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United States Patent Application Publication	20250258219
Kind Code	A1
Publication Date	August 14, 2025
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ALIGNING CONNECTORS IN A TEST SYSTEM

Abstract

An example test system includes a probe card configured to contact a device under test (DUT); a module including a first optical connector configured to contact a second optical connector on the DUT, with the first optical connector being for a fiber optic cable; and a motion system configured to move into, and out of, contact with the module. When the motion system is in contact with the module, the motion system is configured to move the module relative to the DUT in order to align the first optical connector to the second optical connector.

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Appl. No.: **18/440167**

Filed: **February 13, 2024**

Publication Classification

Int. Cl.: **G01R31/28** (20060101); **G01R1/073** (20060101)

U.S. Cl.:

CPC **G01R31/2891** (20130101); **G01R1/07342** (20130101); **G01R31/2887** (20130101);

Background/Summary

TECHNICAL FIELD

[0001] This specification describes example implementations of systems and processes for aligning connectors in a test system.

BACKGROUND

[0002] A test system is configured to test the operation of a device. A device tested by a test system is referred to as a device under test (DUT). An example of a type of DUT that may be tested using a test system is a silicon photonic device (SPD). An example SPD is a device manufactured on a silicon chip or wafer, which is configured to produce, to manipulate, and/or to detect light.

SUMMARY

[0003] An example test system includes a probe card configured to contact a device under test (DUT); a module including a first optical connector configured to contact a second optical connector on the DUT, with the first optical connector being for a fiber optic cable; and a motion system configured to move into, and out of, contact with the module. When the motion system is in contact with the module, the motion system is configured to move the module relative to the DUT in order to align the first optical connector to the second optical connector. The test system may include one or more of the following features, either alone or in combination.

[0004] The motion system may be configured for electrical control or for pneumatic control. The motion system may include robotics configured to operate in multiple degrees of freedom. The motion system may be configured to move the module so as to move the first optical connector by single-digit millimeters or by less than one millimeter. The module may include a first plate. The first plate may include indentations. The motion system may include a motor and a second plate. The second plate may include protrusions configured to engage the indentations to enable movement of the module relative to the probe card and the DUT. The motion system may be configured to move the module towards or away from the probe card to cause the protrusions to engage to, or to disengage from, the indentations. The first plate may include three indentations and the second plate may include three protrusions to engage respective ones of the three indentations. A cross-section of the module may be substantially "T" shaped.

[0005] The test system may include one or more springs between the first plate and the probe card. The one or more springs may bias the first plate above the probe card and enable movement of the module in multiple degrees of freedom.

[0006] The probe card may include a probe head. The probe head may include electrical connections configured to contact corresponding electrical connections on the DUT. The fiber optic cable may route through the module. The test system may include a test instrument configured to test the DUT through the fiber optic cable and the first optical connector. The fiber optic cable may include a second connector configured to connect to, and to disconnect from, a backplane of the test system.

[0007] The module may include a first plate. The motion system may include a motor and a second plate. The first plate and the second plate may be magnetically attracted to each other to create connection of the first plate and the second plate in order to enable movement of the module relative to the probe card and the DUT. The first plate and the second plate may include components to implement a mechanical latch to hold the first plate and the second plate together in order to enable movement of the module relative to the probe card and the DUT. At least one of the first plate or the second plate may include a suction device configured to apply suction to hold the first plate and the second plate together in order to enable movement of the module relative to the probe card and the DUT.

[0008] The first optical connector may include silicon in which one or more optical structures are set. The first optical connector may include glass in which one or more optical structures are set.

[0009] The test system may include a control system configured to execute a test program to control movement of the motion system to control movement of the module relative to the probe

card and the DUT. The DUT may include a semiconductor wafer or a semiconductor package. The motion system may be configured to move the module in six degrees of freedom. The motion system may be configured to move the module in degrees of freedom, which include: forward/backward, up/down, left/right, yaw, pitch, and roll.

[0010] The test system may include multiple instances of the module. Each instance of the module may be for aligning a respective first optical connector to a respective second optical connector on a respective DUT. The motion system may be configured to move into contact with each instance of the module and to move each instance of the module relative to the respective DUT.

[0011] The test system may include multiple instances of the module. Each instance of the module may be for aligning a respective first optical connector to a respective second optical connector on a respective DUT. The test system may include multiple instances of the motion system. Each instance of motion system may be configured to move into contact with each respective instance of the module and to move each respective instance of the module relative to the respective DUT.

