LIDAR SYSTEM, CONTROL METHOD, AND CONTROL APPARATUS

[0001] This application claims priority to Chinese Patent Application No. 202410325031.8, filed with the China National Intellectual Property Administration on March 20, 2024 and entitled "LIDAR SYSTEM, CONTROL METHOD, AND CONTROL APPARATUS", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] This application relates to the field of detection technologies, and more specifically, to a lidar system, a control method, and a control apparatus.

BACKGROUND

[0003] Vertical resolution is an important indicator for evaluating performance of lidars. To obtain a higher vertical resolution, a multi-line lidar may be used. The multi-line lidar uses a plurality of transmitting apparatuses and corresponding detectors. Transceiver channels may be formed between the transmitting apparatuses and the corresponding detectors, and a higher vertical resolution can be obtained by arranging the plurality of transceiver channels in a vertical direction. Increasing a quantity of transceiver channels can improve a vertical resolution of the multi-line radar, and can also increase a detection range of the lidar in the vertical direction. However, limited by costs and space available for arrangement, it is difficult to add excessive transceiver channels.

[0004] When a lidar with a small quantity of channels is used, disposing a scanning apparatus can improve a vertical resolution, and can also implement wide-field detection. However, intervention of the scanning apparatus may cause an uneven distribution of point clouds, and a phenomenon of transmit-receive angle delay may also exist, affecting speed measurement and ranging performance of the lidar. Therefore, when the scanning apparatus is used, how to ensure speed measurement and ranging performance of the lidar becomes an urgent problem to be resolved.

SUMMARY

[0005] This application provides a lidar system, a control method, and a control apparatus, to improve speed measurement and ranging performance of a lidar when a scanning apparatus is used.

[0006] According to a first aspect, a lidar system is provided. The lidar system includes a transmitting unit, a first scanning unit, and a second scanning unit. The transmitting unit is configured to transmit a detection beam, the first scanning unit and the second scanning unit are disposed on a propagation path of the detection beam, the first scanning unit is configured to oscillate around a first axis to perform slow-axis scanning on the detection beam, and the second scanning unit is configured to continuously rotate around a second axis in a clockwise direction or a counter-clockwise direction to perform fast-axis scanning on the detection beam. A scanning period of the second scanning unit includes a first time period and a second time period, the second scanning unit performs idle scanning in the first time period, and the second scanning unit completes scanning the detection beam in object space for one fast-axis period in the second time period. The first scanning unit is configured to: rotate from a first angular position to a second angular position in the first time period, and keep the angular position unchanged in the second time period.

[0007] For example, the first scanning unit may be an oscillating mirror or a galvanometer mirror, and the second scanning unit may be a rotating mirror. On the propagation path of the detection beam, after the detection beam is transmitted by the transmitting unit, the detection beam may first pass through the first scanning unit and then pass through the second scanning unit, or may first pass through the second scanning unit and then pass through the first scanning unit.

[0008] For example, the idle scanning may include scanning outside a range of the field of view/a range of an effective field of view. For example, when the second scanning unit is a pentagonal prism with five reflective surfaces, a scanning angle corresponding to each scanning period of the pentagonal prism is 144°. It is assumed that the horizontal field of view is 120°, and in each scanning period of the pentagonal prism, a scanning angle of 24° may be in an idle scanning phase. In the idle scanning phase, the transmitting unit may transmit or may not transmit the detection beam.

[0009] In an embodiment, for an oscillation process of the first scanning unit, the first scanning unit does not continuously rotate from one end of the oscillation process to the other end of the oscillation process, but oscillates from one end to the other end in a step manner. In this manner, the first scanning unit can adjust the angular position in the first time period, and keep the angular position unchanged in the second time period.

[0010] In an actual scenario, angular resolutions of some regions in the field of view region

need to be improved. For example, in a manner of using a slow scanning mirror and a fast scanning mirror, an angular resolution in the vertical field of view is usually adjusted by adjusting a rotation speed of the slow scanning mirror. However, because adjusting the rotation speed of the slow scanning mirror needs to consume a specific amount of time, when the slow scanning mirror continuously rotates, for a multi-channel lidar, scanning trajectories of different channels in the field of view region may overlap in a time period of adjusting the rotation speed of the slow scanning mirror. As a result, point clouds are unevenly distributed, affecting performance of the lidar.

[0011] In this application, the angular position of the first scanning unit is adjusted in the idle scanning phase in the scanning period of the second scanning unit, and when scanning is performed in a range of the field of view in the scanning period of the second scanning unit, the angular position of the first scanning unit remains unchanged. In this manner, interference to a point cloud distribution in the process of adjusting the angular position of the first scanning unit can be avoided, impact of continuous rotation of the first scanning unit on a scanning trajectory can be avoided, and speed measurement and ranging performance of the lidar system can be ensured when the scanning apparatus is used.

[0012] With reference to the first aspect, in some implementations of the first aspect, in a plurality of consecutive scanning periods of the second scanning unit, the angular position of the first scanning unit is in a first angular interval, the first angular interval may include a plurality of angular positions, and the first angular position and the second angular position are two adjacent angular positions in the plurality of angular positions. The first angular interval corresponds to a first field of view region in a vertical field of view of the system, and a vertical angular resolution in the first field of view region is determined based on an included angle between the first angular position and the second angular position.

[0013] With reference to the first aspect, in some implementations of the first aspect, the plurality of angular positions may further include a third angular position adjacent to the first angular position, and an included angle between the first angular position and the third angular position is equal to the included angle between the first angular position and the second angular position; and/or the plurality of angular positions may further include a fourth angular position adjacent to the second angular position, and an included angle between the second angular position and the fourth angular position is equal to the included angle between the first angular position and the second angular position.

[0014] In this application, angular positions in a same angular interval are distributed at equal spacings, so that a field of view region corresponding to the angular interval in the vertical field of view can have a uniform angular resolution.

[0015] With reference to the first aspect, in some implementations of the first aspect, the first angular position is in a second angular interval, the second angular position is in a third angular interval, the second angular interval may further include a fifth angular position adjacent to the first angular position, and the third angular interval may further include a sixth angular position adjacent to the second angular position. The second angular interval corresponds to a second field of view region in a vertical field of view of the system, the third angular interval corresponds to a third field of view region in the vertical field of view of the system, and the second field of view region is adjacent to the third field of view region. A vertical angular resolution in the second field of view region is determined based on an included angle between the first angular position and the fifth angular position. A vertical angular resolution in the third field of view region is determined based on an included angle between the second angular position and the sixth angular position.

[0016] In this application, when a plurality of angular intervals are involved, angular positions in a same angular interval are distributed at equal spacings, and different angular position variations are used in different angular intervals, so that different field of view regions in the vertical field of view can have different angular resolutions, thereby facilitating setting and planning of different angular resolution regions in a vertical field of view region.

[0017] With reference to the first aspect, in some implementations of the first aspect, the system may further include a receiving unit and a waveguide apparatus, where the receiving unit is configured to receive return light of the detection beam, and the waveguide apparatus is configured to guide the return light to the receiving unit. The waveguide apparatus meets the following condition: A waveguide light spot formed by processing, by the waveguide apparatus, a beam whose propagation direction is opposite to that of the return light has a non-uniform light field intensity distribution.

[0018] In this application, the waveguide mode spot of the waveguide apparatus has a non-uniform light field intensity distribution, which can alleviate a deterioration effect of a transmit-receive angle delay on a speed measurement and ranging function of a lidar.

[0019] With reference to the first aspect, in some implementations of the first aspect, the waveguide light spot has a non-uniform light field intensity distribution in a direction of the second axis.

[0020] With reference to the first aspect, in some implementations of the first aspect, that the waveguide light spot has a non-uniform light field intensity distribution may include: light field intensity of the waveguide light spot is distributed with a right-side offset in the fast axis direction, distributed with a left-side offset in the fast axis direction, symmetrically distributed on left and right sides of the fast axis direction, or asymmetrically distributed on left and right sides of the fast axis direction.

[0021] In this application, the waveguide mode spot having a non-uniform light field intensity distribution is disposed in the second direction or the fast-axis direction, so that different coupling efficiencies can be provided for focused light spots of return light of targets from near to far, and a change in echo power received in a detection range can be slower, thereby increasing a dynamic range of the system.

[0022] With reference to the first aspect, in some implementations of the first aspect, the waveguide apparatus may include at least one of the following: an optical device formed by a plurality of waveguides based on a beam combining process, a waveguide having a multi-fork structure, or a grating coupler.

[0023] With reference to the first aspect, in some implementations of the first aspect, the transmitting unit may include a plurality of beam transmitting channels, the plurality of beam transmitting channels may be disposed in an array with equal spacings, and each of the plurality of beam transmitting channels may be configured to transmit one detection beam.

[0024] With reference to the first aspect, in some implementations of the first aspect, that second scanning unit completes scanning the detection beam in the object space for one fast scanning period may include: The second scanning unit completes one scan of the detection beam in a horizontal field of view of the system.

[0025] According to a second aspect, a control method is provided. The method may be performed by a lidar system, or may be performed by an intelligent driving device in which the lidar system is disposed, or may be performed by a chip or a processor corresponding to the lidar system. In some possible implementations, the chip or the processor corresponding to the lidar system may be disposed in a radar, or may be disposed outside the radar.

[0026] The lidar system may include a first scanning unit and a second scanning unit, and the first scanning unit and the second scanning unit are disposed on a propagation path of a detection beam. The first scanning unit may be configured to oscillate around a first axis to perform slow-axis scanning on the detection beam. The second scanning unit may be configured to continuously rotate around a second axis in a clockwise direction or a counter-clockwise direction to perform fast-axis scanning on the detection beam. A scanning period of the second scanning unit includes a first time period and a second time period, the second scanning unit performs idle scanning in the first time period, and the second scanning unit completes scanning the detection beam in object space for one fast-axis period in the second time period.

[0027] The method includes: controlling the first scanning unit to rotate from a first angular position to a second angular position in the first time period; and controlling the first scanning unit to keep the angular position unchanged in the second time period.

[0028] With reference to the second aspect, in some implementations of the second aspect, in

a plurality of consecutive scanning periods of the second scanning unit, the angular position of the first scanning unit is in a first angular interval, the first angular interval may include a plurality of angular positions, and the first angular position and the second angular position are two adjacent angular positions in the plurality of angular positions. The first angular interval corresponds to a first field of view region in a vertical field of view of the system, and a vertical angular resolution in the first field of view region is determined based on an included angle between the first angular position and the second angular position.

