

Planar motor displacement device

Cross-reference to Related Applications

5 This patent application claims priority to the Chinese patent application No.202010468071.X filed on May 28, 2020, and titled “Planar motor displacement device”, which is incorporated herein by reference in its entirety.

Technical field

10 The invention relates to the field of precision motion, and in particular to a planar motor displacement device.

Background

15 The magnetic levitation planar motor motion stage is mainly used in semiconductor equipment, such as scanning projection photolithography machines, wafer cutting machines, flip-chip bonding machines, etc, and its function is to carry wafers for precise movement with micro-nano precision to achieve precise processing of wafers. The magnetic levitation planar motor motion stage generally includes a set of planar motors, a set of six-degree-of-freedom displacement measurement system, a set of power amplifiers, and a set of motion controllers. For
20 example, documents US6496093 and EP3320400B1 innovate on the topology of planar motors, but the six-degree-of-freedom displacement measurement system still uses traditional solutions.

25 The traditional six-degree-of-freedom displacement measurement system integrates a set of three-axis laser interferometer and a set of eddy current displacement sensors. The three-axis laser interferometer is used to measure the X-direction translation, Y-direction translation and Z-direction rotation of the motion stage in real time; at least three eddy current displacement sensors are used to measure the X-direction rotation, Y-direction rotation and Z-direction translation
30 of the motion stage in real time. However, laser interferometers are expensive and

their accuracy is very sensitive to the measurement environment: temperature changes, humidity changes, and air flow can cause disturbances and reduce their accuracy. The cost of eddy current displacement sensors is also very high. Another solution is to use a planar grating system instead of the laser interferometer, but the cost of the planar grating is in the same order of magnitude as the laser interferometer. Both solutions are very susceptible to environmental interference, such as airflow, particle pollution, stains, etc., resulting in reduced sensor accuracy or even complete failure, and causing the motion stage malfunctions.

Summary of the invention

The purpose of the present invention is to provide a displacement device to solve the problems in the prior art that the magnetic levitation planar motor motion stage is too expensive and susceptible to environmental interference.

To this end, the present invention provides a planar motor displacement device, comprising a mover and a stator, wherein

the stator is provided with a magnet array extending in a plane, the magnet array forms a working area, and at least one first direction planar grating and at least one second direction planar grating are laid on the stator, traces of the at least one first direction planar grating ruler are parallel to each other and spaced apart along a first direction, traces of the at least one second direction planar grating ruler are parallel to each other and spaced apart along a second direction, the first direction and the second direction intersect with each other;

the mover is provided with a first direction three-phase coil array and a second direction three-phase coil array, and is configured to be movable above the working area, and is provided with at least one first direction reading head and at least one second direction reading head, the at least one first direction reading head and the at least one second direction reading head respectively move within a laid range of the at least one first direction planar grating and the at least one second direction planar grating along with the movement of the mover.

In one embodiment, the traces of the at least one first direction planar grating

and/or the at least one second direction planar grating are made of conductive material.

In one embodiment, the first direction and the second direction are orthogonal to each other, and the magnet array is a two-dimensional Halbach array.

5 In one embodiment, the at least one first direction reading head is at least two first direction reading heads, or the at least one second direction reading head is at least two second direction reading heads.

In one embodiment, the at least one first direction reading head is two first direction reading heads located at one pair of diagonal corners of the working area, 10 and the at least one second direction reading head is two second direction reading heads located at the other pair of diagonal corners of the working area.

In one embodiment, the at least one first direction planar grating is two first direction planar grating rulers covering one pair of diagonal areas of the working area, and/or the at least one second direction planar grating is two second direction 15 planar grating rulers covering the other pair of diagonal areas of the working area, the traces of the at least one first direction planar grating and the traces of the at least one second direction planar grating are spaced apart at equal intervals.

In one embodiment, the at least one first direction reading head is two first direction reading heads located at spaced positions on one edge of the working area, 20 and the at least one second direction reading head is one second direction reading head located on an edge of the working area opposite to the one edge.

In one embodiment, the at least one first directional planar grating is at least one first directional planar grating covering an area near one corresponding edge of the working area, and the at least one second directional planar grating is one second 25 direction planar grating covering an area near one corresponding edge of the working area.

In one embodiment, the working area is provided with at least three Hall sensor arrays that are not on the same straight line.

