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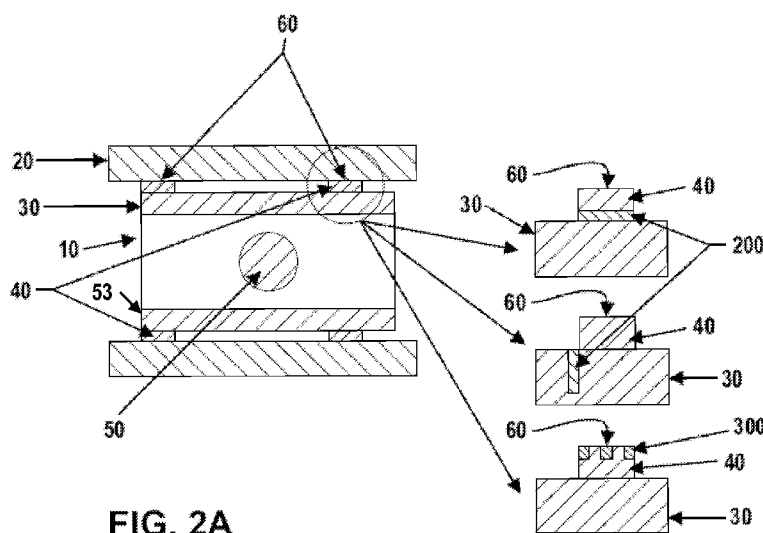
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**(54) Title:** FRICTION HEAT MANAGEMENT INJECTION SUPPORT RINGS FOR IFE HOHLRAUMS



**(57) Abstract:** A target for a fusion reactor operating under LIFE reactor conditions. The target may have a hohlraum having a central portion, an upper target half, and a lower target half, which help define a cylinder with a high-Z material on the inner walls. An inner bore is formed by the central portion, upper target half, and lower target half, and defined by the inner wall of the cylinder. A capsule is suspended in the central portion of the bore by two plastic membranes on the ends of the upper and lower target halves. First and second support rings disposed on the outsides of the target halves engage a wall of a barrel through which the target is propelled. The support rings are of material having a lower thermal conductance than the material of the cylinder walls.



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## FRICTION HEAT MANAGEMENT INJECTION SUPPORT RINGS FOR IFE HOHLRAUMS

### CROSS-REFERENCE TO RELATED APPLICATIONS

5           **[0001]** This application claims the benefit of U.S. Provisional Application No. 61/783,612, filed on March 14, 2013. The entire disclosure of the above application is incorporated herein by reference.

### STATEMENT OF GOVERNMENT RIGHTS

10           **[0002]** The United States Government has rights in this invention pursuant to Contract No. DE-AC52-07NA27344, between the U.S. Department of Energy and Lawrence Livermore National Security, LLC, for the operation of Lawrence Livermore National Laboratory.

### FIELD

15           **[0003]** The present disclosure relates to Fusion energy offers the promise of abundant, truly sustainable energy. One out of every 6500 atoms of hydrogen in ordinary water is deuterium, giving a cup of water the energy content of close to 19 gallons of gasoline. In addition, fusion would be  
20 environmentally friendly, producing no combustion products or greenhouse gases. While fusion is a process that occurs in the nucleus of an atom, the products of the fusion reaction (helium and a neutron) are not radioactive, and with proper design a fusion power plant would be passively safe, and would produce no long-lived radioactive waste. Fusion has high energy efficiency and  
25 so makes efficient use of land resources compared with wind and solar energy. Design studies show that electricity from fusion can be cost competitive with other energy sources.

### BACKGROUND

30           **[0004]** This section provides background information related to the present disclosure which is not necessarily prior art.

**[0005]** Inertial confinement fusion (ICF) is a promising way to obtain fusion energy from inexpensive starting materials. Generally, ICF systems use a single laser, the driver, whose beam is split up into a number of beams which are

subsequently individually amplified by a trillion times or more. These are sent into the reaction chamber (called a target chamber) by a number of mirrors, positioned in order to illuminate the target evenly over its whole surface. The heat applied by the driver causes the outer layer of a fuel pellet to explode.

