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— *as to the identity of the inventor (Rule 4.17(i))*

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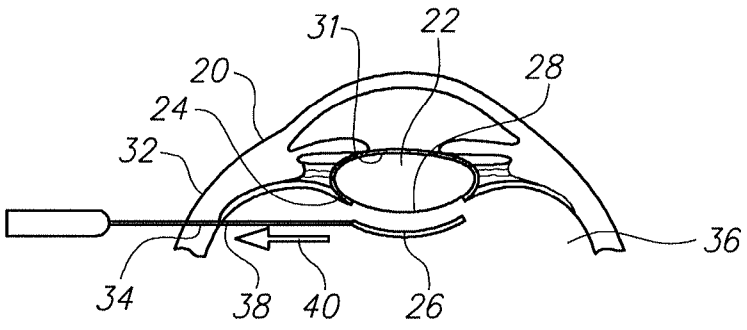
— *with international search report (Art. 21(3))*

(54) Title: POSTERIOR CAPSULOTOMY USING LASER TECHNIQUES



(57) Abstract: A system and method are provided for removing a natural lens and inserting an Intraocular Lens (IOL) into the lens capsule of an eye. Specifically, this is accomplished by inserting the IOL through an opening on the posterior capsule that is created using a focused laser beam. The system includes a laser unit, a detector for creating images of the interior of the eye, and a computer that controls the cooperative functions of the detector and the laser unit. Based on images of the posterior capsule provided by the detector, the computer is used to control movements of the focal point through tissue of the posterior capsule to perform Laser Induced Optical Breakdown (LIOB) on posterior capsule tissue. The result is a laser capsulotomy that creates an opening through the posterior capsule allowing the natural lens to be removed and the IOL to be implanted.

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POSTERIOR CAPSULOTOMY USING LASER TECHNIQUES

This application claims the benefit of U.S. Provisional Patent Application Serial No. 61/671,312, titled POSTERIOR CAPSULOTOMY USING LASER TECHNIQUES, filed July 13, 2012. The entire contents of Application Serial No. 61/671,312 are hereby incorporated by reference herein.

FIELD OF THE INVENTION

The present invention pertains generally to ocular laser surgery. More particularly, the present invention pertains to capsulotomy procedures that employ a femtosecond laser. The present invention is particularly, but not exclusively, useful for performing a posterior capsulotomy procedure to insert an Intraocular Lens (IOL) into the lens capsule of an eye.

BACKGROUND OF THE INVENTION

A common treatment for a cataract involves removal of the diseased lens from a patient's eye followed by replacement with an Intraocular Lens (IOL). Originally, the entire lens and capsule were removed and replaced. More modernly, the lens is removed from the capsule, *in situ*, and the new IOL is inserted into the capsule.

In a typical cataract procedure, access to the lens is obtained and the lens is fragmented and / or emulsified. For example, the lens can be emulsified using a traditional ultrasonic handpiece (a process known as "phacoemulsification"), or, more modernly, the lens can be fragmented using a femtosecond laser. Once fragmented or emulsified, the lens material can be removed from the capsule, for example, by aspirating the material using an aspiration needle. Once the lens material has been removed, an IOL can be inserted into the remaining portion of the lens capsule.

To perform the procedures described above, an opening in the lens capsule is required. Two possibilities for this opening include an anterior capsulotomy in which an opening is made on the anterior surface of the lens

capsule and a posterior capsulotomy in which an opening is made on the posterior surface of the lens capsule. Typically, for an anterior capsulotomy, the surgeon gains access to the capsule and lens through incisions that are made on the cornea or limbus. However, these incisions can adversely affect the refractive properties of the eye, including the inducement of undesirable astigmatism.

Another drawback associated with a typical anterior capsulotomy procedure involves anatomical considerations. In more detail, access to the anterior capsule surface necessarily involves transit through the relatively small anterior chamber of the eye. Unfortunately, there are a number of surgical problems associated with passing tools, such as the phacoemulsification probe and aspiration needle, through the small anterior chamber of the eye. Moreover, the anterior capsulotomy procedure can disturb other fragile anatomical structures that are anterior to the crystalline lens.

