



US 20140332508A1

(19) **United States**

(12) **Patent Application Publication**

Cilia et al.

(10) **Pub. No.: US 2014/0332508 A1**

(43) **Pub. Date: Nov. 13, 2014**

(54) **PROCESS OF LASER WELDING WITH A CALIBRATION UNIT WITH REFRACTION MEANS**

(71) Applicant: **OPTEC S.P.A.**, Novara (NO) (IT)

(72) Inventors: **Matteo Cilia**, Novara (NO) (IT); **Tiberio Bosotti**, Rescaldina (MI) (IT)

(73) Assignee: **OPTEC S.P.A.**, Novara (NO) (IT)

(21) Appl. No.: **14/358,476**

(22) PCT Filed: **Nov. 8, 2012**

(86) PCT No.: **PCT/IB2012/056250**

§ 371 (c)(1),

(2), (4) Date: **May 15, 2014**

(30) **Foreign Application Priority Data**

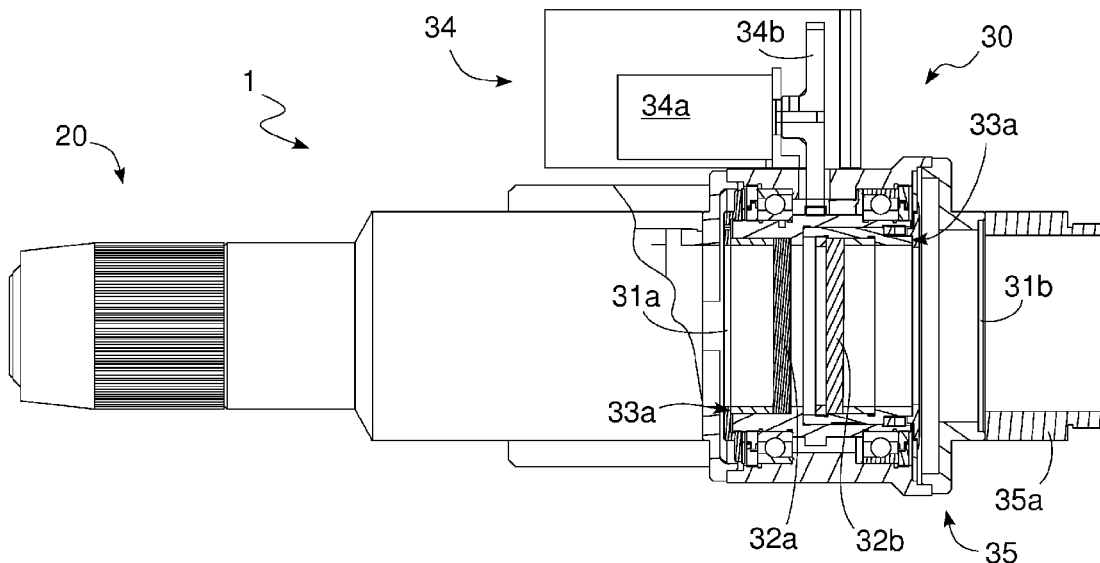
Nov. 16, 2011	(EP)	11189281.6
Feb. 21, 2012	(EP)	12156294.6

Publication Classification

(51) **Int. Cl.**
B23K 26/06 (2006.01)
G02B 26/08 (2006.01)
B23K 26/20 (2006.01)

(52) **U.S. Cl.**
 CPC *B23K 26/0652* (2013.01); *B23K 26/20* (2013.01); *G02B 26/0883* (2013.01)
 USPC **219/121.64**

(57) **ABSTRACT**
 Provided is a laser welding process, including: emitting and propagating a laser beam having a diameter of between 30 µm and 1.5 mm along a first optical axis; refracting said laser beam including deviating the laser beam along a second optical axis that is different to said first optical axis; and moving the laser beam simultaneously with said refracting step, comprising rotating said laser beam in relation to an axis of rotation substantially parallel to said first optical axis maintaining the arrangement of said second optical axis constant with respect to said first optical axis, wherein said moving step, said second optical axis is moved in a feed direction so as to execute a helicoidal weld bead, and said rotation is performed at a speed of between 10 Hz and 500 Hz, and in that said laser beam has a diameter of between 30 µm and 1.5 mm.



