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OPTICAL SENSING ASSEMBLY AND ENCODER

Abstract

An optical sensing assembly includes a scale, a sensor, and a light source. The scale includes first and second pattern areas. The first pattern area includes first patterns periodically arranged in first and second directions. The second pattern area includes second patterns periodically arranged in the first and second directions. The sensor is configured to move relative to the scale in the first direction and includes first, second, third, and fourth sensing areas. The first and third sensing areas are configured to sense changes of the first pattern area in the first and second directions respectively. The second and fourth sensing areas are configured to sense changes of the second pattern area in the first and second directions respectively. The light source is configured to emit light toward the scale.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION
[0001] This application claims priority to China Application Serial Number 202410188326.5, filed Feb. 20, 2024, which is herein incorporated by reference.
BACKGROUND
Technical Field
[0002] The present disclosure relates to an optical sensing assembly and an encoder.
Description of Related Art
[0003] With the advancement of technology, encoder technology is widely used in precision instrument control fields such as motor speed measurement and position detection. For example, absolute encoders can be used to detect the rotational speed, rotation direction, and rotation position of the motor.
[0004] In the conventional technology, optical encoders often use gray code or M code to obtain absolute position information, and their main architectures include light transmitters, light receivers, code disks, and processing circuits. Among them, the light emitter and light receiver of a reflective optical encoder are arranged on the same side relative to the code disk, and the required signal output is obtained by appropriately designing the pattern on the code disk.
[0005] However, since the conventional architectures of encoder and encoding method are very sensitive to positional deviations, the encoders need to be extremely precise in assembly and alignment. Moreover, as the demand for encoder accuracy increases, the sensing area of the corresponding light receiver has also been greatly reduced. As a result, external environmental pollution such as oil, dirt, and particulates will have a serious impact on the sensing of absolute position signals.
[0006] Accordingly, how to develop an optical sensing assembly and an encoder using the same that are different from the previous ones to improve the problems and shortcomings of the conventional technology, to achieve high-precision absolute position sensing, to have a higher ability to withstand environmental pollution, and to enhance the robustness of the encoder becomes an important issue to be solved by those in the industry.
SUMMARY
[0007] An aspect of the disclosure is to provide an optical sensing assembly and an encoder to solve the foregoing problems.
[0008] According to an embodiment of the disclosure, an optical sensing assembly includes a scale, a sensor, and a light source. The scale includes a first pattern area and a second pattern area. The first pattern area includes a plurality of first patterns periodically arranged in a first direction and a second direction. The second pattern area includes a plurality of second patterns periodically arranged in the first direction and the second direction. The sensor is configured to move relative to the scale in the first direction and includes a first sensing area, a second sensing area, a third sensing area, and a fourth sensing area. The first sensing area is configured to sense a change of the first pattern area in the first direction. The second sensing area is configured to sense a change of the second pattern area in the first direction. The third sensing area is configured to sense a change of the first pattern area in the second direction. The fourth sensing area is configured to sense a change of the second pattern area in the second direction. The light source is configured to emit light toward the scale.
[0009] In one or more embodiments of the present disclosure, the first patterns arranged along the

first direction are gradually shifted in the second direction.
[0010] In one or more embodiments of the present disclosure, the first patterns are arranged in a plurality of columns. The columns have a pitch in the first direction. The first patterns in each of the columns have another pitch in the second direction. After passing a distance of M times the pitch along the first direction, the columns are gradually shifted in the second direction by a distance of the another pitch. M is an integer greater than 2.
[0011] In one or more embodiments of the present disclosure, when the sensor moves a distance of M times the pitch in the first direction relative to the scale, the first sensing area generates M periodic signals and the third sensing area generates one periodic signal.
[0012] In one or more embodiments of the present disclosure, the second patterns arranged along the first direction are gradually shifted in the second direction.
[0013] In one or more embodiments of the present disclosure, the second patterns are arranged in a plurality of columns. The columns have a pitch in the first direction. The second patterns in each of the columns have another pitch in the second direction. After passing a distance of N times the pitch along the first direction, the columns are gradually shifted in the second direction by a distance of the another pitch. N is an integer greater than 2.
[0014] In one or more embodiments of the present disclosure, when the sensor moves a distance of N times the pitch in the first direction relative to the scale, the second sensing area generates N periodic signals and the third sensing area generates one periodic signal.
[0015] In one or more embodiments of the present disclosure, sensing units of each of the first sensing area, the second sensing area, the third sensing area, and the fourth sensing area are arranged into a phased-array.
[0016] According to an embodiment of the disclosure, an encoder includes an optical sensing assembly and a signal processing unit. The optical sensing assembly includes a scale and a sensor. The scale includes a first pattern area and a second pattern area. The first pattern area includes a plurality of first patterns periodically arranged in a first direction and a second direction. The second pattern area includes a plurality of second patterns periodically arranged in the first direction and the second direction. The sensor is configured to move relative to the scale in the first direction and includes a first sensing area, a second sensing area, a third sensing area, and a fourth sensing area. The first sensing area is configured to sense a change of the first pattern area in the first direction and accordingly generate a first sensing position signal. The second sensing area is configured to sense a change of the second pattern area in the first direction and accordingly generate a second sensing position signal. The third sensing area is configured to sense a change of the first pattern area in the second direction and accordingly generate a third sensing position signal. The fourth sensing area is configured to sense a change of the second pattern area in the second direction and accordingly generate a fourth sensing position signal. The signal processing unit is connected to the sensor and configured to: calculate a first sensing position information, a second sensing position information, a third sensing position information, and a fourth sensing position information respectively from the first sensing position signal, the second sensing position signal, the third sensing position signal, and the fourth sensing position signal; generate a first synthesized position information according to the first sensing position information and the second sensing position information; generate a second synthesized position information according to the third sensing position information and the first synthesized position information; generate a third synthesized position information according to the fourth sensing position information and the first synthesized position information; and generate a fourth synthesized position information according to the second synthesized position information and the third synthesized position information.
[0017] In one or more embodiments of the present disclosure, the first patterns arranged along the first direction are gradually shifted in the second direction.
[0018] In one or more embodiments of the present disclosure, the first patterns are arranged in a plurality of columns. The columns have a pitch in the first direction. The first patterns in each of

