METHOD AND APPARATUS FOR DETERMINING ROTATION CENTER POINT IN OPTICAL FIBER MOVING PROCESS, DEVICE AND MEDIUM

TECHNICAL FIELD

[0001] The present application relates to the field of optical fibers, and particularly relates to a method and an apparatus for determining a rotation center point in an optical fiber moving process, a device and a medium.

BACKGROUND

[0002] In high-precision optical systems, precise control of the position of an optical fiber tip is critical, however, due to factors such as small deviation between the optical fiber tip and a target position, mechanical vibrations, and temperature changes, it is an extreme challenge to achieve high-precision alignment at a sub-micron level; and especially in applications that a wafer is only a few tens of microns below an optical fiber, even slight movements may cause collisions due to unexpected changes in the position of the optical fiber tip when adjusting the optical fiber angle. Traditional optical fiber alignment methods depend heavily on manual adjustments or simple automated devices, which may easily lead to misalignment or collision due to the inability to precisely control a rotation center point (a point without changing the position while rotating in a three-dimensional space) of an optical fiber. Not only does this affect the alignment accuracy, but it may also lead to device damage and inefficiency.

[0003] Therefore, it is urgently to solve the technical problem that existing optical fiber alignment methods cannot accurately control the rotation center point of the optical fiber, which is easy to lead to dislocation or collision.

SUMMARY OF THE INVENTION

Technical Problems

[0004] A main objective of the present application is to provide a method and an apparatus for determining a rotation center point in an optical fiber moving process, a device and a medium to solve the technical problem that existing optical fiber alignment methods cannot accurately control the rotation center point of an optical fiber, which is easy to lead to dislocation or collision.

Solutions to Problems

Technical Solutions

[0005] In order to achieve the above object, the first aspect of the present application provides a method for determining a rotation center point in an optical fiber moving process, the method comprises:

[0006] estimating the position of a rotation center point corresponding to an optical fiber tip based on an initial position of the optical fiber tip;

[0007] taking a first coordinate axis in a three-dimensional local coordinate system as a selected axis to perform rotation operation, wherein the rotation operation includes: controlling the optical fiber tip to rotate by a preset angle along the current selected axis;

[0008] acquiring the current position of the optical fiber tip, and performing translation operation on the optical fiber tip by taking the initial position as a target, wherein, the translation operation comprises: adjusting the moving positions of the optical fiber tip within two coordinate axes perpendicular to the current selected axis in a local coordinate system;

[0009] updating the position of the rotation center point based on the position of the optical fiber tip after translation, and obtaining an updated difference value of the corresponding position of the rotation center point under the current selected axis;

[0010] circulating the rotation operation and translation operation under the current selected axis, when the updated difference value of the corresponding position of the rotation center point under the current selected axis is less than a preset threshold, completing the rotation operation and translation operation under the current selected axis, switching a second coordinate axis in the local coordinate system as the selected axis, and continuing the rotation operation and translation operation; and

[0011] when the updated difference value of the corresponding position of the rotation center point under the current selected axes is also less than the preset threshold, obtaining the rotation center point of an optical fiber.

[0012] Further, before the step of taking a first coordinate axis in a three-dimensional local coordinate system as a selected axis to perform rotation operation, the method comprises:

[0013] identifying the rules of transformation from a global coordinate system to the local coordinate system according to the probe installation orientation;

[0014] identifying a first positioning instruction, and activating a selected probe for estimation of the rotation center point;

[0015] controlling probes other than the selected probe to move out of a camera picture;

[0016] selecting a target based on the current camera picture, and transforming the position of the selected target in the global coordinate system into the position in the local

coordinate system based on the rules of transformation; and

[0017] controlling the optical fiber tip to move according to the transformed local coordinates of the target to obtain the initial position of the optical fiber tip.

[0018] Further, after the step of when the updated difference value of the corresponding position of the rotation center point under the current selected axes is also less than the preset threshold, obtaining the rotation center point of an optical fiber, the method comprises:

[0019] switching a third coordinate axis in the local coordinate system as the selected axis, and continuing the rotation operation and translation operation.

[0020] Further, the step of taking a first coordinate axis in a three-dimensional local coordinate system as a selected axis to perform rotation operation comprises:

[0021] identifying the selected axis currently rotating locally in the first rotation instruction, and a preset rotation angle; and

[0022] based on the initial position of the optical fiber tip, controlling the optical fiber tip to rotate by a preset angle along the selected axis by adjusting the posture of the probe.

[0023] Further, the step of acquiring the current position of the optical fiber tip, and performing translation operation on the optical fiber tip by taking the initial position as a target comprises:

[0024] calculating compensation parameters of the optical fiber tip on the corresponding coordinate axis according to two coordinate axes perpendicular to the current selected axis; and

[0025] according to the compensation parameters, controlling the optical fiber tip to move in a linear degree of freedom of the corresponding coordinate axis by the probe, and monitoring the position of the optical fiber tip in real time by an overlooking camera and a side-looking camera, and verifying the position of the optical fiber tip by an image processing algorithm.

[0026] Further, the step of updating the position of the rotation center point based on the position of the optical fiber tip after translation, and obtaining an updated difference value of the corresponding position of the rotation center point under the current selected axis comprises:

[0027] calculating a new position of the rotation center point based on the position of the optical fiber tip after movement; and

[0028] comparing the difference between the newly calculated position of the rotation center point and the previous position of the rotation center point to obtain the updated difference value of the position of the rotation center point.

[0029] Further, the step of circulating the rotation operation and translation operation under the current selected axis, when the updated difference value of the corresponding position of the rotation center point under the current selected axis is less than a preset threshold,

completing the rotation operation and translation operation under the current selected axis, switching a second coordinate axis in the local coordinate system as the selected axis, and continuing the rotation operation and translation operation comprises:

[0030] identifying whether the updated difference value of the position of the rotation center point under the current selected axis meets the preset threshold;

[0031] if the preset threshold is not met, continuing to control the optical fiber tip to perform rotation operation and translation operation based on the current selected axis until the preset threshold is met; and

[0032] if the preset threshold is met, identifying the second coordinate axis in the local coordinate system other than the first coordinate axis selected by the user, updating the selected axis based on the second coordinate axis, and continuing to control the optical fiber tip to perform rotation operation and translation operation based on the current selected axis until the updated difference value of the position of the rotation center point under the current selected axis also meets the preset threshold.

[0033] Further, the step of when the updated difference value of the corresponding position of the rotation center point under the current selected axes is also less than the preset threshold, obtaining the rotation center point of an optical fiber includes:

[0034] identifying whether the updated difference value of the position of the rotation center point under all the selected axes is less than the preset threshold; and

[0035] if the updated difference value is less than the preset threshold, acquiring the current position of the optical fiber tip, namely obtaining the rotation center point of the optical fiber.