[0012] An example method is performed on a test system. The method incudes the following operations: causing a motion system to come into contact with a module, where the module includes a first optical connector configured to contact a second optical connector on a DUT, and where movement of the motion system is automated; controlling the motion system to cause the first optical connector to align to the second optical connector and to contact the second optical connector; and testing the DUT though a fiber optic path that includes the first optical connector and the second optical connector. The method may include one or more of the following features either alone or in combination.

[0013] Controlling the motion system may be performed to move the module so as to move the first optical connector by single-digit millimeters or by less than one millimeter. Controlling the motion system may be performed to move the module in six degrees of freedom relative to the DUT.

[0014] Any two or more of the features described in this specification, including in this summary section, may be combined to form implementations not specifically described in this specification.

[0015] At least part of the devices, circuitry, systems, techniques, and processes described in this specification may be implemented or controlled by executing, on one or more processing devices, instructions that are stored on one or more non-transitory machine-readable storage media. Examples of non-transitory machine-readable storage media include read-only memory, an optical disk drive, memory disk drive, and random access memory. At least part of the devices, circuitry, systems, techniques, and processes described in this specification may be implemented or controlled using a computing system comprised of one or more processing devices and memory storing instructions that are executable by the one or more processing devices to perform various control operations. The devices, circuitry, systems, techniques, and processes described in this specification may be configured, for example, through design, construction, composition, arrangement, placement, programming, operation, activation, deactivation, and/or control.

[0016] The details of one or more implementations are set forth in the accompanying drawings and the following description. Other features and advantages will be apparent from the description and drawings, and from the claims.

Description

DESCRIPTION OF THE DRAWINGS

[0017] FIG. **1** is a block diagram of an example test system configured to align an optical connector on the test system to an optical connector on a device under test (DUT).

[0018] FIG. **2** is a partial, cross-sectional, perspective view of components included in an example implementation of the test system of FIG. **1**.

[0019] FIG. **3** is a bottom, perspective view of components included in an example probe head in an example implementation of the test system of FIG. **1**.
[0020] FIG. **4** is a partial, top view of components included in an example probe card in an example implementation of the test system of FIG. **1**
[0021] FIG. **5** is a top, perspective view of components included in an example probe card in an example implementation of the test system of FIG. **1**.
[0022] FIG. **6** is a block diagram of another implementation of example test system configured to align an optical connector on the test system to an optical connector on a DUT.
[0023] FIG. **7** is a block diagram of another implementation of example test system configured to align an optical connector on the test system to an optical connector on a DUT.
[0024] FIG. **8** is a flowchart containing operations included in an example process for aligning optical connectors on a test system and on a DUT.
[0025] FIG. **9** is a block diagram of an example test system configured to incorporate the components shown in FIGS. **1** to **8**.
[0026] Like reference numerals in different figures indicate like elements.

DETAILED DESCRIPTION

[0027] In testing of silicon photonic devices (SPDs), optical test fibers may need to be aligned to the SPD to micron to submicron precision for optical tests to be accurate. This may be accomplished by moving the optical fibers relative to the SPD while recording input or output optical power, and moving to the point with the highest optical power. In some cases, the SPD has to make electrical contact to the tester before optical alignment, and neither the SPD nor the tester can move laterally after electrical contact is made without risking damage to the electrical connections, so the optical subsystem moves relative to the tester and SPD. An issue is that all SPDs have similar requirements for a motion system, but some SPDs may have different spacing of fibers (e.g., a 250 micron (μm) pitch or a 127 μm pitch) or different arrangements of input and output fibers. It may be useful to change the arrangement of fibers when testing a different DUT, while re-using the same motion system. This means that a reliable coupling should be made between the tester and the optical subsystem whenever the probe card is changed. Examples of such coupling systems are described herein.
[0028] More generally, described herein are example implementations of systems and processes configured to test optical devices, such as SPDs. An SPD may be or include a device manufactured on a silicon chip or wafer, which is configured to produce, to manipulate, and/or to detect light. Examples of SPDs may include, but are not limited to, laser diodes, light-emitting diodes (LEDs), solar and photovoltaic cells, displays, fiber optic transceivers, and optical amplifiers. An SPD that is being tested, or that is to be tested, by a test system is a device under test (DUT).
[0029] An example SPD includes an optical connector, which is referred to as the “SPD optical connector”. The SPD optical connector may optically connect to optical components on the SPD, such as one or more optical fibers or waveguides. The SPD optical connector may be part of an optical-electrical interface, which also electrically connects to electrical components on the SPD, such as an LED. The SPD optical connector is configured to connect to an optical connector of a test system, which is referred to as the “tester optical connector”. Connection between the SPD optical connector and the tester optical connector creates an optical path over which optical signals can pass between the SPD and the test system. Optical signals from the test system to the SPD may be used to test the SPD. For example, the intensity, polarity and/or wavelength of optical signals may represent data to be processed by the SPD or may represent parameters of voltage or current to be applied to the SPD, for example, to illuminate an LED. Optical signals from the SPD to the test system may represent data or parameters that are produced by operation the SPD, including in response to received signals to test the SPD.
[0030] SPD optical connectors for different DUTs may be at different locations. The systems and processes described herein are therefore used to move the tester optical connector relative to the

