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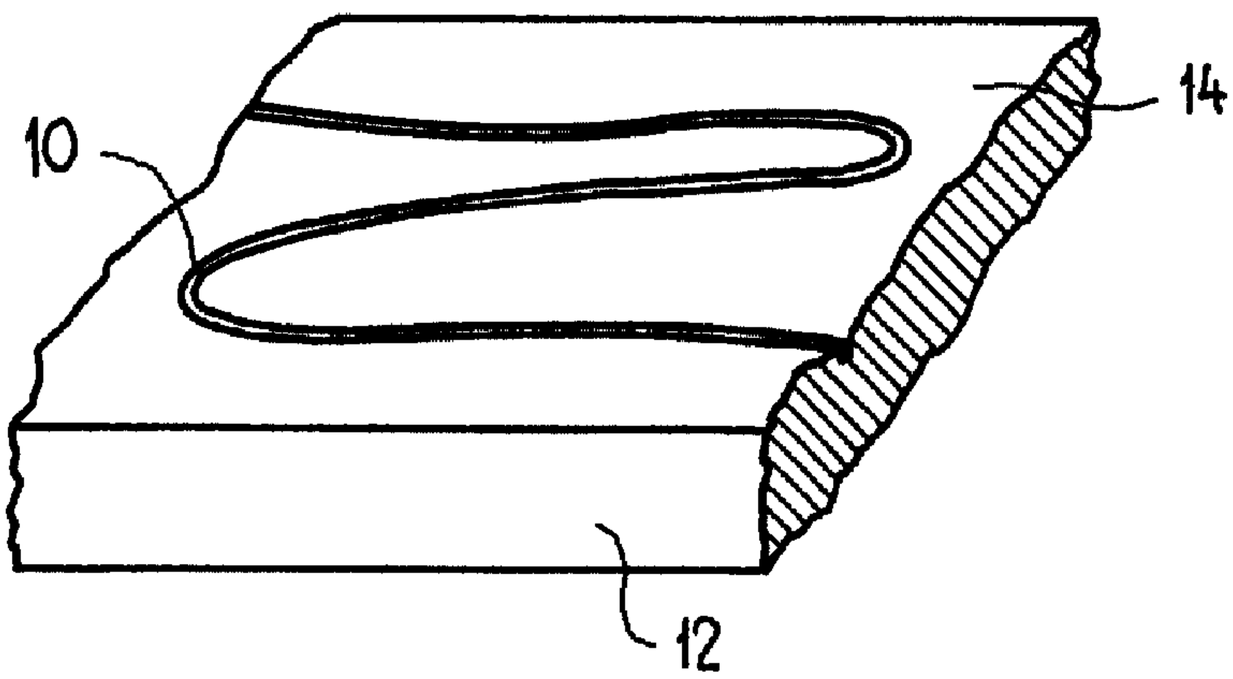
(54) **AMPLIFICATEUR DE PUISSANCE POUR L'AMPLIFICATION DE FAISCEAUX LASER, METHODE POUR SA PRODUCTION ET UTILISATION DE L'AMPLIFICATEUR DE PUISSANCE**

(54) **POWER AMPLIFIER FOR AMPLIFYING A LASER BEAM, METHOD FOR PRODUCING IT AND USE OF THE POWER AMPLIFIER**



(57) A power amplifier. The power amplifier is used for amplifying laser beams with the aid of an amplifier fiber (1) arranged along a curved line. The amplifier fiber (10) is arranged on or in a receiving body (12). The receiving body (10) is made of a material having a sufficient thermal conductivity for carrying off the dissipated heat being generated in the amplifier fiber (10). The amplifier fiber (10) is preferably arranged in a groove of the receiving body (12). In the method for producing the power amplifier, such a groove in the receiving body (12) for receiving the amplifier fiber (10) is generated by means of chemical, electro-erosive, or by non-cutting or cutting mechanical processing. In connection with the use of the amplifier in a mobile object, for example in a terminal for the transmission of data in space, the receiving body (12) is made of a material which not only has a large thermal conductivity, but also a low specific weight.

CA 02292143 1999-12-14

ABSTRACT

A power amplifier. The power amplifier is used for amplifying laser beams with the aid of an amplifier fiber (1) arranged along a curved line. The amplifier fiber (10) is arranged on or in a receiving body (12). The receiving body (10) is made of a material having a sufficient thermal conductivity for carrying off the dissipated heat being generated in the amplifier fiber (10). The amplifier fiber (10) is preferably arranged in a groove of the receiving body (12).

In the method for producing the power amplifier, such a groove in the receiving body (12) for receiving the amplifier fiber (10) is generated by means of chemical, electro-erosive, or by non-cutting or cutting mechanical processing.

In connection with the use of the amplifier in a mobile object, for example in a terminal for the transmission of data in space, the receiving body (12) is made of a material which not only has a large thermal conductivity, but also a low specific weight.

