A new Variation of the Long Trace Profiler Principle

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INTRODUCTION

The increasing number and variety of optical element characterizations at the Helmholtz-Zentrum Berlin / BESSY II as well as the multifunctional technical options offered by the known Long Trace Profiler (LTP) principle [1] have motivated us to propose a design for an optical measuring system based on this principle.
We introduce the option of using various reflecting phase shifting plates to take advantage of the two dimensional properties of CCD cameras. Applying a scanning head with two double mirrors can reduce the problem of glass inhomogeneities.
We plan to install and test the instrument in the BESSY Optics Laboratory, re-using the granite base of the first BESSY-LTP, made in 1995, that is currently out of operation.
We present the layout and features of this optical measuring system as well as the design of a first implementation in order to launch further discussions.

MULTIFUNCTIONALITY OF THE LTP PRINCIPLE

Despite its outstanding performance and the good experiences we have had with the autocollimator measuring head (AC) [3] installed at the BESSY-NOM [2], it would be useful to have in addition to the AC a multifunctional LTP based measuring system. Although the NOM-AC provides an excellent measuring performance in the curvature range from infinity down to ~6 meter, it fails to accomplish some other measuring tasks. Figures A, B and C show some typical LTP applications and application ideas.

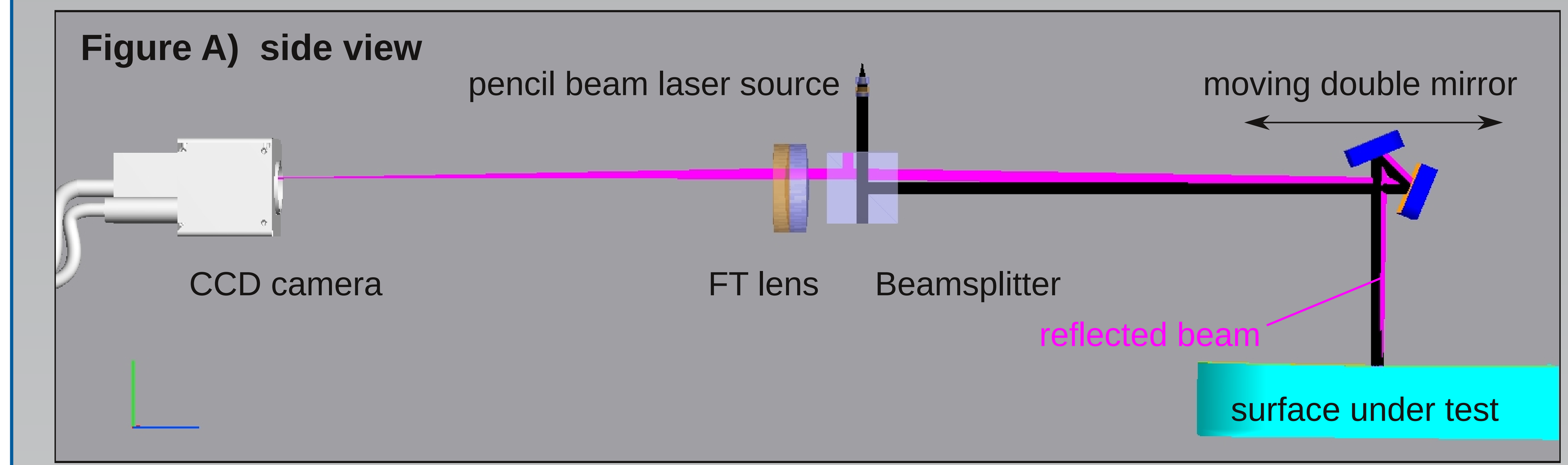


Figure A)
Scheme of a conventional LTP measuring setup, enabling slope measurements down to ~1 m curvature.

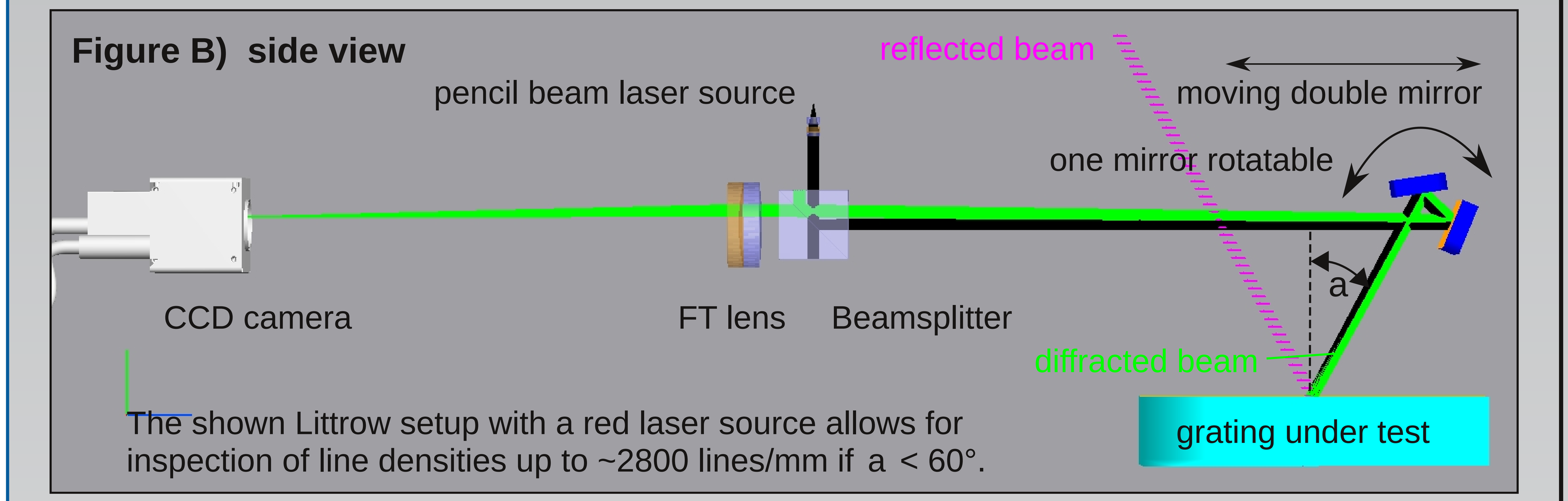


Figure B)
In a "Littrow setup" the LTP is suitable for inspecting the uniformity of grating line densities [4].

