Digital holographic microscopy for micro-systems investigation in near infrared

Yves Delacrétaz[1], **Isabelle Bergoënd**[1] **and Christian Depeursinge**[1]

[1]Ecole Polytechnique Fédérale de Lausanne (EPFL)
Advanced Photonics Laboratory, Station 17, 1015 Lausanne Switzerland.
email: yves.delacretaz@epfl.ch

Summary

We have demonstrated the suitability of digital holographic microscopy (DHM) with near infra-red illumination for micro-optical elements and silicon micro-systems characterization, opening a wide field of quality control applications.

Introduction

Interferometric measurement techniques have been increasingly considered as a valuable approach for micro-systems quality check [1]. Repetto *et al.* reported on an infrared holographic setup for metallic films on silicon wafers inspection [2], but structures imbedded in silicon are difficult to observe in 3D and constitute an increasing demand of engineers realizing 3D devices. DHM is a contact-free, non destructive full-field optical measurement technique with real-time capabilities enabling the access to both amplitude and phase of the field back-reflected or transmitted from the sample under investigation [3]. When using the transmission configuration, the phase signal computed from the acquired field is proportional to the refractive index *n(z)* integrated along the optical axis. Quantitative measurement on either the topology for a homogeneous specimen, or the refractive index for specimens of known topology can thus be achieved.

Moreover, it is possible to create a full tomographic view of the refractive index by acquiring holograms under different specimen orientations [4]. Another approach is to acquire holograms for a limited number of orientations only, which allows for the rendering of stereoscopic phase images, giving access to the positioning of structures like channels or wells when looking through silicon micro-fluidics components for example.

Here we propose to use DHM with an illumination in the near infrared spectrum bandwidth, where the silicon is known to have small absorption. With such an illumination condition, it is possible to observe a wider range of specimens than in the visible spectrum. The counterpart is a somewhat reduced resolution due to the wavelength increase.

Approach

A distributed feedback fibered source working at 1551.2 nm with an emission spectrum width of 11 pm is used in a transmission DHM. The setup is depicted on Fig. 1. First, the light is separated in a reference arm (R) and an object (O) arm with the help of the beam splitter cube BS1. The light scattered by S is collected with a microscope

objective (MO), to observe a magnified version of the object. The beam splitter BS2 is used to recombine R and O, in order to acquire the hologram on the camera. The mirror M2 is placed so that there is an angle between the propagation directions of R and O, providing an off-axis configuration and enabling Fourier-space filtering of the image term for phase signal reconstruction by numerical propagation.

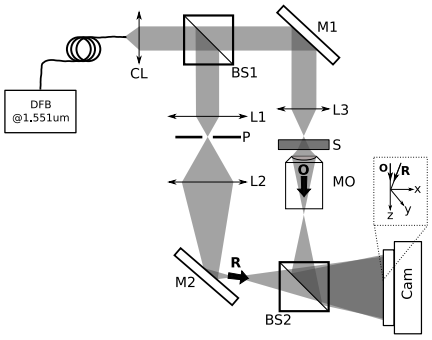
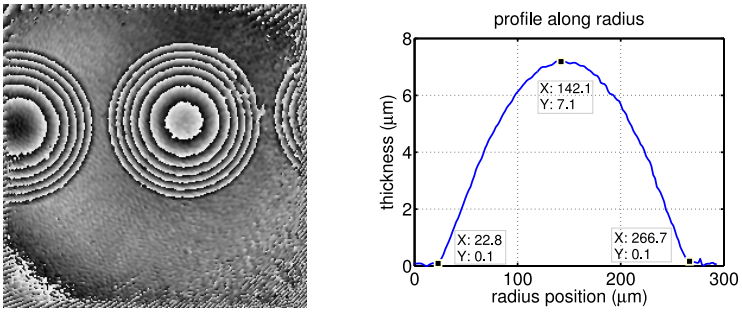


Figure 1: DHM transmission configuration. DFB: Distributed feedback laser. CL: Collimating lens. L1 + P + L2: reference beam cleaner. M: Mirrors. L3: Condenser. S: Sample. MO: Microscope Objective. BS: Cube beam splitters. Cam: InGaAs/CMOS hybrid IR Camera.

Fig. 2a presents the reconstructed phase image obtained when investigating a micro-lens, using a 20x microscope objective and illuminated with a wavelength of 1551.2 nm. The thickness profile depicted on fig. 2b has been calculated considering a constant refractive index of 1.444 in order to express the corresponding thickness as a function of the unwrapped phase signal.



(a) (b)

Figure 2: Fused silica micro-lens. (a): phase image, (a): thickness profile line.

Perspectives

Robustness and speed are undoubtedly two main advantages of DHM for applications in a closed-loop production process. Quantitative phase measurement can be embedded in the production chain for real-time quality check.

References

[1] N. Krishna Mohan and P. Rastogi, Opt Lasers Eng **47**, 199 (2009).
[2] L. Repetto, R. Chittofrati, E. Piano, and C. Pontiggia, Opt Commun **251**, 44 (2005).
[3] E. Cuche, P. Marquet, and C. Depeursinge, Applied Optics **38**, 6994 (1999).
[4] F. Charrière, A. Marian, F. Montfort, J. Kuehn, T. Colomb, E. Cuche, P. Marquet, and C. Depeursinge, Opt. Lett. **31**, 178 (2006).