



**(51) International Patent Classification:**  
**G02B 3/00 (2006.01)**

**(21) International Application Number:**

PCT/US2014/047927

**(22) International Filing Date:**

24 July 2014 (24.07.2014)

**(25) Filing Language:**

English

**(26) Publication Language:**

English

**(30) Priority Data:**

61/858,706

26 July 2013 (26.07.2013)

US

(71) **Applicants:** **KNOWLES ELECTRONICS, LLC** [US/US]; 1151 Maplewood Drive, Itasca, Illinois 60143 (US). **OPTOTUNE AG** [CH/CH]; Bernstrasse 388, CH-8935 Dietkon (CH).

(72) **Inventors:** **KING, Charles**; 206 Pleasant Street, Oak Park, Illinois 60302 (US). **CHAUNCEY, Graetzel**; Puntenstrasse 3B, CH-8143 Stallikon (CH). **DAVOINE, Laurent**; 6 D Rue Des Fleurs, F-68300 St. Louis (FR). **MONTI, Chris**; 360 Comstock Drive, Elgin, Illinois 60124 (US). **SCHMIDHAEUSLER, Thomas**; Rothausstrasse 13, CH-8635 Duernten (CH). **BUEELER, Michael**; Schachenstrasse 1A, CH-5412 Vogelsang AG (CH). **SALT, Martin**; Buecheiring 13, CH-8134 Adliswil (CH). **KUKALEVA, Natalia**; Winterhurerstrasse 400, CH-8051 Zurich (CH). **LIEBETRAUT, Peter**; Steinmurlistrasse 48a, CH-8953 Dietikon (CH).

(74) **Agents:** KRATZ, Rudy et al.; Fitch, Even, Tabin & Flannery, LLP, 120 S. LaSalle Street, Suite 1600, Chicago, Illinois 60603 (US).

**(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, LT, 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, 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))

*[Continued on next page]*

**(54) Title:** OPTICAL APPARATUS AND METHOD

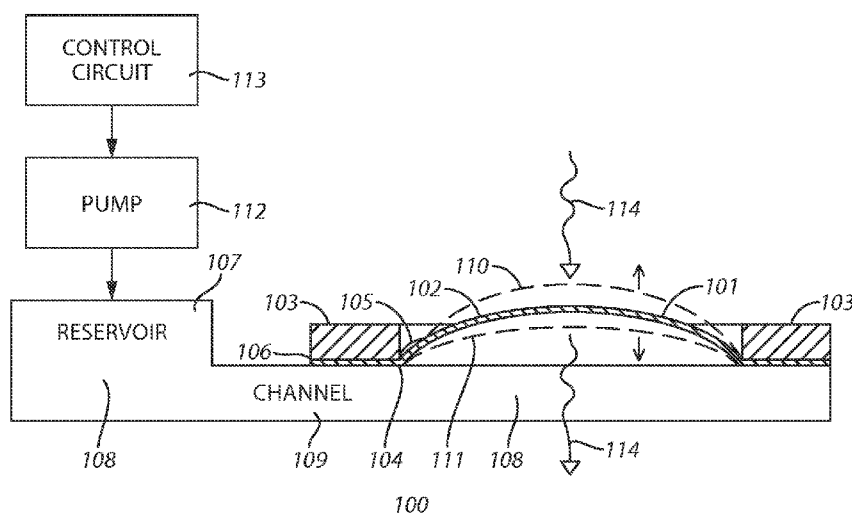


FIG. 1

**(S7) Abstract:** A deformable optical lens with a lens membrane having an optically active portion that is configured to be shaped over an air-membrane interface according to a spherical cap and Zernike polynomials is provided. The spherical cap and the Zernike polynomials comprise a Zernike [4,0], (Noll[11]) polynomial and are sufficient to model the deformable optical lens to within approximately 2 micrometers.



— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(88) **Date of publication of the international search report:**  
19 March 2015

## INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/US2014/047927****A. CLASSIFICATION OF SUBJECT MATTER****G02B 3/00(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)  
G02B 3/00; A61F 2/14; G02B 5/04; A61F 2/16; G02B 3/12; G02B 1/06; G02B 17/08; G02B 3/14Documentation 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 modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
eKOMPASS(KIPO internal) & Keywords:deformable, optical lens, membrane, active portion, shape, interface, zernike polynomial, spherical cap, shaper and Noll**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013-0176628 A1 (BATCHKO, ROBERT G. et al.) 11 July 2013 See paragraphs [0078]–[0150] and figures 1, 15.	1–7, 18–31
A	US 2010-0232161 A1 (ASCHWANDEN, MANUEL et al.) 16 September 2010 See paragraphs [0073]–[0144] and figure 8.	1–7, 18–31
A	US 2007-0263293 A1 (BATCHKO, ROBERT G. et al.) 15 November 2007 See paragraphs [0077]–[0146] and figures 2A–2F.	1–7, 18–31
A	JP 2005-258049 A (OLYMPUS CORP.) 22 September 2005 See paragraphs [0007]–[0042] and figure 1.	1–7, 18–31
A	EP 2559405 A2 (POWERSVISION, INC.) 20 February 2012 See claims 1–10 and figures 3A–4B.	1–7, 18–31



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

"&amp;" document member of the same patent family

Date of the actual completion of the international search

26 January 2015 (26.01.2015)

Date of mailing of the international search report

**26 January 2015 (26.01.2015)**

Name and mailing address of the ISA/KR

International Application Division  
Korean Intellectual Property Office  
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 302-701,  
Republic of Korea

Facsimile No. ++82 42 472 3473

Authorized officer

KIM, Jin Ho

Telephone No. +82-42-481-8699



**INTERNATIONAL SEARCH REPORT**International application No.  
**PCT/US2014/047927****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. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
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 the extra 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 any 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. ☒ 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.: 1-7, 18-31

**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.

Group I : Claims 1-7, 18-31 are directed to a deformable optical lens with a lens membrane having an optically active portion that is configured to be shaped over an air-membrane interface according to a spherical cap and Zernike polynomials.

Group II : Claims 8-17, 32-36 are directed to a deformable optical lens subsystem comprising: a lens shaper; a fixed solid lens; a barrel; and a deformable lens membrane.

Group III: Claims 37-47 are directed to a multi-optical element assembly comprising: deformable optical lenses; a reflective surface; a folded optical axis; and an optical path.

Group IV: Claims 48-75 are directed to an optical apparatus comprising: a deformable optical lens; an optical housing; at least one fluid reservoir; a surround structure; and at least one elastomeric structure.

Group V : Claims 76-99, 116-143, 156-166, 176-193 are directed to an optical apparatus comprising: a deformable optical lens; a fixed lens; a sensor; and an optical path.

Group VI: Claims 100-115 are directed to an optical apparatus comprising: a reflector; and a deformable optical lens including a membrane, a lens shaper, a fluid and a barrel.

Group VII: Claims 144-155 are directed to an optical apparatus comprising: an optical portion including a deformable optical lens; and a pump portion.

Group VIII: Claims 167-175 are directed to a pump comprising: a magnetic circuit return structure; a first coil; a second coil; a first magnet; a second magnet; a first actuator; and a second actuator.

Group IX: Claims 194-197 are directed to an optical apparatus comprising: a first deformable optical lens; a barrel; a first set of contact points; and a second set of contact points.

Group X: Claims 198-207 are directed to an optical apparatus comprising: a deformable optical lens having a lens shaper having a top surface, an inner surface, and an outside surface; and a well-defined lens shaper edge.

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2014/047927**

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013-0176628 A1	11/07/2013	None	
US 2010-0232161 A1	16/09/2010	CN 102422185 A CN 102422185 B EP 2406669 A2 EP 2406669 A4 JP 2012-520486 A KR 10-2012-0034596 A TW 201107811 A US 2014-285911 A1 US 8699141 B2 WO 2010-104904 A2 WO 2010-104904 A3	18/04/2012 05/11/2014 18/01/2012 17/10/2012 06/09/2012 12/04/2012 01/03/2011 25/09/2014 15/04/2014 16/09/2010 24/02/2011
US 2007-0263293 A1	15/11/2007	AU 2002-32910 A1 EP 2153252 A1 EP 2162769 A1 EP 2162769 A4 JP 2010-527035 A US 2002-0158866 A1 US 2004-0114203 A1 US 2006-0114534 A1 US 2007-0030573 A1 US 2008-0218873 A1 US 2008-0231963 A1 US 2008-0285143 A1 US 2009-0052049 A1 US 2009-0284489 A1 US 2010-0128357 A1 US 2010-0128358 A1 US 2010-0208357 A1 US 2010-0232031 A1 US 2011-0007161 A1 US 7072086 B2 US 7218429 B2 US 7218430 B2 US 7646544 B2 US 7672059 B2 US 7697214 B2 US 7701643 B2 US 7706077 B2 US 7755840 B2 US 7948683 B2 US 8064142 B2 US 8503875 B2 US 8559115 B2 US 8854423 B2 WO 02-033657 A2 WO 02-033657 A3	29/04/2002 17/02/2010 17/03/2010 25/01/2012 05/08/2010 31/10/2002 17/06/2004 01/06/2006 08/02/2007 11/09/2008 25/09/2008 20/11/2008 26/02/2009 19/11/2009 27/05/2010 27/05/2010 19/08/2010 16/09/2010 13/01/2011 04/07/2006 15/05/2007 15/05/2007 12/01/2010 02/03/2010 13/04/2010 20/04/2010 27/04/2010 13/07/2010 24/05/2011 22/11/2011 06/08/2013 15/10/2013 07/10/2014 25/04/2002 06/09/2002

