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The Editor

Dr. Stefan Bäumer

Philips Applied Technologies
Eindhoven, Netherlands

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Various lenses used in optical pickup units
by Penta HT Optics, Eindhoven

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List of Contributors

Stefan Bäumer

Philips Applied Technologies
Optics & Sensors
HTC 7 / 4A
NL – 5656 AE Eindhoven
The Netherlands

Thomas Bauer

Jenoptik Polymer Systems
Am Sandberg 2
D-07819 Triptis
Germany

Jukka-Tapani Mäkinen

VTT Technical Research Centre
of Finland
P.O. Box 1100
FI-90571 Oulu
Finland

Koji Minami

Zeon Corporation
Division of Specialty
Plastics & Components
1-6-2, Marunouchi, Chiyoda-ku
Tokyo, 100-8246
Japan

Michael Pfeffer

Optical Engineering
Physical Engineering Course
FH Ravensburg-Weingarten
Postfach 1261
D-88241 Weingarten
Germany

Ulrike Schulz

Fraunhofer Institut IOF
Albert Einstein Str. 7
D-07745 Jena
Germany

Thomas Walter

Arburg
Arthur-Hehl-Strasse
D-72290 Lossburg
Germany

Stefan Bäumer is working at the Philips Applied Technologies as senior optical designer. Besides design of general optical system his main areas of interest are in design and metrology of injection molded optics.

Thomas Bauer is working at Jenoptik Polymer Systems Triptis, a plastic optics manufacturer. He is currently head of the development department.

Dieter Marschall is Area Sales & Service Manager for Germany, Austria & Switzerland at Precitech B.V., the European subsidiary of Precitech Inc. (USA), one of the worlds leading manufacturer of “Single Point Diamond Machining Systems” for turning-, milling- and grinding operation.

Koji Minami is working at Zeon Corporation as senior researcher. His main responsibility is application development of Cyclo Olefin Polymer (COP): ZEONEX®/ZEONOR®.

Michael Pfeffer is teaching at the University of Applied Sciences in Weingarten as professor of optical engineering. His major areas of interest are finite element analysis in opto-mechanical engineering, diffractive optics and nanometric structuring of optical surfaces. He is currently dean of the master course Optical Systems Engineering.

Ulrike Schulz received her diploma degree in chemistry in 1986 and her PhD (Dr. rer.nat.) in 1993 from the University of Jena, Germany. She is responsible for the group coatings on polymers at the Fraunhofer Institute of Applied Optics and Precision Engineering in Jena and has authored a number of papers and patents on processes for polymer coating and coating design.

Thomas Walther is working at ARBURG GmbH & Co. KG, a manufacturer of plastic injection moulding machines. He is responsible for the applications engineering department

Jukka-Tapani Mäkinen is working as a senior researcher at the Technical Research Centre of Finland. In addition to optical design work he is doing research on the topics of embedded optics in consumer devices and heterogeneous integration of electronics, optics and mechanics.

1

Introduction

Stefan Bäumer (Philips Centre for Industrial Technology (CFT), Eindhoven, The Netherlands)

Optics has been identified as one of the key technologies for the 21st century. Already now in our daily lives we come across optical technologies in several areas:

- at the supermarket most of the tills work in conjunction with bar code scanning;
- ink jet printers perform automatic calibration and media detection;
- most new mobile phones have an integrated camera;
- music and movies are available on CD and/or DVD players;
- computers store data on optical disks;
- blood sugar measurements are based upon optical technology; and
- LED illumination exists in several applications.

Looking at the examples above, it can be concluded that optical technologies are part of various market segments: consumer electronics, lighting, medical, automotive, sensors in general, security, and biometrics.

In order for these markets to further develop and emerge not only do smart inventions have to be made but also suitable manufacturing technologies have to be developed. For optical technology to really reach out and find applications in the mass market it is essential that optical components and systems can be manufactured in high volumes and at low prices. Many of the other components for high-volume applications as described above are based on silicon technology. Light sources such as LEDs and laser diodes can be manufactured using already developed silicon processing and manufacturing technology. The same holds for detectors such as photodiodes and CCD or CMOS cameras. These wafer-based technologies can cope with (very) high volumes and are of low cost. For integration of optical systems together with silicon devices in high-volume consumer optics, injection molding is the manufacturing method of choice. Once a design is cut into a tool and the proper processing for the application is developed, hundreds of thousand of virtually identical products can be made from that one master. Injection molding of optics is known for showing very little part-to-part variation once the proper process is defined. Also, using multi-cavity molding, low prices per piece and a fast production cycle can be achieved. Using 8-cavity – and

An imaging version of the deflectometer has been implemented and industrialized as well [25]. This implementation is specially suited and geared toward fast and precise measurement of spectacle lenses [26].