Unlike the anterior capsulotomy, access for a posterior capsulotomy can be obtained using incisions through the sclera on the side of the eye. These incisions do not, in general, affect the refractive properties of the eye like the incisions described above that are made on the cornea or limbus. In addition, there is more operating room on the posterior side of the crystalline lens than the small anterior chamber of the eye. And, in many instances, additional room for tool manipulation can be made on the posterior side of the crystalline lens by performing a partial vitrectomy.

Another advantage of a posterior capsulotomy is that the optical barrier (e.g. the anterior surface of the capsule) is maintained intact during a surgical procedure. Lastly, the use of a posterior capsulotomy can provide flexibility for combining the capsulotomy procedure with other surgical procedures in the back of the eye.

In light of the above, it is an object of the present invention to provide a system and method for performing a posterior capsulotomy.

Another object of the present invention is to provide a system and method for performing a posterior capsulotomy procedure to accommodate the insertion of an Intraocular Lens (IOL) into the lens capsule of an eye.

Still another object of the present invention is to provide a system and method for performing a posterior capsulotomy procedure using laser techniques which is simple to implement and is relatively cost effective.

SUMMARY OF THE INVENTION

In accordance with the present invention, a system and method are provided for inserting an Intraocular Lens (IOL) into the lens capsule of an eye. Specifically, this is accomplished by inserting the IOL through an opening that is created through the posterior capsule of the eye. In overview, the system includes a detector for creating images of the interior of the eye, and it includes a laser unit for generating and focusing a laser beam to a focal point. The system further includes a computer that controls the cooperative functions of the detector and the laser unit.

For an operation of the present invention, the computer processes images that are provided by the detector. Specifically, these images are of tissue inside the eye and their processing by the computer is accomplished to establish an accurate location for the posterior capsule of the eye. As envisioned for the present invention, the detector is preferably an imaging unit that employs imaging techniques selected from a group comprising Optical Coherence Tomography (OCT), Scheimpflug imaging, confocal imaging, two-photon imaging, laser (optical) range finding and acoustical imaging.

In addition to receiving images from the detector, the computer also operates the laser unit to generate and focus a laser beam. In detail, the laser beam is preferably a pulsed laser beam wherein each pulse has a duration less than one millisecond. Furthermore, it is necessary that the energy at the focal point of the laser beam be capable of performing Laser Induced Optical Breakdown (LIOB) of tissue of the posterior capsule.

Based on images of the posterior capsule that have been provided by the detector (imaging unit), the computer is used to control movements of the focal point through tissue of the posterior capsule. As indicated above, this is done for the purpose of performing Laser Induced Optical Breakdown (LIOB) on tissue of the posterior capsule. As envisioned for the present invention, the condition of tissue of the posterior capsule is of interest only insofar as it may affect the laser operation. Stated differently, the present invention pertains regardless whether the posterior capsule is initially intact, or somehow torn. In either case, the intent here is to create an opening through the posterior capsule that can be used for inserting the IOL into the lens capsule. Importantly, in this process, the opening is dimensioned and customized to receive a specific IOL into the lens capsule via the opening.

In accordance with a methodology for the present invention, the crystalline lens of an eye is prepared for its removal from the lens capsule at an appropriate time in the particular procedure. As will be appreciated by the skilled artisan, preparation of the lens can be done in any of several different ways that are well known in the pertinent art. For example, techniques such as hydrodissection and phacoemulsification may be used for this purpose. Preferably, laser techniques such as disclosed in U.S. Application Serial No. 13/436,352, which was filed on March 30, 2012 for an invention entitled "System and Method for Performing Lens Fragmentation," can be useful for this same purpose.

At an appropriate time in the procedure, Laser Induced Optical Breakdown (LIOB) is performed on tissue of the posterior capsule of the eye to create a section of separated tissue. In effect, this involves a laser capsulotomy that creates an opening through the posterior capsule, into the lens capsule of the eye. The section of separated tissue is then removed from the lens capsule to establish the opening. As envisioned for the present invention, this removal of the separated tissue section will be accomplished by first incising the sclera to establish an access port to the vitreous body of the eye. A probe can then be advanced through the access port for engagement of the probe with the section of separated tissue. After the probe has

engaged with the separated section of tissue, the separated section of tissue can be removed from the eye by the probe to establish the opening.