[0036] The second aspect of the present application provides an apparatus for determining a center rotation point in an optical fiber moving process, comprising:

[0037] a primary estimation module configured to estimate the position of a rotation center point corresponding to an optical fiber tip based on an initial position of the optical fiber tip;

[0038] a rotating module configured to take a first coordinate axis in a three-dimensional local coordinate system as a selected axis to perform rotation operation, wherein the rotation operation comprises: controlling the optical fiber tip to rotate by a preset angle along the current selected axis;

[0039] a translation module configured to acquire the current position of the optical fiber tip, and perform translation operation on the optical fiber tip by taking the initial position as a target, wherein the translation operation comprises: adjusting the moving positions of the optical fiber tip within two coordinate axes perpendicular to the current selected axis in a local

coordinate system;

[0040] a calculation module configured to update the position of the rotation center point based on the position of the optical fiber tip after translation, and obtain an updated difference value of the corresponding position of the rotation center point under the current selected axis;

[0041] a switching module configured to circulate the rotation operation and translation operation under the current selected axis, when the updated difference value of the corresponding position of the rotation center point under the current selected axis is less than a preset threshold, complete the rotation operation and translation operation under the current selected axis, switch a second coordinate axis in the local coordinate system as the selected axis, and continue the rotation operation and translation operation; and

[0042] a point acquisition module configured to when the updated difference value of the corresponding position of the rotation center point under the current selected axes is also less than the preset threshold, obtain the rotation center point of an optical fiber.

[0043] The third aspect of the present application further provides a computer device, comprising a storage and a processor, wherein the storage is used for storing a computer program, and the processor is used for executing the computer program to implement the steps of the method according to any one of the abovementioned.

[0044] The fourth aspect of the present application further provides a computer-readable storage medium thereon a computer program is stored, wherein the computer program is executed by a processor to implement the steps of the method according to any one of the abovementioned.

Beneficial Effects of the Invention

Beneficial Effects

[0045] According to the present application, accurate control and iterative optimization can realize high-precision alignment at a sub-micron level, thus obviously improving the precision and stability in optical fiber alignment. The problem of error accumulation possibly in a traditional method is avoided, a rotation center point is fixed to avoid collision with a wafer or other parts, and thus expensive optical devices are protected from potential damage. The whole process is highly automatic, so the requirement for manual intervention is reduced, the production efficiency and consistency are improved, moreover, it is supported to adjust a plurality of selected axes (such as Rx, Ry or Rz), and adapted to dynamic factor influence in a complex environment. In conclusion, according to the present application, it not only solves common problems of dislocation and collision in related technology, but also remarkably improves the production efficiency and the reliability of the system, and it is suitable for a high-

precision optical system needing precision alignment at a sub-micron level, and has wide application prospects and important technical value in the fields of optical fiber communication, micro-nano manufacturing and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

[0046] FIG. 1 is a schematic flowchart of a method for determining a center rotation point in an optical fiber moving process according to an embodiment of the present application;

[0047] FIG. 2 is a structural schematic block diagram of an apparatus for determining a center rotation point in an optical fiber moving process according to an embodiment of the present application; and

[0048] FIG. 3 is a structural schematic block diagram of a computer device according to an embodiment of the present application.

[0049] The implementation of the objective, the functional characteristics and the advantages of the present application will be further described with reference to the accompanying drawings in conjunction with embodiments.

DETAILED DESCRIPTION

[0050] In order to make the objective, technical solution and advantages of the present application more clear, the present application is further described in detail below in conjunction with the accompanying drawings and embodiments. It is to be understood that the specific embodiments described herein are only used for interpreting the present application and are not intended to qualify the present application.

[0051] Those skilled in the art may understand that, unless specifically stated, the singular forms "a/an", "one", "above" and "the" used here may also include the plural. It is to be further understood that the wording "including" used in the description of the present invention refers to the existence of features, integers, steps, operations, elements, modules and/or components, but does not preclude the existence or addition of one or more other features, integers, steps, operations, elements, modules, components and/or groups thereof. It is to be understood that when an element is "connected" or "coupled" to another element, it can be connected or coupled directly to other elements, or there can also be intermediate elements. In addition, the term "connection" or "coupling" used here can include either wireless connection or wireless coupling. The wording "and/or" as used here includes all or any of the modules and all combinations of one or more associated listed items.

[0052] Those skilled in the technical field may understand that, unless otherwise defined,

all terms used herein (including technical terms and scientific terms) have the same meanings as those generally understood by those of ordinary skill in the field of the present invention. It is also to be understood that terms, such as those defined in the General Dictionary, should be understood to have meanings consistent with those in the context of prior art and not to be interpreted in an idealized or overly formal meaning unless specifically defined, as is the case here.

[0053] With reference to FIG. 1, an embodiment of the present invention provides a method for determining a rotation center point in an optical fiber moving process. The method includes steps of S1-S6, specifically:

[0054] S1, estimating the position of a rotation center point corresponding to an optical fiber tip based on an initial position of the optical fiber tip;

[0055] S2, performing rotation operation based on a selected axis in a local coordinate system, in which, the rotation operation includes: controlling the optical fiber tip to rotate by a preset angle along the current selected axis;

[0056] S3, acquiring the current position of the optical fiber tip, and performing translation operation on the optical fiber tip by taking the initial position as a target, in which, the translation operation includes: adjusting the moving positions of the optical fiber tip within two linear degrees of freedom perpendicular to the selected axis;

[0057] S4, updating the position of the rotation center point based on the position of the optical fiber tip after translation, and obtaining an updated difference value of the corresponding position of the rotation center point under the current selected axis;

[0058] S5, circulating the rotation operation and translation operation under the current selected axis, when the updated difference value of the corresponding position of the rotation center point under the current selected axis is less than a preset threshold, completing the rotation operation and translation operation under the current selected axis, switching a second coordinate axis in the local coordinate system as the selected axis, and continuing the rotation operation and translation operation; and

[0059] S6, when the updated difference value of the corresponding position of the rotation center point under the current selected axes is also less than the preset threshold, obtaining the rotation center point of an optical fiber.

[0060] As described in step S1, the system needs to estimate the corresponding position of the rotation center point based on the initial position of the optical fiber tip. The rotation center point refers to that in a three-dimensional space, the optical fiber tip can rotate randomly in the three-dimensional space based on the rotation center point, and the rotation center point

does not change own position. This estimation process is the basis of the whole alignment and adjustment, which ensures that clear reference points are provided for all subsequent operations. The estimation of the position of the rotation center point corresponding to the optical fiber tip is performed based on three-dimensional coordinates (x, y, z) in the local coordinate system, and the local coordinate system is a coordinate system which is established with a probe or the optical fiber tip as a reference point, and is usually used for describing the change of the optical fiber tip relative to the initial position; and the specific three-dimensional coordinates of the initial position are obtained by identifying the rules of transformation from the global coordinate system to the local coordinate system according to the probe installation orientation, and geometric, least squares or intelligent optimization algorithms are utilized to estimate the position of the rotation center point primarily. Once the primarily estimated position of the rotation center point is confirmed, the system will save the position data, including its coordinates (x, y, z, Rx, Ry, Rz) in six degrees of freedom. The rotation center point refers to points that do not change position in any rotation in the three-dimensional space. For an operation of rotating around a specific axis, all points on this axis are the rotation center points. In the three-dimensional coordinate system, an origin (0, 0, 0) is usually a special rotation center point for the entire coordinate system.

