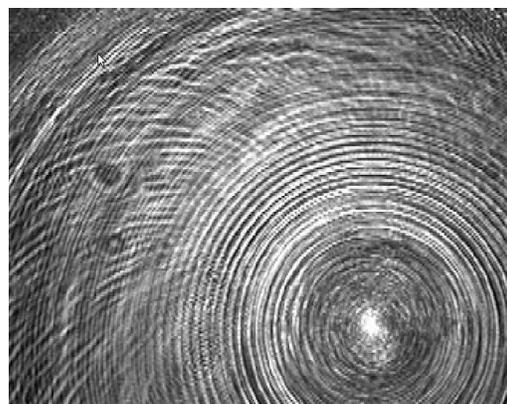
Liquid mirror surface quality is known to be affected by the possible presence of wavelets, propagating over the mercury layer.<sup>2,3</sup> The impact of these wavelets is to diffract light into the wings of the telescope PSF, reducing the energy contained in the PSF central core.<sup>6</sup>

There are different types of wavelets: transitory ones, spiral shaped wavelets and concentric ones. Fig. 1 shows an image of the pupil of a liquid mirror where these different types of wavelets are clearly visible.

The transitory wavelets (appearing as concentric rings on the left side of Fig. 1) are induced by any perturbation transmitted to the mirror (a gust of wind, a fly or a debris impacting the mercury layer, ...). These waves propagate through the surface and are damped rapidly with time. They cannot be avoided but their damping is increased by the use of thinner mercury layers.<sup>3</sup>

Concentric waves may originate due to vibrations transmitted to the rotating dish from its bearing. These vibrations typically have a frequency equal to the eigen frequency of the system bowl+mercury ( $\sim 20$ -30 Hz). They are formed with a pattern of concentric wavelets propagating radially, with a typical amplitude and wavelength of  $\sim 10^{-6}$  (m) and  $\sim 10^{-2}$  (m), respectively.<sup>5</sup> Such wavelets may be avoided thanks to the use of an air bearing system in order to avoid the transmission of vibrations, and by an increased stiffness of the bowl in order to increase its eigen frequency. As their presence reveals a conception or a dish stiffness problem, it is mandatory to suppress them.

Finally, spiral waves are believed to rise because of instability phenomena in the air layer at the interface with the



**Fig. 1** Defocused pupil image acquired with a Shack interferometer at the parabola curvature point. The interferometer was slightly misaligned to make the fringe pattern disappear (image courtesy 7).

mercury, induced by a too high relative velocity between the air and the rotating mercury.<sup>5,7</sup> Their name is related to their spiral pattern as seen in Fig. 1. They may be avoided by covering the rotating mirror with a thin Mylar layer, and thus rotating with the dish.<sup>6</sup> Indeed, the presence of the Mylar captures the air just above the mirror which is rotating with the mercury, thus suppressing friction between the air and the mercury. Their typical amplitude and wavelength are of the order of  $\sim 10^{-6}$  (m) and  $\sim 10^{-2}$  (m), respectively, both increasing with the radius.

Since the different wavelets possibly present on the mercury layer have a different origin, it is important to determine their type in order to suppress them by the appropriate means.

We have developed a new method to detect and characterise the type of wavelets possibly present across the mercury layer. This paper presents a general description of the method and the designed instruments, as well as its mathematical modelling. We then present preliminary measurements performed for the ILMT primary mirror, held in order to validate the method for future on site characterisation of the telescope.