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(54) **Title:** BENDING TOOL CARRIER, TOOL CHANGING STATION, ASSEMBLIES COMPRISING BENDING TOOL CARRIERS, AND TOOL WITH MARKING

(57) **Abstract:** The invention relates to a tool carrier for a press brake or folding press, comprising a tool holder for holding one or more tools. According to the invention, the tool carrier comprises a first and a second transducer, each being capable of transducing electrical energy to light and vice versa, the first and second transducers each being configured to transmit light towards, and to receive light from, the one or more tools held by the tool holder.

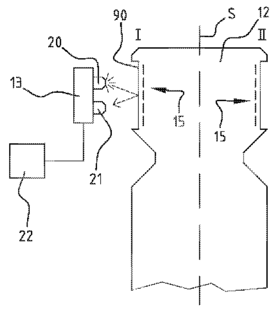

FIG. 9A

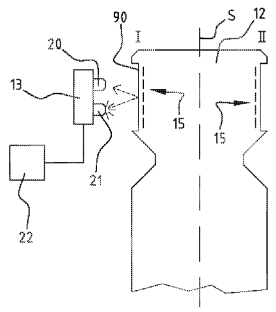

FIG. 9B

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BENDING TOOL CARRIER, TOOL CHANGING STATION, ASSEMBLIES COMPRISING BENDING TOOL CARRIERS, AND TOOL WITH MARKING

The invention relates to a tool carrier for carrying bending tools for use in for instance a press brake or folding press. The tool carrier comprises at least one tool holder for holding one or more tools.

Press brakes are machines used for bending or folding sheet material, such as metal sheets. For that purpose, press brakes include a bottom beam and a top beam, which are movable with respect to each other. The top and bottom beams both hold tools, between which a workpiece is provided for bending. In general, bending tools of a press brake are exchangeable to allow making different types of bends or folds, and to allow servicing the tools. Therefore, press brakes are provided with a clamping system which can releasably clamp the tools. Such a clamping system may comprise a beam for holding one or more tools. Different clamping systems will be described below.

Tools that are not being used, i.e. which are not currently held by the press brake or folding press, may need to be stored for later use, may need to be held for inspection or servicing, or may need to be carried for other reasons. The tool carrier described herein may hold tools using tool holders whilst the tool is not used in the press brake or folding press.

A tool holder of the tool carrier may be similar to a clamping system for a press brake or folding press in that it provides a receiving space for receiving a part of the tool, and for holding the tool by that part in the receiving space. In order to provide accurate and/or safe operation, clamping systems clamp the tools, whilst a tool holder of a tool carrier may or may not clamp tools in place.

Clamping systems may be provided on the top beam of the press brake, on the bottom beam, or on both. Clamping systems extend over substantially the entire width of the press brake, while individual tools normally extend over only a part of the press brake width. A tool of a specific size may be selected for a specific workpiece to be bent or folded. Multiple tools can be placed at various positions in the clamping system to perform different bending or folding operations.

Two types of press brakes can be distinguished. The first type has a clamping system that is an integral part of either the top or bottom beam. A further clamping system may or may not be provided for the other of the top or bottom beam. Such a clamping system, that is an integrated one, can not be detached from its top or bottom beam, and is itself thus not exchangeable with another clamping system, whereas the tools the clamping system can hold are exchangeable. The second type has an exchangeable clamping system that can be fixedly connected to either the top beam or the bottom beam. A further clamping system may or may not be provided for the other of the top or bottom beam. The exchangeable clamping system allows exchanging tools, but can also be detached from its top or bottom beam, for instance for maintenance or for exchanging it for another clamping system. This is used in the art to make one press brake suitable for different tooling types, which may require different clamping systems, and/or to service the clamping system.

Further clamping systems exist that can be clamped by other clamping systems as if they were a tool. Such clamping systems can for instance be clamped by a system for tools of a first type, whereas they themselves can clamp tools of a second type, so that such clamping systems act as an adaptor between a clamping system and a tool that would otherwise be incompatible.

The invention relates to a tool carrier as described above, which can for instance be a clamping system for a press brake or folding press, wherein the clamping system comprises a beam as the tool holder. Nevertheless the invention may also relate to tool carriers that are not clamping systems, which do or do not clamp the tool, such as tool stores in which tools may be stored while they are not being used. It is noted that a tool store is thus different from a folding press or press brake itself, as a tool store does not allow use of the tool for bending while it is in the tool store.

In that regard it is noted that the term tool store is used herein as referring to a tool storage system. A tool store may for instance be comprised of a tool rack, a tool magazine, a tool warehouse, etc.

A tool carrier may comprise multiple tool holders. A tool store for instance may comprise tool holders for several tools of different sizes and shapes, which can be selected as required for performing different bending operations. The tool carrier may comprise tool holders of different types, for instance for upper and bottom tools.

The clamping systems concerned may be integrated with press brakes, be it the bottom beam or top beam, exchangeable clamping systems, and clamping systems acting as an adaptor. Similarly, the invention can be applied to folding presses.

In order to make a desired bend or fold, it is important the press brake is fitted with the right tool, and that the tool is at the right position along the longitudinal direction of the beam.

For that reason, a system capable of identifying and localizing tools known as TIPS marketed by the applicant has become popular. Some details of the TIPS system have been disclosed in EP 1 864 752 A1. EP 1 864 752 A1 discloses in figure 3 a method of positioning, defined in the current application as “to determine the position of”, a tool by emitting light towards the tool using light-emitting devices 12 and receiving reflected light using light-receptive sensors 11.

Although the method of using emitters and receivers is effective for positioning and identifying tools, there is a desire for improvement of said method. In particular, the accuracy of positioning is limited by the size of emitters and sensors. In theory accuracy can be improved by using a larger number of emitters and sensors in different positions. However, the maximum usable amount is limited by space available on the tool and on the beam. As such, the accuracy of the positioning system presented in EP 1 864 752 A1 has an upper bound.

Moreover, the system of EP 1 864 752 A1 allows identification of a limited amount of types of tools. However, the system is limited in the amount of recognizable patterns. Thus, there is also a need to improve the system of EP 1 864 752 A1 by allowing identification of more patterns. The ability to identify more patterns may for instance allow the identification of individual tools, instead of simply the type of tool.

In some cases, it may be beneficial to accurately position the tool in the tool carrier. For instance, when the tool carrier is a clamping system, but also in other cases. As an example, a robot may be used to automatically move a tool from a tool carrier such as a tool store to a press brake or folding press. In this case inaccuracies in the positioning of the tool in the tool carrier may cause corresponding inaccuracies in the position of the tool in the press brake or folding press.

Other situations in which a tool may need to be carried or held, outside of the press brake and/or folding press, are a tool changing station, a manual or automated loading and/or unloading station, or a station to perform tool insertion, facilitate receipt or expedition. The tool carrier could also be applied in a tool inspection and/or servicing station, which could be used to perform maintenance such as cleaning and/or to measure whether the tools need replacement or repair or some other type of maintenance. As such, the tool carrier may be any kind of orientation station, having a longitudinal direction along which the position of the tool may be determined, for instance for placing it at a desired optionally transversal position of a press brake and/or folding press.

In tool carriers there may also be a benefit to reading a larger amount of information from a tool. In the example of the tool store for instance, it may be advantageous to be able to distinguish between many different types of tools, or even between many more different tools themselves.

It is therefore an object of the invention to improve the existing tool carrier by allowing a greater positioning accuracy and/or a larger amount of information to be read from a tool.

Said object is achieved by a tool carrier according to the preamble, which has a first and a second transducer, each being capable of transducing electrical energy to light and vice versa, the first and second transducers each being configured to transmit light towards, and to receive light from, the one or more tools held by the beam

By using transducers which can both emit and receive light, it becomes possible to first produce light with the first transducer and receive preferably the same light, albeit reflected, with the second, and to repeat the process vice versa. As such, two measurements can be taken with the same transducers. The two measurements may be used in conjunction to increase the amount of information on the tool and the position thereof. Since the two measurements can be made with the same components, relatively little space is needed for the components. Accordingly, more information may be encoded on the same amount of space, which may facilitate identification of a particular tool instead of merely its type. Further or alternatively, positioning may become more accurate, as the resolution is increased by placing a relatively large amount of transducers on a relatively small space.

In particular, the use of visible light is envisioned. However, the invention could be applied with other forms of light, such as UV-light and infrared right. UV-light is herein defined as having a wavelength of between 100 nm and 400 nm. Visible light is herein defined as having a wavelength of between 400 nm and 780 nm. Infrared light is herein defined as having a wavelength of between 780 nm and 1000 µm. As such, light is herein defined as having a wavelength of between 100 and 1000 nm.

It is noted that there need not be an unobstructed path between the transducers and the tool. In fact, any object that is transparent or otherwise permeable to the used light may be placed in between without compromising operation of the tool carrier. This characteristic may be advantageously employed by applying a cover over the transducers, the cover being transparent to at least the light produced by the transducers, so as to protect the transducers from inadvertent impacts. A particularly suitable cover may be made of Gorilla Glass as marketed by Corning Inc. of New York, United States (www.corning.com), or a similar type of chemically strengthened glass.

Transducer as used herein refers to a single active component taken in isolation, i.e. not to a system composed of multiple components. Thus, according to the invention the same component that converts light to electricity also converts the electricity to light. This is exactly why fewer components may be needed than the traditional case, in which one component detects light and the other emits it.

The transducers may be part of a sensing system including additional emitting and receiving components, preferably exclusively including other similar or identical transducers.

The transducers may cooperate with each other for detecting the same tool. As such, the transducers may be arranged together in a single tool carrier or tool holder thereof, such as that of/for either an upper beam or a lower beam of a press brake or folding press. The transducers may be arranged close to each other, such as adjacent to each other. In practice, the transducers are arranged on the same tool holder or beam (i.e. on the upper beam or on the lower beam, or on the clamping system thereof). The transducers may be arranged on a shared circuit board. The transducers may be arranged along a receiving space for receiving a tool. As will be explained below, the transducers can be arranged in particular inside the receiving space.

The clamping system as described in herein may be a clamping system for either the upper beam or the lower beam of the press brake or folding press. It is noted that although both beams often include clamping systems, they are not collectively referred to as a clamping system. In fact, the two clamping systems of a press brake operate independently. The invention may be applied to a press brake or folding press including two clamping systems as described in the claims. In particular, the two clamping systems may be an upper and a lower clamping system respectively. The tool carrier may be a tool carrier for top or bottom tools, or may comprise tool holders for top and/or bottom tools.

The transducers may be arranged so as to cooperate for detecting a tool. Light emitted by one transducer may be reflected by the tool and received by the other, and vice versa.

In particular, the at least two transducers may be LED’s. LED’s can suitably be used to produce light at a relatively high efficiency. The photoelectric effect exhibited by LED’s may be used to configure the LED as a transducer for generating a current when light shines on the LED. As such, a LED can be used both as a sensor and as an emitter. The use of LED’s is especially advantageous in the current application, as LED’s can be relatively small, thereby allowing a larger amount of LED’s in the same space.

In particular, red LED’s may be used, for instance having a wave length of approximately 630 nm.

In one embodiment, the tool carrier further comprises a controller for controlling the first and second transducers. Using such a controller, use can be made of the characteristics of the transducers.

In particular, the controller may be configured to send an electrical signal to the first transducer while receiving an electrical signal from the second transducer during at least a first interval.

During said interval, the first transducer is used as an emitter, while the second transducer is used as a sensor. Light produced by the first transducer may be reflected by the tool onto the second transducer. As such, the second transducer may sense certain characteristics of the tool. In the first place, the presence of a reflection may indicate the presence of a tool. Moreover, as certain surface characteristics of the tool may influence characteristics of the reflected light, information may be gained on the surface of the tool from the reflected light.

The controller may be further configured to receive an electrical signal from the first transducer while sending an electrical signal to the second transducer during a second, different interval.

In such a situation, the function of the emitter/sensor is opposite to that described above. As a result, the path taken by light and reflected light is opposite to that presented earlier. In some cases, the information obtained in this way may be the same information as during the first interval, therewith confirming a prior measurement. In other cases, the surface of the tool may differently affect the characteristics of the reflected light. Thus, by using the two transducers alternatingly as sensor/transmitter, a larger amount of information can be obtained without requiring additional components. As no additional transducers are required for obtaining the additional information, no further space is required for said further transducers.

In order to further increase accuracy and/or the amount of information the system can receive, the system may comprise a plurality of first transducers. Accordingly, the controller may then be configured to:

- send an electrical signal to the plurality of first transducers while receiving an electrical signal from the second transducer during at least another, third interval, and/or
- send an electrical signal to the second transducer while receiving an electrical signal from the plurality of first transducers during at least another fourth interval.

Emitting light with and/or receiving light from multiple first transducers allows receiving light reflected by different portions of the surface of the tool. Accordingly, a larger amount of light may be received leading also to an increased amount of information that can be determined from the reflected light. Effectively, such an embodiment allows many-to-one communication and/or one-to-many communication, respectively.

Said effect may be further employed when the system also comprises a plurality of second transducers, wherein the controller is configured to:

- send an electrical signal to the plurality of first transducers while receiving an electrical signal from the plurality of second transducers during at least another, fifth interval.

In such a configuration, many-to-many communication can take place, thereby greatly enhancing the amount of information that can be obtained from the totality of reflected light.

In another embodiment of the tool carrier, the controller is configured to send an electrical signal to at least one of the first and the second transducer, and at the same time receive an electrical signal from the same at least one of the first and the second transducer.

In such a configuration, a single transducer is used both as emitter and as sensor. Accordingly, the amount of emitting and receiving components is doubled without requiring more components.

Principally, it is possible to receive the light of the at least one transducer at another component and/or to receive light that was emitted by another component at the at least one transducer. It is however also possible to receive light reflected by the tool, but emitted by the same at least one transducer.