the columns have another pitch in the second direction. After passing a distance of M times the pitch along the first direction, the columns are gradually shifted in the second direction by a distance of the another pitch. M is an integer greater than 2.
[0019] In one or more embodiments of the present disclosure, when the sensor moves a distance of M times the pitch in the first direction relative to the scale, the first sensing area generates M periodic signals and the third sensing area generates one periodic signal.
[0020] In one or more embodiments of the present disclosure, the second patterns arranged along the first direction are gradually shifted in the second direction.
[0021] In one or more embodiments of the present disclosure, the second patterns are arranged in a plurality of columns. The columns have a pitch in the first direction. The second patterns in each of the columns have another pitch in the second direction. After passing a distance of N times the pitch along the first direction, the columns are gradually shifted in the second direction by a distance of the another pitch. N is an integer greater than 2.
[0022] In one or more embodiments of the present disclosure, when the sensor moves a distance of N times the pitch in the first direction relative to the scale, the second sensing area generates N periodic signals and the third sensing area generates one periodic signal.
[0023] In one or more embodiments of the present disclosure, sensing units of each of the first sensing area, the second sensing area, the third sensing area, and the fourth sensing area are arranged into a phased-array.
[0024] In one or more embodiments of the present disclosure, the signal processing unit is configured to use the first sensing position information and the second sensing position information to calculate the first synthesized position information based on Vernier effect.
[0025] In one or more embodiments of the present disclosure, the signal processing unit is configured to use the third sensing position information and the first synthesized position information to calculate the second synthesized position information based on Vernier effect.
[0026] In one or more embodiments of the present disclosure, the signal processing unit is configured to use the fourth sensing position information and the first synthesized position information to calculate the third synthesized position information based on Vernier effect.
[0027] In one or more embodiments of the present disclosure, the signal processing unit is configured to use the second synthesized position information and the third synthesized position information to calculate the fourth synthesized position information based on Vernier effect.
[0028] Accordingly, in the optical sensing assembly of the present disclosure, the scale includes two pattern areas and the sensor includes four sensing areas. Two of the sensing areas are configured to sense one of the pattern areas, and the other two of the sensing areas are configured to sense the other one of the pattern areas. Since the scale only includes two pattern areas, the optical sensing assembly only requires a smaller area for sensing, thereby increasing the mechanism assembly margin. Moreover, the sensing units in each of the sensing areas are arranged in a phased-array, so the sensing areas have higher resistance to environmental pollution and better assembly positioning margin, thereby enhancing the robustness of the encoder. In addition, the encoding and decoding of the encoder using this optical sensing assembly uses four sets of incremental position signals and Vernier effect, so high-precision absolute position sensing can be achieved.
[0029] It is to be understood that both the foregoing general description and the following detailed description are by examples, and are intended to provide further explanation of the disclosure as claimed.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] The disclosure can be more fully understood by reading the following detailed description of the embodiment, with reference made to the accompanying drawings as follows:

[0031] FIG. **1** is a partial perspective view of an encoder according to an embodiment of the present disclosure;

[0032] FIG. **2** is a partial schematic diagram of a scale in FIG. **1**;

[0033] FIG. **3** is a schematic diagram of a sensor, a light source, and a signal processing unit in FIG. **1**;

[0034] FIG. **4** is a partial schematic diagram of a first pattern area of the scale according to an embodiment of the present disclosure;

[0035] FIG. **5** is a partial schematic diagram of a second pattern area of the scale according to an embodiment of the present disclosure;