[0029] With reference to the second aspect, in some implementations of the second aspect, the plurality of angular positions may further include a third angular position adjacent to the first angular position, and an included angle between the first angular position and the third angular position is equal to the included angle between the first angular position and the second angular position; and/or the plurality of angular positions may further include a fourth angular position adjacent to the second angular position, and an included angle between the second angular position and the fourth angular position is equal to the included angle between the first angular position and the second angular position.

[0030] With reference to the second aspect, in some implementations of the second aspect, the first angular position is in a second angular interval, the second angular position is in a third angular interval, the second angular interval may further include a fifth angular position adjacent to the first angular position, and the third angular interval may further include a sixth angular position adjacent to the second angular position. The second angular interval corresponds to a second field of view region in a vertical field of view of the system, the third angular interval corresponds to a third field of view region in the vertical field of view of the system, and the second field of view region is adjacent to the third field of view region. A vertical angular resolution in the second field of view region is determined based on an included angle between the first angular position and the fifth angular position. A vertical angular resolution in the third field of view region is determined based on an included angle between the second angular position and the sixth angular position.

[0031] With reference to the second aspect, in some implementations of the second aspect, the lidar system in which the first scanning unit and the second scanning unit are disposed further includes a transmitting unit configured to transmit the detection beam. The transmitting unit may include a plurality of beam transmitting channels, the plurality of beam transmitting channels are disposed in an array with equal spacings, and each of the plurality of beam transmitting channels is configured to transmit one detection beam.

[0032] With reference to the second aspect, in some implementations of the second aspect, that second scanning unit completes scanning the detection beam in the object space for one fast

scanning period may include: The second scanning unit completes one scan of the detection beam in a horizontal field of view of the system.

[0033] According to a third aspect, a waveguide apparatus is provided. The waveguide apparatus is configured to guide return light of a detection beam to a receiving unit. The waveguide apparatus meets the following condition: A waveguide light spot formed by processing, by the waveguide apparatus, a beam whose propagation direction is opposite to that of the return light has a non-uniform light field intensity distribution.

[0034] With reference to the third aspect, in some implementations of the third aspect, the waveguide apparatus may include at least one of the following: an optical device formed by a plurality of waveguides based on a beam combining process, a waveguide having a multi-fork structure, or a grating coupler.

[0035] According to a fourth aspect, a lidar system is provided. The lidar system includes a transmitting unit, a third scanning unit, a fourth scanning unit, a receiving unit, and the waveguide apparatus according to any one of the third aspect and the possible implementations thereof. The transmitting unit is configured to transmit a detection beam, and the third scanning unit and the fourth scanning unit are disposed on a propagation path of the detection beam. The third scanning unit is configured to oscillate around a first axis to perform slow-axis scanning on the detection beam. The fourth scanning unit is configured to continuously rotate around a second axis in a clockwise direction or a counter-clockwise direction to perform fast-axis scanning on the detection beam. The receiving unit is configured to receive return light of the detection beam. The waveguide apparatus is configured to guide the return light to the receiving unit.

[0036] With reference to the fourth aspect, in some implementations of the fourth aspect, the waveguide light spot has a non-uniform light field intensity distribution in a direction of the second axis.

[0037] With reference to the fourth aspect, in some implementations of the fourth aspect, that the waveguide light spot has a non-uniform light field intensity distribution may include: light field intensity of the waveguide light spot is distributed with a right-side offset in the fast axis direction, distributed with a left-side offset in the fast axis direction, symmetrically distributed on left and right sides of the fast axis direction, or asymmetrically distributed on left and right sides of the fast axis direction.

[0038] With reference to the fourth aspect, in some implementations of the fourth aspect, the transmitting unit may include a plurality of beam transmitting channels, the plurality of beam transmitting channels may be disposed in an array with equal spacings, and each of the plurality of beam transmitting channels may be configured to transmit one detection beam.

[0039] According to a fifth aspect, a control apparatus is provided. The apparatus includes a

control unit. The control unit is configured to: control a first scanning unit to rotate from a first angular position to a second angular position in a first time period; and control the first scanning unit to keep the angular position unchanged in a second time period.

[0040] According to a sixth aspect, a control apparatus is provided. The apparatus includes: a memory, configured to store a computer program; and a processor, configured to execute the computer program stored in the memory, to enable the apparatus to perform the method according to any one of the second aspect and the possible implementations thereof.

[0041] According to a seventh aspect, a computer program product is provided. The computer program product includes computer program code, and when the computer program code is run on a computer, the computer is enabled to perform the method according to any one of the second aspect and the possible implementations thereof.

[0042] According to an eighth aspect, a computer-readable storage medium is provided. The computer-readable storage medium stores a computer program, and when the computer program is run on a computer, the computer is enabled to perform the method according to any one of the second aspect and the possible implementations thereof.

[0043] According to a ninth aspect, a chip is provided. The chip includes a circuit, configured to perform the method according to any one of the second aspect and the possible implementations thereof.

[0044] According to a tenth aspect, an intelligent driving device is provided. The intelligent driving device includes the system according to any one of the first aspect or the fourth aspect and the possible implementations thereof, or includes the apparatus according to any one of the fifth aspect or the sixth aspect and the possible implementations thereof.

[0045] In an embodiment, the intelligent driving device includes a vehicle.

BRIEF DESCRIPTION OF DRAWINGS

[0046] FIG. 1 is a diagram of a lidar system according to an embodiment of this application;

[0047] FIG. 2 is a diagram of a detection scenario according to an embodiment of this application;

[0048] FIG. 3A and FIG. 3B are a diagram of another detection scenario according to an embodiment of this application;

[0049] FIG. 4A and FIG. 4B are diagrams of scanning trajectories according to an embodiment of this application;

[0050] FIG. 5A and FIG. 5B are diagrams of other scanning trajectories according to an embodiment of this application;

[0051] FIG. 6 is a diagram of another detection scenario according to an embodiment of this application;

[0052] FIG. 7 is a schematic flowchart of a control method according to an embodiment of this application;

[0053] FIG. 8 is a diagram of another detection scenario according to an embodiment of this application;

[0054] FIG. 9 is a diagram of a moving manner of a scanning mirror according to an embodiment of this application;

[0055] FIG. 10 is a diagram of a scanning trajectory according to an embodiment of this application;

[0056] FIG. 11 is a diagram of a scanning trajectory in a field of view region according to an embodiment of this application;

[0057] FIG. 12A to FIG. 12D are diagrams of waveguide mode spots according to an embodiment of this application;

[0058] FIG. 13 is a diagram of focused light spots formed on a receiving surface by targets at different positions according to an embodiment of this application;

[0059] FIG. 14 is a diagram of a change in received echo power according to an embodiment of this application;

[0060] FIG. 15 is a diagram of another detection scenario according to an embodiment of this application;

[0061] FIG. 16 is a diagram of another detection scenario according to an embodiment of this application;

[0062] FIG. 17 is a diagram of another detection scenario according to an embodiment of this application;

[0063] FIG. 18 is a block diagram of a control apparatus according to an embodiment of this application; and

[0064] FIG. 19 is a block diagram of another control apparatus according to an embodiment of this application.

DESCRIPTION OF EMBODIMENTS

[0065] The following describes technical solutions of this application with reference to the accompanying drawings.

[0066] Lidars may use an electromagnetic wave in a specific band, for example, an electromagnetic wave from an ultraviolet band to a far infrared band, or an electromagnetic wave

in a band whose wavelength is from 250 nanometers (nanometer, nm) to 11 micrometers (micrometer, μm). By detecting a scattered-light feature of a target object, related information such as a location and a speed of the target object may be obtained. Compared with other types of radars (such as millimeter wave radars), the lidars have higher measurement precision and a finer time resolution and spatial resolution, and have a broad application prospect in fields such as intelligent transportation, autonomous driving, atmospheric environment monitoring, geographic surveying and mapping, and uncrewed aerial vehicles.

[0067] For example, based on a form of a detection signal, the lidars may be classified into pulse lidars and continuous wave lidars. For example, based on a used modulation scheme, the continuous wave lidars may be classified into an amplitude modulated continuous wave lidar and a frequency modulated continuous wave lidar. The frequency modulated continuous wave lidar may be understood as an implementation of a coherent lidar.

[0068] When a lidar with a small quantity of channels is used, disposing a scanning apparatus can improve a vertical resolution, and can implement wide-field detection.

[0069] FIG. 1 is a diagram of a lidar system according to an embodiment of this application. As shown in FIG. 1, a system 100 includes a transmitting unit 110, a receiving unit 120, and a scanning apparatus 130. The transmitting unit 110 may include one or more light sources. A control apparatus may control an optical driver to drive the light source to emit a detection beam. The receiving unit 120 may include a detection apparatus, configured to obtain a return optical signal, and may detect the return optical signal.

[0070] As shown in FIG. 1, the detection beam 101 (referred to as a beam 101 for short) transmitted by the transmitting unit 110 may be transmitted to a target object through the scanning apparatus 130. When the beam 101 is irradiated to the target object, a part of the return optical signal 102 (which may also be referred to as return light 102) of the detection beam 101 is returned to the lidar system 100 through reflection and scattering of the target object. For example, the return light 102 may be received by the receiving unit 120 through the scanning apparatus 130.

[0071] In some possible implementations, the system 100 may further include another optical element. For example, a passive optical element may be disposed on a propagation path of the beam 101 and/or a propagation path of the return light 102 (for example, between the transmitting unit 110 and/or the receiving unit 120 and the scanning apparatus 130, and/or between the scanning apparatus and the target). The passive optical element may include a beam collimation apparatus (for example, a lens), a polarizer, a polarization beam splitting apparatus, a beam splitting apparatus, and the like. The beam splitting apparatus and the polarization beam splitting apparatus may be configured to obtain a local oscillator optical signal of the beam 101. For example, the beam splitting apparatus disposed between the light source and the scanning apparatus may split

the beam 101 into a first part that is directed to the target object and a second part that can be used as the local oscillator optical signal. Distance information and speed information of the target object may be obtained through beat frequency based on the return light 102 and the local oscillator optical signal of the beam 101.