In one embodiment, the Hall sensor array includes three Hall sensors that are not 30 on the same straight line.

In one embodiment, the three Hall sensors are located at the vertices of an isosceles right triangle.

In one embodiment, a hypotenuse of the isosceles right triangle extends in the first direction or the second direction.

5 In one embodiment, a center distance between adjacent N magnets and S magnets in the magnet array is τ , and a length of a catheti of the isosceles right triangle is a , then $a=\tau/2+n\tau$, n is not an integer less than zero.

In one embodiment, the displacement device includes four Hall sensor arrays, which are arranged at even intervals around the outer periphery of the mover.

10 The displacement device proposed by the present invention integrates a planar motor and a unidirectional planar grating, it uses a unidirectional planar grating and a unidirectional reading head to replace the laser interferometer and the planar grating, thereby reducing the cost of the displacement sensor by two orders of magnitude, and significantly reducing the overall cost of the planar motor motion
15 stage, and enhancing its market competitiveness while improving its measurement accuracy. Wherein the accuracy of the unidirectional planar grating based on the eddy current effect can reach ten nanometers level, and it is not easily affected by the environment; the accuracy of the optical unidirectional planar grating can reach the nanometer or sub-nanometer level, and its accuracy is even higher. By
20 integrating the Hall sensor array, the entire device can realize six-degree-of-freedom magnetic levitation motion, that is, long-travel motion in the X and Y directions, as well as fine-tuning of the other four degrees of freedom.

Description of the drawings

25 FIG.1 is a schematic diagram of a displacement device according to an embodiment of the present invention;

FIG.2 is a schematic diagram of a displacement device according to another embodiment of the present invention.

FIG.3 is a schematic diagram of a magnet array according to yet another
30 embodiment of the present invention;

FIG.4 is a schematic diagram of a magnet array according to yet another embodiment of the present invention;

FIG.5 is a schematic diagram of a magnet array according to yet another embodiment of the present invention.

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List of reference numbers:

500-displacement device; 100-stator; 200-mover; 10-magnet array; 10X-first magnet group; 10Y-second magnet group; 101-first magnet block; 102-second magnet block; 103-third magnet block; 104-fourth magnet block; 20-coil array;
10 201-first X-direction three-phase coil group; 202-first Y-direction three-phase coil group; 203-second X-direction three-phase coil group; 204 -second Y-direction three-phase coil group; 30X-X-direction planar grating; 30Y-Y-direction planar grating; 301-first X-direction planar grating; 302-first Y-direction planar grating; 303-second X-direction planar grating; 304-second Y-direction planar grating;
15 40X-X-direction reading head; 30Y-Y-direction reading head; 401-first X-direction reading head; 402-first Y-direction reading head; 403- second X-direction reading head; 404-second Y-direction reading head; 50-Hall sensor array.

Detailed description of embodiments

20 The preferred embodiments of the present invention will be described in detail below with reference to the accompanying drawings, so that the purpose, features and advantages of the present invention can be more clearly understood. It should be understood that the embodiments shown in the drawings do not limit the scope of the present invention, but are only used to illustrate the essential spirit of the technical
25 solution of the present invention.

In the following description, certain specific details are set forth for purposes of illustrating the various disclosed embodiments to provide a thorough understanding of the various disclosed embodiments. However, those skilled in this art will recognize that embodiments may be practiced without one or more of these

specific details. In other instances, well-known devices, structures, and techniques associated with the present application may not be shown or described in detail to avoid unnecessarily obscuring the description of the embodiments.

Unless the context requires otherwise, throughout the specification and claims, the word "comprise" and variations thereof, such as "includes" and "has" are to be understood in an open, inclusive sense, that is, should be construed as "includes, but not limited to".

In the following description, for clarity of illustration of the structure and mode of operation of the present invention, various directional terms will be used to describe the present invention, but words such as "front", "rear", "left", "right", "outer", "inner", "outward", "inward", "upper", "lower", and the like, should be understood as convenient terms and should not be construed as limiting terms.

Referring to FIG.1, a top view of a planar motor displacement device according to an embodiment of the present invention is shown. The planar motor displacement device 500 comprises a stator 100 and a mover 200. As shown in the figure, the plane of the drawing is the XY plane, in which the horizontal direction to the right in the drawing is the X direction, the upward direction in the drawing is the Y direction, and the direction perpendicular to the plane of the drawing is the Z direction. In this embodiment, the X direction, Y direction and Z direction are orthogonal to each other. However, it should be understood that the X direction, Y direction and Z direction are not necessarily orthogonal to each other, as long as they intersect with each other. The following embodiments of the present invention will be described by taking the case where the X direction, the Y direction and the Z direction are orthogonal to each other as an example.

