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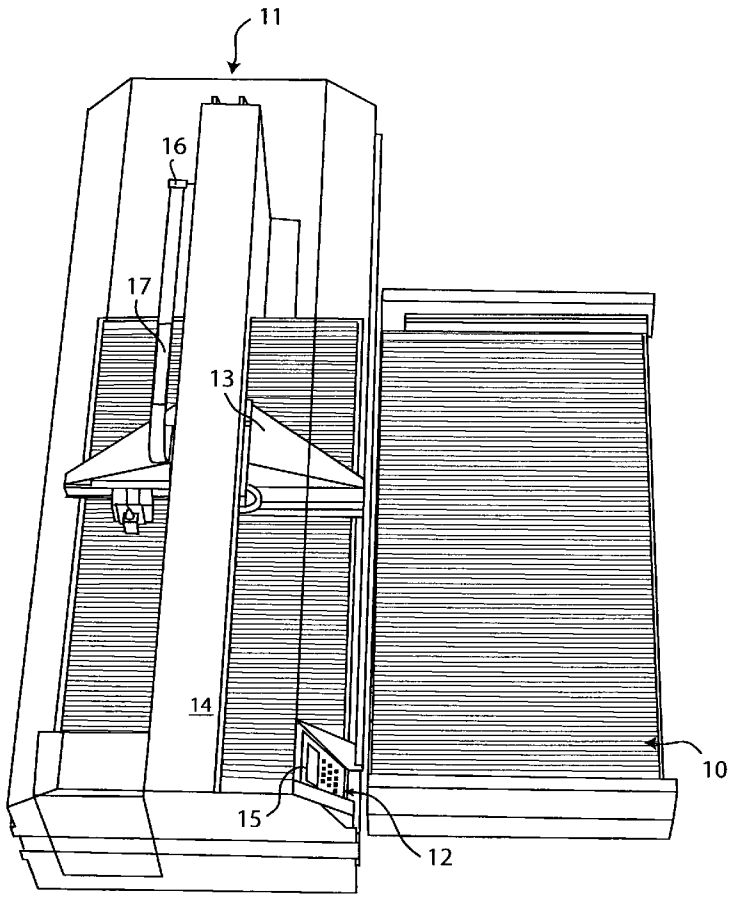
[Continued on next page]

(54) Title: MACHINE TOOL FOR LASER CUTTING OF SHEET AND PIPE MATERIALS USING A OPTICAL FIBRE FOR TRANSMITTING THE LASER BEAM



(57) Abstract: The present application relates to a tool machine for laser cutting of materials, comprising a support table (10) for the materials, a main cutting unit (11), a control panel (12) integrated on the machine, remote controlled and managed by a PC, and a laser cutting head (13) connected to a cooling unit, and moveable over the table by means of a numerical control system, wherein the laser cutting head (13) is connected to an optical fibre laser generator. The laser cutting head (13) is also equipped with a system that automatically controls the height of the material surface to be cut, as well as an optical fibre motion and protection system (17) which moves the laser beam on the machine.

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Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

MACHINE TOOL FOR LASER CUTTING OF SHEET AND PIPE MATERIALS USING A OPTICAL FIBRE FOR TRANSMITTING THE LASER BEAM

The present invention relates in general to a tool machine to be used for the laser cutting of metal and non-metal materials.

More particularly, the invention relates to a flatbed tool machine for the laser cutting of materials having an innovative technological structure.

The invention is extended to cover the application of the laser generator on the tool machine, the automatized guide system of the laser head, as well as the protection and guide system of the laser beam on the machine.

Laser cutting, and above all, the type used for cutting very thick materials, is always performed using carbon dioxide (CO_2) gaseous laser sources, in other words Nd-Yag gaseous laser sources (Neodymium-Yttrium-Aluminium).

It is known that CO_2 laser sources are able to provide an extremely powerful high quality beam for cutting sheet metal and metal plate; in addition various types of cutting machine tools are used for practical applications, using lens and/or mirror systems for high precision beam focus.

On the other hand, Nd-YAG lasers are normally used for material surface marking because of the high quality of the beam at low power.

Recent developments relating to this type of laser have led to the discovery that Nd-YAG lasers are also able to provide good beam quality, comparable to CO_2 lasers, even at power output levels over 100W; consequently this has made it possible to use Nd-YAG lasers for material cutting, with results that are comparable to those obtained with CO_2 lasers.

However, in this case as well, there are considerable transmission losses, low beam quality and basic instability in the emitted power.

The aim of the present invention therefore, is to resolve the problems described above, and in particular, to create a tool machine to laser cut materials, able to provide laser beams of very high quality, without the problems related to cooling and thermal lenses.