Power Amplifier for Amplifying a Laser Beam, Method for Producing It and Use of the Power Amplifier

The invention relates to a power amplifier for amplifying a laser beam in accordance with the preamble of claim **1**, a method for producing the power amplifier in accordance with the preamble of claim **11**, and use of the power amplifier in accordance with the preamble of claim **12**.

In general, several meters of an optical amplifier fiber, i.e. a glass fiber, are required for amplifying a laser beam by means of this amplifier fiber. Conventionally, this amplifier fiber is arranged in the form of an air-cored coil. It is known that the efficiency of a power amplifier can be increased in a simple manner in that the amplifier fiber is arranged not along a straight line, but along a curved line, wherein the best results are obtained if the curvature changes along the line both as to the degree as well as to the sign.

The arrangement of the amplifier fiber as a free coil has the disadvantage, particularly when using the power amplifier in a vacuum, that the removal of dissipated heat from the amplifier fiber which is generated, for example, as a result of pumped light because of power losses in the amplifier fiber, is not assured to a satisfactory extent. The results of insufficient heat removal are an uneven temperature distribution and possibly overheating of the amplifier fiber.

It is the object of the invention to

- provide an improved power amplifier of the type mentioned at the outset, which avoids the disadvantages of the prior art,
- disclose a method for producing such a power amplifier, and
- propose a use of such a power amplifier.

In accordance with the invention, this object is attained

- for the power amplifier in accordance with the invention by the features of the characterizing portion of claim **1**,
- for the method in accordance with the invention by the features of the characterizing portion of claim **11**, and
- for the use in accordance with the invention by the features of the characterizing portion of claim **12**.

Advantageous further embodiments of the power amplifier in accordance with the invention are defined by claims **2** to **10**.

With the power amplifier in accordance with the invention, the amplifier fiber is not only supported at some points - as in conventional arrangements -, but is arranged in a recess in a receiving body made of a material, whose heat conductivity assures a sufficient removal of the heat being generated in the amplifier fiber. Thus, the amplifier fiber is essentially fixed in place over its entire length on or in the receiving body. This fixation of the amplifier fiber on or in the receiving body furthermore permits the use of greater variations in the curvature of the amplifier fiber over a shorter length than amplifier fibers which are free, or respectively are held only in spots, and results in an increase in efficiency.

In order to assure perfect functioning of the power amplifier, it is necessary to avoid the creation of differences in the heat expansion of the amplifier fiber and the receiving body. For this purpose, materials will be used for the amplifier fiber and the receiving body, whose coefficients of heat expansion are matched to each other.

If materials with different heat expansion are used for the amplifier fiber and the receiving body, it is necessary to take care that these different heat expansions do not lead to impermissibly great mechanical stresses or even the breaking of the amplifier fiber. This can occur if the amplifier is fixed in place over almost its entire length, but has zones free of fixation, in which it can move in relation to the receiving body.

Another advantage of the novel arrangement is that, with a suitable design and arrangement of the receiving body, the latter can simultaneously be used as a shielding device against high- energy radiation, particularly for the amplifier fiber.

With the novel power amplifier, the amplifier fiber is preferably arranged on the surface of the receiving body, generally in a groove. The maximum width and depth of the groove here is slightly greater than the diameter of the amplifier fiber.

The receiving body preferably has the shape of a plate or a dish.

As already mentioned, the efficiency of such power amplifiers can be increased if the amplifier fiber is arranged in the form of a curved line, preferably with a curvature which changes along the line both as to the degree as well as to the sign. It is particularly advantageous to arrange the amplifier fiber in a zig-zag shape, or in several approximately parallel windings, for example in the shape of a spiral, kidney, lobe, dumbbell or meander. Here, respectively two areas of the amplifier then are located approximately parallel with each other.

With the arrangement of the amplifier fiber in a groove of the receiving body and in the just mentioned shape with several windings, the respectively approximately parallel extending adjoining groove sections, in which appropriate areas of the amplifier fiber are arranged, are separated from each other by a dam, or respectively a wall, made from the material of the receiving body. The dam is curved in a manner corresponding to the groove, or respectively amplifier fiber. For fixing the amplifier fiber in place at a first groove point, the groove at a second groove point, namely at the point of the next winding which adjoins the first groove point, is widened by a deformation of the dam. Because of this, the first mentioned groove point is narrowed to such an extent, that the amplifier fiber is fixed in place there. The fastening, or respectively fixation in place, of the amplifier fiber at further groove points takes place correspondingly.

For making the fixation of the amplifier fiber by means of deformation of the dam in certain areas easier, in a preferred embodiment slits, which are provided transversely to the groove, are arranged in the receiving body, by means of which the dam is divided into easily deformable tabs. These are then bent in the slit direction in such a way that they cover one of the adjoining groove sections and the amplifier fiber therein.