In order to distinguish between the origin of light from different emitters, they may be controlled to or be configured to emit light with mutually different characteristics. In particular, the frequency or intensity may mutually vary. Additionally, a variation in time of for instance the intensity may be used to give a particular emitter unique characteristics. As an example, emitters may be distinguished from each other if they blink at different frequencies.

The skilled person will appreciate that the terms ‘first’ and ‘second’ relating to the transducers herein are used only to distinguish between the transducers. In fact, the transducers need not be different in kind or type. As such, a plurality of the same or similar transducers may be used in the tool carrier as described herein.

In order to provide the functionality described above, the controller may be configured to alternatingly select different ones of the plurality of transducers as the first or second transducers. As such, one of the transducers may act as the first transducer at one point in time, and act as the second transducer at another point in time. Moreover, multiple transducers may be selected as first and/or second transducers. Accordingly, providing a plurality of transducers and selecting first and second transducers as desired allows operation of the system in many different operating modes, each giving rise to information that would otherwise be unobtainable. As such, a system with multiple transducers that are controlled to switch their functionality is very versatile and may further increase accuracy of the amount of encodable information.

Selecting one or more transducers as the first or second transducers need not be a separate act. In fact, controlling the transducers as described above is regarded as having selected those transducers in accordance.

In yet another embodiment of the tool carrier, the controller is configured to control the first and/or the second transducer to transmit light at different intensity levels.

The larger the intensity of the light, the larger the surface of the tool that will reflect back sufficient light to be detected. As such, by varying the intensity of the emitted light, a selection can be made between which parts of the tool are seen. As an example, first a relatively small part of the tool can be sensed by using a relatively low intensity. Then, a larger part of the tool can be sensed by using a relatively high intensity. As the larger part of the tool would normally include the smaller part, the influence of the newly sensed areas can be determined by appropriate signal processing.

The controller may be configured to determine a characteristic of an electric signal received from the first and/or the second transducer, the characteristic being for instance a power, a frequency, a voltage or a current level.

The controller may accordingly be used to digitize the received signal. The digitized signal may comprise information on the characteristics, so that signals with different characteristics can be distinguished. This may allow processing the signals so as to determine information on the basis of the characteristics.

In particular, the characteristic may be a voltage level. The voltage may be measured over a resistance, preferably an Ohmic resistance, which is fed by a current provided by the transducer receiving the light.

In a particular embodiment of the tool carrier, the first and second transducers are configured for transmitting light at mutually differing wavelengths.

By transmitting light at mutually differing wavelengths, light emitted from different transducers may be distinguished, even after being reflected by the tool. Additionally or alternatively, the different wavelengths may interact differently with the surface of the tool. As such, probing the tool with different wavelengths may allow retrieving a larger amount of information.

Practically, the at least one holder of the tool carrier, such as the beam of a clamping system, comprises a longitudinal receiving space for receiving at least a part of the one or more tools when held by the holder, and wherein the first and second transducers are arranged in the receiving space.

In such a practical embodiment, the transducers can be placed close to the tool and may therefore easily be able to sense it. Moreover, light from the outside might be at least partly prevented from entering the receiving space by the wall thereof and by the tool. Accordingly, influence of outside light on the transducers is reduced, which accordingly reduces noise in the signal generated by the transducers. Additionally or alternatively, placing the transducers in the receiving space puts them in a relatively protected area, so that the transducers are less likely to be damaged by a workpiece being bent or by other impacts from the outside.

Particularly suitable locations for the transducers are at a side or a blind end of the receiving space as seen in cross section thereof. At such locations, the transducers are less likely to be damaged during insertion or removal of the tool. Moreover when used in a press brake or folding press, the transducers are clear of forces from the beam to the tool which are needed for operating the press brake.

In the case the tool carrier comprises a plurality of transducers, such as a plurality of first and/or second transducers, the transducers may be arranged in a matrix. The matrix may be two-dimensional.

A relatively large surface area can be covered by such an arrangement. The transducers may be arranged in staggered and/or slanted rows and/or columns. A staggered or slanted matrix may allow compensating for any misalignment between the transducers and particular features on the tool. Additionally, a staggered or slanted matrix guarantees an alignment of some, but misalignment for some other transducer with respective features on the tool. The misalignment, in particular the amount thereof, has an effect on the received light. Said effect may be used to enhance accuracy of the localization using reflected light.

Of course it is also possible to create a slanted and/or staggered shape of features on the tool, when the transducers are aligned in a right-angled matrix. Further, both may be slanted/staggered at different angles. The effects described-above will remain unchanged.

The invention also relates to a tool changing station comprising a tool carrier as described herein, and a tool changing robot configured to remove tools from and/or insert tools into the at least one tool holder of the tool carrier in order to automatically change the tooling for a press brake or folding press.

The tool changing robot may benefit from the increased amount of information obtainable by the tool carrier, for instance in identifying which tool is where. Accordingly, a tool changing robot may select a particular tool from a tool carrier acting as a tool store. Moreover, an accurately determined location in the tool carrier may allow the tool changing robot to easily grab the tool, or even to accurately place the tool in a press brake or folding press after the robot takes it out of a tool store.

The tool changing station may comprise a tool station controller, which is configured to, based on information derived from measurements by the first transducer and/or the second transducer, control the robot. Control of the robot may be enhanced accordingly.

The invention also relates to a tool carrier as described above, with a tool, wherein the tool comprises a marking having encoded therein at least an identification number.

The identification number may be usable to uniquely identify the particular tool. As such, no two tools may have the same identification number. The identification number may take the form of a serial number. Being able to uniquely identify particular tools is of use in tracking the performance of a tool for e.g. maintenance or billing purposes.

The marking on the tool may have features of a characteristic dimension similar to or larger than a dimension of the first and/or second transducer.

If the features is similar in size to, or larger than, the transducer, it becomes relatively easy to detect the feature. In particular, the features may have a characteristic size that is approximately half that of the transducers. In such a configuration, it can be guaranteed at least one transducer is completely aligned with a feature.

The marking may comprise features distinguishable by a surface characteristic, such as colour, roughness, reflectance or angle.

Differences in such features will affect the reflection of light differently. Accordingly, the features can be detected using reflected light. Moreover, these surface characteristics may be made relatively easily on a tool, for instance using a laser.

As an example, the greyness or grayscale of the surface could be used as a feature, i.e. the colour could be varied from light grey to black continuously or in the desired amount of discrete steps.

As a first option, the surface characteristic is continuously variable. Optionally, the encoding is analogue. Accordingly, a relatively large amount of information may be stored using a single characteristic. As an example, a colour varying from light-grey to pitch black may be used to represent a continuous variable, or a variable with a relatively large amount of discrete points, as opposed to a binary encoding.

As a second, alternative option, the identification number of the marking is encoded in a discrete code. Such a code may be relatively easy to sense or process.

It is preferable the code is of a higher ordinal than two, e.g. a ternary, quaternary or quintary code, or a code of a higher ordinal. As such, a relatively large amount of information may be stored in a single characteristic. As an example, a code of order n may be achieved by providing a code having features coloured at n different grey levels.

The invention also relates an assembly of a tool carrier as described herein, and a press brake or a folding press, the press brake or folding press comprising a clamping system with a beam for holding one or more tools. The tool carrier may be used to store tools not in use by the press brake or folding press. The previously described tool changing robot, optionally with its controller, may be incorporated in the assembly as well.

The invention also relates to a tool for use in a press brake, the tool comprising a marking having encoded therein at least an identification number, the marking being configured to reflect light received from the first and second transducers.

The tool may have all the above described features, alone or in any suitable combination. The tool may provide the corresponding advantages.

The invention will be further elucidated with reference to the drawings, in which corresponding elements have reference numerals increased by 100, and in which:

Figures 1A and 1B schematically show a side and a front view respectively of a press brake;

Figures 2A schematically shows a perspective view of a clamping system with a tool partially received therein, tilted to show its top surface;

Figure 2B schematically shows a cross section of the clamping system of figure 2A with its tool, now inserted into the clamping system;

Figures 3 – 8 and 15A – 15B schematically show cross sections of variations of the clamping system;

Figures 9A and 9B schematically show two transducers and a tool in cross section;

Figures 10A and 10B schematically show a marking that can be arranged on a tool;

Figures 11A and 11B schematically show arrays of transducers;

Figures 12A – 14B schematically show different ways of operating the transducers; and

Figure 16 schematically shows a tool store with a press brake and tool changing robot.

Throughout the figures, like elements are referred to using like reference numerals. Like reference numerals of different embodiments are increased by one hundred (100).

Figures 1A and 1B show a press brake 1 placed on a ground surface G. The press brake 1 includes a top beam 2 and a bottom beam 3. The top beam 2 is provided with a top clamping system 4. The top clamping system 4 releasably holds a top tool 5. The bottom beam 3 is provided with a bottom clamping system 6, which releasably holds a bottom tool 7. The top and bottom clamping systems 4, 6 each extend over substantially the entire width W of the press brake 1. The top and bottom tools 5, 7 are shown to extend over only part of the width W. Consequently, they may be moved to different positions in longitudinal direction L of the top and bottom clamping systems 4, 6. Multiple tools may be arranged end-to-end in order to provide a greater working width. Alternatively, different tools may be placed at various positions to allow multiple bending or folding operations to be performed without exchanging tools in between operations.

The top beam 2 and the bottom beam 3 are moveable towards and away from each other in the direction of arrow M by means of hydraulic systems 8, although another type of drive system could be used. To this end one of the beams 2, 3 may be movable while the other beam may be stationary, or both beams 2, 3 may be movable. Accordingly, the top and bottom tools 5, 7 are also moveable towards and away from each other. To bend sheet metal, the sheet is inserted between the tools 5, 7 which are then moved towards each other. The top tool 5 then forces the sheet metal into the bottom tool 7 in order to deform the sheet metal by bending. After bending, the tools 5, 7 are moved away from each other by moving the top beam 2 via the hydraulic systems 8. The clamping systems 4, 6 are releasably attached to the top and bottom beam 2, 3 respectively via a suitable locking system. Accordingly, the clamping systems 4, 6 can be exchanged for clamping systems suitable for other tools, or the clamping systems 4, 6 can be taken out for servicing them.

Although not shown, the features described below in relation to the exchangeable clamping systems 4, 6 can also be applied to other types of clamping systems 4, 6, e.g. of the integral or adaptor type.

Figures 2A and 2B show a clamping system 104 for a press brake 1. The clamping system comprises a beam 111 for holding tools 105. The beam 111 comprises a longitudinal receiving space 109 embodied as a slot parallel to the length of the beam 111. The tool 105 is held by the clamping system 104 by placing an adaption 112 thereof in the receiving space 109, and consecutively clamping the adaption 112 of the tool 105 at recesses 110 provided for that purpose. The illustrated adaption 112 with its recesses 110 forms part of a so-called “New Standard style” clamping system. Other clamping systems and techniques for holding tools exist, like e.g. American style and European style. The current disclosure is not limited to the exemplary clamping system described with reference to the figures, but may be more universally used in other clamping systems.

The clamping system 104 further comprises a circuit board 113 with an array of transducers 114 arranged thereon, which will be described in more detail with reference to figures 9 – 14B. The transducers 114 are used to localize and identify the tool 105. For this purpose, the circuit board 113 of figures 2A and 2B is arranged in the receiving space 109. In particular, the circuit board 113 is arranged at the blind end of the receiving space 113, in a recess 123 allowing a surface of the circuit board 113 to lie flush with the blind end of the receiving space. The tool 105 is provided with a marking 115 comprising surface features 116. When the tool 105 is placed in the receiving space 109, the marking 115 faces the circuit board 113, so that the transducers 114 are near the marking 115. The circuit board 113 extends along the longitudinal direction of the beam 111. Accordingly, the tool 105 can be sensed using the transducers 114 regardless of its position in the beam 111. It is noted that for the sake of clarity, not all transducers 114 and surface features 116 have been provided with their own reference numeral. Although not shown here, the circuit board 113 with its transducers 114 may be protected by a transparent cover at least partially closing off the recess 123.

Variations as to the position of the transducers 114 are possible. As a non exhaustive list of examples, reference is made to figures 3 – 8 and figures 15A – 15B. Figures 3 and 4 each show a clamping system 204, 304 for a top beam 202, 302 (not shown), each having a corresponding receiving space 209, 309 (substantially taken up by the tool 205, 305). The transducers 214, 314 (not visible) are provided on circuit boards 213, 313, which in the illustrated embodiments are arranged in recesses 223, 323 in sidewalls of the corresponding receiving spaces 209, 309. As such, the transducers 214, 314 face a side of the tool 205, 305 when it is placed in the receiving space 209, 309.

Further, figures 5 – 8 show clamping systems 406, 506, 606, 706 for bottom beams 419, 519, 619, 719. The clamping systems 406, 506, 606, 706 comprise corresponding receiving spaces 409, 509, 609, 709, for receiving an adaption 412, 512, 612, 712 of a tool 407, 507, 607, 707. Although it is possible to clamp the tool 407, 507, 607, 707 in the receiving space 409, 509, 609, 709, it is envisioned the tool 407, 507, 607, 707 is configured to rest with shoulders 417, 517, 617, 717 on a top surface 418, 518, 618, 718 of the bottom beam 419, 519, 619, 719. Figures 5, 6 and 7 show that the circuit board 413, 513, 613 carrying the transducers may be arranged in the receiving space 409, 509, 609, for instance in a sidewall thereof (figures 5 and 7) or in a blind end thereof (figure 6). As an alternative, which is shown in figure 8, the transducers may also be arranged on a circuit board 713 on the top surface 718 of the bottom beam 719, so that a shoulder 717 of a tool 707 comes to lie over the circuit board 713 when the tool 707 is held by the clamping system 706. In each of these embodiments the circuit board 413, 513, 613, 713 is shown to be arranged in a recess 423, 523, 623, 723, although that is not strictly necessary for the circuit board 513 in the embodiment of figure 6, which might simply be mounted at the bottom of the receiving space 509.