5           **[0006]**   The material exploding off the surface causes the remaining material on the inside to be driven inwards with great force, eventually collapsing into a tiny near-spherical ball. In modern ICF devices the density of the resulting fuel mixture is as much as one-hundred times the density of lead, around 1000 g/cm<sup>3</sup>. This density is not high enough to create any useful rate of fusion on its  
10           own. However, during the collapse of the fuel, shock waves also form and travel into the center of the fuel at high speed. When they meet their counterparts moving in from the other sides of the fuel in the center, the density of that spot is raised much further.

**[0007]**   Given the correct conditions, the fusion rate in the region highly  
15           compressed by the shock wave can give off significant amounts of highly energetic alpha particles. Due to the high density of the surrounding fuel, they move only a short distance before being "thermalised", losing their energy to the fuel as heat. This additional energy will cause additional fusion reactions in the heated fuel, giving off more high-energy particles. This process spreads outward  
20           from the center, leading to a kind of self-sustaining burn known as ignition.

**[0008]**   A laser fusion power plant operates conceptually like a car engine: fuel is injected (in the form of a small capsule of hydrogen isotopes); a piston is then used to compress and heat the fuel to the point of ignition (with the piston being a large laser); and finally, the spent fuel is exhausted, and the cycle  
25           repeats. Repetition rates of up to 15 times a second (similar to an idling car engine) are sufficient to produce a gigawatt of electrical power from an inertial fusion energy plant.

**[0009]**   Thus operation of the fusion power plants involves delivering a capsule to the fusion chamber at a rate of about 10-20 per second, and exposing  
30           each capsule as it is delivered to intense laser energy in a fusion chamber. The fusion chamber is provided with heat exchange material (such as a lithium blanket) that captures the thermal energy from the ignition process and uses it to produce electricity.

**[0010]** In so-called indirect drive systems, such as the LIFE reactor (for laser inertial fusion energy) the target is a cylindrical apparatus called a hohlraum with a capsule containing the fusion fuel. In fusion plants, the IFE targets are injected into fusion chambers in rates of about 5-20 per second and  
5 at speeds of 5-500 m/sec. Several injector designs accelerate the targets using a barrel. During the injection process, the hohlraum rubs against the barrel wall generating heat. By conductance through the metal of the hohlraum, this heat can increase the temperature of the internal elements of the target including the helium tamping gas used in several target designs. In the time the target is  
10 passing through the barrel, the heat can migrate to the deuterium-tritium (DT) layer of the capsule. These changes in temperature of the DT layer can compromise that ability of the target to implode.

#### SUMMARY

**[0011]** This section provides a general summary of the disclosure, and  
15 is not a comprehensive disclosure of its full scope or all of its features.

**[0012]** Since friction heat between the hohlraum of an indirect drive IFE target and its injection barrel can ultimately lead to unwanted heating of the deuterium/tritium (DT) fuel in the fusion capsule, thermal management through design of the contact region between the hohlraum and the injection barrel  
20 mitigates heating of the DT layer in the capsule. Suitable fusion targets contain a hohlraum with metal walls and an inner bore formed by the inner wall of the cylinder. The hohlraum further contains a capsule suspended in the central portion of the bore by two plastic membranes. There are at least two support rings disposed on the outside of the cylinder. The support rings are disposed in  
25 such a way as to engage the wall of a barrel through which the target is to be propelled into a fusion reactor.

**[0013]** In one embodiment, the support rings are made of an insulating material that is characterized by a thermal conductance lower than that of the metal walls of the cylinder. In another embodiment, an insulating material is  
30 disposed in the cylinder wall at a place between the supporting ring and the capsule. In these embodiments, the insulating material can be disposed as an interrupter in the metal walls between the support rings and the capsule.

[0014] The capsule of the target can be empty when the target is first constructed. For use, a mixture of deuterium and tritium is inserted into the capsule through a thin hole drilled in the capsule.

[0015] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

## DRAWINGS

[0016] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0017] Fig. 1 is a cutaway view of a fusion target showing disposition of the capsule in the center of the target, with support rings on the outside of the cylinder.

[0018] Fig. 2 is a schematic demonstrating operation of the insulating material in the support rings and as an interrupter between the support rings and the capsule.

[0019] Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

## DETAILED DESCRIPTION

[0020] Example embodiments will now be described more fully with reference to the accompanying drawings.

