(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 May 2016 (12.05.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/072891 A1

(51) International Patent Classification:
B23K 26/064 (2014.01) *G02B 15/163* (2006.01)
G02B 13/18 (2006.01)

(21) International Application Number:
PCT/SE2014/051305

(22) International Filing Date:
4 November 2014 (04.11.2014)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **VAUR AB** [SE/SE]; c/o Adetto AB, Klarabergsgatan 29 1 tr, S-111 21 Stockholm (SE).

(72) Inventors: **HÖGBERG, Knyaz Rikard Emanuel**; c/o Ulla Högberg, Rindögatan 17, S-115 36 Stockholm (SE). **STOLYAROV, Yuri Viktorovich**; Nalichnay street 13 flat 30, St. Petersburg, 199106 (RU).

(74) Agent: **AWAPATENT AB**; Box 45086, S-104 30 Stockholm (SE).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

WO 2016/072891 A1

(54) Title: OPTICAL SYSTEM FOR FOCUSING A HIGH ENERGY LASER

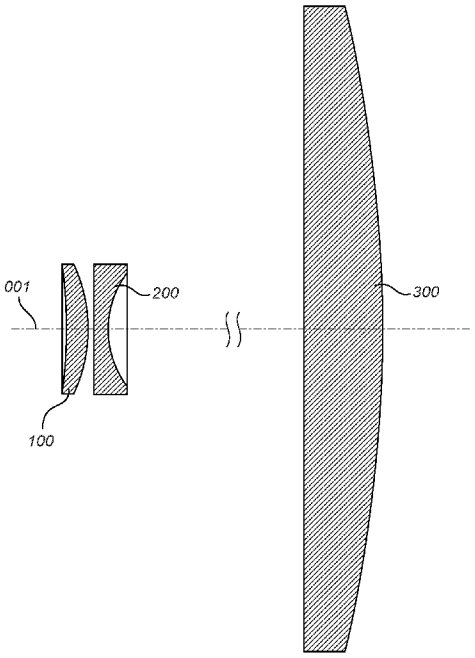

Fig. 1

(57) Abstract: The present specification generally relates to the field of optical systems for lasers and particularly discloses a system for focusing of a high energy laser at an extended distance and particularly discloses an optical system that comprises a first lens element having a first surface and a second surface, where the first surface is concave and the second surface is convex, a second lens element having a first surface and a second surface, where the first surface is flat and the second surface is concave, a third lens element having a first surface and a second surface, where the first surface is flat and the second surface is convex and where the distance between the second lens element and the third lens element is larger than the distance between the first lens element and the second lens element.

OPTICAL SYSTEM FOR FOCUSING A HIGH ENERGY LASER

Technical field

The present specification generally relates to the field of optical systems for lasers and particularly discloses a system for focusing of a high energy laser at an extended distance.

Technical background

Generally, lasers for cutting uses a focused laser beam which either melts, burns or vaporizes away material. The cutting process depends on the power of the laser and the ability to focus the laser beam where the cutting is directed. The focus distance for common industrial systems are on the scale of hundreds of a meter.

A rise in output power from laser, such as from fiber laser sources have led to a range of laser systems. In the general case for a fiber laser, the increased output power is possible due to several factors, including development of large mode diameter double clad fibers and the increase in power and brightness of diode pumps.

However, optical systems for lasers do not offer the ability to utilize a high energy laser in combination with the ability to focus at an extended distance in a mobile environment. Common methods of focusing a laser at an extended distance do not work with high energy lasers and common methods of focusing a high energy laser do not work with extended focus distances.

Further, the concept of a high power laser in a mobile environment is associated with problems related to cooling and durability of the apparatus.

Thus, the inventors of the present invention have identified a need for an improved optical system that is designed to overcome the problems stated above.

One object of the present invention is to provide an optical system which is capable of focusing a high power laser at extended distances with high demands on the robustness needed in mobile applications.

Summary of the invention

The above-mentioned requirements are achieved by the optical system defined by the independent claim. Preferred embodiments are set forth in the dependent claims.

The present invention relates to an optical system for focusing a high energy laser at an extended distance. The optical system comprises, in order as viewed from the laser source, along an optical axis of the system:
- A first lens element having a first surface and a second surface, where the first surface is concave and the second surface is convex;
- A second lens element having a first surface and a second surface, where the first surface is flat and the second surface is concave;
- A third lens element having a first surface and a second surface, where the first surface is flat and the second surface is convex and
in the optical system the distance between the second lens element and the third lens element is larger than the distance between the first lens element and the second lens element.

The terms “first surface” and “second surface” refers to an optical elements first and second surface as viewed from a specified direction.

The term “extended distance” may for an example mean a distance longer than 5, 10, 50, 100 or 500 meters.

The invention is based on the insight that the demands on mobility and cooling in the present application can be solved with a fiber laser. The fiber laser as such is a robust construction where the multiple fiber strands it can be made of increase the surface area available for cooling, hence an effective cooling can be achieved in combination with a robust construction that is suitable for mobile usage. However, utilizing a high power fiber laser is associated with problems related to the ability to focus on extended distances.