Figures 15A and 15B show clamping systems 804 in top beams 811 for holding shoulder bearing tools 805. Tools 805 of this kind comprise shoulders 817 which support against surfaces 818 of the beam 811. As shown in figures 15A and 15B respectively, the circuit board 813 may be arranged in such a surface 818 of the beam 811 on the front and back side of the beam 811. Accordingly, the marking 815 on the tool is provided on the shoulder 817 of the tool 805 corresponding to said surface 818.

As can be deduced from the figures discussed above, the transducers 14, 114, etc. can be placed anywhere on or in the clamping system 4, 6, 104, 106, etc. that allows the transducers 14, 114 etc.

to see the tool 5, 7, 105, 107, etc. when it is held by the clamping systems 4, 6, 104, 106, etc. The marking 15, 115, etc. can be arranged on a corresponding part of the tool 5, 7, 105, 107, etc.

It is noted that transducers 14, 114, etc. need not necessarily be placed on a circuit board 13, 113, etc.

The functioning of the transducers 14 is explained with reference to figures 9A, 9B and further. The features described herein can be applied to any clamping system 4, 6. For the sake of brevity, only the reference numerals of the first embodiment are used for these and the following figures.

The transducers 14 comprise a first transducer 20 and a second transducer 21, arranged together on a circuit board 13. Although only two transducers 14 are shown as an example here, more transducers 14 may be employed. The transducers 14 are arranged on the clamping system 4 so that they will align with a marking 15 provided on a tool 5 when the tool 5 is held by the clamping system 4. In Figures 9A and 9B, two variations of the adaptation 12 of the tool 5 are shown as I and II on either side of a dotted line S. The left-hand variation I comprises a recess 90 machined in the surface of the adaptation 12 to provide a flat surface. The marking 15 (shown herein as a dotted line) is provided in this recess 90 on the flat surface thereof. In the right-hand variation II, the marking 15 is provided directly on the surface of the adaptation 12. As such, it is clear the marking 15 may be provided directly on the tool 5 without additional machining steps, or such steps may be used if desired. In this example, the transducers are LED's that produce light of a visible red color. The clamping system 4 also comprises a controller 22, which is connected to the circuit board 13 in order to control the transducers 20, 21. At a first point in time, shown in figure 9A, the first transducer 20 can be turned on the by the controller 22, in order to shine light (dashed arrow) onto the tool 5 at the location of the marking 15. The marking 15 reflects the light (dashed arrow) back, onto the second transducer 21. The controller 22 is configured to measure a signal generated by the second transducer 21 in response to the received light (dashed arrow). In particular, the controller operates by measuring a voltage across a resistance fed by a current produced by the second transducer 21. As the measured voltage corresponds to the reflected light, which is affected by the marking 15, information on the marking 15 is determined by analysis of the measured voltage. At another point in time, shown in figure 9B, the same system can be used another way. In particular, the second transducer 21 may be turned on the shine light (dashed arrow) onto the marking 15. As shown in figures 9A and 9B together, the function of the transducers can be changed from emitter to receiver. Other functionalities of the transducers will be described below.

First however, reference is made to figures 10A and 10B which respectively show markings 15-1 and 15-2. Each marking of figures 10A and 10B corresponds to only a part of a complete marking 15. Accordingly, break lines are used to indicate the marking may continue in the left and right direction of figures 10A and 10B. Thus, a complete marking 15 may have a generally longitudinal shape, which may extend over the tool in the length direction of the beam in which it is to be clamped. The marking 15-1 of figure 10A comprises, as an example, twenty features 16. In practice, a marking 15 may have many more features 16. The features 16 are shown to differ mutually by providing them with a different line pattern. In practice, the features 16 can be made distinguishable by locally changing a surface characteristic of the tool. For example, the features may comprise a distinct surface roughness levels. In figure 10A, six different line patterns are shown. It is possible to for instance choose six different surface roughness levels. Information can be stored in the marking 15 by setting the particular roughness level of each feature 16. In this example, a discrete encoding of the 6^{th} order, i.e. having six different possibilities for each feature 16, can be used to encode an identification number uniquely identifying a tool.

As an alternative, a continuously variable surface characteristic, such as a grey value can be chosen for each feature 16. This is shown in figure 10B using features with mutually different amounts of lines. In principle, it is possible to vary the grey value continuously. As such, it is not necessary to use discrete levels for encoding.

It is noted that other surface characteristics may be used to represent the features 16, and that discrete encoding can be done using any desired order.

Figures 11A and 11B show transducers 14 arranged in matrices on circuit boards 13. Although a relatively small part of a circuit board 13 is shown in the figures, a larger circuit board 13 may be employed as indicated by the break lines. In practice, a circuit board 13 may have many more transducers 14. It is envisioned the circuit board 13 will be longitudinal in shape, so as to be arranged parallel to the longitudinal direction on a beam of a clamping system, as shown in figure 2A. The circuit board 13 may be the circuit board of the embodiments described in relation to figures 2A – 9B. The matrix of figure 11A is right angled, meaning the transducers 14 are substantially aligned in both the direction of the rows R and the columns C. The transducers 14 may however also be aligned in a staggered matrix as shown in figure 11B, where each row R is displaced with respect to the previous row R, so that the columns C are slanted. Although twenty transducers 14 are shown here, other amounts of transducers can be used.

Figures 12A – 14B show different ways of operating the same transducers 14. First, figure 12A shows a single first transducer 21 emitting light, and eight neighboring transducers operating as second transducers 22 receiving light. The controller can thus receive information from second transducers 22 receiving reflected light. As the light was emitted by a single first transducer 21, figure 12A represents a one-to-many configuration. Figure 12B on the other hand shows a many-to-one configuration, with multiple (in this example eight) first transducers 21 emitting light, and a single receiving second transducer 22. Each transducer, even the first transducers 21 emitting light, can be used at the same time as a receiver 22 for receiving reflected light. The reflected light may origin from itself or from another transducer.

Figure 13A shows a first situation, wherein a first transducer 21 emits light at a first intensity level. Reflected light is received at multiple, but not all second transducers 22. At another moment in time, shown in figure 13B, the first transducer 21 emits light at a higher intensity, so that more light is reflected. Accordingly, more second transducers 22 can be used to receive reflected light.

Figures 14A and 14B respectively show that at different moments in time a different transducer 14 can be used as first transducer 21 or second transducer 22. Thus, depending on the operation mode, a transducer may be controlled to emit light, receive light or both.

Figure 16 shows the press brake 1 of figures 1A and 1B. Next to the press brake 1 is a tool changing robot 50 which has an arm and end effector in order to move tools 5, 7 for the press brake 1. A tool store 51 is arranged near the robot 50. The tool store 51 is a tool carrier, and comprises several tool holders 52, 53. The tool holders 52, 53 shown herein extend longitudinally in the direction away from the viewer of figure 16 into the paper, so that multiple tools 5, 7 may be held by the tool holders 52, 53. Several tool holders 52 are provided for top tools 5, and several tool holders 53 are provided for bottom tools 7. The robot 50 can take tools 5, 7 from the tool store 51 and put tools 5, 7 in the tool store, in order to exchange tools 5, 7 for the press brake. The tool holders 52, 5 are provided with a receiving space 9 (see upper right tool holder 52) for receiving a part of a tool 5. A recess 23 is provided, which houses a circuit board 13 comprising transducers. Accordingly, a tool 5, 7 held by the tool holders 52, 53 can be identified by the transducers as described herein, and the position of the tools 5, 7 can be determined relatively accurately. The robot 50 comprises a controller (not shown) which uses the position information and/or the identity information to control the robot 50 to move about the tools 5, 7 as desired.

The tool holders 52, 53 may have any suitable shape, as long as they can hold a tool 5, 7 and facilitate the transducers for identifying / positioning the tools. Nevertheless, it is possible the tool holders 52, 53 have shapes similar to that of the clamping system as described herein, possibly without means for actually clamping the tools 5, 7. Accordingly, the tool holders and by extension the tool carrier may comprise all features described in relation to the clamping system, in any suitable combination.

Although the invention has been described hereabove with reference to a number of specific examples and embodiments, the invention is not limited thereto. Instead, the invention also covers the subject matter defined by the annexed claims.

As an example, clamping systems for press brakes have been shown, but the invention could equally well be applied to folding presses. Moreover, specific types of clamping systems have been shown, whereas the invention could be applied to other types of clamping systems within the scope of the attached claims. As a particular example, a clamping system for a top beam with a shoulder-supported tool, as is known in the art, could also be provided with the features of the main claim.

Finally, the invention can be extended to any tool carrier that has one or more tool holders.

Claims

1. Tool carrier for carrying bending tools for use in for instance a press brake or folding press, the tool carrier comprising at least one tool holder for holding one or more tools, **characterized by** a first and a second transducer, each being capable of transducing electrical energy to light and vice versa, the first and second transducers each being configured to transmit light towards, and to receive light from, the one or more tools held by the tool holder.

2. Tool carrier according to claim 1, wherein the at least two transducers are LED's.

3. Tool carrier according to any one or more of the preceding claims, further comprising a controller for controlling the first and second transducer.

4. Tool carrier according to claim 3, wherein the controller is configured to send an electrical signal to the first transducer while receiving an electrical signal from the second transducer during at least a first interval.

5. Tool carrier according to claim 4, wherein the controller is further configured to receive an electrical signal from the first transducer while sending an electrical signal to the second transducer during a second, different interval.

6. Tool carrier according to any one or more of claims 3 – 4, comprising a plurality of first transducers, wherein the controller is configured to:

- send an electrical signal to the plurality of first transducers while receiving an electrical signal from the second transducer during at least another, third interval, and/or
- send an electrical signal to the second transducer while receiving an electrical signal from the plurality of first transducers during at least another fourth interval.

7. Tool carrier according to the previous claim, further comprising a plurality of second transducers, wherein the controller is configured to:

- send an electrical signal to the plurality of first transducers while receiving an electrical signal from the plurality of second transducers during at least another, fifth interval.

8. Tool carrier according to any one or more of claims 3 –7, wherein the controller is configured to send an electrical signal to at least one of the first and the second transducer, and at the same time receive an electrical signal from the same at least one of the first and the second transducer.

9. Tool carrier according to the previous claim, the clamping system comprising a plurality of transducers, wherein the controller is configured to:

- alternatingly select different ones of the plurality of transducers as first or second transducers.

10. Tool carrier according to any one or more of claims 3 – 9, wherein the controller is configured to control the first and/or the second transducer to transmit light at different intensity levels.

11. Tool carrier according to any one or more of claims 3 – 10, wherein the controller is configured to determine a characteristic of an electric signal received from the first and/or the second transducer, the characteristic being for instance a power, a frequency, a voltage or a current level.

12. Tool carrier according to any one or more of the preceding claims, wherein the first and second transducers are configured for transmitting light at mutually differing wavelengths.

13. Tool carrier according to any one or more of the preceding claims, wherein the tool holder comprises a receiving space for receiving at least a part of the one or more tools when held by the tool holder, and wherein the first and second transducers are arranged in the receiving space.

14. Tool carrier according to the previous claim, wherein the transducers are arranged at a side or a blind end of the receiving space as seen in cross section thereof.

15. Tool carrier according to any one or more of the preceding claims, further comprising a plurality of first transducers and a plurality of second transducers, wherein the first and second transducers are arranged in a matrix.

16. Tool carrier according to any one or more of the preceding claims, wherein the tool carrier is a tool store, such as a tool carousel or a tool repository, optionally comprising multiple tool holders.

17. Tool changing station comprising a tool carrier according to any one or more of the preceding claims, and a tool changing robot configured to remove tools from and/or insert tools into the at least one tool holder in order to automatically change the tooling for a press brake or folding press.

18. Tool changing station according to the previous claim, including a tool station controller which is configured to, based on information derived from measurements by the first transducer and/or the second transducer, control the robot.

19. Assembly of a tool carrier according to any one or more claims 1 – 16 and a tool, wherein the tool comprises a marking having encoded therein at least an identification number.

20. Assembly of a tool carrier according to any one or more of claims 1 - 16 and a press brake or a folding press, the press brake or folding press comprising a clamping system with a beam for holding one or more tools.

21. Tool for use in a press brake or folding press, the tool comprising a marking having encoded therein at least an identification number, the marking being configured to reflect light received from the first and second transducers.