[0072] In some possible implementations, the transmitting unit 110 may transmit a plurality of detection beams at a same moment. In other words, the transmitting unit 110 may include a plurality of beam transmitting channels.

[0073] In an embodiment, the plurality of detection beams transmitted by the transmitting unit 110 at the same moment may be generated by a plurality of lasers. For example, each laser may correspond to one beam transmitting channel.

[0074] In another embodiment, a single detection light signal generated by a single laser may be split by the beam splitting apparatus to obtain a plurality of detection light signals, so that the transmitting unit 110 can transmit the plurality of detection beams at a same moment through the single laser. To ensure power of the beam transmitted by the transmitting unit 110, in some possible implementations, in the foregoing embodiment, the detection light signals obtained by the beam splitting apparatus through splitting may be respectively routed to the plurality of beam transmitting channels through an optical fiber and a waveguide after passing through an optical amplification apparatus (for example, a semiconductor optical amplifier).

[0075] The following briefly describes a transmitting unit corresponding to a multi-line lidar with reference to FIG. 2.

[0076] FIG. 2 is a diagram of a detection scenario according to an embodiment of this application. A system 200 may include a transmitting unit 210 and a lens group. The lens group may include one or more lenses. For example, as shown in FIG. 2, the lens group may include a lens 220 and a lens 230. The transmitting unit 210 may include a plurality of beam transmitting channels 211 to 21n (n is a positive integer). The following describes the system 200 by using an example in which n=4. It should be understood that, during specific implementation, a value of n may be determined based on a specific requirement. For example, n may be another value like 3, 5, 6, or 8. A quantity of beam transmitting channels is not limited in embodiments of this application.

[0077] For adjacent beam transmitting channels, the plurality of beam transmitting channels may be disposed at a same spacing, or the plurality of beam transmitting channels may be disposed at different spacings. This is not limited in embodiments of this application.

[0078] In an embodiment, as shown in FIG. 2, the beam transmitting channels 211 to 214 may be arranged in an array with equal spacings. The plurality of beam transmitting channels 211 to 214 may respectively correspond to a plurality of lasers, or may correspond to a plurality of optical

fibers or waveguides. The transmitting unit 210 may correspond to the transmitting unit 110, and the lenses 220 and 230 may correspond to the passive optical elements disposed between the transmitting unit 110 and the scanning apparatus 130.

[0079] For example, positions of the beam transmitting channels and focal planes of the lenses 220 and 230 are set, so that directions of the beams transmitted by the beam transmitting channels may be adjusted. For example, as shown in FIG. 2, two beams respectively transmitted by the beam transmitting channels 212 and 213 may intersect at a same position in a propagation process, but there is still a difference between directions of the two beams (as shown in FIG. 2, the difference is represented by an included angle θ). The included angle θ may satisfy the following formula: $\theta=\arctan(d/f)$, where d may represent a spacing distance between the beam transmitting channels 212 and 213, and f may represent a focal length of the lens group.

[0080] FIG. 3A and FIG. 3B are a diagram of a detection scenario according to an embodiment of this application. As shown in FIG. 3A and FIG. 3B, the system 300 may include a transmitting unit 301, a scanning mirror 310, a scanning mirror 320, a lens 330, and a lens 340. FIG. 3A shows a process in which a detection beam transmitted by the transmitting unit 301 is propagated to a target through the scanning mirrors 310 and 320. FIG. 3B shows a process in which return light from the target is propagated to a receiving surface 335 through the scanning mirrors 310 and 320.

[0081] In an embodiment, the transmitting unit 301 may correspond to the transmitting unit 110 or 210, and the scanning mirror 310 and the scanning mirror 320 may correspond to the scanning apparatus 130. In some possible implementations, the lens 330 and the lens 340 may be a same lens.

[0082] In another embodiment, the scanning mirror 310 and the scanning mirror 320 each may be a galvanometer mirror, an oscillating mirror, a rotating mirror, or the like. This is not limited in embodiments of this application. In some possible implementations, a scanning speed of the scanning mirror 320 is greater than a scanning speed of the scanning mirror 310. Correspondingly, the scanning mirror 310 may also be referred to as a slow scanning mirror, and the scanning mirror 320 may also be referred to as a fast scanning mirror.

[0083] As shown in FIG. 3A and FIG. 3B, the scanning mirror 310 may rotate along a rotating shaft 311 in a rotation direction 1, and the scanning mirror 320 may rotate along a rotating shaft 321 in a rotation direction 2. By disposing the two scanning mirrors 310 and 320, fast-axis scanning and slow-axis scanning can be implemented. For example, the rotating shaft 311 may be disposed in a horizontal direction, and the rotating shaft 321 may be disposed in a vertical direction. Through rotation of the scanning mirror 310 and the scanning mirror 320, scanning motions in two directions, namely, the vertical and horizontal directions, can be implemented.

[0084] Rotation processes of the scanning mirror 310 and the scanning mirror 320 are

continuous. For example, the scanning mirror 320 continuously rotates around the axis 321 in the rotation direction 2. For another example, oscillation of the scanning mirror 310 may be decomposed into two continuous rotation processes with opposite rotation directions.

[0085] In the scenario shown in FIG. 3A, the beam transmitted by the transmitting unit 301 passes through the scanning mirror 310 and the scanning mirror 320 in sequence, and is transmitted through the scanning mirror 320 to the target. Through rotation of the scanning mirror 310 and the scanning mirror 320, scanning in a plurality of dimensions can be implemented. In the scenario shown in FIG. 3B, the return light may pass through the scanning mirror 320 and the scanning mirror 310 in sequence, and then be propagated to the lens 340. After passing through the lens 340, the return light may be focused on the receiving surface 335 (for example, an end face of the optical fiber or an end face of the waveguide). Then, the optical fiber, the waveguide, or the like transmits the return light to a detection apparatus of the optical signal (not shown in FIG. 3A and FIG. 3B).

[0086] In a scenario in which a scanning apparatus is used in a lidar system, on one hand, a phenomenon of transmit-receive angle delay is caused; and on the other hand, when a plurality of beam transmitting channels are disposed, a phenomenon of uneven point cloud distribution may exist. The foregoing problem affects speed measurement and ranging performance of the lidar.

[0087] The following briefly describes the transmit-receive angle delay phenomenon by using the scenario shown in FIG. 3A and FIG. 3B as an example.

[0088] For example, it is assumed that at a moment at which the detection beam is transmitted through the scanning mirror 320 to the target, the scanning mirror 320 is in a posture 1 shown in FIG. 3A and FIG. 3B. When the scanning mirror 320 continuously rotates, and corresponding return light is incident from the scanning mirror 320, an angular position of the scanning mirror 320 changes compared with the posture 1 (for example, the scanning mirror 320 is in a posture 2 shown in FIG. 3B at the moment), that is, the phenomenon of transmit-receive angle delay exists. Such a change in the angular position causes an offset of a focusing position of the return light on the receiving surface 335, as shown in FIG. 3B. On one hand, the offset is related to a scanning speed (or a rotation speed) of the scanning mirror 320, and the offset increases as the scanning speed increases. On the other hand, the offset is related to the position of the target, and the offset increases as a distance between the target and the lidar system increases. This offset affects a coupling efficiency at the receiving surface 335, and further degrades the signal transmitted to the detection apparatus. In addition, the degradation effect significantly increases as diameters of the waveguide and the optical fiber decrease.

[0089] The following uses the multi-line lidar shown in FIG. 2 and the scenario shown in FIG. 3A and FIG. 3B as examples to briefly describe the phenomenon of uneven point cloud distribution

with reference to FIG. 4A to FIG. 5B. It is assumed that in the scenarios in FIG. 4A to FIG. 5B, the beam transmitting channels 211 to 214 in the transmitting unit 210 are arranged in an array at equal spacings from top to bottom in a vertical direction.

[0090] For example, FIG. 4A and FIG. 4B are diagrams of scanning trajectories according to an embodiment of this application.

[0091] FIG. 4A may represent a position at which detection is expected to be performed in a field of view region. In other words, FIG. 4A represents a scanning trajectory that is expected to be implemented in the field of view (referred to as an expected scanning trajectory). For example, as shown in FIG. 4A, expected scanning trajectories may be distributed at equal spacings in a vertical field of view direction.

[0092] In an actual scenario, a detection beam transmitted by a single beam transmitting channel performs horizontal scanning in a horizontal field of view through the scanning mirror 320. However, because the scanning mirror 310 continuously rotates, an actual scanning trajectory of the detection beam is inclined relative to the expected scanning trajectory at a specific angle in the vertical field of view direction. For example, the actually generated scanning trajectory may be shown in FIG. 4B.

[0093] In addition, in an actual scenario, an angular resolution of a part of the field of view region may need to be improved. This part of the field of view region may be referred to as a focus region or a region of interest (region of interest, ROI).

[0094] For example, FIG. 5A and FIG. 5B are diagrams of other scanning trajectories according to an embodiment of this application.

[0095] FIG. 5A may represent a position at which detection is expected to be performed in a field of view region. For example, as shown in FIG. 5A, a vertical field of view includes an ROI region and a non-ROI region outside the ROI region. The ROI region and the non-ROI region have different angular resolutions in the vertical direction. For example, to implement a detection intention shown in FIG. 5A, when the ROI region is scanned, the scanning mirror 310 may rotate at a low speed; and when the non-ROI region is scanned, the scanning mirror 310 may rotate at a high speed. In other words, by controlling the scanning mirror 310 to rotate at different speeds in different field of view regions, detection of the ROI region and the non-ROI region shown in FIG. 5A can be separately performed.

[0096] In an actual scenario, the process of adjusting the rotation speed of the scanning mirror 310 occupies a part of time. However, because the spacings between the beam transmitting channels 211 to 214 are a fixed value, in a time period of adjusting the rotation speed of the scanning mirror 310, continuous rotation of the scanning mirrors 310 and 320 causes overlapping of scanning trajectories corresponding to different beam transmitting channels in a range of the

field of view, for example, x-shaped overlapping or z-shaped overlapping, as shown in FIG. 5B. In addition, there is a transition region between the ROI region and the non-ROI region. The foregoing factors may cause an uneven point cloud distribution. For example, scanning trajectories may overlap in the transition region, as shown in FIG. 5B. For another example, in some possible implementations, scanning trajectories may overlap in the ROI region.