Thus, the inventors of the present invention have identified an improved optical system defined above that is designed to focus a high power fiber laser at extended distances.

In one embodiment of the invention, the first surface of the first lens element have a radius of curvature of in the span of in the span of 162mm to 179mm, the second surface of the first lens element have a radius of curvature in the span of 42mm to 47mm, the second surface of the second lens element have a radius of curvature in the span of 28mm to 31mm and the second surface of the second lens element have a radius of curvature in the span of 407mm to 450mm. This design improves the precision of the optical system.

.

In one embodiment of the invention, the first surface of the first lens element have a radius of curvature of in the span of in the span of 169mm to 172mm, the second surface of the first lens element have a radius of curvature in the span of 44mm to 45mm, the second surface of the second lens element have a radius of curvature in the span of 29mm to 30mm and the second surface of the second lens element have a radius of curvature in the span of 424mm to 432mm. This design further improves the precision of the optical system.

In one embodiment of the invention, the first surface of the first lens element have a radius of curvature of in the span of in the span of 170.4794mm to 170.8207mm, the second surface of the first lens element have a radius of

curvature in the span of 44.45366mm to 44.48034mm, the second surface of the second lens element have a radius of curvature in the span of 29.64111mm to 29.6589mm and the second surface of the second lens element have a radius of curvature in the span of 428.4743mm to 428.6457mm. This design further improves the precision of the optical system.

In one embodiment of the invention, the first surface of the first lens element have a radius of curvature of 170.65mm, the second surface of the first lens element have a radius of curvature of 44.467mm, the second surface of the second lens element have a radius of curvature of 29.62mm and the second surface of the second lens element have a radius of curvature of 428.56mm. This design further improves the precision of the optical system.

In one embodiment the first lens element may be in the span of 7.8mm to 8.6mm thick, where the center thickness may be in the span of 6.6mm to 7.4mm and the edge thickness may be in the span of 3.0mm to 3.8mm.

In one embodiment the first lens element may be in the span of 8.0mm to 8.4mm thick, where the center thickness may be in the span of 6.8mm to 7.2mm and the edge thickness may be in the span of 3.2mm to 3.6mm.

In one embodiment the first lens element may be 8.2mm thick, where the center thickness may be 7.0mm and the edge thickness may be 3.4mm.

In one embodiment the second lens element may be in the span of 9.0mm to 11mm thick, where the center thickness may be in the span of 4.4mm to 4.6mm and the edge thickness may be in the span of 10.0mm to 10.4mm.

In one embodiment the second lens element may be in the span of 10.0mm to 10.4mm thick, where the center thickness may be in the span of 4.45mm to 4.55mm and the edge thickness may be in the span of 10.0mm to 10.4mm.

In one embodiment the second lens element may be 10.2mm thick, where the center thickness may be in the span of 4.45mm to 4.55mm and the edge thickness may be 10.2mm.

In one embodiment the third lens element may be in the span of 20mm to 24mm thick, where the center thickness may be in the span of 12mm to 14mm and the edge thickness may be in the span of 20mm to 24mm.

In one embodiment the third lens element may be in the span of 21mm to 23mm thick, where the center thickness may be in the span of 13.1mm to 13.3mm and the edge thickness may be in the span of 21mm to 23mm.

In one embodiment the third lens element may be in the span of 21.9mm to 22.1mm thick, where the center thickness may be 13.2mm and the edge thickness may be in the span of 21.9mm to 22.1mm.

In one embodiment the diameter of the first lens element may be in the span of 35mm to 45mm, the diameter of the second lens element may be in the span of 35mm to 45mm and the diameter of the third lens element may be in the span of 175mm to 225mm.

In one embodiment the diameter of the first lens element may be in the span of 39mm to 41mm, the diameter of the second lens element may be in the span of 39mm to 41mm and the diameter of the third lens element may be in the span of 195mm to 205mm.

In one embodiment the diameter of the first lens element may be 40mm, the diameter of the second lens element may be 40mm and the diameter of the third lens element may be 200mm.

In one embodiment any one or more surface of any lens of the optical system may be aspherical. This design can be used to more finely tune the performance of the optical system. The tuned performance may be aspects of

the optical system such as focal length, general sharpness, accuracy, spherical aberration, astigmatism, coma, distortion or vignette.

The term “aspherical” surface refers to a surface which has a surface with a progressive or non-constant radius of curvature.

Examples of such aspherical surface displacements may be from the group of, but is not limited to, (0.08/Rz0.05), $(0.08/Rz0.05)^{1/2}$, $(0.08/Rz0.05)^{1/3}$, $(0.08/Rz0.05)^{1/4}$, $(0.06/Rz0.05)^{1/2}$, $(0.1/Rz0.05)^{1/2}$, $(0.08/Rz0.04)^{1/2}$ and $(0.08/Rz0.06)^{1/2}$. The aspherical displacement that may be used depend on which performance of the optical system to tune.

