MICROMACHINED SILICON-GLASS MIRAU MICRO-INTERFEROMETERS AS KEY COMPONENTS FOR MINIATURE MOEMS-BASED OPTICAL INSTRUMENTS

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Optical metrology exploits widely various interferometric techniques taking advantage of their unique capability of non-distractive measurement of a broad range of quantities with high accuracy. Interferometers are, hence, basic components implemented in many commercial and research optical instruments for diverse metrological tasks. Miniaturization of interferometers has become an important issue due to new metrology challenges (e.g. in-vivo imaging, multi-point inspection) and overall demand for portable, low-cost systems. The technology of micro-opto-electro-mechanical systems (MOEMS) allows batch fabrication of the micro-interferometers by integration of micro-optical components (mirrors, gratings, lenses), micro-actuators and opto-electronics, into compact mm-size device.

In this work, we demonstrate the application potential of Mirau micro-interferometer as a key component to build MOEMS-based optical instruments. We review the design, the fabrication process and experimental results of chosen demonstrators. Firstly, Mirau configuration is particularly well suited for MOEMS applications due to its compactness, sufficient magnification (up to 50x) and full compatibility of its vertical architecture with wafer-level assembly. Indeed, since all its main components (lens, reference mirror, spacer, beamsplitter) are aligned along optical axis, Mirau micro-interferometer can be batch fabricated by stacking and bonding of corresponding wafers with high lateral/axial alignment precision. This approach was demonstrated in the low-coherence Mirau 5x5 micro-interferometers, developed for a parallel in-line inspection of the MEMS [1]. Secondly, incorporation of microactuators, based on e.g. electrostatic or electrothermal modalities, results in "active" micro-interferometer, capable of spatial scanning of the light beam or precise generation of optical phase shift. The combination of such "active" micro-interferometers with an interferometry-based imaging method, such as sweep source optical coherence tomography (SS-OCT), has high potential for in-vivo medical diagnostics. Single-channel Mirau micro-interferometer with 2-D electrothermal micro-mirror scanner was integrated into an endomicroscopic SS-OCT probe for early stomach cancer detection, providing an axial/transversal resolution of 5.2/9.8µm [2]. For some applications, e.g. skin cancer detection, multi-channel approach is essential in order to increase the field of view (FOV) and to shorten the acquisition time. For this purpose, an active 4x4 array-type Mirau device with electrostatically driven reference micromirrors was developed for a full-field SS-OCT system with large FOV=8x8mm2 [3]. The combination of OCT and a phase-shifting techniques improves the sensitivity and eliminates unwanted image artefacts.

Fig 1. Micromachined Mirau micro-interferometer: a) schematic view [1], b) wafer-level fabrication result (Si-Glass-Si-Glass structure) [2], c) cross-section of individual Mirau structure

[1] J. Albero et al., "Micromachined array-type Mirau interferometer for parallel inspection of MEMS," *J. Micromech. Microeng.*, vol. 21, no. 6, pp. 1-10, Apr. 2011.

[2] P. Struk et al., "Swept-source optical coherence tomography microsystem with an integrated Mirau interferometer and electrothermal micro-scanner," Opt. Lett., vol. 43, no. 19, p. 4847, 2018.

[3] C. Gorecki *et al.*, "Micromachined phase-shifted array-type Mirau interferometer for swept-source OCT imaging: design, microfabrication and experimental validation," *Biomed. Opt. Express*, vol. 10, no. 3, p. 1111, 2019.