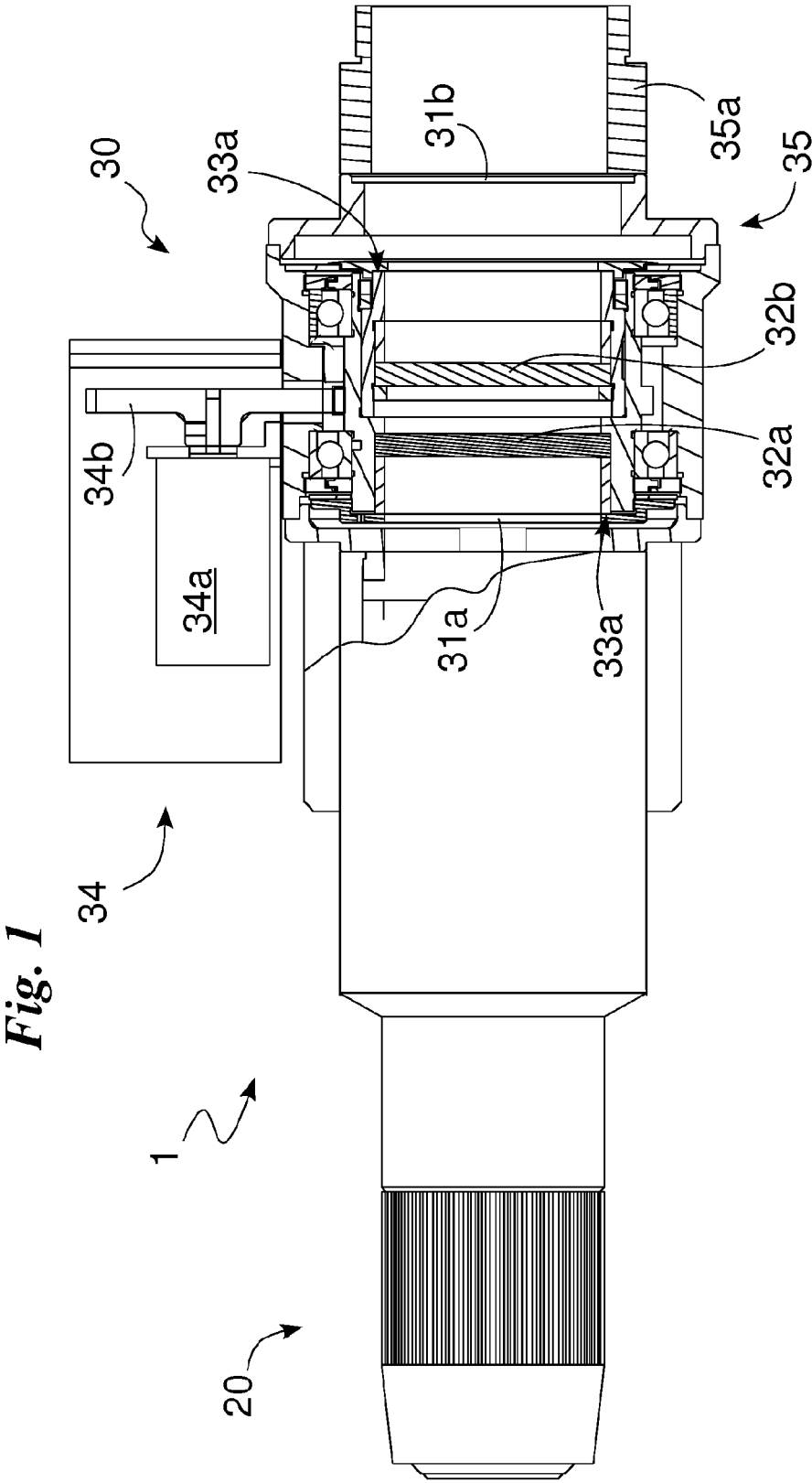
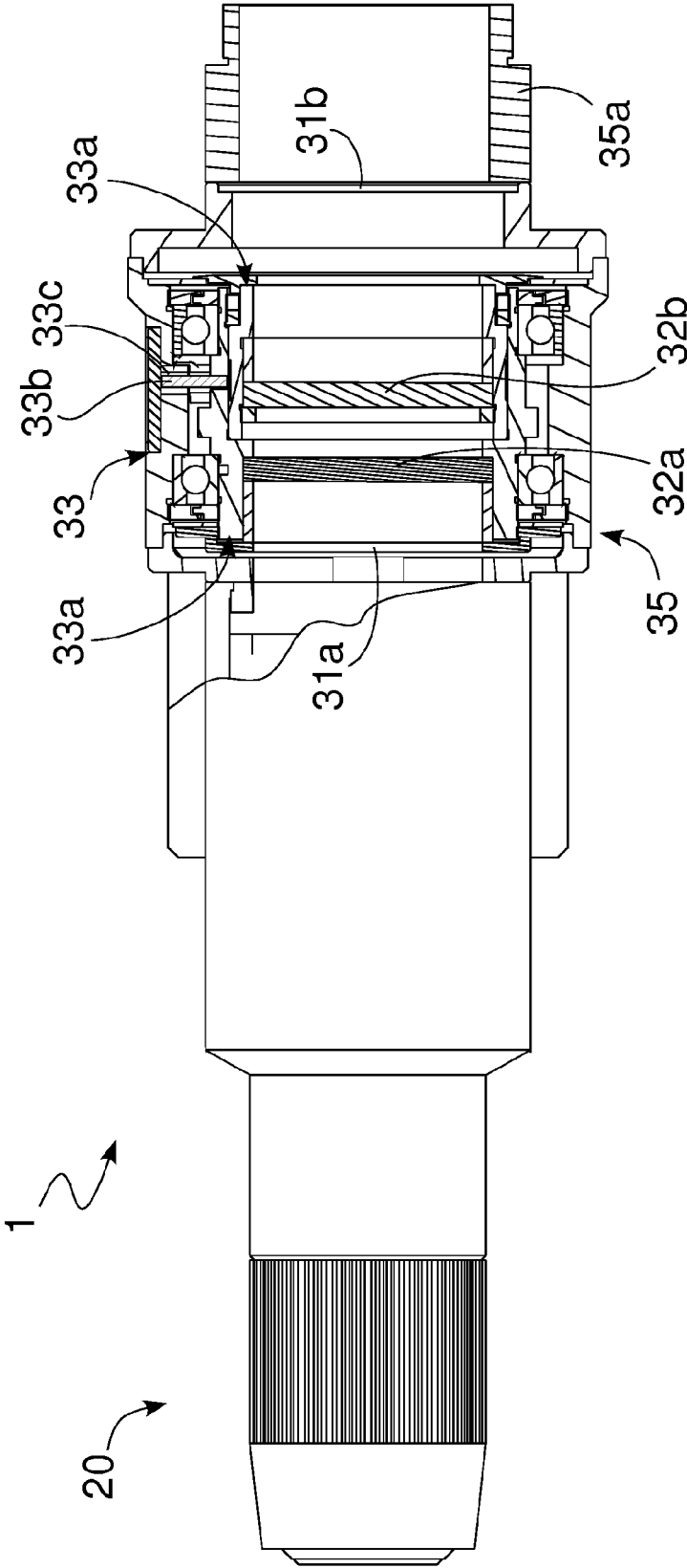