[0061] As described in step S2, in this embodiment, the system first needs to perform a series of necessary preparations to ensure the accuracy and reliability in subsequent operations. Specifically, the system will identify the rules of transformation from the global coordinate system to the local coordinate system according to the probe installation orientation, and activate the selected probe for estimation of the rotation center point. Moreover, the other probes other than the selected probe are controlled to move out of a camera picture at a preset position to avoid interference. Then, the system will select a target based on the current camera picture, transform the position of the selected target in the global coordinate system to the position in the local coordinate system based on the rules of transformation, and control the movement of the optical fiber tip according to the transformed local coordinates of the target, so as to obtain the initial position of the optical fiber tip. For example, if the probe installation orientation is east or west, the transformation relationship between the local coordinate system and the global coordinate system can be:

[0062] for installation in west: global X- > local z, global Y- > local (negative) x, global Z- > local (negative) y.

[0063] For installation in east: global X- > local (negative) z, global Y- > local x, global Z- > local (negative) y.

[0064] After the preparations are completed, the system will enter an actual calibration stage. At this stage, a user or a control system will identify the selected axis (such as Rx, Ry or Rz) that currently performs local rotation and a preset rotation angle (such as 0.1°) contained in a first rotation instruction.Based on the initial position of the optical fiber tip, a six-axis robotic arm can adjust the posture of the probe to rotate the optical fiber tip by a preset angle along the selected axis; and in actual operation, the rotation center point is relative to an origin of the six-axis robotic arm The six-axis robotic arm includes six degrees of freedom of movement, and can support the probe to move in the six degrees of freedom (x, y, z, Rx, Ry, Rz). This process needs very fine control to ensure that each rotation is controllable and accurate, as well as maintaining the stability of the optical fiber tip in the whole rotation process. A corresponding two-dimensional space rotation matrix can be represented as: $R = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}$, and the matrix represents that a point corresponding to the optical fiber tip rotates anticlockwise around the origin on a two-dimensional plane by an angle θ. In addition, the system will record the initial angle of the current selected axis, so that clear reference points can be provided for subsequent rotation and compensation motion. In this way, the optical fiber tip can perform accurate small-angle rotation on the selected axis, thus providing a basis for subsequent adjustment and optimization.

[0065] In order to ensure the accuracy of rotation, the system will also perform real-time monitoring through overlooking and side-looking cameras, and an image processing algorithm is utilized to automatically detect and verify whether the rotation of the optical fiber tip conforms to expectation or not. If there is a deviation, the system will perform further fine adjustment to ensure that each rotation can accurately reflect the intention of the user. Finally, by the detailed preparation and high-precision rotation control, the system can ensure that the optical fiber tip performs accurate small-angle rotation along the selected axis, thereby providing a reliable basis for subsequent adjustment and optimization.

[0066] As described in step S3, the system needs to ensure that the optical fiber tip can accurately return to the initial position after rotating along the selected axis. In order to achieve this purpose, the system will calculate required compensation parameters according to two linear degrees of freedom (two coordinate axes except the selected axis in the local coordinate system, for example, for rotating about Rx, the local positions on a y axis and a z axis are adjusted; for rotating about Ry, the local positions on a z axis and an x axis are adjusted; and for rotating about Rz, the local positions on the x axis and the y axis are adjusted) perpendicular

to the selected axis (such as Rx, Ry or Rz). Then, the six-axis robotic arm will adjust the position of the probe according to the compensation parameters, and thus the optical fiber tip can move within the corresponding linear degrees of freedom until the optical fiber tip completely returns to the initial position. In order to ensure the accuracy of returning, the system will perform real-time monitoring through the overlooking and side-looking cameras, and the image processing algorithm is utilized to automatically detect and verify whether the optical fiber tip returns to the initial position or not. In there is a deviation, the system will perform further fine adjustment to ensure that the optical fiber tip accurately returns to the initial position.

[0067] The rotation center point is relative to the origin of the six-axis instrument arm, so the system will determine whether the optical fiber tip can stop updating the position on the current selected axis according to the updated value of the coordinates of the current position of the rotation center point relative to the origin of the current six-axis robotic arm; (e.g. the updated value is less than the first preset threshold); or the current position of the rotation center point is compared with a recorded position of an updated point of previous rotation under the current selected axis, so as to ensure that the difference therebetween is within an acceptable range (for example, less than the preset threshold, such as 1 μm). If necessary, the compensation motion and verification steps can be repeated until the optical fiber tip completely returns to the initial position. Once it is confirmed that the optical fiber tip successfully returns to the initial position, the system will save new state data, including coordinates of the optical fiber tip on three linear degrees of freedom (x, y, z) and three rotational degrees of freedom (Rx, Ry, Rz).

[0068] The moving positions of the optical fiber tip within the two linear degrees of freedom perpendicular to the selected axis are adjusted to ensure that the optical fiber tip can accurately return to the initial position. This step not only depends on high-precision calculation and control, but also combines real-time visual verification to ensure that each adjustment can accurately reflect the intention of the user, and finally accurate alignment of the optical fiber tip is realized.

[0069] As described in step S4, the system needs to recalculate a new position of the rotation center point according to the current position of the optical fiber tip and obtain the updated difference value of the position of the rotation center point under the current selected axis. This process ensures that the system can gradually approach the most accurate position of the rotation center point after each adjustment, thereby realizing high-precision alignment. Specifically, the system will recalculate the new position of the rotation center point based on

the current position of the optical fiber tip by methods such as the geometric, least squares or intelligent optimization algorithms. Then, the system will compare the difference between the newly calculated position of the rotation center point and the position estimated last time, so as to obtain the updated difference value of the position of the rotation center point. The updated value reflects the influence of the current adjustment on the position of the rotation center point and provides a basis for subsequent iterative optimization.

[0070] In order to ensure the accuracy of calculation, the system will record and save the state data after each adjustment, including the coordinates of the optical fiber tip on the three linear degrees of freedom (x, y, z) and three rotational degrees of freedom (Rx, Ry, Rz). In addition, the system will generate a detailed alignment report, including all key parameters and image evidences which facilitate subsequent data analysis and optimization. In this way, the system can gradually approach the optimal position of the rotation center point in multiple iterations, thus ensuring high precision alignment.

[0071] As described in step S5, the system gradually approaches the most accurate position of the rotation center point of the optical fiber by iterative optimization. Specifically, the system will check whether the updated difference value of the position of the rotation center point under the current selected axis (e.g., Rx, Ry or Rz) is less than the preset threshold (e.g., 1 μm). If the condition is met, the rotation and translation operations under the current selected axis will be stopped, and it is switched to the next selected axis to continue the rotation and translation operations. This process ensures that the alignment accuracy under each selected axis is optimal, thus realizing overall high-precision alignment.There can be two or three selected axes; that is, in some cases, it can be allowed to perform updating operation on the rotation center point by taking two coordinate axes in the three-dimensional coordinate system sequentially as the selected axis, so as to obtain the required rotation center point of the optical fiber. In another case, in order to ensure the fineness of calibration, it is needed to take three coordinate axes in the three-dimensional coordinate system sequentially as the selected axis for the updating operation on the rotation center point, thus obtaining the required rotation center point of the optical fiber.

