

A laser apparatus and a method of directing laser to a workpiece surface

Field of the invention

This invention relates to a laser apparatus that particularly, but not exclusively, performs laser marking for engraving or marking a workpiece surface. The invention also relates to a method of directing laser to a workpiece surface.

Background of the invention

Laser marking is a conventional technology that uses laser to engrave or mark a workpiece surface. Examples of lasers include infrared-type lasers having wavelengths between 1064nm and 11um such as CO₂ lasers, and visible-type lasers having wavelengths between 400-700nm such as green lasers.

Typically, a workpiece with a surface for laser marking is first supported at a predefined position on a platform before a laser-emitting device directs laser onto the workpiece surface to create one or more marks thereon. FIG. 1 shows a conventional laser marking device 100 comprising a computer 102 for controlling a laser generator 104 and a laser beam delivery system 106, to direct a laser beam 108 from the laser generator 104 onto the workpiece placed at the predefined position on the platform such that the workpiece surface corresponds to a marking plane 110 for marking.

Practically, however, the workpiece may not be accurately placed at the predefined position on the platform due to various factors, such as inaccurate workpiece placement or machine vibration. The problem of inaccurate workpiece placement on the platform may be especially apparent if the size of the workpiece is small (e.g. in the order of 0.1mm). This is because small variations in position will cause the one or more marks to vary between different workpieces.

Thus, it is an object of this invention to seek to provide a laser apparatus that addresses the problem of inaccurate workpiece placement for laser processing.

Summary of the invention

A first aspect of the present invention is a laser apparatus comprising: an imaging device having an optical path for capturing an image of a workpiece surface; an laser-emitting device configured to direct laser along a laser path to the workpiece surface, the laser path of the laser-emitting device being separate from the optical path of the imaging device; and a controller coupled to the imaging device and the laser-emitting device, the controller being configured to adjust the laser path of the laser-emitting device based on an image of the workpiece surface as captured by the imaging device.

A second aspect of the invention is a method of directing laser to a workpiece surface, the method comprising the steps of: an imaging device capturing a workpiece surface image along an optical path; a controller receiving the captured workpiece surface image as captured by the imaging device, and adjusting a laser path of a laser-emitting device for directing laser to the workpiece surface, the laser path of the laser-emitting device being separate from the optical path of the imaging device; the laser-emitting device directing laser to the workpiece surface along the adjusted laser path.

Some preferred features/step of the laser apparatus are defined in the dependent claims.

Brief description of the drawings

Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, of which:

FIG. 1 shows a conventional laser marking device;

FIGs. 2a and 2b show different side views of a laser apparatus according to a preferred embodiment of the invention;

FIG. 3 shows a bottom view of the laser apparatus of the preferred embodiment;

FIGs. 4a-4c compare the operations of the conventional laser marking device of FIG. 1 and the laser apparatus of the preferred embodiment, in which a workpiece surface is accurately placed with respect to a marking plane without rotation and offset;

FIGs. 5a-5c compare the operations of the conventional laser marking device of FIG. 1 and the laser apparatus of the preferred embodiment, in which a workpiece surface is inaccurately placed with respect to a marking plane with rotation and offset; and FIG. 6 is a flow chart showing an operation of the laser apparatus of the preferred embodiment.

Detailed description of the preferred embodiments

FIGs. 2a and 2b show different side views of a laser apparatus 200 according to a preferred embodiment. The laser apparatus 200 comprises: i) a laser-emitting device (shown as a laser generator 204 and a laser beam delivery system 206); ii) an imaging device 202 mounted to the laser-emitting device 204, 206; and iii) a controller 208 (e.g. a computer) coupled to the laser-emitting device 204, 206 and the imaging device 202. The controller 208 controls the laser-emitting device 204, 206 to direct a laser beam along a laser path 210 onto a workpiece that is supported at a predefined position on a platform, such that the workpiece surface corresponds to a marking plane 212 for marking.

Further the imaging device 202 is operative to capture an image of the workpiece surface along a defined optical path (FIG. 2b: '214'), and to send the captured image to the controller 208 for processing. Based on this captured image, the controller 208 in turn controls the laser beam delivery system 206 to adjust the laser path 210 of the laser beam, before the laser beam is directed onto the workpiece surface for marking. In particular, the laser path 210 of the laser beam from the laser-emitting device 204, 206 is distinct and separate from the optical path 214 of the imaging device 202.