[0036] FIG. **6** is a partial schematic diagram of a first sensing area of the sensor according to an embodiment of the present disclosure;

[0037] FIG. **7** is a partial schematic diagram of a second sensing area of the sensor according to an embodiment of the present disclosure;

[0038] FIG. **8** is a partial schematic diagram of a third sensing area of the sensor according to an embodiment of the present disclosure;

[0039] FIG. **9** is a partial schematic diagram of a fourth sensing area of the sensor according to an embodiment of the present disclosure;

[0040] FIG. **10** is a schematic diagram illustrating a first sensing position signal and a third sensing position signal obtained by sensing the first pattern area using the first sensing area and the third sensing area respectively;

[0041] FIG. **11** is a schematic diagram illustrating a first sensing position information and a third sensing position information calculated from the first sensing position signal and the third sensing position signal respectively;

[0042] FIG. **12** is a schematic diagram illustrating a second sensing position signal and a fourth sensing position signal obtained by sensing the second pattern area using the second sensing area and the fourth sensing area respectively;

[0043] FIG. **13** is a schematic diagram illustrating a second sensing position information and a fourth sensing position information calculated from the second sensing position signal and the fourth sensing position signal respectively;

[0044] FIG. **14**A is a schematic diagram of a 16-period signal;

[0045] FIG. **14**B is a schematic diagram of a 15-period signal;

[0046] FIG. **14**C is a schematic diagram of a difference signal between the 16-period signal and the 15-period signal;

[0047] FIG. **14**D is a schematic diagram of the difference signal in FIG. **13**C in the form of unsigned 10-bit data; and

[0048] FIG. **15** is a schematic diagram illustrating a position information obtained by a position detection method of the encoder according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0049] Reference will now be made in detail to the present embodiments of the disclosure, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts. However, specific structural and functional details disclosed herein are merely representative for purposes of describing example embodiments, and thus may be embodied in many alternate forms and should not be construed as limited to only example embodiments set forth herein. Therefore, it should be understood that there is no intent to limit example embodiments to the particular forms disclosed, but on the contrary, example embodiments are to cover all modifications, equivalents, and alternatives falling within the scope of the disclosure.

[0050] Reference is made to FIG. **1**. FIG. **1** is a partial perspective view of an encoder **100** according to an embodiment of the present disclosure. As shown in FIG. **1**, in the present embodiment, the encoder **100** includes an optical sensing assembly **110**. The optical sensing assembly **110** includes a scale **111**, a sensor **112**, and a light source **113**. The scale **111** and the sensor **112** are disposed relative to each other and can be displaced relative to each other. For example, the scale **111** can move linearly or rotate relative to the sensor **112**. The light source **113** is disposed on a side of the sensor **112** facing the scale **111** and is configured to emit light toward the scale **111**. The sensor **112** is configured to receive and sense the light reflected by the scale **111**.

[0051] Reference is made to FIG. **2** and FIG. **3**. FIG. **2** is a partial schematic diagram of the scale **111** in FIG. **1**. FIG. **3** is a schematic diagram of the sensor **112**, the light source **113**, and a signal processing unit **120** in FIG. **1**. As shown in FIG. **2** and FIG. **3**, in the present embodiment, the scale **111** includes a first pattern area **111***a* and a second pattern area **111***b*. The first pattern area **111***a* and the second pattern area **111***b* extend in a first direction D**1** and are arranged in a second direction D**2**. The first direction D**1** and the second direction D**2** are perpendicular to each other. The sensor **112** is configured to move relative to the scale **111** in the first direction D**1** and includes a first sensing area **112***a*, a second sensing area **112***b*, a third sensing area **112***c*, and a fourth sensing area **112***d*. The first sensing area **112***a* is configured to sense a change of the first pattern area **111***a* in the first direction D**1**. The second sensing area **112***b* is configured to sense a change of the second pattern area **111***b* in the first direction D**1**. The third sensing area **112***c* is configured to sense a change of the first pattern area **111***a* in the second direction D**2**. The fourth sensing area **112***d* is configured to sense a change of the second pattern area **111***b* in the second direction D**2**.

[0052] In some embodiments where the encoder **100** is linear, the first direction D**1** is X direction and the second direction D**2** is Y direction. In some embodiments where the encoder **100** is rotary, the first direction D**1** is the circumferential (Θ) direction and the second direction D**2** is the radial (R) direction.

[0053] Reference is made to FIG. **4**. FIG. **4** is a partial schematic diagram of a first pattern area **111***a* of the scale **111** according to an embodiment of the present disclosure. As shown in FIG. **4**, in the present embodiment, the first pattern area **111***a* of the scale **111** includes a plurality of first patterns G**1** periodically arranged in the first direction D**1** and the second direction D**2**. Specifically, the first patterns G**1** are arranged in a plurality of columns C**1**. The columns C**1** have a first pitch P**1** in the first direction D**1**. The first patterns G**1** in each of the columns C**1** have another pitch P**1**′ in the second direction D**2**. In other words, the first patterns G**1** of the first pattern area **111***a* constitute a two-dimensional pattern.

