

Description

A laser debonding apparatus and method

5 **Technical Field**

The present invention relates to a technical field of semiconductor manufacturing, and in particular to a laser debonding apparatus, a laser debonding method, and a computer-readable storage medium.

10 **Background**

In a laser debonding apparatus, it is necessary to focus a laser beam, and ensure that a focal point ultimately lands on a sacrificial layer of a bonded component so as to modify the material of the sacrificial layer or cause it to thermally expand, thereby achieving debonding. Since a power density of the laser beam determines whether
15 the sacrificial layer can reach a critical point for modification or thermal expansion, and generally, the power density at a laser focal point is the highest, it is therefore necessary for the laser focal point to be accurately positioned on the sacrificial layer of the bonded component so as to achieve complete debonding of the bonded component. In an optical system for laser debonding, it is crucial to adjust a working
20 distance of a laser scanning head to locate a focal position of the laser beam emitted thereby so that it is precisely focused on the target sacrificial layer, which directly affects the final process results.

In the prior art, an optimal working distance of the laser scanning head is determined primarily by observing the laser interaction effect on the sacrificial layer
25 of the bonded component to find a method for achieving a minimum focal spot. However, the observation-based method typically requires transfer under a microscope; for instance, based on actual process results, a thinnest line obtained from laser scribing are observed under a microscope. This process is not only time-consuming, but also requires multiple adjustments to set the laser scanning head to a
30 working distance suitable for laser debonding. However, this working distance is not

accurate, that is, it may not be the optimal working distance. Performing laser debonding at this working distance may still waste part of the laser energy. Additionally, multiple verifications of process results are required to determine whether it is the optimal working distance. Thus, it cannot meet the needs of systems with strict requirements for scanning accuracy and focal position.

To solve the above-mentioned problems in the prior art, there is an urgent need in the art for an improved laser debonding technique, which is capable of quickly and accurately adjusting the laser emitter to an optimal working distance without requiring multiple process result verifications, thus shortening the process time and improving process efficiency.

Summary

A brief overview of one or more aspects is provided below to provide a basic understanding of these aspects. The summary is not an extensive overview of all of the aspects that are contemplated, and is not intended to identify key or decisive elements in all aspects. The sole purpose of the summary is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

To overcome the above-mentioned defects existing in the prior art, the present invention provides a laser debonding apparatus, a laser debonding method, and a computer-readable storage medium, which is capable of quickly and accurately adjusting the laser emitter to an optimal working distance without requiring multiple process effect verifications, thereby shortening the process duration and improving the process efficiency.

Specifically, according to the above-mentioned laser debonding apparatus provided in a first aspect of the present invention, it comprises: a laser emitter, configured to emit an initial laser for debonding; a beam splitter, configured to split the received initial laser into a first laser beam directed to a focal spot analyser, and a second laser beam directed to a sacrificial layer of a bonded component, wherein a distance from the beam splitter to the focal spot analyser equals to a distance from the beam splitter to the sacrificial layer; an infrared vision module, configured to

acquire an infrared focal spot image of the second laser beam on the sacrificial layer; and a controller configured as: obtaining a spot size of the first laser beam via the focal spot analyser, wherein the spot size of the first laser beam is equivalent to a spot size of the second laser beam; preliminarily adjusting a working distance from the laser emitter to the sacrificial layer to optimize the spot size of the second laser beam; obtaining the infrared focal spot image of the second laser beam via the infrared vision module, and finely adjusting the working distance from the laser emitter to the sacrificial layer, to compensate for an error of the focal spot analyser; and in response to the laser emitter being adjusted to an optimal working distance, performing laser scanning debonding on the sacrificial layer.

Further, in some embodiments of the present invention, the laser emitter, the beam splitter and the bonded component lie on a same straight line, the preliminarily adjusting a working distance from the laser emitter to the sacrificial layer to optimize the spot size of the second laser beam comprises: moving the laser emitter along a direction of the straight line, and adjusting the working distance from the laser emitter to the sacrificial layer; and obtaining a first minimum spot size of the second laser beam as an optimal size, according to a variation pattern of a first round spot size of the first laser beam in the focal spot analyser, wherein the variation pattern of spot size includes a process in which the spot size first decreases from large to small and then subsequently increases from small to large.

Further, in some embodiments of the present invention, the obtaining the infrared focal spot image of the second laser beam via the infrared vision module, and finely adjusting the working distance from the laser emitter to the sacrificial layer, to compensate for an error of the focal spot analyser comprises: determining whether a spot of the second laser beam meets a debonding process requirement, based on the infrared focal spot image of the second laser beam obtained via the infrared vision module; in response to insufficient laser energy of the spot of the second laser beam at the first minimum spot size to ablate the sacrificial layer, continuing to move the laser emitter along the direction of the straight line, to further adjust the working distance from the laser emitter to the sacrificial layer; and obtaining a second minimum spot size of the second laser beam as the optimal size, according to a

variation pattern of a second round spot size of the first laser beam in the focal spot analyser, wherein the second minimum spot size is smaller than the first minimum spot size.

Further, in some embodiments of the present invention, the determining whether a spot of the second laser beam meets a debonding process requirement comprises: in response to the laser energy of the spot of the second laser beam, at the first minimum spot size, ablating a device layer beneath the sacrificial layer, continuing to move the laser emitter along the direction of the straight line, to further adjust the working distance from the laser emitter to the sacrificial layer; and obtaining a third minimum spot size of the second laser beam as the optimal size, according to the variation pattern of a third round spot size of the first laser beam in the focal spot analyser, wherein the third minimum spot size is larger than the first minimum spot size.

Further, in some embodiments of the present invention, the laser debonding apparatus further comprises: a movable platform, placed with the bonded component thereon, the in response to the laser emitter being adjusted to an optimal working distance, performing laser scanning debonding on the sacrificial layer comprises: fixing the laser emitter at a position corresponding to the optimal working distance; in response to a bonded area on the sacrificial layer being completely ablated by the second laser beam, determining a position of next bonded area to be ablated, by means of the infrared focal spot image of the sacrificial layer captured by the infrared vision module; and translating the bonded component along an X-direction and/or a Y-direction via the movable platform, to irradiate the second laser beam onto the next bonded area to be ablated.

Further, in some embodiments of the present invention, after performing laser scanning debonding on the sacrificial layer, in response to the laser emitter being adjusted to an optimal working distance, in response to a completion of the laser scanning debonding, obtaining a full infrared image of the sacrificial layer via the infrared vision module, to detect whether debonding has been completed in every bonded area of the sacrificial layer; in response to an existence of at least one bonded area with incomplete debonding, marking the at least one bonded area, and moving

the movable platform to scan the at least one bonded area again via the second laser beam; and in response to a completion of debonding in every bonded area, transfer a peeled device layer to a next process.