The laser beam delivery system 206 comprises a set of galvo mirrors 216a, 216b that are controllable by the controller 208 to rotate about their respective rotational axes, to thereby direct the laser beam in an X- or Y-direction to a position on the marking plane 212. The laser beam delivery system 206 may also comprise: a convergent f-theta lens (not shown) for focusing the laser beam onto the marking plane 212; and a light box 218 for illuminating the workpiece surface prior to imaging.

As the galvo mirrors 216a, 216b are used for reflecting the laser beam from the laser generator 204 but are not necessary to allow light from the workpiece surface to transmit through to reach the imaging device 202 for image capture, it is not required for the galvo mirrors 216a, 216b to be specially constructed (e.g. via specialized coating processes) to allow for both laser reflection and light transmission. Consequently, the galvo mirrors 216a, 216b do not have to be, for example, dichroic mirrors, which are compatible for both laser reflection and light transmission. This advantageously reduces the complexity and costs for constructing the laser beam delivery system 206. This also means that the imaging device 202 could be used with different types of the laser generator 204.

Referring to FIG. 2b, it can be seen that the imaging device 202 specifically includes: i) a camera 222 for capturing images; ii) another light box 220 for illuminating the workpiece surface; and iii) a set of fixed mirrors 224a, 224b, in which the fixed mirror 224a is configured to reflect light from the light box 220 onto the workpiece surface whereas the fixed mirror 224b is configured to reflect light along the optical path 214 from the workpiece surface to the camera 222.

As the fixed mirrors 224a, 224b are used for reflecting light but are not necessary to allow any laser to transmit through to reach the marking plane 212, it is not required for the fixed mirrors 224a, 224b to be specially constructed (e.g. via specialized coating processes) to allow for both laser reflection and light transmission. Consequently, the fixed mirrors 224a, 224b do not have to be, for example, dichroic mirrors that are compatible for both laser reflection and light transmission. This advantageously reduces the complexity and costs for constructing the imaging device 202. This also means that the imaging device 202 could be used with different types of the laser generator 204.

Since the laser path 210 of the laser beam from the laser-emitting device 204, 206 is distinct and separate from the optical path 214 of the imaging device 202, the laser apparatus 200 has to be calibrated during set-up of the laser apparatus 200. For example, since the marking plane 212 corresponds to the workpiece surface for marking, the controller 208 may determine position coordinates of a point on the marking plane 212 at

which the laser beam directs. At the same time, the controller 208 also determines position coordinates of a corresponding point on the marking plane 212 that is detected by the camera 222. Based on the position coordinates of these corresponding points on the marking plane 212, the controller 208 determines a compensating factor that takes into account the positional difference between those corresponding points on the marking plane 212. This compensating factor is then pre-stored in the controller 208, and the calibration process is completed.

Alternatively, the controller 208 may control the laser-emitting device 204, 206 to form a pattern on a sample workpiece surface based on position coordinates of the laser-emitting device 204, 206. The imaging device 202 then captures an image of the pattern and analyzes the pattern based on position coordinates of the imaging device 202. The differences in the position coordinates of the pattern as formed by the laser-emitting device 204, 206 and as captured by the imaging device 202 are then calculated by the controller 208 to derive a compensating factor. This compensating factor is then pre-stored in the controller 208, and the calibration process of the laser apparatus 200 is completed.

In addition, the controller 208 also pre-stores a reference template comprising reference fiducials in relation to the workpiece surface for marking. For instance, the reference template may comprise a plurality of distinctive features (e.g. corners of a rectangle) at predetermined coordinate positions. During operation, the controller 208 compares these predetermined coordinate positions of the reference fiducials against corresponding coordinate positions of features on the workpiece surface as detected by the camera 222. Positional errors of the workpiece surface relative to the marking plane 212 may be due to translational and/or rotational errors of the workpiece fiducials relative to the reference fiducials of the pre-stored reference template. In the presence of a positional error of the workpiece surface relative to the marking plane 212, the controller 208 accordingly compensates for the workpiece positional error by adjusting the galvo mirrors 216a, 216b of the laser beam delivery system 206 through another compensating factor, such that the direction of the laser path 210 takes into account the workpiece positional error. Optionally, the controller 208 may also analyze the captured workpiece surface image to derive the

compensating factor, without comparing the captured image against the reference template, based on a machine learning process of the laser apparatus 200.