SPD in order to align the tester optical connector to the SPD optical connector. The systems and processes described herein may be used to finely align the tester optical connector relative to the SPD optical connector. For example, a probe card containing the tester optical connector may also connect electrically to the SPD. Deviations in placement of the SPD optical connector relative to these electrical connections may be accounted for by moving the tester optical connector relative to the SPD to align the tester optical connector to the SPD optical connector. In some implementations, alignments of the tester optical connector to the SPD optical connector may be on the order of single-digit microns (μm) or less than one micron (μm), that is, sub-micron. In some implementations, alignments of the tester optical connector to the SPD optical connector may be on the order of tens of microns or more. Any amount of alignment may be implemented.

[0031] In some implementations, the SPD may be part of—for example, manufactured on-a semiconductor wafer or a semiconductor package containing multiple SPDs to be tested. The probe head, or a component thereof like the probe card, may move across the wafer to test the SPDs on the wafer. For each SPD, the probe head may connect electrically to the SPD and move the tester optical connector relative to the SPD to align the tester optical connector to a corresponding SPD optical connector. Following testing, individual SPDs may be separated from the wafer.

[0032] FIG. **1** is a block diagram of components of an example test system **10** of the type described above. FIG. **2** shows, in partial cross-section, components of an implementation of the system of FIG. **1**. FIG. **3** shows, in perspective, a bottom view of part of a probe head containing components of an implementation of the system of FIG. **1**. FIG. **4** is a top view of part of a probe card containing components of an implementation of the system of FIG. **1**. FIG. **5** show, in perspective, a top view of a probe card containing components of an implementation of the system of FIG. **1**.

[0033] Referring to FIG. **1**, test system **10** includes a probe card **11** configured to contact a DUT, such as SPD **12** on wafer **14**. An example probe card includes electrical and mechanical interfaces that enable testing operation of a device while the device is still part of wafer **14**. Probe card **11** may be a printed circuit board (PCB) or other structure configured to provide electrical connection between SPD **12** and test electronics in probe head **17**. For example, probe card **11** may include one or more conductive layers and vias configured the pass electrical signals between the SPD and test electronics. Probe card **11** may include one or more passive and/or active electronic devices to condition, to process, and/or route electrical signals.

[0034] Probe card **11** may include electrically-conductive pads or electrical connectors **15***a*, **15***b* configured to accept, and to mate to, one or more electrical connectors, lines, or cables **17***a*, **17***b* from test electronics in probe head **17**. Probe card **11** also includes one or more electrically-conductive pads or electrical connectors **19** configured to connect to corresponding electrically-conductive pads or electrical connectors **20** on SPD **12**. The resulting electrical connections create an electrical pathway from SPD **12**, through probe card **11**, to test electronics in probe head **17**. Electrical signals may pass between SPD **12** and the probe head over this electrical pathway.

[0035] In this example, probe card **11** also includes a through-hole **21** to accommodate part of module **22**. As described below, module **22** is a structure having a shaft **24** to hold tester optical connector **25** and to move tester optical connector **25** relative to SPD **12** and SPD optical connector **25**.

[0036] Through-hole **21** may pass entirely through probe card **11** to allow shaft **24** of module **22** to pass through probe card **11** so that tester optical connector **25** can contact a corresponding SPD optical connector **26** on SPD **12**. Through-hole **21** may be circular in shape. The dimensions of through-hole **21** may be based on the amount of movement needed for shaft **24** to move within probe card **11** and the size of shaft **24**. For example, through-hole **21** may have a diameter on the order of single-digit centimeters or double-digit millimeters. Such dimensions may accommodate shaft **24** and enable movement of shaft **24** within through-hole **21** in a range of single-digit microns (μm) or less. Such dimensions may also enable movement of shaft **24** within through-hole **21** in a range of single-digit millimeters or more to enable both coarse and fine alignments between tester optical connector **25** and SPD optical connector **26**.