In one embodiment the first lens element may be moveably arranged along the optical axis. This design can be used to more finely tune the focus of the optical system. The movement may be an offset, changed during usage of the system or while the system is in hibernation. The movement may for an example be operated manually, by a control unit or by an automated procedure.

In one embodiment the second lens element may be moveably arranged along the optical axis. This design can be used to more finely tune the focus of the optical system. The movement may be an offset, changed during usage of the system or while the system is in hibernation. The movement may for an example be operated manually, by a control unit or by an automated procedure.

In one embodiment the first and second lens elements may be moveably arranged along the optical axis and the first and second lens elements are further arranged to move in tandem. This design can be used to more finely tune the focus of the optical system. The movement may be an offset, changed during usage of the system or while the system is in hibernation. The movement may for an example be operated manually, by a control unit or by an automated procedure.

In one embodiment at least one of the lens elements may be rotatably arranged around the optical axis. This design will reduce the influence of thermal hot spots and spatial fluctuations of the laser radiation.

In one embodiment, the material of the lens elements may be chosen according to the laser used and the requirements on the system as such. As a non limiting example, materials such as different kinds of glass, plastics, quartz, ZnSe, GaAs, Ge may be used for any lens and in any combination. The refractive index may for an example be 1.45, 1.44968 or in the span of 1.4493 to 1.4499.

In one embodiment, the power of the utilized laser may be between 20 and 60 kW.

The laser source may be at least one from the group comprising gas lasers, solid-state lasers, fiber lasers, photonic crystal lasers, semiconductor lasers, dye lasers and free-electron lasers, or any combination thereof. The laser source may for an example operate in continuous wave operation, pulsed operation with Q-switching, mode-locking or pulsed pumping. Any combination is possible, for an example a continuous wave fiber laser with a Yb solid state source.

The optical system may be optimized depending on different laser sources and utilizations.

According to a second aspect, the present invention relates to an optical device for focusing a high energy laser at an extended distance. The optical device may comprise an optical system according to any embodiment of the first aspect, a housing at least partially encapsulating the optical system, an inlet for attaching a laser source and an outlet for emitting a focused high energy laser.

In one embodiment, the optical device may utilize a fiber laser or any other laser source previously discussed.

In one embodiment, the optical device may be cooled in a passive manner or actively, by for an example a liquid, a gas, a peltier device, a heatsink or any combination thereof.

Short description of the appended drawings

The invention is described in the following illustrative and non-limiting detailed description of exemplary embodiments, with reference to the appended drawings, wherein:

Figure 1 is a cross sectional side view of an optical system according to a first aspect of the present invention.

Figure 2 is a cross sectional side view of an optical system according to one embodiment of the invention that is mounted in an enclosure.

Figure 3 is a cross sectional side view of the first lens element according to one embodiment of the invention.

Figure 4 is a cross sectional side view of the second lens element according to one embodiment of the invention.

Figure 5 is a cross sectional side view of the third lens element according to one embodiment of the invention.

All figures are schematic, not necessarily to scale, and generally only show parts which are necessary in order to elucidate the invention, wherein other parts may be omitted or merely suggested. Throughout the figures the same reference signs designate the same, or essentially the same features.

Detailed description of preferred embodiments of the invention

Figure 1 shows an optical system comprising a first lens element (100), a second lens element (200) and a third lens element (300). The first lens element has a first surface (110) and a second surface (120). The first surface is concave and the second surface is convex. Further, the first lens element has a thickness (170), a central thickness (160) and an edge thickness (150). The second lens element (200) has a first surface (210) and a second surface (220). The first surface of the second lens element is essentially flat, the second surface of the second lens element is concave. Further, the second lens element has a thickness (270), a central thickness (260) and an edge thickness (250). The third lens element has a first surface (310) and a second surface (320). The first surface of the third lens element is essentially flat, the second surface of the third lens element is convex. Further, the third lens element has a thickness (370), a central thickness (360) and an edge thickness (350). All lens elements are aligned along an optical axis (001).

Figure 2 shows an optical device housing an optical system. The optical system comprising a first lens element (100), a second lens element (200) and a third lens element (300). All lens elements are aligned along an optical axis (001) in the center of the optical device.

Figure 3 shows the first lens element. The first lens element has a first surface (110) and a second surface (120). The first surface is concave and the second surface is convex. Further, the first lens element has a thickness (170), a central thickness (160) and an edge thickness (150).

Figure 4 shows the second lens element. The second lens element has a first surface (210) and a second surface (220). The first surface is concave and the second surface is convex. Further, the second lens element has a thickness (270), a central thickness (260) and an edge thickness (250).

Figure 5 shows the third lens element. The third lens element has a first surface (310) and a second surface (320). The first surface is concave and

the second surface is convex. Further, the third lens element has a thickness (370), a central thickness (360) and an edge thickness (350).

Aspects of a general optical system are well known in the art and will not be described in greater detail.

With the above-described configuration, the lens system is adapted to efficiently contribute to the demands put on the system, while allowing the use of a high energy laser.

While specific embodiments have been described, the skilled person will understand that various modifications and alterations are conceivable within the scope as defined in the appended claims.