[0054] In the present embodiment, the shape of each of the first patterns G**1** is square, but the disclosure is not limited thereto. In some embodiments, the scale **111** adopts a reflective structure, so the first patterns G**1** are high-reflective areas, and the area outside the first patterns G**1** is a low-reflective area. In some embodiments, the scale **111** adopts a transmissive structure, so the first patterns G**1** are high light-transmitting areas, and the area outside the first patterns G**1** is a low light-transmitting area.

[0055] In particular, the first patterns G**1** arranged along the first direction D**1** are gradually shifted in the second direction D**2**. Specifically, as shown in FIG. **4**, after passing a distance of M times the first pitch P**1** along the first direction D**1**, the columns C**1** are gradually shifted in the second direction D**2** by a distance of the another pitch P**1**′. M is an integer greater than 2. In other words, each of the first patterns G**1** has a third pitch P**3** in the first direction D**1**, and the third pitch P**3** is M times the first pitch P**1**. Correspondingly, when the sensor **112** moves a distance of M times the first pitch P**1** in the first direction D**1** relative to the scale **111**, the first sensing area **112***a* generates M periodic signals and the third sensing area **112***c* generates one periodic signal.

[0056] In some embodiments, M is an integer greater than 2. For example, as shown in FIG. **4**, N is 12 (That is, the columns C**1** will be gradually shifted by a distance of one pitch P**1**′ in the second direction D**2** after passing a distance of 12 times the first pitch P**1** along the first direction D**1**), but the disclosure is not limited thereto.

[0057] Reference is made to FIG. **5**. FIG. **5** is a partial schematic diagram of a second pattern area **111***b* of the scale **111** according to an embodiment of the present disclosure. As shown in FIG. **5**, in the present embodiment, the second pattern area **111***b* of the scale **111** includes a plurality of second patterns G**2** periodically arranged in the first direction D**1** and the second direction D**2**. Specifically, the second patterns G**2** are arranged in a plurality of columns C**2**. The columns C**2** have a second pitch P**2** in the first direction D**1**. The second patterns G**2** in each of the columns C**2** have another pitch P**2**′ in the second direction D**2**. In other words, the second patterns G**2** of the second pattern area **111***b* constitute a two-dimensional pattern.

[0058] In the present embodiment, the shape of each of the second patterns G**2** is square, but the disclosure is not limited thereto. In some embodiments, the scale **111** adopts a reflective structure, so the second patterns G**2** are high-reflective areas, and the area outside the second patterns G**2** is a low-reflective area. In some embodiments, the scale **111** adopts a transmissive structure, so the second patterns G**2** are high light-transmitting areas, and the area outside the second patterns G**2** is a low light-transmitting area.

[0059] In particular, the second patterns G**2** arranged along the first direction D**1** are gradually shifted in the second direction D**2**. Specifically, as shown in FIG. **5**, after passing a distance of N times the second pitch P**2** along the first direction D**1**, the columns C**2** are gradually shifted in the second direction D**2** by a distance of the another pitch P**2**′. N is an integer greater than 2. In other words, each of the second patterns G**2** has a fourth pitch P**4** in the first direction D**1**, and the fourth pitch P**4** is N times the second pitch P**2**. Correspondingly, when the sensor **112** moves a distance of N times the second pitch P**2** in the first direction D**1** relative to the scale **111**, the second sensing area **112***b* generates N periodic signals and the fourth sensing area **112***d* generates one periodic signal.

[0060] Through the aforementioned structural configurations, during the relative movement of the sensor **112** and the scale **111** in the first direction D**1**, the sensor **112** can use the first sensing area **112***a* and the third sensing area **112***c* to simultaneously to sense the first pattern area **111***a* and use the second sensing area **112***b* and the fourth sensing area **112***d* to simultaneously sense the second pattern area **111***b*. Since the scale **111** only includes two pattern areas, the optical sensing assembly **110** only requires a smaller area for sensing, thereby increasing the mechanical assembly margin.

[0061] In some embodiments, N is an integer greater than 2. For example, as shown in FIG. **5**, N is 12 (That is, the columns C**2** will be gradually shifted by a distance of one pitch P**2**′ in the second direction D**2** after passing a distance of 12 times the second pitch P**2** along the first direction D**1**), but the disclosure is not limited thereto.