Another type of fixation of the amplifier fiber consists in designing the cross section of the groove in such a way that, at a defined distance from the groove entrance, it is narrower than at the groove entrance; a dovetail-like cross section can be considered to be an example of such shaping. The amplifier fiber is then introduced into the groove by an elastic deformation of the dam, or respectively of the wall, and subsequently held in place there.

The amplifier fiber can also be fixed in place on the receiving body by means of an adhesive or lacquer.

With the method in accordance with the invention for producing a power amplifier, in which the amplifier fiber is arranged in a groove, this groove can be produced by chemical, electro-erosive, or by non-cutting or cutting mechanical processing.

Power amplifiers in accordance with the invention are often employed in mobile apparatus, for example in terminals for optical data transmission in space. In this case, the receiving bodies are produced in accordance with the invention from a material which not only has great heat conductivity, but also is comparatively light, for example of aluminum, an aluminum oxide, aluminum nitride, beryllium oxide, boric nitride or copper- tungsten; suitable plastic materials are also usable which, however, do not provide a shielding effect and for this reason are not suitable in cases in which such a shielding effect is necessary.

Further properties and advantages of the invention will be described extensively in what follows by means of exemplary embodiments and with reference to the drawings. Shown are in:

Fig. 1, portions of a receiving body with an amplifier fiber arranged therein in a diagram,

Fig. 2, a top view on an amplifier fiber in a spiral-like arrangement,

Fig. 3, a top view on an amplifier fiber in a lobe-like arrangement,

Fig. 4, a top view on an amplifier fiber in a meander-like arrangement,

Fig. 5, a receiving body with a groove which does not change in height, for receiving the amplifier fiber in a section transversely to the longitudinal direction of the groove,

Fig. 6, a receiving body with a groove which does change in height, for receiving the amplifier fiber in a section transversely to the longitudinal direction of the groove,

Fig. 7, a receiving body with an amplifier fiber fastened by means of an adhesive on its surface in a section transversely to the longitudinal direction of the groove,

Fig. 8, a receiving body with portions of two windings of an amplifier fiber received in adjoining sections of a groove in a view from above, and

Fig. 9, a receiving body with an amplifier fiber in a groove, wherein the dam has been divided into tabs by means of slits.

It is pointed out here, that the drawing figures are not to scale, and that statements, such as "above" and "below", relate to the arrangement in the respective drawing figure.

Fig. 1 shows an amplifier fiber **10** intended for a power amplifier in accordance with the invention, which is arranged in a plate-shaped receiving body **12**. The amplifier fiber **10** follows a zig-zag-shaped bent line, wherein the curvature along the amplifier fiber **10** is not constant, but is changed - for increasing the efficiency of the power amplifier - both in the degree as well as the sign. Here, the amplifier fiber **10** is located in a groove, not represented in the surface **14** of the receiving body **12**. However, it could also be arranged on the surface **14** of the receiving body **12**, or in the interior of the receiving body **12**.

Figs, **2**, **3** and **4** show amplifier fibers **10**, whose topical course follows other curved lines, respectively in several windings, than the amplifier fiber represented in **Fig. 1**, namely, in accordance with **Fig. 2**, a spiral-like line, in accordance with **Fig. 3**, a lobe-like line, and in accordance with **Fig. 4**, a meander-like line. The minimum curvature in each case must be of such a size that any breaking danger of the amplifier fiber **10** is prevented. The lines can also be three-dimensional, which

is advantageous in respect to increasing the efficiency of the power amplifier, but considerably complicates the arrangement in the receiving body.

Fig. 5 shows a receiving body **12** with a groove **16** for receiving the cylindrical amplifier fiber **10**. The groove **16** is intended to receive an amplifier fiber which is arranged in a zig- zag-like manner, or respectively in windings, and is not represented in **Fig. 5**, and is therefore also embodied in a zig- zag-like manner, or respectively in windings. Groove sections **16.1**, **16.2**, **16.3**, which adjoin in cross section, are separated by corresponding wall, or respectively dam, sections **18.1**, **18.2**, **18.3** of a wall, or respectively dam **18**, formed by the material of the receiving body **12**. The groove **16** is approximately square in cross section, wherein the lateral lengths a of the square are slightly larger than the diameter of the amplifier fiber to be arranged in the groove **16**. Fixation in place of the amplifier fiber in a groove **16** of such a cross section is provided with the aid of a lacquer or adhesive and/or by local deformation of the dam **18**, such as is described further down in connection with **Fig. 8** and **Fig. 9**.

