

TRIANGULAR OPTICAL MEASUREMENT SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Chinese patent application No. 202412000451.1, filed on December 31, 2024, and titled “TRIANGULAR OPTICAL
5 MEASUREMENT SYSTEM”, the content of which is hereby incorporated herein in its entirety by reference.

TECHNICAL FIELD

[0002] The present application relates to the technical field of optical detection, and in particular, to a triangular optical measurement system.

10 BACKGROUND

[0003] A 3D linear scanning optical detecting system is an optical system for high-precision three-dimensional measurement and detection. In such a system, a laser or high-power LED linear light source and an industrial camera are positioned at fixed relative positions with a certain angle. When linear scanning is performed on a surface of an object,
15 changes in positions of reflection points of rays on the surface of the object are captured by the industrial camera. Three-dimensional coordinates of the points on a surface of a test object are calculated in real time through a triangulation method. Compared to related contact-based measuring methods, the 3D linear scanning optical detecting system has advantages of being non-contact and non-destructive. The 3D linear scanning optical
20 detecting system is suitable for measuring objects with complex shapes or sensitive surfaces, and can quickly and efficiently generate three-dimensional topographical information of the

surface of the object. The 3D linear scanning optical detecting system is widely applied to industrial detection such as semiconductor wafer detection, photoresist thickness measurement and microstructure topography measurement of semiconductor components. However, in related optical detection systems, the use of a single light source for
5 illumination results in insufficient information acquisition, leading to shortcomings such as low detection precision or low detection efficiency.

SUMMARY

[0004] According to embodiments of the present invention, a triangular optical measurement system capable of improving detection accuracy or detection efficiency is
10 provided.

[0005] A triangular optical measurement system includes an illumination module and an imaging module,

wherein the illumination module includes a first functional light splitting element and at least two first light sources, the first functional light splitting element is configured to split
15 illumination light emitted from the at least two first light sources to form at least two non-coherent linear lights having different characteristics, which are incident along a same direction onto a surface of a test object;

the imaging module is configured to collect reflected light of the at least two non-coherent linear lights for imaging,

20 the illumination module further includes slit elements, a slit of each of the slit elements is adjustable in position along a width direction, so that optical paths of the at least two

non-coherent linear lights are different or coincident.

[0006] In an embodiment, the first functional light splitting element is configured to reflect and transmit at least two beams of light having different characteristics so that the at least two beams of light exit along a same direction without generating interference, so as to
5 form two non-coherent linear lights for simultaneous detection of the test object.

[0007] In an embodiment, the imaging module includes at least one first image collector configured to simultaneously collect reflected images of the at least two non-coherent linear lights as attention-region images for one cycle.

[0008] The triangular optical measurement system further includes a control module
10 configured to periodically collect attention-region images on the test object when the test object is displaced along a preset scanning path.

[0009] In an embodiment, the control module is configured to control the imaging module to perform image collecting with exposure according to a set period. In addition, the control module is further configured to control a displacement of the test object along the
15 preset scanning path within the set period to be consistent with a width of an attention region onto which each of the at least two non-coherent linear lights is incident on the test object along the preset scanning path, so that attention regions corresponding to each image collection are continuous and non-overlapping along the preset scanning path.

[0010] In an embodiment, the control module is configured to control the imaging
20 module to perform image collection with exposure according to a set period. In addition, the control module is further configured to control a displacement of the test object along the

preset scanning path within the set period to be less than a width of an attention region onto which each of the at least two non-coherent linear lights is incident on the test object along the preset scanning path, so that attention regions corresponding to each image collection are continuous and at least partially overlapping along the preset scanning path.

5 [0011] In an embodiment, the at least two non-coherent linear lights includes a first linear light and a second linear light arranged in parallel. A scanning region of the first linear light in a current attention region overlaps with a scanning region of the second linear light in a previous continuous attention region.

[0012] In an embodiment, the first functional light splitting element is configured to
10 split the illumination light to form non-coherent linear lights having different wavelengths or different polarization states.

[0013] In an embodiment, each of the slit elements is disposed between the first functional light splitting element and corresponding one of the at least two first light sources. The illumination light emitted from each of the at least two first light sources passes
15 through corresponding one of the slit elements to form a linear light output to the first functional light splitting element.

[0014] In an embodiment, a slit of each of the slit elements is adjustable in position along a width direction, so that optical paths of the non-coherent linear lights are different or coincident.

20 [0015] In an embodiment, a number of the at least one first image collector is two or more than two. The imaging module further includes a second functional light splitting

element. The second functional light splitting element is configured to transmit or reflect linear lights reflected from the test object, to split non-coherent linear lights having different characteristics and transmit the non-coherent linear lights to corresponding one of the at least one first image collector.

5 [0016] In an embodiment, the illumination module further includes a first lens and a first microscope objective. The first functional light splitting element, the first lens, and the first microscope objective are sequentially arranged along an optical path. Non-coherent linear lights output from the first functional light splitting element are incident onto the surface of the test object after passing through the first lens and the first microscope
10 objective.

[0017] In an embodiment, the imaging module further includes a second lens and a second microscope objective. The second microscope objective, the second lens, and the second functional light splitting element are sequentially arranged along an optical path. The linear lights reflected from the test object is transmitted to the second functional light
15 splitting element through the second microscope objective and the second lens for transmission or reflection, and to be splitted into non-coherent linear lights having different characteristics and transmitted to corresponding one of the at least one first image collector.

[0018] In an embodiment, the first functional light splitting element is configured as a dichroic mirror or a polarization light splitting element, and the second functional light
20 splitting element is configured as a dichroic mirror or a polarization light splitting element.

[0019] In an embodiment, the illumination module further includes second image

collectors, and the imaging module further includes second light sources. In the imaging module, the second functional light splitting element is configured to split illumination light emitted from corresponding one of the second light sources into linear lights having different characteristics and transmit the linear lights to the test object. In the illumination
5 module, the first functional light splitting element is configured to split the linear lights reflected from the test object to form linear lights having different characteristics and transmit the linear lights to corresponding one of the second image collectors.