[0097] In view of this, embodiments of this application provide a lidar system, a control method, and a control apparatus, to ensure speed measurement and ranging performance of a lidar when a scanning apparatus is used.

[0098] For example, FIG. 6 is a diagram of a detection scenario according to an embodiment of this application. As shown in FIG. 6, a detection system 400 may include a transmitting unit 410, a first scanning unit 420, and a second scanning unit 430. For example, the detection system 400 may be a lidar system.

[0099] The transmitting unit 410 may transmit a detection beam. The first scanning unit 420 and the second scanning unit 430 are disposed on a propagation path of the detection beam. For example, the transmitting unit 410 may correspond to the transmitting unit 110 or 210. In other words, in some embodiments, the transmitting unit 410 may include a plurality of beam transmitting channels. For another example, the detection beam transmitted by the transmitting unit 410 may first pass through the first scanning unit 420, then pass through the second scanning unit 430, and then be propagated to a target, as shown in FIG. 6. For another example, the detection beam transmitted by the transmitting unit 410 may first pass through the second scanning unit 430, then pass through the first scanning unit 420, and then be propagated to the target. In other words, in some embodiments, different from the manner shown in FIG. 6, on the propagation path of the detection beam, the second scanning unit 430 may alternatively be disposed between the transmitting unit 410 and the first scanning unit 420.

[00100] The first scanning unit 420 may oscillate around its rotation axis, to perform slow-axis scanning on the detection beam. For example, the first scanning unit 420 may be an oscillating mirror, a galvanometer mirror, or the like. The second scanning unit 430 may continuously rotate around its rotation axis in a clockwise direction or a counterclockwise direction, to perform fast-axis scanning on the detection beam. For example, the second scanning unit may be a rotating mirror. The first scanning unit 420 and the second scanning unit 430 may implement scanning in a plurality of dimensions. For another example, an average rotation speed of a scanning unit performing fast-axis scanning is greater than an average rotation speed of a scanning unit performing slow-axis scanning.

[00101] For example, a scanning period of the second scanning unit 430 may include a first time period and a second time period. The second scanning unit 430 performs idle scanning in the

first time period, and completes one fast-axis period of the detection beam in object space in the second time period.

[00102] In an embodiment, the second scanning unit 430 is a prism, and the prism may include three reflective surfaces (reflective surfaces #1 to #3). When a reflective surface rotates to the propagation path of the detection beam, the reflective surface may function as a scanning mirror. For example, the prism rotates clockwise from an initial position. When the rotation angle is within 0° to 120°, the reflective surface #1 may function as a scanning mirror; when the rotation angle is within 120° to 240°, the reflective surface #2 may function as a scanning mirror; and when the rotation angle is within 240° to 360°, the reflective surface #3 may function as a scanning mirror. A scanning angle of the reflective surface #1, #2, or #3 is 240°. It is assumed that a horizontal field of view is 130°, and a corresponding idle scanning angle is 110°. It is assumed that time in which a single reflective surface can be used as a scanning mirror is 24 ms (that is, the scanning period is 24 ms), and time used by the detection beam to complete one fast axis period in the object space is 13 ms. In this scenario, the idle scanning time is 11 ms. In other words, in this scenario, the first time period is 11 ms, and the second time period is 13 ms.

[00103] In another embodiment, the second scanning unit 430 is a quadrilateral prism, and the quadrilateral prism may include four reflective surfaces. A corresponding rotation angle for a single reflective surface to function as a scanning mirror may be 90°, and a scanning angle of a single reflective mirror may be 180°. It is assumed that a horizontal field of view is 130°, and a corresponding idle scanning angle is 50°. It is assumed that the scanning period is 18 ms. In this scenario, the first time period may be 5 ms, and the second time period may be 13 ms.

[00104] In some possible implementations, the second scanning unit 430 may alternatively be in another form, for example, a pentagonal prism, a hexagonal prism, or a rotating mirror in another form. The horizontal field of view and the scanning period of the second scanning unit may be set according to an actual requirement.

[00105] For example, the first scanning unit 420 may be configured to: rotate from a first angular position to a second angular position in the first time period, and keep the angular position unchanged in the second time period. The first angular position may be any angular position. The second angular position may be any angular position different from the first angular position.

[00106] In an embodiment, for the second scanning unit 430, in a same scanning period, the first time period may be before the second time period. Correspondingly, the first scanning unit 420 may first rotate from the first angular position to the second angular position in the first time period, and then remain at the second angular position in the second time period.

[00107] In another embodiment, for the second scanning unit 430, in a same scanning period, the first time period may be after the second time period. Correspondingly, the first scanning unit

420 may first keep the first angular position in the second time period, and then rotate from the first angular position to the second angular position in the second time period.

[00108] In another embodiment, time required by the first scanning unit 420 to rotate from the first angular position to the second angular position may occupy a part or all of the first time period. For example, the first scanning unit 420 may be controlled to rotate when the first time period starts, and the first scanning unit 420 may be controlled to stop rotating when the first time period ends. In this way, the first scanning unit 420 may rotate from one angular position to another angular position in the first time period. For another example, the first scanning unit 420 may be controlled to rotate after a period of time since the first time period starts, and the first scanning unit 420 may be controlled to stop rotating in advance before the first time period ends. In this manner, when control precision is not precise, difficulty of keeping the angular position of the first scanning unit 420 unchanged in the second time period can be reduced.

[00109] In this embodiment of this application, the angular position of the first scanning unit is adjusted in the idle scanning phase in the scanning period of the second scanning unit, and when scanning is performed in a range of the field of view in the scanning period of the second scanning unit, the angular position of the first scanning unit remains unchanged. In this manner, interference to a point cloud distribution in the process of adjusting the angular position of the first scanning unit can be avoided, impact of continuous rotation of the scanning mechanism on a scanning trajectory can be avoided, and speed measurement and ranging performance of the lidar system can be ensured when the scanning apparatus is used.

[00110] In some possible implementations, in a plurality of consecutive scanning periods of the second scanning unit, the angular position of the first scanning unit may be in a first angular interval. The first angular interval may include a plurality of angular positions. In the plurality of consecutive scanning periods, the first scanning unit may rotate from one of the plurality of angular positions to another angular position adjacent to the angular position. In other words, for any one of the plurality of scanning periods, the first angular position and the second angular position related to the scanning period may be two adjacent angular positions in the first angular interval.

[00111] For example, the first angular interval may correspond to a first field of view region in a vertical field of view region. An angular position in the first field of view region may be determined based on an included angle between adjacent angular positions in the first angular interval.

[00112] In some possible implementations, for any one of the plurality of consecutive scanning periods, the angular position in the first angular interval includes a third angular position adjacent to the first angular position, and/or a fourth angular position adjacent to the second angular position. An included angle between the first angular position and the third angular position may be equal

to an included angle between the first angular position and the second angular position, and/or an included angle between the second angular position and the fourth angular position may be equal to the included angle between the first angular position and the second angular position.

[00113] In an embodiment, an angular interval A includes an angular position #1 to an angular position #4. In a scanning period #1 of the second scanning unit 430, the first scanning unit 420 rotates from the angular position #1 to the angular position #2. In a scanning period #2 of the second scanning unit 430, the first scanning unit 420 rotates from the angular position #2 to the angular position #3. In a scanning period #3 of the second scanning unit 430, the first scanning unit 420 rotates from the angular position #3 to the angular position #4. The scanning period #1 to the scanning period #3 are consecutive, and the angular position #1 to the angular position #4 are sequentially adjacent to each other. For example, for the scanning period #1, the angular position #3 may be understood as the fourth angular position. For another example, for the scanning period #2, the angular position #1 may be understood as the third angular position, and the angular position #4 may be understood as the fourth angular position. For another example, angular positions in the angular interval A may be distributed at equal spacings. In other words, an included angle between the angular position #1 and the angular position #2, an included angle between the angular position #2 and the angular position #3, and an included angle between the angular position #3 and the angular position #4 are equal. In a field of view region corresponding to the angular interval A in the vertical field of view, an angular resolution in the vertical direction may be equal to the included angle.

[00114] In this embodiment of this application, angular positions in a same angular interval are distributed at equal spacings, so that a field of view region corresponding to the angular interval in the vertical field of view has a uniform angular resolution.

[00115] In some possible implementations, for a scanning period of the second scanning unit, the first angular position and the second angular position related to the scanning period may be located in different angular intervals. For example, the first angular position is in a second angular interval, and the second angular position is in a third angular interval. The second angular interval may further include a fifth angular position adjacent to the first angular position, and the third angular interval may further include a sixth angular position adjacent to the second angular position.

[00116] For example, the second angular interval may correspond to a second field of view region in the vertical field of view region, and a vertical angular resolution in the second field of view region may be determined based on an included angle between the first angular position and the fifth angular position. The third angular interval may correspond to a third field of view region in the vertical field of view region, and a vertical angular resolution in the third field of view region

may be determined based on an included angle between the second angular position and the sixth angular position.

[00117] In an embodiment, an angular interval B includes an angular position #5 and an angular position #6, and an angular interval C includes an angular position #7 and an angular position #8. In a scanning period #4 of the second scanning unit 430, the first scanning unit 420 rotates from the angular position #5 to the angular position #6. In a scanning period #5 of the second scanning unit 430, the first scanning unit 420 rotates from the angular position #6 to the angular position #7. In a scanning period #6 of the second scanning unit 430, the first scanning unit 420 rotates from the angular position #7 to the angular position #8. For example, for the scanning period #5, the angular position #5 may be understood as the fifth angular position, and the angular position #8 may be understood as the sixth angular position. For another example, in a field of view region corresponding to the angular interval B in the vertical field of view, an angular resolution in the vertical direction may be equal to an included angle between the angular position #5 and the angular position #6. For another example, the angular interval B may further include another angular position, and the angular positions in the angular interval B may be distributed at equal spacings, and an included angle between adjacent angular positions is equal to the included angle between the angular position #5 and the angular position #6. Similarly, in a field of view region corresponding to the angular interval C in the vertical field of view, an angular resolution in the vertical direction may be equal to an included angle between the angular position #7 and the angular position #8.

[00118] In this embodiment of this application, when a plurality of angular intervals are involved, angular positions in a same angular interval are distributed at equal spacings, and different angular position variations are used in different angular intervals, so that different field of view regions in the vertical field of view can have different angular resolutions, thereby facilitating setting and planning of different angular resolution regions in the vertical field of view region.

