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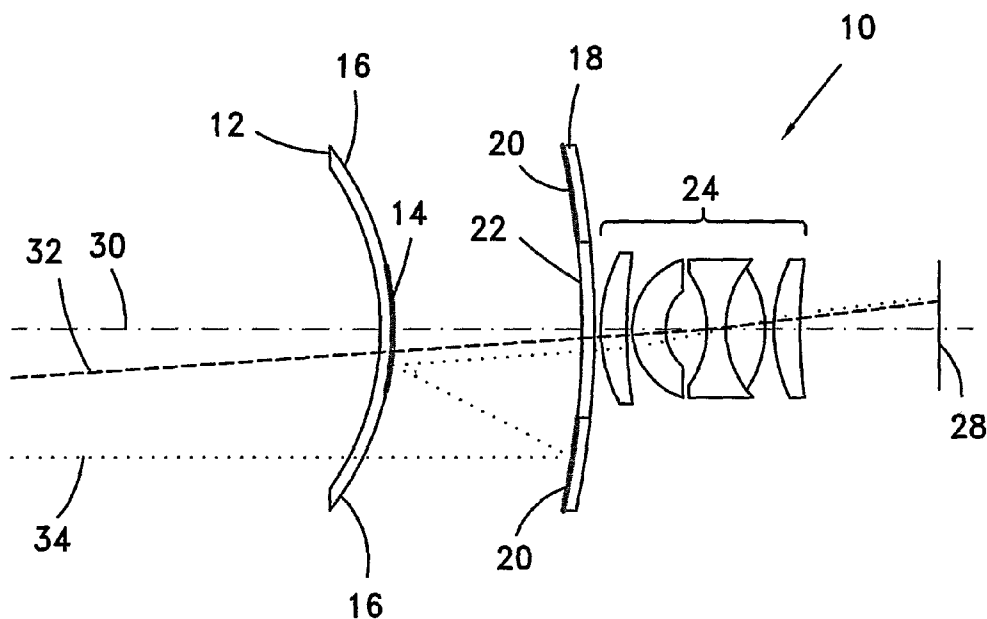
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(54) Title: DUAL FIELD OF VIEW OPTICS



(57) Abstract: The invention is an optical system, which simultaneously captures two images of a scene. The system has no moving parts and each image has a different field of view. The system of the invention comprises a dichroic filter, a single detector, and additional optical elements. The dichroic filter divides the light entering the system into a first spectral range and a second spectral range. The additional optical elements focus the light that enters the system onto the planar surface of the detector, which has a surface comprising a matrix of pixels, each of which comprises at least two subpixels. One of the subpixels is sensitive to light in the first spectral range and the other is sensitive to light in the second spectral range. The first image is captured on the set of subpixels sensitive to the first spectral range and the second image is simultaneously captured on the other set of subpixels.

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## DUAL FIELD OF VIEW OPTICS

### 5 Field of the Invention

The invention is related to the field of optical systems. Specifically the invention is an optical system that provides a dual field of view using a single detector without the use of moving parts.

### 10 Background of the Invention

A familiar requirement of many optical systems is that they be able to provide two images of a scene; the first having a wide field of view at relatively low magnification and the second having a narrow field of view at higher magnification.

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Optical systems that meet these requirements are known in the prior art. For example, EP 0128 815 and GB 2 212 936 are two published patent applications, which describe optical systems similar to that of a Cassegrainian telescope in which the secondary mirror is coated with a dichroic layer that reflects one range of wavelengths and transmits a second range of wavelengths, thereby allowing images having two different fields of view to be focused on a single detector.

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The main problem with the teachings of these two applications is how to separately view the two images focused on the detector a problem whose solution is not address in either publication. A solution to the problem is provided by the inventor of GB 2 212 936 in a later filed application, which eventually issued as US 4,950,056. In the invention described in this patent a pair of Risley prisms are introduced into the optical path of the narrow field of view. Rotation of the prisms shifts the location of image in the image plane and thereby provides spatial separation of the images with the two

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fields of view on the face of the detector. A similar solution is provided in US 5,161,051 by the use of a combination of a wedged plate and a dual filter, which passes light in two different wavelength bands in its top and bottom portions.