[0037] In some implementations, probe card **11** includes a support structure **27**. Support structure **27** may be connected physically to probe card **11** and, in some cases, need not include electrical connections to probe card **11**. As shown, in this example, support structure **27** is elevated relative to the rest of probe card **11** to support a part **29** of module **22** that interfaces to a motion system **31**. Support structure **27** may be elevated relative to the rest of probe card **11** to prevent damage to structures, such as passive and/or active electronic devices, on probe card **11** under support structure **27**. In some cases, such damage could, in the absence of support structure **27**, occur during movement of module **22** relative to SPD **12**, as described below.

[0038] Module **22** may be considered to be part of probe card **11**. In some implementations, module **22** includes system interface **29** and shaft **24**. In this example, system interface **29** and shaft **24** are orthogonal to each other; however, in other implementations, the angle between system interface **29** and shaft **24** may be oblique. Shaft **24** holds tester optical connector **25**. Tester optical connector **25** may be connected to, or an integral part of (for example, formed as part of), shaft **24**. As a result, tester optical connector does not move relative to shaft **24**, but rather moves along with movement of shaft **24**.

[0039] Tester optical connector **25** is configured to optically connect fiber optics, such as fiber optic cable **30**, to complementary SPD optical connector **26**. Examples of types of optical connectors that may be used for tester optical connector **25** and complementary SPD optical connector **26** include, but are not limited to, ST (straight tip) connectors, SC (standard connector) connectors, LC (Lucent® connector) connectors, 10G-CX4 connectors, Infiniband™ (4x) connectors, MTRJ (mechanical transfer-registered jack (connectors), MTP/MPO connectors, RJ-45 (registered jack-45) connectors, D4 connectors, ESCON (enterprise systems connection) connectors, opti-jack connectors, FDDI (fiber distributed data interface) connectors, MU (multi-termination unibody) connectors, CS® connectors, or SN® compact connectors.

[0040] In some implementations, tester optical connector **25** may include silicon in which optical structures, which make optical connection to SPD optical connector **26**, are set. In some implementations, tester optical connector **25** may include glass in which optical structures, which make optical connection to SPD optical connector **26**, are set.

[0041] Shaft **24** may be hollow or partially hollow with a through-hole therein to receive and to hold fiber optic cable **30**. An example fiber optic cable **30** includes one or more optical fibers, e.g., either single mode, multimode, polarization-maintaining or a mixture of the three, over which optical signals pass. Fiber optic cable **30** connects optically to tester optical connector **25** so that optical signals can pass between fiber optic cable **30** and SPD **12** via an optical connection between tester optical cable **30** and SPD optical cable **30**. In some implementations, shaft **24** may hold multiple fiber optic cables that connect optically to tester optical connector **25** to enable optical signals to pass between each fiber optic cable **30** and SPD **12** via an optical connection between tester optical cable **30** and SPD optical cable **30**. Shaft **24** may hold fiber optic cable **30** tightly or loosely. For example, when fiber optic cable **30** is held tightly, fiber optic cable does not move through or relative to shaft **24**. For example, when fiber optic cable **30** is held loosely, fiber optic cable **30** may move through or relative to shaft **24**.

[0042] Module **22** also includes system interface **29**. System interface **29** is so named because it is the part of module **22** that mechanically interfaces to motion system **31**, described below. In some implementations, system interface **29** is a plate or other flat structure containing indentations that are configured for mating to motion system **31**. In some implementations, system interface **29** need not be flat but rather may have any shape that is complementary to the part of motion system **31** that mates to module **22** or that enables that part of the motion system to mate to module **22**.

[0043] System interface **29** may be hollow or partially hollow with a through-hole therein to receive and to hold fiber optic cable **30**. Accordingly, fiber optic cable **30** passes through both shaft **24** and system interface **29**. System interface **29** may hold fiber optic cable **30** tightly or loosely.

For example, when fiber optic cable **30** is held tightly, fiber optic cable does not move through or relative to system interface **29**. For example, when fiber optic cable **30** is held loosely, fiber optic cable **30** may move through or relative to system interface **29**.