The stator 100 is provided with a magnet array 10 extending substantially on a plane, and the magnet array 10 forms a working area. Preferably, the magnet array 10 extends in an XY plane. The mover 200 is provided with a coil array 20, so that the mover 200 can be suspended above the working area through interaction with the

magnet array 10. In the embodiment shown, the mover 200 is in the shape of a generally square plate, but it should be understood that the mover 200 can also be configured in other shapes as needed, such as a rectangular plate, a circular plate, etc. In the embodiment shown, the coil array 20 is disposed on the upper surface of the mover 200. However, it should be understood that the coil array 20 can also be disposed on the lower surface of the mover 200. In the embodiment shown, the coil array 20 includes a first X-direction three-phase coil group 201, a first Y-direction three-phase coil group 202, a second X-direction three-phase coil group 203, and a second Y-direction three-phase coil group 204. The first X-direction three-phase coil group 201 and the second X-direction three-phase coil group 203 are arranged in one pair of diagonal areas of the three-phase coil array 20, and the first Y-direction three-phase coil group 202 and the second Y-direction three-phase coil group 204 are arranged in the other pair of diagonal areas of the three-phase coil array 20. Wherein, the three-phase coil groups are preferably arranged in the same plane. The first and second X-direction three-phase coil groups 201 and 203 are able to interact with the magnet array 10 to generate thrust in the X-direction and Z-direction, and the first and second Y-direction three-phase coil groups 202 and 204 are able to interact with the magnet array 10 to generate thrust in the Y-direction and Z-direction, thereby driving the mover 200 to move with six degrees of freedom within the working area, namely translation in the X, Y, Z directions and rotation around the X, Y, and Z directions. It should also be understood that three-phase coil groups may also be arranged on the mover 200 in other ways. By arranging one X-direction three-phase coil group and one Y-direction three-phase coil group on the mover 200, the mover 200 can realize translation in the X-direction, Y-direction, and Z-direction as well as rotation in the X-direction and Y-direction, and by adding one X-direction or Y-direction three-phase coil group, the mover 200 can realize rotation in the Z-direction. Therefore, in order to achieve six degrees of freedom of motion, it is necessary to provide at least three three-phase coil groups, including at

least one X-direction coil group and at least one Y-direction coil group.

As shown in Fig.1, four reading heads are provided on the mover 200: a first X-direction reading head 401, a first Y-direction reading head 402, a second X-direction reading head 403, and a second Y-direction reading head 404 respectively provided near the four vertices of the mover 200. However, it should be understood that the positions of the four reading heads are not limited to this, as long as they can form a quadrilateral. Four planar gratings are correspondingly laid on the mover 200: a first X-direction planar grating 301, a first Y-direction planar grating 302, a second X-direction planar grating 303 and a second Y-direction planar grating 304. The planar gratings may be an optical grating, a magnetic grating, a capacitive grating or a grating based on the eddy current principle. Accordingly, traces of the grating may be made of light-conducting materials (ie., transparent materials), magnetically conductive materials, or electrically conductive materials. Preferably, the traces are made of electrically conductive material. Preferably, the planar gratings do not overlap in the working area, thereby preventing the coordinate values read by the reading head through the grating traces from being confused. In the embodiment shown, the first X-direction planar grating 301 and the second X-direction planar grating 303 are respectively located in one pair of diagonal areas of the working area, which are the lower left corner area and the upper right corner area in the figure shown; and the first Y-direction planar grating 302 and the second Y-direction planar grating 304 are located in the other pair of diagonal areas of the working area, which are the upper left corner area and the lower right corner area in the figure shown. Correspondingly, during the movement of the mover 200, the above-mentioned four reading heads respectively move within the laid ranges of the first X-direction planar grating 301, the first Y-direction planar grating 302, the second X-direction planar grating 303 and the second Y-direction planar grating 304, thereby reading the X coordinates of the first and second X-direction reading heads and the Y coordinates of the first and second Y-direction reading heads through the

traces of the planar grating. The displacement signals are read through four reading heads and fed back to the controller, and control signals are provided by the controller to control the translation of the mover 200 in the X and Y directions and the rotation around the Z direction.