Further, in some embodiments of the present invention, the laser emitter
5 comprises: a laser, configured to provide the initial laser; an optical assembly, configured to adjust a transmission angle of the initial laser, to transmit the initial laser to the beam splitter.

Further, in some embodiments of the present invention, the optical assembly
10 comprises a collimating and beam-expanding system, a reflecting mirror and a field lens, wherein the collimating and beam-expanding system is configured to adjust a spot size of the initial laser, to make it match a spot size of the field lens, and the reflecting mirror is configured to reflect the initial laser into the field lens, so that the field lens focuses the initial laser onto the sacrificial layer.

Further, in some embodiments of the present invention, the reflecting mirror is
15 connected to a motor, and driven by the motor to rotate, to adjust a reflection angle of the reflecting mirror in an oscillating manner, and finely adjust an exit optical path of the second laser beam reflected by the reflecting mirror, thereby enabling the second laser beam to perform local scanning on the sacrificial layer.

Further, in some embodiments of the present invention, the laser debonding
20 apparatus further comprises: a power meter, disposed above the reflecting mirror, and configured to detect a power value of a reflected light of the second laser beam, incident on the bonded component that is reflected via a surface of the bonded component.

Further, in some embodiments of the present invention, the laser debonding
25 apparatus further comprises: an infrared thermal imager, disposed above the bonded component, and configured to obtain a temperature distribution map of the sacrificial layer, the in response to the laser emitter being adjusted to an optimal working distance, performing laser scanning debonding on the sacrificial layer comprises: respectively obtaining a power value of the second laser beam incident on the
30 sacrificial layer and a temperature distribution map of the sacrificial layer via the power meter and the infrared thermal imager; and in response to a presence of

abnormal temperature values in the temperature distribution map, adjusting an output power of the laser, and performing power monitoring during a power adjustment process via the power meter.

Further, in some embodiments of the present invention, the laser debonding apparatus further comprises: a laser rangefinder, disposed at a bottom of the focal spot analyser, and configured to detect a distance from the beam splitter to the focal spot analyser and a distance from the beam splitter to the sacrificial layer, wherein the distance from the beam splitter to the focal spot analyser is fixed as L , a distance from a light exit port of the laser rangefinder to the beam splitter is L_1 , a distance from the light exit port to the bonded component is L_2 , and a thickness of a carrier layer above the bonded component is d , such that $L = L_1 + L_2 + d$.

Further, in some embodiments of the present invention, a ratio range of the first laser beam to the second laser beam after the initial laser is split by the beam splitter ranges from 1:9 to 3:7.

Further, in some embodiments of the present invention, the infrared vision module comprises an infrared camera, an infrared light source and a filter, wherein the filter is disposed in front of a lens of the infrared camera, and is configured to filter out a reflected light of the second laser beam that is incident on the bonded component and reflected via a surface of the bonded component.

Additionally, according to the above-mentioned laser debonding method provided in a second aspect of the present invention, it comprises following steps: emitting an initial laser for debonding via a laser emitter in the above-mentioned laser debonding apparatus provided in the first aspect of the present invention, wherein the initial laser is split into two beams by a beam splitter, a first laser beam is directed to a focal spot analyser, a second laser beam is directed to a sacrificial layer of a bonded component, and a distance from the beam splitter to the focal spot analyser equals to a distance from the beam splitter to the sacrificial layer; obtaining a spot size of the first laser via the focal spot analyser, wherein the spot size of the first laser is equal to a spot size of the second laser; preliminarily adjusting a working distance from the laser emitter to the sacrificial layer to optimize the spot size of the second laser beam; obtaining an infrared focal spot image of the second laser beam via an infrared vision

module, and finely adjusting the working distance from the laser emitter to the sacrificial layer, to compensate for an error of the focal spot analyser; and in response to the laser emitter being adjusted to an optimal working distance, performing laser scanning debonding on the sacrificial layer.

5 Additionally, according to a third aspect of the present invention, there is further provided a computer-readable storage medium having a computer instruction stored thereon. When the computer instruction is executed by a processor, the above-mentioned laser debonding method provided in the second aspect of the present invention is implemented.

Brief Description of the Drawings

10 The above features and advantages of the present invention will be better understood after reading the detailed description of the embodiments of the present disclosure in conjunction with the following figures. In the figures, components are not necessarily drawn to scale, and components having similar related features may have the same or similar reference numerals.

15 Fig. 1 illustrates a schematic structural diagram of a laser debonding apparatus according to some embodiments of the present invention.

20 Fig. 2 is a partial enlarged view of an area among a beam splitter, a focal spot analyser, and a bonded component as shown in Fig. 1.

 Fig. 3 illustrates a flow chart of a laser debonding method according to some embodiments of the present invention.

 Fig. 4 illustrates a schematic structural diagram of a laser debonding apparatus according to other embodiments of the present invention.

25 Fig. 5 illustrates a flow chart of a laser debonding method according to an embodiment of the present invention.

Reference numerals

100	laser debonding apparatus;
110	laser emitter;
111	laser;

	112	collimating and beam-expanding system;
	113	reflecting mirror;
	114	field lens;
	120	beam splitter;
5	130	infrared vision module;
	131	infrared camera;
	1310	lens;
	132	infrared light source;
	133	filter;
10	134	semi-transparent and semi-reflective mirror;
	140	focal spot analyser;
	150	bonded component;
	151	sacrificial layer;
	152	carrier layer;
15	153	device layer;
	160	movable platform;
	170	laser rangefinder;
	210	initial laser;
	211	first laser beam;
20	212	second laser beam;
	S310~S330	steps;
	410	power meter;
	420	infrared thermal imager; and
	S510~S570	steps.

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Detailed Description of Embodiments

The embodiments of the present invention are described in the following detailed description. Other advantages and effects of the present invention will be readily apparent to those skilled in the art from this disclosure. Although the description of the present invention will be described in conjunction with the

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preferred embodiments, this is not a limitation of the present invention. On the contrary, the invention is described in connection with the embodiments so as to cover other alternatives or modifications that are possible in the embodiments of the present invention. In order to provide a thorough understanding of the present invention,
5 many specific details are included in the following description. The present invention may also be practiced without these details. In addition, some specific details are omitted in the description in order to avoid confusing or obscuring the present invention.

In the description of the present invention, it should be noted that the terms
10 "installation", "connecting", and "connected" should be understood broadly unless explicitly stated and defined otherwise. For example, the terms "installation", "connecting", and "connected" may be either a fixed connection, a detachable connection, or an integral connection; the terms may be either a mechanical connection or an electrical connection; the terms also may be either a direct
15 connection, an indirect connection through an intermediate medium, or an internal connection between two components. The specific meaning of the above terms in the present invention can be understood in a specific case by those skilled in the art.