Fig. 2



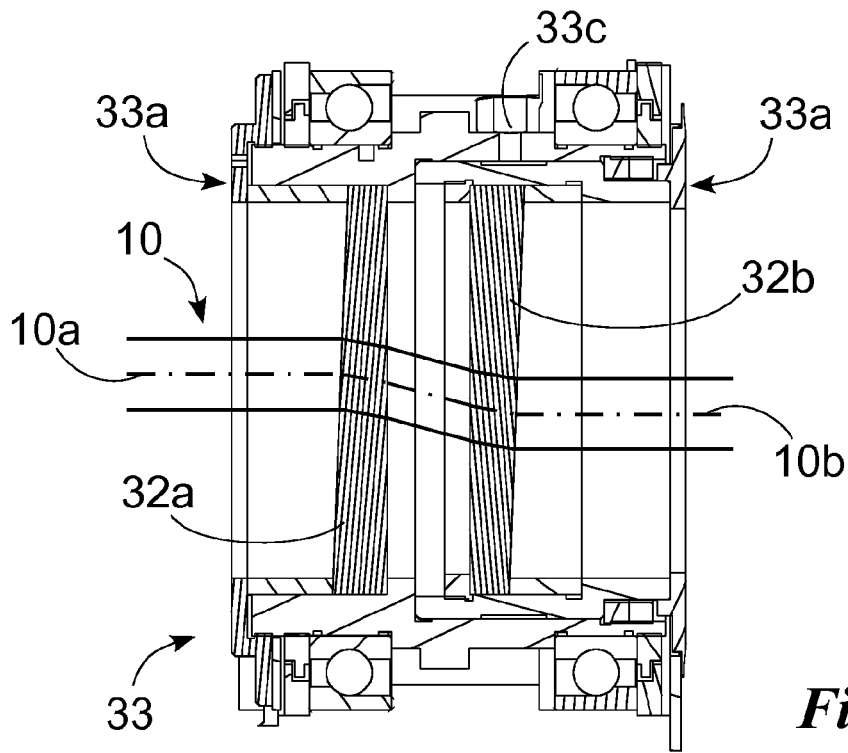


Fig. 3a

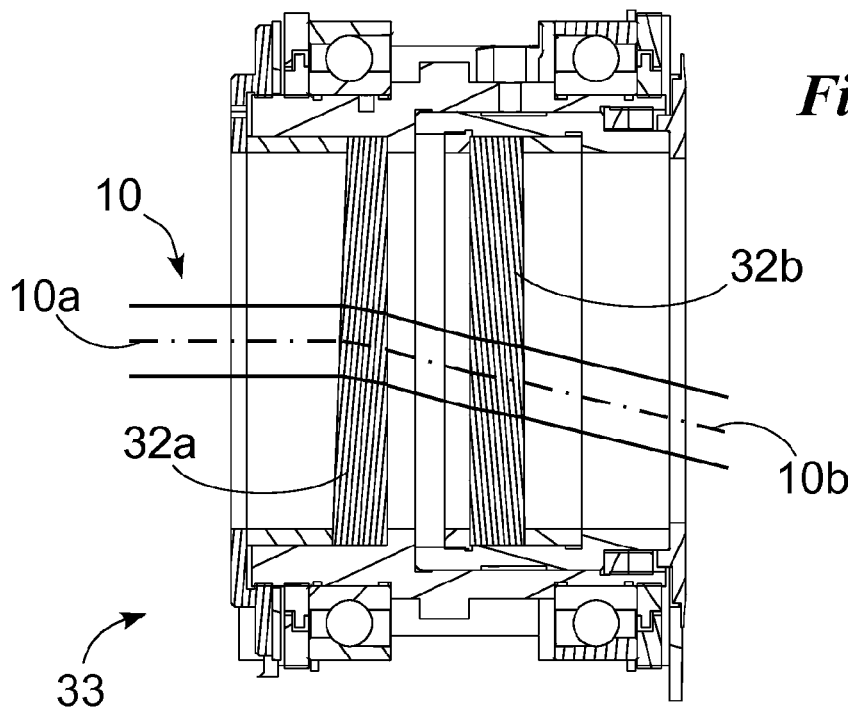


Fig. 3b

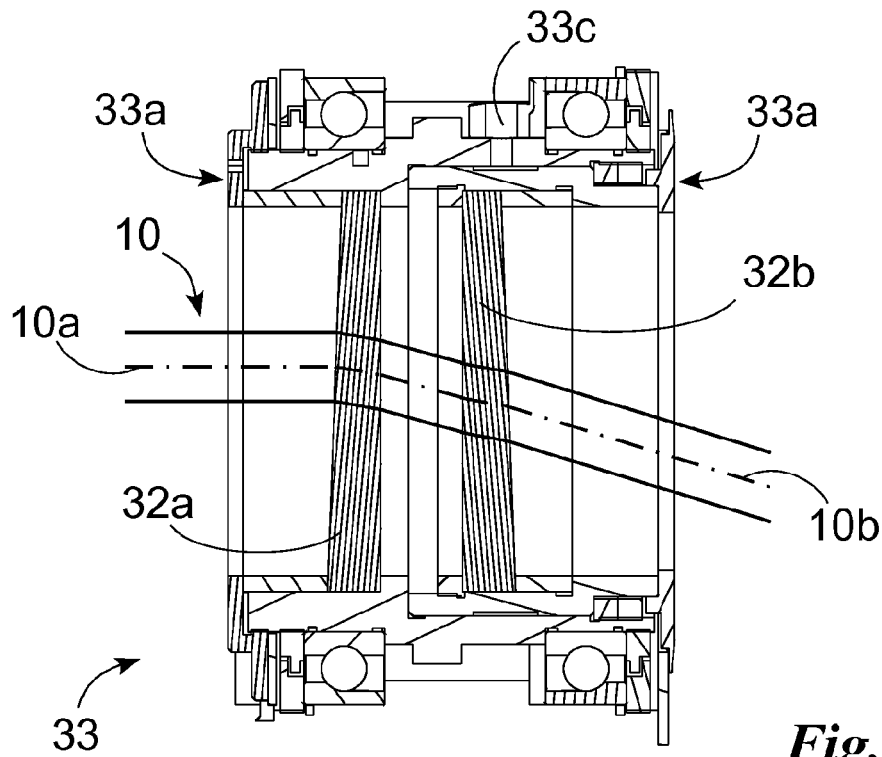


Fig. 3c

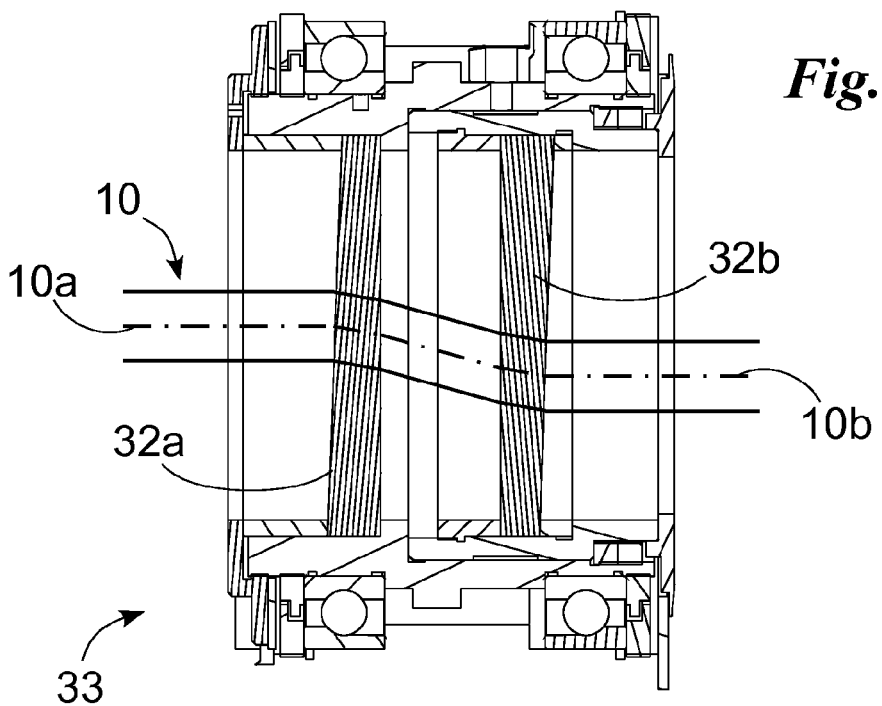


Fig. 3d

**PROCESS OF LASER WELDING WITH A
CALIBRATION UNIT WITH REFRACTION
MEANS**

[0001] The present invention relates to a device and a process for laser welding, of the type pointed out in the preamble of the independent claims.

[0002] It is known that presently laser welding is increasingly more frequently used because it is more practical and quicker to be carried out as compared with the other known welding techniques. This preference for laser welding is due not only to the high speed and automation degree, but also to the better quality of the weld bead, due to the absence of thermally altered regions and residual stresses at said bead.

[0003] Known devices for laser welding substantially consist of a gas laser source (He, Ar, CO₂, for example), or a solid means (ruby, NdYAG, for example) implementing the laser beam; and an optical system which concentrates the laser beam at the beam axis and directs it to the welding region.

[0004] In detail, the laser beam, due to the optical system, is focused on the welding region in such a manner that it strikes on that region with a limited incidence section, referred to as spot, causing fusion of same. In greater detail, when the beam hits the welding region, it vaporises the metal and therein generates a thin capillary of ionised metal vapour that, by almost completely absorbing the laser beam power, enables fusion of the metal so that welding is accomplished. The above mentioned known art has some important drawbacks.

[0005] A first drawback lies in the fact that although the weld beads obtained with laser welding are of better quality than those obtained with other welding methods, they still have defects that can lead to breakages or other similar problems.

[0006] Said defects are due to the fact that the metal vapour escapes from the capillary and reduces power absorption by the material, thus limiting the penetration of the weld.

[0007] Said reduced penetration may lead to inadequate joining of the edges of the parts being welded and thus to the creation of a weld that cannot guarantee a high joining force between the parts.

[0008] Another defect, due to the incorrect formation of the metal vapour, consists of the fact that the weld bead often contains air bubbles which reduce the quality of said weld.

[0009] A further problem is that if welding is not performed correctly, cracks or other defects can occur which weaken the weld bead.

[0010] Another problem, which is no less important, lies in the complexity of adjusting the speed at which the laser beam moves, the intensity of the laser beam and the other operating parameters of a laser welding device.

[0011] These problems are particularly important when welding thin sheets, which cannot easily be welded using laser welding technology.

