Spatioangular Resolution Tradeoff in Integral Photography

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Presentation at EGSR 2006

Early work on integral photography

F. Ives (1903)

G. Lippmann (1908)

Nov. 14, 1933. C. W. KANOLT 1,935,471

PRODUCTION OF STEREOSCOPIC PICTURES

Filed Aug. 7, 1930 3 Sheets-Sheet 1

Fig. 1.

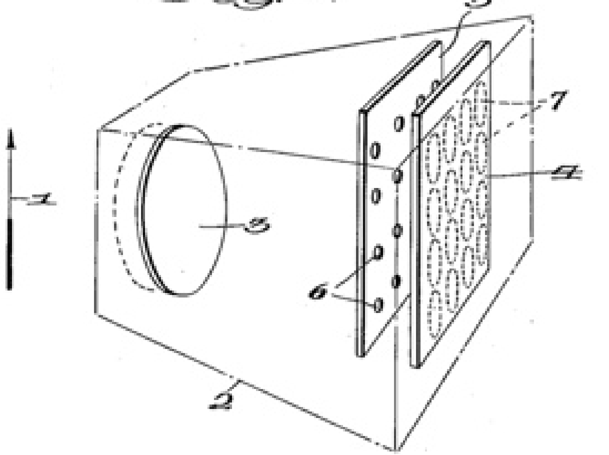


Fig. 2.

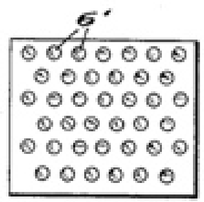


Fig. 3.

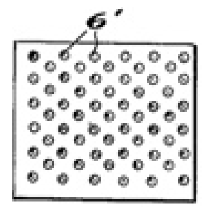


Fig. 4.

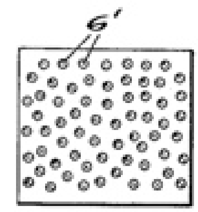


Fig. 5.

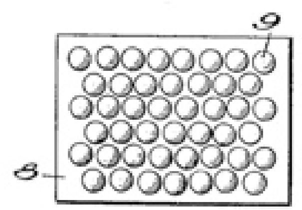
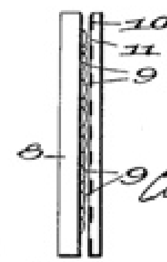


Fig. 6.



Inventor

Clarence W. Kanolt

By Vernon E. Hodges

Attorney

Dec. 15, 1936. D. F. W. COFFEY 2,063,985

APPARATUS FOR MAKING A COMPOSITE STEREOGRAPH

Filed May 24, 1935 4 Sheets-Sheet 3

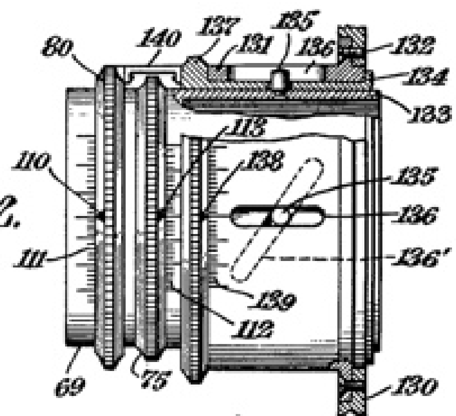


Fig. 22.

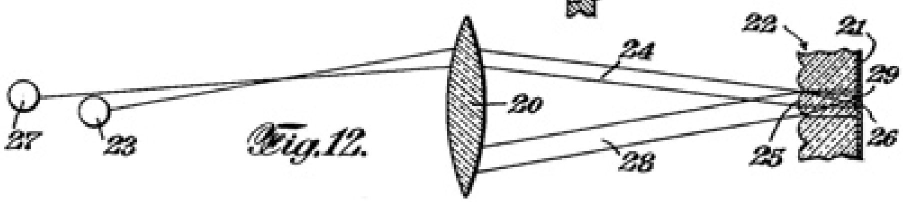


Fig. 12.