[0062] Reference is made to FIG. **6**, FIG. **7**, FIG. **8**, and FIG. **9**. FIG. **6** is a partial schematic diagram of the first sensing area **112***a* of the sensor **112** according to an embodiment of the present disclosure. FIG. **7** is a partial schematic diagram of the second sensing area **112***b* of the sensor **112** according to an embodiment of the present disclosure. FIG. **8** is a partial schematic diagram of the third sensing area **112***c* of the sensor **112** according to an embodiment of the present disclosure. FIG. **9** is a partial schematic diagram of the fourth sensing area **112***d* of the sensor **112** according to an embodiment of the present disclosure. As shown in FIGS. **6** to **9**, the first sensing area **112***a* includes a plurality of sensing units A**1**+, B**1**+, A**1**−, B**1**− arranged into a phased-array. The second sensing area **112***b* includes a plurality of sensing units A**2**+, B**2**+, A**2**−, B**2**− arranged into a phased-array. The third sensing area **112***c* includes a plurality of sensing units A**3**+, B**3**+, A**3**−, B**3**− arranged into a phased-array. The fourth sensing area **112***d* includes a plurality of sensing units A**4**+, B**4**+, A**4**−, B**4**− arranged into a phased-array. Specifically, the sensing units A**1**+, B**1**+, A**1**−, B**1**− of the first sensing area **112***a* adopt a periodic phase array arrangement in the first direction D**1**. That is, the interleaved arrangement of the sensing unit A**1**+, the sensing unit B**1**+, the sensing unit A**1**−, and the sensing unit B**1**− in sequence is repeated for a plurality of cycles. The sensing units A**2**+, B**2**+, A**2**−, B**2**− of the second sensing area **112***b* adopt a periodic phase array arrangement in the first direction D**1**. That is, the interleaved arrangement of the sensing unit A**2**+, the sensing unit B**2**+, the sensing unit A**2**−, and the sensing unit B**2**− in sequence is repeated for a plurality of cycles. The sensing units A**3**+, B**3**+, A**3**−, B**3**− of the third sensing area **112***c* adopt a periodic phase array arrangement in the second direction D**2**. That is, the interleaved arrangement of the sensing unit A**3**+, the sensing unit B**3**+, the sensing unit A**3**−, and the sensing unit B**3**− in sequence is repeated for a plurality of cycles. The sensing units A**4**+, B**4**+, A**4**−, B**4**− of the fourth sensing area **112***d* adopt a periodic phase array arrangement in the second direction D**2**. That is, the interleaved arrangement of the sensing unit A**4**+, the sensing unit B**4**+, the sensing unit A**4**−, and the sensing unit B**4**− in sequence is repeated for a plurality of cycles. By adopting the phased-array arrangement, the first sensing area **112***a*, the second sensing area **112***b*, the third sensing area **112***c*, and the fourth sensing area **112***d* can have higher resistance to environmental pollution and better assembly positioning margin, thereby enhancing the robustness of the encoder **100**.

[0063] Reference is made to FIG. **10**. FIG. **10** is a schematic diagram illustrating a first sensing position signal and a third sensing position signal obtained by sensing the first pattern area **111***a* using the first sensing area **112***a* and the third sensing area **112***c* respectively. As shown in FIG. **10**, in the present embodiment, after sensing a change of the first pattern area **111***a* in the first direction D**1**, the first sensing area **112***a* will correspondingly generate the first sensing position signal. In detail, the sensing units A**1**+, B**1**+, A**1**−, B**1**− of the first sensing area **112***a* will generate first sensing position signals SA**1**+, SB**1**+, SA**1**−, SB**1**− respectively. After sensing a change of the first pattern area **111***a* in the second direction D**2**, the third sensing area **112***c* will correspondingly generate the third sensing position signal. In detail, the sensing units A**3**+, B**3**+, A**3**−, B**3**− of the third sensing area **112***c* will generate third sensing position signals SA**3**+, SB**3**+, SA**3**−, SB**3**− respectively.

[0064] As shown in FIG. **3**, in the present embodiment, the encoder **100** further includes a signal processing unit **120** (shown in dashed lines). The signal processing unit **120** is connected to the sensor **112** and configured to process the first sensing position signals SA**1**+, SB**1**+, SA**1**−, SB**1**− generated by the first sensing area **112***a* and the third sensing position signals SA**3**+, SB**3**+, SA**3**−, SB**3**− generated by the third sensing area **112***c*. In the present embodiment, the signal processing unit **120** is integrated with the sensor **112**, but the disclosure is not limited thereto. In practical applications, the signal processing unit **120** and the sensor **112** may not be integrated together and connected through additional components.

[0065] Reference is made to FIG. **11**. FIG. **11** is a schematic diagram illustrating a first sensing position information and a third sensing position information calculated from the first sensing position signal and the third sensing position signal respectively. In the present embodiment, the signal processing unit **120** is configured to calculate the first sensing position information (as shown in FIG. **11**) from the first sensing position signals SA**1**+, SB**1**+, SA**1**−, SB**1**− (as shown in FIG. **10**). For example, the first sensing position information can be calculated through an arctangent function (i.e., ATAN function). The first sensing position information also has the first pitch P**1**. In addition, the signal processing unit **120** is further configured to calculate the third sensing position information (as shown in FIG. **11**) from the third sensing position signals SA**3**+, SB**3**+, SA**3**−, SB**3**− (as shown in FIG. **10**). For example, the third sensing position information can be calculated through an arctangent function. The third sensing position information also has the third pitch P**3**.

