

# Diamond Light Source Proceedings

<http://journals.cambridge.org/DLS>

Additional services for *Diamond Light Source Proceedings*:

Email alerts: [Click here](#)

Subscriptions: [Click here](#)

Commercial reprints: [Click here](#)

Terms of use : [Click here](#)

---

## Test of precision weak-link stage systems with large travel range and subnanometre-scale resolution

D. Shu and J. Maser

Diamond Light Source Proceedings / Volume 1 / Issue MEDSI-6 / October 2011 / e41  
DOI: 10.1017/S2044820110000729, Published online: 15 December 2010

**Link to this article:** [http://journals.cambridge.org/abstract\\_S2044820110000729](http://journals.cambridge.org/abstract_S2044820110000729)

### How to cite this article:

D. Shu and J. Maser (2011). Test of precision weak-link stage systems with large travel range and subnanometre-scale resolution. *Diamond Light Source Proceedings*, 1, e41 doi:10.1017/S2044820110000729

**Request Permissions :** [Click here](#)

Contributed paper

# Test of precision weak-link stage systems with large travel range and subnanometre-scale resolution

D. SHU<sup>1†</sup> AND J. MASER<sup>1, 2</sup>

<sup>1</sup>Advanced Photon Source, Argonne National Laboratory, Argonne, IL 60439, USA

<sup>2</sup>Center for Nanoscale Materials, Argonne National Laboratory, Argonne, IL 60439, USA

(Received 11 June 2010; revised 17 October 2010; accepted 4 November 2010)

The precision ball-bearing- or roller-bearing-based stage systems provide large travel range. However, they have difficulties in meeting subnanometre resolution, high tilting stiffness and high straightness of trajectory with a single guiding system. It is always a dream to have a compact single flexure stage to cover a large travel range with very high positioning resolution. Based on an advanced structure design with the laminar overconstrained weak-link technique, we have designed and constructed a two-dimensional linear precision weak-link stage system for nanopositioning of a specimen holder for the linear multilayer Laue lenses test setup at the Advanced Photon Source Sector 26. This system provides subnanometre resolution, coupled with subnanometre metrology at a travel range of several millimetres. The two-dimensional weak-link stage system is designed with high structure stiffness using laminar overconstrained weak-link mechanisms. In this paper we present the preliminary test results of a linear precision weak-link stage system with subcentimetre travel range and subnanometre positioning resolution.

---

## 1. Introduction

Recent developments in hard X-ray focusing at the nanometre scale with linear multilayer Laue lenses (MLLs), as reported by Kang *et al.* (2006), have demonstrated promising new X-ray optics for focusing hard X-rays to a spot of a few nanometres. To use X-ray optics with a nanometre-scale resolution limit, scanning X-ray nanoprobes with corresponding mechanical positioning capability need to be designed.

Based on our design experiences of precision stages using high-stiffness laminar overconstrained weak-link mechanisms Shu, Toellner & Alp (2006) for the Argonne Center for Nanoscale Materials (CNM)/Advanced Photon Source (APS) hard X-ray nanoprobes (Maser *et al.* 2006; Shu *et al.* 2009), we have developed a new two-dimensional weak-link stage system for nanopositioning of a specimen holder for an MLL-based hard X-ray nanofocusing test setup at the APS Sector 26. With a new weak-link linear guiding structure, this system provides subnanometre

† Email address for correspondence: shu@aps.anl.gov

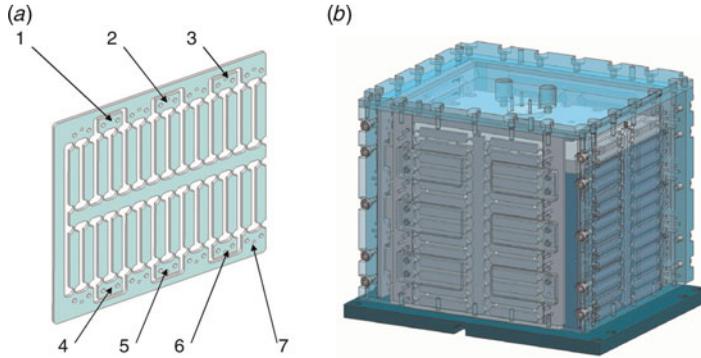


FIGURE 1. (a) A three-dimensional model of the fishbone-shaped multiple parallelogram weak-link structure. Items 1–6 are terminals mounted to the fixed base. Item 7 is the moving part. (b) A three-dimensional model of the vertical weak-link stage APS T8-31.

resolution, coupled with subnanometre metrology and a travel range of several millimetres.

## 2. Fishbone-shaped laminar weak-link linear guiding structure

A ‘fishbone’-shaped multiple parallelogram weak-link linear guiding structure has been designed as shown in figure 1(a) (Shu & Maser). The 2 mm thick 118 mm × 116 mm weak-link module is a bounded laminar structure with eight thin-metal weak-link sheets. Two groups of mounting terminals have been arranged on the weak-link module: terminals 1–6 are terminals for a mounting base and terminals on frame 7 are mounted on a carriage. Finite-element simulation shows that with a 17 N force applied on the carriage, a 1.6 mm carriage displacement is performed with a 974 MPa maximum Von Mises stress, which is about 81% of the tensile yield strength of the stainless steel 17-7 PH. Thus, if the carriage is driven by the same level of push–pull force, the weak-link linear stage will have a travel range of 3.2 mm (Shu & Maser 2009).