[0021] In one embodiment, a target for a fusion reactor operating under LIFE reactor conditions is provided. The target contains a hohlraum having a central portion, an upper target half, and a lower target half, wherein the central portion, upper target half and lower target half define a cylinder having metal inner and outer walls. The hohlraum further contains an inner bore formed by the central portion, upper target half, and lower target half and further defined by the inner wall of the cylinder. The target further contains a capsule suspended in the central portion of the bore by two plastic membranes on the

ends of the upper and lower target halves. A first support ring is disposed on the outside of the cylinder on the lower target half and a second support ring is disposed on the outside of the cylinder on the upper target half. The support rings are disposed so as to be able to engage the wall of a barrel through which the target is propelled during operation of a fusion reactor using the target. In one embodiment, the first and second support rings are made of material having a lower thermal conductance than the metal of the cylinder walls. When the target is propelled down the barrel of an injector in the operation of the LIFE reactor, the supports rings make contact with the inner barrel surface, and the insulating material prevents from the cylinder walls from increasing in temperature.

**[0022]** In another embodiment, an insulating material is provided in the wall of the hohlraum, disposed between the support rings and the capsule. When the target is injected, the support rings make contact with the inner surface of the barrel and are heated by friction. The insulating material disposed in the hohlraum wall between the support rings and the capsule prevents friction heat from being transferred to the part of the target near the capsule. By using the insulating material as described herein, IFE targets for a fusion reactor can be successfully injected into the fusion chamber without deleteriously affecting the ability of the target to ignite when exposed to laser energy in the fusion chamber. In various embodiments, the targets are injected into the fusion reaction chamber at a rate of 5-50 per second, or about 10-20 per second. Conveniently, the injection can proceed using a gun barrel because the insulating materials of the target mitigate against the temperature increase that would otherwise occur.

**[0023]** A variety of insulating materials can be used. Non-limiting examples include ceramic based materials, glass based ceramics (e.g., Macor® produced by Corning, Inc.), rubbers, and plastics. DLC (diamond-like carbon) is also a suitable material. Depending on the nature of the material, the insulating material can be applied in a variety of techniques, such as swaging, die casting, electrodeposition, sintering, and press fitting. Particulate slurries, such as nanoparticles or other materials enmeshed in an adhesive or binder, can be painted on, optionally with multiple layers to build up a thicker coat.

**[0024]** Phase change materials can also be used. Phase change materials include those that undergo a phase change at a certain temperature, the advantage being that heat can be absorbed without an increase in temperature. In various embodiments, a mixture of particles is used wherein  
5 some of the particles undergo a phase change and others remain in their original phase. Examples include paraffin particles or a foam metal structure with a material that changes phase.

**[0025]** To minimize frictional contact and build up heat, it is preferred to make the support rings as narrow as possible so that the areal contact  
10 between the rings and the barrel is a minimum. When the rings are made of the same material as the walls, it is preferred to use an approximately 50 micron thick construct as the ring. However, when the rings are made of an insulating material, it is preferred to make them thicker, as that will increase the insulating capacity. In a non-limiting embodiment, the target is made of a hohlraum having  
15 a length of about 1.3 to 1.5 cm, an inner diameter of about 1 cm and an outer diameter of 1.1 cm or greater. As shown in the cutaway Fig. 1 below, the inner bore of the hohlraum is not necessarily cylindrical, but takes on a shape designed to maximize the exposure of the capsule to the incoming laser light.

**[0026]** Fig. 1 shows a cutaway view of a target 10 having a capsule 50  
20 disposed between capsule support membranes 55 of a cylindrical hohlraum 53. As shown in cutaway, the hohlraum 53 has a front helium compartment 52 and an interior helium compartment 54. There is an IR shield 58 between the compartment 52 and compartment 54. There is further an LED window 56 on either end of the cylindrical hohlraum 53. Support rings 40 are shown on the  
25 cylindrical hohlraum 53 disposed on the outside wall of a cylindrical body of the hohlraum 53. In use, the support rings 40 contact the barrel of an injector gun (not shown) and transfer friction heat to the cylindrical hohlraum 53. The helium in the front compartment 52 dissipates the heat. The heat reaching the interior compartment 54 can result in overheating of the deuterium/tritium fuel layer in  
30 the capsule 10.

**[0027]** The heat generated by the friction between the target hohlraum 53 and the barrel and its effect on the temperature of the deuterium/tritium layer

can be minimized and mitigated by a combination of one or more of the following design features.

