Optical, Mechanical and electro-optical Design of an Interferometric Test Station for Massive Parallel Inspection of MEMS and MOEMS

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1 Introduction

Reduced costs and enhanced reliability are essential for the further growth of the M(O)EMS market. This requires tests on wafer-level during production to detect faulty sensors before the subsequent packaging and assembly steps. In contrast to currently commercial optical test systems the concept of the system to be developed within the EU project SMARTIEHS pursues the parallel measurement of multiple dies [1] and thus a significant reduction of measurement time.

2 Inspection concept

The parallel testing is realized by an exchangeable micro-optical probing wafer which is adapted and aligned with the M(O)EMS wafer under test. The probing wafer comprises an interferometer array whose configuration, spacing and resolution depends on the M(O)EMS object. The corresponding illumination, imaging and excitation unit are modular and can be adapted and optimized for specific devices.

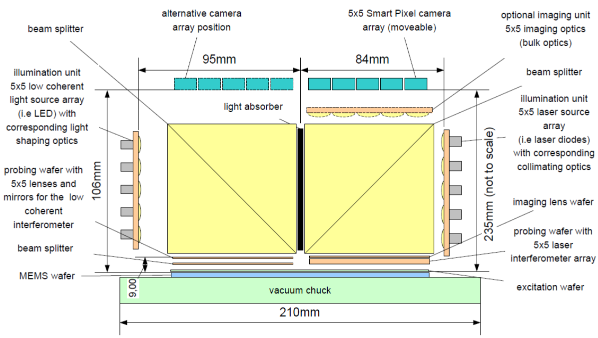
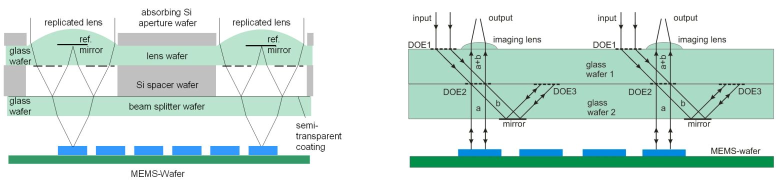


Figure 1: SMARTIEHS instrument configuration: Side view with dimensions

The demonstrator under construction uses a 5x5 interferometer array processed by standard micro-fabrication technologies. The multi-functionality of the system is given by two different probing wafer configurations, an array of low coherent interferometers (LCI) and an array of laser interferometers (LI). An array of smart-pixel cameras is designed for the detection of the interferometer signals. Figure 1 shows a sketch of the probe system with the integrated inspection system. The configuration of the two different interferometer arrays is shown in Figure 2. The left side of the image shows the low coherent interferometer array (Mirau) and the right side the laser interferometer array (Twyman-Green). The interference signals are generated in the micro-optical interferometers which are fabricated in a regular matrix on a 4-inch wafer stack.



a) low coherent Mirau interferometer to measure shape and deformation

b) laser Twyman-Green interferometer to measure vibrations

Figure 2: Preliminary interferometer design

A glass wafer consisting of Indium Tin Oxide (ITO) electrodes is applied for electrostatic excitation for dynamic testing of passive structures [2]. For the deformation measurements a tailor made pressure chuck is used.

3 Smart pixel camera design

Figure 3 shows the configuration of the imager array camera. The smart pixel imagers are placed in a 5x5 matrix at the camera module which transfers the images via a high speed frame grabber to the PC. Each channel is equipped with a smart-pixel CMOS imager for detection of the optical signal. The smart-pixel architecture allows the demodulation of the electro-optical signal at the detection level with demodulation frequencies up to 100 kHz. The electronic circuit at the pixel level not only allows amplitude demodulation but also the extraction of the modulation phase and is well suited for use with LCI and LI interferometry.

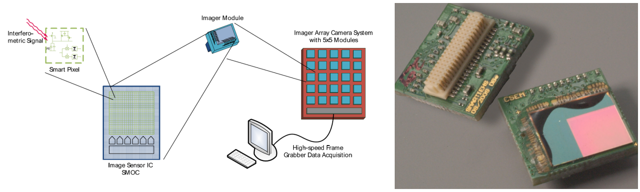


Figure 3: Configuration of the smart pixel camera (left) and imager modules (right)

4 Scanning drive design and controller

A high precision scanning platform is needed for focusing the measurement interferometer towards the M(O)EMS devices in z-direction. Furthermore the platform has to realize a highly uniform movement of the optical system with respect to the low coherence measurements. LCI requires a scan over a range of 0.6 mm with a linearity of < 1%. LI requires positioning accuracies with a measurement error < 10 nm and stability in the nanometer range. The design concept integrates three voice coil drives and three commercial interferometers (Figure 4).