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2014/047927**

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		WO 2005-015267 A2	17/02/2005
		WO 2005-015267 A3	30/06/2005
		WO 2008-138005 A1	13/11/2008
		WO 2008-138010 A1	13/11/2008
		WO 2010-123920 A2	28/10/2010
		WO 2010-123920 A3	24/02/2011
JP 2005-258049 A	22/09/2005	US 2006-0028736 A1	09/02/2006
		US 7110191 B2	19/09/2006
EP 2559405 A2	20/02/2013	AU 2003-300879 A1	09/07/2004
		AU 2003-300879 B2	22/07/2010
		AU 2005-299661 A1	04/05/2006
		AU 2006-265668 A1	11/01/2007
		AU 2006-304339 A1	26/04/2007
		AU 2007-340043 A1	10/07/2008
		AU 2010-235988 A1	11/11/2010
		CA 2507694 A1	01/07/2004
		CA 2507694 C	31/07/2012
		CA 2584472 A1	04/05/2006
		CA 2613580 A1	11/01/2007
		CA 2626269 A1	26/04/2007
		CA 2674816 A1	10/07/2008
		CN 101547663 A	30/09/2009
		CN 101547663 B	08/10/2014
		EP 1585563 A2	19/10/2005
		EP 1585563 A4	21/03/2012
		EP 1816984 A2	15/08/2007
		EP 1906882 A2	09/04/2008
		EP 1948084 A2	30/07/2008
		EP 2094193 A2	02/09/2009
		EP 2559405 A3	26/06/2013
		JP 2006-518222 A	10/08/2006
		JP 2008-517663 A	29/05/2008
		JP 2008-544817 A	11/12/2008
		JP 2009-511230 A	19/03/2009
		JP 2010-514507 A	06/05/2010
		JP 4480585 B2	16/06/2010
		US 2004-0169816 A1	02/09/2004
		US 2005-0119740 A1	02/06/2005
		US 2006-0041307 A1	23/02/2006
		US 2006-0100701 A1	11/05/2006
		US 2007-0010880 A1	11/01/2007
		US 2007-0106377 A1	10/05/2007
		US 2007-0203578 A1	30/08/2007
		US 2007-0213817 A1	13/09/2007
		US 2008-0015689 A1	17/01/2008
		US 2008-0046074 A1	21/02/2008
		US 2008-0046075 A1	21/02/2008
		US 2010-0228346 A1	09/09/2010

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2014/047927**Patent document  
cited in search reportPublication  
datePatent family  
member(s)Publication  
date

US 2010-0324672 A1	23/12/2010
US 7122053 B2	17/10/2006
US 7217288 B2	15/05/2007
US 7247168 B2	24/07/2007
US 7261737 B2	28/08/2007
US 7485144 B2	03/02/2009
US 7637947 B2	29/12/2009
US 8361145 B2	29/01/2013
US 8454688 B2	04/06/2013
WO 2004-054471 A2	01/07/2004
WO 2004-054471 A3	26/02/2009
WO 2006-047383 A2	04/05/2006
WO 2006-047383 A3	14/12/2006
WO 2007-005778 A2	11/01/2007
WO 2007-005778 A3	15/11/2007
WO 2007-047530 A2	26/04/2007
WO 2007-047530 A3	23/04/2009
WO 2008-077040 A2	26/06/2008
WO 2008-077040 A3	12/09/2008
WO 2008-082957 A2	10/07/2008
WO 2008-082957 A3	24/12/2008