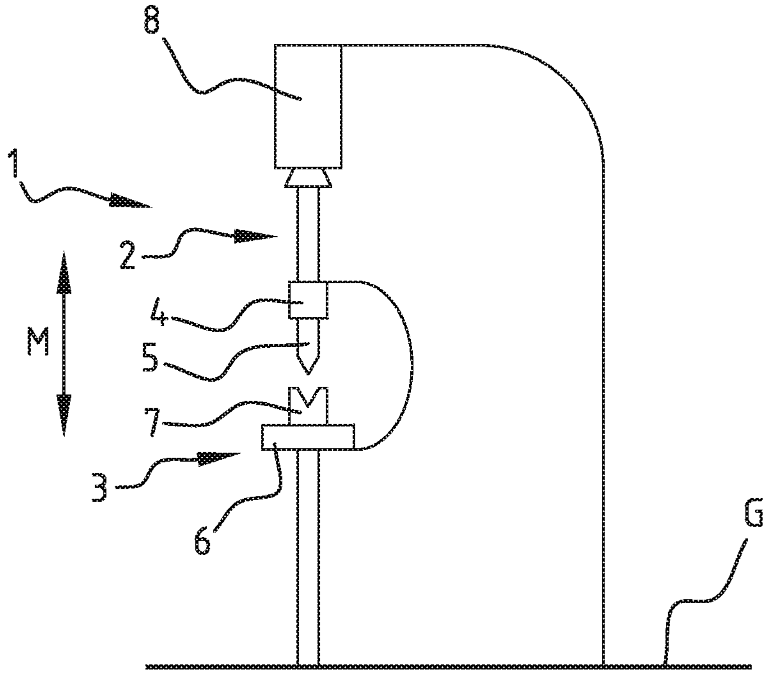

FIG. 1A

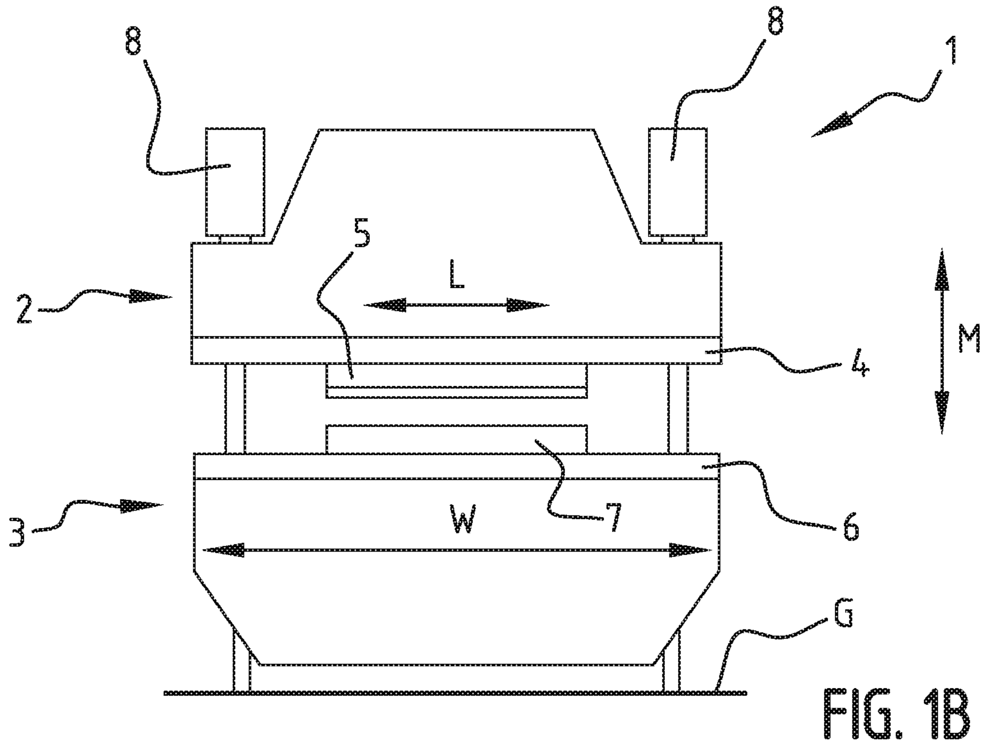

FIG. 1B

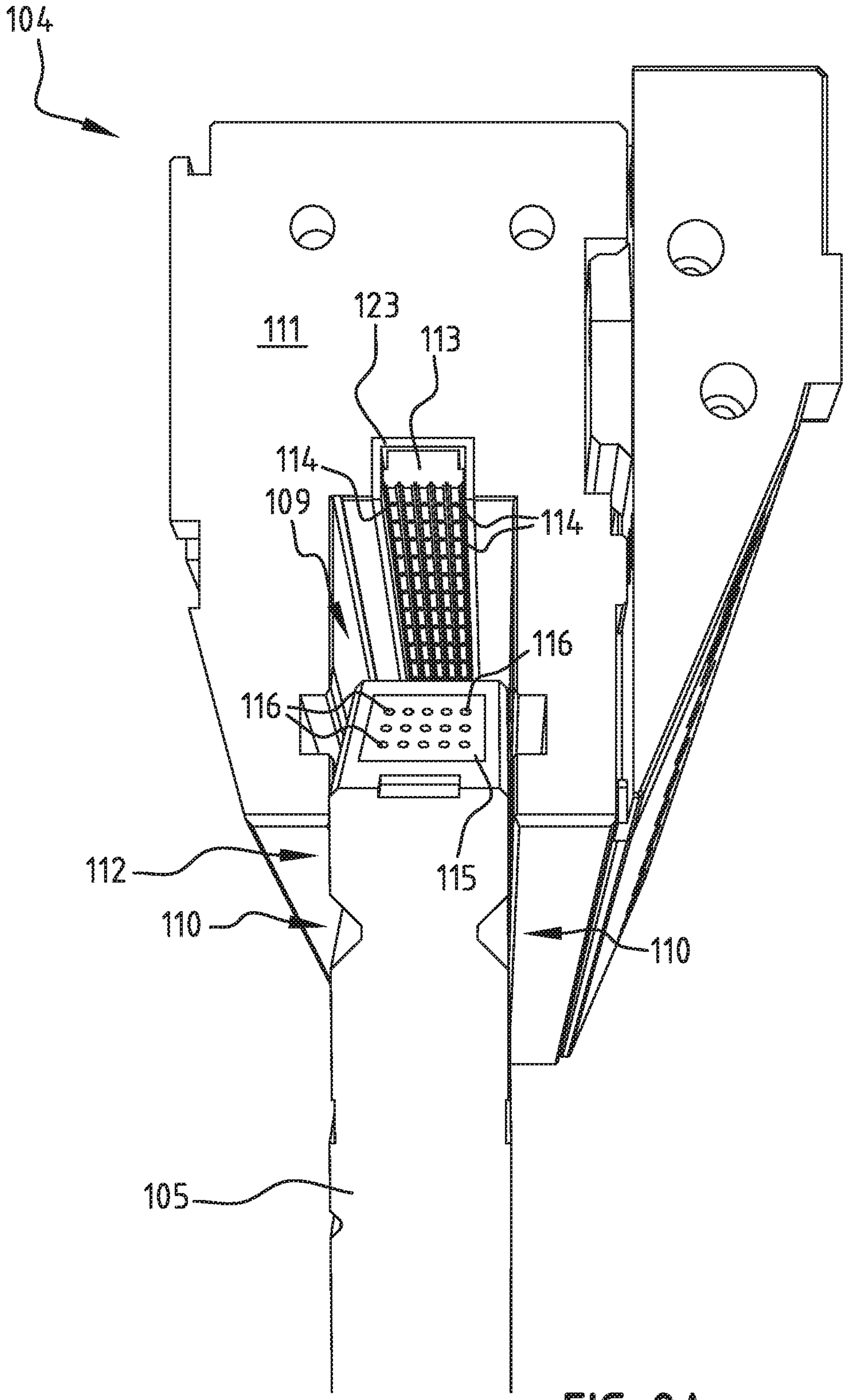

FIG. 2A

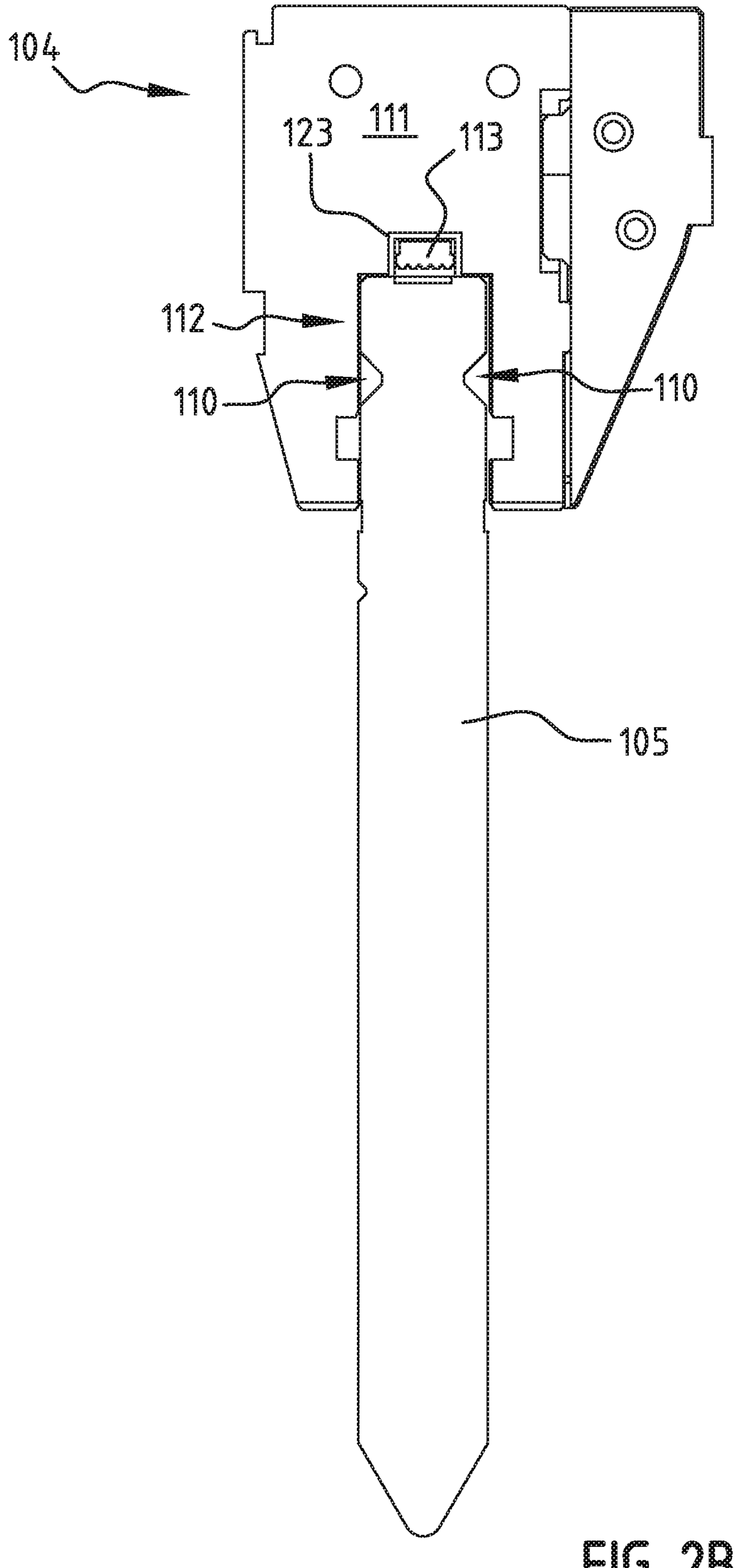

FIG. 2B

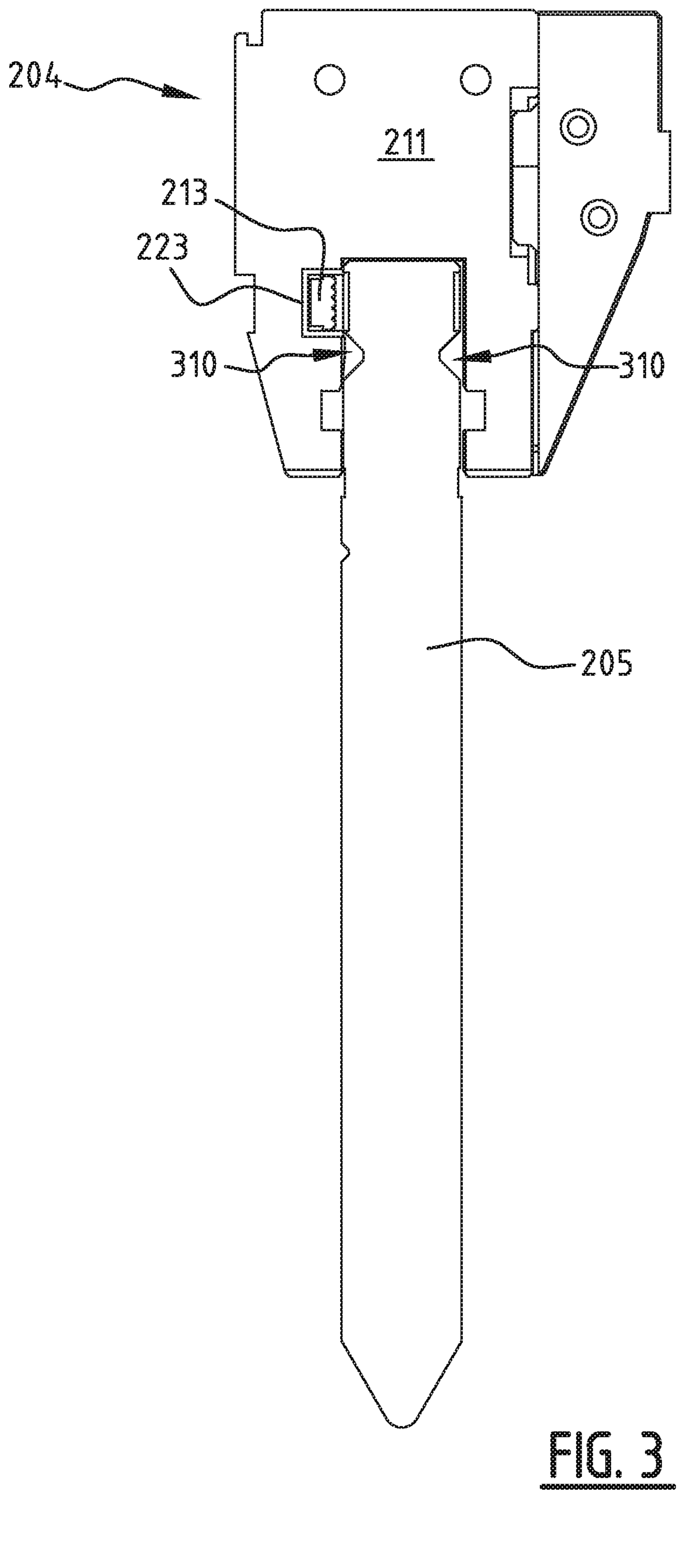

FIG. 3

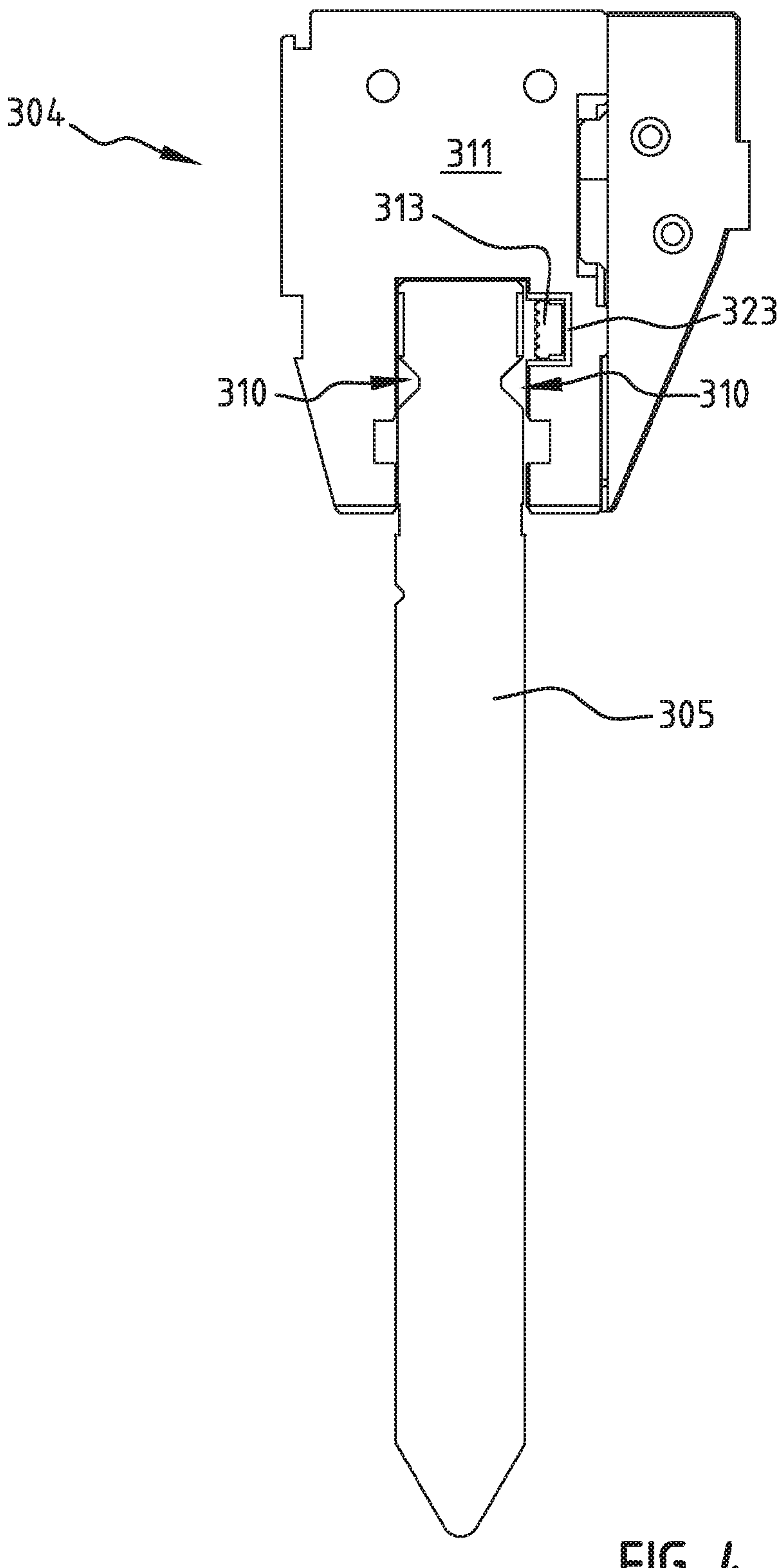

FIG. 4

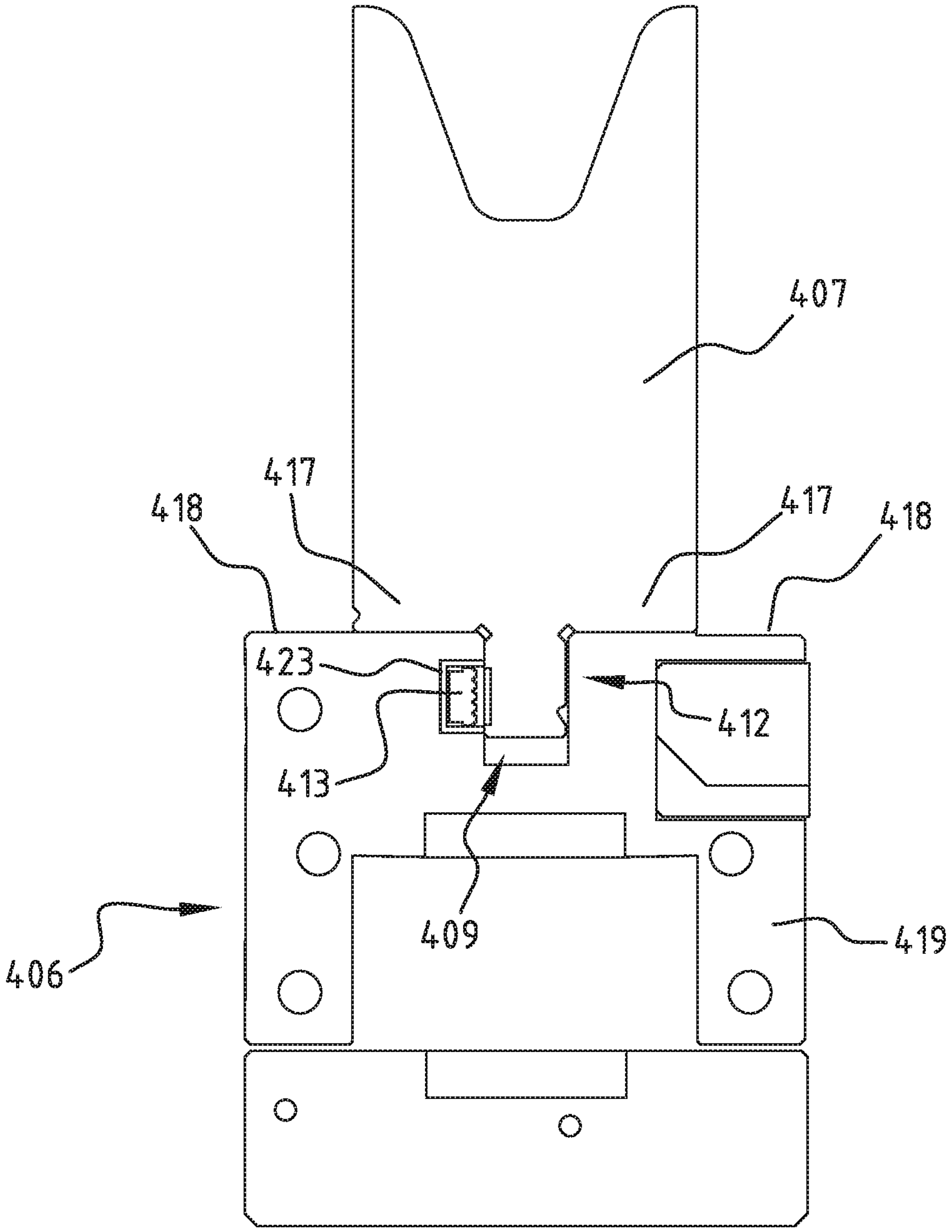

FIG. 5

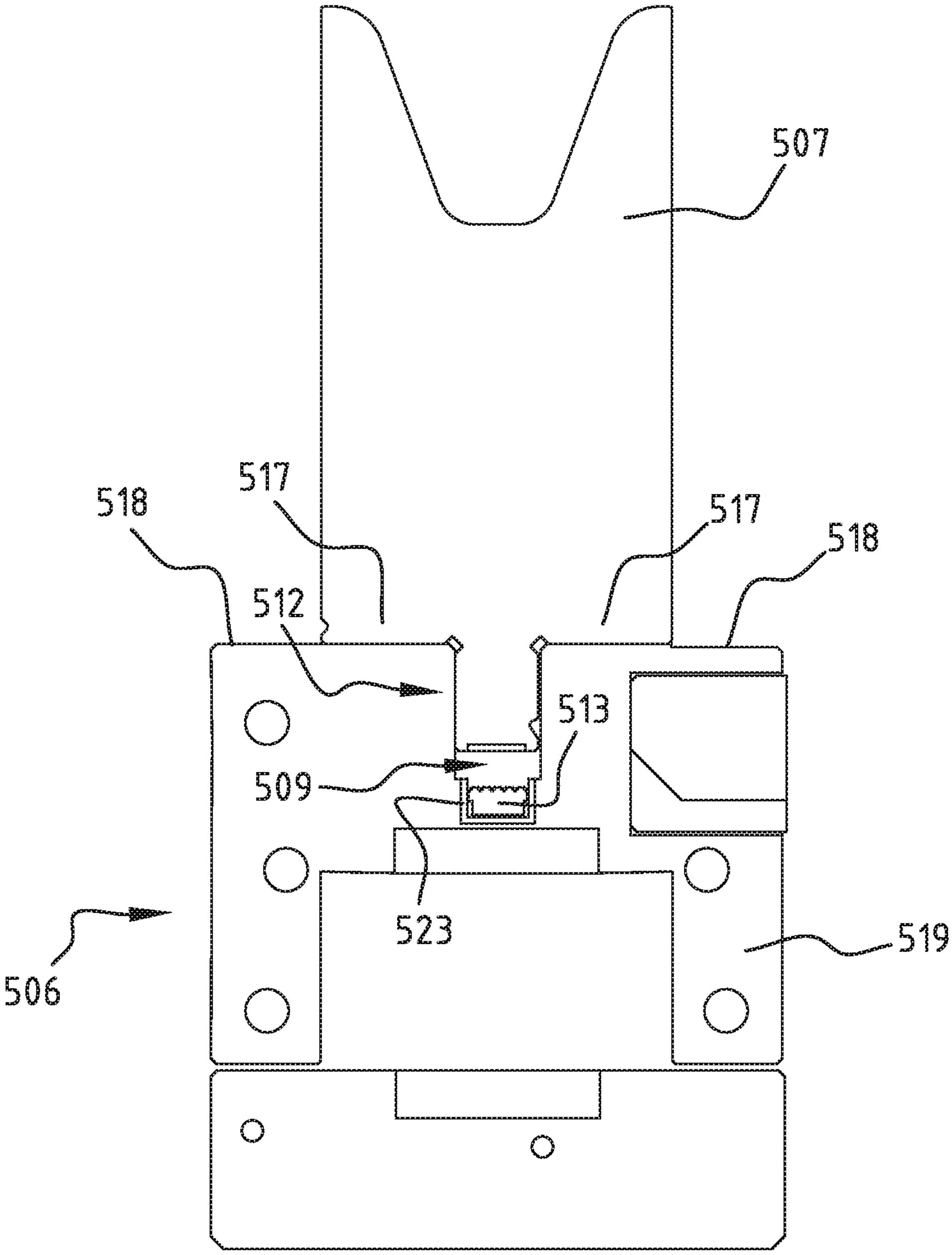

FIG. 6

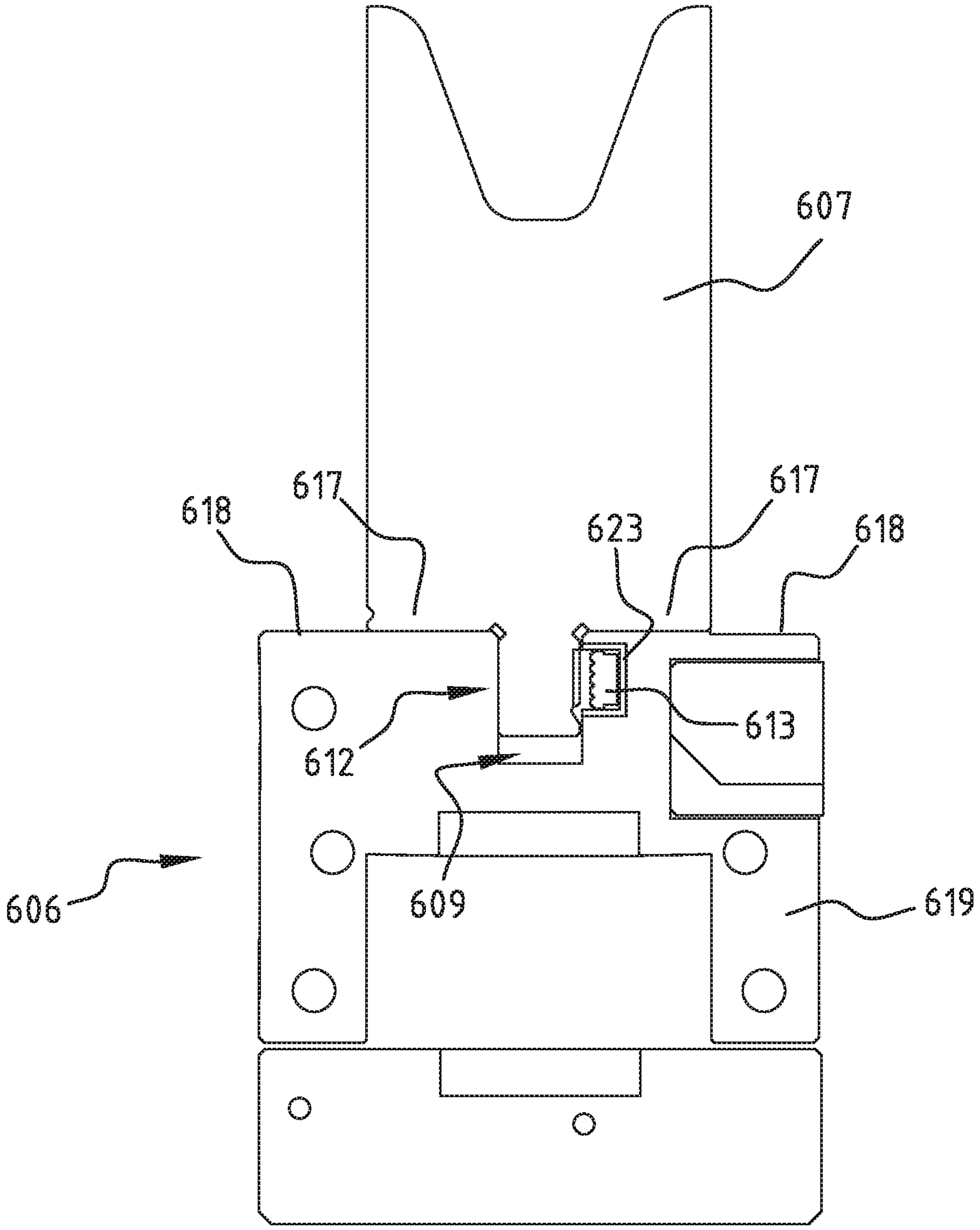

FIG. 7