5 Although in the embodiment shown, a total of four planar gratings and four reading heads are provided, it should be understood that the number of X-direction reading heads and Y-direction reading heads is not limited to this, and at least one X-direction reading head and at least one Y-direction reading head and corresponding at least one X-direction planar grating and at least one Y-direction
10 planar grating may be provided. When only one X-direction reading head and one Y-direction reading head are provided, the translation of the mover 200 in the X and Y directions can be calculated and controlled based on the coordinate values read from the two reading heads. When another X-direction reading head or another Y-direction reading head is provided, the displacement signals can be read from the
15 three reading heads and fed back to the controller, and control signals are provided by the controller to control the translation in the X and Y directions and the rotation around the Z direction of the mover 200. It should also be understood that in order to extend the movement distance of the mover 200 in the X-direction and Y-direction in the working area, the X-direction reading head and the Y-direction reading head
20 should be spaced as far as possible, so as to avoid the overlapping of the X-direction planar grating and the Y-direction grating to the greatest extent. It should also be understood that the arrangement of the reading heads on the mover 200 and the planar grating in the working area is not limited to the above embodiment, as long as the reading heads are appropriately spaced, and the laying range of the planar
25 grating corresponding to the reading heads is not smaller than the movement range of the reading heads on the mover 200.

FIG.2 shows an embodiment in which three reading heads and two planar gratings 30X and 30Y are provided on the mover 200, in which an X-direction

reading head 40X and a first Y-direction reading head 302 and a second Y-direction reading head 304 are provided. Wherein the first Y-direction reading head 302 and the second Y-direction reading head 304 are arranged at two adjacent corner positions of the mover 200, which are the upper left corner and the upper right corner in the figure, and the X-direction reading head 40X is arranged at the midpoints of an edge opposite to the edge where two Y-direction reading heads are located. Correspondingly, the X-direction planar grating 30X is arranged below the working area, and the Y-direction planar grating 30Y is arranged above the working area. However, it should be understood that the positions of the three reading heads are not limited to this. As long as the reading heads are properly spaced apart so that the corresponding planar gratings do not overlap, and the laid range of the corresponding planar gratings is not less than the movement range of the reading heads on the mover 200. In this embodiment, two Y-direction reading heads correspond to one Y-direction planar grating, but it should be understood that two Y-direction planar gratings spaced apart from each other may also be provided. According to this configuration, the three reading heads can be used to measure and control the movement of the three degrees of freedom of the mover 200, namely, X-direction translation, Y-direction translation, and Z-direction rotation.

The magnet array 10 shown in FIG. 1 is a two-dimensional Halbach array, in which a plurality of N magnets, S magnets and H magnets are arranged periodically in rows in a two-dimensional Halbach manner in an XY plane. That is, the H magnets are provided between adjacent N magnets and S magnets, and the magnetization direction of the H magnet points toward the adjacent N magnets. Wherein, the center distance between adjacent N magnets and S magnets is τ , and the angle between the arrangement direction of the magnets N-H-S-H-N-H-S-H and the X direction is $\alpha=\pi/4$.

A top view of another embodiment of the magnet array 10 is shown in FIG.3, compared with the embodiment of the magnet array 10 shown in FIG.1, the only

difference is that in the magnet array shown in FIG.2 H magnets are removed from the embodiment of the magnet array shown in FIG.1. Similarly, N magnets and S magnets are arranged periodically in rows in an XY plane. N magnets and adjacent S magnets are spaced apart each other, and the center distance between adjacent N magnets and S magnets is τ . The angle between the arrangement direction of the magnets S-N-S-N and the X direction is $\alpha=\pi/4$.

A top view of yet another embodiment of magnet array 10 is shown in FIG. 4, in which the magnet array 10 comprises a first magnet group 10X and a second magnet group 10Y, which are arranged in alternating rows and columns along the X direction and the Y direction. The first magnet group 10X includes four magnets successively arranged in a one-dimensional Halbach array along the Y direction: an S magnet, an H magnet, an N magnet and an H magnet in an S-H-N-H arrangement, wherein the magnetization direction of the H magnet points to the N magnet, the center distance between the adjacent N magnet and S magnet is τ . The second magnet group 10Y includes four magnets successively arranged in a one-dimensional Halbach array along the X direction: an S magnet, an H magnet, an N magnet and an H magnet in an S-H-N-H arrangement, wherein the magnetization direction of the H magnet points to the N magnet, the center distance between the adjacent N magnet and S magnet is τ . That is, the second magnet group 10Y is formed by rotating the first magnet group 10X counterclockwise by 90° along in XY plane in a top view.