Once an opening has been established through the posterior capsule of the eye, the crystalline lens of the eye can be extracted (removed) from the lens capsule of the eye. The extracted lens can then be removed from the eye through the access port that has been created through the sclera. Specifically, this may include removing the whole lens through the scleral incision using mechanical cutters and macelators such as scissors, lassos, guillotine cutters, cautery devices, aqua-jets, ultrasonic blades, a combination of a laser and another extraction device, or any other device or technique sufficient to remove the lens.

Once the crystalline lens has been extracted (removed), an IOL can be introduced through the sclera and inserted through the opening in the posterior capsule to replace the extracted lens. As an additional feature of the present invention, LIOB marks can be established on the lens capsule during the procedure to assist in aligning the IOL in the lens capsule. Such feature may be particularly useful for properly orienting a toric IOL that is to be used for the correction of astigmatism.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features of this invention, as well as the invention itself, both as to its structure and its operation, will be best understood from the accompanying drawings, taken in conjunction with the accompanying description, in which similar reference characters refer to similar parts, and in which:

Fig. 1 is a schematic presentation of components for the system of the present invention;

Fig. 2A is a cross section view of the anterior portion of an eye showing the removal of tissue from the posterior capsule of the eye to create an opening into the lens capsule; and

Fig. 2B is a cross section view of the anterior portion of the eye as seen in Fig. 2A, showing the insertion of an Intraocular Lens (IOL) through the opening into the lens capsule of the eye, after the crystalline lens of the eye has been removed from the lens capsule.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring initially to Fig. 1, a system in accordance with the present invention is shown and is generally designated 10. As shown, the system 10 includes a laser unit 12 and a computer 14. As shown, the computer 14 is connected with the laser unit 12 for the purposes of guiding and controlling the movement of a laser beam 16 that is generated and focused by the laser unit 12. Necessarily, the laser unit 12 is of a type that generates a pulsed laser beam 16 which is capable of performing Laser Induced Optical Breakdown (LIOB) on sub-surface anatomical tissue. Preferably, the laser beam 16 will have laser pulses with pulse durations in the femtosecond range.

Fig. 1 also shows that the system 10 can include a detector 18 for creating images of the interior of the eye 20. For example, the detector 18 can include an imaging unit that employs imaging techniques such as Optical Coherence Tomography (OCT), Scheimpflug imaging, confocal imaging, two-photon imaging, laser (optical) range finding and acoustical imaging. As shown, the computer 14 is connected to the detector 18 to receive and process image data from the detector 18 and control the operation of the detector 18. More specifically, images of tissue inside the eye 20 can be processed by the computer 14 to establish an accurate location for the crystalline lens 22 and posterior capsule 24 of the eye 20.

Fig. 2A illustrates a procedure for creating a section of separated tissue 26 and removing the tissue 26 from the posterior capsule 24 of the eye 20 to create an opening 28 into the posterior capsule 24. For this procedure, images of the posterior capsule 24 (Fig. 1) are provided by the detector 18 to the computer 14 which uses the image data to control movements of the focal point through tissue of the posterior capsule 24. As this is done, Laser

Induced Optical Breakdown (LIOB) occurs on tissue of the posterior capsule 24 to create a section of separated tissue 26. Once the separated tissue is removed, an opening 28 is established through the posterior capsule 24 that can be used for removing the lens 22 and / or inserting an IOL 30 (Fig. 2B) into the lens capsule 31. For this process, the opening 28 can be dimensioned and customized to allow a specific IOL 30 (Fig 2B) to pass through the opening 28 and be implanted into the lens capsule 31.

Continuing with Fig. 2A, it can be seen that the separated tissue 26 can be removed from the eye 20, by first incising the sclera 32 to establish an access port 34 to the vitreous body 36 of the eye 20. As shown, a probe 38 can then be advanced through the access port 34 for engagement of the probe 38 with the section of separated tissue 26. After the probe 38 has engaged with the separated section of tissue 26, the separated section of tissue 26 can be removed from the eye 20 by the probe 38 (in the direction of arrow 40) and through access port 34 to establish the opening 28. Once an opening 28 has been established through the posterior capsule 24 of the eye 20, as shown, the crystalline lens 22 can be extracted from the lens capsule 31 and removed from the eye 20 through the access port 34.