[0044] Referring also to FIGS. **2**, **4**, and **5**, system interface **29** may be circular or have any other appropriate shape taken along cross-section A-A. System interface **29** may have multiple indentations arranged around a radius thereof or at any other appropriate locations on system interface **29**. In the example of FIGS. **2**, **4**, and **5** system interface **29** includes three indentations **32***a*, **32***b*, and **32***c*; however, other implementations may contain more than three indentations or fewer than three indentations; for example, one, two, four, five, six, and so forth indentations. The indentations may have shapes that complement or accommodate shapes of protrusions on motion system **31**, as described below. In the example of FIGS. **2**, **4**, and **5**, the indentations have a stadium shape in lateral or horizontal cross-section, which is a rectangle with round ends. However, in other implementations, the indentations may have shapes that include, but are not limited to, round, oval, oval or circular ending in a pointed V-shape at one end, elliptical, or rectangular in lateral or horizontal cross-section. In some implementations, the longitudinal or vertical cross-section of module **22** of FIGS. **1** and **2** is generally “T”-shaped, as shown in the figures.

[0045] Referring to FIG. **1**, system **10** may include one or more springs **34***a*, **34***b* between system interface **29** and support structure **27** of probe card **11** (see also FIG. **2**). In some implementations, there are three springs located at roughly the same radius as the indentations but on the other side of system interface **29** from the indentations. However, this is not a requirement and the springs may be at any appropriate locations. As shown, springs **34***a*, **34***b* bias system interface **29** above probe card **11** and enable movement of module **22** in multiple degrees of freedom. That is, springs **34***a*, **34***b* bias system interface **29** to a position above probe card **11** that is imposed by the spring load. In some implementations, springs **34***a*, **34***b* are connected to support structure **27** in such as way as to enable movement of module **22** in six degrees of freedom relative to SPD **20**, which include forward/backward, up/down, left/right, yaw, pitch, and roll. For example, the springs may slide across the surface of support structure **27** or within tracks (not shown) on support structure **27**. Because support structure offset relative to the rest of the probe card, this movement will not damage circuitry or components on the probe card.

[0046] Referring to FIG. **1**, the up/down movement along arrows **35** enables creation of an optical connection between tester optical connector **25** and SPD optical connector **26**. Referring to FIG. **3** forward/backward and left/right movement along arrows **36** and **37**, respectively, enables movement of module **22** relative to SPD **12** and, thus, of tester optical connector **25** relative to SPD optical connector **26** to align the two for connection. The yaw, pitch, and roll movements may facilitate creation of the optical connection between tester optical connector **25** and SPD optical connector **26** by enabling, e.g., additional force to be applied to part of tester optical connector **25**.

[0047] As shown in FIG. **1**, fiber optic cable **30** may terminate in an optical connector **39** that is configured to connect to, and to disconnect from, a backplane **40** of probe head **17**. The connection and disconnection may enable connection to different test instruments in the test system, examples of which are described herein.

[0048] As shown in FIG. **1**, test system **10** includes motion system **31** configured to move into, and out of, contact with module **22** in the directions of arrows **33**, e.g., through movement of the motion system alone or in response to movement of part of probe head **17** relative to probe card **11**. When motion system **31** is in contact with module **22**, motion system **31** is configured to move module **22** relative to SPD **12** in order to align tester optical connector **25** to the SPD optical connector **26**. To this end, motion system **31** includes a connecting structure **41**, such as a plate.

[0049] Referring also to FIG. **3**, connecting structure **41** may be circular or have any other appropriate shape. Connecting structure **41** includes protrusions that mate to complementary indentations on system interface **29**. In some implementations, connecting structure **41** may have multiple protrusions arranged around a radius thereof. In the example of FIGS. **1** and **3**, connecting structure **41** includes three protrusions (only 41a, 41c shown in FIG. **1**); however, other implementations may contain more than three protrusions or fewer than three protrusions; for example, one, two, four, five, six, and so forth protrusions. The protrusions may have shapes and locations that complement the shapes and locations of indentations on system interface **29**, as noted above. In some implementations, the protrusions have a stadium shape in lateral or horizontal cross-section, which is a rectangle with round ends. However, in other implementations, the protrusions may have shapes that are, but are not limited to, round (e.g., ball-shaped), oval, elliptical, oval or circular with a V-shape at one end, or rectangular in lateral or horizontal cross-section.

[0050] In some implementations, motion system **31** includes robotics that is controllable to cause connecting plate to move in the six degrees of freedom described previously. In some implementations, the robotics include a housing **42** that holds one or more motors configured to move connecting structure **41** relative to system interface **29** in the six degrees of freedom described previously. Motion system **31** may be implemented using electrical control or pneumatic control in some implementations.

