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Declaration under Rule 4.17:
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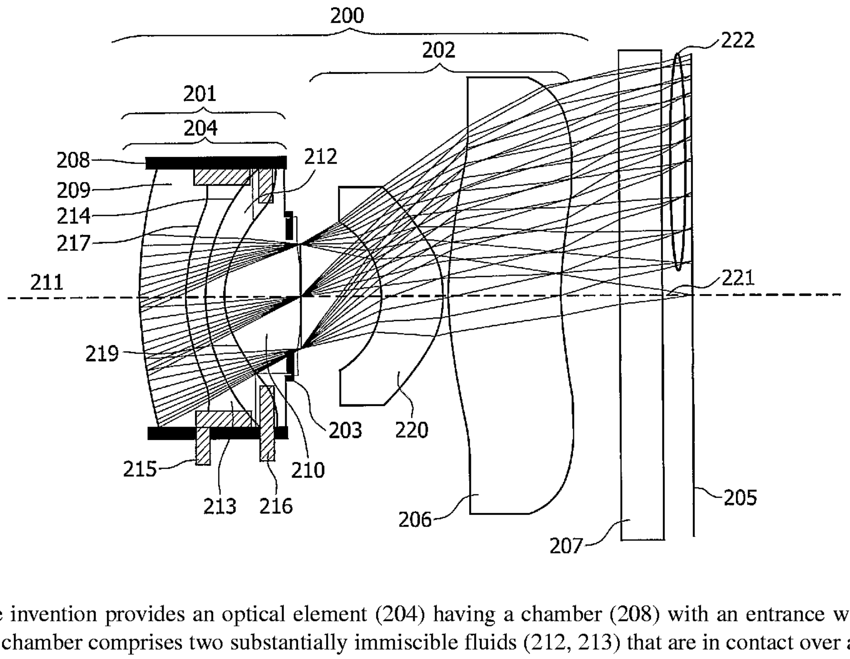
[Continued on next page]

(54) **Title:** VARIABLE OPTICAL ELEMENT COMPRISING IMMISCIBLE FLUIDS



(57) **Abstract:** The invention provides an optical element (204) having a chamber (208) with an entrance window (209), an exit window (210). The chamber comprises two substantially immiscible fluids (212, 213) that are in contact over a meniscus (214). At least one of the entrance window (209) or exit window (210) comprises a surface with a curvature (217, 219) that is in contact with one of the fluids. The Abbe-number of the material of this at least one of the entrance and exit windows (209, 210) has a substantial difference with the Abbe-number of the fluid being in contact with the surface having a curvature. By selecting and tuning several optical parameters such as radius, refractive index and Abbe numbers related to these windows and fluids it is possible to design a substantially achromatic optical element or optical lens system.

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CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

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VARIABLE OPTICAL ELEMENT COMPRISING IMMISCIBLE FLUIDS

FIELD OF THE INVENTION

The present invention relates to a variable optical element comprising a first fluid and a second fluid which are in contact over a meniscus, to a lens system including such an optical element, to an imaging system including such an optical lens system, and to a method of designing such a variable optical element, lens system and optical imaging system.

BACKGROUND OF THE INVENTION

A variable lens is a device in which one or more properties of the lens can be controllably adjusted, e.g. in which the focal length or the position of the lens can be altered.

The general trend in the development of image sensors for camera modules is that they constantly increase in resolution. Starting from low-resolution sensors such as the 100k-pixels range CIF image sensors and 300k-pixel range VGA image sensors, there are presently high-resolution, mega-pixels image sensors available. These higher resolutions not only require a focusing function of the optical lens system in order to be able to employ the high resolution over the entire object distance range (e.g. 10 cm to infinity), they also require a lens system containing at least two aspherical lenses to meet other optical performance requirements, such as related to aberrations.

In the international patent application WO2003/069380 a camera module containing an electrowetting lens enclosed by curved lenses as variable lens system is disclosed. An applied voltage controls the shape of the meniscus between both fluids of the electrowetting lens and therefore the optical power of the electrowetting lens. As a result by using such an electrowetting lens in an imaging system, the variable meniscus radius is able to fulfill the focusing requirement and therefore it is possible to remove the defocus of the image. As the meniscus of an electrowetting lens is substantially spherical, it will not significantly contribute to removing optical aberrations in the image such as coma, distortion and spherical aberration.