[00119] In some possible implementations, the system 400 may further include a receiving unit 440, and the receiving unit 440 may be configured to receive return light of the detection beam.

[00120] In some possible implementations, the system 400 may further include a waveguide apparatus 450, and the waveguide apparatus 450 may be configured to guide the return light to the receiving unit 440. For example, the return light of the detection beam may be converged on a receiving coupling surface of the waveguide apparatus 450, and the waveguide apparatus 450 may guide the return light converged on the receiving coupling surface to the detection apparatus, for detection of the return light.

[00121] For example, a waveguide light spot formed by processing, by the waveguide apparatus

450, the beam whose propagation direction is opposite to that of the return light has a non-uniform light field intensity distribution. For example, the waveguide light spot has a non-uniform light field intensity distribution in an axis direction of the second scanning unit 430. For another example, the light field intensity of the waveguide light spot is distributed with a right-side offset in the fast axis direction. For another example, the light field intensity of the waveguide light spot is distributed with a left-side offset in the fast axis direction. For another example, the light field intensity of the waveguide light spot is symmetrically distributed on left and right sides of the fast axis direction. For another example, the light field intensity of the waveguide light spot is asymmetrically distributed on left and right sides of the fast axis direction.

[00122] For example, the waveguide apparatus 450 may include: an optical device formed by a plurality of waveguides based on a beam combining process, a waveguide having a multi-fork structure, or a grating coupler.

[00123] In some possible implementations, the receiving unit 440 may include a plurality of beam receiving channels. A quantity of beam receiving channels included in the receiving unit 440 is the same as a quantity of beam transmitting channels included in the transmitting unit 410. The system 400 may include a plurality of waveguide apparatuses 450. For example, for a detection beam transmitted by one beam transmitting channel, one waveguide apparatus 450 may guide return light of the detection beam to a beam receiving channel corresponding to the beam transmitting channel.

[00124] It should be noted that the descriptions of the detection system in FIG. 6 are merely an example. A specific structure of the detection system is not limited in embodiments of this application. For example, in some possible implementations, the receiving unit 440 may be coupled to the transmitting unit 410. For another example, different from the manner shown in FIG. 6, in some possible implementations, the receiving unit 440 and the transmitting unit 410 may be disposed coaxially. For another example, in some possible implementations, passive optical elements such as a lens and a polarizer may be disposed between the transmitting unit 410 and/or the receiving unit 440 and the scanning unit.

[00125] For example, FIG. 7 is a schematic flowchart of a control method according to an embodiment of this application. The method 500 may be performed by a lidar system, or may be performed by an intelligent driving device in which the lidar system is disposed, or may be performed by a control apparatus corresponding to the lidar system, or may be performed by a chip or a processor in the control apparatus. The control apparatus corresponding to the lidar system may be coupled to the system, or may be independent of the system. The method 500 may include the following steps.

[00126] S510: Control a first scanning unit to rotate from a first angular position to a second

angular position in a first time period.

[00127] S520: Control the first scanning unit to keep the angular position unchanged in a second time period.

[00128] For example, a scanning period of the second scanning unit may include a first time period and a second time period. The first angular position may be any angular position, and the second angular position may be any angular position different from the first angular position.

[00129] In an embodiment, for a scanning period of the second scanning unit, when a first time period of the scanning period starts, an angular position of the first scanning unit may be understood as the first angular position; and when the first time period ends, an angular position of the first scanning unit may be understood as the second angular position.

[00130] In another embodiment, after the first time period starts, the first scanning unit may first remain the angular position of the first scanning unit at the first angular position for a period of time, and then rotate from the first angular position to the second angular position.

[00131] In another embodiment, the first scanning unit may rotate to the second angular position a period of time before the first time period ends, and then keep the angular position of the first scanning unit unchanged until the first time period ends.

[00132] In another embodiment, the angular position of the second scanning unit may be kept at a specific angular position in the second time period through negative feedback adjustment.

[00133] For example, in a same scanning period, when the first time period is before the second time period, step S510 may be first performed. In a same scanning period, when the first time period is before the second time period, step S520 may be first performed.

[00134] For example, for the first scanning unit, the second scanning unit, the first time period, the second time period, the first angular position, and the second angular position, refer to the related descriptions in the system 400.

[00135] With reference to FIG. 8 to FIG. 11, the following describes and explains the rotation manner of the first scanning unit 420 in the system 400 and the method 500.

[00136] For example, FIG. 8 is a diagram of a detection scenario according to an embodiment of this application. As shown in FIG. 8, a system 700 may include a transmitting unit 301, a scanning mirror 710, and a rotating mirror 720. The system 700 may be understood as an extension or variation of the system 400.

[00137] In some possible implementations, the scanning mirror 710 may use a same structure, appearance, and construction as the scanning mirror 310. A difference from the scanning mirror 310 is that a rotation process of the scanning mirror 710 is controlled according to the method 500, instead of implementing oscillation of the scanning mirror 710 through two consecutive rotation processes with opposite rotation directions. The scanning mirror 710 may be used as an example

of the first scanning unit 420.

[00138] In an embodiment, a function of the scanning mirror 710 can be implemented by controlling rotation of the scanning mirror 310 according to the method 500.

[00139] In some possible implementations, the rotating mirror 720 is a rotating mirror including a plurality of reflective surfaces, and an appearance of the rotating mirror 720 may be a pentagonal prism or approximately a pentagonal prism, as shown in FIG. 8. When the reflective surfaces 721 to 725 are located on a propagation path of a detection beam, the reflective surfaces 721 to 725 may correspond to the scanning mirror 320, and may implement an effect of the scanning mirror 320. The rotating mirror 720 may be used as an example of the second scanning unit 430.

[00140] In an embodiment, a rotating shaft 730 may be vertically disposed. When the rotating mirror 720 rotates around the rotating shaft 730, the beam from the scanning mirror 710 may be scanned in a horizontal direction. When the rotating shaft 311 is disposed horizontally, and the scanning mirror 710 rotates around the rotating shaft 311, a scanning process in a vertical direction may be implemented.

[00141] The reflective surface 721 is used as an example. It is assumed that the rotating mirror 720 rotates clockwise. From time at which the rotating mirror 720 is located at an angular position at which the reflective surface 721 starts to be on a propagation path of a detection beam to time at which the rotating mirror 720 is located at an angular position at which the reflective surface 725 starts to be located on the propagation path of the detection beam, the reflective surface 721 may be used as the scanning mirror 320. During the period in which the reflective surface 721 is used as the scanning mirror 320, an emergent beam formed on the reflective surface 721 by an incident beam from the scanning mirror 710 rotates with the rotation of the rotating mirror 720. During the period in which the reflective surface 721 is used as the scanning mirror 320, an angle at which the rotating mirror 720 rotates is 72°. Correspondingly, a scanning angle that can be implemented by the rotating mirror 720 in the horizontal direction is 144°.

[00142] In this scenario, because the scanning angle that can be implemented by the rotating mirror 720 in the horizontal direction is 144°, correspondingly, a horizontal field of view (horizontal field of view, HFOV) may be set to a maximum of 144°. A vertical field of view (vertical field of view, VFOV) is related to the rotatable angle of the scanning mirror 710. It is assumed that the horizontal field of view (for example, 120°) of the system 700 is less than the scanning angle. When the horizontal field of view is less than the scanning angle, a scanning period of the rotating mirror 720 may include a first time period and a second time period.

[00143] With reference to FIG. 9 and FIG. 10, the following briefly describes, by using the scenario shown in FIG. 8 as an example, a manner of adjusting the angular position of the first scanning unit.

[00144] For example, FIG. 9 is a diagram of a moving manner of the scanning mirror according to an embodiment of this application. As shown in FIG. 9, the scanning mirror 710 may move in a step manner. After stepping from one angular position to another angular position, the scanning mirror 710 stays at the another angular position for a period of time, and then steps to a next angular position.

[00145] As shown in FIG. 9, in one step period, the scanning mirror 710 may perform stepping a plurality of times (for example, 20 times). An angular position of the scanning mirror 710 may be gradually adjusted from an angular interval 1 to an angular interval 5 as the stepping progresses. For the angular interval 1 to the angular interval 5, one angular interval may include one or more angular positions. In a same angular interval, a same step angle may be used for a plurality of angular positions. Steps between different angular intervals may be adjusted according to an actual requirement. For example, the angular interval 1 may include one angular position. For another example, the angular interval 2 may include two angular positions. For another example, in the angular interval 3, stepping is implemented between five angular positions in the interval based on a step angle of 0.25°. For another example, in the angular interval 4, stepping is implemented between 10 angular positions in the interval based on a step angle of 0.1°. For another example, in the angular interval 5, stepping may be implemented between two angular positions in the interval based on a step angle of 0.5°. Different angular resolutions may be implemented at different positions in the vertical field of view region based on different step angles.

[00146] For example, it is assumed that the transmitting unit 701 corresponds to the transmitting unit 210 shown in FIG. 2, where the beam transmitting channels 211 to 214 are disposed. For example, the scanning mirror 710 starts to move from the angular interval 1. The scanning mirror 710 may rotate to an angular position 1-1 in the angular interval at a moment #1, and may remain at the angular position until a moment #2. Between the moment #1 and the moment #2, the system 700 may implement one scan of the effective field of view region in the horizontal direction under a scanning action of the first optical surface (for example, the reflective surface 721) of the rotating mirror 720. For example, the horizontal effective field of view region is 120°. For another example, after that, the rotating mirror 720 performs idle scanning from the moment #2 to a moment #4. Correspondingly, the scanning mirror 710 may rotate to the first angular position (namely, an angular position 2-1) in the angular interval 2 at the moment #4, or may rotate to the angular position 2-1 in advance (for example, at a moment #3) before the moment #4. For another example, the scanning mirror 710 may remain at the angular position 2-1 until a moment #5. Correspondingly, the system 700 may implement one scan in the effective field of view region in the horizontal direction under a scanning action of the second optical surface (for example, the reflective surface 725) of the rotating mirror 720. For another example, after that, the rotating

mirror 720 performs idle scanning from the moment #5 to a moment #7. Correspondingly, the scanning mirror 710 may rotate to the second angular position (namely, an angular position 2-2) in the angular interval 2 at the moment #7. For another example, the scanning mirror 710 may remain at the angular position 2-2 until a moment #8. Correspondingly, the system 700 may implement one scan in the effective field of view region in the horizontal direction under a scanning action of the third optical surface (for example, the reflective surface 724) of the rotating mirror 720. In the foregoing manner, the scanning mirror 710 may be stepped from the angular interval 1 to the angular interval 5. With reference to FIG. 10, the following describes a scanning trajectory generated by the system 700 when the scanning mirror 710 rotates in the foregoing manner.