[0072] Specifically, the system checks the updated difference value of the position of the rotation center point under the current selected axis (Rx, Ry or Rz) one by one to ensure that the updated value of each axis is recorded and evaluated. If the updated difference value of the position of the rotation center point under the current selected axis is less than the preset threshold (e.g. 1 μm), it will be determined that the condition is met. If the threshold condition is not met, the optical fiber tip will be continuously controlled to rotate by a preset angle along

the axis, and the moving positions of the optical fiber tip within two linear degrees of freedom perpendicular to this axis are adjusted based on the position before rotation, and then the updated value is recalculated; and once the updated difference value of the position of the rotation center point under the current selected axis meets the threshold condition, the system will stop the rotation and translation operations under this axis. The system switches to the next selected axis (e.g. from Rx to Ry, and then from Ry to Rz), and repeats the rotation and translation operations until the updated difference value of the position of the rotation center point under all selected axes is less than the preset threshold. The number of rotation axes in different modes can be different, for example, in a case that accurate alignment in the three-dimensional space is required to ensure that the optical fiber tip can approach the target from multiple directions, it can be calibrated sequentially under three axes (Rx, Ry, Rz); in another case that there is a certain tolerance, and it allows a large error range in one direction, in order to save calculation resources and improve calculation efficiency, it can be calibrated sequentially under only two axes (such as Rx, Ry), which can not only reduce unnecessary complexity, but also reduce the hardware and time costs of the system. Each time the selected axis is switched, the system will save current state data, including the coordinates of the optical fiber tip within six degrees of freedom (x, y, z, Ry, Ry, Rz), ensuring that all adjustments have detailed records

[0073] In step S5, by repeated iterative optimization, the updated difference value of the position of the rotation center point under each selected axis is ensured to be less than the preset threshold, thus it can gradually approach the most accurate position of the rotation center point of the optical fiber. The system selects the appropriate number of axes according to different types of coupling requirements, which ensures that the operation process is simplified and the efficiency is improved while the alignment accuracy is improved. This process not only depends on accurate threshold setting and real-time verification, but also combines detailed record and report generation, ensuring that each adjustment can accurately reflect the intention of the user, and finally realizing the high-precision alignment of the optical fiber tip. By this way, the system ensures the high-precision alignment of the optical fiber tip in a plurality of degrees of freedom, and it is suitable for a high-precision optical system needing precision alignment at a sub-micron level.

[0074] As described in step S6, the system ensures that the updated difference value of the position of the rotation center point under all selected axes (e.g., Rx, Ry, Rz) is less than the preset threshold (e.g., 1 μm) by multiple iterative optimizations. Once the updated values of all selected axes meet the threshold condition, the system will confirm that the current

position of the optical fiber tip is the final rotation center point of the optical fiber. This process ensures that the optical fiber tip achieves high-precision alignment in a plurality of degrees of freedom, and avoids overall deviation caused by error in any axis.

[0075] In one embodiment, after the step of when the updated difference value of the corresponding position of the rotation center point under the current selected axes is also less than the preset threshold, obtaining the rotation center point of an optical fiber, the method includes:

[0076] S10, switching a third coordinate axis in the local coordinate system as the selected axis, and continuing the rotation operation and translation operation; and

[0077] S12, when the updated difference value of the corresponding position of the rotation center point under the current selected axis is also less than the preset threshold, obtaining the optimized rotation center point of the optical fiber.

[0078] In this embodiment, for example, in a case that the alignment requirement can be met by only two axes (e.g., Rx, Ry), only two axes can be selected for calibration and updating, which simplifies the operation process and improves the efficiency. But for some cases requiring high fineness, three axes (Rx, Ry, Rz) are needed to realize the accurate alignment in the three-dimensional space, that is, it is optimized based on three axes. In this way, the system ensures the high-precision alignment of the optical fiber tip in a plurality of degrees of freedom, and it is suitable for the high-precision optical system needing precision alignment at a sub-micron level. After the rotation operation and translation operation on the second coordinate axis are completed, the third coordinate axis is switched as the selected axis, and the rotation operation and translation operation are continued until the updated difference value of the corresponding position of the rotation center point under to the current selected axis is also less than the preset threshold, thus obtaining the optimized rotation center point of the optical fiber.

[0079] In one embodiment, before the step of taking a first coordinate axis in a three-dimensional local coordinate system as a selected axis to perform rotation operation, the method includes:

[0080] S20, identifying the rules of transformation from the global coordinate system to the local coordinate system according to the probe installation orientation;

[0081] S21, identifying a first positioning instruction, and activating a selected probe for estimation of the rotation center point;

[0082] S22, controlling probes other than the selected probe to move out of a camera picture;

[0083] S23, selecting a target based on the current camera picture, and transforming the

position of the selected target in the global coordinate system into the position in the local coordinate system based on the rules of transformation;

[0084] S24, controlling the optical fiber tip to move according to the transformed local coordinates of the target to obtain the initial position of the optical fiber tip.

[0085] In this embodiment, in order to ensure accurate determination of the rotation center point of the optical fiber, before rotation operation is carried out based on the selected axis in the local coordinate system, the system will firstly set the rules of transformation from the global coordinate system to the local coordinate system according to the specific installation orientation of the probe (referring to the east or west in the global coordinate system; or the right or left). Then, the system identifies and responds to the first positioning instruction, activates the selected probe for estimation of the rotation center point, and controls all the probes other than the selected probe to move out of the camera picture at the preset position so as to avoid interference. For example, the overlooking camera, it is installed at the top of a machine and provides a visual angle for overlooking. The overlooking camera is mainly used for monitoring the relative position between the optical fiber tip and the target position, especially the alignment condition in the horizontal plane. By means of the overlooking camera, the system can detect the change in position of the optical fiber tip on the x-y plane in real time and verify the effect of each adjustment. It is facilitated to ensure that the optical fiber tip can accurately return to the initial position in the plane, and transverse deviation is avoided. In addition, the system further includes the side-looking camera, and the side-looking camera is installed on the side face of the machine and provides a visual angle for side-looking. The side-looking camera is mainly used for monitoring the perpendicular alignment condition between the optical fiber tip and the target position, especially the position relation in the z-axis direction. Through the side-looking camera, the system can detect the change in position of the optical fiber tip on the z-axis in real time and verify the effect of each adjustment. It is facilitated to ensure that the optical fiber tip can return to the initial position accurately in the perpendicular direction and avoid height deviation. The overlooking camera and side-looking camera work together, and whether the position of the optical fiber tip meets the expectation is automatically detected by real-time monitoring and verified by image processing algorithms. If there is a deviation, the system will perform further fine adjustment to ensure that each adjustment can accurately reflect the intention of the user. Then, the system will select the target based on the current camera picture, and transform the position of the selected target in the global coordinate system into the position in the local coordinate system according to the previously set rules of transformation. Finally, the system will control the optical fiber tip to move to the designated

position according to the transformed target local coordinates, so as to obtain the initial position of the optical fiber tip. These initialization and calibration steps ensure that all subsequent operations are performed in a correct coordinate system, thereby improving the alignment accuracy, and providing a solid basis for subsequent rotation and translation operations. Especially for a case that three axes (Rx, Ry, Rz) are needed to realize accurate alignment in the three-dimensional space. For a case that the alignment requirement can be met by only two axes (e.g., Rx, Ry), it can simplify the operation process and improve the efficiency. In this way, the system ensures high-precision alignment of the optical fiber tip in the plurality of degrees of freedom, and it is suitable for the high-precision optical system needing precision alignment at a sub-micron level.