The known electrowetting lens has limited magnification, field flattening and aberration reduction possibilities due to the limited number of optical surfaces. As a result, the module is only suitable for low-resolution cameras such as CIF and VGA. For cameras with for higher resolution sensors such as the 500k-pixel range (S)VGA image sensors, the 1M-pixel range XGA image sensors and mega-pixel devices this is not sufficient.

In the US-patent application US2001/017985 a camera lens stack is disclosed containing an electrowetting lens, having flat entrance and exit windows, and containing separate lens groups in front and behind the electrowetting lens. The focusing is performed through movement of the first lens group. The electrowetting lens has a zoom function. It is not contributing to an improvement of other optical performances

None of the above disclosures addresses the problem of achromatization, which is needed to achieve a good optical color correction of the imaging lens system.

Achromatization is the reduction of the dispersive optical power in an optical system. A dispersive optical power is resulting from the dependence of refractive index n of the materials of the optical elements on the wavelength of the light. The Abbe-number V can express this wavelength dependence:

$$V = \frac{n(\lambda_d) - 1}{n(\lambda_F) - n(\lambda_C)} \qquad (1)$$

where $n(\lambda_i)$ is the refractive index at wavelength λ_i, with λ_d=587.6nm, λ_F=486.1nm and λ_C=656.3nm. The dispersion must be well corrected in order to obtain a high optical quality. Conventional lens systems employ grating structures susceptible to haze, or costly doublet components for color correction.

For example, a conventional lens system is rendered achromatic by forming a cemented doublet or by combining an ordinary refractive lens and a diffractive lens. For the cemented doublet, normally the two elements forming the lens have substantially the same refractive index and different Abbe-numbers. In order to provide achromatization, the optical powers K1 and K2 and the Abbe-numbers V1 and V2 of the two elements are chosen such that they comply with the equation:

$$\frac{K1}{V1} + \frac{K2}{V2} = 0 \qquad (2)$$

Another method to achromatize a refractive lens is by adding a diffractive structure. The Abbe number of a diffractive lens depends only on the range of wavelengths used in the application and the Abbe number has a fixed value of −3.452 for the range required for camera modules.

Both the above mentioned methods for providing an achromatic lens system are not applicable for electrowetting lenses, because in electrowetting lenses the optical power changes with the radius of the meniscus between the two fluid depending on the applied voltage, while the above mentioned methods apply to fixed optical power lenses only.

In a not pre-published European patent application EP 04100100.9 (applicant's reference PHNL040008) an electrowetting lens is proposed that has achromatic properties. It discloses such a system can be made achromatic by tuning the optical properties (e.g. Abbe-numbers) of the liquids involved e.g. mixing or dissolving well-chosen substances for the liquids. Fluid-based variable lenses make up a lens system that can be made achromatic. For instance, to make the interface between the fluids achromatic the refractive index n and Abbe-number V for the fluids 'i' and 'n' must obey the relation:

$$\frac{V_i}{V_n} = \frac{n_i - 1}{n_n - 1} \quad (3)$$

For an electrowetting lens with flat entrance and exit windows surfaces it is sufficient to achromatize only the fluid-fluid interface. For electrowetting lenses with curved entrance and exit window surfaces this will result in non-optimal achromatic properties.

It is an object of the invention to provide a variable lens system that has substantial achromatic properties.

SUMMARY OF THE INVENTION

The object of the invention is achieved by an optical element having a chamber having an entrance window, an exit window and an optical axis extending longitudinally through the chamber, the chamber containing a first fluid and a second fluid in contact over a meniscus extending transverse the optical axis, the fluids being substantially immiscible, at least one of the entrance window or exit window comprising a surface being in contact with one of the first or the second fluid, said surface having a curvature, and the Abbe-number of the material of said at least one of the entrance and exit windows having a substantial difference with the Abbe-number of the fluid being in contact with the surface having a curvature.

When the Abbe-numbers of the curved window surface and the contacting fluid are substantially equal, it is not possible to use this interface for achromatization of the optical element or the total optical lens system. In case the Abbe-numbers of the curved window surface and the contacting fluid are substantially different, it is possible to use these optical properties in the overall design to achieve a substantial achromatized optical lens system.

A final overall design of an optical lens system is usually the result of an optimization of all aspects of the imaging in order to meet the system specifications related for example to, resolution, field of view, maximum chief-ray angles and optical aberrations such as distortion, spherical aberration and chromatic aberrations.