In addition, "up", "down", "left", "right", "top", "bottom", "horizontal", "vertical" used in the following description shall be understood as the orientation
20 described in the paragraph and shown in the related figure. The relative term is used for convenience of description only, and does not mean that the device described therein is to be manufactured or operated in the specific orientation, and therefore should not be construed as limiting the present invention.

Understandably, although the terms "first", "second", "third", etc. may be used
25 to describe various components, regions, layers and/or portions to distinguish different components, regions, layers and/or portions, the order of these components, regions, layers and/or portions described above should not be limited by the terms. Therefore, a first component, region, layer and/or portion mentioned below may be also mentioned as a second component, region, layer and/or portion without departing
30 from some embodiments of the present invention.

As mentioned above, in the prior art, an optimal working distance of the laser

scanning head is determined primarily by observing the laser interaction effect on the sacrificial layer of the bonded component to find a method for achieving a minimum focal spot. However, the observation-based method typically requires transfer under a microscope; for instance, based on actual process results, a thinnest line obtained from laser scribing are observed under a microscope. This process is not only time-consuming, but also requires multiple adjustments to set the laser scanning head to a working distance suitable for laser debonding. However, this working distance is not accurate, that is, it may not be the optimal working distance. Performing laser debonding at this working distance may still waste part of the laser energy. Additionally, multiple verifications of process results are required to determine whether it is the optimal working distance. Thus, it cannot meet the needs of systems with strict requirements for scanning accuracy and focal position.

To overcome the above-mentioned defects existing in the prior art, the present invention provides a laser debonding apparatus, a laser debonding method, and a computer-readable storage medium, which is capable of quickly and accurately adjusting the laser emitter to an optimal working distance without requiring multiple process effect verifications, thereby shortening the process duration and improving the process efficiency.

In some non-limiting embodiments, the above-mentioned laser debonding apparatus provided in a first aspect of the present invention can be used to implement the above-mentioned laser debonding method provided in a second aspect of the present invention.

Specifically, in some non-limiting embodiments, a third aspect of the present invention further provides a computer-readable storage medium having a computer instruction stored thereon. When the computer instruction is executed by a processor, the above-mentioned laser debonding method provided in the second aspect of the present invention is implemented.

A working principle of the above-mentioned laser debonding apparatus will be described hereinafter in conjunction with some embodiments of the laser debonding method. Those skilled in the art will appreciate that these embodiments of the laser debonding method are merely some non-limiting implementations provided by the

present invention, intended to clearly demonstrate the main concept of the present invention and provide some specific solutions convenient for the public to implement, rather than to limit all operating modes or all functions of the laser debonding apparatus. Similarly, the laser debonding apparatus is also merely a non-limiting implementation provided by the present invention, and does not impose limitations on executing entities of each step in the laser debonding method.

Please refer to Fig. 1, Fig. 1 illustrates a schematic structural diagram of a laser debonding apparatus according to some embodiments of the present invention.

As shown in Fig. 1, in some embodiments of the present invention, a laser debonding apparatus 100 may comprise a laser emitter 110, a beam splitter 120, an infrared vision module 130, and a controller (not shown in the drawings). The laser emitter 110 can be used to emit an initial laser 210 for debonding. The beam splitter 120 can be used to split the received initial laser 210 into a first laser beam 211 directed to a focal spot analyser 140, and a second laser beam 212 directed to a sacrificial layer 151 of a bonded component 150, wherein a distance from the beam splitter 120 to the focal spot analyser 140 equals to a distance from the beam splitter 120 to the sacrificial layer 151. The infrared vision module 130 can be used to acquire an infrared focal spot image of the second laser beam 212 on the sacrificial layer 151.

Specifically, as shown in Fig. 1, in some embodiments, the bonded component 150 may be formed by bonding a carrier layer 152 and a device layer 153. By integrating circuits on a wafer, a die (or integrated circuit die) capable of performing specific functions can be formed. As technology advances, thicker wafer devices are difficult to meet the heat dissipation and packaging requirements of high-end chips; therefore, in the semiconductor field, it is often necessary to thin down wafers used as devices to achieve the required thickness. However, when the thickness of a wafer is reduced to less than 200 μm , the ultra-thin wafers will become fragile and tend to experience warpage. Therefore, the carrier layer 152, which has high mechanical strength, can be used to support such structurally fragile device layer 153. Optionally, the carrier layer 152 can be made of a glass substrate or a silicon substrate for carrying (the device layer 153).

Continuing with Fig. 1, the laser emitter 110 may comprise a laser 111 and an

optical assembly. The laser 111 is configured to provide the initial laser 210. When a glass substrate is selected for the carrier layer 152, the laser 111 can emit an ultraviolet (UV) laser beam to penetrate the glass substrate, reach the sacrificial layer 151, and ablate it, thereby performing UV laser debonding. However, when a silicon substrate is selected for the carrier layer 152, the laser 111 can emit an infrared (IR) laser beam to penetrate the silicon substrate, reach the sacrificial layer 151, and ablate it, thereby performing IR laser debonding.

The optical assembly in the laser emitter 110 can be used to adjust a transmission angle of the initial laser 210, to transmit the initial laser 210 to the beam splitter 120, and then the beam splitter 120 can direct the laser beam of the initial laser 210 to the sacrificial layer 151 for laser debonding.

In some optional embodiments, the optical assembly may further comprise a collimating and beam-expanding system 112, a plurality of reflecting mirrors 113, and a field lens 114. The collimating and beam-expanding system 112 can be used to improve a spatial divergence angle of the initial laser 210, thereby enhancing the collimation of the laser beam of the initial laser 210, so that it meets the aperture requirements of the subsequent optical components. In these embodiments, the collimating and beam-expanding system 112 can reduce the divergence angle of the initial laser 210 and, as the beam waist radius increases, enlarge a spot size of the initial laser 210 so as to match a spot size of the field lens 114, thereby achieving the purpose of collimating and expanding the initial laser 210. The reflecting mirrors 113 can be used to reflect the initial laser 210 into the field lens 114, so that the field lens 114 can focus the initial laser 210 onto the sacrificial layer 151.

Continuing with Fig. 1, the beam splitter 120 in the laser debonding apparatus 100 may be selected as a semi-transparent and semi-reflective mirror. As shown in Fig. 1, optionally, the laser emitter 110, the beam splitter 120 and the bonded component 150 may be located along a same straight line. A portion of the initial laser 210 can pass through the beam splitter 120 and travel toward the bonded component 150 located opposite so as to interact with the sacrificial layer 151, while another portion of the initial laser 210 can be reflected by the beam splitter 120 at a certain angle into the focal spot analyser 140, to obtain a size of the laser spot at this moment

via the focal spot analyser 140.