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US 5,751,473 also describes an optical system in which images of a scene having two different fields of view are simultaneously focused on a single detector. The optical system described in this publication is more complex than those of the previously described publications. In this patent is  
10 described a cold finger, which is coated in different areas with different coatings, acts as a filter, which causes spatial separation of the two images, each in its own wavelength band, on the detector surface. The detector comprises two detecting layers, the first of which absorbs and detects 3-5  
15 micron radiation and the second layer 8-12 micron radiation. The electronic read-out system connected to the detector array is capable of discriminating between the images by alternately reading the signals from each of the layers of the detector. on which the energy from a particular one of the two wavelength bands falls.

20 In the prior art solutions, in which each of the fields of view is assigned a separate location on the detector, the quality and resolution of each of the images suffers since only a portion (generally on the order of 50%) of the theoretically available pixels are used for each of the images.

25 In one embodiment described in 5,751,473 this drawback is overcome by alternately pivoting part of the optical elements into and out of the optical path from the scene being viewed to the detector. This allows a temporal separation of the images on the entire surface of the detector as opposed to the spatial separation provided by the above described embodiment.  
30 Another method of imaging a scene with two different fields of view is to use two different detectors as is described in US 5,181,145.

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It is therefore a purpose of the present invention to provide an optical system that overcomes the limitations of the prior art by utilizing the entire active surface of a detector to simultaneously provide two images of a scene,  
5 each image having a different field of view.

It is another purpose of the present invention to provide an optical system that requires no moving parts to simultaneously provide two images of a scene, each image having a different field of view.  
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Further purposes and advantages of this invention will appear as the description proceeds.

### **Summary of the Invention**

15 The invention is an optical system, which simultaneously captures two images of a scene, each image having a different field of view. The system of the invention has no moving parts and comprises:

- (a) A dichroic filter that divides the light entering the system into a first spectral range and a second spectral range.
- 20 (b) A single detector having a surface comprising a matrix of pixels, each of the pixels comprising at least two subpixels. The first of the subpixels is sensitive to light in the first spectral range and the second of the subpixels is sensitive to light in the second spectral range.
- 25 (c) Additional optical elements, which focus the light that enters the system on the planar surface of the detector.

The first of the two images is captured on the subpixels that are sensitive to light in the first spectral range and the second of the two images is simultaneously captured on the subpixels that are sensitive to light in the  
30 second spectral range.

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In a preferred embodiment of the optical system of the invention: the light entering the system is in the visible wavelength band, the dichroic filter is a coating on one of the optical elements, the dichroic filter coating transmits blue light and reflects red light, and the detector is a CCD comprising at least subpixels sensitive to blue light and subpixels sensitive to red light.

In a preferred embodiment of the optical system of the invention, the additional optical elements comprise two groups positioned one after the other along on a common optical axis with the detector: a front group comprising a reflective afocal telescope, and a common positive lens assembly focused to infinity located between the front afocal telescope and the detector. The area of the front group surrounding the optical axis has zero optical power for transmitted light and all lenses of the positive lens assembly are corrected for color aberration over the first and second spectral ranges. The afocal telescope comprises: a front lens comprising a dichroic filter coating created on the central portion of the lens and an annular area surrounding the coating that is transparent to the incoming light and a primary mirror comprising an annular reflecting layer surrounding a central area that is transparent to the incoming light.

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All the above and other characteristics and advantages of the invention will be further understood through the following illustrative and non-limitative description of preferred embodiments thereof, with reference to the appended drawings.

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### **Brief Description of the Drawings**

- Fig. 1 shows a small area comprising four pixels of a RGB CCD detector;
- Fig. 2 is a graphical representation showing the relative response to visible light as a function of wavelength for the detector shown in Fig. 1;
- 30 - Fig. 3 schematically shows an optical system according to the present invention; and

- 5 -

- Fig. 4 shows the transmission/reflection curve of a dichroic coating suitable for use in the present invention.

### Detailed Description of Preferred Embodiments

5 The invention is an optical system for simultaneously capturing on a single detector two images of a scene, each image having a different field of view. The system of the invention has no moving parts. A dichroic filter, which is coated on lens surface, is used to divide the light that enters the system into two spectral ranges and a single tricolor (RGB) CCD detector is used to  
10 capture the images.

A standard RGB CCD detector based on a Bayer Filter comprising alternate rows of red and green filters and blue and green filters is used in the device of the invention. In this detector, each pixel is divided into four separate  
15 areas or "subpixels" one of which is sensitive to red, one sensitive to blue, and two sensitive to green. Fig. 1 shows a small area comprising four pixels of such a detector. Fig. 2 is a graphical representation showing the relative response to visible light as a function of wavelength for the detector shown in Fig. 1.