4.3.4

Tactile Profiling

The classical way of measuring surface profiles is using mechanical tactile instruments. The most widely used and known one is the Form Talysurf of Taylor Hobson. The instrument was introduced first in 1984 and since then became an industry standard in surface profiling. The Form Talysurf is a tactile sensor with a very fine tip. The tip is brought in contact with the surface under test, and then the surface is profiled along lines. This is done by scanning the tip across the surface under test. Figure 4.9 illustrates the contact of the fine tip with the surface under test.



Figure 4.9 Contact profiling (photo courtesy of Taylor Hobson Ltd. [27]).

The main advantage of this technology is that the surface is profiled in direct contact, leaving no ambiguities on where the surface under test is. Furthermore with this method, most free-form and aspheric surfaces can be handled. Figure 4.10 shows the example of an aspheric surface that is very difficult to measure with optical metrology. This type of surface is quite common in recent designs for camera modules for cell phone cameras.

One of the problems of measuring this type of surfaces is the changing curvature of the surface and the fairly steep slopes. Therefore, an optical profiler would have to have a considerable measurement range. The Talysurf can handle this type of surfaces easily. Depending on the instrument, scans up to 200 mm in the

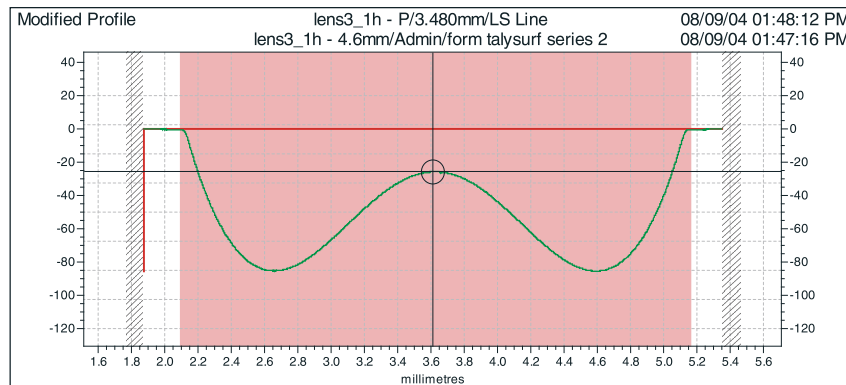


Figure 4.10 W-shaped aspheric surface (vertical scale in micrometer).

lateral (x -) direction can be done. Using the newest model PGI 1240 (Figure 4.11), the range in the z -direction is 12.5 mm. The sampling rate in the x -direction lies between 0.125 and $1.0\ \mu\text{m}$ (depending on the scan length) with an uncertainty of $0.3\ \mu\text{m} + 0.03 \times \text{scan length}$. The repeatability in height can be as good as $0.04\ \mu\text{m}$ at a resolution of $0.8\ \text{nm}$. Maximum slope angles that can be measured lie between $\pm 35^\circ$. As with many other instruments, also for the Form Talysurf proper calibration of the system is the key. Over the years, Taylor Hobson has developed sophisticated calibration routines that enable the instrument to perform at a high level. Since this is a contact-probing instrument, both inserts and molded optical components can be measured with this technique.

A new member in the Talysurf family is the PGI BLU [29]. This new instrument was especially developed to cope with very high numerical aperture lenses as used

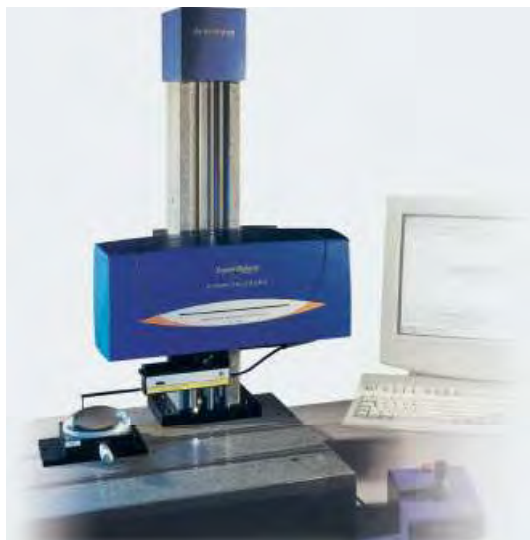


Figure 4.11 Form Talysurf PGI 1240 (photo courtesy of Taylor Hobson Ltd. [28]).

in BluRay technology and also in cell phone cameras. The main difference between this one and the PGI1240 is that the instrument is moving relative to the part under test. By doing so, the actual probe can stay well within its measurement and accuracy range, while sophisticated software puts the probe data and mechanical scan data together to one continuous (aspheric) surface. Again, precision mechanical movements are combined with high accurate probes, giving locally the required resolution. Figure 4.12 illustrates this principle.