[0012] In this situation the technical purpose of the present invention is to develop a device and process for laser welding able to substantially overcome the inconveniences mentioned above.

[0013] Within the sphere of said technical purpose one important aim of the invention is to create a device and process for laser welding that can be used to obtain particularly high-quality weld beads, even with extremely thin metal sheets.

[0014] In detail, an important aim of the invention is to conceive a device and a process for laser welding that are able to produce weld beads almost devoid of faults.

[0015] Another aim of the invention is to obtain a device and a process for laser welding that can be easily used and adjusted.

[0016] The technical task mentioned and the aims specified are achieved by a device and a process for laser welding as claimed in the appended independent claims.

[0017] Preferred embodiments are highlighted in the sub-claims.

[0018] The features and advantages of the invention are hereinafter clarified by the detailed description of a preferred embodiment of the invention, with reference to the accompanying drawings, in which:

[0019] FIG. 1 shows a section of the device for laser welding according to the invention;

[0020] FIG. 2 is a section of the device for laser welding taken along a sectional plane perpendicular to the plane in FIG. 1; and

[0021] FIGS. 3a-3d highlight some possible arrangements of a portion of the welding device according to the invention.

[0022] With reference to the drawings, the device for laser welding according to the invention is generally identified by reference numeral 1.

[0023] It is adapted to be used for joining a plurality of pieces, usually of metal, with each other, by use of a laser beam 10. Device 1 is suitable to be used for automation of production processes such as those concerning the car industry, for example. To this aim, it is adapted to be disposed on an actuating system, such as a mechanical arm, a robot or other similar system capable of moving device 1 so as to shift the laser beam 10 in such a manner that weld beads of suitable length can be obtained.

[0024] The laser welding device 1 mainly comprises an emitter unit 20 adapted to emit the laser beam 10 that is emitted along a first optical axis 10a and a calibration unit 30 passed through by the laser beam 10 and adapted to guide and calibrate said laser beam 10 enabling it to carry out the welding operation.

[0025] The emitter unit 20 consists of any source that, suitably stimulated, emits a laser beam 10, i.e. a monochromatic light beam with the typical divergence of the optical fibre or of the laser type, subsequently collimated and propagating along the first optical axis 10. Preferably, the emitter unit 20 is a fibre laser such as IPG's fibre laser and, more preferably, the laser beam emitted by unit 20 has a wavelength substantially included between 1030 and 1070 nm.

[0026] Once the laser beam 10 has come out of the emitter unit 20, it encounters along the first optical axis 10a, the calibration unit 30 determining orientation and size of the spot, i.e. the surface on which the beam 10 strikes carrying out the welding operation.

[0027] The calibration unit 30 comprises collimation and focusing lenses adapted to determine the spot section, refraction means adapted to be passed through by the laser beam 10 and to deviate the laser beam 10 along a second optical axis 10b different from the first optical axis 10a, a guide structure 33 engaging the refraction means and adapted to enable the same means to carry out at least one first movement in which the mutual arrangement of the optical axes 10a and 10b is maintained constant, and actuating members 34 adapted to move the refraction means. The calibration unit 30 further has a holding structure 35 defining a volume in which at least the collimation and focusing lenses and the refraction means are disposed and provided with a cover 35a adapted to enable easy access to said inner volume.

[0028] The collimation and focusing lenses are preferably two in number and, more preferably, comprise a collimation lens **31a** adapted to carry out collimation of the laser beam **10**, and a focusing lens **31b** adapted to focus the laser beam **10** enabling welding to be carried out. Said two lenses **31a** and **31b** are placed in such a manner that the refraction means is interposed between said lenses so that the laser beam **10** first passes through the collimation lens **31a**, then the refraction means and finally the other lens, i.e. the focusing lens **31b**.

[0029] The refraction means is made of a material adapted to be passed through by the laser beam **10** and having such a refraction index that the laser beam **10** is deviated along the second optical axis **10b**. In particular, said means is of optical glass, i.e. a glass characterised by a chemical composition capable of ensuring a high degree of isotropy and, in particular, the same refraction index along the whole structure.

[0030] In detail, the refraction means comprises at least one solid of refraction substantially defining optical prisms, which solid, when the laser beam **10** passes through it, is able to deviate the laser beam **10** along a second optical axis **10b** different from the first one **10a**. In particular, the means comprises an optical prism, i.e. a block that, according to the first optical axis **10a**, is bounded by two flat base faces defining the inlet surface and outlet surface of the laser beam **10**.

[0031] Preferably, along the second optical axis **10b** and appropriately also along the first optical axis **10a**, the laser beam has a diameter of between 30 μm and 1.5 mm and more preferably of between 30 μm and 500 μm . It also has a power preferably of between 10 kW and 30 kW.

[0032] Advantageously, the refraction means comprises two optical prisms that are preferably substantially identical so as to define a first optical prism, i.e. a first refraction means **32a**, and a second optical prism, i.e. a second refraction means **32b**.

[0033] The optical prisms and therefore the refraction means have the adjoining faces, i.e. the base surfaces and in particular the outlet surface of the first prism **32a** and the inlet surface of the second prism **32b**, substantially parallel to each other and preferably substantially perpendicular to the first optical axis **10a**. In addition, the optical prisms have the outer bases, i.e. the inlet surface of the first prism **32a** and the outlet surface of the second prism **32b** suitably inclined to each other. In detail, they have these outer bases inclined to said adjoining bases and in greater detail, inclined to the adjoining bases according to substantially equal inclination angles. In particular, this inclination angle is substantially smaller than 2°, preferably smaller than 1° and more preferably equal to 0° 16' 33" \pm 0° 0' 30".