[0020] Details of one or more embodiments of the present invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages
10 of the present invention will become more apparent and more readily understood from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] To more clearly illustrate the technical solutions in the embodiments of the present invention, the accompanying drawings used in the description of the embodiments
15 will be briefly introduced below. It is apparent that the drawings in the following description are only some embodiments of the present invention. For those skilled in the art, other drawings may also be derived from these drawings without creative efforts.

[0022] FIG. 1 is a schematic structural diagram of a triangular optical measurement system according to an embodiment.

20 [0023] FIG. 2 is a schematic diagram of an operating principle of a triangular optical measurement system according to an embodiment.

[0024] FIG. 3 is a schematic structural diagram of a triangular optical measurement system according to another embodiment.

[0025] FIG. 4 is a schematic diagram of a linear scanning on a surface of a test object according to an embodiment.

5 [0026] FIG. 5 is a timing diagram of illumination and imaging according to an embodiment.

[0027] FIG. 6 is a timing diagram of illumination and imaging according to another embodiment.

[0028] FIG. 7 is a schematic diagram of image acquisition of an attention region of a
10 test object according to some embodiments.

[0029] FIG. 8 is a timing diagram of illumination and imaging of single-light-source illumination detection.

[0030] FIG. 9 is a schematic diagram of image collection for attention regions of a test object by single-light-source illumination detection in the related art.

15 [0031] FIG. 10 is a schematic diagram of another representation of a second solution in FIG. 7.

DETAILED DESCRIPTION

[0032] The technical solutions in the embodiments of the present invention will be described clearly and completely with reference to the accompanying drawings in the
20 embodiments of the present invention. Apparently, the embodiments as described are merely some rather than all of the embodiments of the present invention. All other

embodiments obtained by one skilled in the art on the basis of the embodiments in the present invention without involving any inventive effort fall within the protection scope of the present invention.

[0033] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by those skilled in the art to which the present invention belongs. The terms used herein in the description of the present invention are for the purpose of describing specific embodiments only, and are not intended to limit the present invention.

[0034] It should be understood that “connection” in the following embodiments should be understood as “electrical connection”, “communicating connection”, and the like if the connected circuits, modules, units, and the like have electrical signals or data transmission therebetween.

[0035] As used herein, the singular forms “a”, “an”, and “the” may also include the plural forms unless the context clearly indicates otherwise. It should also be understood that the terms “include/comprise”, “having”, or the like specify the presence of stated features, integers, methods, operations, components, portions, or combinations thereof, but do not preclude the possibility of the presence or addition of one or more other features, integers, methods, operations, components, portions, or combinations thereof.

[0036] Referring to FIGs. 1 and 2, a triangular optical measurement system is provided in an embodiment. The triangular optical measurement system includes an illumination module 100, an imaging module 200, and a control module (not shown in the drawings).

The illumination module 100 includes a first functional light splitting element 110 and at least two first light sources. The first functional light splitting element 110 is configured to split illumination light emitted from the at least two first light sources to form at least two non-coherent linear lights having different characteristics. The non-coherent linear lights are
5 incident along a same direction (indicating that transmission directions are substantially the same, and are not required to be completely parallel) onto a surface of a test object. The imaging module 200 includes at least one first image collector and is configured to simultaneously collect reflected images of the at least two non-coherent linear lights as attention-region images for one cycle. The control module is configured to periodically
10 collect attention-region images on the test object when the test object is displaced along a preset scanning path.

[0037] The test object may be a wafer or other products requiring surface image detection. The number of the at least one first light source may be two or more, for example, including a first light source A, a first light source B, and the like. A first light source may
15 be a constant-on type first light source, providing illumination light continuously. Alternatively, the first light source may be a strobe-type light source, providing illumination light by flashing once within a cycle. The type of the illumination light emitted from the first light source is not limited. For example, the first light source may be a laser light source with different wavelengths or different polarization states, a wide-spectrum light
20 source with different wavelengths or different polarization states, or the like.

[0038] Correspondingly, the first functional light splitting element 110 is configured to

split the illumination light of each first light source to form non-coherent linear lights having different characteristics. The illumination light may be splitted to form non-coherent linear lights having different wavelengths or different polarization states. Referring to FIG. 2, the first functional light splitting element 110 in this embodiment may specifically be implemented as a dichroic mirror or a polarization light splitting element. The polarizing light splitting element may specifically be a polarization light splitting prism or a polarization light splitter. The dichroic mirror may specifically be implemented as a light splitting element such as a short-wave pass dichroic mirror, a long-wave pass dichroic mirror, a multi-band dichroic mirror, or the like. The short-wave pass dichroic mirror may have high transmittance for light below a cutoff wavelength and high reflectivity for light above the cutoff wavelength. The long-wave pass dichroic mirror may have high transmittance for light above a starting wavelength and high reflectivity for light below the starting wavelength. The multi-band dichroic mirror may have three or more transmission or reflection bands. For example, the multi-band dichroic mirror may have high transmittance for a band between the cut-off wavelength and the starting wavelength and high reflectivity for other bands.

[0039] The above specific examples are merely illustrative of the first functional light splitting element 110. In other embodiments, any element capable of reflecting and transmitting two beams of light having different wavelengths (or polarization states) originating from a reflective surface and a transmissive surface of the functional light splitting element, respectively, and then emitting the reflected and transmitted light along

the same direction towards the test object is acceptable.

[0040] It should be emphasized that, the first functional light splitting element 110 in the present invention may be different from a common light splitting prism or light splitter. The common light splitting prism or light splitter may only have a single light splitting
5 function, and lack the characteristic of selectively reflecting or transmitting light of different wavelengths or polarization states. In contrast, the first functional light splitting element 110 in the present invention is capable of reflecting and transmitting at least two beams of light with different characteristics, causing the light to exit along the same direction without interference (or with low coherence). Thus, the test object can be detected simultaneously
10 by using the generated two non-coherent linear light, and the detection efficiency can be improved.