[0086] In one embodiment, the step of taking a first coordinate axis in a three-dimensional local coordinate system as a selected axis to perform rotation operation includes:

[0087] S30, identifying the selected axis currently rotating locally in the first rotation instruction, and the preset rotation angle; and

[0088] S31, based on the initial position of the optical fiber tip, controlling the optical fiber tip to rotate by a preset angle along the selected axis by adjusting the posture of the probe.

[0089] In this embodiment, the system will firstly identify the first rotation instruction, which contains the selected axis (e.g., Rx, Ry or Rz) currently rotating locally and the preset rotation angle (e.g., 0.1°). This identification process ensures the accuracy and controllability in subsequent rotation operations. The selection of the selected axis depends on the user needs or the automatic selection of the system, and the preset rotation angle is set according to the actual application scenario to ensure that each rotation is accurate and controllable. After the rotation instruction is identified, the system will adjust the posture of the probe based on the initial position of the optical fiber tip so as to rotate the optical fiber tip by a preset angle along the selected axis. Specifically, the six-axis robotic arm accurately controls the change in posture of the probe according to the transformed local coordinates of the target to ensure that the optical fiber tip can rotate at a specified angle and direction. This process requires very fine control to ensure that each rotation is controllable and accurate, and the stability of the optical fiber tip is maintained throughout the rotation process.

[0090] Specifically, it is to be ensured that the microscope, the digital cameras (overlooking and side-looking) and the six-axis robotic arm are started and work normally to complete hardware calibration. The system identifies the selected axis (such as Rx, Ry or Rz) currently rotating locally in the first rotation instruction and the preset rotation angle (such as

0.1°). Based on the initial position of the optical fiber tip, the six-axis robotic arm adjusts the posture of the probe to rotate the optical fiber tip by a preset angle along the selected axis. Real-time monitoring is carried out by the overlooking and side-looking cameras, and whether the rotation of the optical fiber tip meets the expectation is automatically detected and verified by the image processing algorithm. If there is a deviation, the system will perform further fine adjustment. In summary, in steps S30 and S31, it is ensured that the optical fiber tip can rotate at a small angle accurately along the selected axis by identifying the rotation instruction and accurately controlling the posture of the probe, which provides a reliable basis for subsequent adjustment and optimization. This process not only depends on a high-precision control mechanism, but also combines real-time monitoring and feedback to ensure that each adjustment can accurately reflect the intention of the user, and finally realizes the high-precision alignment of the optical fiber tip.

[0091] In one embodiment, the step of acquiring the current position of the optical fiber tip, and performing translation operation on the optical fiber tip by taking the initial position as a target includes:

[0092] S40, calculating compensation parameters of the optical fiber tip on the corresponding coordinate axis according to two coordinate axes perpendicular to the current selected axis; and

[0093] S41, according to the compensation parameters, controlling the optical fiber tip to move in the linear degree of freedom of the corresponding coordinate axis by the probe, and monitoring the position of the optical fiber tip in real time by the overlooking camera and the side-looking camera, and verifying the position of the optical fiber tip by the image processing algorithm.

[0094] In this embodiment, the system will firstly calculate the compensation parameters of the optical fiber tip in the corresponding degree of freedom according to the two linear degrees of freedom perpendicular to the selected axis (e.g., Rx, Ry or Rz). Specifically,

[0095] for rotating about Rx, local positions in y and z directions are adjusted.

[0096] For rotating about Ry, local positions in local z and x directions are adjusted.

[0097] For rotating by Rz, local positions in local x and y directions are adjusted.

[0098] The compensation parameters are calculated based on the difference between the current position of the optical fiber tip and the initial position, so that the required movement amount can be accurately reflected by each adjustment. Through geometric calculation or least square method and other methods, the system can accurately calculate the compensation

parameters on each degree of freedom, and thus the basis is provided for subsequent translation operation. After the compensation parameters are calculated, the system will control the optical fiber tip to move in the linear degree of freedom of the corresponding coordinate axis through the probe according to the parameters. The six-axis robotic arm will accurately adjust the posture of the probe according to the calculated compensation parameters, so that the optical fiber tip can move to the target position in the designated direction. Moreover, the system monitors the position of the optical fiber tip in real time by the overlooking camera and the side-looking camera installed on the machine, and automatically detects and verifies whether the optical fiber tip returns to the initial position by the image processing algorithm. If there is a deviation, the system will further perform fine adjustment to ensure that the optical fiber tip accurately returns to the initial position.

[0099] According to this embodiment, the compensation parameters are accurately calculated and the position of the optical fiber tip is monitored in real time, so that the optical fiber tip can accurately return to the initial position in two linear degrees of freedom perpendicular to the selected axis, and a reliable basis is provided for subsequent adjustment and optimization. This process not only depends on the high-precision calculation and control mechanism, but also combines real-time monitoring and feedback, so that the intention of the user can be accurately reflected by each adjustment, and finally high-precision alignment of the optical fiber tip is realized.

[0100] In one embodiment, the step of updating the position of the rotation center point based on the position of the optical fiber tip after translation, and obtaining an updated difference value of the corresponding position of the rotation center point under the current selected axis includes:

[0101] S50, calculating a new position of the rotation center point based on the position of the optical fiber tip after movement; and

[0102] S51, comparing the difference between the newly calculated position of the rotation center point and the previous position of the rotation center point to obtain the updated difference value of the position of the rotation center point.

[0103] In this embodiment, the six-axis robotic arm is an operation object used for controlling the optical fiber tip in actual operation, so the current coordinates of the origin of the six-axis robotic arm correspondingly change along with a virtual position of the optical fiber tip, meanwhile, the system will recalculate the new position of the rotation center point based on the change in coordinates of the origin of the six-axis robotic arm. Specifically, the system will recalculate the new position of the rotation center point by the geometric,. Each

method has applicable scenario and advantages to ensure the accuracy and reliability of the calculation results. After calculating the new position of the rotation center point, the system will compare the newly calculated position of the rotation center point with the position of the rotation center point estimated last time to obtain the updated difference value of the position of the rotation center point. This updated value reflects the influence of the current adjustment on the position of the rotation center point, which provides a basis for the subsequent iterative optimization. Specifically, the system will calculate the difference between the two positions to ensure that the effect of each adjustment can be quantified and recorded. If the updated value is less than the preset threshold (e.g. 1 μm), it is considered that the rotation center point under the current selected axis is accurate enough; otherwise, the system will continue to adjust and verify until the updated values of all the selected axes meet the threshold conditions.

[0104] In one embodiment, the step of circulating the rotation operation and translation operation under the current selected axis, when the updated difference value of the corresponding position of the rotation center point under the current selected axis is less than a preset threshold, completing the rotation operation and translation operation under the current selected axis, switching a second coordinate axis in the local coordinate system as the selected axis, and continuing the rotation operation and translation operation includes:

[0105] S60, identifying whether the updated difference value of the position of the rotation center point under the current selected axis meets the preset threshold;

[0106] S61, if the preset threshold is not met, continuing to control the optical fiber tip to perform rotation operation and translation operation based on the current selected axis until the preset threshold is met; and

[0107] S62, if the preset threshold is met, identifying the second coordinate axis in the local coordinate system other than the first coordinate axis selected by the user, updating the selected axis based on the second coordinate axis, and continuing to control the optical fiber tip to perform rotation operation and translation operation based on the current selected axis until the updated difference value of the position of the rotation center point under the current selected axis also meets the preset threshold.