**[0028]** The friction surface of the support rings 40 can be minimized to reduce the total frictional heat generated. Second, the friction surface can be moved to regions farther away from the capsule 50 such that the heat generated at the support rings 40 takes longer to migrate to the capsule. If the time for the heat to migrate from the frictional contact area to the capsule 50 is long enough, the temperature build up will be insignificant during the brief time the target 10 takes to emerge from the barrel and fly to the center of the reaction chamber.

**[0029]** Especially in accordance with the current teachings, the heat generated by friction can be minimized by inserting a low thermal conductance region between the contacting support rings 40 and the capsule 50 to interrupt the heat conduction path. In another embodiment, a phase change material is used near the contact regions to absorb frictional heat. In the various embodiments discussed herein, the hohlraum 53 material may be a high Z (i.e., atomic number greater than 53) material, for example and without limitation, lead or gold on the inside. The remainder of the hohlraum 53 could otherwise be formed from, for example and without limitation, materials in bulk such as ceramic or plastic.

**[0030]** Various embodiments are illustrated in Fig. 2. Fig. 2a shows a target 10 moving down a barrel 20. The target 10 has support rings 40 which contact the barrel at barrel contact points 60. The support rings 40 make direct contact with the hohlraum walls 30.

**[0031]** The insets illustrate various ways of preventing the friction heat at the contact points 60 from heating the capsule 50 to an undesired temperature. In Fig. 2b, an insulating material 200 is applied between the support ring 40 and the walls 30 of the hohlraum 53. In Fig. 2b, an insulating material 200 is disposed in the wall 30 of the hohlraum 53 in order to interrupt the flow of heat from the contact points 60 through the support ring 40 to the capsule 50. In Fig. 2d, a phase change material 300 is shown applied to the surface of the support ring 40. Not shown in Fig. 2 is an embodiment where the entire support ring is made of insulating material 200.

**[0032]** As shown in Fig. 2a, support rings 40 on the target hohlraum walls 30 move friction heat load from the contact 60 to injector barrel walls 20 away from the capsule 50 in order to minimize the heat load to the capsule during the target 10 injection into the fusion chamber.

5       **[0033]** In various embodiments, the target 10 has a tiny fuel capsule contained in a small gold cylinder approximately the size of a pencil eraser.

10       **[0034]** The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within  
15       the scope of the disclosure.

## CLAIMS

What is claimed is:

1. A target for a fusion reactor operating under LIFE reactor  
5 conditions, comprising:  
a hohlraum having a central portion, an upper target half, and a  
lower target half, the central portion, upper target half, and lower target half  
defining a cylinder with a high-Z material on the inner walls and an inner bore  
formed by the central portion, upper target half, and lower target half and defined  
10 by the inner wall of the cylinder;  
a capsule suspended in the central portion of the bore by two  
plastic membranes on the ends of the upper and lower target halves;  
a first support ring disposed on the outside of the cylinder on the  
lower target half; and  
15 a second support ring disposed on the outside of the cylinder on  
the upper target half, wherein the support rings are disposed so as to engage the  
wall of a barrel through which the target is propelled, wherein the first and  
second support rings comprise material having a lower thermal conductance  
than the material of the cylinder walls.
- 20 2. The target of claim 1, wherein the support comprises an insulating  
material.
3. The target of claim 1, wherein the support rings comprise a phase  
change material.
4. The target of claim 1, wherein the capsule contains deuterium and  
25 tritium.
5. The target of claim 1, wherein the inner bore contains helium and  
the two ends of the bore are sealed with windows.
6. The target of claim 1 wherein the inner walls comprise gold.

7. The target of claim 1, wherein the inner wall is made of lead, or mercury or xenon or iodine or some combination thereof.

8. A method of operating a fusion power plant, comprising injecting a target according to claim 1 into a reaction chamber and heating the target with  
5 laser light.