[00147] For example, FIG. 10 is a diagram of the scanning trajectory according to an embodiment of this application.

[00148] As shown in FIG. 10, the rotating mirror 720 may separately complete one scan in the effective horizontal field of view within the moment #1 to the moment #2, the moment #4 to the moment #5, the moment #7 to the moment #8, and a moment #9 to a moment #10. The time periods may correspond to the second time period. The rotating mirror 720 may separately perform idle scanning from the moment #2 to the moment #4, from the moment #5 to the moment #7, and from the moment #8 to the moment #9.

[00149] In an embodiment, a scanning period #1 of the rotating mirror 720 may include the moment #1 to the moment #4. In other words, in the scanning period, the second time period is before the first time period.

[00150] In another embodiment, a scanning period #2 of the rotating mirror 720 may include the moment #2 to the moment #5. In other words, in the scanning period, the first time period is before the second time period.

[00151] In another embodiment, a scanning period #3 of the scanning mirror 720 may include the moment #3 to the moment #6. A time period between the moment #2 and the moment #3 is equal to a time period between the moment #5 and the moment #6. In other words, in the scanning period, the first time period may be a non-consecutive time period.

[00152] In another embodiment, a start point of a scanning period of the rotating mirror 720 may be the same as or different from a moment at which the reflective surface of the rotating mirror 720 enters the propagation path of the detection beam. The scanning period #2 is used as an example. For the scanning period #2, a start point is the moment #2, and an end point is the moment #5. For example, the reflective surface 721 of the rotating mirror 720 may be on the propagation path of the detection beam from the moment #1 to the moment #4, and the reflective surface 725 of the rotating mirror 720 may be on the propagation path of the detection beam from

the moment #4 to the moment #7. For another example, the reflective surface 721 of the rotating mirror 720 may be on the propagation path of the detection beam before the moment #2, and after that, the reflective surface 725 of the rotating mirror 720 may be on the propagation path of the detection beam from the moment #2 to the moment #5. For another example, the reflective surface 721 of the rotating mirror 720 may be on the propagation path of the detection beam before the moment #3, and after that, the reflective surface 725 of the rotating mirror 720 may be on the propagation path of the detection beam from the moment #3 to the moment #6.

[00153] For example, FIG. 11 is a diagram of a scanning trajectory in the field of view region according to an embodiment of this application. For example, in the field of view region, scanning trajectories corresponding to the scanning manners in FIG. 9 and FIG. 10 may be shown in FIG. 11.

[00154] As shown in FIG. 11, a field of view region 1 to a field of view region 5 may respectively correspond to the angular interval 1 to the angular interval 5. For example, compared with the field of view region 1 and the field of view region 5, the field of view regions 3 and 4 may be understood as ROI regions. Compared with the scanning trajectory in FIG. 5B, when an ROI region is involved, scanning trajectories do not overlap each other, there is no transition region between the ROI region and the non-ROI region, and the plurality of beam transmitting channels do not perform scanning on a same detection position a plurality of times. A uniform point cloud distribution can be obtained.

[00155] With reference to FIG. 12A to FIG. 15, the following describes and explains the waveguide apparatus 350 in the system 600.

[00156] For example, FIG. 12A to FIG. 12D are diagrams of waveguide mode spots according to an embodiment of this application. The waveguide mode spots in FIG. 12A to FIG. 12D may be an example of the waveguide mode spot of the waveguide apparatus 350. For example, as shown in FIG. 12A, in a first direction, the waveguide mode spot may be offset to the right side. A deeper color at a position on the waveguide mode spot may indicate that light field intensity at the position is stronger. The light field intensity may be gradient. For another example, as shown in FIG. 12B, the waveguide mode spot may be left-right asymmetric. For another example, as shown in FIG. 12C, the waveguide mode spot may be left-right symmetric. For another example, as shown in FIG. 12D, the waveguide mode spot may be offset to the left side.

[00157] In an embodiment, the first direction may correspond to an offset direction of a focal point of the return light on the receiving surface when a posture of the scanning mirror changes in FIG. 3B. For example, the first direction may be a direction of a rotation axis of the second scanning unit. For another example, the first direction may be a fast axis direction.

[00158] As described above, due to rotation of the scanning mirror, the focused spot formed by

the return light of the target on the receiving surface may have an offset, for example, as shown in FIG. 3B. The offset increases as the rotation speed of the scanning mirror increases. When the rotation speed of the scanning mirror remains unchanged, the offset increases as a distance between the target and the lidar increases.

[00159] For example, FIG. 13 is a diagram of focused spots formed on the receiving surface by targets at different positions. As shown in FIG. 13, as the distance between the target and the lidar increases, an offset of the focused light spot of the return light of the target on the receiving surface in the first direction increases. In addition, when a conventional waveguide is used on the receive side of the lidar system (for example, the system 100, 300, or 400), because a waveguide mode spot of the conventional waveguide apparatus has a uniform light field intensity distribution, only an echo of the target at a specific distance can reach the maximum coupling efficiency, and a transmit-receive angle delay may cause a decrease in a coupling efficiency of the echo of the target at another distance.

[00160] For example, when the waveguide apparatus 450 is used on the receive side of the lidar system (for example, the system 100, 300, or 400), received echo energy can be coupled to the waveguide apparatus 450 as much as possible by matching the waveguide mode spot of the waveguide apparatus 450 with the focused light spot of the return light on the receiving surface. Because the waveguide apparatus 450 has a non-uniform waveguide mode spot, different coupling efficiencies may be set for a light spot of converged return light at different positions of the waveguide mode spot of the waveguide apparatus 450.

[00161] In an embodiment, for a nearby target, return light of the target has high echo energy, and a low coupling efficiency may be set in a region in which a focused light spot of the return light is located. For a distant target, return light of the target has low echo energy, and a high coupling efficiency may be set in a region in which a focused light spot of the return light is located.

[00162] For example, FIG. 14 is a diagram of a change in received echo power according to an embodiment of this application. For example, for the lidar provided with the conventional waveguide and the lidar provided with the waveguide apparatus 450, changes in received echo power of the two lidars with respect to a distance to a target may be shown in FIG. 14.

[00163] In this embodiment of this application, echoes of targets from a near distance to a far distance are all received into the waveguide apparatus 450. Different coupling efficiencies are set for light spots of return light of the targets from the near distance to the far distance, so that a change in received echo power in a detection range is slower, thereby increasing a dynamic range of the system.

[00164] For example, FIG. 15 is a diagram of another detection scenario according to an embodiment of this application. The system 800 may be understood as an extension or variation

of the system 400.

[00165] In an embodiment, a transmitting unit and a receiving unit may be coupled to an apparatus 810. In the system 800, optical elements such as a lens, a polarization beam splitting apparatus, and a beam deflection apparatus may be disposed on propagation paths of a detection beam and return light. Some optical elements may also be coupled to the apparatus 810.

[00166] In another embodiment, when the transmitting unit uses a plurality of beam transmitting channels (for example, beam transmitting channels 211 to 214), correspondingly, the receiving unit may include a plurality of beam receiving channels, for example, beam receiving channels 251 to 254, as shown in FIG. 15. The beam receiving channels 251 to 254 may respectively correspond to the beam transmitting channels 211 to 214. For a single beam receiving channel, a corresponding waveguide apparatus 450 may be disposed to guide return light converged by the lens to the beam receiving channel.

[00167] In another embodiment, the apparatus 810 may be coupled to a laser light source, and a plurality of beam transmitting channels may be formed through optical splitting. In some possible implementations, the apparatus 810 may be coupled to a plurality of laser light sources.

[00168] For example, the apparatus 810 may be a silicon photonic chip. For example, the silicon photonic chip may use a silicon nitride waveguide platform, a silicon oxynitride waveguide platform, or a silicon-on-insulator (silicon-on-insulator, SOI) waveguide platform. For another example, the silicon photonic chip may use a multi-layer waveguide platform in which a plurality of types of waveguides are stacked. A material platform used by the silicon photonic chip is not limited in embodiments of this application.

[00169] For example, FIG. 16 is a diagram of another detection scenario according to an embodiment of this application. A system 900 may be understood as a variant or extension of the system 400, 700, or 800. An apparatus 910 may be understood as an extension or variant of the apparatus 810, and an apparatus 920 may have a same function as the apparatus 910.

[00170] As shown in FIG. 16, a control apparatus may control a laser driver to drive a laser light source to emit light. A plurality of beams corresponding to a plurality of beam transmitting channels may be obtained through a beam splitter based on a beam generated by the laser light source. After passing through a beam amplification apparatus, the beam may be propagated to a scanning mirror 710 through a lens and a polarization beam splitting apparatus, and then transmitted toward a target after passing through a rotating mirror 720. Return light generated at the target is transmitted to the polarization beam splitting apparatus after passing through the rotating mirror 720 and the scanning mirror 710. After being split by the polarization beam splitting apparatus, the light is propagated to a coupler, and then may be propagated to a detector after passing through a mixer. A plurality of trans-impedance amplifiers (trans-impedance amplifier,

TIA) may be disposed between the control apparatus and the detector.

[00171] In the system 900, the scanning mirror 710 may be controlled to rotate in the manner shown in FIG. 7 to FIG. 11. The coupler may correspond to the waveguide apparatus 450.

[00172] For example, FIG. 17 is a diagram of another detection scenario according to an embodiment of this application. A system 1000 may be understood as a variant or extension of the system 400, 700, 800, or 900. An apparatus 1010 may be understood as a variant or extension of the apparatus 910. An optical element 1020 may include a lens, an aperture, a polarizer, a beam collimation apparatus, and the like. A scanning apparatus 1030 may include a first scanning unit 420 and a second scanning unit 430.

[00173] In an embodiment, the apparatus 1010 may be a silicon photonic chip.