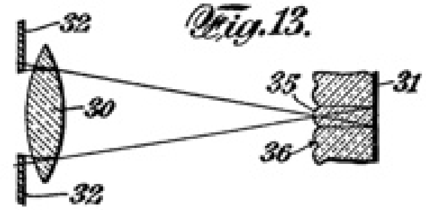


Fig. 13.

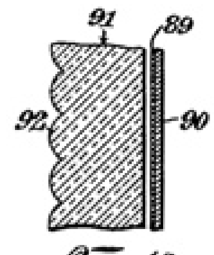
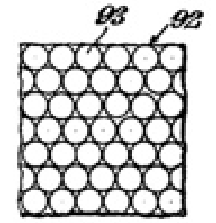


Fig. 16.



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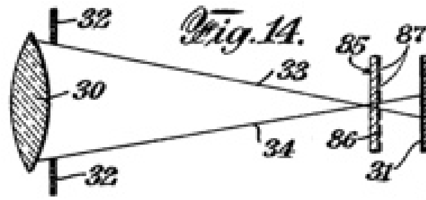
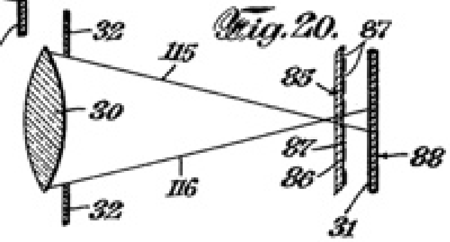


Fig. 14.



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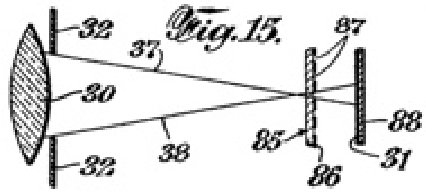


Fig. 15.