It can therefore be necessary to tune the optical properties of the fluids and lens materials involved, by choosing for example suitable materials for the lenses or mixing or dissolving well-chosen substances for the fluids, such that the total optical lens system can be made substantially achromatic and the use of costly conventional achromatization methods is avoided.

When curved surfaces are allowed for the entrance and/or exit windows of the electrowetting lens, it is also possible to tune these curvatures with respect to the overall optical design of the system for optimizing of other aberrations such as distortion, spherical aberration or field curvature. The curved surfaces can for example be spherical or aspherical.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 schematically shows an optical lens system according to the invention.

Figure 2 shows the wavefront aberrations of an optical lens system design according to the invention.

Figure 3 shows the modulus of the optical transfer function for different wavelengths of an optical lens system design according to the invention.

Figure 4 illustrates a variable focus image capture device including an optical lens system according to the embodiments of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 schematically shows an optical lens system according to the invention. The optical lens system (200) comprises two lens groups 201 and 202 and a stop 203 located between the first and second lens group. The first lens group 201 comprises a variable lens, such as an electrowetting lens 204, and acts as a variable focus lens. The second lens group 202 determines the optical magnification using a lens 220 to match size of the images with the size of the image sensor 205 located behind the optical lens system. Also it reduces the chief-ray angle by means of a field-flattening lens 206. The image sensor 205 is covered with a transparent cover 207, for example a plane-parallel plate.

The electrowetting lens 204 has a chamber 208 provided with an entrance window 209 and an exit window 210, and an optical axis 211 extending longitudinally through the chamber. The chamber contains a first fluid 213 and a second fluid 212 in contact over a meniscus 214 extending transverse the optical axis. The radius of curvature of the surface of the entrance window 217 being in contact with the first fluid 213, has the same sign as the curvature of the meniscus 214 between the first and second fluid. Also the curvature of the surface of the exit window 219, being in contact with the second fluid 212, has the same sign as the curvature of the meniscus 214 between the first and second fluid. This leads to a reduction of the building height. The windows as well as the lenses can be made of glass, plastic or other suitable material.

The two fluids 212 and 213 used are being substantially immiscible. The first fluid 213 is an electrically insulating fluid, such as silicone oil or an alkene referred to herein as oil, and the second fluid 212 is an electrically conducting fluid, such as water containing a salt solution. The two fluids preferably have an equal density, so that the lens operates independently of its orientation, i.e. without dependency on gravitational effects on the fluids. Depending on the requirements of the optical system the design can also lead to a situation in which the first fluid can be the electrically isolating fluid and the second fluid the conducting fluid.

A first electrode 215 in the chamber is typically a cylinder with a radius between 1 and 20mm, but can have a different shape, for instance conical, depending on the shape and geometry of the chamber. Electrode 215 is electrically insulated from the fluids by an insulating coating, for instance formed of parylene-N covered with a hydrophobic top coating of AF-1600. A second, usually annular electrode 216 is arranged at an end of the chamber, in this case near the exit window. This second electrode 216 is arranged with at least one part in connection with the second fluid 212. This connection may be a direct contact, or a capacitive coupling over a thin insulating layer.

When no voltage is applied to the electrodes 215 and 216, the fluids are in contact over a meniscus 214 having a curvature. The meniscus can be changed to have a smaller or larger radius of curvature by applying a voltage over the electrodes. Further, a plurality of different shapes of the meniscus can be realized, dependent on the configuration of the chamber and the arrangement of the electrodes

When using curved surfaces for at least one of the entrance or exit window the surfaces of the optical element may take part in the overall optical design. The curvatures of the windows may be used as extra number of degrees of freedom for the optical design to optimize the optical performance of the optical lens system. The curvatures of the windows may be adapted for aberration corrections by applying aspherical surfaces and achromatization of the electrowetting lens, the lens group in which it is applied, or even the total optical lens system.

The optical element may be used in an optical lens system that can comprise more lenses with optical power. It is the object of the invention that the optical element not only acts as a focusing or zooming device, but that it may also act as chromatic aberration reduction element for the other elements in the optical lens system.

A refractive index difference between the materials of the curved window and contacting fluid gives the interface some optical power. A substantially equal refractive index for both materials will result in substantially no optical power of the interface. However, in both cases a difference in Abbe-number will result in a difference in optical power for the different wavelengths. This difference in optical power for the different wavelengths can be used to correct the chromatic aberrations of the system.