[0034] Therefore, the refraction means **32a** and **32b** can consist of right cylinders of oblique section in which the axes are substantially coincident with the first optical axis **10a**, the bases constitute the adjoining surfaces parallel to each other, and the oblique sections identify the outer bases that are inclined to the bases by said inclination angle.

[0035] At the refraction means **32a** and **32b** the calibration unit **30** has the guide structure **33** engaging the refraction means **32a** and **32b** so as to enable the means **32a** and **32b** themselves to carry out at least one first movement in which the mutual arrangement of the optical axes **10a**, **10b** is maintained constant.

[0036] In detail, the guide structure **33** allows the refraction means **32a** and **32b** to carry out at least one first movement, in which the mutual arrangement of the optical axes **10a**, **10b** is maintained constant, and a second movement in which the

mutual arrangement of the optical axes **10a**, **10b** is varied. In greater detail, the guide structure **33** allows the actuating members **34** both to move the refraction means **32a** and **32b** jointly when the laser welding device **1** is carrying out the welding operation, and to mutually move them when device **1** is carrying out no welding operation.

[0037] In particular, when welding is being carried out, the guide structure **33** allows the actuating members **34** to move both the refraction means **32a** and **32b** without varying the mutual arrangement of the optical axes **10a** and **10b**, i.e. leaving the inclination and distance between the two axes **10a** and **10b** substantially unchanged. Preferably, during execution of the welding operation, the actuating members **34**, as better described in the following, rotate the refraction means **32a** and **32b** jointly about a rotation axis substantially parallel to the first optical axis **10a** and, more preferably, about an axis substantially coincident with the first optical axis **10a**. Said first movement is preferably performed at a speed of rotation of between 10 Hz and 500 Hz, more preferably between 100 Hz and 500 Hz and even more preferably between 200 Hz and 300 Hz.

[0038] Alternatively, when no welding is being executed, the guide structure **33** allows the actuating members **34** to vary the mutual arrangement of the optical axes **10a** and **10b** mutually moving the refraction means **32a** and **32b** and preferably moving one alone of the means **32a** and **32b** leaving the other substantially stationary.

[0039] In particular, when no welding is being executed, the actuating members **34** rotate one of the refraction means **32a** and **32b** substantially about the first optical axis **10a** so as to vary the mutual inclination of the oblique sections of the means **32a** and **32b** and therefore the inclination of the second optical axis **10b** relative to the first optical axis **10a**.

[0040] In FIGS. **3a-3c** some diagrams of possible inclinations of the second optical axis **10b** relative to the first optical axis **10a** are reproduced. In detail, in FIG. **3a** the oblique sections of the refraction means **32a** and **32b** are substantially parallel, making the two optical axes lie on two distinct straight lines parallel to each other. On the contrary, in FIGS. **3b** and **3c** the oblique sections of the means **32a** and **32b** are mutually rotated through 90° and 180° respectively, relative to the figure, so that the second optical axis **10b** forms two distinct inclination angles with the first optical axis **10a**.

[0041] Alternatively, the actuating members **34** translate one alone of the refraction means **32a** and **32b**, preferably along the first axis **10a**, so as to vary the distance between the refraction means **32a** and **32b** and therefore the distance between the optical axes **10a** and **10b**. In particular, this translation enables the distance between the first axis **10a** and the release point to be modified, said release point being the point of the oblique section from which the laser beam **10** emerges from the second optical prism **32b**, leaving the mutual inclination of the oblique sections and therefore the inclination between the two optical axes **10a** and **10b** substantially unchanged.

[0042] An example of this translation is shown in FIGS. **3a** and **3d** and from a comparison of same it is possible to note that a variation in the distance between the refraction means modifies the distance between the first axis **10a** and the release point, i.e. the point at which the laser beam **10** leaves the oblique section of the second optical prism.

[0043] In a further alternative example, members **34** move one of the refraction means **32a** and **32b** causing a rotational-translational movement of this one relative to the other, pref-

erably along the first optical axis **10a**, so as to vary both the mutual inclination between the axes **10a** and **10b** and the distance between the first axis **10a** and said release point.

[0044] In order to enable the above described particular movement of the refraction means **32a** and **32b**, members **34** comprise an actuating apparatus adapted to move at least one of the refraction means **32a** and **32b** and a connection mechanism adapted to make the means **32a** and **32b** either rigidly fastened to each other or connected in a motion-admitting manner, so as to move them jointly or relative to each other.

[0045] The guide structure **33** comprises two movable bodies **33a** each of which is rigidly connected to one of the refraction means **32a** and **32b**, and a fastening block **33b** adapted to create a constraint between the movable bodies **33a** enabling the refraction means **32a** and **32b** to be moved jointly or, alternatively, adapted to release such a constraint so that the movable bodies **33a** and therefore the means **32a** and **32b** can be moved mutually.

[0046] The movable bodies **33a** consist of two cylinders having axes substantially coincident with each other and, more specifically, substantially coincident with the first optical axis **10a**. Said cylinders are partly superposed and the more external one, preferably corresponding to the first optical prism **32a** has a through hole **33c** through which the fastening block **33b** abuts against the other movable body **33a** so that the refraction means **32a** and **32b** are rigidly mutually connected.

[0047] Members **34**, mechanically connected to at least one of the movable bodies **33a**, have the actuating apparatus that, through said mechanism, moves at least one movable body **33a** and, therefore, at least one of the means **32a** and **32b**.