Further, please refer to Fig. 2, Fig. 2 is a partial enlarged view of an area among a beam splitter, a focal spot analyser, and a bonded component as shown in Fig. 1.

As shown in Fig. 2, in some embodiments, the laser debonding apparatus 100 further comprises a laser rangefinder 170. The laser rangefinder 170 may be disposed at a bottom of the focal spot analyser 140, and configured to detect a distance from the beam splitter 120 to the focal spot analyser 140 and a distance from the beam splitter 120 to the sacrificial layer 151, wherein the distance from the beam splitter 120 to the focal spot analyser 140 may be fixed as L , a distance from a light exit port of the laser rangefinder 170 (located at the bottom of the laser rangefinder 170) to the beam splitter 120 may be L_1 , a distance from the light exit port to the bonded component may be L_2 . A thickness of the carrier layer 152 may be d , such that $L = L_1 + L_2 + d$, where L is the actual distance from the beam splitter 120 to a focal point on the sacrificial layer 151. In these embodiments, since the field lens 114 has a fixed focal length and the addition of the beam splitter 120 does not alter the focal length of the field lens 114, it follows that introducing the laser rangefinder 170 can ensure that the distance from the beam splitter 120 to the sacrificial layer 151 is equal to the distance from the beam splitter 120 to the focal spot analyser 140. Thus, the spot size data of the first laser beam 211 detected by the focal spot analyser 140 can be used to represent the spot size data of the second laser beam 212 on the sacrificial layer 151.

In some embodiments, a ratio range of the first laser beam 211 to the second laser beam 212 after the initial laser 210 is split by the beam splitter 120 may range from 1:9 to 3:7. The ratio range of the first laser beam 211 and the second laser beam 212 needs to be such that an energy of the first laser beam 211 reaching the focal spot analyser 140 is not so weak that the focal spot analyser 140 cannot acquire data, nor so strong that it damages the focal spot analyser 140, while an energy of the second laser beam 212 reaching the sacrificial layer 151 is sufficient to produce an ablation effect on the sacrificial layer 151.

Continuing with Fig. 1, in some embodiments, the infrared vision module 130 may be disposed on a right side of the beam splitter 120, and is primarily configured to detect an action effect of the second laser beam 212 on the sacrificial layer 151.

The infrared vision module 130 may comprise an infrared light source 132 and an infrared camera 131, and is configured to acquire infrared images using infrared energy radiated by objects. Specifically, after a single-point action of the second laser beam 212 is completed, a light generated by the infrared light source 132 illuminates the position on the sacrificial layer 151 that has been acted upon by the second laser beam 212, and the infrared camera 131 takes photos of this position to obtain the effect of the laser action at this position.

Optionally, a semi-transparent and semi-reflective mirror 134 may be disposed between the infrared light source 132 and the camera lens 1310, thereby enabling the infrared light beam emitted by the infrared light source 132 to be reflected so as to direct it onto an optical path of the camera lens 1310. Further, the infrared vision module 130 may comprise a filter 133. The filter 133 may be disposed in front of a lens 1310 of the infrared camera 131, and is configured to filter out a reflected light of the second laser beam 212 that is incident on the bonded component 150 and reflected via a surface of the bonded component 150 (i.e., a surface of the carrier layer 152), thereby preventing the reflected light from entering the infrared camera 131 and damaging the camera.

In some embodiments of the present invention, the controller in the laser debonding apparatus 100 may be configured as: obtaining a spot size of the first laser beam 211 via the focal spot analyser 140, wherein the spot size of the first laser beam 211 is equivalent to a spot size of the second laser beam 212; preliminarily adjusting a working distance from the laser emitter 110 to the sacrificial layer 151 to optimize the spot size of the second laser beam 212; obtaining the infrared focal spot image of the second laser beam 212 via the infrared vision module 130, and finely adjusting the working distance from the laser emitter 110 to the sacrificial layer 151, to compensate for an error of the focal spot analyser 140; and in response to the laser emitter 110 being adjusted to an optimal working distance, performing laser scanning debonding on the sacrificial layer 151. By integrating the spot position and size of the first laser beam 211 obtained by the focal spot analyser 140, wherein the spot size is equivalent to that of the second laser beam 212, with the spot position and size of the second laser beam 212 collected by the infrared vision module 130, it is capable to

reduce the time required to determine the optimal working distance of the laser emitter 110, and to improve the accuracy of judging the actual laser ablation effect produced at such optimal working distance.

The following will combine with a laser debonding method provided in the second aspect of the present invention to specifically describe the aforesaid steps performed by the controller. Specifically, please refer to Fig. 3, Fig. 3 illustrates a flow chart of a laser debonding method according to some embodiments of the present invention.

As shown in Fig. 3, in some embodiments of the present invention, the laser debonding method may comprise following steps. First, step S310 may be performed: emitting an initial laser for debonding via a laser emitter in the laser debonding apparatus.

Specifically, in conjunction with Fig. 1, in some embodiments, the initial laser 210 for debonding may be emitted by the laser 111 in the laser emitter 110. For example, the initial laser 210 may be an infrared laser beam. The initial laser 210 may be adjusted in transmission angle by the optical assembly, to transmit it to the beam splitter 120. The initial laser 210 is split into two beams by the beam splitter 120, wherein a first laser beam 211 may be reflected into the focal spot analyser 140 for analysing spot size data of the laser beam, and a second laser beam 212 may be transmitted toward the sacrificial layer 151 of the bonded component 150 for generating an ablation effect on the sacrificial layer 151. Furthermore, a laser rangefinder 170 may be used to ensure that a distance from the beam splitter 120 to the focal spot analyser 140 equals to a distance from the beam splitter 120 to the sacrificial layer 151.

Next, continuing with Fig. 3, step S320 may be performed: obtaining a spot size of the first laser via the focal spot analyser.

Specifically, in conjunction with Fig. 1, since the field lens 114 in the laser debonding apparatus 100 has a fixed focal length, and the addition of the beam splitter 120 does not alter the focal length of the field lens 114, it follows that ensuring that the distance from the beam splitter 120 to the sacrificial layer 151 is equal to the distance from the beam splitter 120 to the focal spot analyser 140 allows the spot size

data of the first laser beam 211 detected by the focal spot analyser 140 to be used to represent the spot size data of the second laser beam 212 on the sacrificial layer 151. The spot size of the first laser beam 211 detected by the focal spot analyser 140 may be equivalent to the spot size of the second laser beam 212 impinging on the sacrificial layer 151.

Next, continuing with Fig. 3, step S330 may be performed: preliminarily adjusting a working distance from the laser emitter to the sacrificial layer to optimize the spot size of the second laser beam.