[0041] The number of first image collectors may be one or more, for example, including a first industrial camera, a second industrial camera, and the like. The type of the first image collector is not unique, and may be a linear-array camera, a planar-array camera, or the like.
15 When a single first image collector is provided, the reflected image of the at least two non-coherent linear lights may be collected by the first image collector. When a plurality of first image collectors are provided, reflected images of one or more line lights with different characteristics may be collected by each of the plurality of first image collectors. In this embodiment, a plurality of first image collectors are used to collect linear lights of different
20 wavelengths/polarization states separately, so that better imaging can be achieved.

[0042] The control module may be connected to an object carrying platform for

supporting the imaging module and the test object. The control module may be configured to control the object carrying platform to drive the test object to move along the preset scanning path to generate displacement (i.e., preset step displacement), and control the imaging module to perform exposure and image collection, thereby obtaining
5 attention-region images on the test object. An attention-region image refers to an image obtained by performing image collection on an attention region on the test object in each cycle. Specifically, the attention region may be determined according to a field of view (FOV) of the first image collector. For example, when the first image collector is implemented as a linear-array camera, the FOV of the first image collector may include $1 \times n$
10 or $2 \times n$ pixel areas. In this case, the attention region may be set to have a size of m or $m/2$ FOVs. When the first light source flashes once or remains constantly on in each cycle, the linear-array camera may perform multiple exposures to acquire images of all $m \times n$ pixels of the attention region for the cycle, thereby obtaining the attention-region image. When the first image collector is implemented as a planar-array camera, the FOV of the first image
15 collector is relatively large (which may be understood as approximately square). However, in general triangulation measurements, the shape of each frame of image is a strip-like region of interest corresponding to the shape of the linear light. To ensure continuity of the strip-like region of interest, the preset step displacement may be generally less than the FOV width in the displacement direction, resulting in overlap between two consecutive FOVs. In
20 this scenario, a strip-like region of interest (ROI) area containing linear light may be selected in the FOV as the attention region, and scanning may proceed sequentially based

on this ROI area. That is, in an ROI scanning mode, attention regions may or may not be overlapped. It can be understood that if the first image collector is a common linear-array camera, the attention region may be a region formed by stitching a plurality of exposure images within one cycle. If the first image collector is a TDI (time delay integration) camera,
5 the attention region may also be an FOV region or an ROI region of the TDI camera.

[0043] When each first light source flashes once within one cycle, the control module may be configured to control each first image collector to perform one or more exposures, collecting the reflected image of the non-coherent linear light on the surface of the test object to obtain the attention-region image for the cycle, thereby capturing surface feature
10 information of the test object in real time. Different heights of the surface of the test object can be analyzed by combining the attention-region images collected from different cycles. By using a plurality of first light sources to provide illumination and utilizing the first functional light splitting element 110 to split the illumination light from each first light source to form non-coherent linear lights with different characteristics, image information
15 of these non-coherent linear lights with different characteristics can be captured on the surface of the test object, and thus more detailed and accurate images can be acquired.

[0044] In addition, the control module is further configured to determine three-dimensional height information of the test object in the current attention region based on reflected image information of the linear light in the attention-region image. Furthermore,
20 a complete image of the test object can be formed by sequentially stitching adjacent attention regions (as shown in FIG. 4). The complete image of the test object can be used

for analyzing three-dimensional height information, two-dimensional size information, or the like of the surface of the test object. Since the imaging module 200 in the present invention is configured to collect the reflected images of at least two non-coherent linear lights as the attention-region images for one cycle simultaneously, regardless of whether the optical paths of the at least two non-coherent linear lights are different or coincide, a current attention-region images (or an attention-region image for the cycle) may contain reflected image information of the at least two non-coherent linear lights simultaneously. The control module may be further configured to analyze and process the reflected images of a plurality of non-coherent linear lights in each attention-region image to accomplish topography or size reconstruction. It can be seen that, under the same scanning time and/or when the same number of attention-region images are acquired, more or richer surface information of the test object can be acquired in the present invention (as shown in the second solution and the third solution of FIG. 7) compared to the related art (as shown in FIG. 9). In addition, under the same scanning area of the test object, the scanning speed can be increased by at least double (time can be reduced by at least half) in the present invention (as shown in the first solution of FIG. 7) compared to that in the related art (as shown in FIG. 9).

[0045] Referring to FIG. 2, the illumination module 100 may further include a first lens 120 and a first microscope objective 130 in an embodiment. The first functional light splitting element 110, the first lens 120, and the first microscope objective 130 may be sequentially arranged along an optical path. Non-coherent linear lights output from the first functional light splitting element 110 may be incident on the surface of the test object after

passing through the first lens 120 and the first microscope objective 130.

[0046] Referring to FIGs. 1 and 2, the illumination module 100 may further include a first housing 101. A first functional light splitting element 110 and a first lens 120 may be disposed in the first housing 101. The first housing 101 may be provided with fiber
5 mounting interfaces, such as a fiber mounting interface a and a fiber mounting interface b, which are respectively connected to corresponding first light sources via fibers. Furthermore, the illumination module 100 may further include a first objective lens converter 140 disposed on the first housing 101. There are a plurality of first microscope objectives 130 having different magnifications, and the first microscope objectives 130 are disposed on the
10 first objective lens converter 140. The first objective lens converter 140 may drive the first microscope objectives 130 to rotate relative to the first housing 101. An infinity correction optical system may be formed by the combination of the first lens 120 and the first microscope objectives 130 in the illumination module 100. The first microscope objectives 130 having different magnification can also be reasonably selected and combined as
15 required to optimize illumination. A line width of the illumination from the first light source can be changed by the first microscope objectives 130, thereby achieving a zoom function for imaging illumination.