Fig. 2B shows that an IOL 30 can be introduced through the access port 34 in the sclera 32 and inserted through the opening 28 (in the direction of arrow 42 and into the lens capsule 31. As shown, probe 44 can be used to place the IOL 30 into the lens capsule 31. As an additional feature of the present invention, LIOB marks (not shown) can be established on the lens capsule 31 during the procedure to assist in aligning the IOL 30 in the lens capsule 31. For example, these LIOB marks may be used to properly orient a toric IOL (not shown) that is to be used for the correction of astigmatism.

While the particular Posterior Capsulotomy Using Laser Techniques as herein shown and disclosed in detail is fully capable of obtaining the objects and providing the advantages herein before stated, it is to be understood that it is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended to the details of construction or design herein shown other than as described in the appended claims.

What is claimed is:

1. A system for inserting an Intraocular Lens (IOL) into the lens capsule of the eye comprising:

a detector for creating images of the interior of the eye;

a laser unit for generating a laser beam, and for focusing the laser beam to a focal point; and

a computer connected to the detector, and to the laser unit, for processing an image from the detector for use in controlling movements of the focal point to create an opening through tissue of the posterior capsule of an eye for inserting the IOL in the lens capsule of the eye through the opening in the posterior capsule.

2. A system as recited in claim 1, wherein the opening is established by creating a section of tissue separated from the posterior capsule, and the system further comprises at least one probe, wherein a probe is advanced through an access port in the sclera to engage with the section of separated tissue for withdrawal of the separated section of tissue from the eye, and wherein a probe is used to insert the IOL through the access port into the lens capsule.

3. A system as recited in claim 1 wherein the laser beam is a pulsed laser beam.

4. A system as recited in claim 3 wherein each pulse in the pulsed laser beam has a duration less than one millisecond.

5. A system as recited in claim 1 wherein the energy at the focal point of the laser beam is capable of performing Laser Induced Optical Breakdown (LIOB) of the tissue of the posterior capsule.

6. A system as recited in claim 1 wherein the detector is an optical imaging unit.

7. A system as recited in claim 6 wherein the optical imaging unit employs imaging techniques selected from a group comprising Optical Coherence Tomography (OCT), Scheimpflug imaging, confocal imaging, two-photon imaging, laser (optical) range finding and acoustical imaging.

8. A system as recited in claim 1 wherein the opening is dimensioned to receive a specific IOL into the lens capsule via the opening.

9. A method for performing ophthalmic surgery inside an eye which comprises the steps of:

performing Laser Induced Optical Breakdown (LIOB) on tissue of the posterior capsule of the eye to create a section of separated tissue defining an opening into the lens capsule of the eye;

removing the section of separated tissue from the lens capsule to establish the opening;

extracting the lens of the eye from the lens capsule of the eye through the opening in the posterior capsule; and

implanting an optical device in the lens capsule through the opening in the posterior capsule to replace the extracted lens.

10. A method as recited in claim 9 wherein the performing step comprises the steps of:

generating a pulsed laser beam;

focusing the pulsed laser beam to a focal point; and

directing the focal point of the pulsed laser beam onto tissue of the posterior capsule inside the eye.

11. A method as recited in claim 10 wherein the performing step further comprises the steps of:

creating images of the inside of the eye; and

using an image from the creating step to control movements of the focal point through tissue of the posterior capsule to create the opening.

12. A method as recited in claim 11 wherein the creating step is accomplished using imaging techniques selected from a group comprising Optical Coherence Tomography (OCT), Scheimpflug imaging, confocal imaging, two-photon imaging, laser (optical) range finding and acoustical imaging.

13. A method as recited in claim 9 wherein the removing step comprises the steps of:

incising the sclera to establish an access port to the vitreous body of the eye;

advancing a probe through the access port for engagement of the probe with the section of separated tissue; and

withdrawing the separated section of tissue from the eye with the probe to establish the opening.