A top view of yet another embodiment of magnet array 10 is shown in FIG.5, in which the magnet array 10 comprises a plurality of square sub-arrays periodically arranged in rows and columns along the X and Y directions. The sub-array consists of a first magnet block 101, a second magnet block 102, a third magnet block 103 and a fourth magnet block 104. In the embodiment shown, the first magnet block 101 is arranged in the upper left area of the sub-array, the second magnet block 102 is arranged in the lower left area of the sub-array, the third magnet block 103 is

arranged in the lower right area of the sub-array, and the fourth magnet block 104 is arranged in the upper right area of the sub array. Wherein the first magnet block 101 includes S magnets and H magnets successively arranged along the Y direction, and the magnetization direction of the H magnet is away from the adjacent S magnet.

5 The second magnet block 102 includes S magnets and H magnets successively arranged along the X direction, and the magnetization direction of the H magnet is away from the adjacent S magnet. The third magnet block 103 includes N magnets and H magnets successively arranged along the Y direction, and the magnetization direction of the H magnet points to the adjacent N magnet. The fourth magnet block
10 104 includes N magnets and H magnets successively arranged along the X direction, and the magnetization direction of the H magnet points to the adjacent N magnet. Wherein the second magnet block 102 is formed by rotating the first magnet block 101 counterclockwise by 90° in the XY plane in a top view. The fourth magnet block 104 is formed by rotating the third magnet block 103 counterclockwise by 90°
15 in the XY plane in a top view. The Y-direction center distance between the S magnet in the first magnet block 101 and the N magnet in the third magnet block 103 is τ , and the X-direction center distance between the S magnet in the second magnet block 102 and the N magnet in the fourth magnet block 104 is τ .

Although only the above four embodiments of the magnet array 10 are
20 described in this specification, it should be understood that the magnet array 10 of the present invention can adopt any magnet array of a planar motor stator, existing or to be developed.

In order to realize the movement in six degrees of freedom, Hall sensor arrays
50 are further provided on the mover 200. Each Hall sensor array 50 can obtain its
25 displacement in the Z direction by measuring the magnetic field intensity generated by the magnet array 10, the Hall sensor may be configured to measure the magnetic field intensity in the X direction, Y direction or Z direction, and is preferably configured to measure the magnetic field intensity in the Z direction. By at least

three Hall sensor arrays 50 that are not arranged on the same straight line to measure the Z-direction displacement at three positions of the mover, and combining the output signals of the three Hall sensor arrays, the displacement of the three degrees of freedom of the mover 200 can be calculated, that is, the translation of the mover 200 in the Z direction, the rotation in the X direction, and the rotation in the Y direction. The Hall sensor arrays 50 are preferably arranged in the same plane, and more preferably, the plane where the Hall sensors are located is further away from the magnet array than the plane where the three-phase coil groups are located.

In the embodiment shown in FIG.1, the mover 200 comprises four Hall sensor arrays 50, which are arranged around the periphery of the mover 200 and are evenly spaced apart from each other. Each Hall sensor array 50 includes three Hall sensors distributed in a triangle. In the embodiment shown, the three Hall sensors are located at the vertices of an isosceles right triangle. The hypotenuse of the isosceles right triangle extends along the X direction or the Y direction. In this embodiment, the center distance between adjacent N magnets and S magnets in the magnet array 10 is τ , then the length of the right angle side of the isosceles right triangle is a, then

$$a=\tau/2+n\tau, n \text{ is an integer not less than zero.}$$

The Hall sensor array 50 in this arrangement can be applied to the case where the magnets in the magnet array 10 are arranged in rows and columns along an angle $\alpha=\pi/4$ to the X direction. For example, when the embodiment of the magnet array 10 shown in FIG.2 is used, the Hall sensor array 50 arranged in the above-mentioned isosceles right-angled triangle may also be applied.

Although only one embodiment of the Hall sensor array 50 is described above, it should be understood that the number and arrangement of sensors in the Hall sensor array 50 can also be changed as needed without departing from the scope of the present invention.