[0047] Referring to FIGs. 2 and 3, the illumination module 100 may further include slit elements 150 disposed between the first functional light splitting element 110 and the first
20 light sources. The illumination light emitted from each first light source may pass through corresponding one of the slit elements 150 to form linear light to be output to the first

functional light splitting element 110. Specifically, each of the slit elements 150 may be implemented as a grating plate. The slit elements 150 may be disposed between the fiber mounting interfaces and the first functional light splitting element 110. The illumination light may be transmitted from the first light sources to the fiber mounting interfaces via the
5 fiber. After passing through the slit elements 150 at different slit positions, light spots become narrow line shapes, forming two lines of rays. These two lines of rays pass through the first functional light splitting element 110 with functional selectivity, being splitted into two lines of linear lights with different spectra or different polarization states.

[0048] A slit of each of the slit elements 150 may be adjustable in position along a
10 width direction, so that optical paths of the at least two non-coherent linear lights are different or coincide. By adjusting positions of two slits on a slit element 150 along a width direction of the slit element 150, relative positions of emitted linear lights at an object side of the illumination module 100 can be changed. Consequently, a spacing in the width direction of the linear lights at an image side of the illumination module 100 (i.e., the linear
15 lights projected onto the test object) can be changed to a suitable range. The distance between the two slits on the slit element 150 can be adjusted according to actual conditions, and the optical paths of the generated two lines of linear lights can be changed to satisfy different testing requirements. It can be understood that the positions of the slit elements 150 are not unique. Since diverging light from the first light sources maintains divergent
20 characteristics after passing through the first functional light splitting element 110, the slit elements 150 may be disposed anywhere along an optical axial direction after the first light

source (A or B) and before the first lens 120. In other embodiments, the slit elements 150 may also be disposed between the first functional light splitting element 110 and the first lens 120 (specifically, a tube lens with a collimating effect), and the optical paths of the non-coherent linear lights may also be different or coincide by adjusting the slit elements

5 150. Specifically, referring to FIGs. 2 and 3, two slit elements 150 may be implemented as a grating plate A and a grating plate B with linear slits. It can be seen that alternative positional arrangements for the grating plate A and the grating plate B at least include: a first solution that the grating plate A may be located between the light source A and the first functional light splitting element 110, and the grating plate B may be located between the

10 first functional light splitting element 110 and the first lens 120; a second solution that the grating plate A may be located between the first functional light splitting element 110 and the first lens 120, and the grating plate B may be located between the light source B and the first functional light splitting element 110; and a third solution that both the grating plate A and the grating plate B may be located between the first functional light splitting element

15 110 and the first lens 120. In the above alternative first to third solutions, the grating plate A and the grating plate B may be arranged in a staggered manner in a direction perpendicular to an optical axis, to prevent one grating plate (A or B) from blocking the slit path of the other grating plate (B or A). In the alternative first and second solutions, the positions of the grating plate A and the grating plate B are different, and by default, the slits on the

20 respective grating plates are independently arranged. The alternative third solution may further include in detail: third-1 sub-solution that each of the grating plate A and the grating

plate B may be provided with a slit and the positions of the two linear light spots may be different or coincident by adjusting the relative distance between the grating plate A and the grating plate B in the width direction; and third-2 sub-solution that the grating plate A may be provided with a slit, the grating plate B may be provided with two slits, the grating plate

5 A and the grating plate B may be both arranged on a grating switcher, and a target grating plate can be switched into either or both of an illumination light path and an imaging light path by rotating or translating the grating switcher (similar to that the target objective lens can be switched into the light path to participate in illumination and/or imaging by rotating the objective lens converter), enabling direct switching of the two lines of linear light spots

10 at different positions (corresponding to the grating plate B being in the light path and the grating plate A being out of the light path) or coincident (corresponding to the grating plate A being in the light path and the grating plate B out of the light path). The advantages of the original solution (the solution shown in FIG. 2 and FIG. 3) and the alternative first and second solutions are that the grating plates are separately and independently arranged and

15 have sufficient adjustment space, which is convenient for the user to operate. The advantage of the alternative third-1 sub-solution is that the relative distance between the grating plates is directly adjusted without the grating switcher required in the third-2 sub-solution, which avoids the redundancy of optical elements. The advantage of the alternative third-2 sub-solution is that the grating plate A and the grating plate B are both located on a same

20 plane and both on a focal plane, which can form an optimal conjugate relationship, and the light spot configuration required by the user can be achieved by simple switching. The above

solutions can be selected or switched by the user according to actual detection requirements or operating conditions. Other variable scenarios will not be described in detail.

[0049] Referring to FIG. 2, the number of the first image collectors may be two or more than two in an embodiment. The imaging module 200 may further include a second functional light splitting element 210. The second functional light splitting element 210 may be configured to transmit or reflect the linear light reflected from the test object, and then the linear light may be splitted into non-coherent linear lights with different characteristics. The non-coherent linear lights may be transmitted to the corresponding first image collector. The second functional light splitting element 210 may also be implemented as a light splitting element such as a dichroic mirror or a polarization light splitting element. The functions of the second functional light splitting element 210 may be substantially the same as those of the first functional light splitting element 110, except that the second functional light splitting element 210 is configured to split two beams of non-coherent linear lights with different characteristics from the same direction and transmits the two beams of non-coherent linear lights to the corresponding first image collector. Different materials have different spectral responses at different wavelengths and have different polarization reflection characteristics. For different material features of the surface of the test object, the first functional light splitting element 110 and the second functional light splitting element 210 each having functional selectivity may be used in the illumination module 100 and the imaging module 200. Thus, rays with different spectra or different polarization states may be selectively splitted from the illumination light and the imaging light, so that light spots

irradiated on the surface of the test object may be linear or strip-shaped. This facilitates relatively quick and accurate acquisition of depth information of surface features of the test object, thereby enabling multi-spectral detection or polarization imaging detection. Consequently, richer and clearer feature images can be obtained, allowing for more accurate
5 extraction of detailed information from complex backgrounds.