Another aim of the present invention is to provide a flatbed tool machine to laser cut materials that permits the construction of an extremely reliable pumping architecture with very high power stability and concentration, which will result in a considerable

reduction in piercing times and greatly increased cutting speed.

A further aim of the invention is to provide a tool machine to laser cut materials, which is able to eliminate the use of lasering gas, as well as the lens units and mirror units used on traditional type machines.

By no means the last aim of the present invention is to provide a tool machine to laser cut materials, which is extremely reliable and efficient from a practical point of view, which has a long work life, and which has very reasonable running costs compared to prior art equipment.

These and other aims, according to the present invention, are achieved by a tool machine to laser cut materials according to the appended claim 1; the other subordinate claims include other technical characteristics describing details of the invention.

Advantageously, the tool machine according to the invention is equipped with a laser source having a new concept, with a completely innovative "fiberlaser" architecture, thus providing excellent laser beam quality results and very powerful emission levels (practically unlimited).

The system provides a valid alternative to CO_2 or Nd-YAG type lasers for application in the field of metal cutting, whether in sheet, plate, or pipe form.

An optical fibre source is created using an active means wherein optical radiation is generated, a pumping source able to excite the doped ions (or the gas molecules in the case of carbon dioxide or CO_2) and two mirrors to create the resonant cavity.

In particular, the aspect that distinguishes a fibre laser source from a solid-state source (such as Nd-YAG for example) is the presence of:

- an optical fibre which replaces the crystal bar,
- various "single" pump diodes to replace the common bars, and
- Bragg gratings, once again in optical fibre, to replace the mirrors.

By analysing the optical fibre laser ("fiberlaser") in more detail, it can be seen that, in spite of their individual simplicity, each of the aforesaid base elements provides the source with unique functional characteristics.

In fact, first of all, thanks to a very reduced doped nucleus (of only 5 microns) the active fibre provides laser beams of extremely high quality in a very

efficient manner without any cooling or thermal lens problems.

Furthermore, the use of single pumping diodes that replace the bars of prior art, provide a pumping architecture that is extremely reliable. (In reference to "fiberlasers" MTBF levels over 30,000 working hours are commonplace, in other words, levels are far higher than those obtained using solid-state laser sources).

Lastly, thanks to the intrinsic syntonizing quality and reduced insertion loss, the optical fibre Bragg gratings provide resonant cavities that have high precision syntonization with the emitted wave length of the source, as well as very high emitted power stability levels.

Further characteristics and advantages of the present invention will be made more apparent from the following description of an embodiment, provided as a preferred example, but in no way limiting, of a tool machine for laser cutting of materials, according to the invention and the appended drawings, wherein:

- figure 1 shows a front view in perspective of the flat-bed tool machine for laser cutting of materials, according to the invention;

- figure 2 shows a rear view in perspective of the flat-bed tool machine for laser cutting of materials, according to the invention;
- figure 3 shows a front view of the flat-bed tool machine for laser cutting of materials, according to the invention;
- figure 4 shows a partial and enlarged plane view seen from above, of the flat-bed tool machine for laser cutting of materials, according to the invention;
- figure 5 shows a tentative outline for the application of an automatic laser cutting head height control system, used on the flat-bed tool machine according to the present invention;
- Figure 6 shows a plane view from above of a fibre protection and guide system that moves the laser beam on the flatbed tool machine according to the invention.

In reference to the aforesaid figures, the flat-bed tool machine for laser cutting of materials, according to the present invention is constructed with external protection and shielding that guarantee complete isolation of the machining area during the work cycle, and that is mainly composed of a support table for the materials 10 including the optional supply of a pallet change system, a main cutting unit 11, an integrated

control panel 12 and a laser cutting head 13, connected to a cooling unit, as is the laser generator.

In particular the machine is designed and constructed with a fixed modular central guide system, to guarantee high structure resistance strength and maximum rigidity at high speed and during acceleration; this ensures rapid simultaneous positioning speed on the three axes X, Y, Z on table 14, or the pipe support chuck, for an extremely vast operating capacity.

Furthermore, the machine can be preferably flatbed type for machining sheet metal; in other words, it can be used on 4-5 axes for pipe machining.

The system is able to provide high repeatability precision and circular/linear interpolation on 3 or 5 axes.

In addition, the machine includes a remote controlled control panel 12, controlled from a personal computer integrated on the machine; the control panel 12 is equipped with a colour display 15 and an integrated PLC for the execution of auxiliary functions.

The cutting head 13 is equipped with an automatic height control system and an anti-collision control system for constant machining precision, this protecting the cutting unit; the aforesaid cutting head

13 is also equipped with a system for high pressure and/or compressed air gas feed to the laser generator.