[0048] The actuating apparatus comprises at least one motor **34a**, preferably of the electric type, which moves at least one of the movable bodies **33a** through a motion-transmitting mechanism **34b** such as a toothed wheel, a belt or other similar element for example, that is suitable for engagement with this movable body **33a** and for performing said motion-transmitting function. In particular, if the fastening block **33b** creates the constraint between the movable bodies **33a**, i.e. if the apparatus allows said first movement, motor **34a** moves the refraction means **32a** and **32b** jointly, while, if the fastening block **33b** does not create the constraint between the movable bodies **33a**, i.e. if the apparatus enables said second movement, the motor **34a** is able to only move the first one of the refraction means **32a** leaving the second **32b** substantially stationary.

[0049] Finally, the mutual movement of the refraction means **32a** and **32b** preferably takes place leaving the first means **32a** kinematically connected to the motor **34a** and moving the second of the refraction means **32b**, more preferably manually moving the second of the refraction means **32b**.

[0050] To ensure high accuracy during this manual movement, a ring nut or other operating element can be provided, so as to be easily accessible from the outside of the machine, for enabling accurate movement of the second of the refraction means **32b**, and a graduated scale or similar solution capable of quantifying the movement of the second of the refraction means **32b** relative to the first **32a**.

[0051] The invention comprises a new process for laser welding which is performed using the device **1** and according to the parameters described above.

[0052] First the process contemplates an installation step in which the laser welding device **1** is fastened to an actuating

system, such as a mechanical arm, a robot or other similar system moving device **1** while the welding is being carried out.

[0053] At this point, a plurality of steps are provided that take place in a substantially simultaneous manner.

[0054] In detail, the process comprises an adjusting step in which, using the second movement, arrangement of the second optical axis **10b** relative to the first optical axis **10a** is varied; an emission step in which the laser beam **10** is emitted which has the first optical axis **10a** as the propagation direction; a refraction step in which the laser beam **10** is deviated along the second optical axis **10b**; an actuating step using the first movement in which the laser beam **10** is rotated relative to a rotation axis substantially parallel to the first optical axis **10a**, arrangement of the second optical axis **10b** being maintained constant relative to the first optical axis **10a**; and a welding step in which device **1**, moved by the actuating system, makes the laser beam **10** strike on the pieces to be welded forming the weld bead.

[0055] In the adjusting step the refraction means **32a** and **32b** are mutually moved so as to deviate the laser beam **10** along the second optical axis **10b**, i.e. in a propagation direction different from the first axis **10a**. In this adjusting step, the operator acts on the guide structure **33** and, in particular, removes the fastening block **33b** so as to release the constraint between the movable bodies **33a**, and the cover **35a** is moved away from the rest of structure **35** so that it is possible to manually act on the movable body **33a** relating to the second of the refraction means **32b**.

[0056] Now the operator acts on the movable body **33a** thus actuating the refraction means **32a** and **32b** according to the second movement, i.e. moving the second of the refraction means **32b** relative to the first of the refraction means **32a** so as to vary the mutual position of the oblique sections and therefore the arrangement of the second optical axis **10b** relative to the first optical axis **10a**.

[0057] Once the desired arrangement of the two optical axes **10a** and **10b** has been achieved, the operator puts the cover again on structure **32** and places the fastening block **33b** back in the through hole **33c** locking the movable bodies **34** and therefore the refraction means **32a** and **32b** in this position.

[0058] The calibration step is thus terminated and the emission step starts in which the laser beam **10** is emitted.

[0059] In this step, the laser beam **10** comes out of the emitter unit **20**, propagates along the first optical axis **10a** and finally passes through the collimation lens **31a** of the calibration unit **30**.

[0060] At this point the refraction step begins in which, before the laser beam **10** passes through the focusing lens **31b** the refraction means **32a** and **32b** deviate the laser beam **10** along the second optical axis **10b** and, almost simultaneously, the actuating step begins in which the refraction means **32a** and **32b**, in accordance with the second movement, are rotated jointly around substantially the first optical axis **10a**.

[0061] The combination of the refraction step and the actuation step and therefore the combined refraction of the refraction means **32a** and **32b** and rotation of the refraction means **32a** and **32b** themselves, defines a spot having a circular motion concentric with the first optical axis **10a**.

[0062] In addition, almost simultaneous with said refraction and actuation steps, in the welding process the welding step is carried out in which the actuating system moves the second optical axis of the laser welding device **1** so that the

spot hits the pieces to be welded along the whole region in which formation of the helicoidal weld bead is provided.

[0063] The speed at which the welding device **1** moves, which substantially determines the speed of execution of the weld bead, is preferably between 0.5 m/min and 10 m/min and more preferably between 7 m/min and 10 m/m.

[0064] In conclusion, during execution of a welding operation, the spot at the region in which the weld bead is provided carries out a helical motion due to the synergistic effect of the three refraction, actuation and welding steps. In fact, almost simultaneously, the laser beam **10** is deviated along a second optical axis **10b** by the refraction means **32a** and **32b**, set in rotation by the actuating means **34** relative to the first optical axis **10a** and, finally translated along the whole weld bead.

[0065] The diameter of the helicoid, and thus the diameter of the weld bead, is preferably between 1 mm and 4 mm, whereas the diameter of the weld spot is that of said laser beam, i.e. preferably between 30 μm and 1.5 mm and more preferably between 30 μm and 500 μm .

[0066] The invention enables important advantages to be achieved.

[0067] A first important advantage is represented by the high quality of the weld bead obtained by means of the above described laser welding device and process.

[0068] In particular, the applicant has discovered that laser welding of thin sheets requires a low specific power, that is a low ratio between total laser power and diameter of the laser beam, to prevent complete fusion and undesired cutting of the sheet.