Specifically, in conjunction with Fig. 1, in some embodiments, the laser emitter 110 may be moved along a direction of the straight line to adjust the working distance from the laser emitter 110 to the sacrificial layer 151. In the embodiments shown in Fig. 1, the laser emitter 110 may be moved in a Z-direction to change the working distance from the laser emitter 110 to the sacrificial layer 151. A series of spot size data corresponding to the first laser beam 211 emitted by the laser emitter 110 at different working distances can be obtained by the focal spot analyser 140.

Subsequently, a first minimum spot size of the second laser beam 212 can be obtained as an optimal size according to a variation pattern of a first round spot size of the first laser beam 211 in the focal spot analyser 140, wherein the variation pattern of spot size may include a process in which the spot size first decreases from large to small and then subsequently increases from small to large. The smaller the size of the laser spot, the greater the corresponding laser power density; therefore, when the laser power emitted by the laser 111 is fixed, finding a minimum spot size of the second laser beam 212 radiating onto the sacrificial layer 151 allows obtaining the maximum laser power density for debonding, which is conducive to rapidly ablating the sacrificial layer 151 or modifying the sacrificial layer 151 to cause its peeling off. By moving the laser emitter 110 in the Z-direction and observing in the focal spot analyser 140 the process in which the spot size of the first laser beam 211 first decreases from large to small and then increases from small to large, it is equivalent to obtaining the process in which the spot size of the second laser beam 212 on the sacrificial layer 151 first decreases from large to small and then increases from small to large, thereby making it possible to obtain the first minimum spot size of the second

laser beam 212. In embodiments of the present invention, the working distance of the laser emitter 110 may be preliminarily adjusted by observing the spot condition of the first laser beam 211 in the focal spot analyser 140, to thereby preliminarily determine the operating position of the laser emitter 110.

5 Next, continuing with Fig. 3, step S340 may be performed: obtaining an infrared focal spot image of the second laser beam via an infrared vision module, and finely adjusting the working distance from the laser emitter to the sacrificial layer, to compensate for an error of the focal spot analyser.

10 Specifically, due to mechanical tolerances and the like in the installation of the focal spot analyser 140, there may be a deviation between the adjusted working distance and the actually desired operating position; that is, there remains an error in the adjustment of the working distance, which may cause a certain impact especially on systems with strict requirements for scanning accuracy and focal position, and thus may fail to meet their stringent system requirements. In response to this, further, in
15 some embodiments of the present invention, an infrared vision module 130 may be added to assist the focal spot analyser 140 in jointly adjusting the working distance of the laser emitter 110. The infrared vision module 130 may be used to directly observe the action effect of the second laser beam 212 at a target position (i.e., on the sacrificial layer 151), thereby assisting the focal spot analyser 140 in quickly and
20 accurately finding the optimal working distance of the laser emitter 110.

 Specifically, understood in conjunction with Fig. 1, in some embodiments, based on the infrared focal spot image of the second laser beam 212 obtained via the infrared vision module 130, it is possible to determine whether a spot of the second laser beam 212 meets the process requirements for debonding. When the infrared
25 focal spot image shows that the laser energy of the spot of the second laser beam 212 at the first minimum spot size is insufficient to ablate the sacrificial layer 151, the controller may control the laser emitter 110 to continue moving along the direction of the straight line (e.g., the z-direction) to adjust the working distance from the laser emitter 110 to the sacrificial layer 151. Then, based on a variation pattern of a second
30 round spot size of the first laser beam 211 detected by the focal spot analyser 140, it is equivalent to obtaining a second minimum spot size of the second laser beam 212

as the optimal size, wherein the second minimum spot size is smaller than the first minimum spot size. At this point, the laser energy of the spot of the second laser beam 212 with the second minimum spot size is greater than the laser energy of the spot of the second laser beam 212 with the first minimum spot size obtained previously, and thus is sufficient to meet the process requirements for ablating the sacrificial layer 151.

However, when the infrared focal spot image shows that the laser energy of the spot of the second laser beam 212 at the first minimum spot size ablates a device layer beneath the sacrificial layer, the controller may control the laser emitter 110 to continue moving along the direction of the straight line (e.g., the z-direction) to adjust the working distance from the laser emitter 110 to the sacrificial layer 151. Then, based on a variation pattern of a third round spot size of the first laser beam 211 detected by the focal spot analyser 140, it is equivalent to obtaining a third minimum spot size of the second laser beam 212 as the optimal size, wherein the third minimum spot size is larger than the first minimum spot size. At this point, the laser energy of the spot of the second laser beam 212 with the third minimum spot size is slightly lower than the laser energy of the spot of the second laser beam 212 with the first minimum spot size obtained previously, and thus can meet the process requirements of only ablating the sacrificial layer 151 without damaging the device layer 153.

Once the laser emitter 110 completes one movement in the Z-direction, a series of spot size data can be obtained, along with the corresponding position information of the laser emitter 110 at a certain Z-direction and the infrared focal spot image information of the sacrificial layer 151. By analysing the spot size data, the controller can obtain the optimal operating position of the laser emitter 110, while the infrared focal spot image captured by the infrared vision module 130 can be used to compensate for the mechanical installation errors of the focal spot analyser 140.

In the above-described embodiments, by analysing the results of the infrared vision module 130, it is possible to obtain the actual action effect of the second laser beam 212 on the sacrificial layer 151 of the bonded component 150 when the laser emitter 110 is at a certain position, thereby determining whether it meets the actual process requirements. On this basis, finely adjusting is then performed, which makes

it possible to more accurately determine whether the current operating position of the laser emitter 110 is at the optimal working distance, thereby reducing errors caused by deviations generated during the actual installation of the focal spot analyser 140 that could ultimately prevent achieving the optimal process effect, and such that the adjustment effect of the laser emitter 110 is better.

Finally, continuing with Fig. 3, step S350 may be performed: in response to the laser emitter being adjusted to the optimal working distance, perform laser scanning debonding on the sacrificial layer.

Specifically, as shown in Fig. 1, in some embodiments, the laser debonding apparatus 100 may further comprise a movable platform 160, placed with the bonded component 150 thereon. After the infrared vision module 130 is used to assist the focal spot analyser 140 in jointly adjusting the working distance of the laser emitter 110 to the optimal working distance, fixing the laser emitter 110 at an operating position corresponding to the optimal working distance. Then, in response to a bonded area on the sacrificial layer 151 being completely ablated by the second laser beam 212, a position of next bonded area to be ablated can be determined by means of the infrared focal spot image of the sacrificial layer 151 captured by the infrared vision module 130. Then, the controller may control the movable platform 160 to translate the bonded component 150 in an X-direction and/or a Y-direction, such that the second laser beam 212 can irradiate onto the next bonded area to be ablated, to perform ablation on the next bonded area in the sacrificial layer 151. Optionally, the moving distance of the bonded component 150 carried and moved by the movable platform is preferably greater than the diameter of the focused spot of the second laser beam 212, thereby making it possible to obtain another set of spot data and the infrared focal spot image of the sacrificial layer 151.