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In Fig. 3 is schematically shown an optical system 10 according to the present invention. The optical system shown in Fig.3 is presented in order to illustrate the principles of the invention and is not meant to limit the invention in any way. Optical system 10 is a dual FOV camera having a  
25 relationship of 1:3 between the two fields of view. The optical system 10 has no moving parts. The scene being viewed is to the left and light arriving from the scene passes through front lens 12, primary mirror 18, and lens set 24 which act together to focus it on the face of RGB CCD detector 28. All of the elements of the system are arranged symmetrically on the optical axis  
30 30.

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Front lens 12 is made of a material that is transparent to visible light, i.e. optical quality glass. On the central area of the back side of front lens 12 a circular dichroic filter coating 14 is created by vacuum deposition or any other technique known in the art. An annular transparent region 16  
5 surrounds the dichroic filter coating 14 on the center of lens 12.

Primary mirror 18 comprises a curved substrate which supports on its front surface a totally reflecting annular reflective area 20 surrounding a central circular transparent area 22. The substrate can be for example made from  
10 optical glass and the reflective area made by vacuum deposition of an aluminum layer. In another embodiment the substrate could be made of metal that is highly polished to create reflective area 20 and a large hole bored in the center to form transparent area 22.

15 The radius of curvature of primary mirror 18 is such that any ray of light that passes through the annular transparent area 16 on the front lens 12 and impinges on annular reflective area 20 will be reflected back towards the front lens and will impinge on the circular dichroic filter coating 14. The radius of curvature of the front lens 12 is such that any ray of light reflected  
20 from circular dichroic filter coating 14 will pass through the transparent area 22 of the primary mirror.

Fig. 4 shows the transmission/reflection curve of a dichroic coating created specifically for use in the present invention. The vertical axis represents the  
25 transmission/reflection as a fraction of the maximum value and the horizontal axis shows the wavelength in nanometers. The transmission of the coating is shown by the solid squares and the reflection by the solid circles. When a beam of visible light impinges on a surface covered with the dichroic coating whose characteristics are shown in Fig. 4, then all of the  
30 blue, some of the green, and none of the red components of the incident beam will pass through the coating and all of the red, some of the green, and

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none of the blue will be reflected. In the remainder of the description the green components will be ignored for simplicity.

Referring to Fig. 3, numeral 32 identifies a typical ray of visible light from the distant scene that impinges on the center of the front lens 12, i.e. is incident on the dichroic filter coating 14. When ray 32 impinges on dichroic coating 14, the red components of the light are reflected backwards and are blocked from passing through the remainder of optical system 10 and reaching the detector 28. The blue component of ray 32 passes through dichroic layer 14, transparent area 22 in the primary mirror 18, and lens group 24 and is focused onto the surface of CCD detector 28.

Numeral 34 identifies a typical ray of visible light from a distant scene that passes through the annular transparent region 16 of the front lens 12. Ray 34 will be reflected by the annular reflective coating 20 on primary mirror 18 onto the dichroic filter coating 14. When the reflected ray encounters dichroic layer 14, the blue component of ray 34 passes through front lens 12 and exits the optical arrangement 10. The red component of ray 34 is reflected from dichroic layer 14 and passes through transparent area 22 in the primary mirror 18 and lens group 24 and is focused onto the surface of CCD detector 28. Both the blue beam 32 and the red beam 33 travel through refractive lens set 24. The lenses of assembly 10 are corrected for color aberration in such a way as to enable the light from both beams to be focused on the same plane. Methods of making these corrections as well as determining the exact design of the number and characteristics of the lens in lens set 24 required for a given camera are well known in the art and therefore will not be further discussed herein. It is also to be noted that, in order to prevent the detection of green light, a filter can be provided at any convenient location in the optical path before the detector. Additionally, the dichroic filter can be designed in many different ways, for example to transmit red and reflect blue or to transmit/reflect green and

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reflect/transmit either red or blue. Also different filters may be applied on the subpixels in order to match dichroic filters and desired spectral ranges.

The term field of "view FOV of the camera" is used to refer to the angular  
5 field of view in radians. For a circular detector,  $FOV = d/f$ , wherein  $d$  is the diameter of the detector and  $f$  is the focal length of the system. For a rectangular detector,  $FOV = h/f \times w/f$ , wherein  $h$  and  $w$  are the height and width respectively of the detector. By comparing the paths of beams 32 and 34 through the optical system 10 it is seen that for the arrangement shown,  
10 ray 32 represents the short focal length path creating the wide field of view (WFOV) image, which will be recorded on the blue subpixels of the CCD and ray 34 represents the long focal length path and narrow field of view (NFOV) image, which will be recorded on the red subpixels of the CCD.