14. A method as recited in claim 9 wherein the optical device is an Intraocular Lens (IOL).

15. A method as recited in claim 14 further comprising the step of establishing LIOB marks on the lens capsule to assist in aligning the IOL in the lens capsule.

16. A method as recited in claim 14 further comprising the step of dimensioning the opening to receive a specific IOL into the lens capsule via the opening.

17. A computer program product for performing ophthalmic surgery inside an eye to create an opening through the posterior capsule of the eye for inserting an Intraocular Lens (IOL) into the lens capsule of the eye, wherein the computer program product comprises program sections for respectively:

processing images from inside the eye, wherein the images are obtained by a detector to establish an accurate location for the posterior capsule of the lens capsule of the eye;

operating a laser unit in response to images obtained by the detector to generate a laser beam, and to focus the laser beam to a focal point to perform Laser Induced Optical Breakdown (LIOB) on tissue of the posterior capsule; and

controlling movements of the focal point through tissue of the posterior capsule to create an opening through the posterior capsule for use in inserting the IOL into the lens capsule through the opening.

18. A computer program product as recited in claim 17 further comprising a program section for monitoring an extraction of the lens of the eye from the lens capsule of the eye through the opening in the posterior capsule, and for monitoring an insertion of the IOL into the lens capsule through the opening in the posterior capsule to replace the extracted lens.

19. A computer program product as recited in claim 17 further comprising a program section for establishing LIOB marks on the lens capsule to assist in aligning the IOL in the lens capsule.

20. A computer program product as recited in claim 17 further comprising a program section for dimensioning the opening to receive a specific IOL into the lens capsule via the opening.

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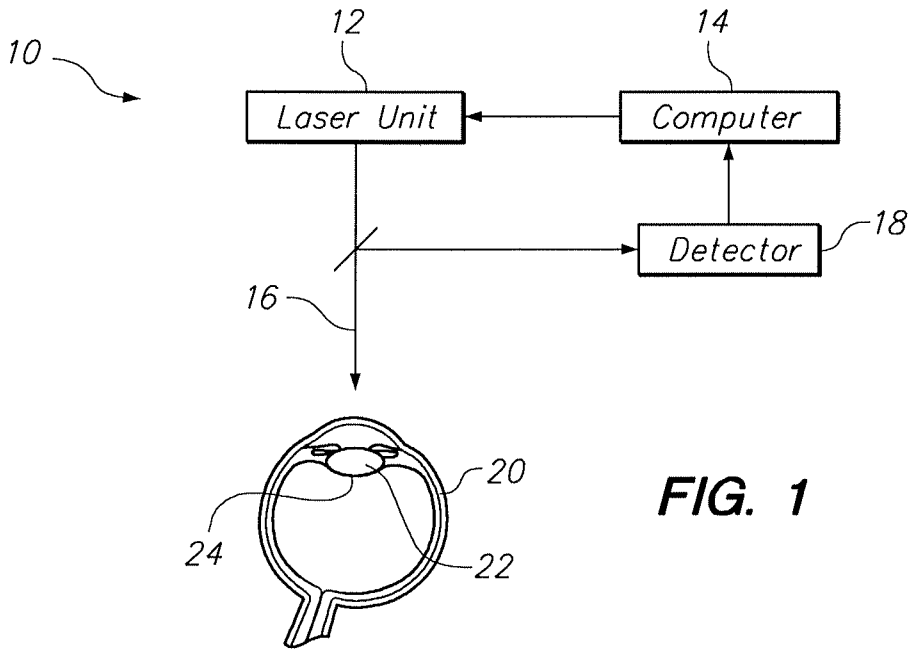