CLAIMS

1. An optical system for focusing a high energy laser at an extended distance, where the extended distance is more than 10 meters, the optical system comprises, in order as viewed from the laser source, along an optical axis (001) of the system:

a first lens element (100) having a first surface (110) and a second surface (120), where the first surface is concave and the second surface is convex;

a second lens element (200) having a first surface (210) and a second surface (220), where the first surface is flat and the second surface is concave;

a third lens element (300) having a first surface (310) and a second surface (320), where the first surface is flat and the second surface is convex; and

where the distance between the second lens element and the third lens element is larger than the distance between the first lens element and the second lens element.

2. An optical system according to claim 1, wherein the first surface of the first lens element have a radius of curvature of in the span of in the span of 162mm to 179mm; the second surface of the first lens element have a radius of curvature in the span of 42mm to 47mm; the second surface of the second lens element have a radius of curvature in the span of 28mm to 31mm and the second surface of the second lens element have a radius of curvature in the span of 407mm to 450mm.

3. An optical system according to claim 1, wherein the first surface of the first lens element have a radius of curvature of in the span of in the span of 169mm to 172mm; the second surface of the first lens element have a radius of curvature in the span of 44mm to 45mm; the second surface of the second lens element have a radius of curvature in the span of 29mm to 30mm and

the second surface of the second lens element have a radius of curvature in the span of 424mm to 432mm.

4. An optical system according to claim 1, wherein the first surface of the first lens element have a radius of curvature of in the span of 170.4794mm to 170.8207mm; the second surface of the first lens element have a radius of curvature in the span of 44.45366mm to 44.48034mm; the second surface of the second lens element have a radius of curvature in the span of 29.64111mm to 29.6589mm and the second surface of the second lens element have a radius of curvature in the span of 428.4743mm to 428.6457mm.

5. An optical system according to claim 1, wherein the first surface of the first lens element have a radius of curvature of 170.65mm; the second surface of the first lens element have a radius of curvature of 44.467mm; the second surface of the second lens element have a radius of curvature of 29.62mm and the second surface of the second lens element have a radius of curvature of 428.56mm.

6. An optical system according to any one claim 1 to 5, wherein at least one surface of at least one lens element having a cross-section of an aspherical shape when cut with a plane parallel to the light axis.

7. An optical system according to any one claim 1 to 6, wherein the first lens element is moveably arranged along the optical axis.

8. An optical system according to any one claim 1 to 6, wherein the second lens element is moveably arranged along the optical axis.

9. An optical system according to any one claim 1 to 6, wherein the first and second lens elements are moveably arranged along the optical axis, and the first and second lens elements are further arranged to move in tandem.

10. An optical system according to any one claim 1 to 9, wherein at least one of the lens elements is rotatably arranged around the optical axis.

11. An optical system according to any one claim 1 to 10, wherein at least one of the lens elements is made from a material having a refractive index in the span of 1.4493 to 1.4499.

12. An optical system according to any one claim 1 to 11, wherein the diameter of the first lens element is 40mm, the diameter of the second lens element is 40mm and the diameter of the third lens element is 200mm.

13. An optical device for focusing a high energy laser at an extended distance, the device comprises:

an optical system according to claim 1;

a housing at least partially encapsulating the optical system;

an inlet for attaching a laser source;

an outlet for emitting a focused high energy laser.

14. A mobile optical unit for focusing a high energy laser at an extended distance, the unit comprises:

an optical device according to claim 13;

a laser source attached to the inlet;

