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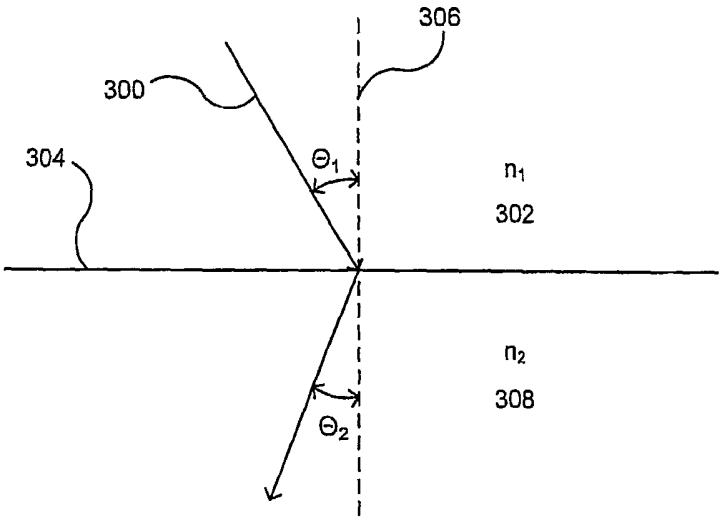
(88) Date of publication of the international search report:
26 January 2006

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

(54) Title: REFRACTIVE BOUNDARY ELEMENTS, DEVICES, AND MATERIALS



(57) Abstract: An optical device includes an interface (304) between two or more media (302 and 308). The refractive indices (n1 and n2), orientations of media, and alignment relative to a propagating wave (300) define a refractive boundary at which reflections may be reduced or eliminated, and at which, for certain incident angles, rays may be refracted on the same side of the normal (306) as the incident ray (300).

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INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : G02B 05/30
US CL : 359/494
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)
U.S. : 359/494,495,485,487,488; 349/16,193,194

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)
EAST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 6,667,095 B2 (WHEATLEY et al) 23 December 2003 (23.12.2003) fig. 1 and tables I and III	1,2,4, 8, 11-32 --- 44-51, 53, 60-64
Y	US 4,582,655 (GREENER) 15 April 1986, column 3, line 14-column 6, line 66 and table I	44-51, 53, 60-64
X	ZHANG, FLUEGEL and MASCARENHAS, "Total Negative Refraction in Real Crystals for Ballistic Eleckons and Light'' Physical Review Letters, No. 15, October 10, 2003, Doc. No. 157404 (pp. 1-4), especially fig. 3.	1-3, 5-8
A	US 2003/0227415 A1 (Joannopoulos et el) 11 December 2003 (11.12.2003), fig. 1	1-32, 44-64
A	HOUCK, BROCK, and CHUANG, "Experimental Observations of a Left-handed Material That Obeys Snell's Lam'' Physical Review Letters, No. 13, April 4, 2003, Doc No. 137401 (pp. 1-4)	1-32, 44-64
A	PENDRY, J.B., "Negative Refraction Makes a Perfect Lens'' Physical Review Letters, No. 18,-October 30, 2000, pp. 3966-3969	1-32, 44-64

☒ 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 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

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INTERNATIONAL SEARCH REPORT

International application No.
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C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SHELBY, SMITH, and SCHULTZ, "Experimental Verification of a Negative Index of Refraction,'' Science, Vol. 292, April 6, 2001, pp. 77-79	SHELBY, SMITH, and SCHULTZ, "Experimental Verification of a Negative Index of Refraction,'' Science, Vol. 292, April 6, 2001, pp. 77-79
A	LIU, Zheng; "Negative Refraction and Omnidirectional Total Transmission at a Planar Interface Associated with a Uniaxial Medium,'' Physical Review B 69, March 4, 2004, Doc. No. 115402 , 6 pp.	SHELBY, SMITH, and SCHULTZ, "Experimental Verification of a Negative Index of Refraction,'' Science, Vol. 292, April 6, 2001, pp. 77-79

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US05/08585

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.: 9,10,52 and 54-59
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:
Not all variables were defined.

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:
Please See Continuation 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 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.: 1-32 and 44-64

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.
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BOX III. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claim(s) 1-38, 44-64 and 65-69, drawn to an optical element/apparatus for interacting with electromagnetic energy.

Group II, claim(s) 39-43, drawn to a method of producing a refractive element.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The inventions are related a process of making and product made and are distinct because the product as claimed could be made by another materially different process as evidenced by Ishikawa et al. US 6,831,722

Further within Group I, this application contains claims directed to more than one species of the generic invention. These species are deemed to lack unity of invention because they are not so linked as to form a single general inventive concept under PCT Rule 13.1.

In order for more than one species to be examined, the appropriate additional examination fees must be paid. The species are as follows:

Species I, claim(s) 1-32 and 44-64

Species II, claim(s) 33-38

Species III, claim(s) 65-69

The species listed above do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, the species lack the same or corresponding special technical features for the following reasons:

Species I, claim(s) 1-32 and 44-64 is drawn to an optical element with two layers and three optical indices of refraction related by a geometric mean.

Species II, claim(s) 33-38 is drawn to an optical element with two portions and four permittivities satisfying a specific relationship.

Species III, claim(s) 65-69 is drawn to an apparatus for interacting with electromagnetic energy with three or more sections having different electromagnetic parameters.