The innovative constructive technology and performance achieved by the tool machine according to the invention comprise an exclusive innovation in the laser cutting sector; in fact, the tool machine, object of the present invention, uses a fibre laser generator ("fiberlaser") and also comprises a particular numerically controlled movement technique for the laser cutting head 13.

In special reference to the appended figure 5, the optical fibre source is created using an optical fibre 20 as the active means, which generates the optical radiation, various single quartz pumping diodes 21 able to excite the doped ions, and Bragg lens or gratings 22, in optical fibre to create the resonant cavities.

Thanks to a doped nucleus of only 5 micron, the active fibre 20 is able to provide laser beams 23 of extremely high quality without any cooling problems; furthermore, the use of single pumping diodes 21 provide the possibility of long work life and extremely reliable pumping architecture.

Lastly, the optical fibre Bragg gratings 22 provide resonant cavities syntonized with great precision on

the emitted source wave length, as well as extremely stable emitted power.

As previously stated, this cutting method can be applied to sheet metal and metal plate such as steel, steel alloys, stainless steel, copper and copper alloys, aluminium and aluminium alloys, to cut thicknesses between 0.1 mm and 100 mm, in all shapes and sizes currently on the market; in addition, the same technology can be used on these materials for slot-cutting, drilling, pipe section and intersection (square, round, oval, rectangular), with thickness between 0.1 mm and 40 mm, and/or sections within a circle with a maximum diameter of approximately 920 mm and with a current market length of approximately 12,000 mm.

The use of fibre laser generators on cutting machines according to the invention, provides an obvious range of advantages, the first being the fact that, because the generator is constructed from modular units in solid state, this means the use of lasering gas can be eliminated completely, together with the relative piping and turbine for gas compression.

Furthermore, the fact that the laser beam travels inside the optical fibres, this permits the elimination of the optical bench laser beam transport , as well as

the relative lens units and mirror units used in prior art systems.

Lastly, the cutting head 13 can be equipped with a single lens, with the addition of a protective shield and filter; this simple and efficient concept is able to guarantee long work life.

The use of fibre laser generators also provides very high beam density, since the beam power can be concentrated on a surface that varies between 0.05 mm and 0.1 mm; as a result, the piercing time is reduced to a minimum and cutting speed is increased considerably.

Considering the reduced energy consumption, spare parts, and technical gas required for cutting operations, the use of fibre laser generators lowers management and running costs to a great extent when compared to prior art cutting systems.

As was stated previously, the numerical control tool machine (CNC) for laser cutting according to the invention, also includes an automatic capacitative type guide system, with automatic height control of the fibre 20 laser cutting head 13; in fact the optical fibre 20 generated laser represents the actual cutting unit, in other words, the actual tool that performs the cutting of the material using the laser generator,

while the automatic control system, illustrated in figure 5, maintains the focal point on the sheet metal and/or pipe 25 at a constant distance B by means of a capacitive sensor 24.

This application is completely innovative and is very important when cutting sheet metal and pipes using fibre lasers.

A further excellent technical characteristic of said tool machine according to the present invention is provided by a fibre 20 guide and protection system which moves the laser beam 23 on the machine.

The fibre 20 that transports the optical fibre laser is inserted inside a plastic protective sheath 16, and in turn inserted into a chain 17 of flexible tubing 18 with controlled curve radius, as can be seen in figures 1, 2, 4, and 6; the plastic protection 16 is fixed at the beginning and the end of the chain 17, paying close attention to the fibre 20, which is compelled to flow through the interior of the protection 16 (as shown in detail in figure 6). The flow-through system described which provides for controlling the motion of the fibre 20 and its level of wear, therefore permits the transport of the optical fibre 20 generated laser power in a reliable manner at industrial level for

application in sheet metal and pipe 25 cutting, as described previously.

The descriptions above have clearly illustrated the characteristics of the tool machine for laser cutting of materials, object of the present invention, as they have also illustrated the obvious advantages.

Naturally numerous variants can be applied to the tool machine in question, while remaining within the context of the innovative concept of the invention, and obviously, in the practical embodiment of the invention, all materials, shapes and sizes of the details described can be of any type according to necessity and can be replaced with others which are technically equivalent.

CLAIMS

1. A tool machine for laser cutting of materials (25), comprising at least a main cutting unit (11), a control panel (12) integrated on the machine, remote controlled and managed by a PC, and at least a laser cutting head (13) inserted in the cutting unit (11) of the machine, being moveable on a work table (14) or on a pipe support chuck, by means of a numerical control system, characterised in that said laser cutting head (13) is connected to at least an optical fibre (20) laser generator.

2. Tool machine according to claim 1, characterised in that it comprises at least an external protection and shielding, conceived to guarantee the isolation of the work area during the work operation, and at least one support table (10) for the materials to be cut.

