Design and realization of a measurement machine for the universal non-contact measurement of large freeform optics with 30 nm uncertainty

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Abstract
A new measurement machine is being developed capable of universal, non-contact and fast measurement of freeform optics with a measurement uncertainty of 30 nm (2σ). The detailed design is now almost complete and realization is progressing rapidly. The ambitious requirements are still expected to be met and completion is expected in the 3rd quarter of 2007.

1 Introduction
New fabrication technologies enable generation of freeform and aspherical optics (figure 1), but a suitable metrology tool is still lacking. In 2004 Technische Universiteit Eindhoven, TNO Science & Industry and NMI Van Swinden Laboratory therefore started the NANOMEFOS project. Aim of this project is to design, build and test a measurement machine capable of non-contact, universal and fast (<15 minutes) measurement of freeform optical surfaces up to $\varnothing 500 \times 100$ mm with an uncertainty of 30 nm (2σ).

2 Machine design
Since [1] the design has been modified extensively, the detailed design is almost complete and realization is progressing rapidly. The design can be divided into three main modules: the motion system (1), the metrology system (2) and the non-contact probe (3), as shown in figure 2.
2.1 Motion system

The machine consists of a granite base (5) which is suspended on vibration isolators. The motion system positions the optical probe in radial, vertical and slope direction relative to the product (4) which is rotating continuously (1 rev/s) on an air-bearing spindle. The probe is mounted on a pivoting axis $\psi$ to position it perpendicular to the surface. The vertical Z-stage (6) on which this axis is mounted is aligned directly to a vertical plane of the granite base by 3 air bearings, to provide an accurate plane of motion (figure 3, left). The stages have been split into position and force frames to prevent distortions and hysteresis (PF and FF in figure 3), the motors are aligned to the centers of gravity and the scales have minimal Abbe offset relative to the probe.
2.2 Metrology system

The metrology system (figure 4) measures the probe and product position relative to a metrology frame (1). The axial, radial and tilt error motion of the spindle is measured using the multi-probe method [2] incorporating 7 capacitive sensors (2). The position of the optical probe is measured using a dual pass interferometer setup (3). It measures directly in Abbe onto the probe pivoting axis, thereby eliminating all critical stage errors from the metrology loop.

![Figure 4: Metrology loop](image)

2.3 Non-contact probe

The third module is the non-contact probe, which requires nanometer uncertainty combined with 5 mm axial range and 5° acceptance angle to surface inclination. Therefore a dual stage optical probe is being developed, consisting of a differential confocal system [3] combined with an elastic guidance and an interferometer (figure 5). The normalized differential signal of the two photo-diodes (PD) yields a linear focus-error signal (FES) with a range of about 2 µm. By moving the objective, the range is increased to 5 mm, with maintained nanometer resolution. The low moving mass of 50 g enables freeforms to be measured swiftly (< 15 min.). These two systems

![Figure 5: Probe principle](image)
have been combined in a very compact module, as further explained in [4].

3 Conclusion

The detailed design of the machine is almost completed and realization is progressing rapidly. The granite base block and aluminum R-stage position frame are shown below. The ambitious requirements are still expected to be met, and hardware completion is expected in the 3rd quarter of 2007.

![Granite base block and R-stage position frame](image)

**Figure 6: Granite base block and R-stage position frame**

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References:


