High Stability Piezomotor Driven Mirror Mounts for LINC-NIRVANA

A. Bramigk*[a]; H. Marth[a]; R.-R. Rohloff[b]
[a]Physik Instrumente (PI) GmbH & Co. KG, Auf der Römerstraße 1, D-76228 Karlsruhe
[b]Max-Planck-Institut für Astronomie (MPIA), Königsstuhl 17, D-69117 Heidelberg

ABSTRACT

For the LINC-NIRVANA (LN) project, MPIA requested an appropriate motorized mount for initial alignment of two dichroic beam splitters in the instrument [1]. These dichroic mirrors which reflect the visible light and transmit the NIR are located close to the pupil plane are therefore very sensitive to tilt and flexure errors which could be introduced to the wave-front sensor. Considering this the following high level specifications were requested in a very tight operating envelope: range of adjustment tip and tilt ±2° around the major axis of the elliptical mirror, resolution of adjustment <0.5 arcsec , position repeatability <1 arcsec, static position stability within an elevation 0° up to 90° <20 arc seconds and a minimum eigenfrequency >110Hz.
Keyword list: Piezo, NEXLINE®, PiezoWalk, nanopositioning, gimbal mount, mirror alignment

1. INTRODUCTION

Because of the very limited space and very high mechanical stability requirements a classical design based on DC Servo- / Stepper actuators could not be used. The loss of stiffness due to actuator and coupling components like ball tips or wire linkage compromised operating performance. For this reason, these common actuation solutions in mechanical design could not be used. A solution based on a very compact piezoelectric walk drive was found that could meet all requirements, trade named as NEXLINE® [2]. The layout of this kind of actuator allowed the integration of a one degree of freedom rigid coupling to the moving frame. The other degree of freedom was provided by the actuator itself. This coupling element, a type of leaf spring, is an integral part of the actuator runner. To maintain high stiffness the end of the runner was directly mounted to the moving frame while the actuator housing was fixed to the base.

Figure 1. Gimbal mirror mount with NEXLINE® drive and matching drive electronics

This rigid conjunction gave outstanding performance gain in a small envelope compared to classical motor driven solutions. In this case it resulted in a high first resonant frequency of system of 125 Hz with the dichroic mirror as a load of about 1 kg.

2. MECHANICAL DESIGN

The drive units are integrated inside the frame structure and placed at a maximum radial position to optimize system stiffness. The mechanism consists of three aluminum frames: stage base (shaded orange), inner (shaded purple) and outer moving frame (shaded green). An overview in detail is shown in the image below fig.2.

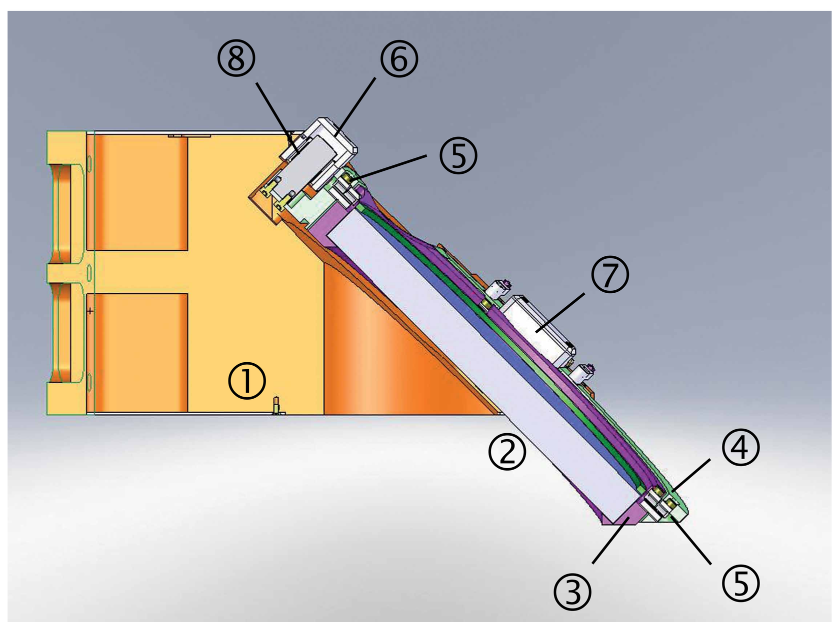


Figure 2. CAD model cut along the Y axis of the stage base (orange part 1), Dichroic mirror (2); inner gimbal (3); outer gimbal (4); Flexural pivot bearing (5); drive X-axis (6); drive Y-axis (7); runner (8)