INVENTOR

Douglas Fredwill Winnek Coffey

BY

Kenyon & Kenyon

ATTORNEYS

Nov. 22, 1955 J. T. GRUETZNER **2,724,312**

MEANS FOR OBTAINING THREE-DIMENSIONAL PHOTOGRAPHY

Filed May 7, 1952 2 Sheets-Sheet 1

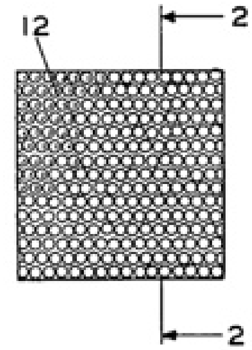


FIG. 1

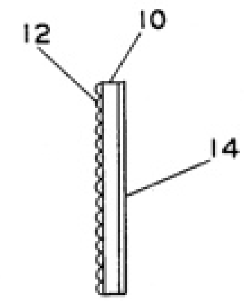


FIG. 2

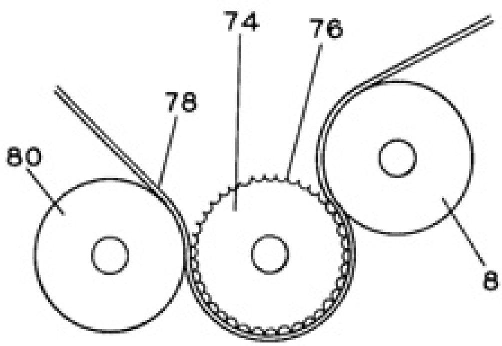


FIG. 7

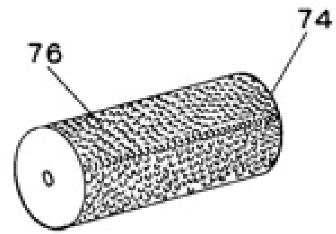


FIG. 8

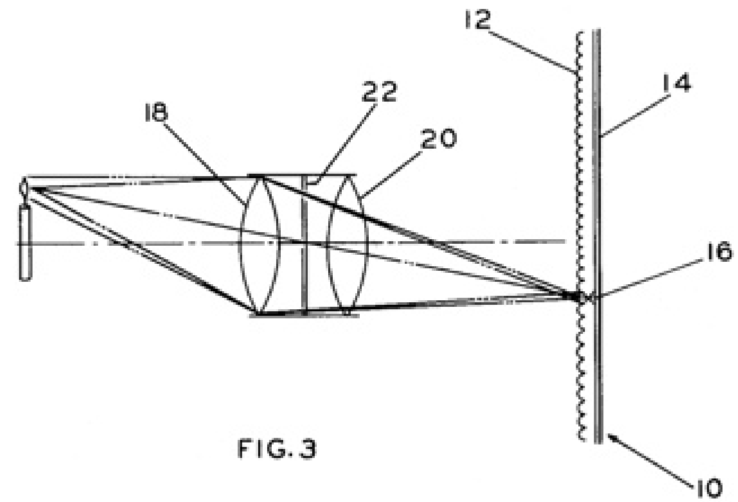
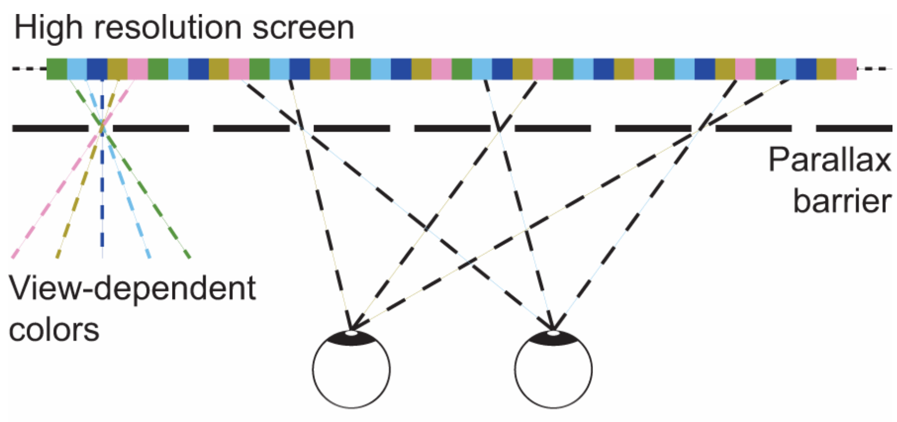


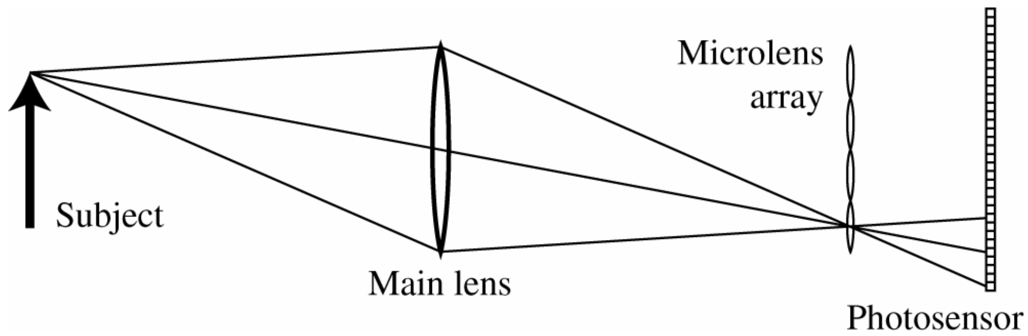
FIG. 3

INVENTOR.
JOHN T. GRUETZNER
BY
ATTORNEYS

Display – Camera duality



(From Zwicker et al).



(From Ng et al.)

Low angular resolution is typical:

Small number of cameras (100) or
Small number of pixels behind each micro lens (100)

Both possible due to Lambertian surface of observed object (slow change in radiance in angular directions at surface).
Very sparse sampling is OK with view morphing.