[0108] In this embodiment, the system will firstly check whether the updated difference value of the position of the rotation center point under the current selected axis (e.g., Rx, Ry or Rz) is less than the preset threshold (e.g., 1 μm). This check ensures that the effect of each adjustment can be quantified and recorded. Specifically, the system will compare the difference between the newly calculated position of the rotation center point and the position of the rotation center point estimated at last to obtain the updated difference value of the rotation

center point position, and determine whether the updated value is less than the preset threshold. If the updated difference value of the position of the rotation center point under the current selected axis does not meet the preset threshold, the system will continue to control the optical fiber tip to perform rotation and translation based on the current selected axis until the preset threshold is met. This includes: controlling the optical fiber tip to rotate along the current selected axis according to the preset angle, and adjusting the posture of the probe to move the optical fiber tip within two linear degrees of freedom perpendicular to the selected axis so as to ensure that it returns to the initial position. Moreover, the position of the optical fiber tip is monitored in real time by the overlooking camera and the side-looking camera, and it is verified by the image processing algorithm whether it meets the expectation. If there is a deviation, the system will perform further fine adjustment to ensure that each adjustment can accurately reflect the intention of the user.

[0109] Once the updated difference of the position of the rotation center point under the current selected axis meets the preset threshold, the system will identify the next selected axis (second coordinate axis) (e.g., switch from Rx to Ry, and then from Ry to Rz), and continue to control the optical fiber tip to perform rotation operation and translation operation based on the next selected axis until the updated difference of the position of the rotation center point under the next selected axis also meets the preset threshold. For each selected axis, the system will repeat the above rotation and translation operations until the updated difference value of the position of the rotation center point under all selected axes (corresponding to different numbers of updates of the selected axis in different modes) meets the preset threshold. In the whole process, the system will check the updated difference value of the position of the rotation center point under each selected axis one by one to ensure that no factors that may affect the overall alignment accuracy are omitted. The preset threshold (e.g., 1 μm) is set according to the actual application requirements to ensure that the required alignment accuracy can be achieved in different application scenarios.

[0110] By repeated iterative optimization, the system can ensure that the updated difference value of the position of the rotation center point under each selected axis is less than the preset threshold, so as to gradually approach the most accurate position of the rotation center point of the optical fiber. This process not only depends on accurate threshold setting and real-time verification, but also combines detailed record and report generation to ensure that each adjustment can accurately reflect the intention of the user, and finally realizes the high-precision alignment of the optical fiber tip. In addition, the system uses the overlooking and side-looking cameras to monitor and process images in real time, which ensures that each

adjustment can be verified accurately, and improves the reliability and accuracy of alignment. The whole process is highly automated, reduces the need for manual intervention, improves the production efficiency and consistency, and is suitable for high-precision optical systems needing precision alignment at a sub-micron level.

[0111] In one embodiment, the step of when the updated difference value of the corresponding position of the rotation center point under the current selected axes is also less than the preset threshold, obtaining the rotation center point of an optical fiber includes:

[0112] S70, identifying whether the updated difference value of the position of the rotation center point under all the selected axes is less than the preset threshold; and

[0113] S71, if the updated difference value is less than the preset threshold, acquiring the current position of the optical fiber tip, namely obtaining the rotation center point of the optical fiber.

[0114] In this embodiment, firstly, if the updated difference value of the position of the rotation center point under all the selected axes is less than the preset threshold, the system will confirm that the current position of the optical fiber tip is the final rotation center point of the optical fiber. Specifically, the system will save the current coordinates of the optical fiber tip in six degrees of freedom (x, y, z, Rx, Ry, Rz) and confirms the coordinates as the final rotation center point of the optical fiber. This indicates the completion of the whole alignment process, and ensures high-precision alignment of the optical fiber tip in the plurality of degrees of freedom. The whole process is highly automated, reduces the demand of manual intervention, and improves the production efficiency and consistency.

[0115] FIG. 2 is a structural schematic block diagram of an apparatus for determining a center rotation point in an optical fiber moving process according to an embodiment of the present application, the apparatus includes:

[0116] a primary estimation module configured to estimate the position of a rotation center point corresponding to an optical fiber tip based on an initial position of the optical fiber tip;

[0117] a rotating module configured to take a first coordinate axis in a three-dimensional local coordinate system as a selected axis to perform rotation operation, in which, the rotation operation includes: controlling the optical fiber tip to rotate by a preset angle along the current selected axis;

[0118] a translation module configured to acquire the current position of the optical fiber tip, and perform translation operation on the optical fiber tip by taking the initial position as a target, in which, the translation operation includes: adjusting the moving positions of the optical fiber tip within two linear degrees of freedom perpendicular to the selected axis;

[0119] a calculation module configured to update the position of the rotation center point based on the position of the optical fiber tip after translation, and obtain an updated difference value of the corresponding position of the rotation center point under the current selected axis;

[0120] a switching module configured to circulate the rotation operation and translation operation under the current selected axis, when the updated difference value of the corresponding position of the rotation center point under the current selected axis is less than a preset threshold, complete the rotation operation and translation operation under the current selected axis, switch a second coordinate axis in the local coordinate system as the selected axis, and continue the rotation operation and translation operation; and

[0121] a point acquisition module configured to: when the updated difference value of the corresponding position of the rotation center point under the current selected axes is also less than the preset threshold, obtain the rotation center point of an optical fiber.

[0122] Further, the apparatus further includes an initialization module which is configured to:

[0123] identify the rules of transformation from the global coordinate system to the local coordinate system according to the probe installation orientation;

[0124] identify a first positioning instruction, and activate a selected probe for estimation of the rotation center point;

[0125] control the probe other than the selected probe to move out of a camera picture;

[0126] select a target based on the current camera picture, and transform the position of the selected target in the global coordinate system into the position in the local coordinate system based on the rules of transformation; and

[0127] control the optical fiber tip to move according to the transformed local coordinates of the target to obtain the initial position of the optical fiber tip.

[0128] Further, the apparatus further includes a third switching module which is configured to:

[0129] switch a third coordinate axis in the local coordinate system as the selected axis, and continue the rotation operation and translation operation; and

[0130] when the updated difference value of the position of the rotation center point corresponding to the current selected axis is also less than the preset threshold, obtain the optimized rotation center point of the optical fiber.

[0131] Further, the rotating module 200 further includes a first rotating unit which is configured to:

[0132] identify the selected axis currently rotating locally in the first rotation instruction,

and the preset rotation angle; and

[0133] based on the initial position of the optical fiber tip, control the optical fiber tip to rotate by a preset angle along the selected axis by adjusting the posture of the probe.