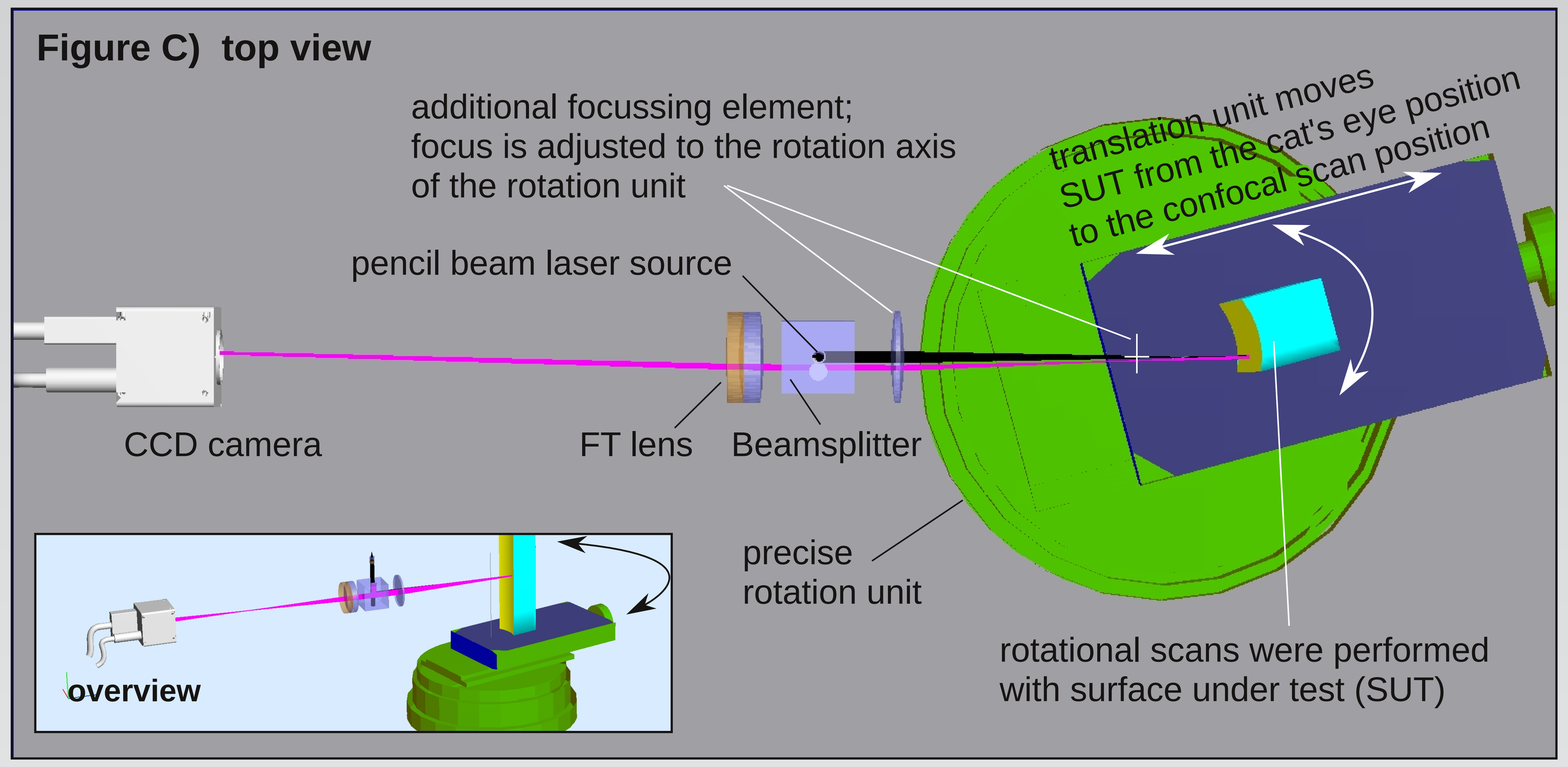


Figure C)
Setup for deflectometric measurements of approximately spherical profiles down to ~ 30 mm radius [5,6,7,8].
Rotational scans were performed along spherical profiles of a SUT by usage of a precise rotation unit.

Diode laser source
Schäfter+Kirchhoff type 51nanoFCM, 635 nm, outside the housing (not shown)

Laser attenuator
for laser intensity adjustment (attenuator not shown)

Fiber

Fiber collimator

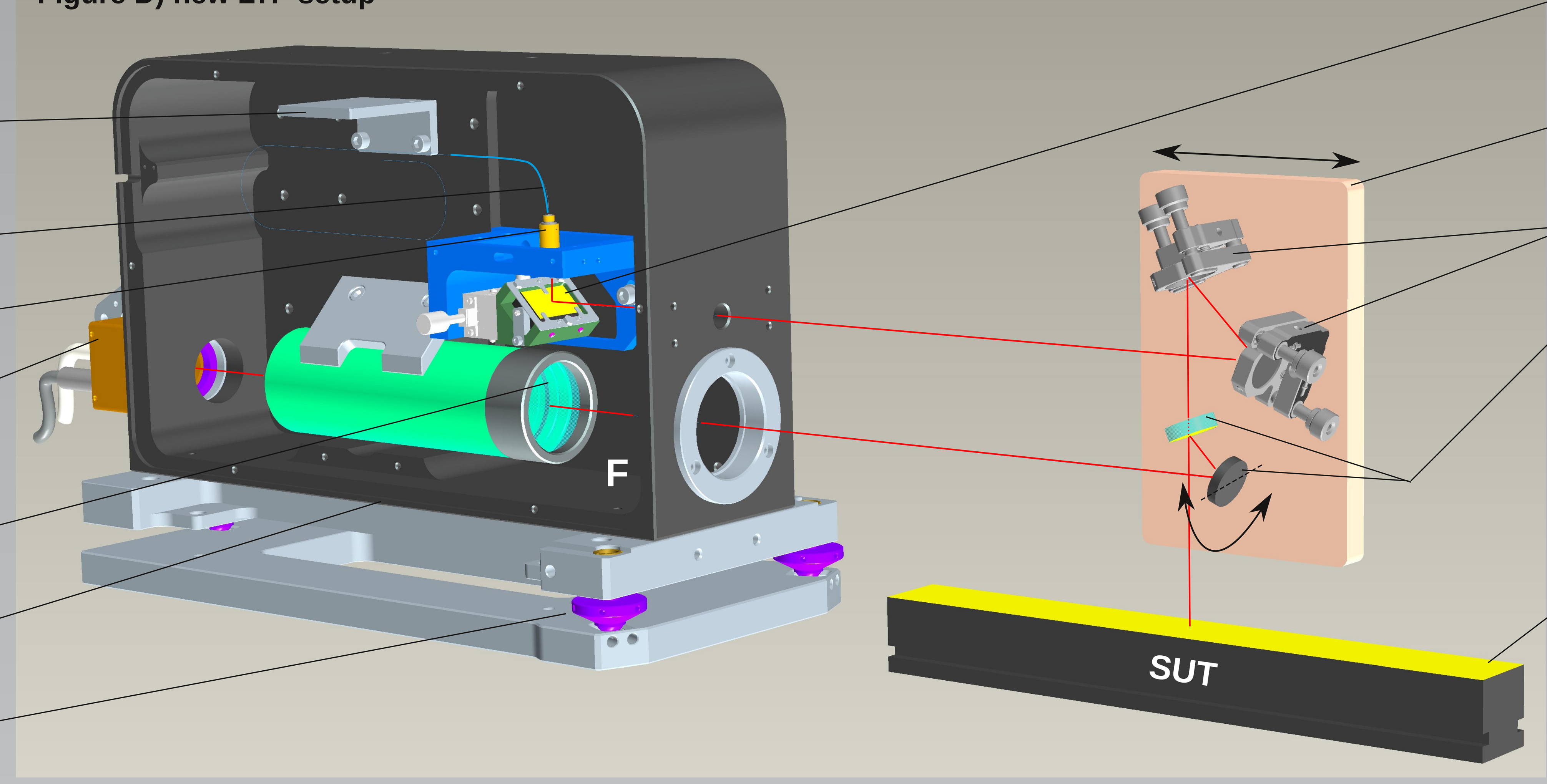
CCD camera
Type BM-500CL monochrom, 2456 x 2058 pixels, 3.45 µm square pixels, 15 frames / second

