Parallel-Kinematics 6-Axis Positioning System:

Ultra-Precise 6D-Measuring System for Optical Surfaces

Inserts for precision optical molds make high demands on the testing process. Today, such testing can easily be automated with the help of interferometric measuring devices. Parallel-kinematics Hexapod 6-axis alignment systems even make it possible to integrate testing directly in the manufacturing process.

Fig. 1: The tighter the tolerances required for a product, the higher the precision required of the testing equipment. The optical mold inserts for production of plastic or glass lenses have especially high precision requirements.
(Illustration: Fraunhofer Institute for Production Technology, IPT)

The integration of testing equipment for optical mold inserts (Fig. 1) directly into the manufacturing cell avoids complex and time-consuming setup steps and completely eliminates rechucking errors. The new testing unit developed by the Fraunhofer Institute for Production Technology (IPT) in Aachen, Germany tests the optical mold inserts directly in-line, on the production machine. Discrepancies are calculated and the error is fed back into the process where it can, if necessary, trigger automatic reworking of the optical surface. Automated interferometric surface testing is the key to the system.

Interferometric testing: non-contact, fast and extremely precise

Interferometric optical mold testing uses the interference pattern (fringe pattern) which gives information about the topography of the test sample. Image processing algorithms automatically recognize and evaluate shape deviations with nanometer accuracy. The interferometer must, of course, be positioned very precisely relative to the optical surface.

First, coarse adjustment aligns the beam reflected off the test surface with the CCD sensor. Then, with the fine adjustment, a well-defined interference pattern is created. The automated fine-adjustment algorithm uses the Fast Fourier Transformation (FFT) technique to analyze the fringe pattern. The adjustment strategy is based on an evaluation system newly developed at the Fraunhofer IPT, which determines the topology from a single interference pattern.

In order to test both spherical and aspherical elements, motion in six degrees of freedom is required (Fig.3). For this purpose, a PI parallel-kinematics positioning system is used. In addition to very high accuracy, it offers further advantages such as low inertia, uniformly high dynamic performance for all motion axes, and a compact design with a large aperture.

Hexapod: Six Degrees of Freedom and Freely Definable Pivot Point

The PI M-840 Hexapod chosen also provides rapid settling after a move, a linear travel range of up to 100 mm and a rotational travel range up to 60°. The large working space makes it possible to measure spherical surfaces with a radius of up to 100 mm. Also important for both the coarse and fine alignment process is the

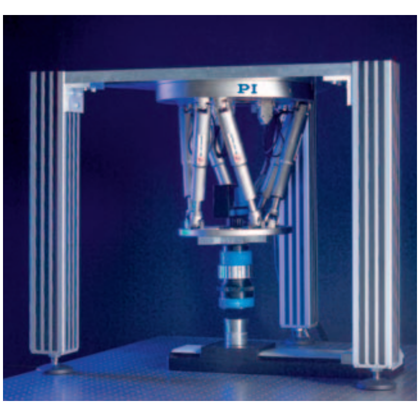

Fig. 2: The Hexapod is mounted on a 20 mm thick aluminum plate. The parallel-kinematic design and large aperture allow for the interferometer to be integrated into the Hexapod. Images are captured by a CCD camera and evaluated in real time. A MATLAB program, controls the position of the Hexapod.
(Photo: Physik Instrumente, PI / Fraunhofer Institute for Production Technology, IPT)

freely definable pivot point, which is not affected by motion. The optical mold testing interferometer system achieves impressive values: 3 µm accuracy in X and Y, 1 µm in Z – with repeatabilities also of 3 µm and 1 µm, respectively. The rotational minimum incremental motion of only 0.017 arc minutes (5 µrad) is over an order of magnitude better than the required 1 arc minute.

Simple Integration

It was surprisingly easy to integrate the Hexapod into the application's automation environment. Control is simplified by the Hexapod controller's open interface architecture, which facilitates programming with high-level commands using any of a variety of included drivers (COM Object or DLL). The Hexapod controller can thus be operated by external programs, such as the MATLAB programs employed for image processing and analysis in the testing interferometer. The flexibility of the Hexapod system played an important part in making possible the first fully integrated automated testing device for optical components with complex geometries. The new interferometer will significantly simplify quality control while providing higher precision than otherwise possible.

Karl Vielhaber, MSc, scientific assistant at the Fraunhofer Institute for Production Technology (IPT) in Aachen, Germany and Ellen-Christine Reiff, M.A., Editorial Service Stutensee

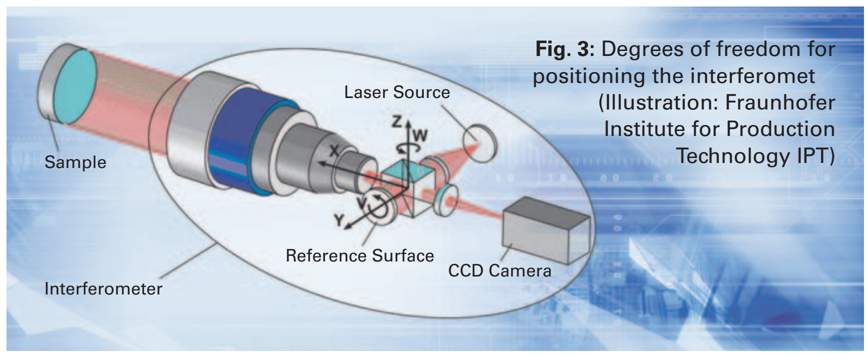

Fig. 3: Degrees of freedom for positioning the interferomet (Illustration: Fraunhofer Institute for Production Technology IPT)

USA

PI (Physik Instrumente) L.P.
16 Albert Street
Auburn, MA 01501
Tel. +1 508 832 3456
Fax +1 508 832 0506

5420 Trabuco Road, Suite 100
Irvine, CA 92620-5743
Tel: +1 949 679 9191
Fax: +1 949 679 9292
info@pi-usa.us
http://www.pi-usa.us

JAPAN

PI-Japan Co., Ltd.
2-38-5 Akebono-cho
Tachikawa-shi
J-Tokyo 190-0012
Tel. +81 42 5267300
Fax +81 42 5267301

Hanahara Dai-ni-Building #703
4-11-27 Nishinakajima,
Yodogawa-ku, Osaka-shi
J-Osaka 532
Tel. +81 6 63045605
Fax +81 6 63045606
info@pi-japan.jp
http://www.pi-japan.jp

CHINA

Physik Instrumente
(PI Shanghai) Co., Ltd.
Building No. 7-301
Longdong Avenue 3000
201203 Shanghai
Tel. +86 21 68790008
Fax +86 21 68790098
info@pi-china.cn
http://www.pi-china.cn

FRANCE

Polytec PI S.A.
32 rue Delizy
F-93694 Pantin Cedex
Tel. +33 1 48103930
Fax +33 1 48100803
pi.phot@polytec-pi.fr
http://www.polytec-pi.fr

GREAT BRITAIN

Lambda Photometrics Ltd.
Lambda House · Batford Mill
GB-Harpenden, Hertfordshire
AL5 5BZ
Tel. +44 1582 764334
Fax +44 1582 712084
pi@lambdaphoto.co.uk
http://www.lambdaphoto.co.uk

ITALY

Physik Instrumente (PI) S.r.l.
Via G. Marconi, 28
I-20091 Bresso (MI)
Tel. +39 02 66501101
Fax +39 02 66501456
info@pionline.it
http://www.pionline.it