[0051] In some implementations, system interface **29** is or includes a first plate and connecting structure **41** is or includes a second plate. The first plate and the second plate may be magnetically attracted to each other to create and/or to hold or supplement a connection of the first plate and the second plate in order to enable movement of module **22** relative (e.g., towards or away from) to probe card **11** and the SPD **12**. In some implementations, the first plate and the second plate include components to implement a mechanical latch to hold the first plate and the second plate together in order to enable movement of module **22** relative to probe card **11** and the SPD **12**. In some implementations, at least one of the first plate or the second plate is connected to a suction device (not shown) configured to apply suction through the plate to the other plate to hold the first plate and the second plate together in order to create and/or to hold or supplement a connection the first plate and the second plate in order to enable movement of module **22** relative to probe card **11** and the SPD **12**.

[0052] Referring to FIG. **6**, in some implementations, the test system includes multiple instances of module **22**. Each instance **22***a* to **22***b* of module **22** is arranged at a different location relative to a wafer **50** under test. Each instance **22***a*, **22***b* of module **22** is configured to connected to motion system **51**, which is an implementation of motion system **31**, and, by virtue of movement of the motion system, align a different tester connector to respective SPD connector on wafer **50**. The motion system **51** is configured to move into contact with each instance **22***a*, **22***b* of module **22** and to move each instance of the module relative to the SPD to make the connection.

[0053] Referring to FIG. **7**, in some implementations, there may be multiple instances of motion system **51***a*, **51***b*, which are movable to contact respective instances **22***a*, **22***b* of the module **22**. Each instance of the motion system is controlled as described herein. Each motion system may be paired with a particular module in that the motion system is only capable of contacting and moving that particular module. Each motion system/module pair may be used to move over a predefined area of wafer **50**. Each area for each motion system/module pair may be separate and may not overlap.

[0054] FIG. **8** is a flowchart showing operations included in an example process that may use the test systems described herein. The operations of process **54** may be controlled by, or performed by, a control system, such as that described herein. Process **54** is described with respect to the example implementation shown in FIG. **1**.

[0055] Process **54** includes causing motion system **31** to come into contact with module **22**. This may include causing (**54***a*) connecting structure **41** to contact system interface **29**. Movement of the motion system may be automated in the sense that its movements do not include or require physical intervention from a user. The motion system is controlled (**54***b*) to cause a first optical connector to align to a second optical connector and to contact the second optical connector. For example, motion system **31** may control module **22** as described herein to cause shaft **24** to move relative to SPD **12**, thereby aligning tester optical connector **25** with SPD optical connector **26**. In this regard, the control system may know the location of each SPD optical connector and control module **22** to move to that location. The control system may control module **22** to move downward in the direction of arrows **19** of FIG. **1** to cause tester optical connector **25** to mate to SPD optical connector **26**. Thereafter, the control system may initiate and control (**54***c*) testing the SPD (which is a DUT) through a fiber optic path created through mating of tester optical connector **25** and SPD optical connector **26**.

[0056] FIG. **9** is a block diagram showing example components of example automatic test equipment (ATE) **55** that includes a testing device/apparatus (referred to also as a "tester") **56** and a control system **57**.

[0057] ATE **55** includes probe head **59**, examples of which is described with respect to FIG. **1** and elsewhere herein. Probe head **59** includes multiple test instruments **60***a* to **60***n* (where n>3), each of which may be configured, as appropriate, to implement and/or to control testing of DUTs such as SPDs. Although only four test instruments are shown, ATE **55** may include any appropriate number of test instruments, including one or more residing outside of probe head **59**. The test instruments may connect to a backplane **61**, which may include optical connector(s) that mate to optical connector **39** of FIG. **1**

[0058] The test instruments may be hardware devices that may each include one or more processing devices and/or circuitry **62** to implement and to control testing and memory **64** to store test data and or test programs to test SPDs. The test instruments may be configured—for example, programmed—to output test signals such as optical and/or electrical signals to test SPDs. The test signals to test the SPDs may be or include commands, instructions, data, parameters, variables, test vectors, and/or any other information designed to elicit response(s) from the SPD. The one or more processing devices **62** may also execute instructions to communicate with control system **57** and/or and to analyze responses to the test signals.

[0059] Probe card **65**, examples of which are described with respect to FIG. **1** and elsewhere herein, may be electrically and mechanically connected to probe head **59** and controllable by one or more of the test instruments and/or the control system to make optical and electrical contact with SPDs on a wafer **70** held on chuck **71** to test the SPDs. Operation of individual components of the probe card, such as those described herein, may be controlled by one or more of test instruments **60***a* to **60***n* and/or by control system **57**.