[00174] In the system 1000, a control and data processing apparatus may control a laser driver to drive a light source to emit light. A detection beam generated by the laser light source passes through a beam splitter and an optical amplifier, and may be emitted from the apparatus 1010 through a transmit-side coupler. The light may be propagated to a target through the optical element 1020 and the scanning apparatus 1030. For example, the laser light source may be a frequency modulated continuous wave (frequency modulated continuous wave, FMCW) laser light source.

[00175] In the system 1000, return light of the detection beam may be propagated to a photodiode (photodiode, PD) array after passing through a receive-side coupler and a mixer, and then the PD array detects a return optical signal. For example, the receive-side coupler may correspond to the waveguide apparatus 450.

[00176] In the system 1000, local oscillator light of the detection beam may be obtained through an asymmetric Mach-Zehnder interferometer (asymmetric Mach-Zehnder interferometer, AMZI) and a local oscillator light splitter. In addition, an analog-to-digital conversion operation in a control and data processing process may be performed by an analog-to-digital converter (analog-to-digital converter, ADC).

[00177] In some possible implementations, the control and data processing apparatus may control, according to the method 500, a scanning mirror in the scanning apparatus 1030 to move.

[00178] In some possible implementations, the system 1000 may further include a TIA amplification circuit, an ADC sampling circuit, a laser driver circuit, a control and data processing circuit, and the like.

[00179] The foregoing describes in detail the method provided in embodiments of this application with reference to FIG. 7 to FIG. 11. The following describes in detail apparatuses provided in embodiments of this application with reference to FIG. 18 and FIG. 19. Descriptions of apparatus embodiments correspond to the descriptions of the method embodiments. Therefore, for content that is not described in detail, refer to the foregoing method embodiments.

[00180] For example, FIG. 18 is a block diagram of a control apparatus (referred to as an apparatus 2000) according to an embodiment of this application. The apparatus may include a control unit 2010.

[00181] The apparatus 2000 may include units for performing any one of the methods in FIG. 7 to FIG. 11, and the units in the apparatus 2000 may be configured to perform corresponding procedures in any one of the method embodiments in FIG. 7 to FIG. 11.

[00182] When the apparatus 2000 is configured to perform the method 500 in FIG. 7, the control unit 2010 may be configured to perform steps S510 and S520 in the method 500.

[00183] Specifically, the control unit 2010 may be configured to: control a first scanning unit to rotate from a first angular position to a second angular position in a first time period; and control the first scanning unit to keep the angular position unchanged in a second time period.

[00184] For example, the control apparatus may be a lidar, or may be a chip or a processor in the lidar, or may be a terminal (for example, a computing platform) that is in an intelligent driving device and that is configured to perform signal processing or control on the radar, or may be a chip or a processor in the terminal, or may be a chip or a processor in a control apparatus corresponding to the lidar.

[00185] In some possible implementations, the apparatus 2000 may further include an obtaining unit 2020. The obtaining unit 2020 may be configured to obtain a scanning period of a second scanning unit, and may be configured to determine the first time period and the second time period.

[00186] It should be understood that division into the units in the foregoing apparatus is merely logical function division. During actual implementation, all or some of the units may be integrated into one physical entity, or may be physically separated. All the units of the apparatus may be implemented in a form of software invoked by a processor, or may be implemented in a form of a hardware circuit. Alternatively, some of the units are implemented in a form of software invoked by a processor, and the remaining units are implemented in a form of a hardware circuit.

[00187] In a specific implementation process, the control unit 2010 may be implemented by at least one processor or a processor-related circuit, and the obtaining unit 2020 may be implemented by at least one transceiver or a transceiver-related circuit. In an example, the one or more processors may control the first scanning unit to rotate from the first angular position to the second angular position in the first time period. In an example, the one or more processors may control the first scanning unit to keep the angular position unchanged in the second time period. For example, in a specific implementation process, the apparatus 2000 may be an intelligent driving device in which a lidar is disposed, or a chip or a processor disposed in the intelligent driving device.

[00188] For example, FIG. 18 is a block diagram of another control apparatus 3000 (referred to

as an apparatus 3000 below) according to an embodiment of this application. The apparatus 3000 may include a processor 3010, an interface circuit 3020, and a memory 3030. The processor 3010, the interface circuit 3020, and the memory 3030 are connected through an internal connection path. The memory 3030 is configured to store instructions. The processor 3010 is configured to execute the instructions stored in the memory 3030, to receive/send some parameters through the interface circuit 3020. Optionally, the memory 3030 may be coupled to the processor 3010 through an interface, or may be integrated with the processor 3010.

[00189] It should be noted that the interface circuit 3020 may include but is not limited to a transceiver apparatus like an input/output interface (input/output interface), to implement communication between the apparatus 3000 and another device or a communication network. For example, communication with a radar and/or an internal circuit of an intelligent driving device may be implemented through the interface circuit 3020.

[00190] In embodiments of this application, the processor is a circuit having a signal processing capability. In an implementation, the processor may be a circuit having an instruction reading and running capability, for example, a central processing unit (central processing unit, CPU), a microprocessor, a graphics processing unit (graphics processing unit, GPU) (which may be understood as a microprocessor), or a digital signal processor (digital signal processor, DSP). In another implementation, the processor may implement a specific function based on a logical relationship of a hardware circuit. The logical relationship of the hardware circuit is fixed or reconfigurable. For example, the processor is a hardware circuit implemented by an application-specific integrated circuit (application-specific integrated circuit, ASIC) or a programmable logic device (programmable logic device, PLD), for example, a field programmable gate array (field programmable gate array, FPGA). In a reconfigurable hardware circuit, a process in which the processor loads a configuration document to implement a hardware circuit configuration may be understood as a process in which the processor loads instructions to implement functions of some or all of the units. In addition, the processor may alternatively be a hardware circuit designed for artificial intelligence, and may be understood as an ASIC, for example, a neural network processing unit (neural network processing unit, NPU), a tensor processing unit (tensor processing unit, TPU), or a deep learning processing unit (deep learning processing unit, DPU).

[00191] An embodiment of this application further provides a computer program product. The computer program product includes computer program code. When the computer program code is run on a computer, the computer is enabled to perform any one of the method embodiments in FIG. 7 to FIG. 11 and possible implementations of the method embodiments.

[00192] An embodiment of this application further provides a computer-readable storage medium. The computer-readable storage medium stores program code or instructions. When the

computer program code or the instructions are executed by a processor of a computer, the processor is enabled to implement any one of the method embodiments in FIG. 7 to FIG. 11 and possible implementations of the method embodiments.

[00193] An embodiment of this application further provides a chip, including a circuit, configured to perform any one of the method embodiments in FIG. 7 to FIG. 11 and possible implementations of the method embodiments.

[00194] An embodiment of this application further provides a lidar system. The lidar system includes a transmitting unit 410, a receiving unit 440, a waveguide apparatus 450, a third scanning unit, and a fourth scanning unit. The third scanning unit and the fourth scanning unit may be disposed on a propagation path of a detection beam. The third scanning unit may be configured to oscillate around a first axis to perform slow-axis scanning on the detection beam. The fourth scanning unit may be configured to continuously rotate around a second axis to perform fast-axis scanning on the detection beam.

[00195] In an embodiment, the third scanning unit and the fourth scanning unit may respectively include a first scanning unit 420 and a second scanning unit 430.

[00196] In another embodiment, a scanning mirror 310 and a scanning mirror 320 may be respectively used as examples of the third scanning unit and the fourth scanning unit.

[00197] An embodiment of this application further provides an intelligent driving device. The intelligent driving device may include the foregoing lidar system, or include any one of the lidar systems 400 to 1000, or may include the foregoing apparatus 2000 or 3000.

[00198] For example, the intelligent driving device may be a vehicle. The vehicle in embodiments of this application is a vehicle in a broad sense, and may be a transportation means (for example, a commercial vehicle, a passenger vehicle, a motorcycle, a flight vehicle, or a train), an industrial vehicle (for example, a forklift truck, a trailer, or a tractor), an engineering vehicle (for example, an excavator, a bulldozer, or a crane), an agricultural device (for example, a lawn mower or a harvester), a recreation device, a toy vehicle, and the like. A type of the vehicle is not specifically limited in embodiments of this application. For example, the vehicle in this application may include a pure electric vehicle (pure electric vehicle/battery electric vehicle, pure EV/battery EV), a hybrid electric vehicle (hybrid electric vehicle, HEV), a range extended electric vehicle (range extended electric vehicle, REEV), a plug-in hybrid electric vehicle (plug-in hybrid electric vehicle, PHEV), a new energy vehicle (new energy vehicle, NEV), or the like.

[00199] A person of ordinary skill in the art may be aware that, in combination with the examples described in embodiments disclosed in this specification, units and algorithm steps may be implemented by electronic hardware or a combination of computer software and electronic hardware. Whether the functions are performed by hardware or software depends on particular

applications and design constraint conditions of the technical solutions. A person skilled in the art may use different methods to implement the described functions for each particular application, but it should not be considered that the implementation goes beyond the scope of this application.

[00200] It may be clearly understood by a person skilled in the art that, for convenient and brief description, for a detailed working process of the foregoing system, apparatus, and unit, refer to a corresponding process in the method embodiments. Details are not described herein again.

[00201] In the several embodiments provided in this application, it should be understood that the disclosed system, apparatus, and method may be implemented in other manners. For example, the described apparatus embodiments are merely examples. For example, division into the units is merely logical function division. There may be another division manner during actual implementation. For example, a plurality of units or components may be combined or integrated into another system, or some features may be ignored or not performed. In addition, the displayed or discussed mutual couplings or direct couplings or communication connections may be implemented through some interfaces. The indirect couplings or communication connections between the apparatuses or units may be implemented in an electrical form, a mechanical form, or another form.

[00202] The units described as separate parts may or may not be physically separate, and parts displayed as units may or may not be physical units, and may be located at one position, or may be distributed on a plurality of network units. Some or all of the units may be selected based on actual requirements to achieve the objectives of the solutions of embodiments.

[00203] In addition, functional units in embodiments of this application may be integrated into one processing unit, each of the units may exist alone physically, or two or more units are integrated into one unit.