15. A mobile optical unit according to claim 14, wherein the laser source utilizes a fiber laser.

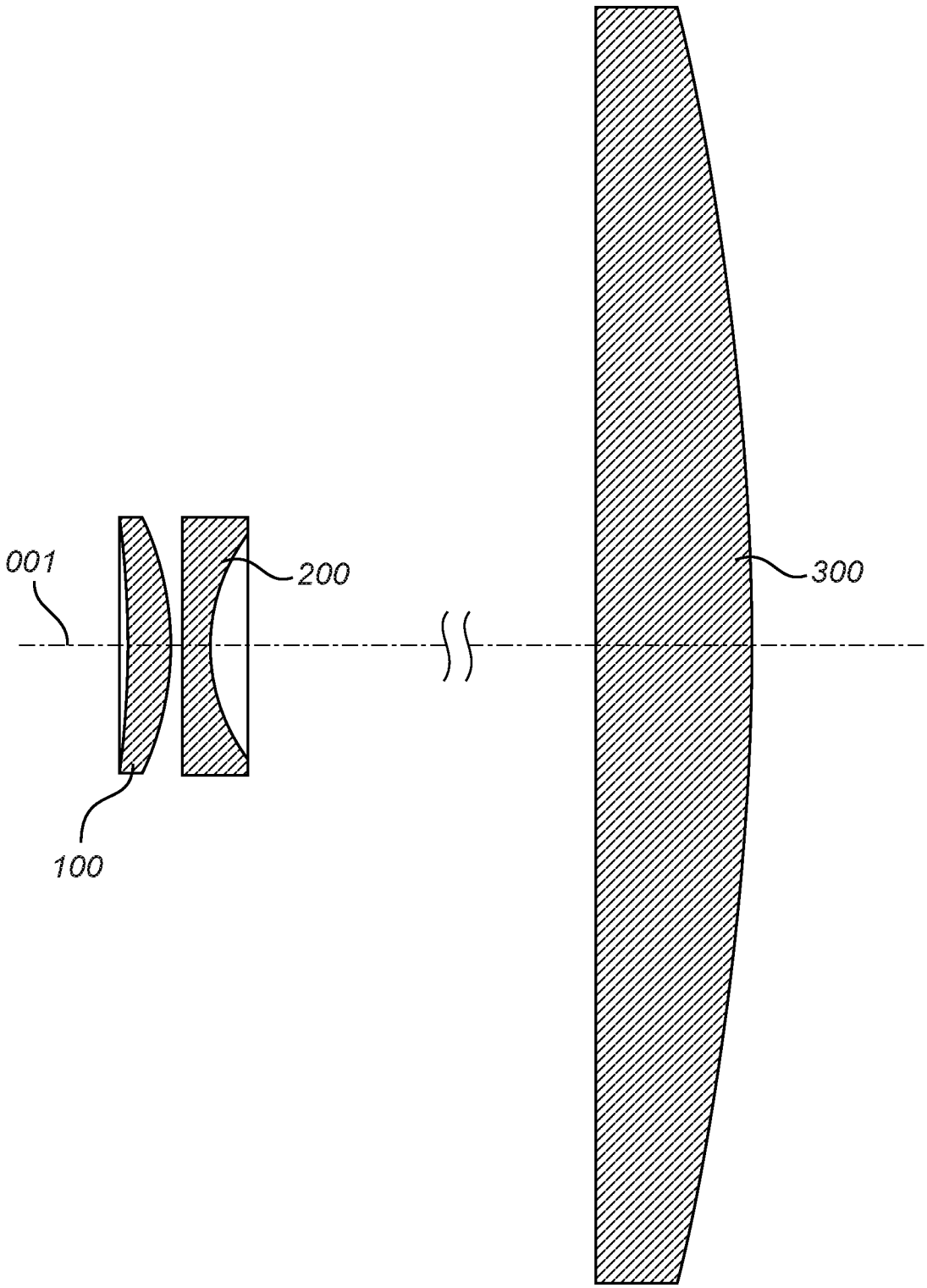

Fig. 1

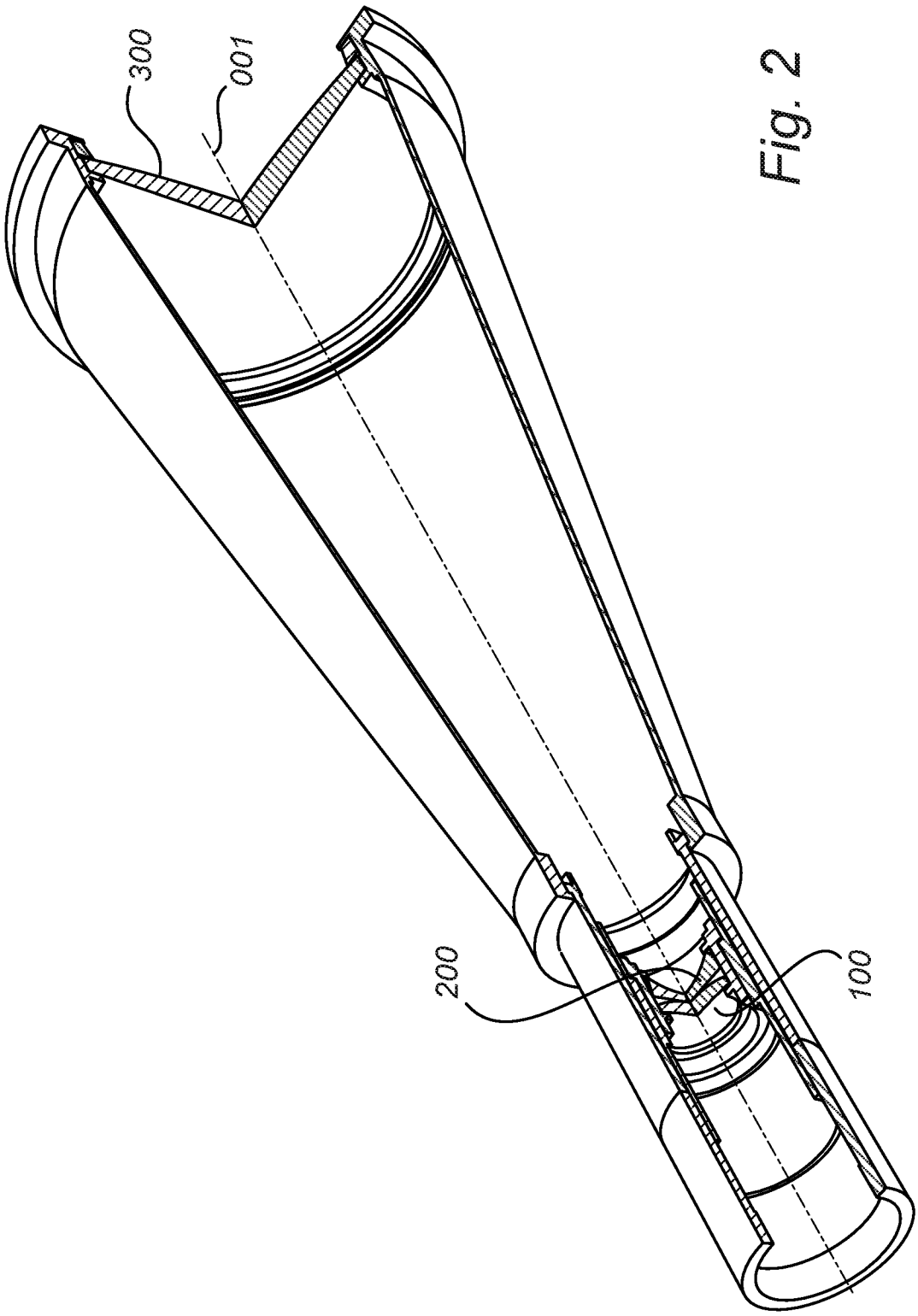

Fig. 2

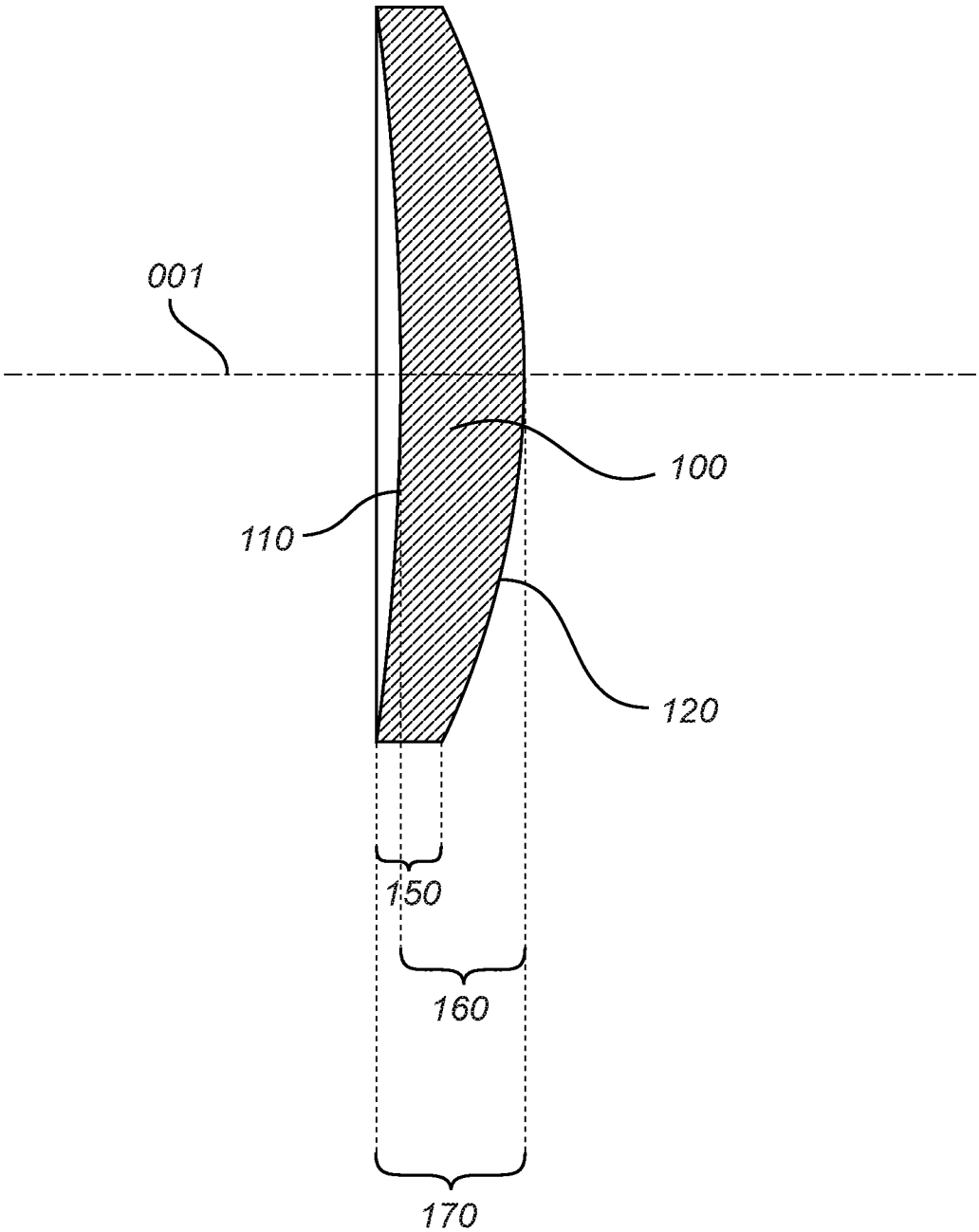

Fig. 3

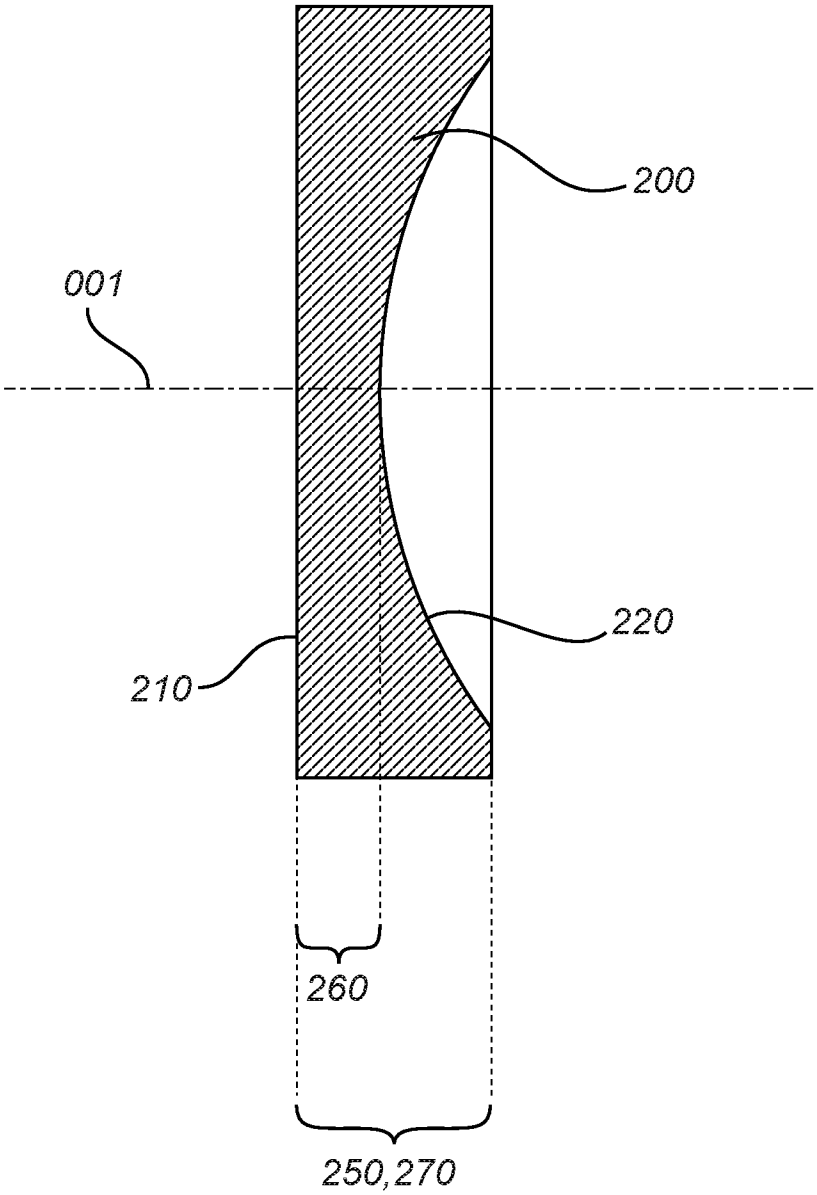

Fig. 4

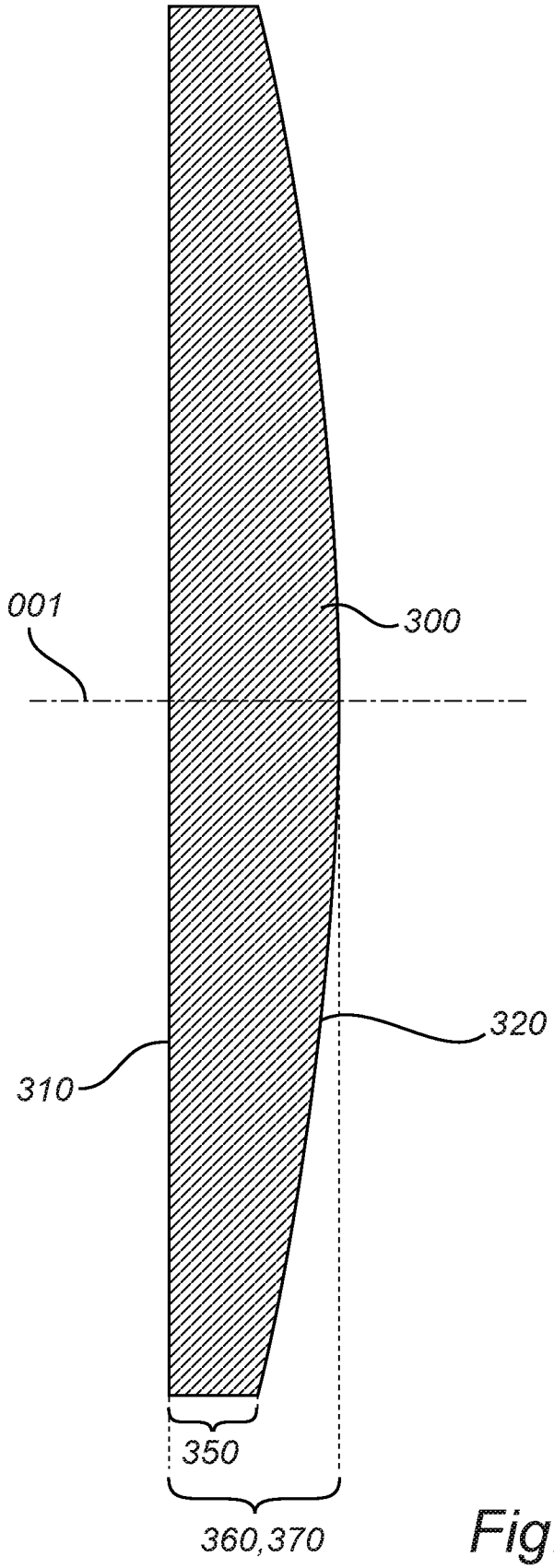

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2014/051305

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: B23K, G02B

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 102313968 A (HANS LASER TECHNOLOGY CO LTD), 11 January 2012 (2012-01-11); figure 2 --	1-12
X	US 4707073 A (KOCHER ROBERT C), 17 November 1987 (1987-11-17); figure 2 --	1-15
A	CN 102262282 A (HANS LASER TECHNOLOGY CO LTD), 30 November 2011 (2011-11-30); whole document; figures --	1-12
