Spatial area shifting method for long depth object measurement using optical frequency comb laser based interferometers

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A femtosecond laser generates a frequency comb spectrum with an interval frequency in the MHz band and the beat signals of the harmonic frequency orders in optical domain synthesizes the radio frequency (RF) signals that can be observed by an available commercial fast photodiode. [1] A profile measurement system employing the RF domain of the frequency comb laser is regarded as a profilometry that has a centimeter-wavelength and is nowadays becoming great potential for industrial applications.

In our previous researches, a profilometer measured a meter-order depth object's profile with accuracy of 4 μm at the root mean square (RMS) error. The optical wave reflected from the object was sampled and converted into electrical signal by a single pixel camera. [1] The single pixel camera was constructed by two digital micromirror devices (DMDs) and a fast photodiode (PD), where the DMD encoded the object wave and the fast PD detected the beat signals of the harmonic frequency orders in the object wave.

The object's profile can be obtained by a raster scanning with simple single binary point masks or random scanning with random masks. Accordingly, the spatial resolution of the frequency comb profilometer was determined by the size of the binary points in the mask displayed on the DMD. The size and the number of the binary points were decided by the dynamic range of the PD. Currently, the profile measurement with the mask which had 10 × 10 binary points and their size was 0.304 mm.

In this reseach, we develop a new method for measuring the profile of the object using the frequency comb and the optical profilometers. The experiment setup was described in Fig.1. The random mask encoded the object wave in the frequency comb interferometer [1] was replaced by a single binary point one that is constructed by $x \times y$ pixels of the DMD, the position of the binary point was shifted x pixels in horizontal and y pixels in vertical directions after a measurement. Here, $x > \Delta x \geq 1$, $y > \Delta y \geq 1$ where x, y were chosen so that the intensity of the encoded object light was in the sensible range of the PD. Denoting X, Y calculated are the number of pixels of DMD, $M = X/\Delta x$ and $M = Y/\Delta y$, are integral numbers, the number of measurements required to achieved the profile of the object was $M \times N$. Consequently, the resolution of the frequency comb profilometer was $\Delta x \times \Delta y$.

Employing the profile obtained by the frequency profilometor, the reference mirror was moved to an appropriate position so that the very accurate and the profile can be partly observed with high lateral and axial resolutions using the low-coherence interference with the chromatic phase shifting technique [2]. The combination of the frequency comb and the optical profilometers allowed measuring the meter-order depth object profile with and sub-micron axial resolution.

Figure 2(a) shows an actual object. Figure 2(b) shows the reconstruction result. The detail of the research will be discussed in our presentation.

[1] Q. D. Pham and Y. Hayasaki, Appl. Opt. **54**, 39-44 (2015).
[2] Q. D. Pham and Y. Hayasaki, Optics Express **21**, 19003-19011 (2013).

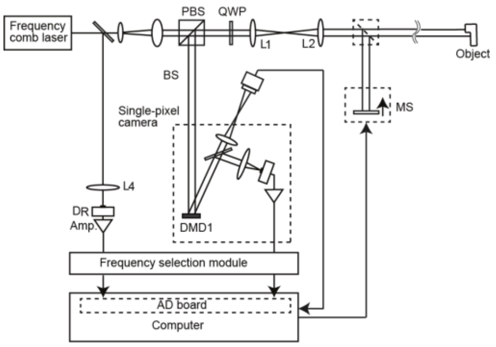

Fig. 1. Experiment setup.

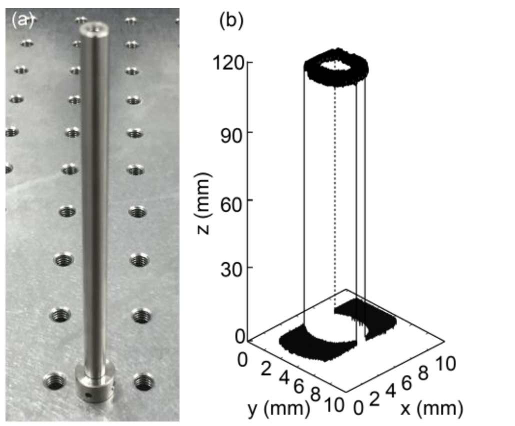

Fig. 2. (a) Object and (b) its reconstruction profile measured by the proposed system.