Technical Note No.2

Surface profile measurement by phase shift interferometry

1. Outline

(1) The phase difference ϕ between the reference light and the measurement light in the interferometer is computed by measuring the change in intensity of the interference light when multiple phase differences are given between the reference light and the measurement light in the interferometer.

(2) The height h of each point is obtained from the phase difference ϕ and the wavelength λ of the measurement light using the following formula:
$h = (\lambda/4\pi)\cdot\phi$

(3) As the phase difference obtained by this method has an ambiguity of $2\pi N$ (N is an integer), an unwrapping calculation is carried out by assuming that the height changes continuously.

(4) Therefore, this method is suitable for precise measurement of flat surfaces with a height range not exceeding several μm such as glass surfaces, film surfaces and magnetic head surfaces.

(5) The following algorithms are available in SP-500.
- Number of steps: 4-steps; 5-steps; 7-steps
- Unwrapping: Neighborhood-pixel method; MST (Minimum Spanning Tree) method

2. Principle of PSI

Interference between the light reflected from the surface of the object of measurement and the reflected light from the reference surface is considered. If the phase difference between both lights is ϕ and the height from the reference surface is h, then $\phi = 4\pi h/\lambda$.

In the phase shift interferometry, the phase difference ϕ is computed from the multiple interference images obtained when the reference surface in the interference microscope is driven by a piezo element (PZT) and the reference light path is changed for a known amount.

Although a minimum of 3 images is theoretically sufficient, the computationally simpler 4-step method is usually used. In this method, the unit of phase shift is $\pi/2$ and the phase is changed for 4 times for 0, $(1/2)\pi$, π, and $(3/2)\pi$. This means shifts for 0, $(1/8)\lambda$, $(1/4)\lambda$, and $(3/8)\lambda$ if the wavelength of the light source is λ. If the intensity of the interference light for each time is a, b, c and d respectively, the phase ϕ can be represented with a simple formula as follows:

$$\phi = \tan^{-1} [(a - c)/(b - d)].$$

As the phase difference obtained by this method has an ambiguity of 2πN (N is an integer), an unwrapping calculation is carried out on the assumption that the height changes continuously.

Although there are many algorithms for the unwrapping calculation, the Neighborhood-pixel unwrapping method, which is the simplest, and the MST (Minimum Spanning Tree) method, which is the most robust although computation time is lengthy, are available in SP-500. (thanks to provision of guidance and software by Dr. Jun-ichi Kato of the Optical Engineering Laboratory of the RIKEN, the Institute of Physical and Chemical Research)

3. Features

(1) The height resolution is in the sub-nanometer order.

(2) Measurement can be carried out regardless of the change in the reflectance factor on the surface.

(3) Measurement of the height of all points in the frame can be made within 1 second just by taking in 4 to 5 images.

(4) As unwrapping is required when converting the phase into the height, this method is applicable only to surfaces that are sufficiently flat compared with the wavelength.

4. Applications

(1) Surfaces of concave lens

Results are shown in Figure 1 and Figure 2. The surface profiles were measured in the nm order.