A	CN 101236303 A (HANS LASER TECHNOLOGY CO LTD), 6 August 2008 (2008-08-06); whole document; figures --	1-12

☒ 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
26-06-2015	29-06-2015
Name and mailing address of the ISA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Authorized officer Finn Klemming Eklöf Telephone No. + 46 8 782 28 00

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2014/051305

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2014067085 A1 (HANS LASER TECHNOLOGY CO LTD ET AL), 8 May 2014 (2014-05-08); whole document; figures --	1-12
A	KR 20090030477 A (PARK HAE JONG), 25 March 2009 (2009-03-25); whole document; figures --	1-12
A	EP 1081525 A2 (SUMITOMO ELECTRIC INDUSTRIES), 7 March 2001 (2001-03-07); whole document; figures --	1-12
A	WO 2004075174 A2 (JP SERCEL ASSOCIATES INC ET AL), 2 September 2004 (2004-09-02); whole document; figures --	1-12
A	EP 0723834 A1 (LUMONICS LTD), 31 July 1996 (1996-07-31); whole document; figures --	1-12
A	WO 2012127040 A1 (CENTRE NAT RECH SCIENT ET AL), 27 September 2012 (2012-09-27); whole document; figures --	1-15
A	US 5448410 A (FREEDENBERG CANDACE J ET AL), 5 September 1995 (1995-09-05); whole document; figures -- --------	1-12

International application No.
PCT/SE2014/051305

Continuation of: second sheet

International Patent Classification (IPC)

B23K 26/064 (2014.01)
G02B 13/18 (2006.01)
G02B 15/163 (2006.01)

CN	102313968	A	11/01/2012	NONE			
US	4707073	A	17/11/1987	CA	1261407	A1	26/09/1989
				JP	6257267	A	12/03/1987
CN	102262282	A	30/11/2011	NONE			
CN	101236303	A	06/08/2008	CN	100538438	C	09/09/2009
WO	2014067085	A1	08/05/2014	NONE			
KR	20090030477	A	25/03/2009	KR	100897797	B1	15/05/2009
EP	1081525	A2	07/03/2001	DE	60025663	T2	07/09/2006