9. The method according to claim 8, comprising injecting the targets at a rate of 5-50 per second using a gun barrel.

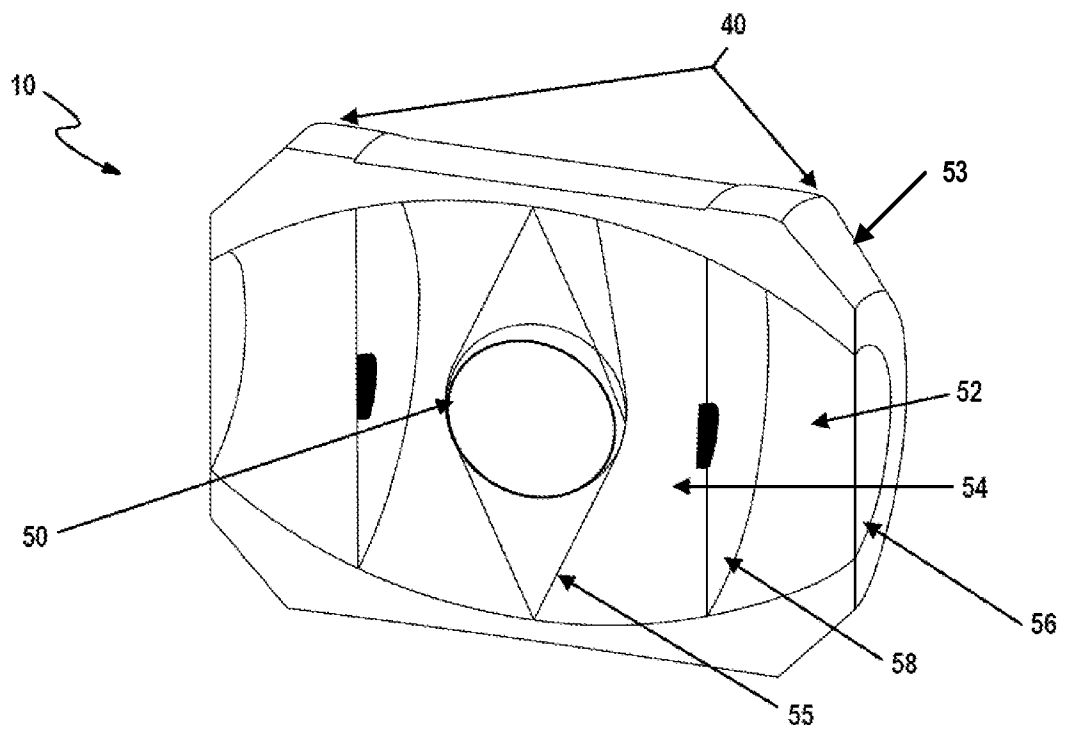
10. A fusion target, comprising:  
a hohlraum having a central portion, an upper target half, and a  
10 lower target half, the central portion, an upper target half and a lower target half defining a cylindrical external shape with high-Z material inner walls and an inner bore formed by the central portion, an upper target half and a lower target half and defined by the inner wall of the cylinder;  
a capsule suspended in the central portion of the bore by two  
15 plastic membranes on the ends of the upper and lower target halves;  
a first support ring disposed on the outside of the cylinder on the lower target half; and  
a second support ring disposed on the outside of the cylinder on the upper target half, wherein the support rings are disposed so as to engage the  
20 wall of a barrel through which the target is propelled, wherein the cylinder walls between the support ring and the capsule comprise an insulating material having lower thermal conductance than the metal walls of the cylinder.