Typically, camera lenses are designed with positive lenses made from a glass or a plastic, and having positive radii and being in contact with air. Air under normal conditions has high Abbe-number of about 90. This results only in positive contributions to the chromatic aberration. Negative contributions for compensation can for example be introduced by applying buried lens-lens interfaces in a doublet with suitable interface radius as well as refractive indices and Abbe-numbers matching the design. The number of usable glasses and plastics are limited, and the use of doublets is not cost effective.

In this invention the combination of the optical parameters of the fluids and the optical properties of the window materials is used to obtain a cost effective substantial achromatic optical lens system. The optical lens system may comprise the optical element only or the optical element and one or more refractive or diffractive elements.

Generally, depending on the choice of the oil used as a fluid, the refractive index of the oil may vary between 1.25 and 1.65. Likewise, depending on the type and amount of salt added, the salt solution used as the other fluid may have a refractive index varying between 1.32 and 1.50. Similarly, additives to the oil or the salted solution can change the Abbe-number of the fluid. This means that there is a possibility to tune the optical parameters of the applied fluids over a wide range to match the design on chromatic aberrations.

To be able to have sufficient freedom in choosing the appropriate lens materials and fluids for the optical lens system design it is preferred to allow a wide range of refractive indices. This can result for example in a substantial difference in refractive index of the material used for the window and the contacting fluid. The requirement for achromatization in formula (3) can also be written as

$$\frac{\Delta V}{V_n} = \frac{\Delta n}{n_n - 1} \qquad (4)$$

were ΔV is the difference in Abbe-number of material n and i, and Δn the difference between the refractive index of material n and i. Allowing a substantial difference in refractive indices also requires a substantial difference in Abbe-numbers for the window and fluid to optimize the design for a substantially achromatized electrowetting lens.

The choice of materials for windows, fluids and curvatures may also be optimized for substantially achromatizing the total optical lens system. In that case the requirement as given in formula (2) has to be adapted to for example all surface in the optical lens system. The requirement for an achromatic lens system design then is

$$\sum_i \frac{K_i}{V_i} + \sum_j \left[\frac{(n_j - 1)}{R_j V_j} - \frac{(n_{j+1} - 1)}{R_j V_{j+1}} \right] = 0 \qquad (5)$$

where K_i is the optical power and V_i the Abbe number of conventional lens element i, and j sums over all the fluid menisci present in the optical system. The refractive index and Abbe number of the first fluid are n_j the V_j, respectively and that of the second fluid n_{j+1} the V_{j+1}, respectively while the radius of the meniscus is R_j.

With relative large differences in Abbe-numbers between the window with the curved surface and the contacting fluid it is relative easy to correct the chromatic aberration of the device or system. It also allows the use of smaller radii for surfaces having optical power.

It is therefore preferred that the difference in Abbe-numbers between the window with the curved surface and the contacting fluid is larger than 5.

It is even more preferred that the difference in Abbe-numbers between the window with the curved surface and the contacting fluid is larger than 10.

Figure 1 shows an example of a design according to the invention. It is a F/2.8, f=3.97mm auto focus camera lens with 66 degrees field of view, an entrance pupil of 1.42mm and a building height of 6.5mm to be used in combination with a mega-pixel type image sensor. All lenses (209, 210, 220, 206) have aspherical surface in order to optimize the optical quality of the image. The meniscus 214 is substantially spherical. The Abbe-number of the enclosing plastic lenses 209 and 210 of the electrowetting lens 204 is 55.8 and their refractive index is about 1.532 at a 560nm wavelength. The conducting fluid 212 comprises salted water and has an Abbe-number of 38 and a refractive index of 1.376 at 560nm wavelength, while the Abbe-number of the first non-conducting fluid 213, which is a silicone oil, is 28 with a refractive index of 1.552 at 560nm wavelength. By proper choice of the radii of the lenses the optical system can be made substantially achromatic.

Figure 2 shows the wavefront aberrations of the optical lens system according to the above design. Wavefront aberrations W in micrometers versus the normalized entrance pupil coordinate Px respectively Py are plotted for three wavelengths 490nm, 560nm and 625nm. In Figure 2a this is shown for a field angle of 0 degrees and in Figure 2b for a field angle of about 33 degrees. The maximum scale in vertical direction of both diagrams is 50 micrometer. These graphs show that the aberrations for the different wavelengths have the same tendency and that the differences of the aberrations between the different wavelengths are sufficiently small to have a substantially achromatized optical lens system.