[0050] Furthermore, the imaging module 200 may further include a second lens 220 and a second microscope objective 230. The second microscope objective 230, the second lens 220, and the second functional light splitting element 210 may be sequentially arranged along an optical path. The linear light reflected from the test object may be transmitted to
10 the second functional light splitting element 210 through the second microscope objective 230 and the second lens 220 for transmission or reflection, and to be splitted into non-coherent linear lights having different characteristics and transmitted to the corresponding first image collector. An infinity correction optical system may be formed by the combination of the second microscope objective 230 and the second lens 220. The
15 number of pixels on the industrial camera corresponding to the linear light imaging may be changed by the second microscope objective 230. In this way, the imaging can be optimized, more detailed and accurate images can be acquired, and the detection precision of the whole system can be improved.

[0051] In addition, the imaging module 200 may further include a second housing 201.
20 The second lens 220 and the second functional light splitting element 210 may be disposed in the second housing 201, and the first image collector may be disposed on the second

housing 201. As shown in FIG. 1, the imaging module 200 may further include a second objective lens converter 240 disposed on the second housing 201. A plurality of second microscope objectives 230 may be provided, and the second microscope objectives 230 may have different magnifications. Each of the second microscope objectives 230 may be
5 disposed on the second objective lens converter 240, and may be driven by the second objective lens converter 240 to rotate relative to the second housing 201. The second microscope objectives 230 having different magnifications can be reasonably selected and combined as required to optimize imaging, thereby ensuring optimal imaging accuracy and resolution.

10 [0052] The illumination module 100 and the imaging module 200 may be provided with a plurality of microscope objectives having different magnifications, respectively. The corresponding objective lens converters may be used to achieve illumination and imaging with different magnifications. For structural features of varying sizes on the surface of the test object, microscopic objective lenses having different magnifications can be reasonably
15 selected and combined to optimize imaging and illumination, thereby ensuring optimal imaging accuracy and resolution.

[0053] In an embodiment, taking the case where the first functional light splitting element 110 and the second functional light splitting element 210 are configured as the dichroic mirrors as an example, the first light sources may be laser sources or
20 wide-spectrum light sources of different wavelengths. Referring to FIGs. 1 to 3, in the illumination module 100, the illumination fibers may be provided in the fiber mounting

interface a and the fiber mounting interface b, respectively. Meanwhile, the slit elements 150 may be provided between the fiber mounting interface a, the fiber mounting interface b and the first functional light splitting element 110, respectively. The two slit elements 150 may have different slit positions. In addition, the two slit elements 150 may have the same slit width different slit widths, or slit widths that can be selected based on the characteristic sizes of the surface of the test object. The illumination light emitted from the first light source A and the illumination light emitted from the first light source B may be guided into the first housing 101 via the illumination fibers. In this process, two lines of linear lights may be formed by the light passing through the slit elements 150 at different slit positions.

These two lines of linear lights may be splitted by the dichroic mirror into two lines of linear lights of different spectra. These two lines of linear lights, after magnification through the combination of the first lens 120 and the first microscope objective 130, may irradiate the same attention region on the surface of the test object, forming two lines of different field-of-view detection, as shown by the linear light WL1 and the linear light WL2 in FIG. 4.

After being reflected by the surface of the test object, the two lines of illumination linear lights may enter the second microscope objective 230 and the second lens 220 in the imaging module 200 for magnification again, and then may be selectively splitted by the dichroic mirror. In this way, the linear light WL1 may be imaged onto the first industrial camera, and the linear light WL2 may be imaged onto the second industrial camera, thereby achieving simultaneous dual-field-of-view imaging detection.

[0054] In another embodiment, taking the case where the first functional light splitting

element 110 and the second functional light splitting element 210 are polarization light splitting prisms as an example, the first light sources may be laser sources or wide-spectrum light sources having different polarization states. If the test object is a polarization-maintaining material, image contrast and color saturation can be enhanced by using polarization imaging detection, specific structures or features can be more effectively highlighted, and imaging quality can be improved. Similarly referring to FIGs. 1 to 3, in the illumination module 100, the illumination fibers may be provided in the fiber mounting interface a and the fiber mounting interface b, respectively. Meanwhile, the slit elements 150 may be provided between the fiber mounting interface a, the fiber mounting interface b, and the first functional light splitting element 110, respectively. The two slit elements 150 may have different slit positions. In addition, the two slit elements 150 may have the same slit width different slit widths, or slit widths that can be selected based on the characteristic sizes of the surface of the test object. The illumination light emitted from the first light source A and the illumination light emitted from the first light source B may be guided into the first housing 101 via the illumination fibers. In this process, two lines of linear lights may be formed by the light passing through the slit elements 150 at different slit positions. These two lines of linear lights may be splitted by the polarization light splitting prism into two lines of linear lights having different polarization states: s-polarized light and p-polarized light. Then, these two lines of linear lights, after magnification through the combination of the first lens 120 and the first microscope objective 130, may irradiate the same attention region on the surface of the test object, forming two lines of different

field-of-view detection. After being reflected by the surface of the test object, the polarization states remain unchanged, the two lines of illumination linear light may enter the second microscope objective 230 and the second lens 220 in the imaging module 200 for magnification again, and then may be selectively splitted by the polarization light splitting prism. In this way, the linear light WL1 (s-polarized light) may be imaged onto the first industrial camera, and the linear light WL2 (p-polarized light) may be imaged onto the second industrial camera, and thus simultaneous dual-field-of-view imaging detection can be achieved.

[0055] In the above two embodiments, by using laser sources or wide-spectrum light sources having different wavelengths or different polarization states as illumination light sources, and adapting dichroic mirrors or polarization light splitting prism having different functionalities, two lines of linear lights having different spectra or different polarization states may be splitted. This enables more effective identification and analysis of structural features of the surface of the test object. These two lines of linear lights may irradiate the same attention region on the surface of the test object to form two lines of different field-of-view detection. The illumination linear light emitted from the first light source A may be denoted as WL1, which is captured and imaged by the first industrial camera. The illumination linear light emitted from the first light source B may be denoted as WL2, which is captured and imaged by the second industrial camera. In this way, simultaneous dual-field-of-view imaging can be achieved, and thus visual angle blind area can be reduced, a larger viewing angle range can be covered, the overall coverage rate of the system can be

improved, and the detection speed can be increased significantly. After being reflected by the surface of the test object, the two lines of linear lights may enter the imaging module 200. The industrial camera in the imaging module 200 may be implemented as a linear-array camera with a high frame rate or a planar-array cameras in ROI mode. The two
5 industrial cameras may be configured to capture image information within different spectra or different polarization state ranges simultaneously, acquiring global information of the surface of the test object in real time at a high speed. This enables a high-speed linear scanning functionality, avoiding image blur issues caused by high-speed object movement.