[0134] Further, the translation module 300 further includes a first translation unit which is configured to:

[0135] calculate compensation parameters of the optical fiber tip on the corresponding coordinate axis according to two coordinate axes perpendicular to the current selected axis; and

[0136] according to the compensation parameters, control the optical fiber tip to move in the linear degree of freedom of the corresponding coordinate axis by the probe, and monitor the position of the optical fiber tip in real time by the overlooking camera and the side-looking camera, and verify the position of the optical fiber tip by the image processing algorithm.

[0137] Further, the calculation module 400 further includes a first calculation unit which is configured to:

[0138] calculate a new position of the rotation center point based on the position of the optical fiber tip after movement; and

[0139] compare the difference between the newly calculated position of the rotation center point and the previous position of the rotation center point to obtain the updated difference value of the position of the rotation center point.

[0140] Further, the switching module 500 further includes a first switching unit which is configured to:

[0141] identify whether the updated difference value of the position of the rotation center point under the current selected axis meets the preset threshold;

[0142] if the preset threshold is not met, continue to control the optical fiber tip to perform rotation operation and translation operation based on the current selected axis until the preset threshold is met; and

[0143] if the preset threshold is met, identify the second coordinate axis in the local coordinate system other than the first coordinate axis selected by the user, update the selected axis based on the second coordinate axis, and continue to control the optical fiber tip to perform rotation operation and translation operation based on the current selected axis until the updated difference value of the position of the rotation center point under the current selected axis also meets the preset threshold.

[0144] With reference to FIG. 3, an embodiment of the present application further provides a computer device. The computer device can be a server, and the internal structure of the computer device can be shown in FIG. 3. The computer device includes a processor, an

internal memory, a storage medium (nonvolatile storage medium) and a network interface which are connected through a system bus. The processor designed by the computer is used for providing calculation and control capabilities. The memory of the computer device includes the storage medium (nonvolatile storage medium) and an internal memory. The storage medium (nonvolatile storage medium) stores an operating system, a computer program and a database. The internal memory provides an environment for operation of the operating system and the computer program in the storage medium (nonvolatile storage medium). The database of the computer device is used for storing use data and the like in the process of the method for determining the rotation center point in the optical fiber moving process. The network interface of the computer device is used for communicating with an external terminal through network connection. Furthermore, the computer device can be also provided with an input apparatus, a display screen and the like. The computer program is executed by the processor to implement the method for determining the rotation center point in the optical fiber moving process, including the following steps: performing rotation operation based on a selected axis in a local coordinate system, in which, the rotation operation includes: controlling the optical fiber tip to rotate by a preset angle along the current selected axis; acquiring the current position of the optical fiber tip, and performing translation operation on the optical fiber tip by taking the initial position as a target, in which, the translation operation includes: adjusting the moving positions of the optical fiber tip within two linear degrees of freedom perpendicular to the selected axis; estimating the position of a rotation center point corresponding to an optical fiber tip based on an initial position of the optical fiber tip; taking a first coordinate axis in a three-dimensional local coordinate system as a selected axis to perform rotation operation, in which, the rotation operation includes: controlling the optical fiber tip to rotate by a preset angle along the current selected axis; acquiring the current position of the optical fiber tip, and performing translation operation on the optical fiber tip by taking the initial position as a target, in which, the translation operation includes: adjusting the moving positions of the optical fiber tip within two coordinate axes perpendicular to the current selected axis in the local coordinate system; updating the position of the rotation center point based on the position of the optical fiber tip after translation, and obtaining an updated difference value of the corresponding position of the rotation center point under the current selected axis; circulating the rotation operation and translation operation under the current selected axis, when the updated difference value of the corresponding position of the rotation center point under the current selected axis is less than a preset threshold, completing the rotation operation and translation operation under the current selected axis, switching a second coordinate axis in the local coordinate system as the selected

axis, and continuing the rotation operation and translation operation; and when the updated difference value of the corresponding position of the rotation center point under the current selected axes is also less than the preset threshold, obtaining the rotation center point of an optical fiber. Those skilled in the art can understand that the structure shown in FIG. 3 is only a block diagram of a part of the structure related to the present application scheme, and does not constitute a limitation on the computer device applied thereon to the present application scheme.

[0145] An embodiment of the present application also provides a computer-readable storage medium thereon a computer program is stored, the computer program is executed by a processor to implement the method for determining the rotation center point in the optical fiber moving process, including the following steps: performing rotation operation based on a selected axis in a local coordinate system, in which, the rotation operation includes: controlling the optical fiber tip to rotate by a preset angle along the current selected axis; acquiring the current position of the optical fiber tip, and performing translation operation on the optical fiber tip by taking the initial position as a target, in which, the translation operation includes: adjusting the moving positions of the optical fiber tip within two linear degrees of freedom perpendicular to the selected axis; estimating the position of a rotation center point corresponding to an optical fiber tip based on an initial position of the optical fiber tip; taking a first coordinate axis in a three-dimensional local coordinate system as a selected axis to perform rotation operation, in which, the rotation operation includes: controlling the optical fiber tip to rotate by a preset angle along the current selected axis; acquiring the current position of the optical fiber tip, and performing translation operation on the optical fiber tip by taking the initial position as a target, in which, the translation operation includes: adjusting the moving positions of the optical fiber tip within two coordinate axes perpendicular to the current selected axis in the local coordinate system; updating the position of the rotation center point based on the position of the optical fiber tip after translation, and obtaining an updated difference value of the corresponding position of the rotation center point under the current selected axis; circulating the rotation operation and translation operation under the current selected axis, when the updated difference value of the corresponding position of the rotation center point under the current selected axis is less than a preset threshold, completing the rotation operation and translation operation under the current selected axis, switching a second coordinate axis in the local coordinate system as the selected axis, and continuing the rotation operation and translation operation; and when the updated difference value of the corresponding position of the rotation center point under the current selected axes is also less than the preset threshold,

obtaining the rotation center point of an optical fiber. It is to be understood that the computer-readable storage medium in this embodiment may be a volatile readable storage medium or a non-volatile readable storage medium.

[0146] Those of ordinary skill in the art may understand that all or part of the process in the method for realizing the above embodiments can be completed by instructing the relevant hardware through the computer program, the computer program may be stored in a non-volatile computer-readable storage medium, and the computer program may include a flow such as the embodiments of each of the methods when executed. Any reference to memory, storage, database or other medium provided in the present application and used in the embodiment may include non-volatile and/or volatile memory. Non-volatile memory can include read-only memory (ROM), programmable ROM (PROM), electrically programmable ROM (EPROM), electrically erasable programmable ROM (EEPROM), or flash memory. Volatile memory may include random access memory (RAM) or external cache memory. For illustrative purposes rather than limitations, RAM is available in many forms, such as Static RAM (SRAM), Dynamic RAM (DRAM), Synchronous DRAM (SDRAM), Dual Rate SDRAM (SSRSDRAM), Enhanced SDRAM (ESDRAM), Synchlink DRAM (SLDRAM), Memory Bus (Rambus) Direct RAM (RDRAM), Direct Memory Bus Dynamic RAM (DRDRAM), and Memory Bus Dynamic RAM (RDRAM), etc.