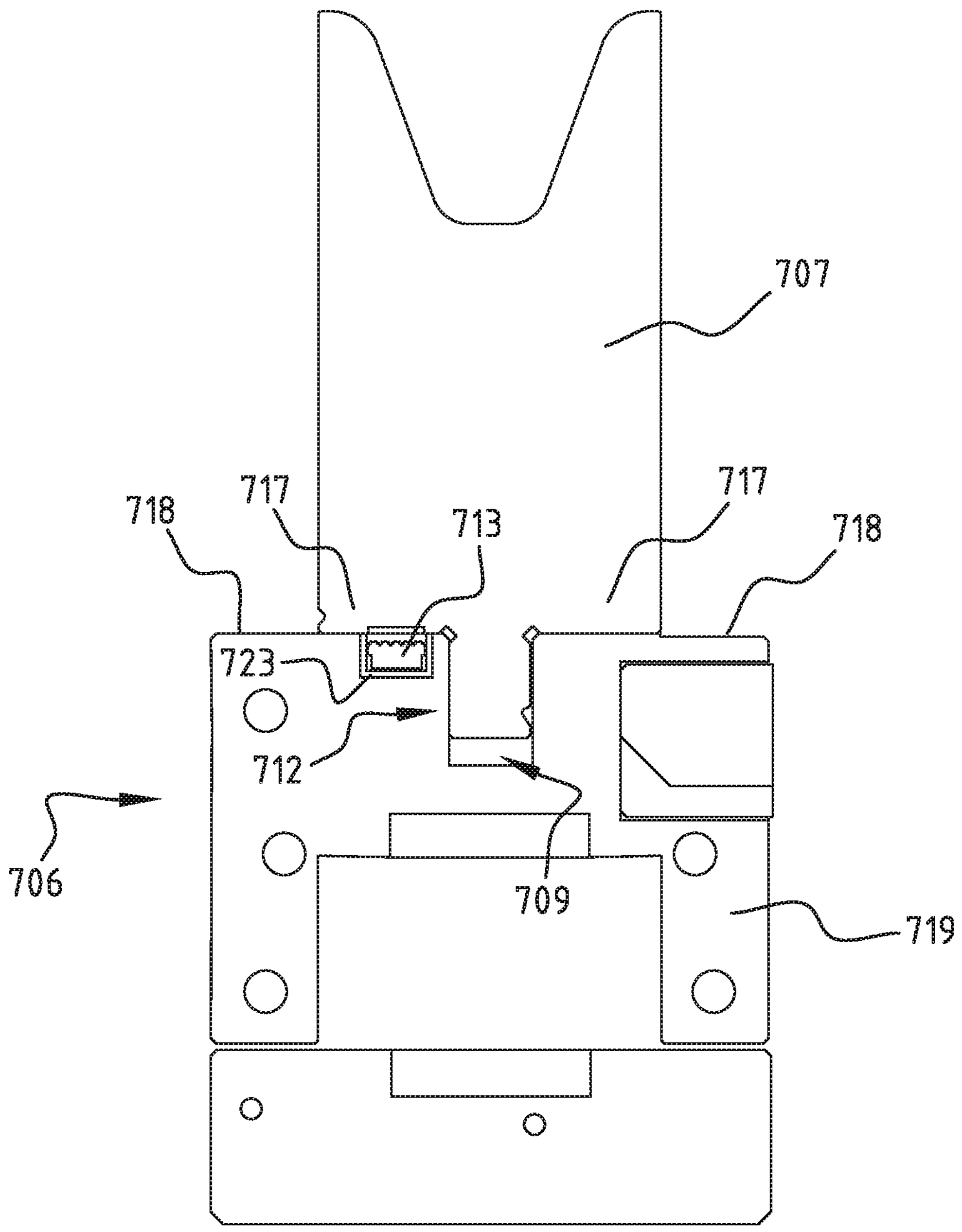

FIG. 8

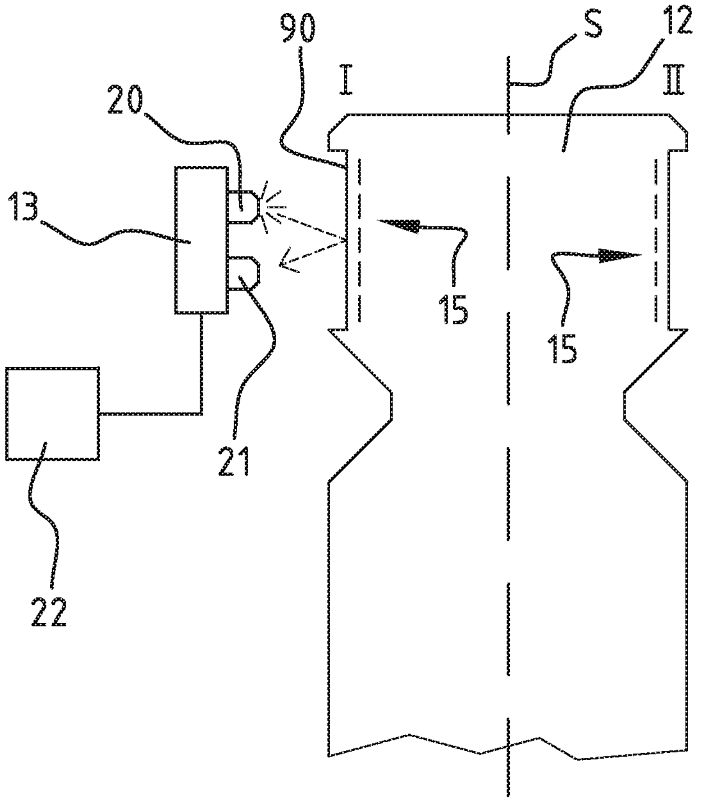

FIG. 9A

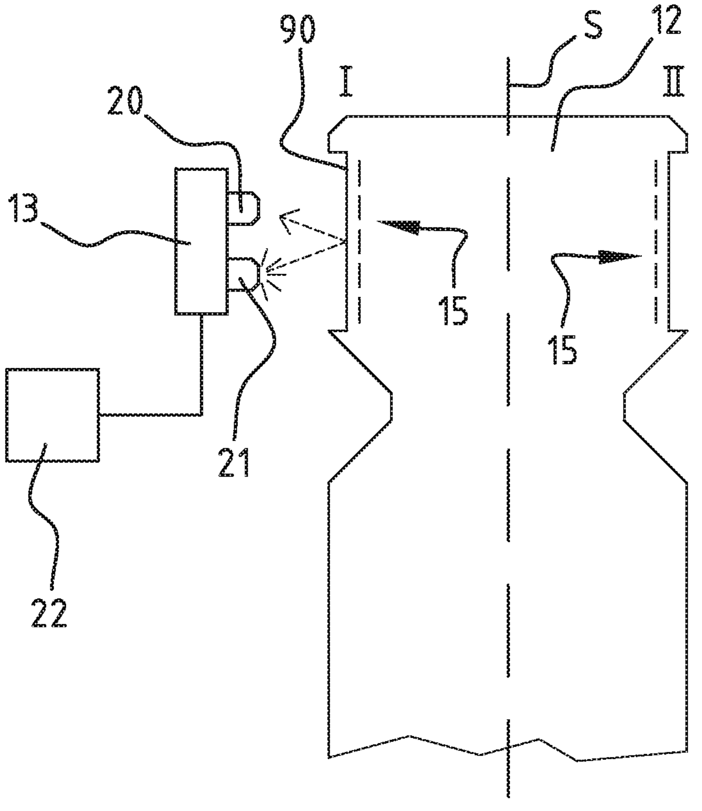

FIG. 9B

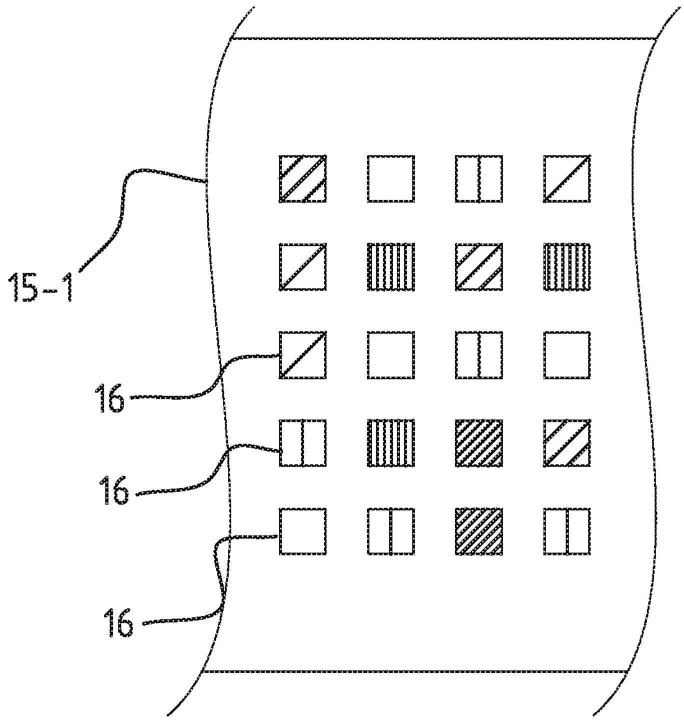

FIG. 10A

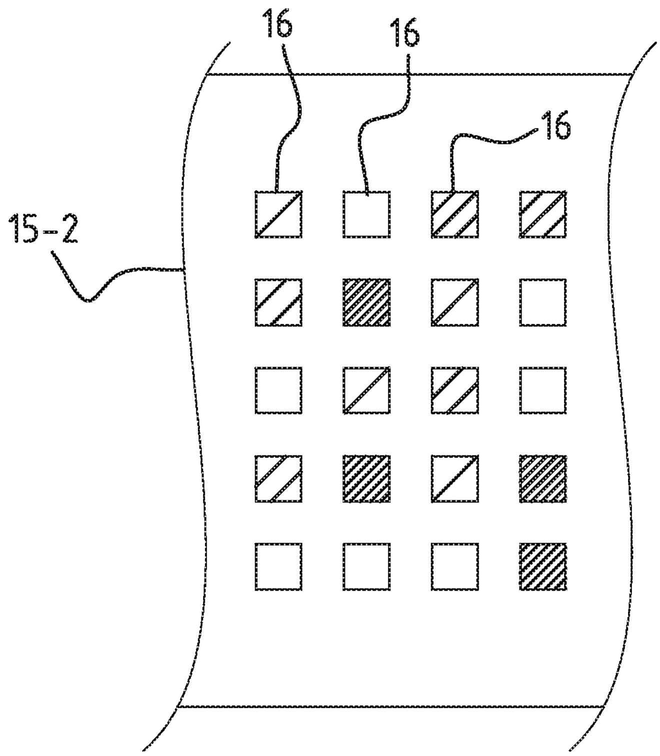

FIG. 10B

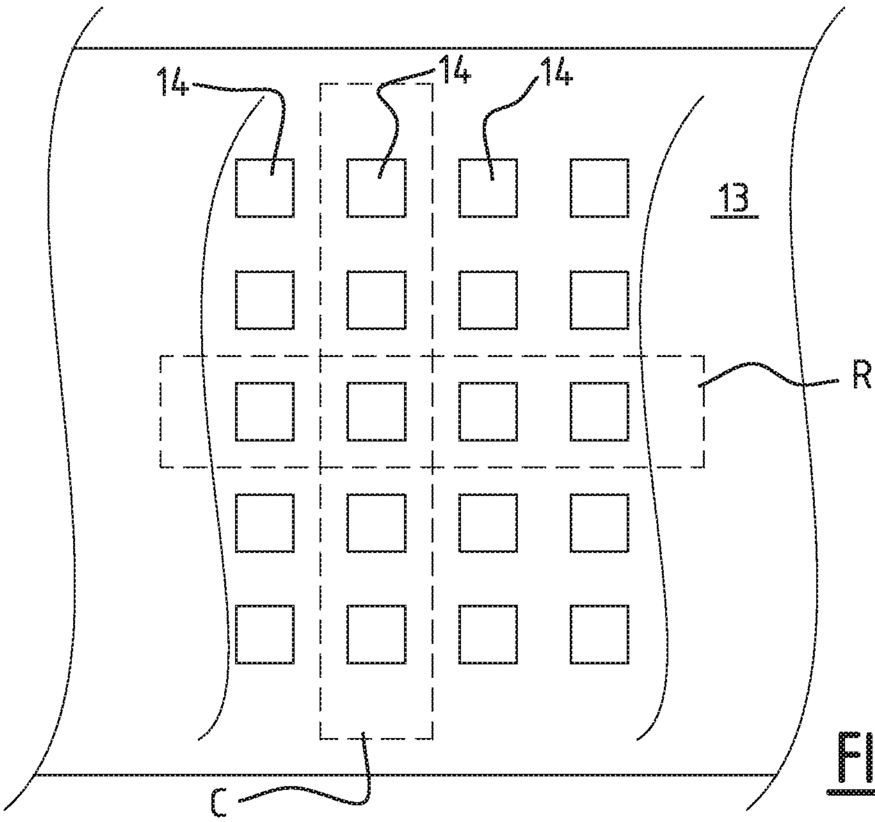

FIG. 11A

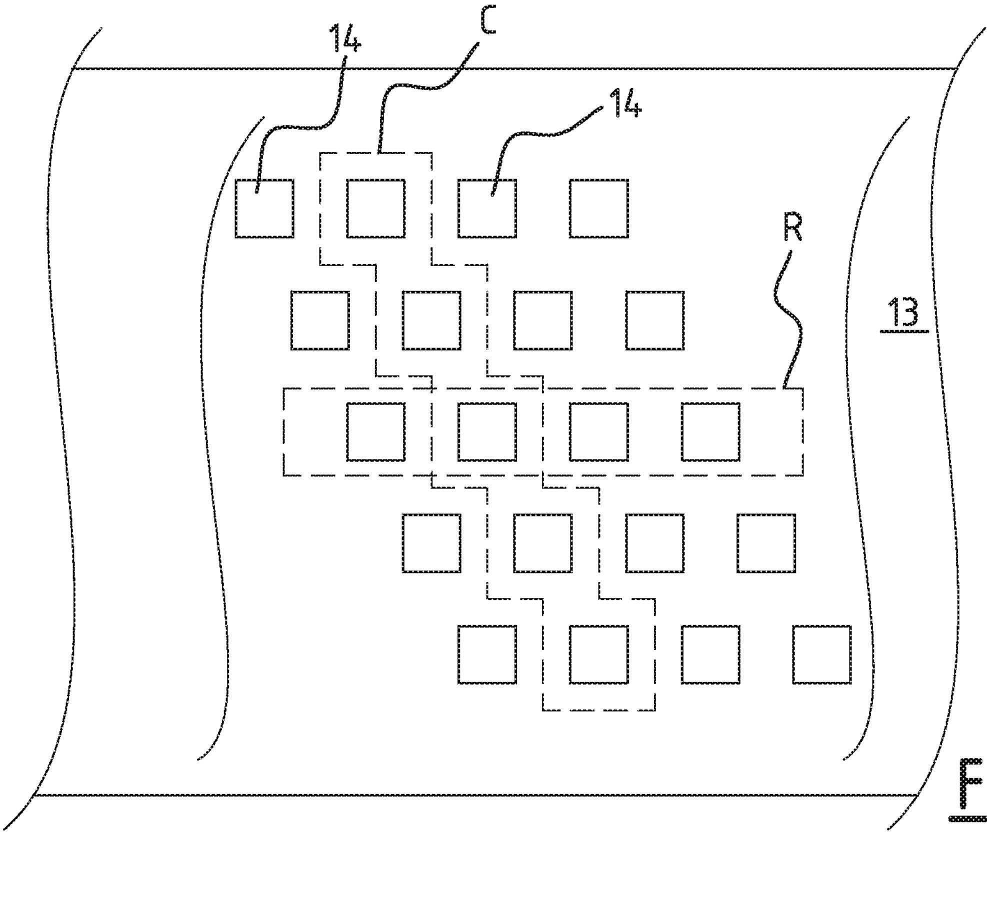

FIG. 11B

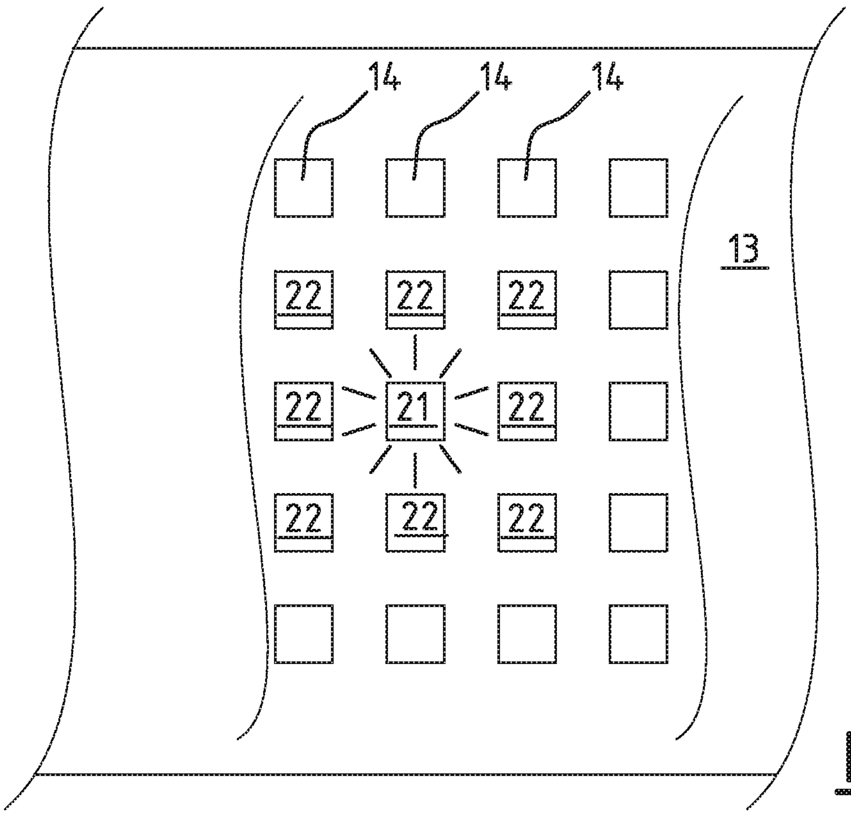

FIG. 12A

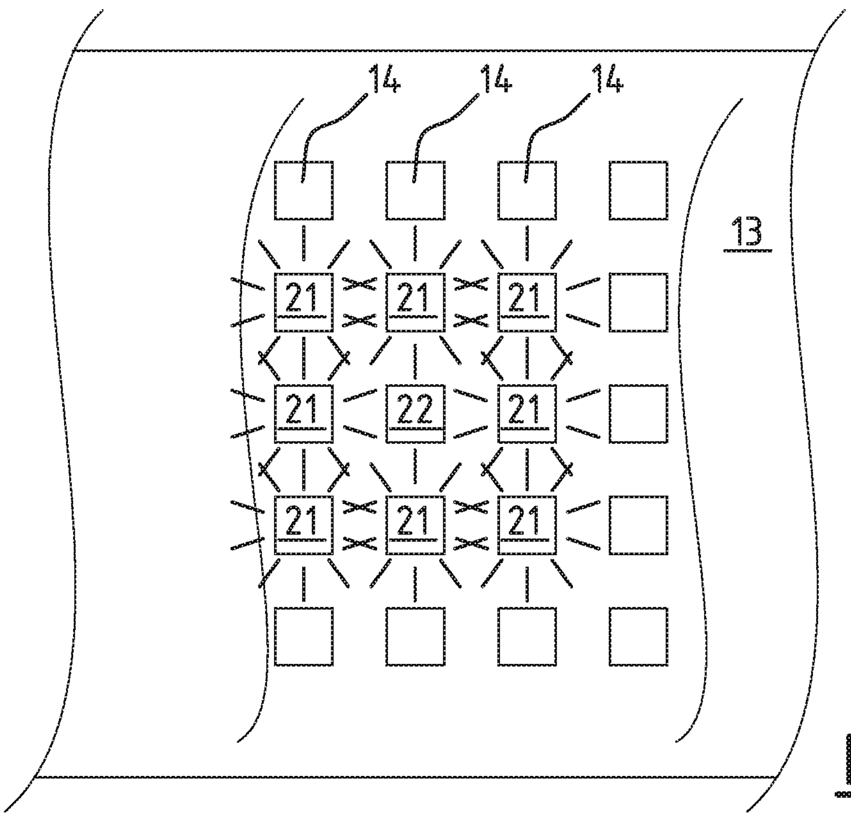

FIG. 12B

