

## 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.

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. Discre-



**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)

pancies 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.

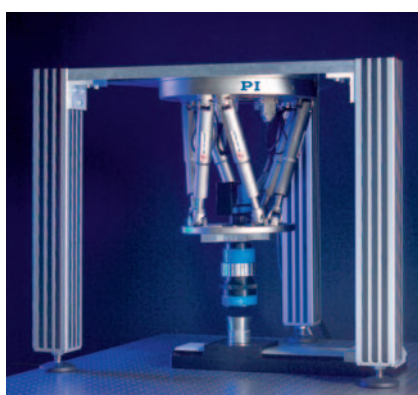
First, coarse adjustment aligns the beam reflected off the test surface with the CCD sensor. Then, with the fine adjustment, a well-defined interference pattern is created. The automated fine-adjustment algorithm uses the Fast Fourier Transformation (FFT) technique to analyze the fringe

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  $\mu\text{m}$  accuracy in X and Y, 1  $\mu\text{m}$  in Z – with repeatabilities also of 3  $\mu\text{m}$  and 1  $\mu\text{m}$ , respectively. The rotational minimum incremental motion of only 0.017 arc minutes (5  $\mu\text{rad}$ ) is over an order of magnitude better than the required 1 arc minute.

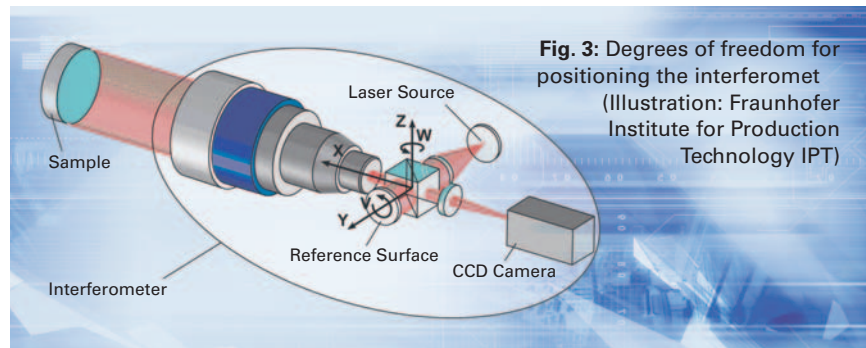
### Simple Integration

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 signifi-

cantly simplify quality control while providing higher precision than otherwise possible.

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

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