Big number of pixels in each camera (100, 000)

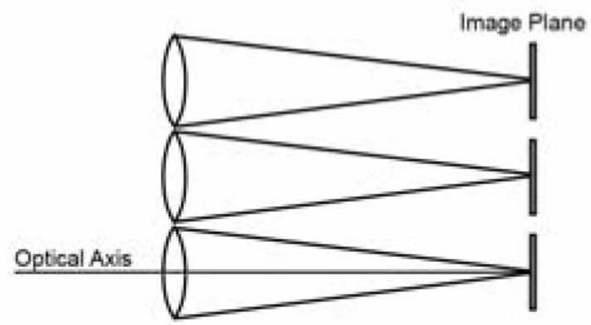
Capture 4D radiance with 2D sensor

Two ways of multiplexing:
(1) big array of small angular images
(2) small array of big spatial images

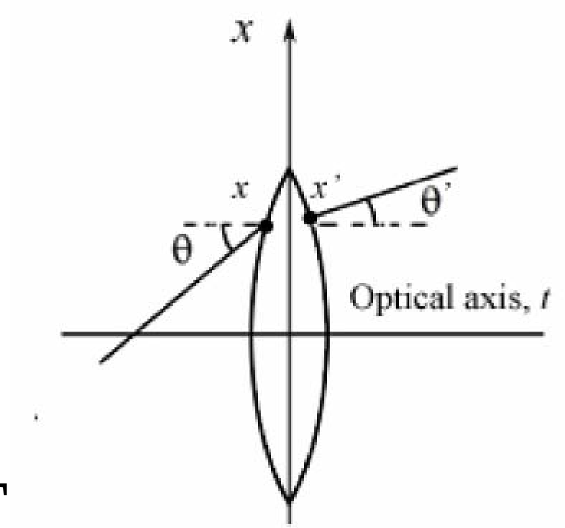
We want to trade angular for spatial resolution. At low angular resolution case (1) has significant problem at boundary pixels.

We have chosen to work on optical design (2).

Design 2



Optics



Light field transform at a lens

$$\begin{pmatrix} x' \\ \theta' \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{pmatrix} \begin{pmatrix} x \\ \theta \end{pmatrix}$$

Light field traveling distance T

$$\begin{pmatrix} x' \\ \theta' \end{pmatrix} = \begin{pmatrix} 1 & T \\ 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ \theta \end{pmatrix}$$

Light field transform at a prism (affine transform)

$$\begin{pmatrix} x' \\ \theta' \end{pmatrix} = \begin{pmatrix} x \\ \theta \end{pmatrix} + \begin{pmatrix} 0 \\ \alpha \end{pmatrix}$$

Light field transform at a shifted lens

$$\begin{pmatrix} x' \\ \theta' \end{pmatrix} = \begin{pmatrix} x \\ \theta \end{pmatrix} - \begin{pmatrix} s \\ 0 \end{pmatrix}$$

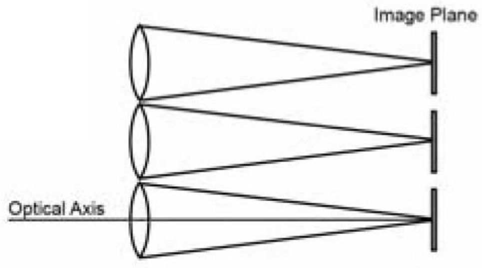
$$\begin{pmatrix} x'' \\ \theta'' \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{pmatrix} \begin{pmatrix} x - s \\ \theta \end{pmatrix}$$

$$\begin{pmatrix} q''' \\ \theta''' \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{pmatrix} \begin{pmatrix} x - s \\ \theta \end{pmatrix} + \begin{pmatrix} s \\ 0 \end{pmatrix}$$

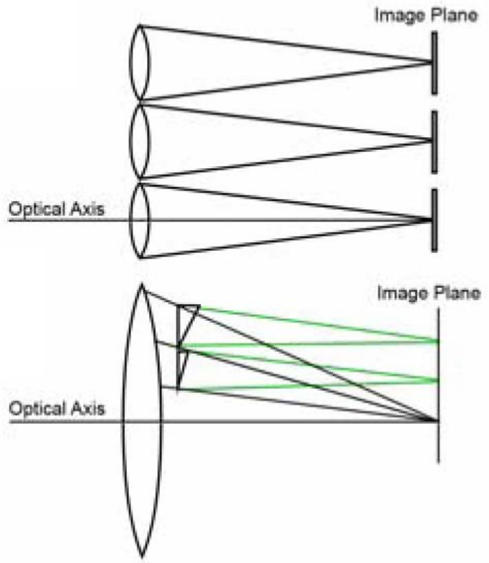
$$\begin{pmatrix} q''' \\ \theta''' \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{pmatrix} \begin{pmatrix} x \\ \theta \end{pmatrix} + \begin{pmatrix} 0 \\ \frac{s}{f} \end{pmatrix}$$