Fourier transform lens (FT lens)
achromatic lens, f = 300 mm, diameter = 50 mm

Aluminum housing
with black coating

Adjustable base plate

Figure D) new LTP setup



Reflecting phase shifting plate
translatable in one direction and exchangeable in order to switch to other pattern types

Moveable double mirror plate
(translation unit not shown)

Double mirror #1

Double mirror #2
at one side the upper mirror has a anti-reflective coating and at the lower side a semi-transmitting reflective coating;
A further option: A precise rotatable lower mirror can extend the angular measuring range of the LTP because a strong deflected beam coming from the SUT, can be deflected back into the operating aperture of the FT lens.

Surface under test (SUT)

Free space (F)
... in front of the FT lens enable change to a conventional LTP setup. A 90 degree deflection mirror and a cubic beamsplitter can be inserted here.

REFLECTING PHASE SHIFTING PLATE

With CCD cameras finding increased application in LTP's [10, 11], it was our idea to experimentally search for a more sophisticated laser beam shaping. For this reason, we designed an exchangeable reflecting phase shifting plate for the new LTP setup. HZB in-house technologies offer the possibility to produce reflection patterns with lithographic methods. It is planned to manufacture structured silicon mirrors with a step height of 225 nm, adapted to the LTP laser wavelength and the designed 45 degree deflection. The effect of several phase shifting patterns on the collimated laser beam was calculated (Figure F) by using the code PHASE [12]. The simplest option - to use only a mirror instead of a phase shifting pattern and thus operating with a gaussian beam - is not shown in this figure.