				JP	3201394	B2	20/08/2001
				JP	2001051191	A	23/02/2001
				KR	20010030071	A	16/04/2001
				TW	477727	B	01/03/2002
				US	6324015	B1	27/11/2001
WO	2004075174	A2	02/09/2004	AT	553475	T	15/04/2012
				CN	1761549	A	19/04/2006
				EP	1595250	A4	25/06/2008
				JP	4704915	B2	22/06/2011
				JP	2011073064	A	14/04/2011
				JP	2006514886	A	18/05/2006
				JP	5518755	B2	11/06/2014
				KR	20050116798	A	13/12/2005
				KR	100790644	B1	02/01/2008
				TW	I248244	B	21/01/2006
				TW	200417096	A	01/09/2004
				US	7388172	B2	17/06/2008
				US	20080242056	A1	02/10/2008
				US	20040228004	A1	18/11/2004
				US	8502112	B2	06/08/2013
				US	7709768	B2	04/05/2010
				US	20100301027	A1	02/12/2010
EP	0723834	A1	31/07/1996	JP	08267264	A	15/10/1996
WO	2012127040	A1	27/09/2012	FR	2973118	B1	23/08/2013
US	5448410	A	05/09/1995	US	5777798	A	07/07/1998
				US	5543963	A	06/08/1996