[0069] The low specific power results in the need to use relatively very large laser beam diameters which may heat the surrounding areas too much, damaging these and making welding impossible.

[0070] On the contrary, a diameter that is too small would result in rapid heat dissipation, a weld bead that is too small and subsequent inadequacy of the weld.

[0071] On the other hand, with the laser welding device **1** it is possible to maintain a small laser beam diameter, heating of the sheet or object to be welded without the heat being entirely dissipated as many points of the helicoidal weld bead are close together and a weld bead with a large diameter because it corresponds to the diameter of the helicoid.

[0072] Said advantages are obtained with the parameters indicated, in particular it is essential that the speed of rotation be within the range specified above. Other important parameters in order to achieve said advantages are the feed speed, the width of the laser beam and of the bead and the total power of the laser.

[0073] Said parameters make it possible to weld sheets of thicknesses up to 0.1 mm.

[0074] This advantage is mainly due to the fact that the laser beam **10**, when it hits the pieces to be welded, transfers less power to the pieces and therefore prevents the metal vapour from coming out of the capillary enabling perfect power absorption by the pieces to be welded and therefore optimising penetration of the weld.

[0075] Another important advantage is represented by the fact that, due to the correct formation of the metal vapour, formation of gas inclusions that would lower the quality of the weld bead is prevented.

[0076] These advantages are due to the particular movement of the spot and therefore the particular movements of the laser beam **10** coming out of the calibration unit **30**.

[0077] In fact, the combined effect of the refraction means **32a** and **32b**, rotation of the refraction means **32a** and **32b** themselves and movement of device **1** determines a higher velocity of the spot that, stopping less on the points of the weld bead, ensures an optimal energy absorption by said pieces.

[0078] Another important advantage, due to the innovative first movement, is represented by the fact that focusing of the spot at the welding region is almost constant for the whole welding duration. This advantage is obtained by the fact that the position of the second optical axis **10b** relative to the first optical axis **10a** is constant and therefore the space travelled over by the laser beam before it reaches the welding region remains substantially constant during execution of the whole weld bead.

[0079] A further advantage is the high flexibility of the welding device **1** that, without the emitter unit **20** requiring to be modified, can be easily adapted to a high variety of pieces.

[0080] In fact, by modifying the mutual position of the refraction means **32a** and **32b**, the spot distance from the first optical axis **10a** can be varied and therefore it is possible to vary the shifting velocity of the spot. In detail, the possibility of modifying the spot velocity enables the amount of energy absorbed by each point of the piece to be varied so as to adapt it to the requirements of the different pieces having different thickness and/or different manufacturing materials.

[0081] The invention is susceptible of variations falling within the inventive idea.

[0082] In particular, the actuating means **34** can comprise two motors preferably of the electric type and at least one control card adapted to control operation of the motors. In this case, the guide structure **33** can consist of kinematic mechanisms that, by individually connecting the refraction means **32a** and **32b** to the motors, make the motors operate the means **32a** and **32b** independently of each other. In this case, when welding is being carried out, the two motors rotate, through structure **34**, the refraction means **32a** and **32b** around the first optical axis **10a** at substantially identical velocities so that the refraction means **32a** and **32b** move jointly and therefore arrangement of the second optical axis **10b** relative to the first optical axis **10a** is not changed.

[0083] On the contrary, during the period in which no welding operation is carried out, the control card controls the two motors that, consequently, are driven at different velocities in such a manner that there is a mutual motion between the refraction means and therefore the arrangement of the second optical axis **10b** relative to the first optical axis **10a** is varied.

1. A laser welding process, comprising:

emitting and propagating a laser beam having a diameter of between 30 μm and 1.5 mm along a first optical axis;

refracting said laser beam comprising deviating the laser beam along a second optical axis that is different to said first optical axis; and

moving the laser beam simultaneously with said refracting step, comprising rotating said laser beam in relation to an axis of rotation substantially parallel to said first optical axis maintaining the arrangement of said second optical axis constant with respect to said first optical axis,

wherein said moving step, said second optical axis is moved in a feed direction so as to execute a helicoidal weld bead, and said rotation is performed at a speed of between 10 Hz and 500 Hz, and in that said laser beam has a diameter of between 30 μm and 1.5 mm.

2. The laser welding process of claim 1, comprising:
prior to said step of emitting and propagating, adjusting
said emission step, in which said arrangement of said
second optical axis with respect to said first optical axis.
3. The laser welding process of claim 2, wherein said
adjusting step comprises changing the inclination of said
second optical axis with respect to said first optical axis.
4. The laser welding process of claim 1, wherein said speed
of rotation is between 100 Hz and 500 Hz.
5. The laser welding process of claim 4, wherein said speed
of rotation is between 200 Hz and 300 Hz.
6. The laser welding process of claim 1, wherein said
rotation defines a diameter of said helicoidal weld bead of
from 1 mm to 4 mm.
7. The laser welding process of claim 1, wherein said laser
beam has a diameter of between 30 μm and 500 μm .
8. The laser welding process of claim 1, wherein said laser
beam has a power of from 10 kW to 30 kW.
9. The laser welding process of claim 1, wherein said
moving along said feed direction is performed at a speed of
from 0.5 m/min to 10 m/min.
10. The laser welding process of claim 9, wherein said
moving along said feed direction is performed at a speed of
from 0.7 m/min to 10 m/min.
11. The laser welding process of claim 1, wherein said
refracting is obtained by refraction means comprising two
solids of refraction substantially defining optical prisms con-
figured to be sequentially passed through by said laser beam.

* * * * *