A further receiving body **12** with a further groove **14** is represented in **Fig. 6**. In contrast to the groove in accordance with **Fig. 5**, which over its height has the same cross section, or respectively the same width a, the cross section of the groove **16** in accordance with **Fig. 6** is changed. Here, the groove **16** has an entry, whose width b is slightly less than the diameter of the amplifier fiber to be arranged in it, but then widens at least to the diameter of the amplification fiber to be arranged in it, and narrows again farther down. Thus, this groove **16** has the approximate shape of a dovetail. In its cross-sectional shape, the dam **18** is complementary to the groove **16**. Here, the introduction of the amplifier fiber into the groove **16** takes place by means of an elastic deformation of the dam **18**; this deformation is made easier by the reduced width c of the narrowest portion of the dam **18**. Following the introduction of the amplifier fiber into the groove **16**, the dam **18** again assumes its original shape, so that the amplifier fiber cannot leave the entry into the groove **16** again because of the reduced width b of the latter.

Fig. 7 shows a receiving body **12** with an amplifier fiber **10** arranged on its surface **14**, but not in a groove, which is fixed in place by means of a bead **20** of an adhesive or lacquer.

A receiving body is represented in portions in **Fig. 8**, which has a groove **16** and an amplifier fiber **10** arranged therein, wherein two groove sections **16.1**, **16.2** of

the groove **16** and two parts **10.1**, **10.2** of the amplifier fiber **10** are arranged parallel. The groove sections **16.1**, **16.2** are separated from each other by an appropriate, also parallel, dam section of the dam **18**. This section of the dam **18** is deformed in four areas **19.1**, **19.2**, **19.3**, **19.4**. Because of the deformed areas **19.1**, **19.3** of the dam **18**, a widening of the groove section **16.2** results at two places, and simultaneously a narrowing of the groove section **16.1** at adjoining points, so that a fixation in place of the part **10.1** of the amplifier fiber **10** takes place at the two last mentioned places. Correspondingly, a widening of the groove section **16.1**, as well as a narrowing of the groove section **16.2**, at respectively two points results from the deformed areas **19.2**, **19.4** of the dam **18**, and therefore a fixation in place of the part **10.2** at these two last mentioned points.

Fig. 9 shows a receiving body **12** with a a reinforcement fiber **10**, which is arranged in a groove **16**. A section **18.1**, or respectively **18.2** of the dam **18** is located on each side of the groove **16**. The dam **18** is divided into tabs **22** by slits **24**. The tabs **22** are deformed for fixing the amplifier fiber **10** in place in the groove **16** in such a way that the upper free edge area of the tabs **22** projects over the amplifier fiber **10**. Only two of the tabs **22** are shown in the representation in **Fig. 9**. It is easy to understand that the directions in which the deformation of the tabs takes place must be selected to be such that not only the portions of the amplifier fiber **10** represented in **Fig. 9**, but also the portions thereof not represented are fixed in place.

WHAT IS CLAIMED IS:

1. A power amplifier for amplifying a laser beam, having an amplifier fiber (10) arranged along a curved line with a topically changing curvature,

characterized in that

- the power amplifier has a receiving body (12), in which the amplifier fiber (10) is received,

- wherein the receiving body (12) has a sufficient thermal conductivity for assuring the removal of heat being generated in the amplifier fiber.

2. The power amplifier in accordance with claim 1,

characterized in that

the amplifier fiber (10) and the receiving body (12) are made of materials whose heat expansion coefficients have been matched to each other.

3. The power amplifier in accordance with claim 1,

characterized in that

the amplifier fiber (10) is arranged in the receiving body (12) in such a way that, in case of a difference between the heat expansion of the amplifier fiber (10) and of the receiving body (12), the mechanical stress of the amplifier fiber (10) is negligible for the function of the power amplifier.

4. The power amplifier in accordance with at least one of claims 1 to 3,

characterized in that

the receiving body (12) is embodied in such a way that it constitutes a shielding device, in particular for the amplifier fiber (10), and in particular against high-energy radiation.

5. The power amplifier in accordance with at least one of claims 1 to 4,

characterized in that

the amplifier fiber (10) is arranged on an outer surface (14) of the receiving body (12), preferably in a groove (16).

6. The power amplifier in accordance with at least one of claims **1** to **5**, **characterized in that**

the receiving body (**12**) has the shape of a plate or a dish.

7. The power amplifier in accordance with at least one of claims **1** to **6**, **characterized in that**

the amplifier fiber (**10**) extends, at least in sections, along several adjoining windings, for example in a zig-zag-, spiral-, kidney-, lobe-, dumbbell- or meander-shape, in such a way that succeeding parts (**10.1**, **10.2**) of the amplifier fiber (**10**) are located approximately next to each other.

8. The power amplifier in accordance with claim **5**, **characterized in that**

the amplifier fiber (**10**) is held in the groove (**16**) by sectional deformations of a dam (**18**) separating the adjoining groove sections (**16.1**, **16.1**).