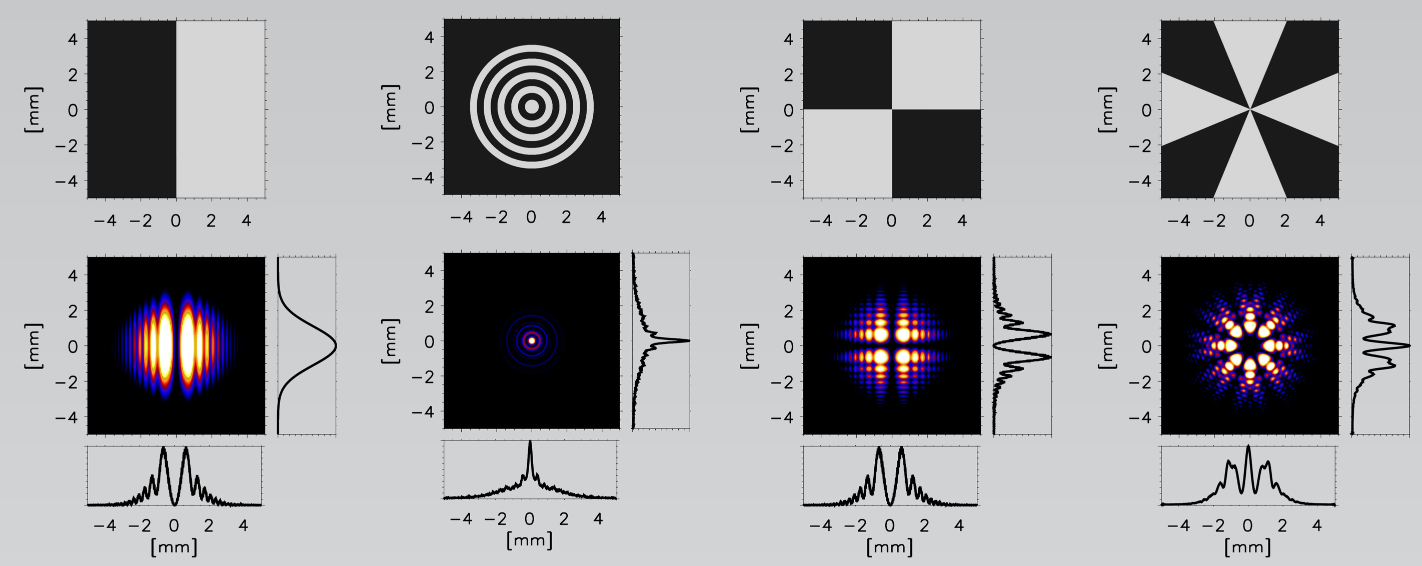
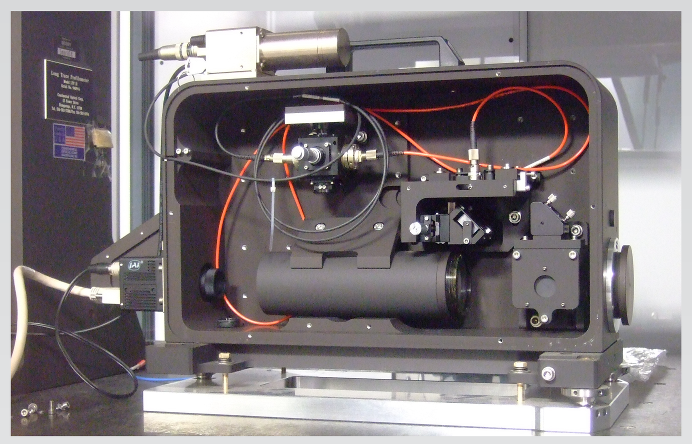


Figure F) Layout of 4 reflecting phase shifting pattern (top); The pattern shifts the laser beam wavefront by 180 degrees between bright and dark sections. The figures below show the corresponding intensity distributions of a gaussian laser beam passing the pattern and then propagating additional 1000 mm.