A shifted lens is equivalent to a lens-prism pair

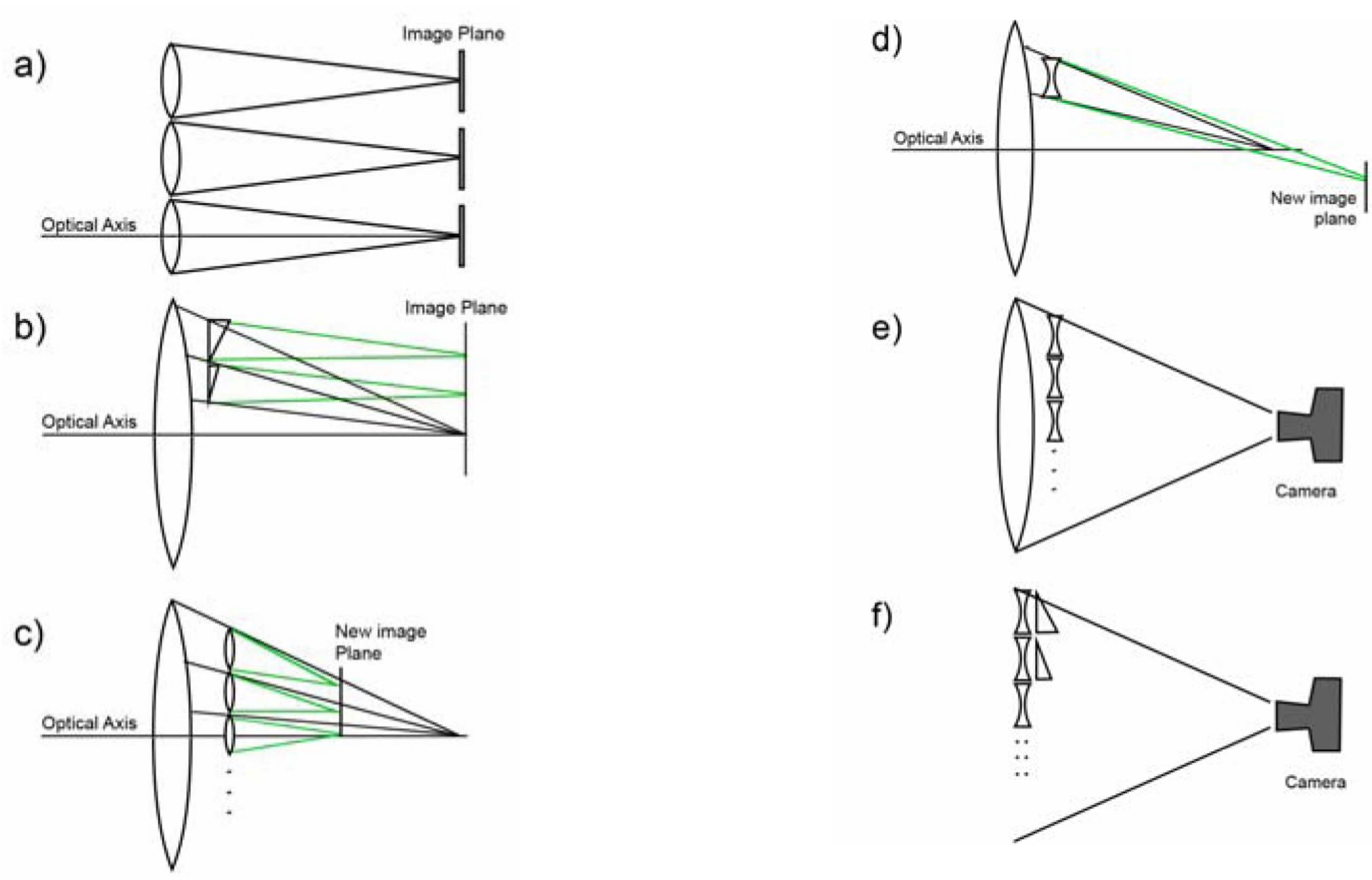
Designs



Designs

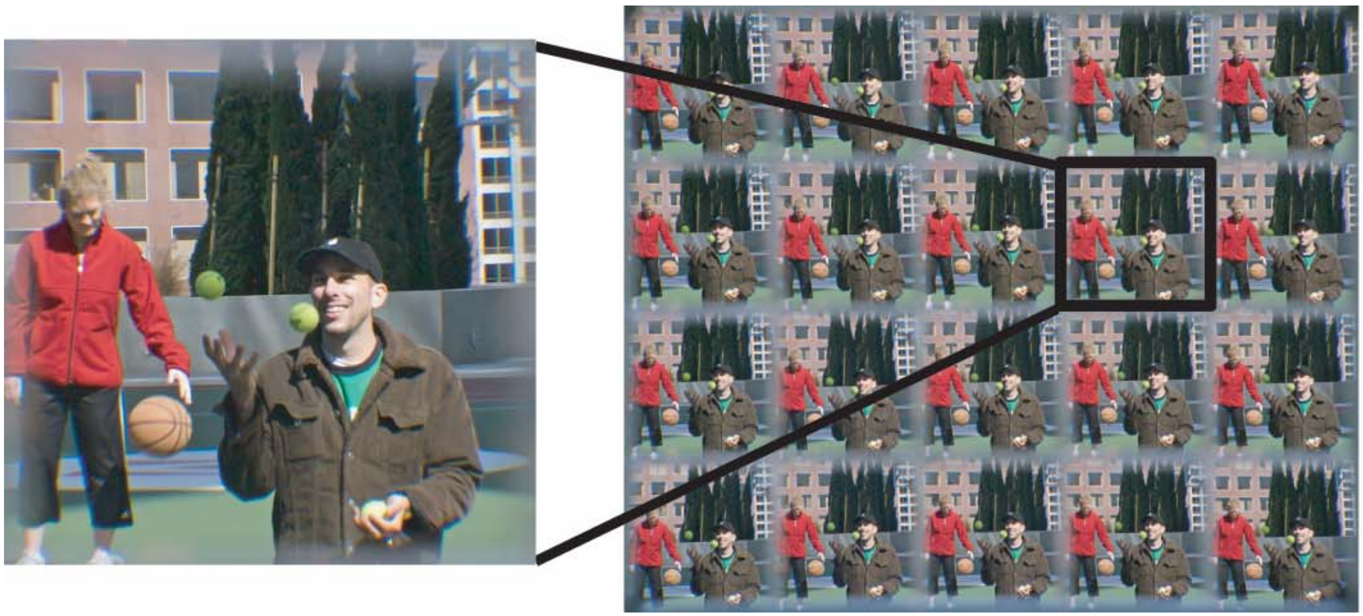


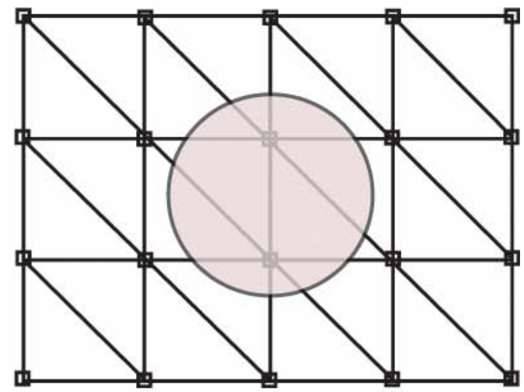
Designs



a)
Image Plane
Optical Axis
b)
Image Plane
Optical Axis
c)
New image
Plane
Optical Axis
d)
Optical Axis
New image
plane
e)
Camera
f)
Camera

3-View Morphing





Refocusing

Conclusion:

The way to increase spatial resolution with a fixed sensor is to trade angular for spatial resolution. Then, view-morph.

The Plenoptic (Adelson–Wang, Ng et al.) design (1) has difficulties at low angular resolution. That's why we chose the other design (2).

We showed optical light field transforms and 5 new camera designs. Lens-prism pairs.