High-Resolution Digital Holography for Micro Mechanical Testing

Xu Lei, Anand Asundi and Miao Jianmin

An urgent need for testing tools

The current rapid growth in MEMS (Micro Electro Mechanical Systems) and NEMS (Nano Electro Mechanical Systems) engineering has motivated an urgent need for the development of testing tools for accurate measurement and characterization of microstructures and devices. On the one hand, miniaturization requires accurate knowledge on the material properties at the micro/nano level; validation of designs and simulations needs references of actual behavior of microstructures. Furthermore, performance of finished products critically depends on the processing parameters. It is necessary to develop powerful techniques that provide quantitative information about the structures enabling control of the fabrication processes.

Digital holography - a novel technology

Digital holography is a novel technology incorporating optical holography and digital reconstruction. It is a perfect match of two growth technologies in Photonics and IT. Holography has been a mainstay of optics with applications in data storage, interferometric testing and inspection and bioengineering. However, for it to merge with the demands of the IT age, it is necessary to include elements of digital technology. This could be done either in the recording stage or the reconstruction stage. In this application, this is done at the reconstruction step by simulating the physical processes with numerical algorithms. Because of the flexibility in manipulating wavefield information, both of the amplitude and phase distributions can readily be extracted from holograms. Digital holography, can therefore, be more efficiently employed in both static and dynamic testing and analysis.

In-line digital micro-holo-interferometry for micromeasurement

The first significant challenge in micro/nano measurement is the dimensional scale of test structures. Increased miniaturization and the diffuse reflecting property of microstructures place difficulties for common microscopic objectives and general-purpose imaging systems due to the dilemma of high magnification and long working distance. The appropriate microscopic scheme needs high resolution imaging and at the same time, ensuring enough working distance for good illumination of the object. Besides this demand on microscopy, improvement of system performance is also urgently required for high measurement accuracy and resolution. With these objectives, in-line digital micro-holo-interferometry (IDMHI) is developed to realize both imaging and interferometric measurement of microstructures (Figure 1).

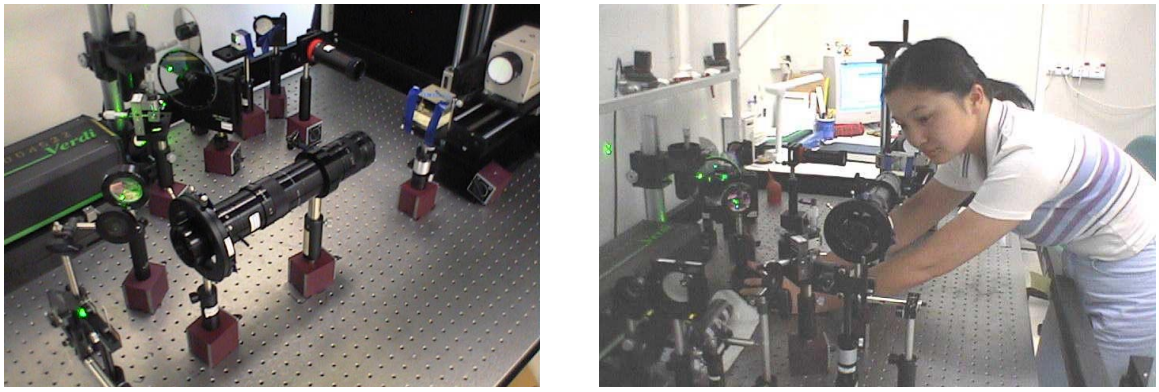

Figure 1. In-line digital micro-holo-interferometry (IDMHI) system

Advantages of the system

The system has the following capabilities and advantages

- Relaxed spatial resolution requirement on CCD sensors;
- Higher lateral resolution;
- Less speckle noise.
- Broad working distance: 50mm-2200mm;
- High lateral resolution: 1.75 mm (NA=0.19);
- High Flexibility.

Applications of the system

- Microscopic resolution capability

A standard USAF resolution test target, at a distance of 59mm is illuminated by a frequency-doubled Nd:YAG laser (λ=0.532μm) with output power of 40mw. Holograms are recorded on a Kodak 4.2i CCD chip with 2048×2048 pixels of $9\mu m\times9\mu m$ size. Figure 2 shows the real image of the target patterns reconstructed at the distance of 300 mm. The results demonstrate the microscopic capability of the proposed system in realizing measurement of structures with lateral dimensions of 5 microns or better.