9. The power amplifier in accordance with claim **8**, **characterized in that**

the dam (**18**) has slits (**20**), which are arranged transversely in respect to the groove (**16**), wherein the sections of the dam (**18**) separating the groove sections (**16.1**, **16.2**) are divided by the slits (**20**) into tabs (**22**), which are easily deformed for fixing the amplifier fiber (**10**) in place and can be bent over the amplifier fiber (**10**) in the direction of the slits (**20**).

10. The power amplifier in accordance with claim **4**, **characterized in that**

the amplifier fiber (**10**) is fastened on the receiving body (**12**) by means of an adhesive or lacquer.

11. A method for producing a power amplifier in accordance with claim **5**, **characterized in that**

the groove (**16**) is created in the receiving body (**12**) by means of chemical, electro-erosive, or by non-cutting or cutting mechanical processing.

12. Use of the power amplifier in accordance with one of claims **1** to **10** in a mobile object, for example a terminal for optical data transmissions in space, **characterized in that**

the receiving body (**12**) is made of a light material, for example of aluminum, an aluminum alloy, aluminum nitride, beryllium oxide, boric nitride, copper-tungsten or a conducting plastic material.

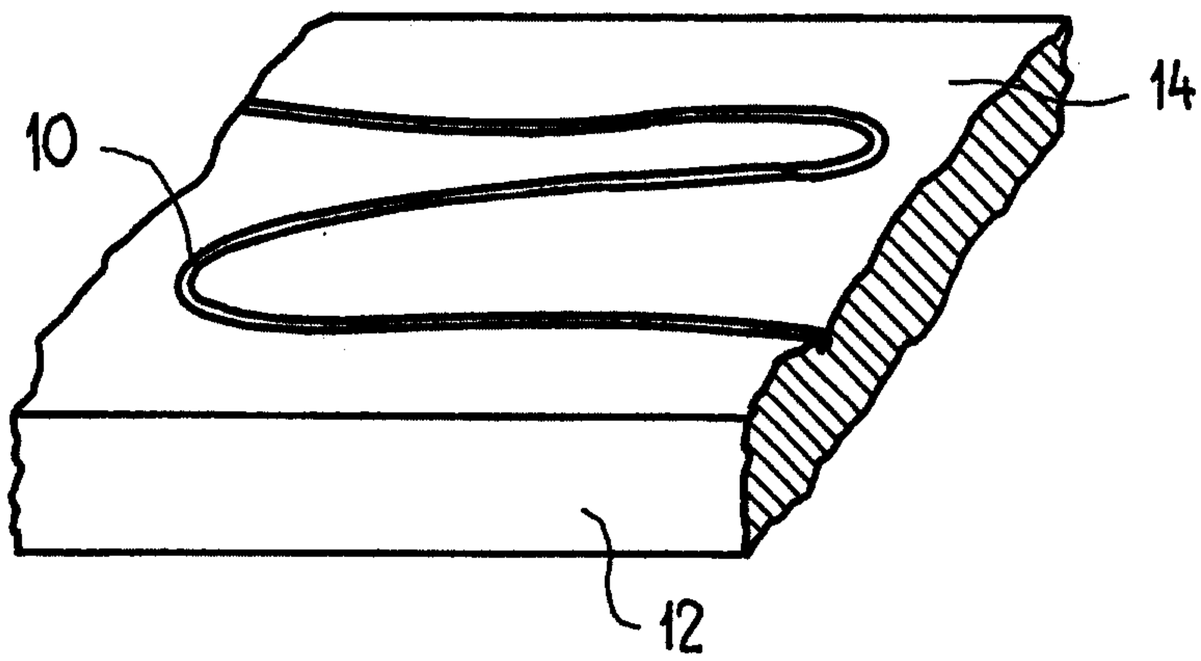