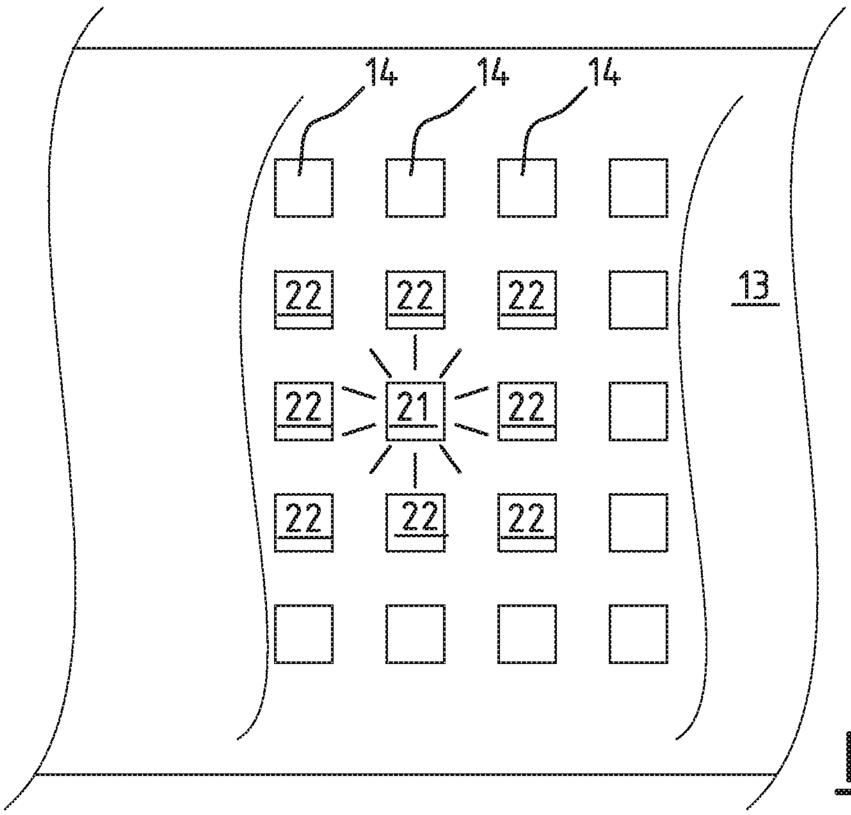

FIG. 13A

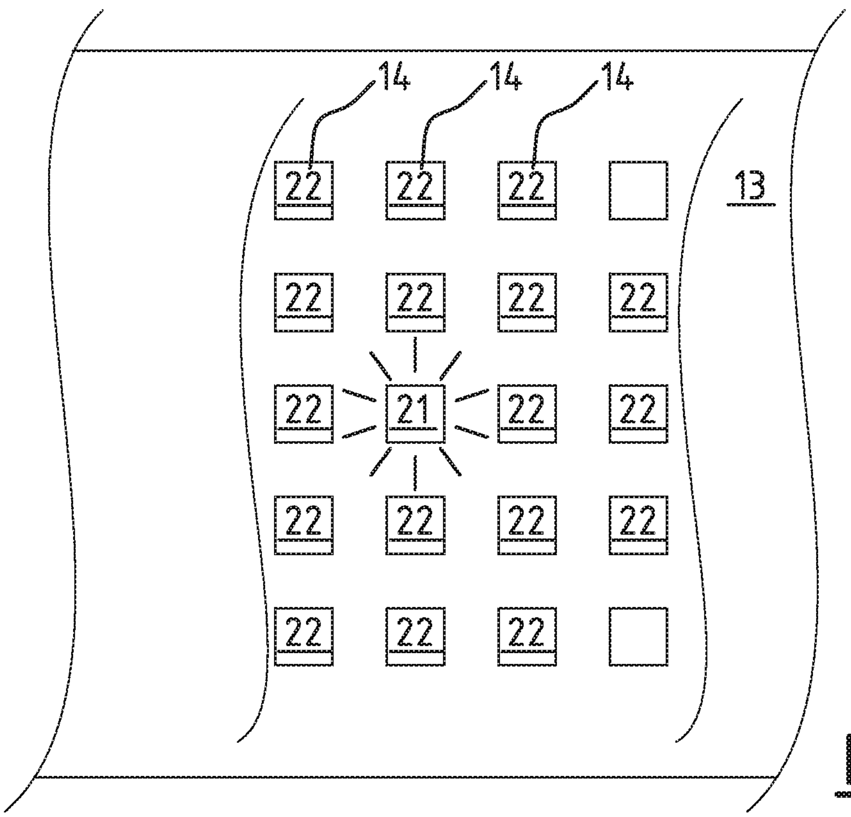

FIG. 13B

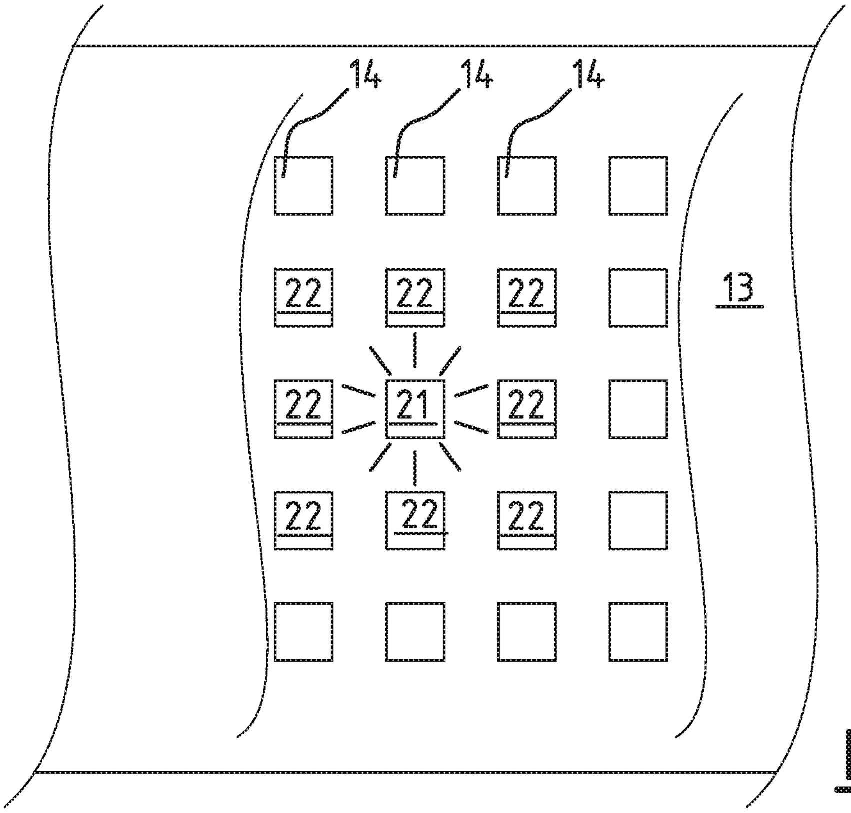

FIG. 14A

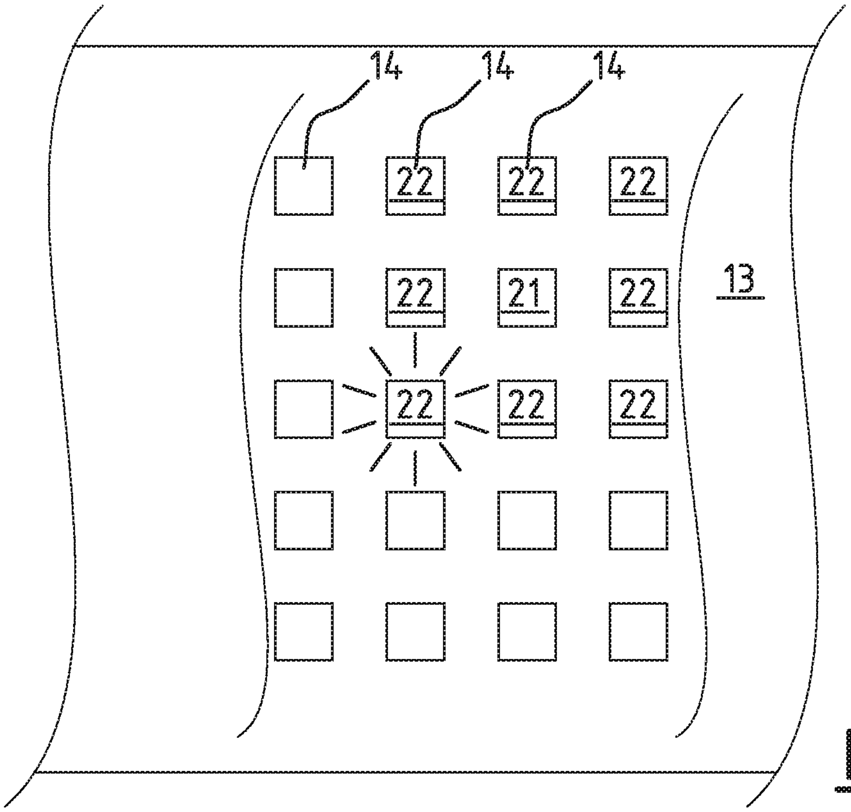

FIG. 14B

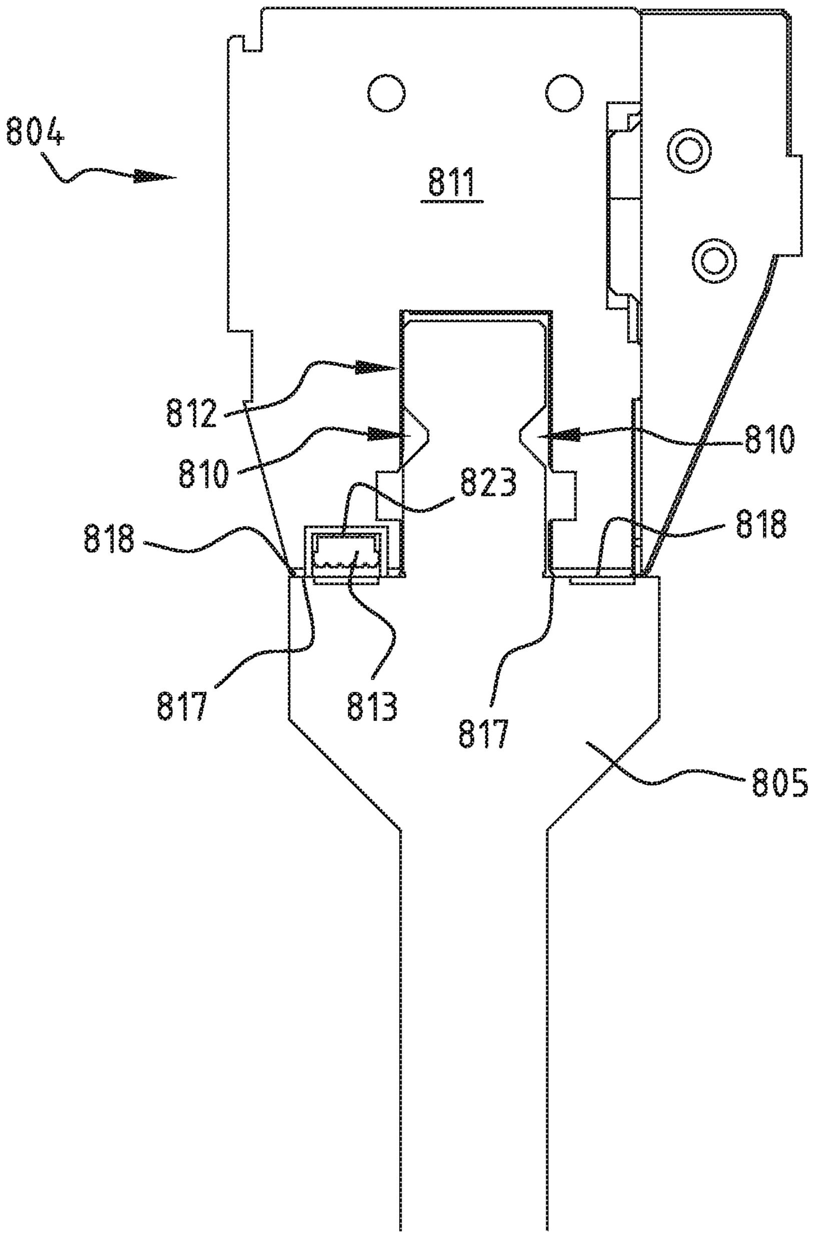

FIG. 15A

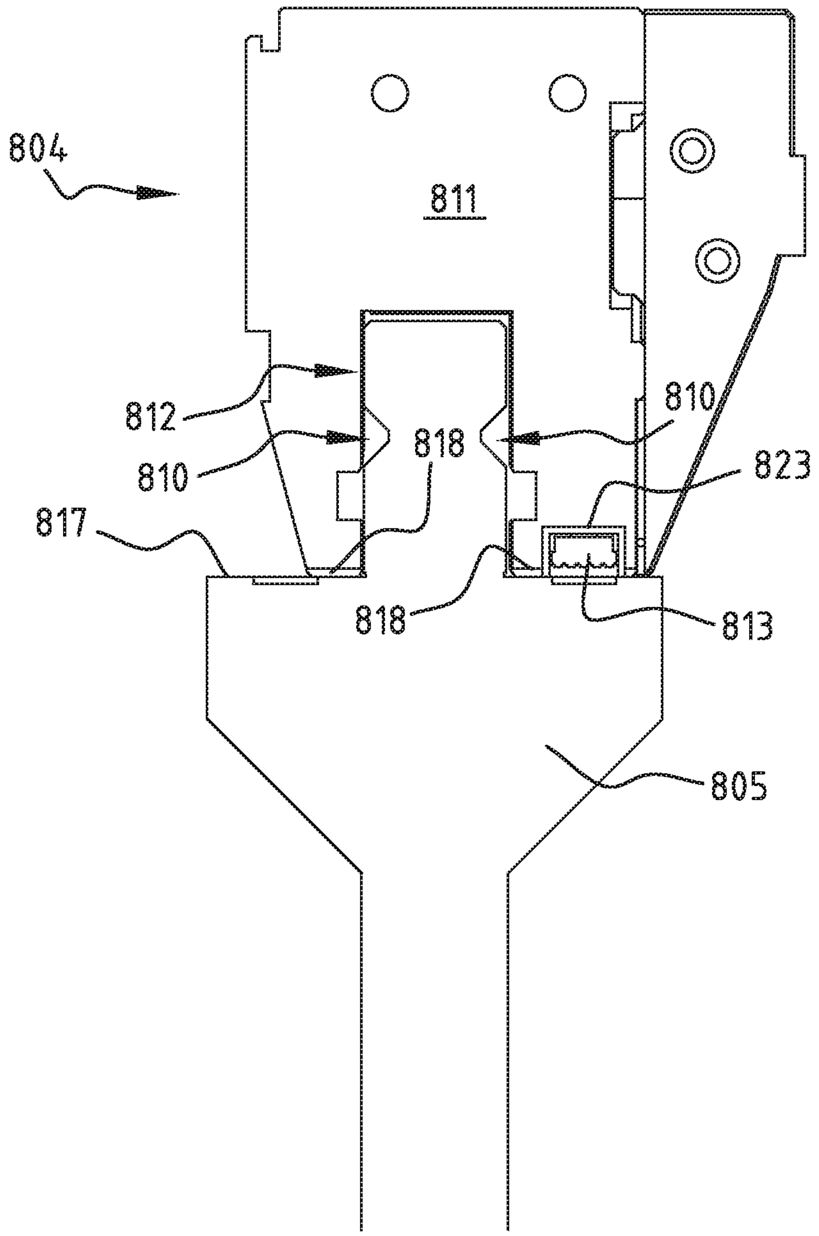

FIG. 15B

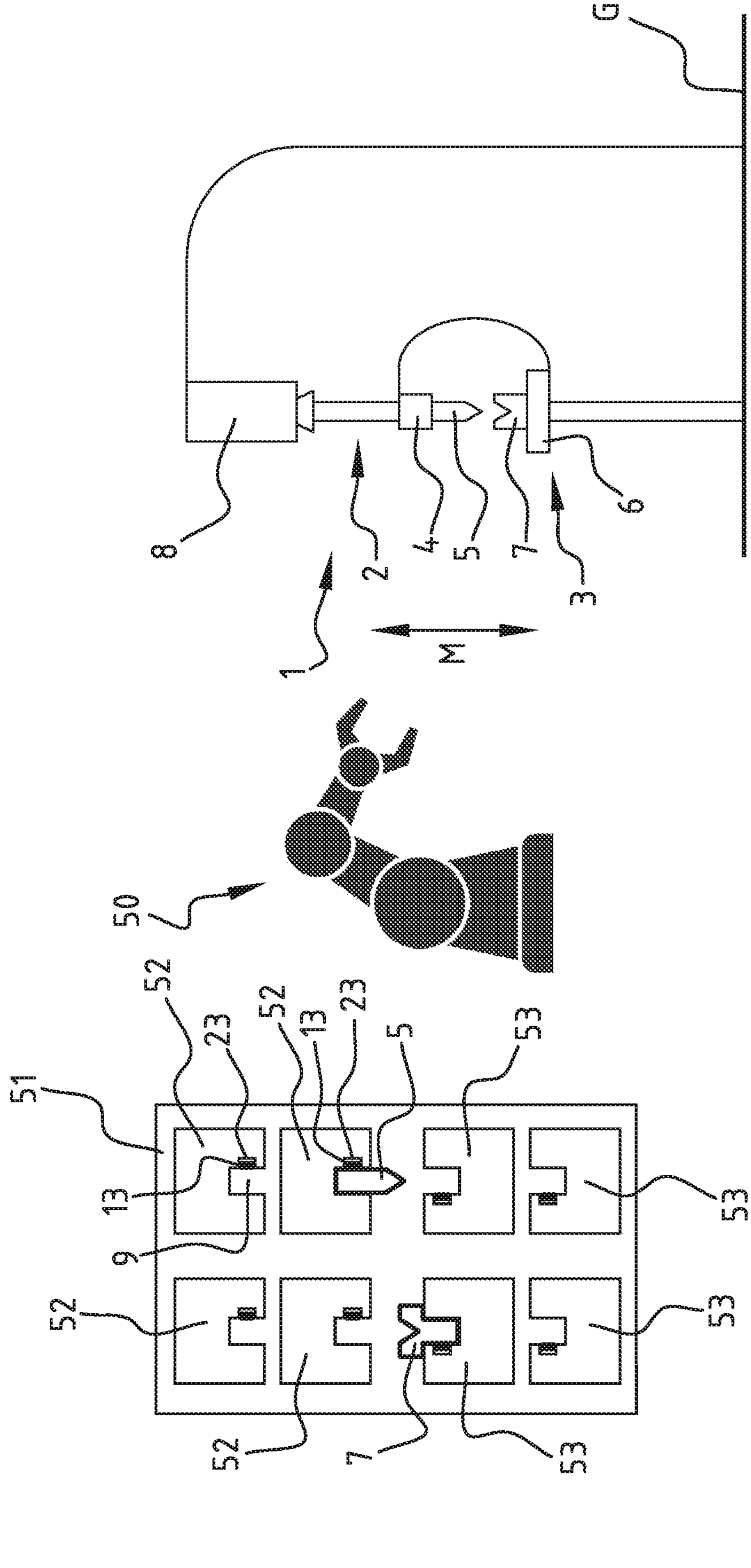

FIG. 16

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2023/050632

A. CLASSIFICATION OF SUBJECT MATTER
INV. B21D5/02 G01D5/25 G05B19/12 B21D5/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B21D G05B G01D G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	WO 2022/255876 A1 (WILA BV [NL]) 8 December 2022 (2022-12-08) the whole document -----	1-21
X	JP 2005 074446 A (AMADA CO LTD) 24 March 2005 (2005-03-24) paragraphs [0016], [0017], [0020] - [0022], [0030]; figures -----	1-21
X	WO 2020/246507 A1 (AMADA CO LTD [JP]) 10 December 2020 (2020-12-10) paragraphs [0033], [0035], [0100]; figures -----	1-21
X	EP 1 864 752 A1 (WILA BV [NL]) 12 December 2007 (2007-12-12) cited in the application paragraphs [0009], [0013], [0022] - [0025]; figures -----	1-21

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 March 2024	22/03/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Knecht, Frank

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2023/050632

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