Figure 3 shows the calculated modulus of the polychromatic optical transfer function of the optical lens system according to the above design, averaged over three relevant wavelengths 490nm, 560nm and 625nm, as a function of the amount of lines per millimeter for a number field angles up to about 33 degrees for both the Px direction and the Py direction. It shows two groups of lines 301 and 302. The group of line 301 are the polychromatic optical transfer functions in the Py direction for angles of 20, 29 and 33 degrees. The group of lines 302 are the polychromatic optical transfer functions in the Px direction for angles of 0, 10, 20, 29 and 33 degrees, as well as in the Py direction for angles of 0 and 10 degrees. It shows that up to 75 lines/mm the modulation is sufficient for a mega-pixel imaging application as used in for example a camera in a mobile telephone.

In the above example design all surfaces of both the entrance and exit windows have surface curvatures in order to be able to reduce aberrations, such as distortion and spherical aberration and building height. Depending on the overall system requirements it may also be possible that only a single surface from entrance or exit window has a curvature to reach sufficiently low aberration levels and sufficiently low chromatic aberrations.

Figure 4A illustrates the use of a variable focus image capture device 421 using an optical lens system 400 according to the invention. A measuring signal, such as a focusing signal, may be derived from the image sensor 405 using techniques as commonly used in cameras using image sensors. The measuring signal is used as input signal for a voltage driver 422. The output of the voltage driver is connected to the electrodes 415 and 416 of the electrowetting lens 404 in the optical lens system 400 for controlling the shape of the meniscus 414. Figure 4B shows an example of an application with the variable focus image capture device 421 integrated in the back of a mobile telephone 423. Other integration positions are also possible.

It is possible to make an electrowetting lens substantially achromatic and avoid the use of costly conventional achromatization methods by tuning the optical properties of the fluids and lens materials involved. This tuning can be done by choosing for example suitable materials for the lenses or mixing or dissolving well-chosen substances for the fluids.

It is obvious for the person skilled in the art this method can also be used to substantially achromatize a lens system comprising such an electrowetting lens by taking other optical interfaces also into account.

The optical element is very suitable for use in optical lens systems and optical imaging systems for camera applications. These camera applications can be for example movie or still picture hand-held cameras or mobile telephone cameras for movie or still picture. Especially for mobile telephone with camera applications there is an increasing need for devices that are small size, have high optical quality, have a low energy use and are robust. Absence of mechanically moving parts, for e.g. focusing or zooming, makes the optical element according to the invention robust. Optical lens systems and imaging systems that use the optical element according to the invention can fulfill those needs.

Although the above descriptions use an optical lens system suitable for small mobile camera systems such as for mobile telephone, the invention also can be used to achromatize, reduce aberrations and reduce building height of other optical systems, for example in microscopy and optical recording applications.

In optical storage applications the need for multiple wavelength reading and recording systems is increasing as such systems are required to read and record multiple disc formats, such as CD, DVD and BD. The described invention can for example be used to compensate wavelength dependent aberrations introduced by other optical elements in the optical system of the application.

The above embodiment and example on the variable lens element use the electrowetting principle for altering the shape of the meniscus. Of course, other methods to change the shape of the meniscus between both fluids are considered to fall within the scope of the invention, for example by means of a pump in combination with a conically shaped electrode arranged to alter controllably the shape and the position of the meniscus.

Furthermore, the invention may be applied to fluid-based lenses that work by altering the position of the meniscus instead of the shape.

CLAIMS:

1. An optical element (204) having

- a chamber (208) having an entrance window (209), an exit window (210) and an optical axis (211) extending longitudinally through the chamber;

the chamber comprising a first fluid (213) and a second fluid (212) in contact over a meniscus (214) extending transverse the optical axis, the fluids being substantially immiscible;

- at least one of the entrance window or exit window comprising a surface (217, 219) being in contact with one of the first or the second fluid, said surface having a curvature;

- and the Abbe-number of the material of said at least one of the entrance and exit windows having a substantial difference with the Abbe-number of the fluid being in contact with the surface having a curvature.

2. An optical element according to claim 1, where said difference in Abbe-numbers is larger than 5.

3. An optical element according to claim 1, where said difference in Abbe-numbers is larger than 10.

4. An optical element according to claim 1, being substantially achromatic.

5. An optical lens system comprising an optical element according to any of the preceding claims.

6. An optical lens system comprising an optical element according to claim 1, in which the optical lens system is substantially achromatic.

