Fiber-optic interference fringe projection for 3D measurement

Silvio Pulwer[1,2], P. Steglich[1,2], C. Villringer[1,2], J. Bauer[1], T. Reusch[1], S. Schrader[1]

[1]*Technische Hochschule Wildau, Photonics Research Group, Wildau, Germany*
[2]*University Tor Vergata Rome, Department of Industrial Engineering, Rome, Italy*

mailto: pulwer@th-wildau.de

This work presents experimental and simulation results of a 3D measurement concept based on fiber optic interference fringe projection. The results of parameter variation studies are discussed along with possible applications in the field of micro-optical 3D measurement systems like endoscopes. It demonstrates the possible integration and practical limitations of a triangulation based measurement system based on fiber–optic interference fringe projection.

1 Setup and requirements

Figure 1 describes the schematic setup we used. A HeNe laser is coupled to the input fiber of a 50:50 y-splitter. The fibers used were polarization maintaining monomode fibers with removed jacket and buffer. A Soleil-Babinet retarder and a polarization controller were used to control the phase shift and polarization angle between both fibers.

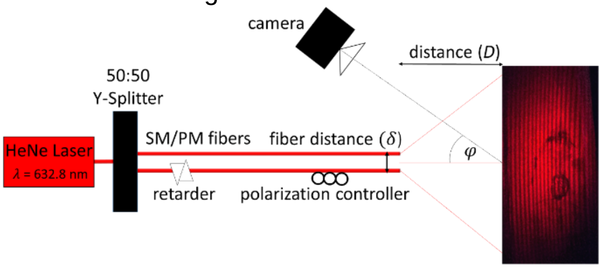

Figure 1 *Setup for the fiber-optic interference fringe projection.*

Each of the fiber ends acts as a point source which emits a spherical wavefront with slight different propagation vectors. The fringes produced are therefore basically Young's fringes and can be seen as parallel fringes with a distance described by $d = \lambda\, \delta / D$. [1]

The intensity distribution of the projected pattern in the object plane, captured by the camera is

$$I(x,y) = cos\left\{\frac{2\pi\delta}{\lambda D}\left[x\, cos\varphi + z_0(x,y)\, sin\varphi\right]\right\}. \quad (1)$$

Accurate and unambiguous 3D shape measurement of objects with surface discontinuities or spatially isolated surfaces are one of the most challenging problems in fringe projection 3D measurement. The obtained wrapped phase map contains true phase discontinuities which are originating from the object surface discontinuities. Therefore it is essential to overcome this problem by phase unwrapping strategies based on multiple phase maps generated by varying the spatial frequency of the projected fringe pattern. [2]

2 Results and discussion

To implement that approach into a micro-optical 3D measurement system, the combination of distance variation between the fibers and a controlled phase shift introduced by the retarder can be used to design the system versatile.

The integration of bundled monomode fibers responds to a variable spatial frequency of the obtained fringe pattern by a discrete level, corresponding to the distance of each fiber core (Figure 2a). Additionally by switching between different pairs of fibers inside the bundle, the alignment of the pattern can be adjusted (Figure 2b).

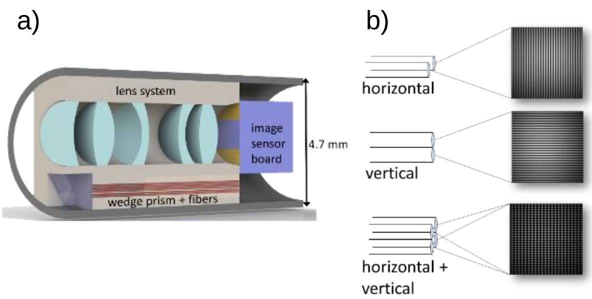

Figure 2 *CAD model of an endoscopic measurement system with integrated fiber bundle and corresponding fringe pattern.*

Because of the remote location of the laser source and control devices, the fiber-optic interference fringe projection system can be designed modular to fit into the distal end of an endoscope. In Figure 3 we show first practical results, based on an endoscopic system with 1 Megapixel image sensor, optics with NA = 0.056 and triangulation angle of 30°.

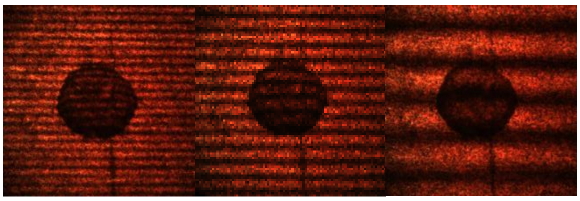

Figure 3. *Image of a defect with diameter = 800 µm and depth = 80 µm with different spatial frequencies of the fringe pattern.*

DGaO-Proceedings 2016 – *http://www.dgao-proceedings.de* – ISSN: 1614-8436 – urn:nbn:de:0287-2016-P023-6

eingegangen: 25.07.2016 veröffentlicht: 17.08.2016

To get a reliable accuracy of 3D monitoring, the surface needs to exhibit a Lambertian scattering behaviour with low correlation length. [3] Due to speckle and random noise, the fringe images should be pre-processed by low-pass filtering. Nevertheless the fringes superimpose with the noise spectrum and they cannot be separated out from noise clearly with filtering techniques.

Literature:

[1] Duan Xiao-jie et al., “Phase stabilizing method based on PTAC for fiber-optic interference fringe projection profilometry,” *Optics & Laser Technology, 47, 137-143,* 2013.

[2] Zappa E, Busca G., “Comparison of eight unwrapping algorithms applied to Fourier-transform profilometry”, Optics and Lasers in Engineering, 46(2): 106–16, Feb 2008.

[3] S. Pulwer et al., "Triangulation-based 3D surveying borescope", Proc. SPIE 9890, Optical Micro- and Nanometrology VI, 989009, April 2016.

DGaO-Proceedings 2016 – *http://www.dgao-proceedings.de* – ISSN: 1614-8436 – urn:nbn:de:0287-2016-P023-6

eingegangen: 25.07.2016 veröffentlicht: 17.08.2016