We designed a gimbal-mount assembly to move the dichroic mirror. This was placed in the inner moving frame with tip/ tilt direction in the x-and y-axis. The short major axis of the elliptical mirror was selected as the X-axis, while the long major axis was defined as the Y-axis. A key design consideration of the positioner is that the Tip/Tilt axis is in plane with the mirror surface to eliminate beam walk due to mirror surface translations. The gimbal-mount joints were designed using Flexural Pivot Bearings. Modified PI NEXLINE® drives were used to move the frames [5]. Another key design consideration is that this drive concept has an extremely low thermal signature to keep a position constant and is self-locking at power shut down. There are two of these motorized mounts integrated in the LN instrument near the piston mirror and beam combiner on top of the cryostat. Two mirror positioners were required due to the binocular optical configuration of the telescope. This required a left hand orientated positioner and a mirror image right hand orientation.

2.1. Sensor Integration

For closed loop operation two LVDT sensors in differential gaging mode were integrated for each axis to measure pure angular motion only. These sensors work as absolute position encoders, which means no reference or limit switches are needed. A closed loop resolution of 0.3 arcsec was achieved. The closed loop resolution of the positioner however is only limited by the LVDT sensor with its signal to noise ratio. In open loop mode the piezo drive is able to move the gimbal at milli-arcsec level due to its analog piezo drive capability.

2.2 Mirror interface

The dichroic mirror was mounted with three clamps on both sides of the substrate (three point support) plus two radial posts and one radial adjustable spring. The clamping force on the pads is adjustable by selecting the thickness of the washers below the clamping springs. An underlayment ring (see fig. 3) with three milled pads is used to protect the mirror.

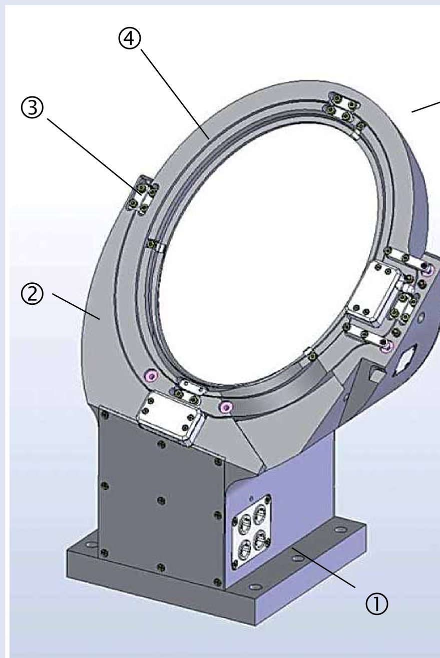


Figure 3. LEMO sockets (1); LVDT sensor (2); clamping spring (3); underlayment ring (4)

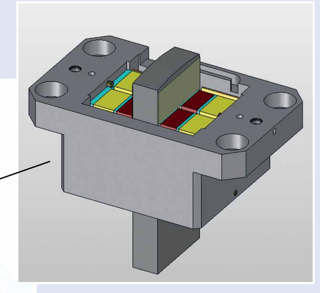


Figure 4. NEXLINE drive detail
Stroke:
± 5 mm
Stepsize:
10 nm up to 8 µm
Analog range:
± 2.5 µm
Force generation:
>40 N
Dimensions:
42 x 16 x 25 mm³

3. LOCATION OF THE SYSTEMS IN THE LINC-NIRVANA EXPERIMENT

An overview from top of the LN experiment is shown in fig. 5. The cryostat is placed in the upper middle below the purple round flange. Above that flange the two dichroic mirrors are mounted.