[0147] It is to be noted that, in this context, the terms "including", "containing" or any other variation thereof are intended to cover non-exclusive inclusion so that a process, apparatus, article or process that includes a series of elements includes not only those elements, but also other elements that are not expressly listed, or that are inherent to such process, apparatus, article or process. In the absence of further restrictions, an element qualified by the phrase "including a/an..." does not preclude the existence of other identical elements in the process, apparatus, article or method that includes that element.

[0148] The foregoing is only a preferred embodiment of the present application, and does not limit the scope of the patent of the present application, and all equivalent structural or equivalent process transformations made by using the contents of the description and drawings of the present application, or directly or indirectly applied in other related technical fields, are similarly included in the scope of patent protection of the present application.

CLAIMS

We claim:

1. A method for determining a rotation center point in an optical fiber moving process, comprising:

estimating the position of a rotation center point corresponding to an optical fiber tip based on an initial position of the optical fiber tip;

taking a first coordinate axis in a three-dimensional local coordinate system as a selected axis to perform rotation operation, wherein the rotation operation includes: controlling the optical fiber tip to rotate by a preset angle along the current selected axis;

acquiring the current position of the optical fiber tip, and performing translation operation on the optical fiber tip by taking the initial position as a target, wherein, the translation operation comprises: adjusting the moving positions of the optical fiber tip within two coordinate axes perpendicular to the current selected axis in a local coordinate system;

updating the position of the rotation center point based on the position of the optical fiber tip after translation, and obtaining an updated difference value of the corresponding position of the rotation center point under the current selected axis;

circulating the rotation operation and translation operation under the current selected axis, when the updated difference value of the corresponding position of the rotation center point under the current selected axis is less than a preset threshold, completing the rotation operation and translation operation under the current selected axis, switching a second coordinate axis in the local coordinate system as the selected axis, and continuing the rotation operation and translation operation; and

when the updated difference value of the corresponding position of the rotation center point under the current selected axes is also less than the preset threshold, obtaining the rotation center point of an optical fiber.

2. The method for determining the rotation center point in the optical fiber moving process according to claim 1, wherein before the step of taking a first coordinate axis in a three-dimensional local coordinate system as a selected axis to perform rotation operation, the method comprises:

identifying the rules of transformation from a global coordinate system to the local coordinate system according to the probe installation orientation;

identifying a first positioning instruction, and activating a selected probe for estimation of the rotation center point;

controlling probes other than the selected probe to move out of a camera picture;

selecting a target based on the current camera picture, and transforming the position of the selected target in the global coordinate system into the position in the local coordinate system based on the rules of transformation; and

controlling the optical fiber tip to move according to the transformed local coordinates of the target to obtain the initial position of the optical fiber tip.

3. The method for determining the rotation center point in the optical fiber moving process according to claim 1, wherein after the step of when the updated difference value of the corresponding position of the rotation center point under the current selected axes is also less than the preset threshold, obtaining the rotation center point of an optical fiber, the method comprises:

switching a third coordinate axis in the local coordinate system as the selected axis, and continuing the rotation operation and translation operation; and

when the updated difference value of the corresponding position of the rotation center point under the current selected axis is also less than the preset threshold, obtaining the optimized rotation center point of the optical fiber.

4. The method for determining the rotation center point in the optical fiber moving process according to claim 1, wherein the step of taking a first coordinate axis in a three-dimensional local coordinate system as a selected axis to perform rotation operation comprises:

identifying the selected axis currently rotating locally in the first rotation instruction, and a preset rotation angle; and

based on the initial position of the optical fiber tip, controlling the optical fiber tip to rotate by a preset angle along the selected axis by adjusting the posture of the probe.

5. The method for determining the rotation center point in the optical fiber moving process according to claim 1, wherein the step of acquiring the current position of the optical fiber tip, and performing translation operation on the optical fiber tip by taking the initial position as a target comprises:

calculating compensation parameters of the optical fiber tip on the corresponding coordinate axis according to two coordinate axes perpendicular to the current selected axis; and

according to the compensation parameters, controlling the optical fiber tip to move in a linear degree of freedom of the corresponding coordinate axis by the probe, and monitoring the position of the optical fiber tip in real time by an overlooking camera and a side-looking camera, and verifying the position of the optical fiber tip by an image processing algorithm.

6. The method for determining the rotation center point in the optical fiber moving process according to claim 1, wherein the step of updating the position of the rotation center point based

on the position of the optical fiber tip after translation, and obtaining an updated difference value of the corresponding position of the rotation center point under the current selected axis comprises:

calculating a new position of the rotation center point based on the position of the optical fiber tip after movement; and

comparing the difference between the newly calculated position of the rotation center point and the previous position of the rotation center point to obtain the updated difference value of the position of the rotation center point.

7. The method for determining the rotation center point in the optical fiber moving process according to claim 1, wherein the step of circulating the rotation operation and translation operation under the current selected axis, when the updated difference value of the corresponding position of the rotation center point under the current selected axis is less than a preset threshold, completing the rotation operation and translation operation under the current selected axis, switching a second coordinate axis in the local coordinate system as the selected axis, and continuing the rotation operation and translation operation comprises:

identifying whether the updated difference value of the position of the rotation center point under the current selected axis meets the preset threshold;

if the preset threshold is not met, continuing to control the optical fiber tip to perform rotation operation and translation operation based on the current selected axis until the preset threshold is met; and

if the preset threshold is met, identifying the second coordinate axis in the local coordinate system other than the first coordinate axis selected by the user, updating the selected axis based on the second coordinate axis, and continuing to control the optical fiber tip to perform rotation operation and translation operation based on the current selected axis until the updated difference value of the position of the rotation center point under the current selected axis also meets the preset threshold.

8. An apparatus for determining a center rotation point in an optical fiber moving process, comprising:

a primary estimation module configured to estimate the position of a rotation center point corresponding to an optical fiber tip based on an initial position of the optical fiber tip;

a rotating module configured to take a first coordinate axis in a three-dimensional local coordinate system as a selected axis to perform rotation operation, wherein the rotation operation comprises: controlling the optical fiber tip to rotate by a preset angle along the current selected axis;

a translation module configured to acquire the current position of the optical fiber tip, and perform translation operation on the optical fiber tip by taking the initial position as a target, wherein the translation operation comprises: adjusting the moving positions of the optical fiber tip within two coordinate axes perpendicular to the current selected axis in a local coordinate system;

a calculation module configured to update the position of the rotation center point based on the position of the optical fiber tip after translation, and obtain an updated difference value of the corresponding position of the rotation center point under the current selected axis;

a switching module configured to circulate the rotation operation and translation operation under the current selected axis, when the updated difference value of the corresponding position of the rotation center point under the current selected axis is less than a preset threshold, complete the rotation operation and translation operation under the current selected axis, switch a second coordinate axis in the local coordinate system as the selected axis, and continue the rotation operation and translation operation; and

a point acquisition module configured to when the updated difference value of the corresponding position of the rotation center point under the current selected axes is also less than the preset threshold, obtain the rotation center point of an optical fiber.

9. A computer device, comprising a storage and a processor, wherein the storage is used for storing a computer program, and the processor is used for executing the computer program to implement the steps of the method according to any one of claims 1 to 7.

10. A computer-readable storage medium thereon a computer program is stored, wherein the computer program is executed by a processor to implement the steps of the method according to any one of claims 1 to 7.