3. Tool machine according to claim 1, characterised in that said laser cutting head (13) and said laser generator are connected to at least a cooling unit.

4. Tool machine according to claim 1, characterised in that said laser cutting head (13) is included within a modular travel system with a central fixed guide, able to ensure rapid simultaneous positioning speed on said work table (14).

5. Tool machine according to claim 1, characterised in that said control panel (12) is equipped with at least one display (15) and at least one integrated PLC system to execute auxiliary functions.

6. Tool machine according to claim 1, characterised in that it uses at least one optical fibre (20) source as an active means, in which the optical radiation is generated, a plurality of single pumping elements (21) and at least two Bragg gratings (22) in optical fibre, to create the resonant cavity, in order to obtain laser beams (23) of extremely high quality, with stable power, reliable and with a long work life.

7. Tool machine according to claim 1, characterised in that, in particular, it is destined for use in cutting sheet metal and metal plate, as well as to cut slots, drill holes, sections and intersections of metal piping.

8. Tool machine according to claim 1, characterised in that said laser cutting head (13) is moved by means of a capacitative type, automatic guide system, with automatic height control, which by means of a capacitative sensor (24) maintains the focal point (B) at a constant distance from the material to be cut (25).

9. Tool machine according to claim 1, characterised in that said optical fibre (20) which moves the laser beam (23) on the machine, is inserted inside at least one protective sheath (16) and in turn inserted inside at least one chain (17) of flexible tubing (18) having controlled curve radius, wherein said sheath (16) is fixed to said chain (17) and that said optical fibre (20) is compelled to flow through the inside of said protective sheath (16).

10. Tool machine for laser cutting of materials (25) as substantially described and illustrated in the appended drawings and conceived for the aims as specified.