Further, please refer to Fig. 4, Fig. 4 illustrates a schematic structural diagram of a laser debonding apparatus according to other embodiments of the present invention.

As shown in Fig. 4, in further embodiments of the present invention, after the aforementioned step S350 is executed, a full infrared image of the entire sacrificial layer 151 in the bonded component 150 may further be obtained through the infrared

camera 131 via the illumination of the infrared light source 132, to detect whether debonding has been completed in every bonded area of the sacrificial layer 151. When there exists at least one bonded area with incomplete debonding, that is, there exists at least one bonding area where the sacrificial layer 151 is not completely destroyed, the controller may mark this bonding area and move the mobile platform 160, so that this bonded area is scanned and ablated again by the second laser beam 212. When there is at least one bonded area with incomplete debonding, that is, there is at least one bonded area where the sacrificial layer 151 is not completely destroyed, the controller may mark this one bonded area, and by moving the movable platform 160, enable this bonded area to be scanned and ablated again via the second laser beam 212. Until every bonded area in the sacrificial layer 151 of the bonded component 150 has completed debonding, the peeled device layer 153 may be transferred to a next process.

Further, continuing back to Fig. 1 as shown, in some preferred embodiments, a plurality of reflecting mirrors 113 in the laser emitter 110 may be connected to a motor (not shown in the drawings), forming a galvanometer assembly. By driving the reflecting mirrors 113 to rotate via the motor, the reflection angles of the reflecting mirrors 113 are vibrationally adjusted, thereby enabling the planning of the scanning path of the galvanometer. Fine-tune the exit optical path of the second laser beam 212 reflected by the reflecting mirrors, and perform the aforementioned steps, so that the second laser beam 212 performs local scanning on the sacrificial layer 151. Compared with the method of finely adjusting the position of the bonded component 150 via the movable platform 160 to re-irradiate the sacrificial layer 151 in a certain bonded area within the sacrificial layer 151 that is not completely destroyed, the galvanometer assembly has a faster moving speed. Therefore, in these preferred embodiments, using the galvanometer assembly can reduce the scanning radiation duration for debonding, shorten the time for local scanning debonding, and thereby improve the efficiency of debonding.

Furthermore, please continue to refer to Fig. 4 as shown; in some preferred embodiments of the present invention, the laser debonding apparatus 100 may further comprise a power meter 410. The power meter 410 may be disposed above the

reflector 113, and may be used to detect a power value of the reflected light of the second laser beam 212, incident on the bonded component 150 that is reflected via a surface of the bonded component 150.

Optionally, as shown in Fig. 4, the laser debonding apparatus 100 may further
5 comprise an infrared thermal imager 420, which may be disposed above the bonded component 150, and configured to obtain a temperature distribution map of the sacrificial layer 151, thereby feeding back the temperature changes during the laser scanning process on the sacrificial layer 151.

Further, during the execution of step S350, a power value of the second laser
10 beam 212 incident on the sacrificial layer 151 and a temperature distribution map of the sacrificial layer 151 may further be respectively obtained via the power meter 410 and the infrared thermal imager 420. When there are abnormal temperature values in the temperature distribution map, the controller may adjust an output power emitted by the laser 111, and perform real-time power monitoring during a power adjustment
15 process via the power meter 410, thereby achieving uniform temperature changes on the sacrificial layer 151 during the debonding process and improving processing quality.

Specifically, as shown in Fig. 4, the second laser beam 212 scans the surface of the bonded component 150, and via the infrared thermal imager 420, it is possible to
20 monitor the temperature changes on the surface of the bonded component 150 during the scanning debonding process, that is to say, the temperature changes of the sacrificial layer 151. The second laser beam 212 is reflected on an upper surface of the bonded component 150, and the reflected light returns along the original path. After passing through the reflecting mirrors 113, it is received by the power meter
25 410, thereby enabling the detection of the power value, which reflects the power status of the laser 111 at this time. Further, in conjunction with the feedback from the infrared thermal imager 420, it is possible to determine whether the power of the laser 111 has reached the optimal process state at this time. Once the infrared thermal imager 420 detects abnormal temperature changes on the surface of the sacrificial
30 layer 151, the abnormal temperatures can be reflected on the power meter 410 in real-time, thereby enabling real-time and accurate adjustment of the output power of the

laser 111. This ensures that during the debonding operation, neither damage to the bonded component 150 caused by excessively high power of the laser 111 nor failure of debonding due to insufficient power will occur.

Among the multiple embodiments mentioned above provided by the present invention, by adding the infrared vision module 130, it is possible to observe the laser focal spot and simultaneously collect the image of the target sacrificial layer 151 after laser action, thereby intuitively and directly determining whether the sacrificial layer 151 has achieved the target process effect. Moreover, the infrared vision module 130 can also synchronously assist with focal spot information to determine whether the working distance of the laser emitter 110 is at the optimal working position. Therefore, with the infrared vision module 130, the result of adjusting the working distance of the laser emitter 110 can be more accurate.

Next, a specific embodiment will be enumerated to fully introduce the entire process of the above-mentioned laser debonding method. As shown in Fig. 5, Fig. 5 illustrates a flow chart of a laser debonding method according to an embodiment of the present invention.

With reference to Figs. 1 and 5, in a specific embodiment, the laser emitter 110 may specifically be a laser scanning head. As shown in step S510, the laser 111 in the laser scanning head may emit a debonding infrared initial laser beam 210. Next, step S520 is executed. The infrared initial laser beam 210 passes through the optical components in the laser scanning head assembly and then is emitted toward the beam splitter 120, where it is split into 10% reflected light and 90% transmitted light. Among them, the 10% reflected light, serving as the first laser beam 211, is emitted toward the focal spot analyser 140, and the 90% transmitted light, serving as the second laser beam 212, is emitted toward the sacrificial layer 151. In step S531, the focal spot analyser 140 may analyse to obtain a spot size of the first laser beam 211, which is the reflected light. In step S532, the second laser beam 212, which is the transmitted light, may focus on the sacrificial layer 151, and at the same time produce destructive effects such as ablation or modification on the sacrificial layer 151. Subsequently, in step S540, an image of the bonded component 150 at this time may be captured via the infrared camera 131 within the infrared vision module 130.

Understandably, the image of the bonded component 150 is that is to say the infrared focal spot image of the sacrificial layer 151, and both the carrier layer 152 and the device layer 153 in the upper layers of the bonded component 150 are selected as wafers.