7. An optical imaging device comprising an optical element according to claim 1, 2, 3 or 4.

8. An optical imaging device comprising an optical lens system according to claim 6.

9. A mobile telephone comprising an optical imaging device according to claim 7 or 8.

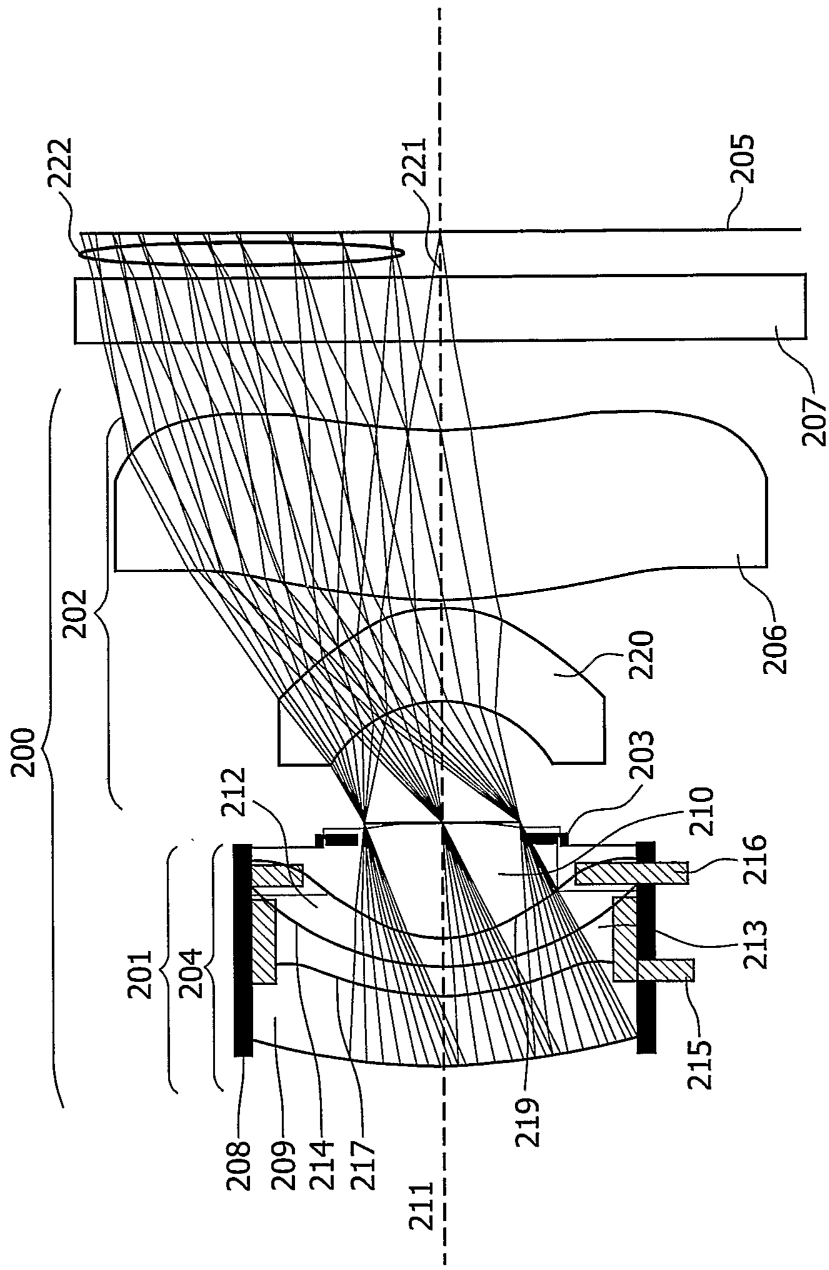
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FIG. 1