15 In the specific example shown in Fig. 3, the detector is a standard  $\frac{1}{4}$ " CCD and the entire camera can be enclosed within a cylindrical case having a diameter of 20mm and a length of 45mm. The output of the camera then is two simultaneous images; the first a blue image having a WFOV of 7x9 degrees, and the second a red image having a NFOV of 2.3x3 degrees. The  
20 lens set 24 can easily be replaced with another set of lenses that will give other fields of view having the same 3:1 ratio between them, e.g. WFOV of 9x18 degrees and NFOV of 3x6 degrees.

Although a specific embodiment of the invention has been described by way  
25 of illustration, it will be understood that the invention may be carried out with many variations, modifications, and adaptations, without departing from its spirit or exceeding the scope of the claims.

### Claims

1. An optical system having no moving parts which simultaneously captures two images of a scene, each image having a different field of view, said system comprising:
  - 5 (a) a dichroic filter that divides the light entering the system into a first spectral range and a second spectral range;
  - (b) a single detector having a surface comprising a matrix of pixels, each of said pixels comprising at least two subpixels, wherein the first of said subpixels is sensitive to light in said first spectral range and the  
10 second of said subpixels is sensitive to light in said second spectral range; and
  - (c) additional optical elements, which focus said light that enters said system on said planar surface of said detector;wherein, the first of said two images is captured on the subpixels that  
15 are sensitive to light in said first spectral range and the second of said two images is simultaneously captured on the subpixels that are sensitive to light in said second spectral range.
2. An optical system according to claim 3, wherein the light entering the  
20 system is in the visible wavelength band.
3. An optical system according to claim 1, wherein the dichroic filter is a coating on one of the optical elements.
- 25 4. An optical system according to claim 3, wherein the dichroic filter coating transmits blue light and reflects red light.
5. An optical system according to claim 1, wherein the detector is a CCD comprising at least subpixels sensitive to blue light and subpixels  
30 sensitive to red light.

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6. An optical system according to claim 1, wherein the additional optical elements comprise two groups positioned one after the other along on a common optical axis with the detector:

(a) a front group comprising a reflective afocal telescope; and

5 (b) a common positive lens assembly focused to infinity located between said front afocal telescope and said detector,

wherein, the area of said front group surrounding said optical axis has zero optical power for transmitted light and all lenses of said positive lens assembly are corrected for color aberration over the first and second  
10 spectral ranges.

7. An optical system according to claim 6, wherein the afocal telescope comprises:

15 (a) a front lens comprising a dichroic filter coating created on the central portion of the lens and an annular area surrounding said coating that is transparent to the incoming light; and

(b) a primary mirror comprising an annular area that reflects incoming light surrounding a central area that is transparent to said incoming light.

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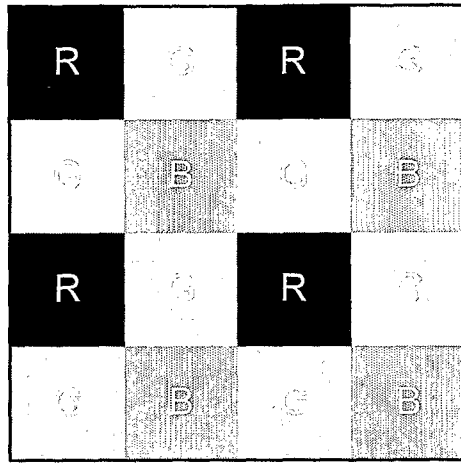