5 Subsequently, step S550 may be executed, by moving the laser scanning head in a z-axis direction and synchronously cooperating with moving the movable platform 160 in an x-axis direction. Herein, the laser scanning head at a z-axis position and a (x, y) coordinate point position in the bonded component 150 can obtain a piece of focal spot data and an infrared focal spot image of the sacrificial
10 layer 151. Different (x, y) coordinate point positions in the bonded component 150 corresponding to the laser scanning head at the same z-axis position can obtain a set of focal spot data and infrared focal spot images. On the other hand, moving the movable platform 160 in the x-axis or y-axis direction can obtain another set of focal spot data and infrared focal spot images. For example, the laser scanning head can be
15 moved in the z-axis direction within a 4mm stroke, with each movement of 200 μ m, and the movable platform can be moved 500 μ m in the x-axis direction (which is larger than the diameter of the focal spot). Then, after one scanning action is completed, 20 sets of focal spot data can be generated within this z-axis movement range.

In step S560, the working position of the laser scanning head may be determined
20 by analysing the data of the focal spot analyser 140. Specifically, it is possible to analyse the 20 sets of focal spot data obtained above via the focal spot analyser 140, which correspond to different z-axis positions of the laser scanning head, to check whether there exists a pattern that the spot size first decreases from large to small and then subsequently increases from small to large within a 3mm range. On the basis
25 that the spot size change is consistent with this pattern, then determine the z-axis working position of the laser scanning head corresponding to the smallest focal spot.

Finally, in step S570, the infrared focal spot image captured by the infrared camera 131 when the laser scanning head is at this z-axis position may be compared to check whether it meets the process requirements. That is, the laser energy of the
30 debonding laser incident on the sacrificial layer is sufficient to destroy the sacrificial layer 151, while not destroying the device layer 153 located below the sacrificial layer

151. Furthermore, the position of laser irradiation can also be intuitively obtained via the infrared focal spot image. If the current position of the laser scanning head meets the process requirements, the laser scanning head may be fixed at this position; if not, further adjustment of its z-axis position may be continued to compensate for the error of the focal spot analyser 140.

In this embodiment, deviations generated during the actual installation of the focal spot analyser 140 may lead to deviation data of the laser scanning head in the z-axis direction. For example, the data of the focal spot analyser 140 may show that z_1 is the position with the smallest focal spot (i.e., light spot), while by comparing the image captured by the infrared camera 131 at this position, it is found that the process effect generated by the laser scanning head at position z_1 is not ideal. At this time, the z-axis position of the laser scanning head with ideal process effect can be searched for from the infrared focal spot images captured by the infrared camera 131, and the laser scanning head can be fixed at this position to perform subsequent laser scanning debonding. That is to say, the working position of the laser scanning head corresponding to the smallest focal spot can be found via the focal spot analyser 140, while the working position of the laser scanning head when the debonding effect is optimal can be obtained through the analysis of the infrared images acquired via the infrared vision module 130, i.e., the optimal working distance.

Although the method is illustrated and described as a series of actions for the purpose of simplifying the explanation, it should be understood and appreciated that these methods are not limited by the order of the actions. Those skilled in the art may understand that some actions may occur in different orders and/or concurrently with other actions that are illustrated and described herein or that are not illustrated and described herein, in accordance with one or more embodiments.

Those skilled in the art will further appreciate that the steps of the methods or algorithms described in connection with the embodiments disclosed herein may be directly embodied in hardware, in software modules executed by a processor, or in combinations of the two. Software modules may reside in RAM, flash memory, ROM, EPROM, EEPROM, register, hard disk, removable disk, CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the

processor such that the processor can read from and write to the storage medium. In the alternative, the storage medium may be integrated into the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal. In the alternative, the processor and the storage medium may reside in the user terminal as discrete components.

In one or more exemplary embodiments, the described functions may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software as a computer program product, the functions may be embodied as one or more instructions or code stored on or transmitted through a computer-readable medium. Computer-readable media includes both computer storage media and communication media, which includes any medium that facilitates the transfer of a computer program from one place to another. Storage medium may be any available medium that can be accessed by a computer. By way of example and not limitation, such computer-readable media may include RAM, ROM, EEPROM, CD-ROM, or other optical disk storage, magnetic disk storage, or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Any connection is also properly referred to as a computer-readable medium. For example, if software is transmitted from a web site, server, or other remote sources using coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then such coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included within the definition of medium. As used herein, the terms "disk" and "disc" include compact discs (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray disc, wherein "disk" typically reproduces data magnetically, while "disc" reproduce data optically with a laser. Combinations of the foregoing should also be included within the scope of computer-readable media.

In summary, the present invention provides a laser debonding apparatus, a laser debonding method, and a computer-readable storage medium, which is capable of quickly and accurately adjusting the laser emitter to an optimal working distance

without requiring multiple process effect verifications, thereby shortening the process duration and improving the process efficiency.

The previous description of the disclosure is provided to enable any person skilled in the art to make or use the disclosure. Various modifications to the present disclosure will be obvious to those skilled in the art, and the general principles defined
5 herein may be applied to other variations without departing from the spirit or scope of the disclosure. Thus, the present disclosure is not intended to be limited to the examples and designs described herein, but is to be accorded the broadest scope of the principles and novel features disclosed herein.

Claims

1. A laser debonding apparatus, comprising:

a laser emitter, configured to emit an initial laser for debonding;

5 a beam splitter, configured to split the received initial laser into a first laser beam directed to a focal spot analyser, and a second laser beam directed to a sacrificial layer of a bonded component, wherein a distance from the beam splitter to the focal spot analyser equals to a distance from the beam splitter to the sacrificial layer;

10 an infrared vision module, configured to acquire an infrared focal spot image of the second laser beam on the sacrificial layer; and

a controller configured as: obtaining a spot size of the first laser beam via the focal spot analyser, wherein the spot size of the first laser beam is equivalent to a spot size of the second laser beam; preliminarily adjusting a working distance from the laser emitter to the sacrificial layer to optimize the spot size of the second laser beam;

15 obtaining the infrared focal spot image of the second laser beam via the infrared vision module, and finely adjusting the working distance from the laser emitter to the sacrificial layer, to compensate for an error of the focal spot analyser; and in response to the laser emitter being adjusted to an optimal working distance, performing laser scanning debonding on the sacrificial layer.

20 2. The laser debonding apparatus according to claim 1, wherein the laser emitter, the beam splitter and the bonded component lie on a same straight line,

the preliminarily adjusting a working distance from the laser emitter to the sacrificial layer to optimize the spot size of the second laser beam comprises:

25 moving the laser emitter along a direction of the straight line, and adjusting the working distance from the laser emitter to the sacrificial layer; and

obtaining a first minimum spot size of the second laser beam as an optimal size, according to a variation pattern of a first round spot size of the first laser beam in the focal spot analyser, wherein the variation pattern of spot size includes a process in

30 which the spot size first decreases from large to small and then subsequently increases

from small to large.