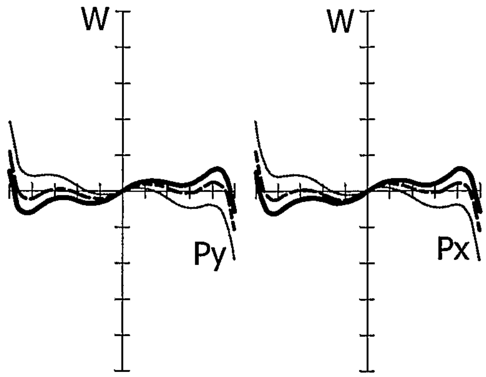

FIG. 2A

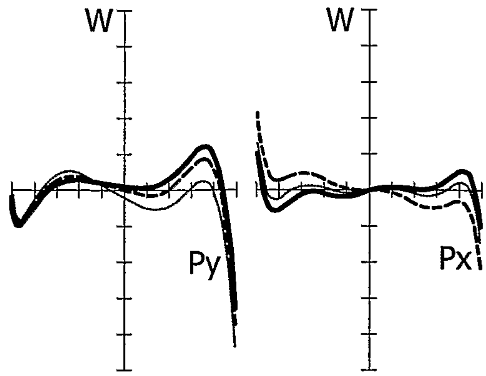

FIG. 2B

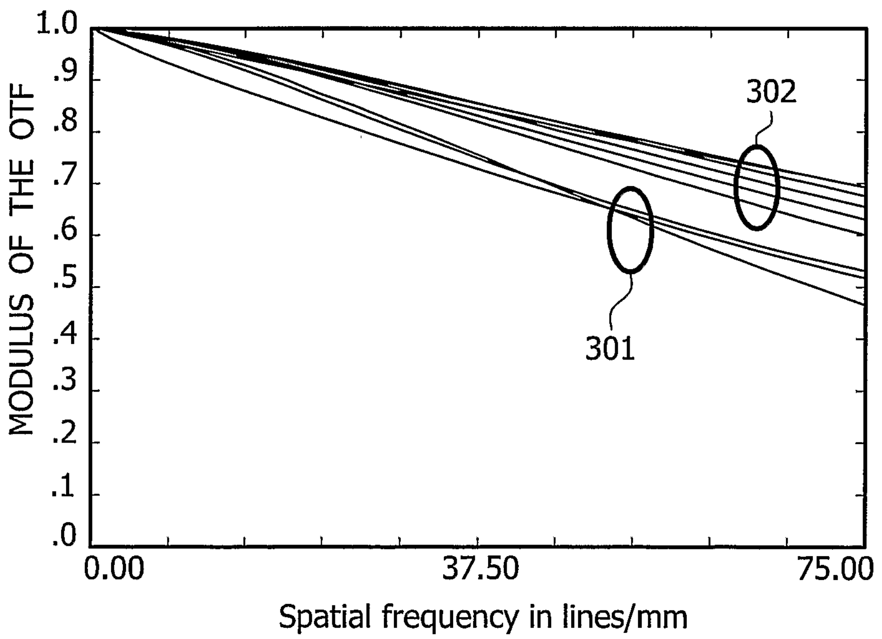

FIG. 3

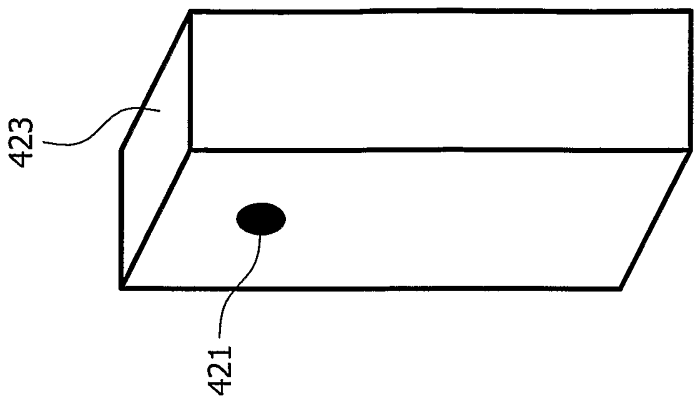

FIG. 4B

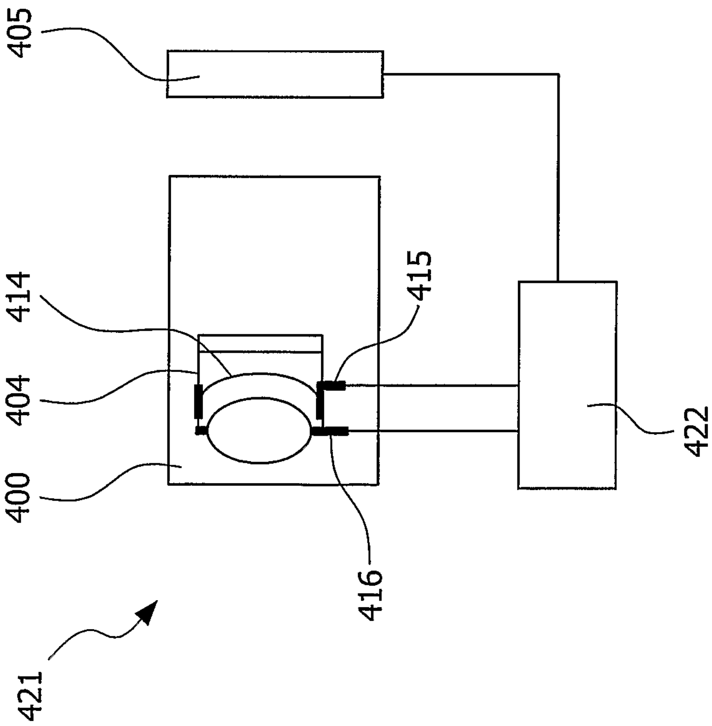

FIG. 4A

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB2005/050760

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B3/14

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 7 G02B

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 practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 03/069380 A (KONINKLIJKE PHILIPS ELECTRONICS N.V; FEENSTRA, BOKKE, J; KUIPER, STEIN) 21 August 2003 (2003-08-21) cited in the application page 4, line 3 - line 14 page 6, line 17 - last line ; figure 4	1-9
X	PATENT ABSTRACTS OF JAPAN vol. 2002, no. 10, 10 October 2002 (2002-10-10) -& JP 2002 169005 A (CANON INC), 14 June 2002 (2002-06-14) abstract; figure 4	1-9

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[X] Further documents are listed in the continuation of box C.

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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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Date of the actual completion of the international search	Date of mailing of the international search report
29 April 2005	09/05/2005

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB2005/050760

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 2001/017985 A1 (TSUBOI TAKAYUKI ET AL) 30 August 2001 (2001-08-30) cited in the application paragraph '0048! - paragraph '0049!; figure 1 paragraph '0083! - paragraph '0084!; figures 7a,7b figure 10a	1-9