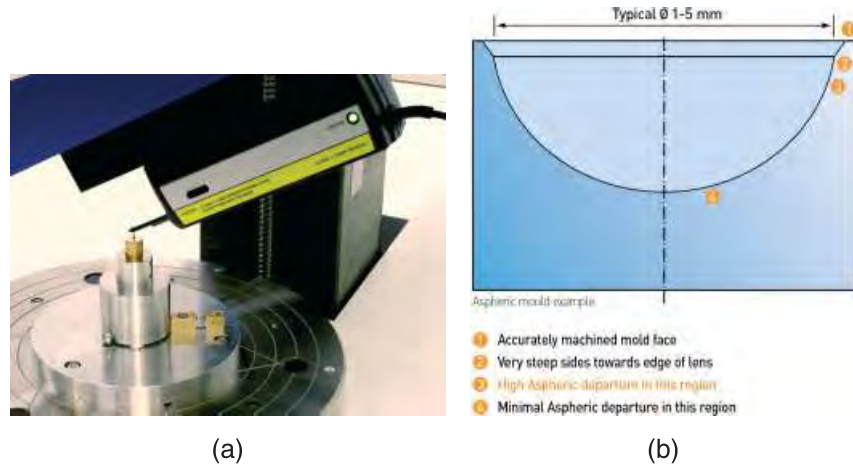


Figure 4.12 (a) PGI BLU. (b) Different measurement regions of an aspheric mold (courtesy of Taylor Hobson Ltd [30]).

The main disadvantages of the Form Talysurf are the measurement speed and the fact that during the measurement the surface under test is in contact with the probe. Although the forces applied to the measurement tip are usually in the millinewton range, traces of the measurement will be visible. For the injection-molded lenses, this is usually not a problem, since in molding many lenses can be produced. However, qualifying the inserts that are used for molding the optical components is more critical. Figure 4.13 shows the intensity map of an optical insert after mechanical profiling. The traces of the probe are clearly visible, as a cross in diagonal direction. Although in absolute height they are only on the order of a couple of nanometers, but they are present.

Another problem encountered when applying tactile probing is the measurement of nonrotational symmetric surfaces. Tactile profiling is producing 2D scans of a surface. If one wants to know the complete 3D form of the surface, the different profiles have to be stitched together.

Up to now, the Talysurf-like instruments are still the standard for characterizing optical surfaces that cannot be profiled in any other way, despite this disadvantage. Also for all other surfaces, the Talysurf is a very useful instrument, provided one has got the time for the measurement. In process control for a limited amount of samples and for initial tool characterization, this is a very valid measurement

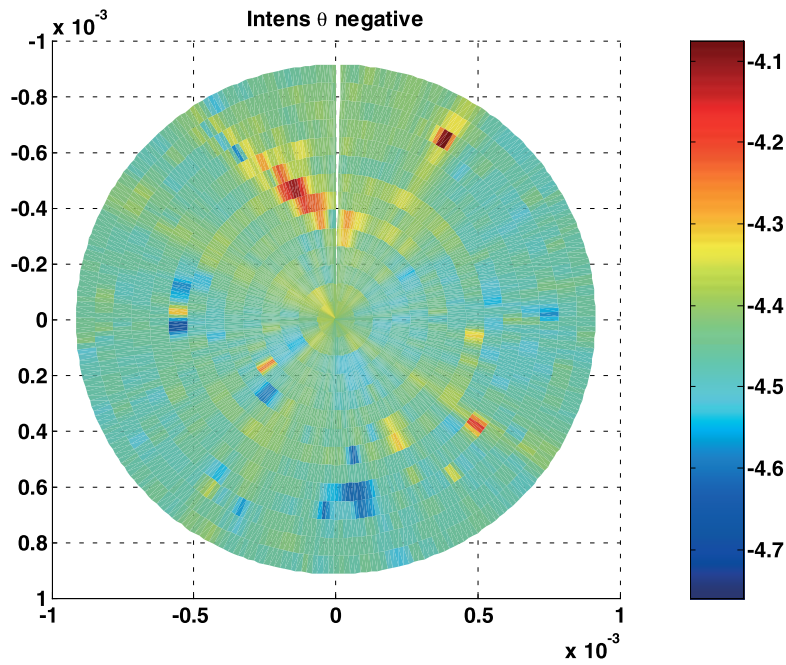


Figure 4.13 Intensity image of a nickel surface.

option. For high-throughput applications, it is advisable to check the other options mentioned.

4.4

Wavefront Metrology

4.4.1

General Concept

In wavefront metrology, a wavefront after interacting with a sample under test is analyzed. In general, for wavefront metrology matrix detectors are used, and hence 3D information is captured fast. The advantage of wavefront metrology is that it can be used not only for surfaces but also for characterizing whole components. In the latter case, optical parts are measured in transmission. Sometimes that opens the way for a functional measurement, where pure surface metrology could have been difficult. In some cases, the combined effect of two surfaces on a wavefront might be less steep or complex than on one of the surfaces alone. This is not only the power measuring the wavefront of components but also a point of attention. When measuring the combined effect of two or more surfaces, it is not always straightforward to single out the root cause of a potential defect. In order