[0056] It can be understood that the manner in which the control module controls the
10 movement of the test object and control the image collection of the imaging module may be not unique. In an embodiment, the control module may be configured to control the imaging module 200 to perform image collection with exposure according to a set period. Furthermore, the control module may be configured to control a displacement of the test object along the preset scanning path within the set period to be consistent with a width of
15 an attention region onto which each of the at least two non-coherent linear lights may be incident on the test object along the preset scanning path, so that attention regions corresponding to each image collection are continuous and non-overlapping along the preset scanning path. The specific value of the set period may also be not unique, and can be set as required.

20 [0057] Specifically, if the slit elements 150 are adjusted so that the optical paths of the two non-coherent linear lights are different. That is, the images of the two linear lights on

the test object do not overlap. Compared to existing single-light-source illumination detecting solutions, the width of the attention region along the preset scanning path is increased by using dual-light-source illumination in the present invention, for example, doubling that of the single-light-source illumination solution. Referring to FIG. 8, assuming
5 that in the single-light-source illumination detecting solution, the light source A provides illumination, the step displacement of the test object in each cycle is denoted as S , and the first industrial camera performs image collection and data conversion processing in each cycle. In the present invention, to make the attention regions continuous and non-overlapping along the preset scanning path, the step displacement of the test object in
10 each cycle can be set to $2S$. Referring to FIG. 5, the two industrial cameras perform image collection and data conversion processing on the corresponding attention-region image in each cycle. Herein, stage may represent the object carrying platform supporting the test object, and the stage may control timing corresponding to the displacement timing of the test object. As shown in the first solution in FIG. 7, each black wireframe may represents an
15 attention region. Two first light sources may be used for illumination, optical paths of the generated two non-coherent linear lights may be different, and then image acquisition may be performed on continuous and non-overlapping attention regions along the preset scanning path, so that the detection speed can be improved compared to the related single-light-source illumination detecting solution. The solution in FIG. 9 is a schematic
20 diagram of image collection for attention regions of a test object by single-light-source illumination detection in the related art.

[0058] If the slit elements 150 are adjusted so that the optical paths of the two non-coherent linear lights coincide, which means that the two linear lights overlap on the test object. Compared to the existing single-light-source illumination detecting solution, the width of the attention region along the preset scanning path can be considered to remain unchanged by using double-light-source illumination in the present invention. Similarly, assuming that in the single-light-source illumination detecting solution, the step displacement of the test object in each cycle is denoted as S, the step displacement of the test object in each cycle as S may also be set as S in the present invention, as shown in FIG. 6. Referring to the third solution in FIG. 7, each black wireframe may represent an attention region. Two first light sources may be used for illumination, optical paths of two generated non-coherent linear lights may coincide, and then image collection may be performed on continuous and non-overlapping attention regions along the preset scanning path. Compared to the related single-light-source illumination detecting solution, the moving speed of the test object can maintain unchanged. However, the detecting accuracy can be improved by performing scanning and collecting on the same position of the test object with two different first light sources.

[0059] In an embodiment, the control module may be configured to control the imaging module 200 to perform image collection with exposure according to a set period, and the control module may be further configured to control a displacement of the test object along the preset scanning path within the set period to be less than a width of an attention region onto which each of the at least two non-coherent linear lights may be incident on the test

object along the preset scanning path, so that attention regions corresponding to each image collection are continuous and at least partially overlapping along the preset scanning path. It can be understood that, regardless of whether the optical paths of the plurality of non-coherent linear lights coincident or not by the slit element 150, the moving speed of the test object can be controlled so that the attention regions in each cycle may be continuous and at least partially overlapping along preset scanning path. For example, the attention regions may be half overlapped or less or more overlapped.

[0060] Specifically, taking the case where the optical paths of the non-coherent linear lights are different by the slit elements 150 as an example, that is, the images of the two linear light on the test object do not overlap. Compared to the existing single-light-source illumination detecting solution, the width of the attention region along the preset scanning path may be increased by using dual-light-source illumination in the present invention, for example, doubling that of the single-light illumination solution. It is also assumed that in the single-light-source illumination detecting solution, the step displacement of the test object in each cycle may be denoted as S , as shown in FIG. 8. Therefore, in order to enable the attention regions to be continuous and overlap along the preset scanning path, the step displacement of the test object in each cycle may be set to any value within $(0, 2S)$. As shown in the second solution in FIG. 7, each of the black wireframe and the gray wireframe may represent an attention region (the black wireframe and the gray wireframe in the figure may be only used to clearly show the overlap between two adjacent attention regions, and the color difference has no other limitation effect). The illumination may be performed by

using multiple light sources, the optical paths of the non-coherent linear lights may be different, and then image collection may be performed on partially overlapping attention regions along the preset scanning path.

[0061] In this embodiment, the at least two non-coherent linear lights may include a
5 first linear light and a second linear light arranged in parallel. A scanning region of the first linear light in a current attention region may be overlapped with a scanning region of the second linear light in a previous continuous attention region. Specifically, referring to the second solution in FIG. 7, the step displacement of the test object may be set to S , resulting in a half overlap between two consecutive attention regions. This allows rays of different
10 characteristics in two consecutive attention regions to illuminate the same position of the test object, which is equivalent to obtaining information by scanning a scanning region of each linear light twice under different wavelength bands or polarization states, leading to more accurate after image fusion. According to the above setting, each attention region can be considered as being scanned twice with different light sources. The scanning speed may
15 be the same as that of the single-light-source illumination detecting solution, and the detection accuracy can be effectively improved. It can be understood that, in other embodiments, the scanning region of the first linear light of the current attention region may also be located between the scanning regions of the two linear lights in the previous attention region. This may be equivalent to that the scanning regions of the linear lights of
20 the first, third, fifth, seventh, ninth, ..., attention regions may be overlapped, and the scanning regions of the linear lights of the second, fourth, sixth, eighth, tenth,..., attention

regions may be overlapped, which can also improve detection accuracy.