[0060] Control system **57** may be configured—e.g., programmed—to communicate with test instruments **60***a* to **60***n* to direct and/or to control testing of the DUTs. In some implementations, this communication **66** may be over a computer network or via a direct connection such as a computer bus or an optical medium. In some implementations, the computer network may be or include a local area network (LAN) or a wide area network (WAN). The control system may be or include a computing system comprised of one or more processing devices **67** (e.g., microprocessor(s)) and memory **69** for storing instructions to control operation of the ATE and/or testing. Memory **69** also stores one or more test programs **84** to execute and/or to send to the test instruments for execution. In this regard, control system **57** may be configured to provide test programs and/or test signals to test instruments **60***a* to **60***n* in the probe head, which the test instrument(s) use to test the SPD. Control system **57** may also be configured to receive SPD response signals (e.g., measurement data) from the test instrument(s) and to determine whether the corresponding DUT has passed or failed testing.

[0061] In some implementations, the control functionality is centralized in processing device(s) **67**. In some implementations, all or part of the functionality attributed to control system **57** may also or instead be implemented on a test instrument and/or all or part of the functionality attributed to one or more test instruments may also or instead be implemented on control system **57**. For example, the control system may be distributed across processing device(s) on one or more of test instruments **60***a* to **60***n*.

[0062] All or part of the example systems and example processes described in this specification and their various modifications may be configured or controlled at least in part by one or more computers such as control system **57** using one or more computer programs tangibly embodied in one or more information carriers, such as in one or more non-transitory machine-readable storage media. A computer program can be written in any form of programming language, including compiled or interpreted languages, and it can be deployed in any form, including as a stand-alone program or as a circuit, part, subroutine, or other unit suitable for use in a computing environment. A computer program can be deployed to be executed on one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a network.

[0063] Actions associated with configuring or controlling the test system and processes described herein can be performed by one or more programmable processors executing one or more computer programs to control or to perform all or some of the operations described herein. All or part of the test systems and processes can be configured or controlled by special purpose logic circuitry, such as, an FPGA (field programmable gate array) and/or an ASIC (application-specific integrated circuit) or embedded microprocessor(s) localized to the instrument hardware.

[0064] Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor will receive instructions and data from a read-only storage area or a random access storage area or both. Elements of a computer include one or more processors for executing instructions and one or more storage area devices for storing instructions and data. Generally, a computer will also include, or be operatively coupled to receive data from, or transfer data to, or both, one or more machine-readable storage media, such as mass storage devices for storing data, such as magnetic, magneto-optical disks, or optical disks. Non-transitory machine-readable storage media suitable for embodying computer program instructions and data include all forms of non-volatile storage area, including by way of example, semiconductor storage area devices, such as EPROM (erasable programmable read-only memory), EEPROM (electrically erasable programmable read-only memory), and flash storage area devices; magnetic disks, such as internal hard disks or removable disks; magneto-optical disks; and CD-ROM (compact disc read-only memory) and DVD-ROM (digital versatile disc read-only memory).

[0065] As used herein, the terms “comprises,” “comprising,” “includes,” “including,” “has,” “having,” “contains,” “containing,” and any variations thereof, are intended to cover a non-exclusive inclusion, such that systems, techniques, apparatus, structures, processes, or other subject matter described or claimed herein that includes, has, or contains an element or list of elements does not include only those elements but can include other elements not expressly listed or inherent to such systems, techniques, apparatus, structures, processes or other subject matter described or claimed herein.

[0066] All examples described herein are non-limiting.

[0067] In the description and claims provided herein, the adjectives “first”, “second”, “third”, and the like do not designate priority or order unless context suggests otherwise. Instead, these adjectives may be used solely to differentiate the nouns that they modify.

[0068] Any mechanical, optical, or electrical connection herein may include a direct physical connection or an indirect connection that includes one or more intervening components. A connection between two electrically conductive components is an electrical connection unless context suggests otherwise. A connection between two optical components is an optical connection unless context suggests otherwise.

[0069] Elements of different implementations described may be combined to form other implementations not specifically set forth previously. Elements may be left out of the systems described previously without adversely affecting their operation or the operation of the system in general. Furthermore, various separate elements may be combined into one or more individual

elements to perform the functions described in this specification.
[0070] Other implementations not specifically described in this specification are also within the scope of the following claims.