STABILITY MEASUREMENT



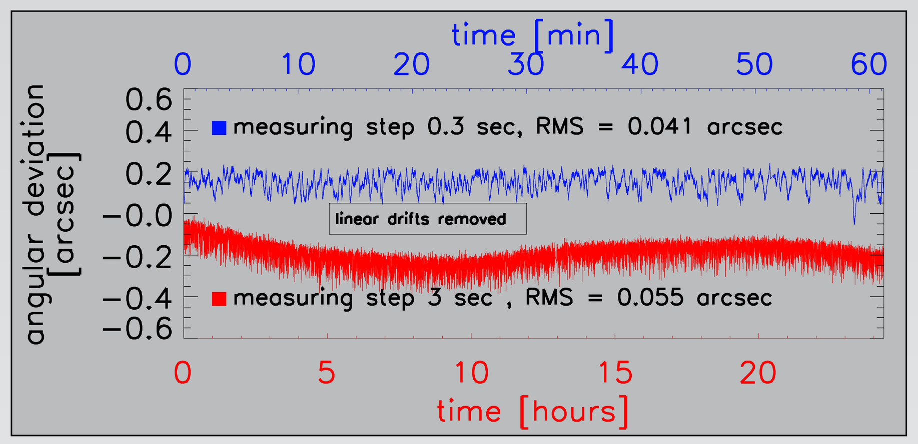
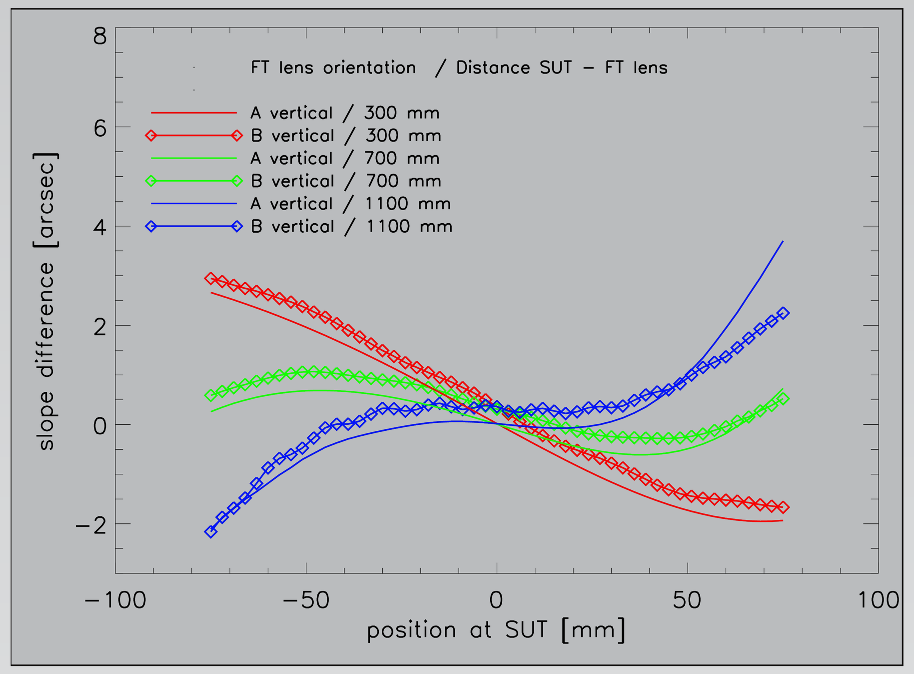


Figure G) photograph of the new LTP setup (left); temporal stability measurements (right); stability measurements were performed with a stable setup including the complete optical path. The SUT was located ~500 mm in front of the FT lens. A position fit of a gaussian intensity distribution was performed for the angle detection.

TWO DOUBLE MIRRORS AND RAYTRACING SUPPORTED MEASUREMENTS

In comparison to a conventional LTP setup, the two moving double mirrors allow the cubic beamsplitter to be removed from the optical path between the surface under test (SUT) and the CCD camera, thus reducing the problem of beam deviations caused by glas inhomogeneities of the beamsplitter.
Furthermore, the reduction of optical elements, which guide the beam from the SUT to the CCD sensor, enables more realistic simulations of the system, because less elements have to be characterized and considered to perform them. As a result, system calibrations by raytracing or raytracing supported measurements are feasible.
In the shown example (Figure E), we have assumed an ideal double mirror #2 and a known wavefront distortion of the FT lens, e.g. measured by interferometric methods. We have simulated the expected slopes for an ideal 10 m spherical mirror, using a raytracing code [9] in a geometrical optic mode to calculate deviations of the central beam. The diagram shows the simulated slopes, measured at 3 different distances between SUT and FT lens and with 2 different FT lens orientations (line A or B vertical oriented). In this case, the complete angular range of the 10 m sphere amounts to ~3100 arcsec.



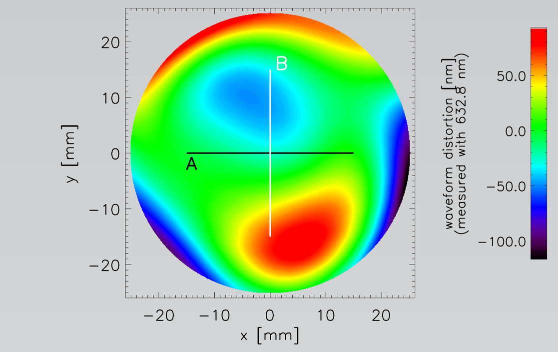


Figure E) Measurement raytracing simulations (left) of an ideal 10 m sphere with the LTP setup as shown in Figure D;
A known wavefront distortion (above) of the FT lens - provided by the supplier in combination with a simulated short-wave distortion was taken into account. For illustration purposes the differences to the ideal slope of the sphere are shown without any LTP optic inbetween.

ACKNOWLEDGEMENTS & REFERENCES

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