## 3. Design of the vertical linear weak-link stage

Using four fishbone-shaped laminar weak-link modules to construct a vertical linear motion guiding structure, we have designed a vertical weak-link stage, APS T8-31, for a scanning sample stage system as shown in figure 1(b).

There are two driver options for the T8-31 weak-link stage: Option one is a commercial Piezoelectrics Transducer (PZT)-based nanopositioning motor, such as the N-214 NEXLINE motor provided by PI GmbH and Co. (Physik Instrumente (PI) and NEXLINE are trademarks of the Physik Instrumente GmbH & Co. Germany). A 10 kg load capacity for 3 mm travel range with 10 nm closed-loop resolution is achieved using N-214 internal grating encoder. Subnanometre resolution is achievable with analog mode within a 3 μm step. Option two is a customized driving mechanism combining a Newport NanoPZ PZA12 actuator (Newport and PZA12 are trademarks of the Newport Corporation, CA, USA) with a PI PZT actuator, which will provide a 10 kg driving force for sub-nanometre-level closed-loop resolution in the entire 3 mm travel range with an external laser encoder.

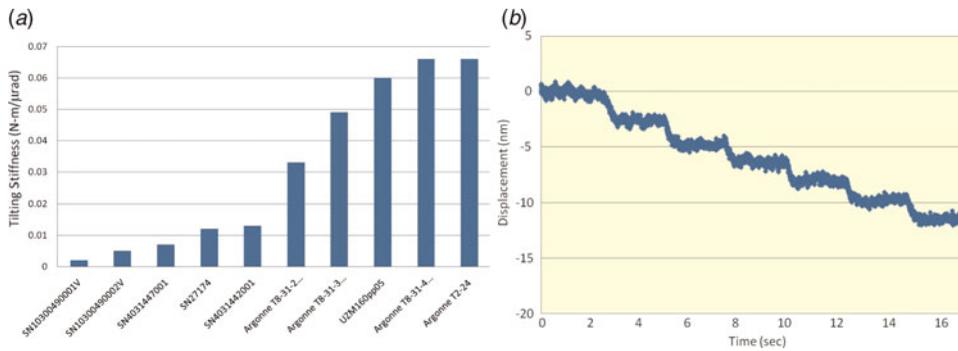


FIGURE 2. (a) Tilting stiffness comparison for the APS T8-31 vertical nanopositioning weak-link stage with cross-roller-bearing stages. (b) Resolution test for the APS T8-31 vertical nanopositioning weak-link stage with six 2 nm vertical displacement steps measured by Polytec OFV heterodyne laser system.

#### 4. Test of the vertical linear weak-link stage

The T8-31 vertical linear weak-link linear stage has demonstrated high tilting stiffness and high straightness of trajectory with nanometre-level positioning sensitivity. As shown in figure 2(a), its tilting stiffness is better than many commercial motor-driven linear bearing-guiding vertical stages with similar structure size. According to a motion straightness-of-trajectory test result, the amount of the tilt is repeatable within 1  $\mu$ rad range with the stage vertical position (Shu & Maser to be published).

Preliminary vibration test results demonstrate that the T8-31 vertical linear weak-link stage with 8 kg load does not amplify the vibration from the mounting base. Figure 2(b) shows a resolution test for the APS T8-31 vertical linear weak-link stage with six 2 nm vertical displacement steps measured by a Polytec OFV heterodyne laser system.

#### 5. Discussions and summary

We present the design and test of vertical linear weak-link stage systems with extended travel range and subnanometre positioning resolution. Horizontal linear stages (APS T8-32 and T8-33) are also designed with the same weak-link mechanisms to fit on the top and bottom of the T8-31 vertical stage to perform subnanometre resolution scanning function in a 3 mm  $\times$  3 mm two-dimensional or 3 mm  $\times$  3 mm  $\times$  3 mm three-dimensional range for a nanoprobe sample holder with a maximum weight of 5 kg. Based on the results of finite-element simulation, it is feasible to scale up or scale down the overall dimension of these weak-link structures for variant nanopositioning applications.

#### Acknowledgements

This work is supported by the US Department of Energy, Office of Science, Office of Basic Energy Sciences under Contract No. DE-AC02-06CH11357.

#### REFERENCES

KANG, H. C., MASER, J., STEPHENSON, G. B., *et al.* 2006 Nanometer Linear Focusing of Hard X-rays by a Multilayer Laue Lens *Phys. Rev. Lett.* **96**(12), 127401–12740.

- MASER, J., WINARSKI, R., HOLT, M., SHU, D., BENSON, C., TIEMAN, B., PREISSNER, C., SMOLYANITSKIY, A., LAI, B., VOGT, S., WIEMERSLAGE, G. & STEPHENSON, G. B. 'Proc. 8th Int. Conf. x-ray microscopy', IPAP Conf. Series 7 (July 2006), 26–29.
- SHU, D. & MASER, J. 2009 *Proceedings of SPIE*, Vol. 7424 7424OD.
- SHU, D. & MASER, J. *The AIP Conference Proceedings of SRI-2009*, Melbourne, to be published.
- SHU, D. & MASER, J. U.S. Patent application in progress for ANL-IN-08-013.
- SHU, D., TOELLNER, T. S. & ALP, E. E. 2006 U.S. Patent granted No. 6,984,335.
- SHU, D. & MASER, J. 2009 *Proceedings of the 9th International Conference on X-ray Microscopy*, IOP Conference Series 186, 012017.