Besides the z-scan the platform enables pitch and roll motions for the parallel alignment of the interferometer array to the MEMS-wafer. To realize a straight-lined and uniform z-motion the platform is weight compensated by pull-springs and guided with star-shaped leaf springs which provide a very high ratio of horizontal to vertical stiffness. The nonlinearity of the leaf springs stiffness is compensated by feed forward control.

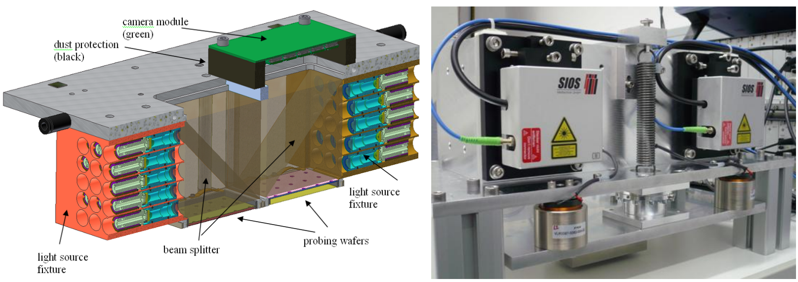


Figure 4: Optical unit with LCI and LI (left); Test setup of scanning platform (right)

The controller of the platform runs on an IPC board, using RTAI Linux as real time operating system. The analogue signals provided by the interferometers are interpolated by an FPGA. As the platform has to be adjusted by tilting moves (pitch and roll) before each measurement, the overall functionality of the controller is designed for separate tilting and traversing (z-scan) motions.

A setpoint generator for one-dimensional motions provides position, velocity and acceleration values for the z-scan in real-time. Since the movement of the three axes is strongly coupled on account of the overall geometry a decoupling is implemented in the controller by transformations of coordinates and conversions of forces so that the coil currents provide the forces necessary for the desired motions.

5 First measurement results of an LCI test setup

Figure 5 shows the interference signal obtained from an optical flat mirror. The flatness within the field of view (FoV) is better than λ/40. The left image shows the intensity of the interference pattern on a slightly tilted mirror. Applying temporal phase shifting the mod2π phase map can be obtained. By adjusting the mirror perfectly horizontal the systematic measurement error can be obtained. The left image shows the phase map for this configuration. The systematic error of the system is less than about λ/20. The error is circular distributed. This might be caused by lens or focussing errors, which will be improved in the final probing wafer.

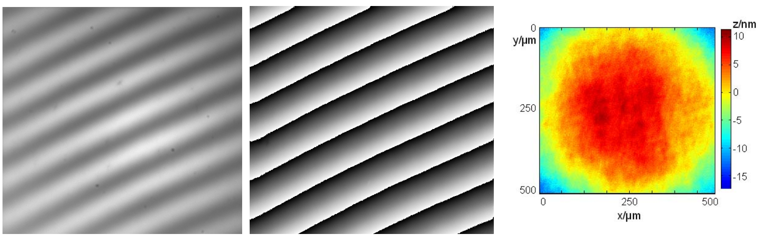


Figure 5: Measurement of a flat mirror: left: fringe pattern intensity, centre: mod2π phase map, right: result of its analysis (systematic error distribution)

6 Conclusions

The presented inspection system concept realizes a parallel approach for the production test of up to 100 M(O)EMS objects simultaneously. A multifunctional approach is implemented by the modular design including the micro-fabricated interchangeable interferometer wafer systems – static as well as dynamic measurements can be performed. Correspondingly two different micro-optical interferometer configurations are presented; a Mirau type low coherent interferometer for shape and deformation measurements and a Twyman-Green type laser interferometer for the measurement of resonance frequency and the spatial vibration mode distribution. The project is now focused on the production of the designed submodules and the integration into the demonstrator in order to validate the concept with the specified parameters.

7 Acknowledgement

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References:

[1] Gastinger, K., Haugholt, K. H., Kujawinska, M., Jozwik, M., Schaeffel, C., Beer, S., Optical, mechanical and electro-optical design of an interferometric test station for massive parallel inspection of MEMS and MOEMS, Proc. SPIE 7389-56, Optical Metrology, Munich, 2009

[2] Michael, S., Kurth S. et al, "MEMS Parameter Identification on Wafer Level using Laser Doppler Vibrometer", Smart Systems Integration, Paris, 321-328 (2007)