P,A	US 2004/227838 A1 (ATARASHI YUICHI ET AL) 18 November 2004 (2004-11-18) paragraph '0078! paragraph '0161! - paragraph '0162!; figure 12 paragraph '0185!; figure 13a; table 1 figure 17a; table 5	1-9
A	US 6 369 954 B1 (BERGE BRUNO ET AL) 9 April 2002 (2002-04-09) abstract; figure 1	1
A	US 4 958 919 A (SIGLER ET AL) 25 September 1990 (1990-09-25) the whole document	1-8
A	PATENT ABSTRACTS OF JAPAN vol. 009, no. 113 (P-356), 17 May 1985 (1985-05-17) -& JP 60 000401 A (CANON KK), 5 January 1985 (1985-01-05) abstract	1-8
A	SAUREI L ET AL: "Design of an autofocus lens for VGA 1/4 -in. CCD and CMOS sensors" PROCEEDINGS OF THE SPIE, SPIE, BELLINGHAM, VA, US, vol. 5249, no. 1, 18 February 2004 (2004-02-18), pages 288-296, XP002285978 ISSN: 0277-786X figure 4a	1,9

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB2005/050760

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 03069380	A	21-08-2003	AU	2003201481	A1	04-09-2003
			EP	1478951	A1	24-11-2004
			WO	03069380	A1	21-08-2003
JP 2002169005	A	14-06-2002	NONE			
US 2001017985	A1	30-08-2001	JP	2001228307	A	24-08-2001
			JP	2001249282	A	14-09-2001
US 2004227838	A1	18-11-2004	JP	2004341201	A	02-12-2004
			JP	2005084387	A	31-03-2005
			WO	2004102246	A1	25-11-2004
US 6369954	B1	09-04-2002	FR	2769375	A1	09-04-1999
			AT	214164	T	15-03-2002
			CA	2306249	A1	15-04-1999
			DE	69804119	D1	11-04-2002
			DE	69804119	T2	28-11-2002
			EP	1019758	A1	19-07-2000
			ES	2171041	T3	16-08-2002
			WO	9918456	A1	15-04-1999
			JP	2001519539	T	23-10-2001
			US	2005002113	A1	06-01-2005
US 4958919	A	25-09-1990	US	5033831	A	23-07-1991
JP 60000401	A	05-01-1985	NONE			