Claims

1. A test system comprising: a probe card configured to move relative to a device under test (DUT); a module connected to optical fibers, the module being associated with the probe card and being configured to move relative to the probe card and the DUT; and a motion system configured to move into, and out of, contact with the module, wherein, when the motion system is in contact with the module, the motion system is configured to move the module relative to the probe card and the DUT in order to align the optical fibers to the DUT and to create an optical connection between the optical fibers and the DUT.
2. The test system of claim 1, wherein the motion system is configured for electrical control or for pneumatic control.
3. The test system of claim 1, wherein the motion system comprises robotics configured to operate in multiple degrees of freedom.
4. The test system of claim 1, wherein the motion system is configured to move the module so as to move the optical fibers by single-digit millimeters or by less than one millimeter.
5. The test system of claim 1, wherein the module comprises a first plate, the first plate comprising indentations; and wherein the motion system comprises a motor and a second plate, the second plate comprising protrusions configured to engage the indentations to enable movement of the module relative to the probe card and the DUT.
6. The test system of claim 5, wherein the motion system is configured to move the second plate towards the first plate to cause the protrusions to engage the indentations.
7. The test system of claim 4, wherein the first plate comprises three indentations and the second plate comprises three protrusions to engage respective ones of the three indentations.
8. The test system of claim 4, wherein a cross-section of the module is substantially “T” shaped.
9. The test system of claim 1, further comprising: one or more springs between the first plate and the probe card, the one or more springs biasing the first plate above the probe card and enabling movement of the module in multiple degrees of freedom.
10. The test system of claim 1, further comprising: a probe head connected to the probe card, the probe head comprising electrical connections configured to contact corresponding electrical connections on the DUT.
11. The test system of claim 1, wherein the optical fibers are part of a fiber optic cable that is routed through the module.
12. The test system of claim 10, further comprising: a test instrument configured to test the DUT through the optical connection and a fiber optic cable, the fiber optic cable comprising a connector configured to connect to, and to disconnect from, a backplane of the test system.
13. The test system of claim 1, wherein the module comprises a first structure; and wherein the motion system comprises a motor and a second structure, the first structure and the second structure being magnetically attracted to each other to create connection of the first structure and the second structure in order to enable movement of the module relative to the probe card and the DUT.
14. The test system of claim 1, wherein the module comprises a first structure; and wherein the motion system comprises a motor and a second structure, the first structure and the second structure comprising components to implement a mechanical latch to hold the first structure and the second plate structure in order to enable movement of the module relative to the probe card and the DUT.
15. The test system of claim 1, wherein the module comprises a first structure; wherein the motion system comprises a motor and a second structure; and wherein at least one of the first structure or the second structure comprises a suction device configured to apply suction to hold the first

structure and the second structure together in order to enable movement of the module relative to the probe card and the DUT.

16. The test system of claim 1, further comprising silicon in which the optical fibers are set.

17. The test system of claim 1, further comprising glass in which the optical fibers are set.

18. The test system of claim 1, further comprising: a control system configured to execute a test program to control movement of the motion system to control movement of the module relative to the probe card and the DUT.

19. The test system of claim 1, wherein the DUT comprises a silicon photonic device on a semiconductor wafer or a semiconductor package.

20. The test system of claim 1, wherein the motion system is configured to move the module in six degrees of freedom.

21. The test system of claim 20, wherein the motion system is configured to move the module in degrees of freedom comprising: forward/backward, up/down, left/right, yaw, pitch, and roll.

22. The test system of claim 1, comprising: multiple instances of the module, each instance of the module for aligning a respective set of optical fibers to a respective DUT; wherein the motion system is configured to move into contact with each instance of the module and to move each instance of the module relative to the respective DUT.

23. The test system of claim 1, comprising: multiple instances of the module, each instance of the module for aligning a respective set of optical fibers to a respective DUT; and multiple instances of the motion system, each instance of motion system being configured to move into contact with each respective instance of the module and to move each respective instance of the module relative to the respective DUT.

24. A method performed on a test system, the method comprising: causing a motion system to come into contact with a module, the module being connected to optical fibers and being configured for movement relative to a probe card and a device under test (DUT), where movement of the motion system is automated; controlling the motion system to move the module to cause the optical fibers to align to the DUT and to create an optical connection between the optical fibers and the DUT; and testing the DUT though a fiber optic path that includes the optical connection.

25. The method of claim 24, wherein controlling the motion system is performed to move the module so as to move the optical fibers by single-digit millimeters or by less than one millimeter.

26. The method of claim 24, wherein controlling the motion system is performed to move the module in six degrees of freedom relative to the DUT.

27. The method of claim 24, wherein the DUT comprises a silicon photonic device on a semiconductor wafer or a semiconductor package.