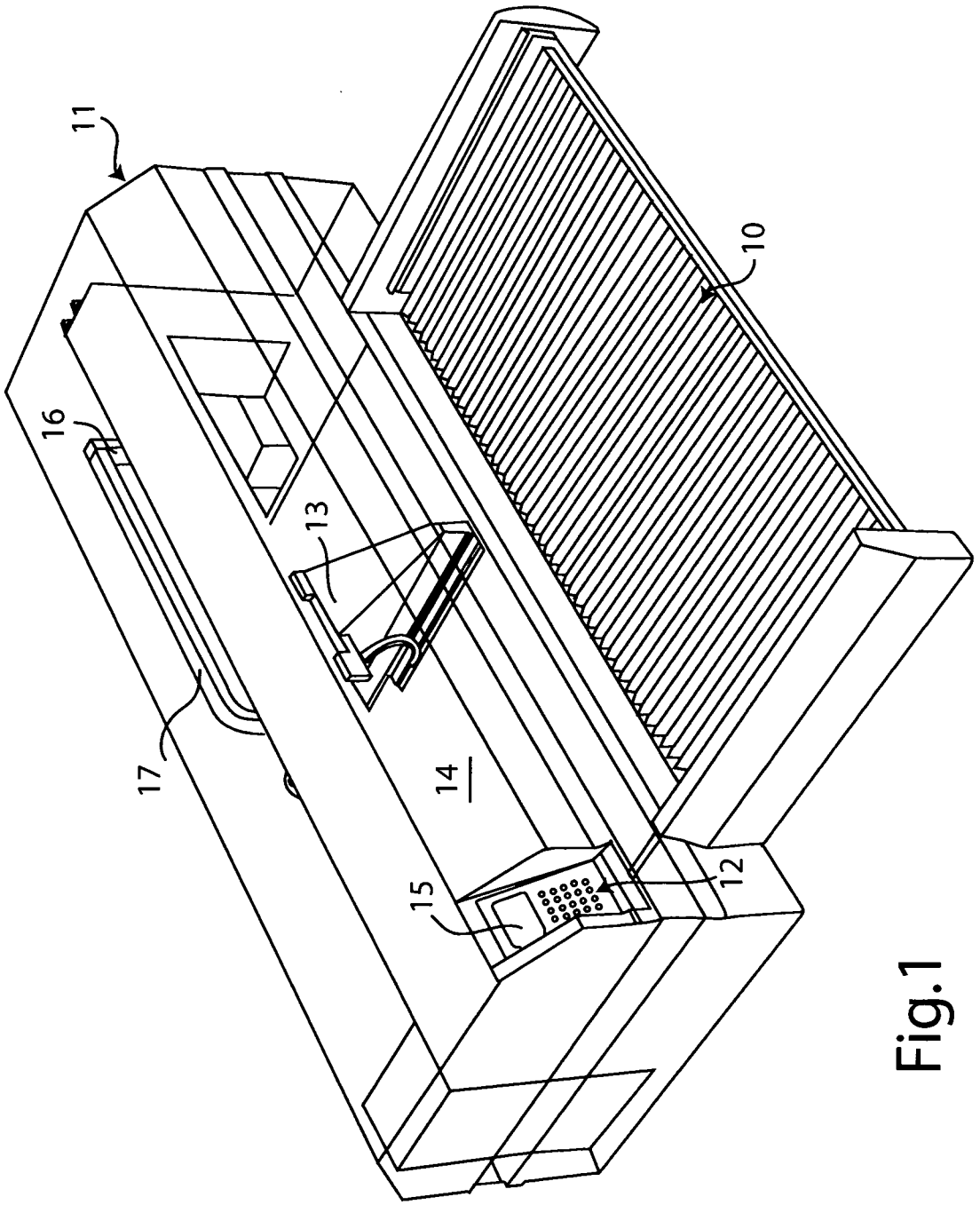

Fig.1

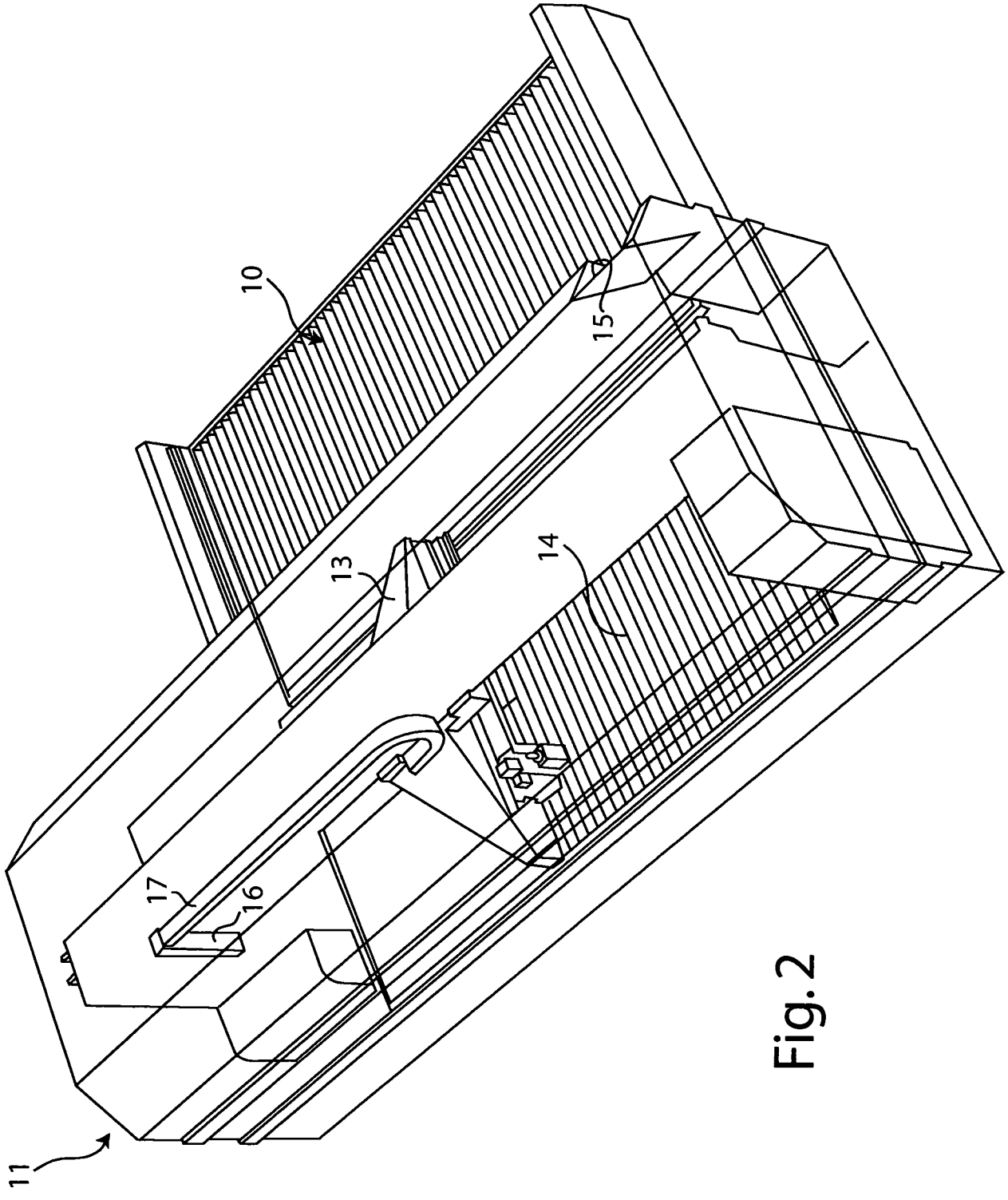

Fig. 2

