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A Subnanometer Linear Displacement Actuator

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Abstract

With the development of synchrotron radiation technology, an actuator with sub-nanometer resolution, 100N driving force, and compatible with ultra-high vacuum environment is required. To achieve synchrotron radiation micro-nano focusing with adjustment resolution of sub-nanometer and high-precision rotation at the nano-arc level, most of the commercial piezoelectric actuators are difficult to meet the requirements of resolution and driving force at the same time. The flexure-based compound bridge-type hinge has the characteristic of amplifying or reducing the input displacement by a certain multiple, and can be used in an ultra-high vacuum environment. According to this characteristic, the bridge-type composite flexible hinge can be combined with commercial piezoelectric actuators , to design a new actuator with sub-nanometer resolution and a driving force of 100N. This poster mainly presents the principle of the new actuator , the design of the prototype and the preliminary test results of its resolution, stroke .

Mechanical design of the Actuator

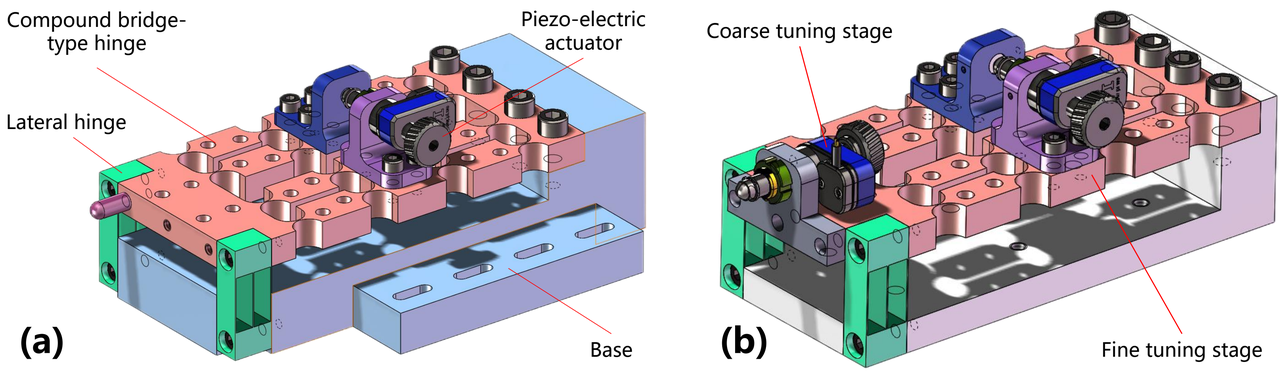
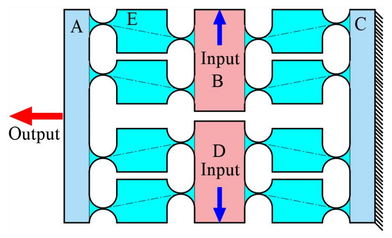
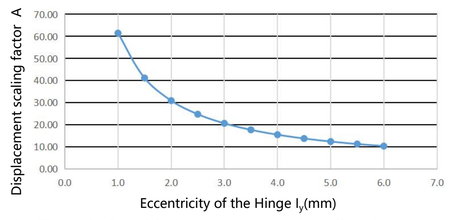


Figure (a) shows a sub-nanometer displacement actuator based on a compound bridge-type hinge design, Figure (b) shows a hierarchical composite actuator with a piezoelectric actuator as a coarse adjustment stage and a sub-nanometer displacement actuator as a fine adjustment stage.