[0066] Reference is made to FIG. **12**. FIG. **12** is a schematic diagram illustrating a second sensing position signal and a fourth sensing position signal obtained by sensing the second pattern area **111***b* using the second sensing area **112***b* and the fourth sensing area **112***d* respectively. As shown in FIG. **12**, in the present embodiment, after sensing a change of the second pattern area **111***b* in the first direction D**1**, the second sensing area **112***b* will correspondingly generate the second sensing position signal SA**2**+, SB**2**+, SA**2**−, SB**2**−. After sensing a change of the second pattern area **111***b* in the second direction D**2**, the fourth sensing area **112***d* will correspondingly generate the fourth sensing position signal SA**4**+, SB**4**+, SA**4**−, SB**4**−.

[0067] Reference is made to FIG. **13**. FIG. **13** is a schematic diagram illustrating a second sensing position information and a fourth sensing position information calculated from the second sensing position signal and the fourth sensing position signal respectively. In the present embodiment, the signal processing unit **120** is further configured to calculate the second sensing position information (as shown in FIG. **13**) from the second sensing position signals SA**2**+, SB**2**+, SA**2**−, SB**2**− (as shown in FIG. **12**). For example, the second sensing position information can be calculated through an arctangent function. The second sensing position information also has the second pitch P**2**. In addition, the signal processing unit **120** is further configured to calculate the fourth sensing position information (as shown in FIG. **13**) from the fourth sensing position signals SA**4**+, SB**4**+, SA**4**−, SB**4**− (as shown in FIG. **12**). For example, the fourth sensing position information can be calculated through an arctangent function. The fourth sensing position information also has the fourth pitch P**4**.

[0068] In the present embodiment, the signal processing unit **120** is further configured to generate a first synthesized position information according to the first sensing position information and the second sensing position information, generate a second synthesized position information according to the third sensing position information and the first synthesized position information; generate a third synthesized position information according to the fourth sensing position information and the first synthesized position information; and generate a fourth synthesized position information according to the second synthesized position information and the third synthesized position information. Specifically, the signal processing unit **120** is configured to use the first sensing position information and the second sensing position information to calculate the first synthesized position information based on Vernier effect. The signal processing unit **120** is further configured to use the third sensing position information and the first synthesized position information to calculate the second synthesized position information based on Vernier effect. The signal processing unit **120** is further configured to use the fourth sensing position information and the first synthesized position information to calculate the third synthesized position information based on Vernier effect. The signal processing unit **120** is further configured to use the second synthesized position information and the third synthesized position information to calculate the fourth synthesized position information based on Vernier effect. The principle of Vernier effect is briefly described as follows.

[0069] Reference is made to FIG. **14**A, FIG. **14**B, FIG. **14**C, and FIG. **14**D. FIG. **14**A is a schematic diagram of a 16-period signal. FIG. **14**B is a schematic diagram of a 15-period signal. FIG. **14**C is a schematic diagram of a difference signal between the 16-period signal and the 15-period signal. FIG. **14**D is a schematic diagram of the difference signal in FIG. **14**C in the form of unsigned 10-bit data. As shown in FIGS. **14**A to **14**D, after subtracting the 15-period signal in FIG. **14**B from the 16-period signal in FIG. **14**A, the difference signal in FIG. **14**C can be obtained. Further, by converting the difference signal in FIG. **14**C into the unsigned 10-bit data form, the single period signal shown in FIG. **14**D can be obtained.

[0070] In some embodiments where the encoder **100** is linear, N is equal to M+1. The first synthesized position information has a first synthesized pitch PS**1**. The second pitch P**2** of the second sensing position information is (M−1)/M times the first pitch P**1** of the first sensing position information, such that the first synthesized pitch PS**1** is (M−1) times the first pitch P**1** or M times the second pitch P**2**. M is an integer greater than 2.

[0071] In some embodiments where the encoder **100** is linear, the second synthesized position information has a second synthesized pitch PS**2**. The first synthesized pitch PS**1** is (M−1)/M times the third pitch P**3**, such that the second synthesized pitch PS**2** is (M−1) times the third pitch P**3** or M times the first synthesized pitch PS**1**. M is an integer greater than 2.

[0072] In some embodiments where the encoder **100** is linear, the third synthesized position information has a third synthesized pitch PS**3**. The first synthesized pitch PS**1** is M/(M+1) times the fourth pitch P**4**, such that the third synthesized pitch PS**3** is M times the fourth pitch P**4** or (M+1) times the first synthesized pitch PS**1**. M is an integer greater than 2.

[0073] In some embodiments where the encoder **100** is linear, the fourth synthesized position information has a fourth synthesized pitch PS**4**. The third synthesized pitch PS**3** is (M+1)/M times the second synthesized pitch PS**2**, such that the fourth synthesized pitch PS**4** is (M+1) times the second synthesized pitch PS**2** or (M+1) times the third synthesized pitch PS**3**. M is an integer greater than 2.