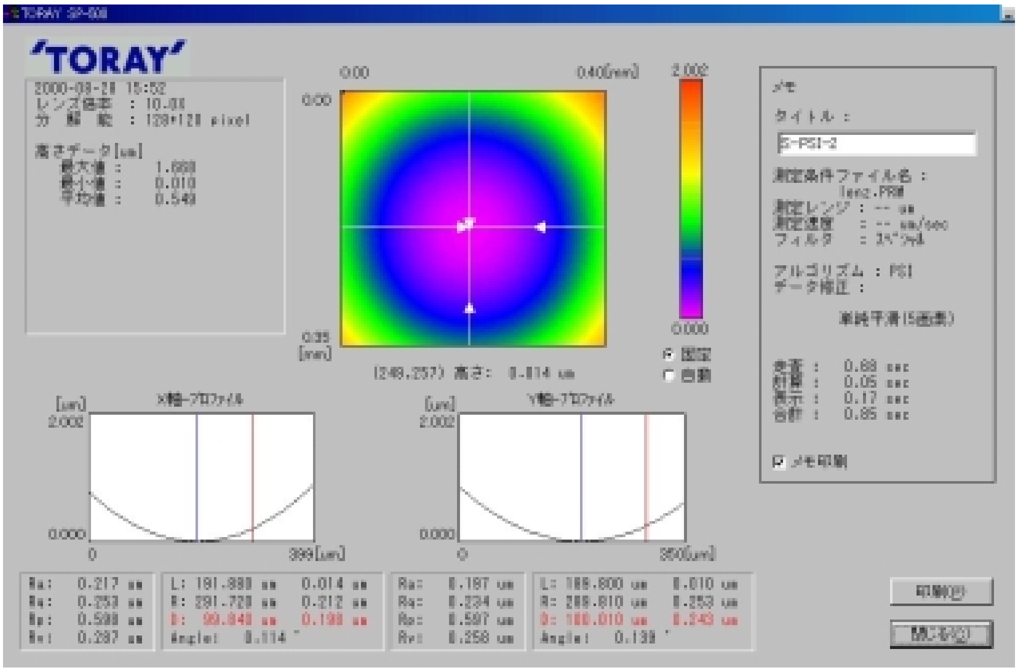

Figure 1 Results of measurement of surfaces of concave lens

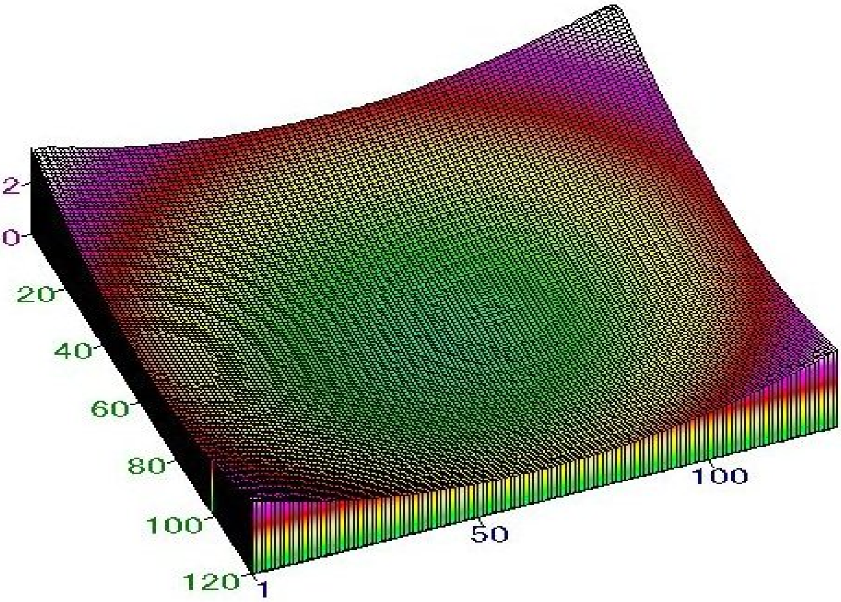

Figure 2　Results of measurement of surfaces of concave lens (3-D view)

(2) Floppy disc media surfaces

Results are shown in Figure 3 and Figure 4. The surface roughness was measured in the submicron order.

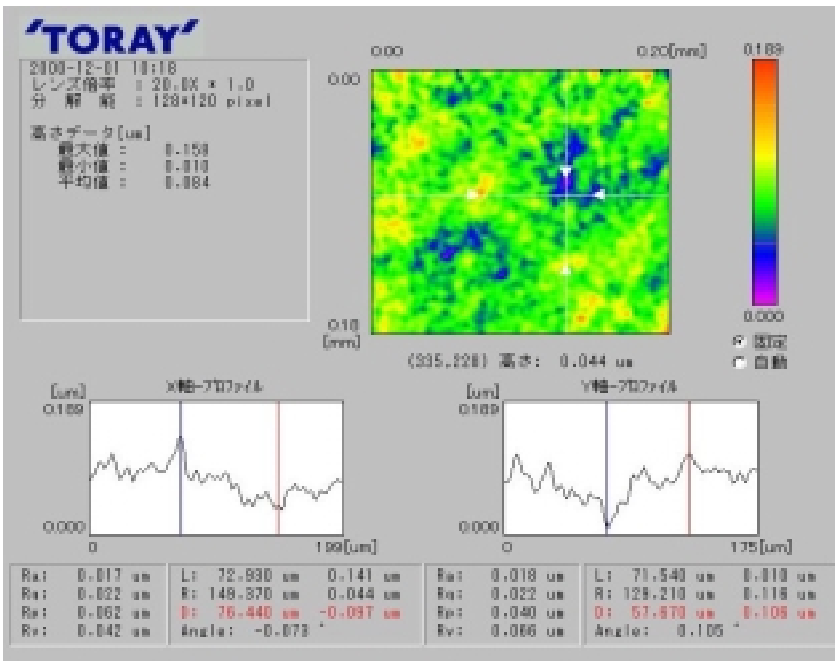

Figure 3　Results of measurement of surfaces of magnetic media

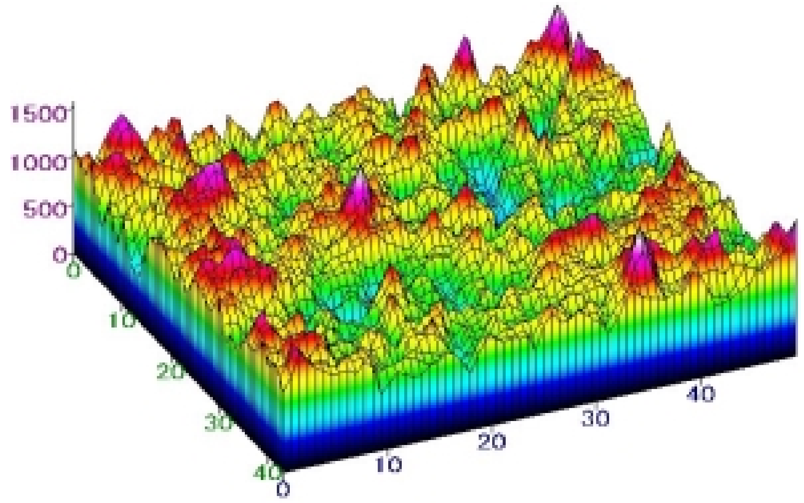

Figure 4　Results of measurement of magnetic media surface　(3-D view)

Toray Engineering Co.
Electronics Division
Display-system marketing department, MED section
Oe 1-1-45, Otsu, Shiga　520-2141 JAPAN
Tel: (+81)77-544-1635
Fax: (+81)77-544-6091
e-mail: torayins@scn.tv
http://www.scn.tv/corp/torayins/