11. The fusion target of claim 10, wherein the insulating material is disposed as an interrupter in the metal walls.

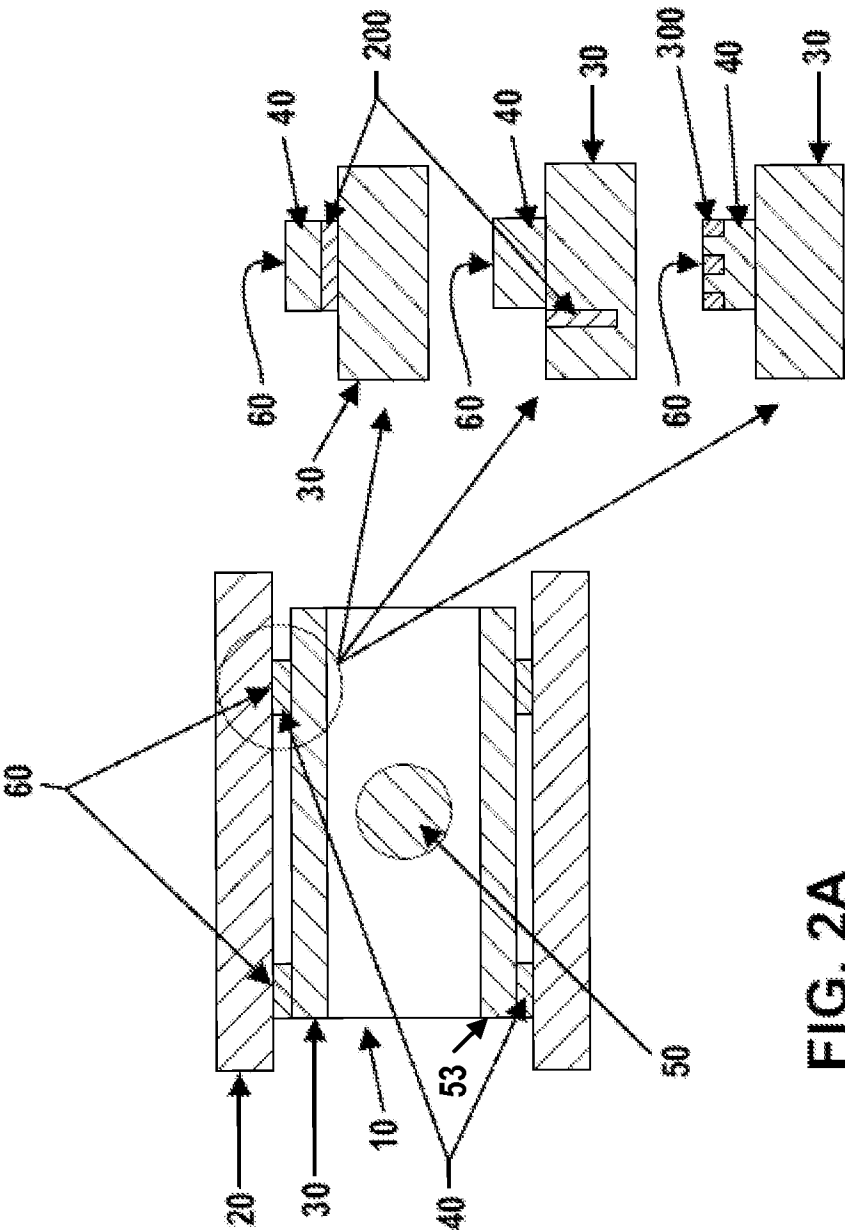
25 12. The fusion target of claim 10, wherein the insulating material is a phase change material.

13. The fusion target of claim 10, wherein the insulating material is a ceramic.

14. The fusion target of claim 10, wherein the insulating material is a rubber.
15. The fusion target of claim 10, wherein the insulating material is a plastic.
- 5 16. The fusion target of claim 10, wherein the capsule contains deuterium and tritium.
17. A method of operating a fusion power plant, comprising injecting a target according to claim 10 into a reaction chamber and heating the target with laser light.
- 10 18. The method according to claim 17, comprising injecting the targets at a rate of 5-50 per second using a gun barrel.



**FIG. 1**



**FIG. 2B**

**FIG. 2C**

**FIG. 2D**

**FIG. 2A**

## INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/US2014/025880****A. CLASSIFICATION OF SUBJECT MATTER****G21B 1/11(2006.01)i**

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)

G21B 1/11; G21B 1/00; G21C 3/07; H05H 1/00; B05D 3/06; G21B 1/03

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) &amp; Keywords: fusion, friction heat, IFE, hohlraum, capsule, support ring

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                    | Relevant to claim No. |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | US 2012-0114088 A1 (PETER A. AMENDT et al.) 10 May 2012<br>See paragraphs [0020]–[0021], claim 1 and figure 2.                        | 1–18                  |
| A         | JP 2002-202391 A (PELIN INC. et al.) 19 July 2002<br>See paragraphs [0006]–[0008] and figure 1.                                       | 1–18                  |
| A         | US 2008-0256850 A1 (VICTOR B. KLEY) 23 October 2008<br>See paragraph [0100] and figure 1.                                             | 1–18                  |
| A         | JP 2009-539117 A (CURTIS A. BIRNBACH) 12 November 2009<br>See paragraphs [0021]–[0023] and figure 1.                                  | 1–18                  |
| A         | JP 2008-281397 A (GRADUATE SCHOOL FOR THE CREATION OF NEW PHOTONICS INDUSTRIES) 20 November 2008<br>See paragraph [0021] and claim 1. | 1–18                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2014/025880**