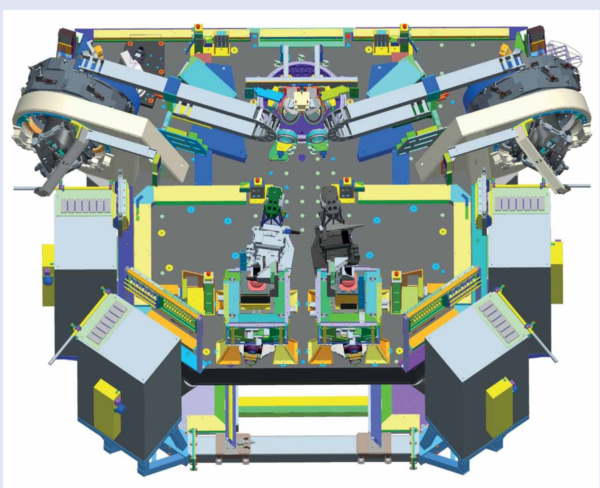


Figure 5. Top view of the LN optical bench

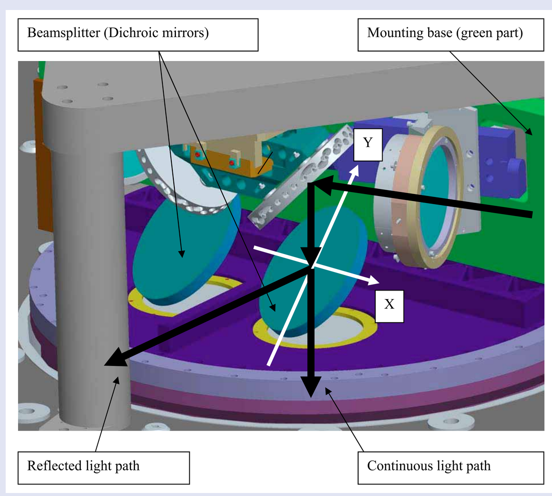


Figure 6. Light path (black arrows) and axis orientation (white arrows) at the dichroic mirrors

Figure 7. Integration of mirror mounts in LN environment- Front view

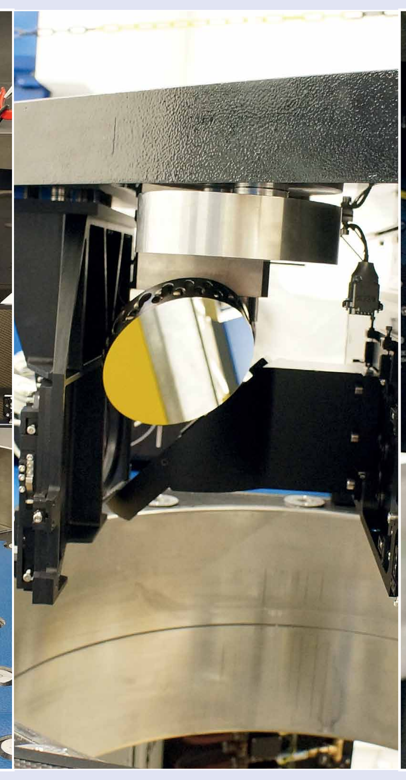


Figure 8. Integration of mirror mounts in LN environment- Side view

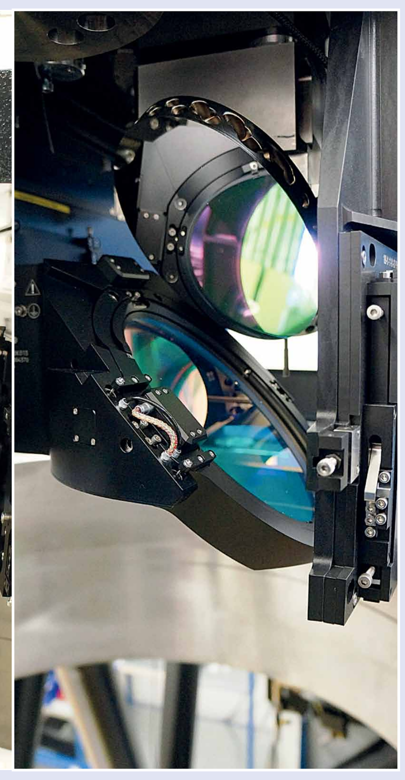


Figure 9. Image of the N-510K013 integrated on the bench.

SUMMERY SPECIFICATION

Technical Data	
Dimensions	198.5 x 230 x 316.5 mm³
Material	Aluminum
Max. weight	7.22 kg each unit
Adjustment	Tilt around the x and y axis of the elliptical mirrors. Rotation axis shall be located at the mirror surface plane. Adjustment mechanism shall be self-locking when motors switched off.
Range of adjustment	± 2° closed loop (± 2.2° hard-stop) Measured with autocollimator
Resolution of adjustment	0.288 arcsec (closed-loop) Due to LVDT sensor range resolution limitation <0.1 arcsec open-loop
Position repeatability	0.3 arcsec
Flexure & Stability (The supporting bench will be tilted up to 90° in one direction)	<15 arcsec of the dichroic surface normal. The specifications must be fulfilled to an elevation up to 60°. The mounting must be operational up to 90°.
Minimum Eigenfrequency	125 Hz measured with Laser Vibrometer
Actuator type	PI NEXLINE® in closed loop operation

4. TEST RESULTS

A test setup to measure the mirror stability had to be designed specifically for the tests required in this project. An autocollimator setup was used to measure the angular displacement during a change in elevation from 0...90° to simulate the all sky pointing angles the instrument package would experience in operation. A mirror stability specification of less than 15 arcsec being achieved over the full operating angle range.