FIGs 4a-4c compare the operations of the conventional laser marking device 100 and the laser apparatus 200, in which a workpiece 400 is accurately placed at a predefined location on a platform without rotation and offset as illustrated in FIG. 4a.

FIG. 4b illustrates the workpiece 400 being accurately marked by the conventional laser marking device 100. The positional accuracy of laser marking on the workpiece 400 is attributed to accurate placement of the workpiece 400 at the predefined position on the platform, such that the workpiece surface corresponds to the marking plane 402. Thus, although there is no feedback to the conventional laser marking device 100 regarding the positional information of the workpiece surface with respect to the marking plane 402, the workpiece 400 will still be accurately marked.

Likewise, FIG. 4c illustrates the workpiece 400 being accurately marked by the laser apparatus 200. In addition to the accurate placement of the workpiece 400 at the predefined position on the platform, there is also feedback to the laser apparatus 200 regarding the positional information of the workpiece surface relative to the marking plane 402 in the form of the workpiece surface image, which is captured by the camera 222 and accordingly analyzed by the controller 208 to ensure accurate marking of the workpiece 400.

FIGs 5a-5c further compare the operations of the conventional laser marking device 100 and the laser apparatus 200, in which the workpiece 400 is not accurately placed at a predefined position on the platform, such that there is rotation and offset of the workpiece surface relative to the marking plane 402 as illustrated in FIG. 5a.

FIG. 5b illustrates the workpiece 400 being inaccurately marked by the conventional laser marking device 100. The positional inaccuracy of laser marking on the workpiece 400 is attributed to inaccurate placement of the workpiece 400 at the predefined position of the

platform. Since there is no feedback to the conventional laser marking device 100 regarding the positional information of the workpiece surface with respect to the marking plane 402, the workpiece 400 is hence inaccurately marked.

On the contrary, FIG. 5c illustrates the workpiece 400 being accurately marked by the laser apparatus 200. Such positional accuracy of laser marking on the workpiece 400 is attributed to the feedback to the laser apparatus 200 regarding the positional information of the workpiece 400 in the form of a workpiece surface image, which is captured by the camera 222 and accordingly analyzed by the controller 208.

FIG. 6 is a flow chart 600 showing an operation of the laser apparatus 200.

First, the laser apparatus 200 performs a calibration step 601 in which the controller 208 derives a first compensating factor that takes into account the positional difference between one or more points on the marking plane 212 at which the laser beam directs and one or more corresponding points on the marking plane 212 detected by the camera 222. Next, the laser apparatus 200 performs an image-capturing step 602 which involves the camera 222 capturing an image of a workpiece surface to be marked by the laser apparatus 200, and the controller 208 either comparing detected fiducials of the captured image against reference fiducials of a reference template prestored in the controller 208 or performing a machine learning process, to derive a second compensating factor that takes into account the positional error of the workpiece surface with respect to the marking plane 212.

Based on the first and second compensating factors, the laser apparatus 200 then adjusts 604 the laser path 210 of the laser beam so that the laser beam is accurately directed on the desired region on the workpiece surface for marking. This may be done by the controller 208 controlling the galvo mirrors 216a, 216b to rotate about their respective rotational axes. Finally, the laser apparatus emits 606 the laser beam from the laser beam delivery system 206 such that the laser path 210 of the laser beam is accurately directed on the workpiece surface for marking.

Since the laser path 210 of the laser beam from the laser-emitting device 204, 206 is distinct and separate from the optical path 214 of the imaging device 202, there is no interference between the laser path 210 of the laser beam and the optical path 214 of the imaging device 202. Accordingly, there is no need for the galvo mirrors 216a, 216b of the laser beam delivery system 206 or the fixed mirrors 224a, 224b of the imaging device 202 to be specially coated for both laser reflection and light transmission through these mirrors. Further, there is no material constraint in terms of choosing the material for constructing the convergent lens (e.g. the f-theta lens) for focusing the laser beam onto the marking plane 212 such that the convergent lens are compatible for both laser and light transmission. Thus, the laser apparatus 200 advantageously reduces the complexity and costs of its construction. This also means that the imaging device 202 could be used with different types of the laser generator 204.