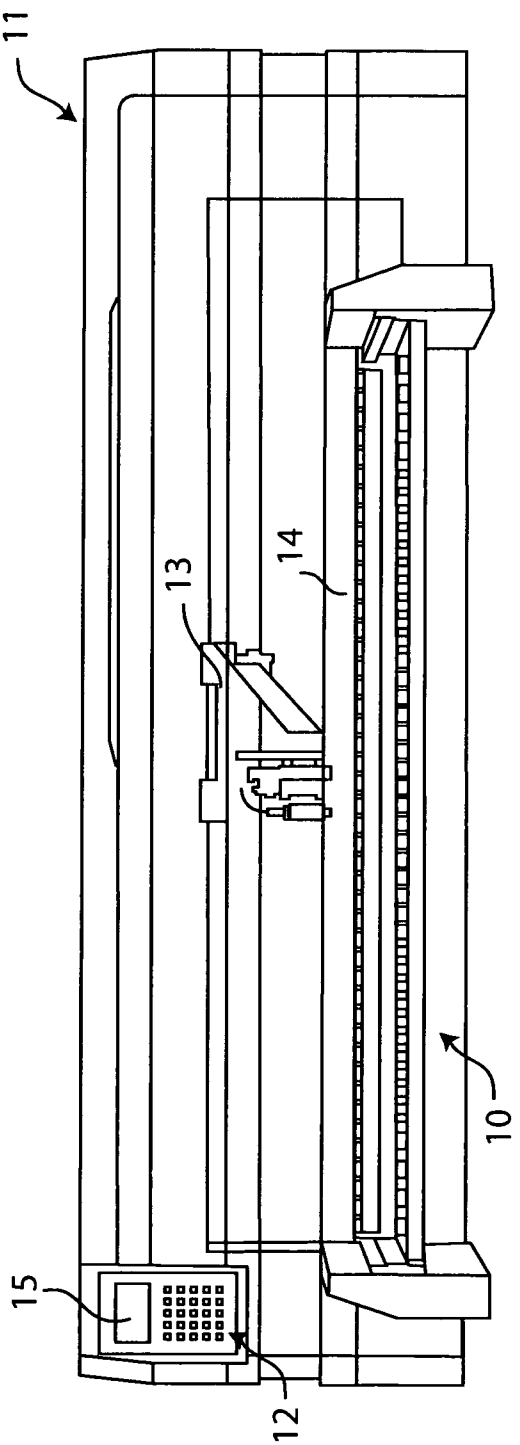

Fig.3

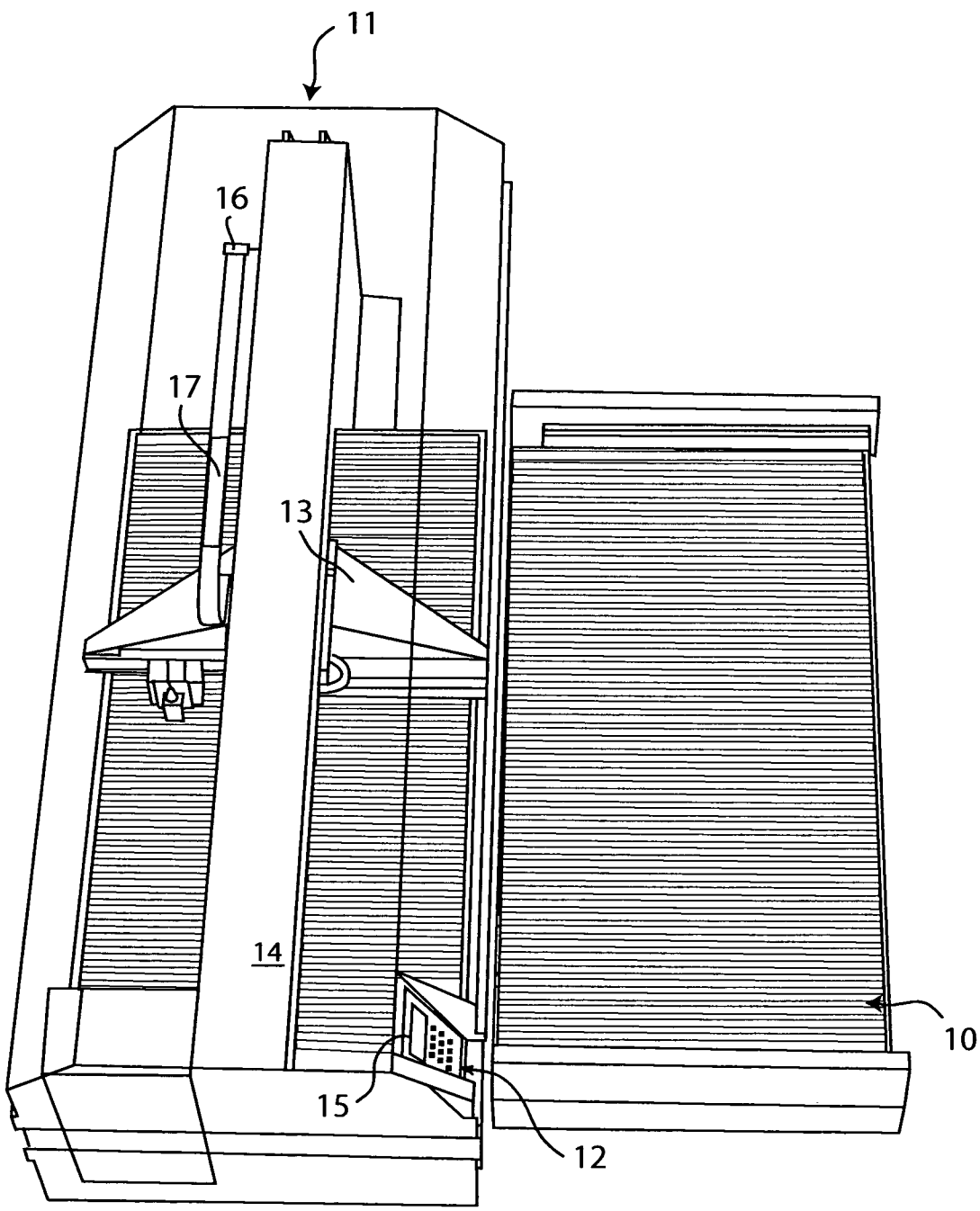

Fig. 4

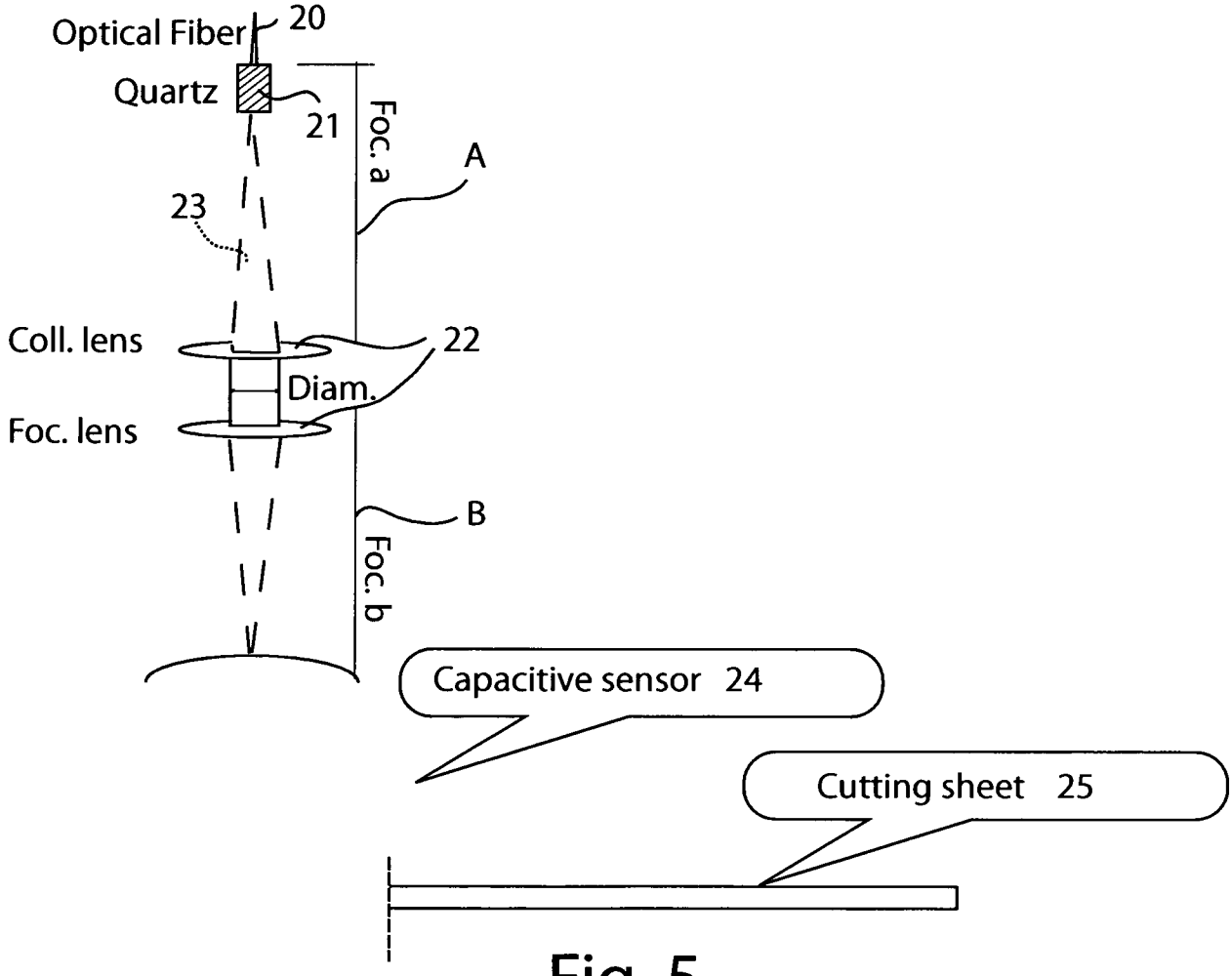
Optical Fiber
20
Quartz
21
Foc. a
A
23
Coll. lens
22
Diam.
Foc. lens
B
Foc. b
Capacitive sensor 24
Cutting sheet 25