Fig. 1

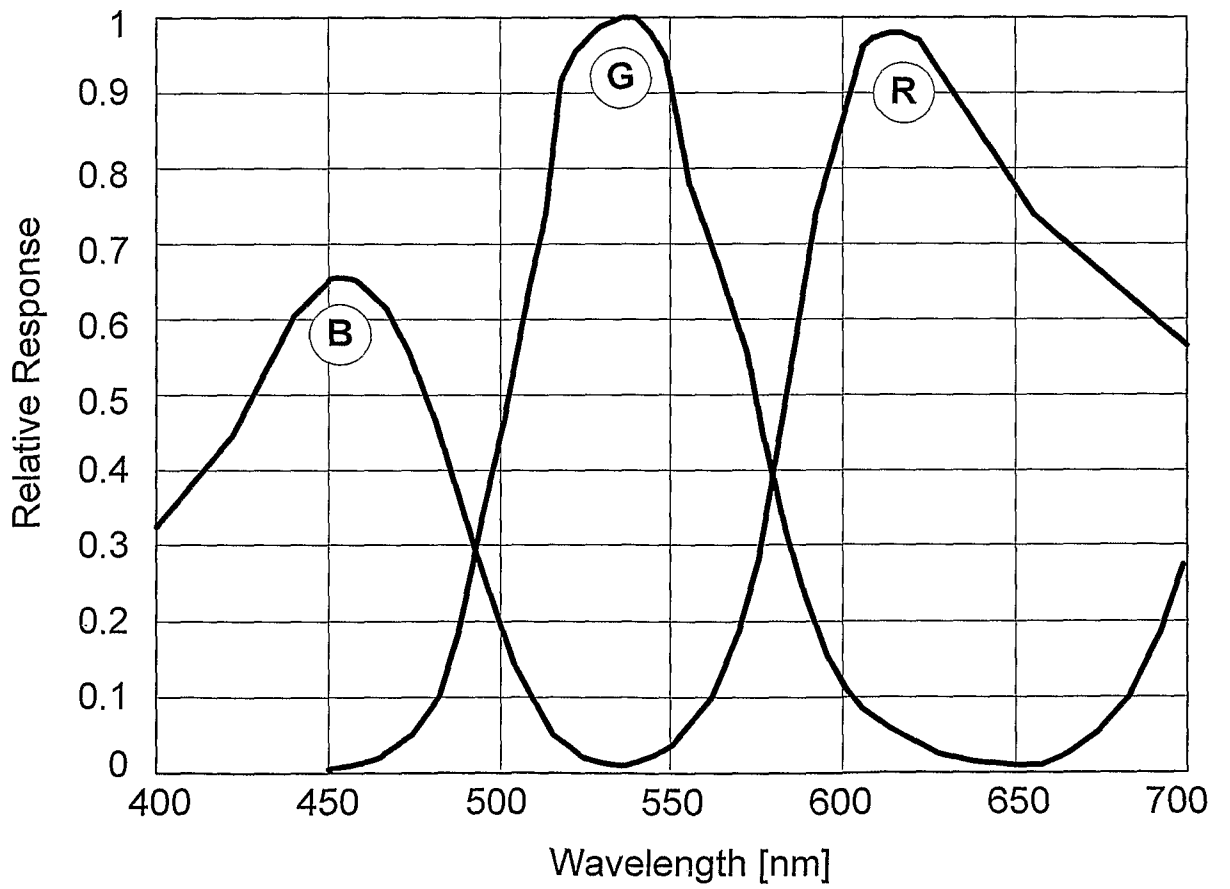


Fig. 2

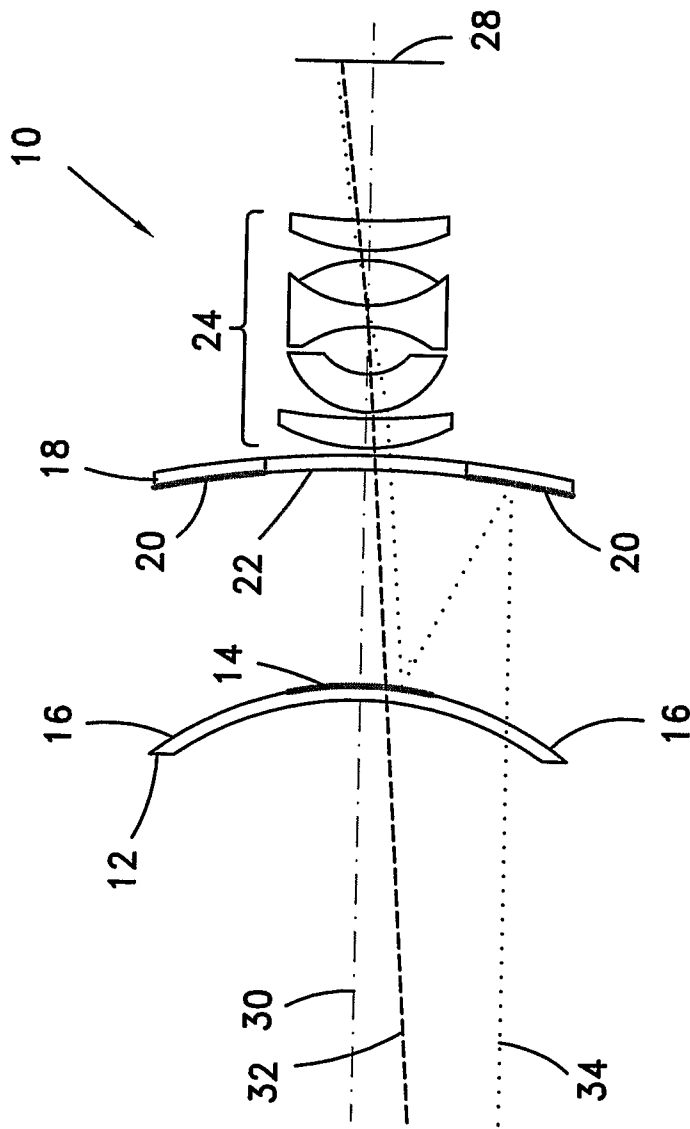


Fig. 3

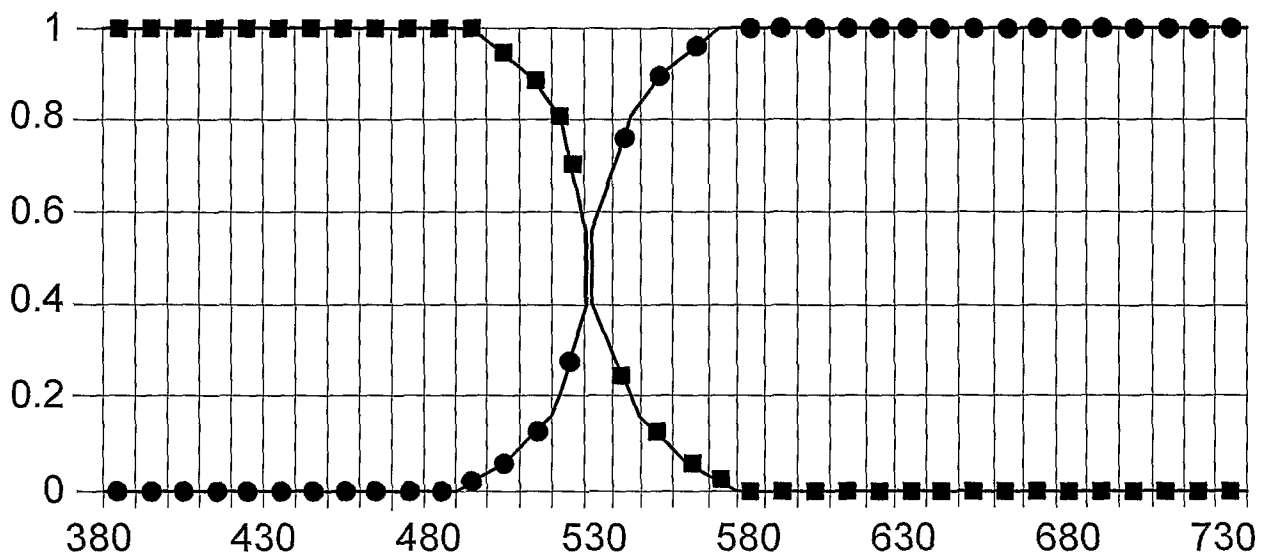


Fig. 4

# INTERNATIONAL SEARCH REPORT

International application No  
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**A. CLASSIFICATION OF SUBJECT MATTER**

INV. G02B17/08  
ADD. H04N1/48 H01L27/00

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

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

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/218686 A1 (LUNDGREN MARK A [US]) 27 November 2003 (2003-11-27)	1,2,5
Y	paragraph [031Y]; figure 4	3,4,6,7
Y	EP 0 128 815 A (REOSC [FR]) 19 December 1984 (1984-12-19) cited in the application page 2, line 1 - page 3, line 6; figure 1	3,4
Y	US 4 453 800 A (FJELDSTED THOMAS P [US]) 12 June 1984 (1984-06-12) column 3, line 67 - column 6, line 63	6,7
A	EP 0 490 497 A (HUGHES AIRCRAFT CO [US]) 17 June 1992 (1992-06-17) cited in the application column 2, line 47 - column 5, line 8; figures 1-3	1-7
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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
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## INTERNATIONAL SEARCH REPORT

International application No  
PCT/IL2006/000885

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 956 555 A (WOODBERRY FRANK J [US]) 11 September 1990 (1990-09-11) column 2, lines 5-36; figure 1 -----	1-7

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/IL2006/000885
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