[0074] For example, under the conditions that M is 32, the first pitch P**1** is 64 μm, the second pitch P**2** is 62 μm, the third pitch P**3** is 2,048 μm, and the fourth pitch P**4** is 2,046 μm, the signal processing unit **120** can generate the first synthesized position information with the first synthesized pitch PS1 of 1,984 μm, the second synthesized position information with the second synthesized pitch PS**2** of 63,488 μm, the third synthesized position information with the third synthesized pitch PS**3** of 65,472 μm, and the fourth synthesized position information with the fourth synthesized pitch PS4 of 2,095,104 μm.

[0075] For example, under the conditions that M is 64, the first pitch P**1** is 64 82 m, the second pitch P**2** is 63 μm, the third pitch P**3** is 4,096 μm, and the fourth pitch P**4** is 4,095 μm, the signal processing unit **120** can generate the first synthesized position information with the first synthesized pitch PS**1** of 4,032 μm, the second synthesized position information with the second synthesized pitch PS**2** of 258,048 μm, the third synthesized position information with the third synthesized pitch PS**3** of 262,080 μm, and the fourth synthesized position information with the fourth synthesized pitch PS**4** of 16,773,120 μm.

[0076] It should be noted that the fourth synthesized position information analyzed by the signal processing unit **120** can be used as preliminary absolute position information. The second synthesized position information or the third synthesized position information analyzed by the signal processing unit **120** can be used as low-precision position information. The third sensing position information, the fourth sensing position information, or the first synthesized position information analyzed by the signal processing unit **120** can be used as medium-precision position information. The first sensing position information or the second sensing position information can be used as high-precision position information.

[0077] Reference is made to FIG. **15**. FIG. **15** is a schematic diagram illustrating a position information obtained by a position detection method of the encoder **100** according to an embodiment of the present disclosure. As shown in FIG. **15**, in the present embodiment, the signal processing unit **120** is further configured to analyze a first position a from the fourth synthesized position information (i.e., the preliminary absolute position information). The signal processing unit **120** is further configured to map the first position a to the second synthesized position information or the third synthesized position information (i.e., the low-precision position information) to analyze a second position b, which is the second cycle position as shown in the figure. The signal processing unit **120** is further configured to map the second position b to the third sensing position information, the fourth sensing position information, or the first synthesized position information (i.e., the medium-precision position information) to analyze a third position c, which is the fifth cycle position as shown in the figure. The signal processing unit **120** is further configured to map the third position c to the first sensing position information or the second sensing position information (i.e., the high-precision position information) to analyze a fourth position d, in which the fourth position d is a high-precision absolute position. This progressive position analyzing step maps an initial absolute position to a low-precision incremental position, maps the low-precision incremental position to a medium-precision incremental position, and maps the medium-precision incremental position to a high-precision incremental position, such that the analyzed position information is a high-precision absolute position. In this way, the encoder **100** of the present embodiment can realize high-precision absolute position sensing.

[0078] According to the foregoing recitations of the embodiments of the disclosure, it can be seen that in the optical sensing assembly of the present disclosure, the scale includes two pattern areas and the sensor includes four sensing areas. Two of the sensing areas are configured to sense one of the pattern areas, and the other two of the sensing areas are configured to sense the other one of the pattern areas. Since the scale only includes two pattern areas, the optical sensing assembly only requires a smaller area for sensing, thereby increasing the mechanism assembly margin. Moreover, the sensing units in each of the sensing areas are arranged in a phased-array, so the sensing areas have higher resistance to environmental pollution and better assembly positioning margin, thereby enhancing the robustness of the encoder. In addition, the encoding and decoding of the encoder using this optical sensing assembly uses four sets of incremental position signals and Vernier effect, so high-precision absolute position sensing can be achieved.
[0079] Although the present disclosure has been described in considerable detail with reference to certain embodiments thereof, other embodiments are possible. Therefore, the spirit and scope of the appended claims should not be limited to the description of the embodiments contained herein.
[0080] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present disclosure without departing from the scope or spirit of the disclosure. In view of the foregoing, it is intended that the present disclosure cover modifications and variations of this disclosure provided they fall within the scope of the following claims.