Fig. 5

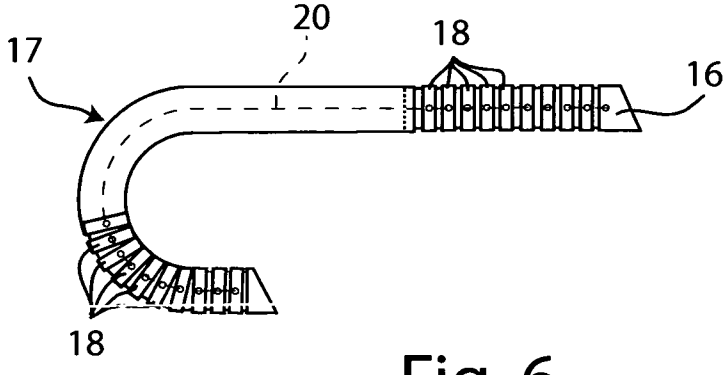
17
20
18
16
18

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2006/012073

A. CLASSIFICATION OF SUBJECT MATTER
INV. B23K26/04 B23K26/06 B23K26/38 B23K26/42 B23K37/02
B23K37/04 B23K26/08 F16G13/16 F16L11/18

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)
B23K F16G F16L H02G

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 practical, 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 Y	JP 2002 001558 A (HITACHI ENGINEERING & SERVICES CO LTD) 8 January 2002 (2002-01-08) abstract; claims; figures 1,2	1-3 4-9
Y	US 6 420 674 B1 (I.E. COLE III ET AL) 16 July 2002 (2002-07-16) column 1, lines 13-57 column 6, lines 12-42 column 12, line 1 - column 15, line 63; figures 1-3,9	4,5,7
Y	WO 00/54925 A (GSI LUMONICS ; G.F. HERMANN ET AL) 21 September 2000 (2000-09-21) page 12, line 19 - page 13, line 28; figure 3	6,8

-/--

[X] Further documents are listed in the continuation of Box C.

[X] 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 document 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
16 March 2007	02/04/2007

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, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Jeggy, Thierry

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2006/012073

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 463 728 B1 (B. DAOUD) 15 October 2002 (2002-10-15) abstract; figures	9
X	JP 11 000774 A (ISHIKAWAJIMA HARIMA HEAVY IND CO LTD) 6 January 1999 (1999-01-06)	1,2,4-6
Y	abstract; claims; figures	8,9
A	US 5 635 086 A1 (J.V. WARREN JR ET AL) 3 June 1997 (1997-06-03) column 3, line 53 - column 4, line 46; figures	1,2,4-6
Y	EP 1 468 775 A (FANUC LTD) 20 October 2004 (2004-10-20) paragraph [0018]; figure 1	8
Y	US 5 660 748 A1 (H. TANAKA ET AL) 26 August 1997 (1997-08-26)	9
A	column 2, line 28 - column 3, line 67; figures; examples	6
Y	US 6 486 436 B1 (K. SHAH ET AL) 26 November 2002 (2002-11-26) column 3, line 43 - column 4, line 7; figures	9
X	US 4 443 684 A1 (S. SAKURAGI ET AL) 17 April 1984 (1984-04-17) column 2, lines 30-59; figures 1,3	1,4,5,7

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 10

Te subject-matter of claim 10 defines a laser machine tool as described and illustrated in the drawings. From such a formulation, it is not clear which precise and distinguishing clear features (in the sense of Article 6 PCT) of this machine tool are effectively defined in claim 10. A meaningfull search is therefore impossible to be achieved.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.5), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

International application No.
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Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 10
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2006/012073

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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