[0062] For the attention region represented by the gray frame in the second solution of FIG. 7, referring to FIG. 10, a scanning region of the first linear light (linear light WL1 region) in the second frame of attention region may be overlapped with a scanning region of the second linear light (linear light WL2 region) in the first frame of attention region, the scanning region of the first linear light (linear light WL1 region) in the third frame of attention region may be overlapped with the scanning region of the second linear light (linear light WL2 region) in the second frame of attention region, the scanning region of the first linear light (linear light WL1 region) in the fourth frame of attention region may be overlapped with the scanning region of the second linear light (linear light WL2 region) in the third frame of attention region, and the like. In the second solution, the scanning region of the first linear light in each frame image of attention region may be overlapped with the scanning region of the second linear light in the previous frame image of attention region. It may be noted that the direction of sequential image collection for the first, second, third, ..., frames in FIG. 10 may be opposite to the direction of the step displacement of the object carrying platform, the dotted line between WL1 and WL2 only represents the corresponding overlapping relationship and has no other special meaning, and the separation between the second, fourth frames and the first, third, fifth frames is for clarity and has no other special meaning.

[0063] In addition, the illumination module 100 may further include second image collectors, and the imaging module 200 may further include second light sources. In the

imaging module 200, the second functional light splitting element 210 may be configured to split the illumination light emitted from corresponding one of the second light sources into linear lights having different characteristics and transmit the linear lights to the test object along the same direction. In the illumination module 100, the first functional light splitting
5 element 110 may be configured to split the linear lights reflected from the test object to form linear lights having different characteristics and transmit the linear lights to corresponding one of the second image collectors. After the positions of the light sources and the image collectors are exchanged, the functions of the first functional light splitting element 110 and the second functional light splitting element 210 may also be exchanged.

10 [0064] Specifically, the second image collectors may be provided on the first housing 101 of the illumination module 100, or may be replaced at the positions of the fiber mounting interfaces. The fiber mounting interfaces may be provided on the second housing 201 of the imaging module 200, or may be replaced at the positions of the first image collectors. In this embodiment, the positions of the light sources and the industrial cameras
15 may be mutually adjusted and replaced according to different application requirements (for example, the positions of the first and second industrial cameras and the fiber mounting interfaces a and b may be mutually exchanged). By adjusting the positions of the light sources and the industrial cameras, the incident angle and distribution of light may be optimized, thereby improving definition and contrast of the image, reducing unnecessary
20 glare and reflections. This makes the system more flexible and efficient, capable of satisfying different application requirements, and enhances measurement accuracy and

image quality of the system.

[0065] The triangular optical measurement system according to the present invention has the following advantages.

[0066] First advantage: multi-spectral detection

5 [0067] The three-dimensional contour information of the surface of the test object may be analyzed by using lasers or wide-spectrum light sources with different wavelengths. The wavelength separation may be performed by using the wavelength selective light splitting elements (such as the dichroic mirrors). The light of different spectra, after being reflected by the surface of the test object, may simultaneously enter different industrial cameras for
10 imaging. Since different materials exhibit different spectral responses at various wavelengths, the reflection information of different materials at different wavelengths can be effectively distinguished through the multi-spectral detection, and thus richer surface characteristic information of the test object can be obtained.

[0068] Second advantage: polarization imaging detection

15 [0069] The three-dimensional contour information of the surface of the test object may be analyzed by using lasers or wide-spectrum light sources with different polarization states. The polarization state separation may be performed by using light splitting elements, such as the polarization light splitting prisms, with polarization state selectivity. The light of different polarization states, after being reflected by the surface of the test object, may
20 simultaneously enter different industrial cameras for imaging. Since different materials have different polarization reflection characteristics, the image contrast and color saturation can

be effectively enhanced through the polarization imaging detection, specific structures or features can be more effectively highlighted, and the imaging quality can be improved.

[0070] Third advantage: high speed detection

[0071] Lasers or wide-spectrum light source with different wavelengths or different polarization states may be used as the illumination light sources. Two lines of linear lights may be formed by the light passing through the slit elements at different slit positions, and splitted into two lines of linear lights with different spectra or different polarization states by light splitting elements with functional selectivity (such as the dichroic mirrors and the polarization splitting prisms). The two lines of linear lights irradiate the same attention region on the surface of the test object to form two lines of different field-of-view detection, so that simultaneous dual-field-of-view imaging can be achieved. In this way, visual angle blind area can be reduced, a larger viewing angle range can be covered, the overall coverage rate of the system can be improved, and the detection speed can be increased significantly. After being reflected by the surface of the test object, the two lines of linear lights may enter an imaging end, which employs high-frame-rate linear-scan cameras or area-scan cameras in ROI mode. The imaging end adopts the linear-array camera with the high frame rate or planar-array camera in ROI mode. The two industrial cameras may be configured to simultaneously capture image information within different spectra or different polarization state ranges, so that global information of the surface of the test object can be obtained in real time at a high speed.