Claims

1. An optical sensing assembly, comprising: a scale comprising: a first pattern area comprising a plurality of first patterns periodically arranged in a first direction and a second direction; and a second pattern area comprising a plurality of second patterns periodically arranged in the first direction and the second direction; a sensor configured to move relative to the scale in the first direction and comprising: a first sensing area configured to sense a change of the first pattern area in the first direction; a second sensing area configured to sense a change of the second pattern area in the first direction; a third sensing area configured to sense a change of the first pattern area in the second direction; and a fourth sensing area configured to sense a change of the second pattern area in the second direction; and a light source configured to emit light toward the scale.
2. The optical sensing assembly of claim 1, wherein the first patterns arranged along the first direction are gradually shifted in the second direction.
3. The optical sensing assembly of claim 2, wherein the first patterns are arranged in a plurality of columns, the columns have a pitch in the first direction, the first patterns in each of the columns have another pitch in the second direction, and after passing a distance of M times the pitch along the first direction, the columns are gradually shifted in the second direction by a distance of the another pitch, wherein M is an integer greater than 2.
4. The optical sensing assembly of claim 3, wherein when the sensor moves a distance of M times the pitch in the first direction relative to the scale, the first sensing area generates M periodic signals and the third sensing area generates one periodic signal.
5. The optical sensing assembly of claim 1, wherein the second patterns arranged along the first direction are gradually shifted in the second direction.
6. The optical sensing assembly of claim 5, wherein the second patterns are arranged in a plurality of columns, the columns have a pitch in the first direction, the second patterns in each of the columns have another pitch in the second direction, and after passing a distance of N times the pitch along the first direction, the columns are gradually shifted in the second direction by a distance of the another pitch, wherein N is an integer greater than 2.
7. The optical sensing assembly of claim 6, wherein when the sensor moves a distance of N times the pitch in the first direction relative to the scale, the second sensing area generates N periodic signals and the fourth sensing area generates one periodic signal.

8. The optical sensing assembly of claim 1, wherein sensing units of each of the first sensing area, the second sensing area, the third sensing area, and the fourth sensing area are arranged into a phased-array.

9. An encoder, comprising: an optical sensing assembly comprising: a scale comprising: a first pattern area comprising a plurality of first patterns periodically arranged in a first direction and a second direction; and a second pattern area comprising a plurality of second patterns periodically arranged in the first direction and the second direction; a sensor configured to move relative to the scale in the first direction and comprising: a first sensing area configured to sense a change of the first pattern area in the first direction and accordingly generate a first sensing position signal; a second sensing area configured to sense a change of the second pattern area in the first direction and accordingly generate a second sensing position signal; a third sensing area configured to sense a change of the first pattern area in the second direction and accordingly generate a third sensing position signal; and a fourth sensing area configured to sense a change of the second pattern area in the second direction and accordingly generate a fourth sensing position signal; and a signal processing unit connected to the sensor and configured to: calculate a first sensing position information, a second sensing position information, a third sensing position information, and a fourth sensing position information respectively from the first sensing position signal, the second sensing position signal, the third sensing position signal, and the fourth sensing position signal; generate a first synthesized position information according to the first sensing position information and the second sensing position information; generate a second synthesized position information according to the third sensing position information and the first synthesized position information; generate a third synthesized position information according to the fourth sensing position information and the first synthesized position information; and generate a fourth synthesized position information according to the second synthesized position information and the third synthesized position information.

10. The encoder of claim 9, wherein the first patterns arranged along the first direction are gradually shifted in the second direction.

11. The encoder of claim 10, wherein the first patterns are arranged in a plurality of columns, the columns have a pitch in the first direction, the second patterns in each of the columns have another pitch in the second direction, and after passing a distance of M times the pitch along the first direction, the columns are gradually shifted in the second direction by a distance of the another pitch, wherein M is an integer greater than 2.

12. The encoder of claim 11, wherein when the sensor moves a distance of M times the pitch in the first direction relative to the scale, the first sensing area generates M periodic signals and the third sensing area generates one periodic signal.

13. The encoder of claim 9, wherein the second patterns arranged along the first direction are gradually shifted in the second direction.

14. The encoder of claim 13, wherein the second patterns are arranged in a plurality of columns, the columns have a pitch in the first direction, the second patterns in each of the columns have another pitch in the second direction, and after passing a distance of N times the pitch along the first direction, the columns are gradually shifted in the second direction by a distance of the another pitch, wherein N is an integer greater than 2.

15. The encoder of claim 14, wherein when the sensor moves a distance of N times the pitch in the first direction relative to the scale, the second sensing area generates N periodic signals and the fourth sensing area generates one periodic signal.

16. The encoder of claim 9, wherein sensing units of each of the first sensing area, the second sensing area, the third sensing area, and the fourth sensing area are arranged into a phased-array.

17. The encoder of claim 9, wherein the signal processing unit is configured to use the first sensing position information and the second sensing position information to calculate the first synthesized position information based on Vernier effect.

18. The encoder of claim 9, wherein the signal processing unit is configured to use the third sensing position information and the first synthesized position information to calculate the second synthesized position information based on Vernier effect.
19. The encoder of claim 9, wherein the signal processing unit is configured to use the fourth sensing position information and the first synthesized position information to calculate the third synthesized position information based on Vernier effect.
20. The encoder of claim 9, wherein the signal processing unit is configured to use the second synthesized position information and the third synthesized position information to calculate the fourth synthesized position information based on Vernier effect.