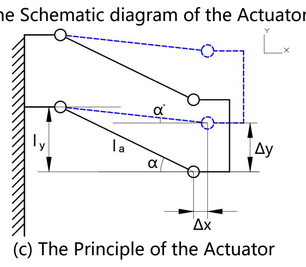
Principle and calculation



(a) The Schematic diagram of the Actuator



(b) The relationship between l_y and scaling factor A



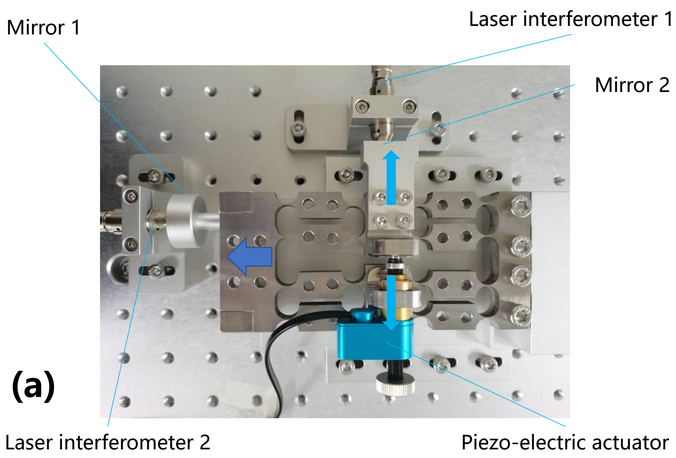
(c) The Principle of the Actuator

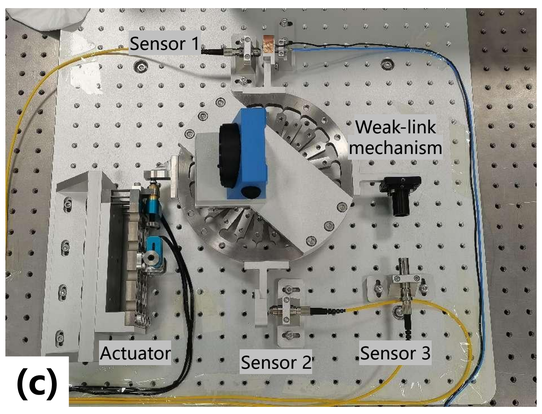
$$l_a\cos\alpha+\Delta x=l_a\cos\alpha^*$$
$$l_a\sin\alpha-\Delta y=l_a\sin\alpha^*$$
$$\alpha=arcs\left(\frac{l_y}{l_a}\right)$$
$$\Delta y^2-2l_a\sin\alpha\,\Delta y+\Delta x^2+2l_a\cos\alpha\,\Delta x=0$$
$$\Delta y=l_a\sin\alpha-\sqrt{l_a^2\sin^2\alpha-\Delta x^2-2l_a\cos\alpha\,\Delta x}$$
$$A=\frac{\Delta y}{\Delta x}=l_a\sin\alpha-\sqrt{\frac{l_a^2\sin^2\alpha-\Delta x^2-2l_a\cos\alpha\,\Delta x}{\Delta x}}$$

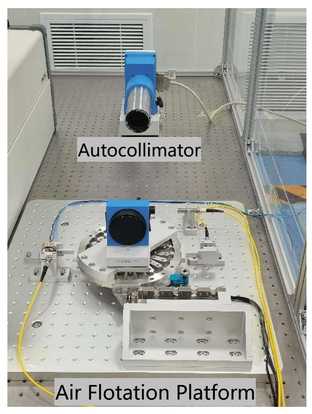
(d) Theoretical calculation of the scaling factor A

Change the displacement scaling factor A by adjusting the value of eccentricity e

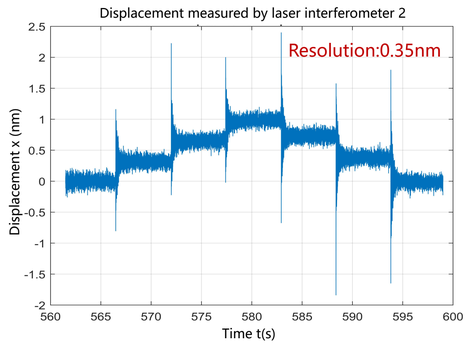
Experiment and result

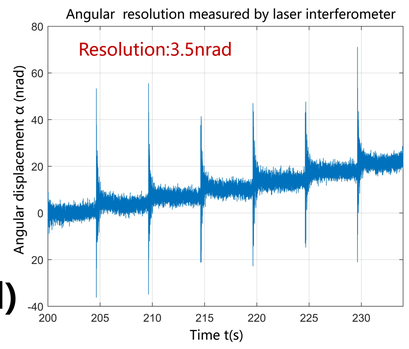






Specifications of the sub-nanometer displacement actuator	
Stroke	Resolution
15um	0.35nm





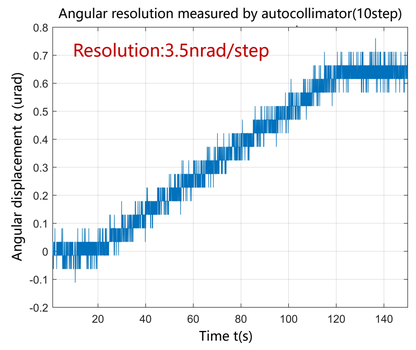


Figure (a) shows the experimental device of the sub-nanometer displacement actuator, and Figure (b) shows the test results.

Figure (c) uses a composite actuator composed of a sub-nanometer displacement actuator and a piezoelectric actuator to push the wheel-shaped flexible hinge, and uses an autocollimator and a laser interferometer to measure the resulting minimum angular displacement. Figure (d) shows the test results.

Conclusion

This poster briefly proposes a method to achieve sub-nanometer displacement actuation at a lower cost and shows preliminary experimental results of the prototype produced.Due to time constraints, relevant tests on the driving force and stability of the driver will be carried out later.

Reference

[1]Shu, D., et al. Applications of Laminar Weak-Link Mechanisms for Ultraprecision Synchrotron Radiation Instruments. in AIP Conference Proceedings. 2007. American Institute of Physics.
[2]Xu, Q. and Y. Li, Analytical modeling, optimization and testing of a compound bridge-type compliant displacement amplifier. Mechanism and Machine Theory, 2011. 46(2): p. 183-200.