Multiple Hall sensor array signals and reading head signals are fed back to the controller, and the controller calculates the control signals according to the preset

control algorithm and controls the coil current through the driver, thereby generating 6 degrees of freedom displacement of the motion stage.

By using the Hall sensor arrays to replace the eddy current displacement sensor and using the planar grating and the reading head to replace the laser interferometer, 5 the planar motor displacement device according to the present invention significantly reduces the cost of the planar motor displacement device, and the movement control precision is improved.

The preferred embodiments of the present invention have been described in detail above, but it should be understood that aspects of the embodiments can be 10 modified if necessary to employ aspects, features and concepts from various patents, applications and publications to provide additional embodiments.

These and other changes can be made to the embodiments in view of the above detailed description. In general, in the claims, the terms used should not be construed as limiting to the specific embodiments disclosed in the specification and 15 claims, but should be understood to include the entire equivalent scopes of all possible embodiments together with these claims.

Claims

1. A planar motor displacement device, wherein,
comprising a mover and a stator, wherein

the stator is provided with a magnet array extending in a plane, the magnet array
5 forms a working area, and at least one first direction planar grating and at least one
second direction planar grating are laid on the stator, traces of the at least one first
direction planar grating are parallel to each other and arranged at intervals along a
first direction, traces of the at least one second direction planar grating are parallel
to each other and arranged at intervals along a second direction, the first direction
10 and the second direction intersect each other;

the mover is provided with a first direction three-phase coil array and a second
direction three-phase coil array, and is configured to be movable above the working
area, and is provided with at least one first direction reading head and at least one
second direction reading head, the at least one first direction reading head and the at
15 least one second direction reading head respectively move within a laid range of the
at least one first direction planar grating and the at least one second direction planar
grating along with the movement of the mover.

2. The planar motor displacement device according to claim 1, wherein traces of
the at least one first direction planar grating and/or the at least one second direction
20 planar grating are made of conductive material.

3. The planar motor displacement device according to claim 1, wherein the first
direction and the second direction are orthogonal to each other, and the magnet array
is a two-dimensional Halbach array.

4. The planar motor displacement device according to claim 1, wherein the at
25 least one first direction reading head is at least two first direction reading heads, or
the at least one second direction reading head is at least two second direction
reading heads.

5. The planar motor displacement device according to any one of claims 1 and 4,
wherein the at least one first direction reading head is two first direction reading

heads located at one pair of diagonal corners of the working area, and the at least one second direction reading head is two second direction reading heads located at the other pair of diagonal corners of the working area.

6. The planar motor displacement device according to claim 1, wherein the at least one first direction planar grating is two first direction planar gratings covering one pair of diagonal areas of the working area, and/or the at least one second direction planar grating is two second direction planar gratings covering the other pair of diagonal areas of the working area, and traces of the at least one first direction planar grating and traces of the at least one second direction planar grating are spaced apart at equal intervals.

7. The planar motor displacement device according to any one of claims 1 and 4, wherein the at least one first direction reading head is two first direction reading heads located at spaced positions on one edge of the working area, the at least one second direction reading head is one second direction reading head located on an edge of the working area opposite to the one edge.

8. The planar motor displacement device according to claim 7, wherein the at least one first directional planar grating is at least one first directional planar grating covering an area near one corresponding edge of the working area, and the at least one second directional planar grating is one second direction planar grating covering an area near one corresponding edge of the working area.

9. The planar motor displacement device according to claim 1, wherein the working area is provided with at least three Hall sensor arrays that are not on the same straight line.

10. The planar motor displacement device according to claim 9, wherein the Hall sensor array includes three Hall sensors that are not on the same straight line.

11. The planar motor displacement device according to claim 10, wherein the three Hall sensors are located at the vertices of an isosceles right triangle.

12. The planar motor displacement device according to claim 11, wherein a

hypotenuse of the isosceles right triangle extends along the first direction or the second direction.

13. The planar motor displacement device according to claim 11, wherein the center distance between adjacent N magnets and S magnets in the magnet array is τ ,
5 and a length of a catheti of the isosceles right triangle is a , then $a=\tau/2+n\tau$, n is an integer not less than zero.

14. The planar motor displacement device according to claim 9, wherein the displacement device includes four Hall sensor arrays being uniformly spaced apart on the outer periphery of the mover.