Fig.1

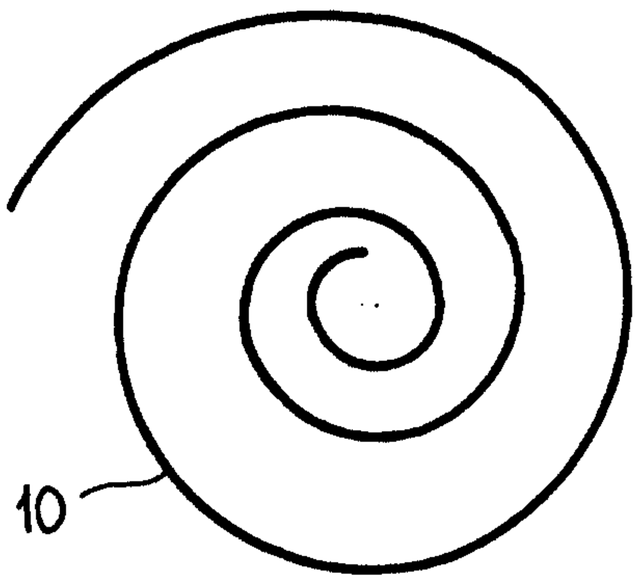


Fig.2

Fig.3

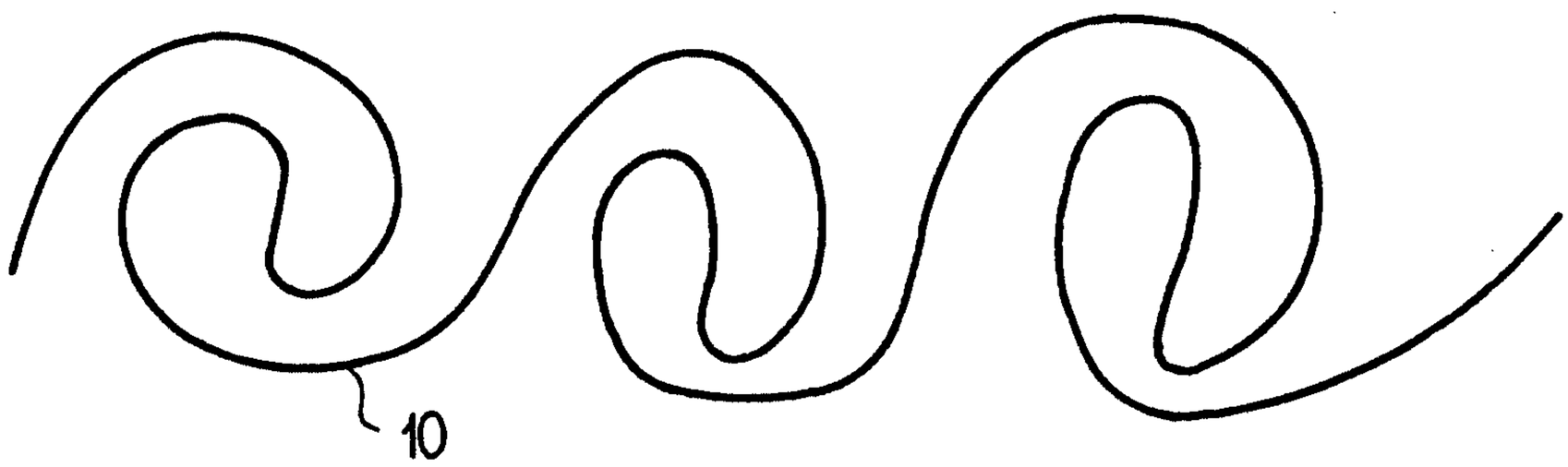


Fig.4

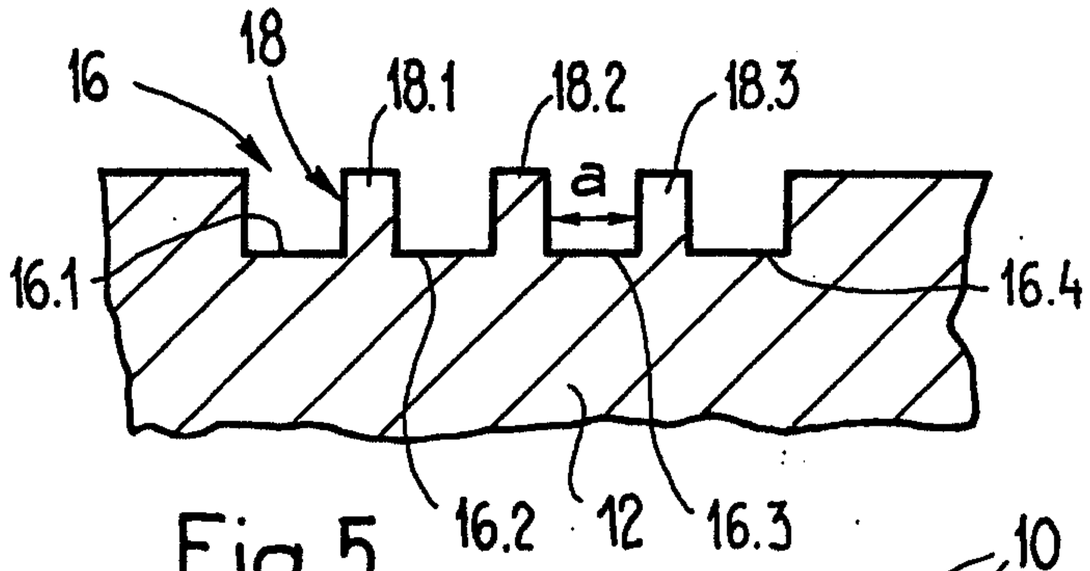


Fig.5

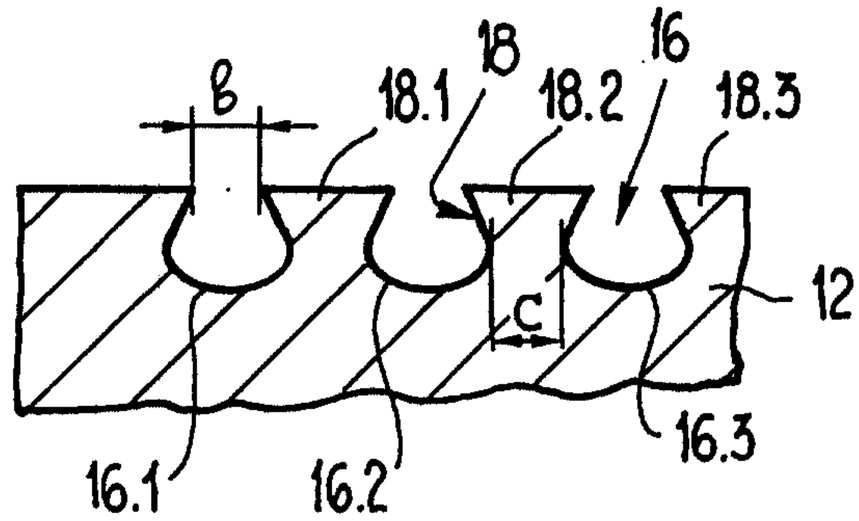


Fig.6

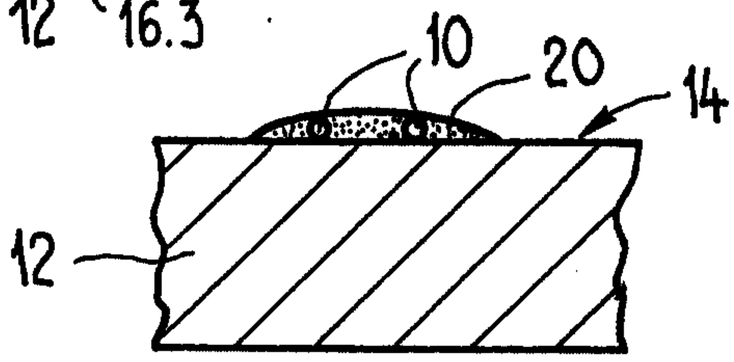


Fig.7

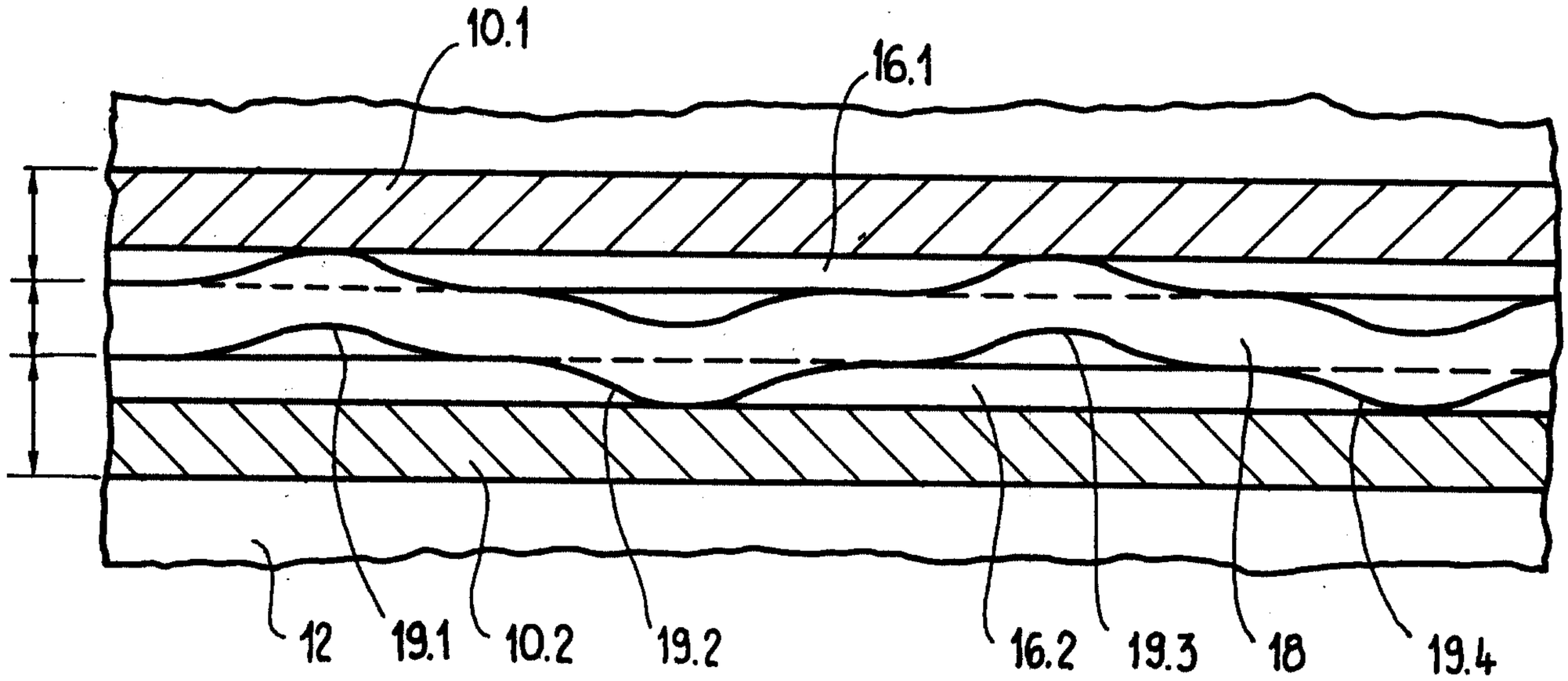

10.1
16.1
12
19.1
10.2
19.2
16.2
19.3
18
19.4

Fig.8

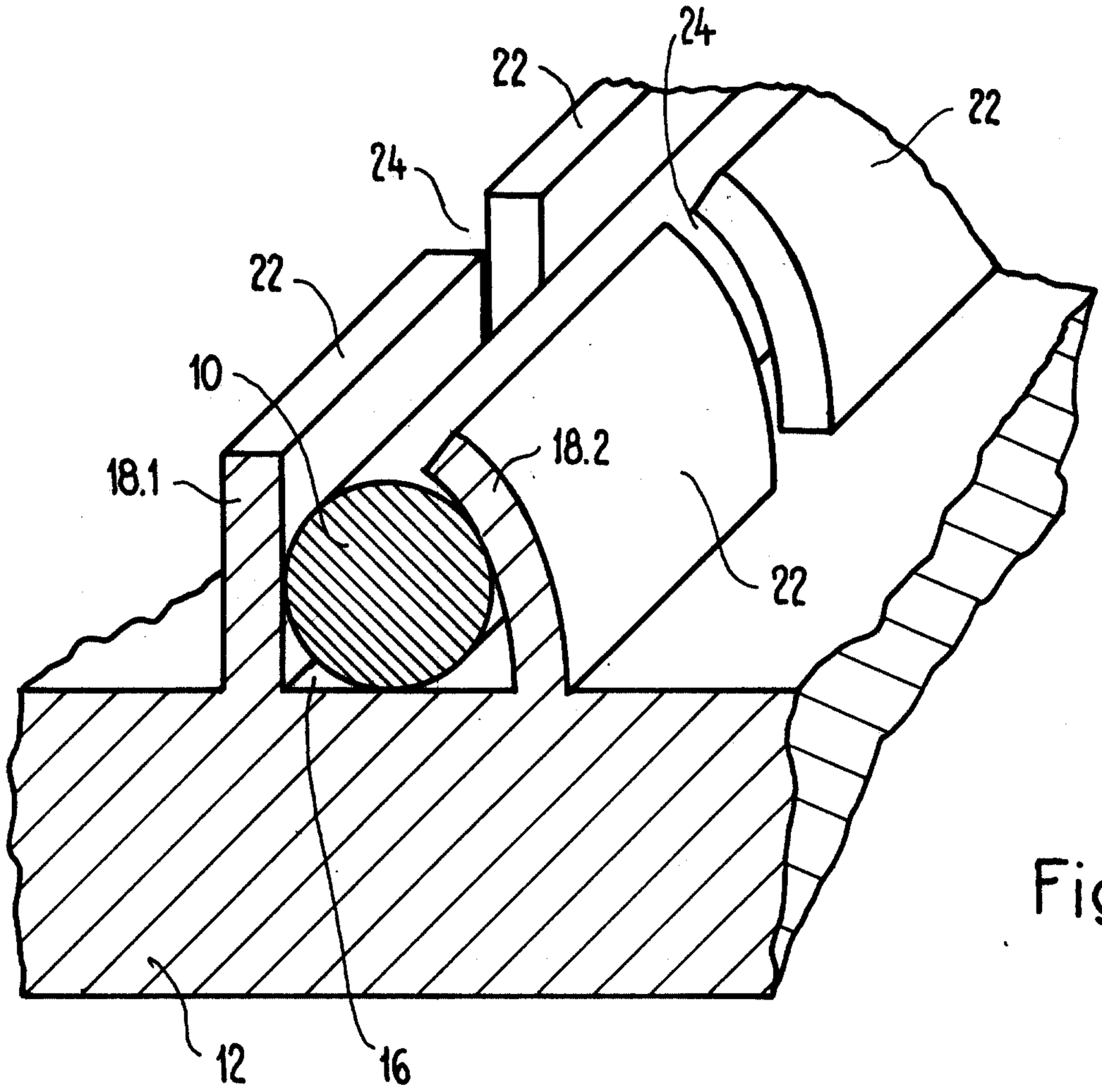

24
22
22
24
22
10
18.1
18.2
22
12
16

Fig.9