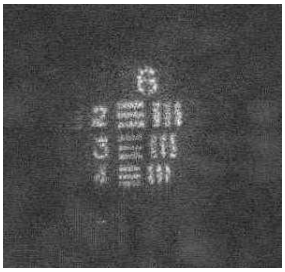

Figure 2. Reconstructed real image of the resolution test target

- Microbeam experiment

Figure 3 demonstrates the application of IDMHI for displacement analysis of a micro-cantilever. The out-of-plane displacement field is measured with a resolution of 6.2 nm on a magnified image of the test structure. This experimental result can serve as accurate input data for further computational or analytical analysis of microstructures as well as design consideration in cantilever structures widely used in the AFM (Atomic Force Microscope) and MEMS devices

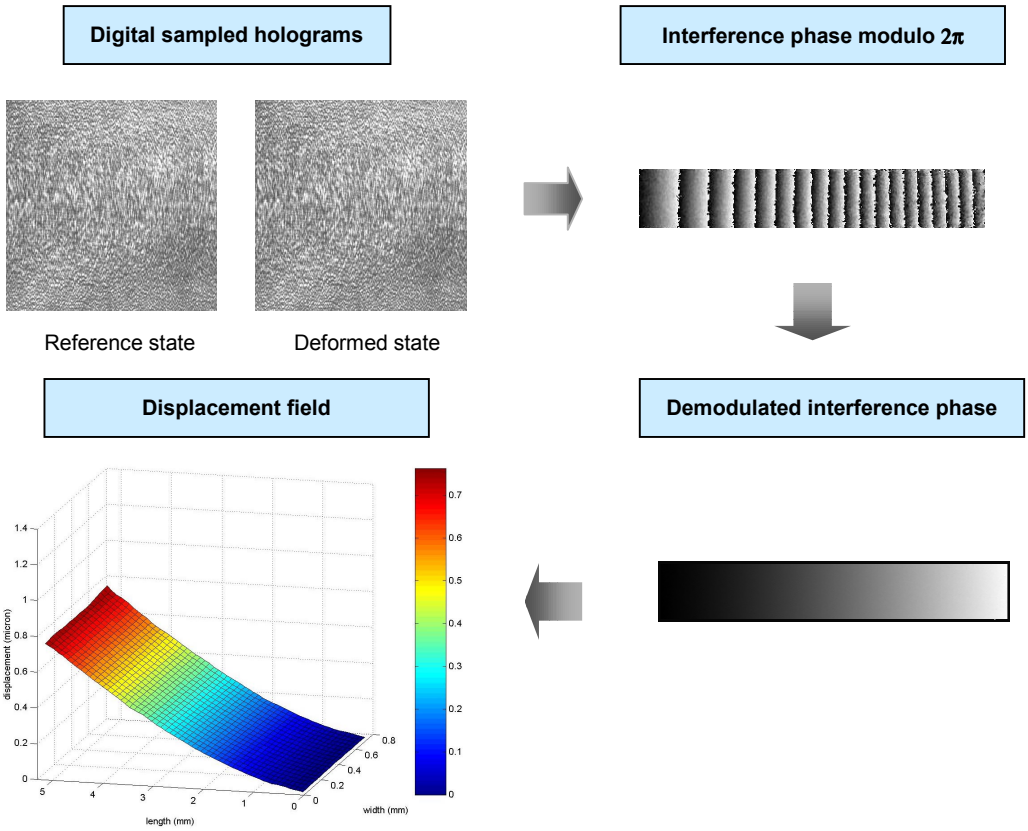

Figure 3. Displacement evaluation of a micro cantilever

For further information on this technology, please contact A/P Anand Asundi, Director of Sensors & Actuators Programme, at
Tel: 790 5936
Email: MASUNDI@NTU.EDU.SG

REFERENCES:

1. L. Xu, X. Peng, J. Miao and A. Asundi, "Digital micro-holo-interferometry for microstructure studies," *Proceedings of SPIE,* **4101**, pp. 543-548, 2000.

2. L. Xu, J. Miao and A. Asundi, "Properties of digital holography based on in-line configuration," *Opt. Eng*. **39**, 3214-3219 (1999).