FIG. 1

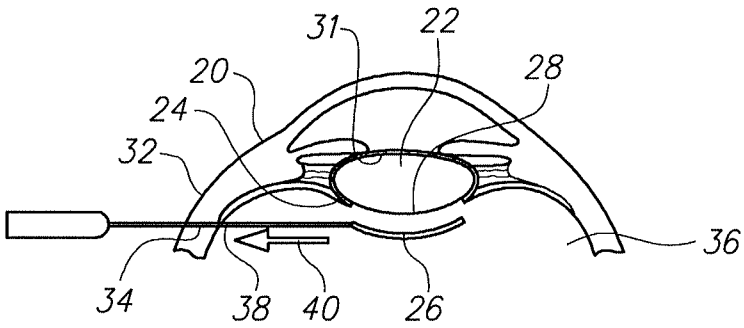

FIG. 2A

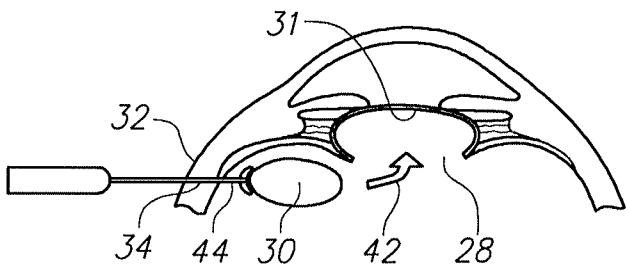

FIG. 2B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/031394

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61F9/008
ADD.

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)
A61F

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 practicable, 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	US 2006/195076 A1 (BLUMENKRANZ MARK S [US] ET AL PALANKER DANIEL V [US] ET AL) 31 August 2006 (2006-08-31) paragraph [0009]; claims 28,29,43 paragraph [0018] paragraph [0045] paragraph [0046] paragraph [0050] paragraph [0056] paragraph [0057] paragraph [0059] paragraph [0068] paragraph [0071] paragraph [0072] paragraph [0075] paragraph [0098] paragraph [0099]	1-8, 17-20

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[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 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
18 June 2013	18/09/2013

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, Fax: (+31-70) 340-3016	Rodríguez Cossío, J

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/031394

Box No. 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. [X] Claims Nos.: 9-16
because they relate to subject matter not required to be searched by this Authority, namely:

Rule 39.1(iv) PCT - Method for treatment of the human or animal body by surgeryRule 39.1(iv) PCT - Method for treatment of the human or animal body by therapy

2. [ ] Claims Nos.:
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:

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 No. 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:

see additional sheet

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 fees, this Authority did not invite payment of additional fees.

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. [X] 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.:

1-6, 8, 17-20(completely); 7(partially)

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/031394

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/089134 A1 (HORVATH CHRISTOPHER [US] ET AL) 12 April 2012 (2012-04-12) paragraph [0011]; claim 1 paragraph [0012] paragraph [0040] paragraph [0077] paragraph [0081] paragraph [0082]	1-8, 17-20
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4

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2013/031394

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FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-6, 8, 17-20(completely); 7(partially)

A system for inserting an intraocular lens into the lens capsule of an eye comprising a detector for creating images of the interior of the eye and a laser unit controlled by a computer to focus the focal point based on the image to create an opening through the posterior capsule of the eye, wherein the detector employs Optical Coherence Tomography.

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2. claim: 7(partially)

A system for inserting an intraocular lens into the lens capsule of an eye comprising a detector for creating images of the interior of the eye and a laser unit controlled by a computer to focus the focal point based on the image to create an opening through the posterior capsule of the eye, wherein the detector employs Scheimpflug imaging.

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3. claim: 7(partially)

A system for inserting an intraocular lens into the lens capsule of an eye comprising a detector for creating images of the interior of the eye and a laser unit controlled by a computer to focus the focal point based on the image to create an opening through the posterior capsule of the eye, wherein the detector employs confocal imaging.

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4. claim: 7(partially)

A system for inserting an intraocular lens into the lens capsule of an eye comprising a detector for creating images of the interior of the eye and a laser unit controlled by a computer to focus the focal point based on the image to create an opening through the posterior capsule of the eye, wherein the detector employs two-photon imaging.

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5. claim: 7(partially)

A system for inserting an intraocular lens into the lens capsule of an eye comprising a detector for creating images of the interior of the eye and a laser unit controlled by a computer to focus the focal point based on the image to create an opening through the posterior capsule of the eye, wherein the detector employs optical range finding.

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6. claim: 7(partially)

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

A system for inserting an intraocular lens into the lens capsule of an eye comprising a detector for creating images of the interior of the eye and a laser unit controlled by a computer to focus the focal point based on the image to create an opening through the posterior capsule of the eye, wherein the detector employs acoustical imaging.
