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## **An ultra-stable, 3-axis goniometer for precise angular positioning for optical metrology of X-ray mirrors**

*Thursday 18 September 2025 16:40 (1 hour)*

Deterministic polishing requires optical metrology instruments capable of accurately measuring X-ray mirrors with slope errors  $< 50$  nrad rms. To improve the performance of the Diamond-NOM slope profiler\* , we have developed an ultra-stable, 3-axis rotation stage to orient the mirror under test\*\* . The goniometer employs a spherical air-bearing, actuated by three piezo-walkers via flexure struts. This provides high stiffness, zero friction, and minimal parasitic errors. Linear interferometers provide positional feedback to the piezo actuators for fast, closed-loop control of 3D angles. Temperature controllers and forced air stabilisation minimise thermal drifts. FEA and dynamic modelling optimised all components via mechatronic principles. The goniometer can accommodate X-ray mirrors up to 500 mm long and 10 kg in mass. It has an angular range of  $\pm 10$  mrad in 3 orthogonal directions, a minimal incremental step of  $< 100$  nrad, and thermal drift of  $\sim 100$  nrad over 30 minutes. Shielding of heat sources reduces air turbulence for probing autocollimators or laser beams. The system is controllable via EPICS to enables dynamical synchronisation with other motion stages and detectors.

### **Footnotes**

\* “Diamond-VeNOM: a high-speed slope profiler for characterising X-ray mirrors”, I-T. Nistea et al, Proc. SPIE 12695, 126950A (2023) <https://doi.org/10.1117/12.2688134>

\*\* “Diamond gnomiometer: ultra stable goniometer”, J. Kelly, Precision Motion Systems & Control workshop, Euspen conference, Netherlands, Nov 2022

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