Moreover, the laser beam delivery system 206 and the imaging device 202 may be separately aligned, since calibration of the laser apparatus 200 can be done by the controller 208 by deriving a compensating factor that takes into account the positional difference between a point on the marking plane 212 at which the laser beam is directed and a corresponding point on the marking plane 212 that is detected by the camera 222.

Furthermore, the feedback of positional information to the laser apparatus 200 regarding a workpiece surface with respect to the marking plane 212 allows the controller 208 to derive another compensating factor that takes into account the positional error of the workpiece surface with respect to the marking plane 212, and adjusting the laser path 210 of the laser beam based on that compensating factor so that the laser beam is accurately directed on the desired region on the workpiece surface for marking. Advantageously, this means that the workpiece can be accurately marked by the laser apparatus 200.

Various embodiments of this invention can also be envisaged without departing from the scope of the invention. For instance, in addition to laser marking, the laser apparatus 200 may also be for laser ablation, laser scribing, or any other kinds of laser processing that

require accurate workpiece positioning. The laser apparatus 200 may also be incorporated in a test handler having at least an imaging zone and a laser-marking zone for marking electronic packages. For instance, the test handler may rotate about a rotational axis to transfer electronic packages from the imaging zone to the laser-marking zone. In this instance, the imaging device 202 (or, particularly, the camera 222) may be positioned in the imaging zone for capturing an image of an electronic package, before the electronic package is transferred to the laser-marking zone for laser-marking by the laser generator 204 and the laser beam delivery system 206. Furthermore, although the position of the laser path 210 of the laser beam is controlled by a galvanometer through the use of galvo mirrors 216a, 216b, an XY-table may be used instead.

Claims

1. A laser apparatus comprising:
 - an imaging device having for capturing one or more images;
 - a first lighting device for emitting light;
 - a first mirror arranged with respect to the lighting device to reflect the light emitted from the lighting device towards a workpiece surface to thereby define a light path for illumination, and a second mirror arranged with respect to the imaging device to reflect an image of the illuminated workpiece surface towards the imaging device to thereby define an optical path for image capturing;
 - a second lighting device for emitting an illumination lighting directly onto the workpiece surface, wherein the second lighting device is located between the mirrors and the workpiece surface;
 - a laser-emitting device configured to direct laser along a laser path to the workpiece surface for laser marking, the laser path of the laser-emitting device being separate from the light path and the optical path;
 - and
 - a controller coupled to the imaging device and the laser-emitting device, the controller being configured to adjust the laser path of the laser-emitting device based on the image of the illuminated workpiece surface as captured by the imaging device.
2. The laser apparatus of claim 1, wherein the controller is configured to compare the captured workpiece surface image against a prestored reference template.
3. The laser apparatus of anyone of the preceding claims, wherein the imaging device is mounted to the laser-emitting device.
4. The laser apparatus of claim 3, wherein the imaging device is inclined at an angle with respect to the laser-emitting device.
5. A method of directing laser to a workpiece surface, the method comprising the steps of:
 - a first lighting device emitting light;
 - a first mirror reflecting the light emitted from the lighting device towards a workpiece surface to thereby define a light path for illumination, and a second mirror reflecting an image of the illuminated workpiece surface towards the imaging device to thereby define an optical path for image capturing;
 - emitting an illumination lighting from a second lighting device directly onto the workpiece surface, wherein the second lighting device is located between the mirrors and the workpiece surface;
 - the imaging device capturing the image of the illuminated workpiece surface image;
 - a controller receiving the captured workpiece surface image as captured by the imaging device, and adjusting a laser path of a laser-emitting device for directing laser to the workpiece surface based on the image of the illuminated workpiece surface as captured by the imaging device; and;
 - the laser-emitting device directing laser to the workpiece surface along the adjusted laser path to laser mark the workpiece surface, the laser path of the laser-emitting device being separate from the light path and the optical path.
6. The method of claim 5, wherein the step of adjusting the laser path of the laser-emitting device comprises comparing the captured workpiece surface image against a reference template prestored in the controller.