3. The laser debonding apparatus according to claim 2, wherein the obtaining the infrared focal spot image of the second laser beam via the infrared vision module, and finely adjusting the working distance from the laser emitter to the sacrificial layer, to compensate for an error of the focal spot analyser comprises:

determining whether a spot of the second laser beam meets a debonding process requirement, based on the infrared focal spot image of the second laser beam obtained via the infrared vision module;

in response to insufficient laser energy of the spot of the second laser beam at the first minimum spot size to ablate the sacrificial layer, continuing to move the laser emitter along the direction of the straight line, to further adjust the working distance from the laser emitter to the sacrificial layer; and

obtaining a second minimum spot size of the second laser beam as the optimal size, according to a variation pattern of a second round spot size of the first laser beam in the focal spot analyser, wherein the second minimum spot size is smaller than the first minimum spot size.

4. The laser debonding apparatus according to claim 3, wherein the determining whether a spot of the second laser beam meets a debonding process requirement comprises:

in response to the laser energy of the spot of the second laser beam, at the first minimum spot size, ablating a device layer beneath the sacrificial layer, continuing to move the laser emitter along the direction of the straight line, to further adjust the working distance from the laser emitter to the sacrificial layer; and

obtaining a third minimum spot size of the second laser beam as the optimal size, according to the variation pattern of a third round spot size of the first laser beam in the focal spot analyser, wherein the third minimum spot size is larger than the first minimum spot size.

5. The laser debonding apparatus according to claim 4, further comprising a

movable platform, placed with the bonded component thereon,

the in response to the laser emitter being adjusted to an optimal working distance, performing laser scanning debonding on the sacrificial layer comprises:

fixing the laser emitter at a position corresponding to the optimal working distance, in response to a bonded area on the sacrificial layer being completely ablated by the second laser beam, determining a position of next bonded area to be ablated, by means of the infrared focal spot image of the sacrificial layer captured by the infrared vision module; and

translating the bonded component along an X-direction and/or a Y-direction via the movable platform, to irradiate the second laser beam onto the next bonded area to be ablated.

6. The laser debonding apparatus according to claim 5, wherein after performing laser scanning debonding on the sacrificial layer, in response to the laser emitter being adjusted to an optimal working distance,

in response to a completion of the laser scanning debonding, obtaining a full infrared image of the sacrificial layer via the infrared vision module, to detect whether debonding has been completed in every bonded area of the sacrificial layer;

in response to an existence of at least one bonded area with incomplete debonding, marking the at least one bonded area, and moving the movable platform to scan the at least one bonded area again via the second laser beam; and

in response to a completion of debonding in every bonded area, transfer a peeled device layer to a next process.

7. The laser debonding apparatus according to claim 1, wherein the laser emitter comprises:

a laser, configured to provide the initial laser;

an optical assembly, configured to adjust a transmission angle of the initial laser, to transmit the initial laser to the beam splitter.

8. The laser debonding apparatus according to claim 7, wherein the optical

assembly comprises a collimating and beam-expanding system, a reflecting mirror and a field lens, wherein the collimating and beam-expanding system is configured to adjust a spot size of the initial laser, to make it match a spot size of the field lens, and the reflecting mirror is configured to reflect the initial laser into the field lens, so that the field lens focuses the initial laser onto the sacrificial layer.

9. The laser debonding apparatus according to claim 8, wherein the reflecting mirror is connected to a motor, and driven by the motor to rotate, to adjust a reflection angle of the reflecting mirror in an oscillating manner, and finely adjust an exit optical path of the second laser beam reflected by the reflecting mirror, thereby enabling the second laser beam to perform local scanning on the sacrificial layer.

10. The laser debonding apparatus according to claim 8, further comprising:
a power meter, disposed above the reflecting mirror, and configured to detect a power value of a reflected light of the second laser beam, incident on the bonded component that is reflected via a surface of the bonded component.

11. The laser debonding apparatus according to claim 10, further comprising:
an infrared thermal imager, disposed above the bonded component, and configured to obtain a temperature distribution map of the sacrificial layer,
the in response to the laser emitter being adjusted to an optimal working distance, performing laser scanning debonding on the sacrificial layer comprises:

respectively obtaining a power value of the second laser beam incident on the sacrificial layer and a temperature distribution map of the sacrificial layer via the power meter and the infrared thermal imager; and

in response to a presence of abnormal temperature values in the temperature distribution map, adjusting an output power of the laser, and performing power monitoring during a power adjustment process via the power meter.

12. The laser debonding apparatus according to claim 1, further comprising:
a laser rangefinder, disposed at a bottom of the focal spot analyser, and

configured to detect a distance from the beam splitter to the focal spot analyser and a distance from the beam splitter to the sacrificial layer, wherein the distance from the beam splitter to the focal spot analyser is fixed as L , a distance from a light exit port of the laser rangefinder to the beam splitter is L_1 , a distance from the light exit port to the bonded component is L_2 , and a thickness of a carrier layer above the bonded component is d , such that $L = L_1 + L_2 + d$.

13. The laser debonding apparatus according to claim 1, wherein a ratio range of the first laser beam to the second laser beam after the initial laser is split by the beam splitter ranges from 1:9 to 3:7.

14. The laser debonding apparatus according to claim 1, wherein the infrared vision module comprises an infrared camera, an infrared light source and a filter, wherein the filter is disposed in front of a lens of the infrared camera, and is configured to filter out a reflected light of the second laser beam that is incident on the bonded component and reflected via a surface of the bonded component.

15. A laser debonding method, comprising following steps:

emitting an initial laser for debonding via a laser emitter in the laser debonding apparatus according to any one of claims 1 to 14, wherein the initial laser is split into two beams by a beam splitter, a first laser beam is directed to a focal spot analyser, a second laser beam is directed to a sacrificial layer of a bonded component, and a distance from the beam splitter to the focal spot analyser equals to a distance from the beam splitter to the sacrificial layer;

obtaining a spot size of the first laser via the focal spot analyser, wherein the spot size of the first laser is equal to a spot size of the second laser;

preliminarily adjusting a working distance from the laser emitter to the sacrificial layer to optimize the spot size of the second laser beam;

obtaining an infrared focal spot image of the second laser beam via an infrared vision module, and finely adjusting the working distance from the laser emitter to the sacrificial layer, to compensate for an error of the focal spot analyser; and

in response to the laser emitter being adjusted to an optimal working distance, performing laser scanning debonding on the sacrificial layer.

- 5 16. A computer-readable storage medium having a computer instruction stored thereon, wherein when the computer instruction is executed by a processor, the laser debonding method according to claim 15 is implemented.