[00204] When the functions are implemented in the form of a software functional unit and sold or used as an independent product, the functions may be stored in a computer-readable storage medium. Based on such an understanding, the technical solutions of this application essentially, or the part contributing to the conventional technology, or some of the technical solutions may be implemented in a form of a software product. The computer software product is stored in a storage medium, and includes several instructions for instructing a computer device (which may be a personal computer, a server, a network device, or the like) to perform all or some of the steps of the methods described in embodiments of this application. The storage medium includes any medium that can store program code, such as a USB flash drive, a removable hard disk, a read-only memory (Read-Only Memory, ROM), a random access memory (Random Access Memory, RAM), a magnetic disk, or an optical disc.

[00205] The foregoing descriptions are merely specific implementations of this application, but

are not intended to limit the protection scope of this application. Any variation or replacement readily figured out by a person skilled in the art within the technical scope disclosed in this application shall fall within the protection scope of this application. Therefore, the protection scope of this application shall be subject to the protection scope of the claims.

CLAIMS

1. A lidar system, comprising a transmitting unit, a first scanning unit, and a second scanning unit, wherein

the transmitting unit is configured to transmit a detection beam, wherein the first scanning unit and the second scanning unit are disposed on a propagation path of the detection beam;

the first scanning unit is configured to oscillate around a first axis to perform slow-axis scanning on the detection beam;

the second scanning unit is configured to continuously rotate around a second axis in a clockwise direction or a counter-clockwise direction to perform fast-axis scanning on the detection beam;

a scanning period of the second scanning unit comprises a first time period and a second time period, the second scanning unit performs idle scanning in the first time period, and the second scanning unit completes scanning the detection beam in object space for one fast-axis period in the second time period; and

the first scanning unit is configured to: rotate from a first angular position to a second angular position in the first time period, and keep the angular position unchanged in the second time period.

2. The system according to claim 1, wherein

in a plurality of consecutive scanning periods of the second scanning unit, the angular position of the first scanning unit is in a first angular interval, the first angular interval comprises a plurality of angular positions, and the first angular position and the second angular position are two adjacent angular positions in the plurality of angular positions; and

the first angular interval corresponds to a first field of view region in a vertical field of view of the system, and a vertical angular resolution in the first field of view region is determined based on an included angle between the first angular position and the second angular position.

3. The system according to claim 2, wherein

the plurality of angular positions further comprise a third angular position adjacent to the first angular position, and an included angle between the first angular position and the third angular position is equal to the included angle between the first angular position and the second angular position; and/or

the plurality of angular positions further comprise a fourth angular position adjacent to the second angular position, and an included angle between the second angular position and the fourth angular position is equal to the included angle between the first angular position and the second angular position.

4. The system according to claim 1, wherein

the first angular position is in a second angular interval, and the second angular position is in a third angular interval;

the second angular interval further comprises a fifth angular position adjacent to the first angular position, and the third angular interval further comprises a sixth angular position adjacent to the second angular position;

the second angular interval corresponds to a second field of view region in a vertical field of view of the system, the third angular interval corresponds to a third field of view region in the vertical field of view of the system, and the second field of view region is adjacent to the third field of view region; and

a vertical angular resolution in the second field of view region is determined based on an included angle between the first angular position and the fifth angular position, and a vertical angular resolution in the third field of view region is determined based on an included angle between the second angular position and the sixth angular position.

5. The system according to any one of claims 1 to 4, wherein the system further comprises a receiving unit and a waveguide apparatus, wherein

the receiving unit is configured to receive return light of the detection beam; and

the waveguide apparatus is configured to guide the return light to the receiving unit, wherein a waveguide light spot formed by processing the return light by the waveguide apparatus has a non-uniform light field intensity distribution.

6. The system according to claim 5, wherein the waveguide light spot has a non-uniform light field intensity distribution in a direction of the second axis.

7. The system according to claim 5 or 6, wherein that the waveguide light spot has the non-uniform light field intensity distribution comprises:

light field intensity of the waveguide light spot is distributed with a right-side offset in the fast axis direction, distributed with a left-side offset in the fast axis direction, symmetrically distributed on left and right sides of the fast axis direction, or asymmetrically distributed on left and right sides of the fast axis direction.

8. The system according to any one of claims 5 to 7, wherein the waveguide apparatus comprises at least one of the following:

an optical device formed by a plurality of waveguides based on a beam combining process, a waveguide having a multi-fork structure, or a grating coupler.

9. The system according to any one of claims 1 to 8, wherein the transmitting unit comprises a plurality of beam transmitting channels, the plurality of beam transmitting channels are disposed in an array with equal spacings, and each of the plurality of beam transmitting channels is configured to transmit one detection beam.

10. The system according to any one of claims 1 to 9, wherein that the second scanning unit completes scanning the detection beam in the object space for one fast scanning period comprises: the second scanning unit completes one scan of the detection beam in a horizontal field of view of the system.

11. A control method, wherein the control method is applied to a lidar system, and the lidar system comprises a first scanning unit and a second scanning unit;

the first scanning unit and the second scanning unit are disposed on a transmission path of a detection beam;

the first scanning unit is configured to oscillate around a first axis to perform slow-axis scanning on the detection beam;

the second scanning unit is configured to continuously rotate around a second axis in a clockwise direction or a counter-clockwise direction to perform fast-axis scanning on the detection beam, wherein a scanning period of the second scanning unit comprises a first time period and a second time period, the second scanning unit performs idle scanning in the first time period, and the second scanning unit completes scanning the detection beam in object space for one fast-axis period in the second time period; and

the method comprises:

controlling the first scanning unit to rotate from a first angular position to a second angular position in the first time period; and

controlling the first scanning unit to keep the angular position unchanged in the second time period.

12. The method according to claim 11, wherein

in a plurality of consecutive scanning periods of the second scanning unit, the angular position of the first scanning unit is in a first angular interval, the first angular interval comprises a plurality of angular positions, and the first angular position and the second angular position are two adjacent angular positions in the plurality of angular positions; and

a first field of view region in a vertical field of view of the lidar system in which the first scanning unit and the second scanning unit are disposed corresponds to the first angular interval, and a vertical angular resolution in the first field of view region is determined based on an included angle between the first angular position and the second angular position.

13. The method according to claim 11 or 12, wherein

the plurality of angular positions further comprise a third angular position adjacent to the first angular position, and an included angle between the first angular position and the third angular position is equal to the included angle between the first angular position and the second angular position; and/or

the plurality of angular positions further comprise a fourth angular position adjacent to the second angular position, and an included angle between the second angular position and the fourth angular position is equal to the included angle between the first angular position and the second angular position.

14. The method according to claim 11, wherein

the first angular position is in a second angular interval, and the second angular position is in a third angular interval;

the second angular interval further comprises a fifth angular position adjacent to the first angular position, and the third angular interval further comprises a sixth angular position adjacent to the second angular position;

the second angular interval corresponds to a second field of view region in a vertical field of view of the system, the third angular interval corresponds to a third field of view region in the vertical field of view of the system, and the second field of view region is adjacent to the third field of view region; and

a vertical angular resolution in the second field of view region is determined based on an included angle between the first angular position and the fifth angular position, and a vertical angular resolution in the third field of view region is determined based on an included angle between the second angular position and the sixth angular position.

15. The method according to any one of claims 11 to 14, wherein the lidar system further comprises a transmitting unit, the transmitting unit comprises a plurality of beam transmitting channels, the plurality of beam transmitting channels are disposed in an array with equal spacings, and each of the plurality of beam transmitting channels is configured to transmit one detection beam.

16. The method according to any one of claims 11 to 15, wherein that the second scanning unit completes scanning the detection beam in the object space for one fast scanning period comprises: the second scanning unit completes one scan of the detection beam in a horizontal field of view of the lidar system in which the first scanning unit and the second scanning unit are disposed.

17. A waveguide apparatus, configured to guide return light of a detection beam to a receiving unit, wherein a waveguide light spot formed by processing the return light by the waveguide apparatus has a non-uniform light field intensity distribution.

18. The waveguide apparatus according to claim 17, wherein the optical element comprises at least one of the following:

an optical device formed by a plurality of waveguides based on a beam combining process, a waveguide having a multi-fork structure, or a grating coupler.

19. A lidar system, comprising a transmitting unit, a third scanning unit, a fourth scanning unit, a receiving unit, and the waveguide apparatus according to claim 17 or 18, wherein

the transmitting unit is configured to transmit a detection beam, and the third scanning unit and the fourth scanning unit are disposed on a transmission path of the detection beam;

the third scanning unit is configured to oscillate around a first axis to perform slow-axis scanning on the detection beam;

the fourth scanning unit is configured to continuously rotate around a second axis in a clockwise direction or a counter-clockwise direction to perform fast-axis scanning on the detection beam;

the receiving unit is configured to receive return light of the detection beam; and

the waveguide apparatus is configured to guide the return light to the receiving unit.

20. The system according to claim 19, wherein the waveguide light spot has a non-uniform light field intensity distribution in a direction of the second axis.

21. The system according to claim 19 or 20, wherein that the waveguide light spot has the non-uniform light field intensity distribution comprises:

light field intensity of the waveguide light spot is distributed with a right-side offset in the fast axis direction, distributed with a left-side offset in the fast axis direction, symmetrically distributed on left and right sides of the fast axis direction, or asymmetrically distributed on left and right sides of the fast axis direction.

22. The system according to any one of claims 19 to 21, wherein the transmitting unit comprises a plurality of beam transmitting channels, the plurality of beam transmitting channels are disposed in an array with equal spacings, and each of the plurality of beam transmitting channels is configured to transmit one detection beam.

23. A control apparatus, comprising:

a memory, configured to store a computer program; and

a processor, configured to execute the computer program stored in the memory, so that the apparatus performs the method according to any one of claims 11 to 16.

24. A computer program product, wherein the computer program product comprises computer program code, and when the computer program code is run on a computer, the method according to any one of claims 11 to 16 is performed.

25. A computer-readable storage medium, wherein the computer-readable storage medium stores a computer program, and when the computer program is executed by a computer, the method according to any one of claims 11 to 16 is implemented.

26. A chip, comprising a circuit and a communication interface, wherein the communication interface is configured to: receive information from another apparatus and input the information

to the circuit, and/or the communication interface is configured to send information in the circuit to another apparatus, and the circuit is configured to perform the method according to any one of claims 11 to 16.

27. A vehicle, comprising the lidar system according to any one of claims 1 to 10, or comprising the lidar system according to any one of claims 19 to 22, or comprising the control apparatus according to claim 23.