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|-------------------------------------------|---------------------|----------------------------|---------------------|
| US 2012-0114088 A1                        | 10/05/2012          | CA 2813965 A1              | 18/05/2012          |
|                                           |                     | CA 2814004 A1              | 18/05/2012          |
|                                           |                     | CA 2815828 A1              | 18/05/2012          |
|                                           |                     | CA 2815837 A1              | 18/05/2012          |
|                                           |                     | EP 2614505 A1              | 17/07/2013          |
|                                           |                     | EP 2617038 A1              | 24/07/2013          |
|                                           |                     | EP 2617268 A1              | 24/07/2013          |
|                                           |                     | EP 2638788 A1              | 18/09/2013          |
|                                           |                     | JP 2014-500487 A           | 09/01/2014          |
|                                           |                     | JP 2014-500488 A           | 09/01/2014          |
|                                           |                     | JP 2014-500489 A           | 09/01/2014          |
|                                           |                     | JP 2014-500490 A           | 09/01/2014          |
|                                           |                     | KR 10-2013-0131330 A       | 03/12/2013          |
|                                           |                     | KR 10-2013-0137183 A       | 16/12/2013          |
|                                           |                     | KR 10-2013-0137641 A       | 17/12/2013          |
|                                           |                     | KR 10-2013-0140031 A       | 23/12/2013          |
|                                           |                     | WO 2012-064668 A1          | 18/05/2012          |
|                                           |                     | WO 2012-064746 A1          | 18/05/2012          |
|                                           |                     | WO 2012-064767 A1          | 18/05/2012          |
|                                           |                     | WO 2012-064773 A1          | 18/05/2012          |
|                                           |                     | WO 2012-064773 A8          | 23/05/2013          |
| JP 2002-202391 A                          | 19/07/2002          | JP 3739697 B2              | 25/01/2006          |
|                                           |                     | RU 2230377 C2              | 10/06/2004          |
| US 2008-0256850 A1                        | 23/10/2008          | US 2013-0037978 A1         | 14/02/2013          |
|                                           |                     | US 7183548 B1              | 27/02/2007          |
|                                           |                     | US 7309446 B1              | 18/12/2007          |
|                                           |                     | US 7514680 B1              | 07/04/2009          |
|                                           |                     | US 8318029 B1              | 27/11/2012          |
| JP 2009-539117 A                          | 12/11/2009          | AU 2007-294621 A1          | 20/03/2008          |
|                                           |                     | AU 2007-294621 B2          | 16/01/2014          |
|                                           |                     | CA 2653707 A1              | 20/03/2008          |
|                                           |                     | CN 101496111 A             | 29/07/2009          |
|                                           |                     | EP 2033197 A2              | 11/03/2009          |
|                                           |                     | EP 2033197 A4              | 26/08/2009          |
|                                           |                     | IL 195593 D0               | 01/09/2009          |
|                                           |                     | KR 10-2009-0037865 A       | 16/04/2009          |
|                                           |                     | KR 10-2013-0138313 A       | 18/12/2013          |
|                                           |                     | NZ 573514 A                | 22/12/2011          |
|                                           |                     | NZ 596166 A                | 28/06/2013          |
|                                           |                     | NZ 596167 A                | 31/05/2013          |
|                                           |                     | NZ 599154 A                | 29/11/2013          |
|                                           |                     | RU 2008150241 A            | 10/07/2010          |
|                                           |                     | US 2008-0063132 A1         | 13/03/2008          |
|                                           |                     | US 2013-0265130 A1         | 10/10/2013          |
|                                           |                     | US 2013-0266104 A1         | 10/10/2013          |
|                                           |                     | WO 2008-033587 A2          | 20/03/2008          |

**INTERNATIONAL SEARCH REPORT**

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| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|-------------------------------------------|---------------------|----------------------------|---------------------|
|                                           |                     | WO 2008-033587 A3          | 26/06/2008          |
|                                           |                     | WO 2008-033587 B1          | 07/08/2008          |
| JP 2008-281397 A                          | 20/11/2008          | JP 4989301 B2              | 01/08/2012          |