Long Range Precision Stage Using Multi Bar Mirrors

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Abstract

In long range precision stage systems, laser interferometers are used to measure the position of stage's target mover. Long length mirrors called bar-mirrors have to be used with laser interferometers to reflect laser. The length of Bar-mirror is proportional to the range of precision stage systems. So, the long length bar-mirrors are must for the long range precision stage systems. However, as the length of bar-mirrors is lengthen, the flatness error of bar-mirror become large. In addition, long length bar-mirror is hard to make, and expensive. Newly proposed long range precision stage system is made up except long length bar-mirror.

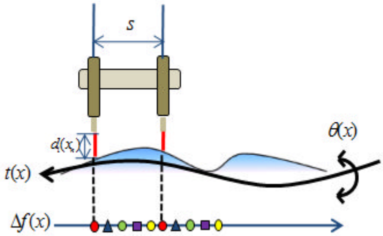
Basic concept of the proposed system is using numerous short bar-mirrors instead of one long length bar-mirror. There are two main problems to realize proposed system. First, there is the alignment error. The alignment error includes the offset error and the tilt error. The offset error means a linear misalignment, and the tilt error means an angular misalignment of each bar-mirrors. To solve the alignment error problem, measure the alignment error and compensate it.

Second, there are discrete parts between bar-mirrors. To reflect laser beam, bar-mirrors do not have to discrete parts on mirror surface. In the proposed system, if the discrete part overlapped with laser beam path, the feedback laser interferometer signal is switched extra laser interferometer's signal.

In this paper, propose new type precision stage using numerous short bar-mirrors, and answers are given to solve two problems of new system. By evaluation experiment, evaluate performences of proposed system.

1 Principle of alignment error measurement

There are many methods to separate these errors and to measure workpiece flatness profiles. The inclination method [1] and the generalized two-point method [2] have



$$d_1(x_n) = f(x_n) + t(x_n) \quad (1)$$
$$d_2(x_n) = f(x_n + s) + t(x_n) + s \times \theta(x_n)$$

$$F(x_n) = f(x_n + s) - f(x_n) \quad (2)$$
$$= d_2(x_n) - d_1(x_n) - s \times \theta(x_n)$$

$$F'(x_n) = F(x_n)/s \quad (3)$$
$$= (d_2(x_n) - d_1(x_n) - s \times \theta(x_n))/s$$

$$p(x_n) = \sum_{i=1}^{n} F'(x_i)s \quad (4)$$
$$= p(x_{n-1}) + F'(x_n)s$$
$$= p(x_{n-1}) + (d_2(x_n) - d_1(x_n) - s \times \theta(x_n))s$$

Figure 1: Principle of the generalized two-point method

been proposed for that purpose. In these methods, two displacement probes are used to measure the flatness profile. The straightness motion of the stage is canceled by the differences of probes' output, and the flatness profile of bar-mirror is obtained by simple data processing operations. The combined method [3], which combines the advantages of the inclination method and the generalized two-point method, is proposed. Also, to realize high accuracy profile measurement many kinds of three-point methods [4, 5] are proposed.

The generalized two-point method is selected to measure the flatness profile of bar-mirrors. Figure 1 shows the principle of the generalized two-point method schematically. Two displacement sensing probes are fixed and can measure the flatness profile of bar-mirror while the stage moves. Assume that the flatness profile of bar-mirror is f(x), the straightness motion of the stage is t(x), and the yaw motion of the stage is θ(x).

2 Sensor switching method

The proposed system has four laser interferometers to measure x, y and theta-z positions. . Generally in three degree of freedom systems, three laser interferometers are used to measure x, y and theta-z positions. However, proposed system has the discrete parts on mirror surface which are impossible to reflect laser beam. Figure 2 is the proposed four sensor system's schematic diagram. The sensor 1 & 2 measure x and theta-z position. The sensor 3 & 4 are used for measuring y position by switching.

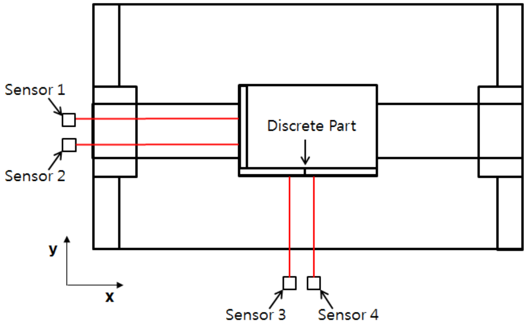


Figure 2: Schematic diagram of proposed system

If the discrete part overlapped with laser beam path, the feedback laser interferometer signal is switched extra laser interferometer's signal.

3 Experiment

By experiment, to confirm these proposed system. Figure 3 shows the proposed system and experiment setup. Two bar-mirrors are aligned in x-axis on precision stage's mover. The length of x-axis bar-mirror is 150 mm and y-axis is 300 mm.

To measure alignment error, capacitive sensors are used. The capacitive sensor interval is 15 mm and sampling period is 3 mm.

To evaluate experiment result, laser calibrator (Renishaw, ML10) is used.

Straightness errors are measured five times each. Figure 4 is the result of straightness error measurement. In table 1, there are quantities of errors compensation.

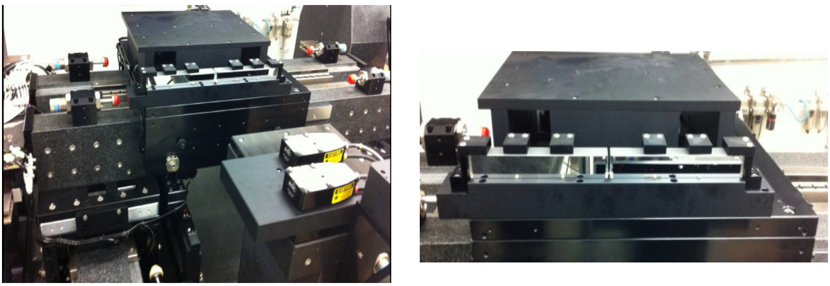


Figure 3: Photography of the precision stage used to experiment

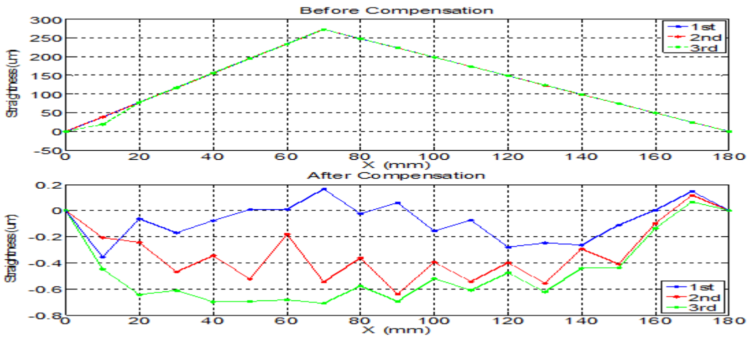


Figure 4: Measurement data of the straightness error

Table 1: The quantites of the straightness error

	Before Compensation	After Compensation
Straightness Error	273.33 um	0.76 um

4 Conclusion

In this paper, new concept precision stage using multi bar-mirror was suggested. Found the solutions to solve alignment error problem and discrete part between bar-mirrors problem. And after evaluate precision stage's straightness error using laser calibrator.

References:

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