[0072] Fourth advantage: high flexibility and scalability

[0073] In semiconductor detection, different materials need to be detected by using the light sources with different wavelengths or different polarization states due to their physical and chemical properties. The method according to the present invention has a highly flexible and scalable architecture, allowing for quick adjustment and expansion system functions according to different application requirements. For example, in combination with the optical characteristics of different surface materials of the test object and the specific target to be detected, the illumination module may be configured to select appropriate light sources, and the imaging module may be configured to selectively assemble light splitting elements (such as dichroic mirrors or polarization light splitting prisms) with different functions, so that the structural features of the surface of the test object can be more effectively identified and analyzed. In addition, the positions of the light sources and the industrial cameras in the present invention may be adjusted and replaced with each other (for example, the positions of the first industrial camera and the fiber mounting interface b may be exchanged with each other). By adjusting the positions of the light sources and the cameras, the incident angle and distribution of the light may be optimized, thereby improving the definition and contrast of the image, reducing unnecessary glare and reflections. This makes the system more flexible and efficient, capable of satisfying different application requirements, and improves the measurement accuracy and image quality of the system.

20 [0074] Fifth advantage: high-accuracy detection

[0075] The imaging module and the illumination module use microscope objectives

with different magnification for illumination and imaging, and the optical characteristics of the microscope objective, such as magnification, numerical aperture (NA), and transmittance may affect the overall imaging quality and detection accuracy. In combination with structural features of different sizes on the surface of the test object, the microscopic
5 objective lenses with different magnification may be reasonably selected and combined to optimize imaging and illumination. In this way, the linear light width of the illumination light source and the number of pixels corresponding to linear light imaging onto an industrial camera may be changed, so that more detailed and accurate images can be obtained, and the detection accuracy of the entire system can be improved.

10 [0076] The various technical features of the embodiments described above can be combined arbitrarily. In order to make the description concise, not all possible combinations of the technical features in the above embodiments have been described. However, any combination of these technical features should be considered as within the scope recorded in this description, provided that no contradiction exists.

15 [0077] The above embodiments only express several implementations of the present invention, and the description thereof is relatively specific and detailed. However, this should not be construed as limiting the patent scope of the present invention. It should be noted that, for those skilled in the art, several modifications and improvements may be made without departing from the concept of the present invention, which all fall within the
20 protection scope of the present invention. Therefore, the protection scope of the present invention shall be defined by the appended claims.

CLAIMS

What is claimed is:

1. A triangular optical measurement system, characterized by comprising an illumination module and an imaging module,
 - 5 wherein the illumination module comprises a first functional light splitting element and at least two first light sources, the first functional light splitting element is configured to split illumination light emitted from the at least two first light sources to form at least two non-coherent linear lights having different characteristics, which are incident along a same direction onto a surface of a test object;
 - 10 the imaging module is configured to collect reflected light of the at least two non-coherent linear lights for imaging; and
 - the illumination module further comprises slit elements, and a slit of each of the slit elements is adjustable in position along a width direction, so that optical paths of the at least two non-coherent linear lights are different or coincident.
- 15
2. The system of claim 1, wherein the imaging module comprises at least one first image collector configured to simultaneously collect reflected images of the at least two non-coherent linear lights as attention-region images for one cycle; and
- the system further comprises a control module configured to periodically collect
- 20 attention-region images on the test object when the test object is displaced along a preset scanning path.

3. The system of claim 2, wherein the control module is configured to control the imaging module to perform image collecting with exposure according to a set period, and the control module is further configured to control a displacement of the test object along the preset scanning path within the set period to be consistent with a width of an attention region onto which each of the at least two non-coherent linear lights is incident on the test object along the preset scanning path, so that attention regions corresponding to each image collection are continuous and non-overlapping along the preset scanning path.
4. The system of claim 2, wherein the control module is configured to control the imaging module to perform image collection with exposure according to a set period, and the control module is further configured to control a displacement of the test object along the preset scanning path within the set period to be less than a width of an attention region onto which each of the at least two non-coherent linear lights is incident on the test object along the preset scanning path, so that attention regions corresponding to each image collection are continuous and at least partially overlapping along the preset scanning path.
5. The system of claim 4, wherein the at least two non-coherent linear lights comprises a first linear light and a second linear light arranged in parallel; a scanning region of the first linear light in a current attention region overlaps with a scanning region of the second linear light in a previous continuous attention region.

6. The system of any one of claims 1 to 5, wherein the first functional light splitting element is configured to split the illumination light to form non-coherent linear lights having different wavelengths or different polarization states.

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7. The system of claim 6, wherein each of the slit elements is disposed between the first functional light splitting element and corresponding one of the at least two first light sources, and the illumination light emitted from each of the at least two first light sources passes through corresponding one of the slit elements to form a linear light output to the first
10 functional light splitting element.

8. The system of any one of claims 2 to 5, wherein a number of the at least one first image collector is two or more than two, the imaging module further comprises a second functional light splitting element, and the second functional light splitting element is
15 configured to transmit or reflect linear lights reflected from the test object, to split non-coherent linear lights having different characteristics and transmit the non-coherent linear lights to corresponding one of the at least one first image collector.

9. The system of claim 8, wherein the illumination module further comprises a first lens and
20 a first microscope objective, the first functional light splitting element, the first lens, and the first microscope objective are sequentially arranged along an optical path, and non-coherent

linear lights output from the first functional light splitting element are incident onto the surface of the test object after passing through the first lens and the first microscope objective.

5 10. The system of claim 8, wherein the imaging module further comprises a second lens and a second microscope objective, the second microscope objective, the second lens, and the second functional light splitting element are sequentially arranged along an optical path, and the linear lights reflected from the test object is transmitted to the second functional light splitting element through the second microscope objective and the second lens for
10 transmission or reflection, and to be splitted into non-coherent linear lights having different characteristics and transmitted to corresponding one of the at least one first image collector.

11. The system of claim 8, wherein the first functional light splitting element is configured as a dichroic mirror or a polarization light splitting element, and the second functional light
15 splitting element is configured as a dichroic mirror or a polarization light splitting element.

12. The system of claim 8, wherein the illumination module further comprises second image collectors, and the imaging module further comprises second light sources; in the imaging module, the second functional light splitting element is configured to split illumination light
20 emitted from corresponding one of the second light sources into linear lights having different characteristics and transmit the linear lights to the test object; and in the

illumination module, the first functional light splitting element is configured to split the linear lights reflected from the test object to form linear lights having different characteristics and transmit the linear lights to corresponding one of the second image collectors.