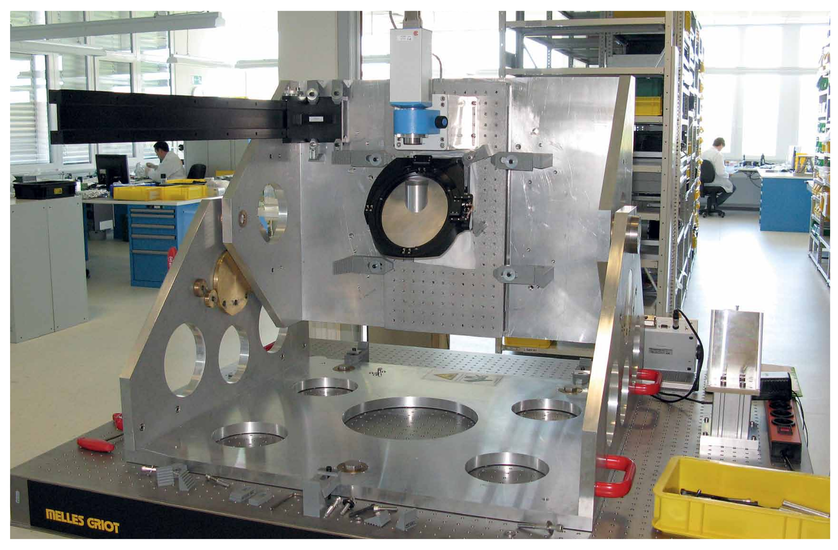
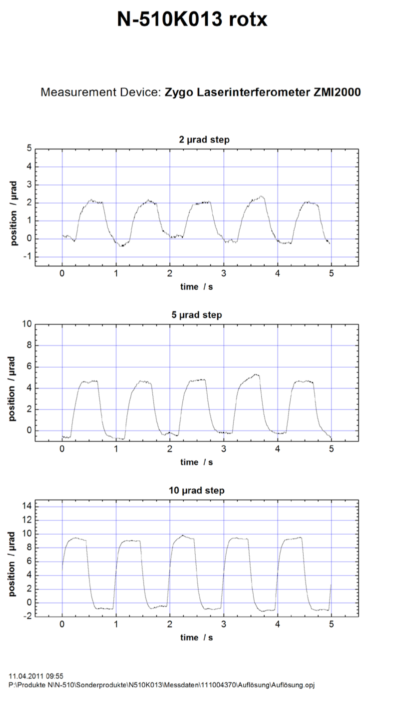


Figure 10. Test setup of system stability for different elevation angels

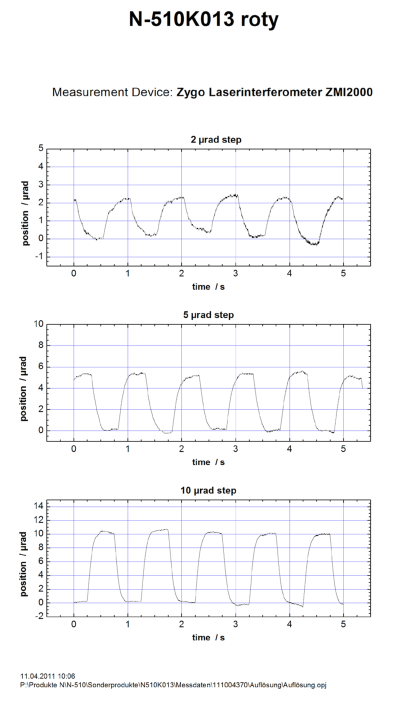
Design Features:

- Compact stiff design
- Tip/Tilt axis in plane with mirror surface
- No heatdissipation in quasistatic operation
- Self-locking at power off
- Easily scalable to different optic sizes
- No light emission from encoders
- Absolute position encoder
- Suitable for vacuum applications

Resolution X axis



Resolution Y axis



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*a.bramigk@pi.ws; phone +49 721 4846-2108;
fax +49 721 4846-2099; pi.de

PIEZO NANO POSITIONING