Lithography optics

Jose Sasian
OPTI 696A

Rules that rule optics

$$RES = k_1 \frac{\lambda}{NA}; \quad DOF = k_2 \frac{n\lambda}{NA^2}$$

k1~0.4-0.8
Raleigh resolution k1=0.61
K2~0.5

Wavelength=193nm

R(193 dry)=147nm
(NA=0.8; k1=0.61)

DOF=151 nm

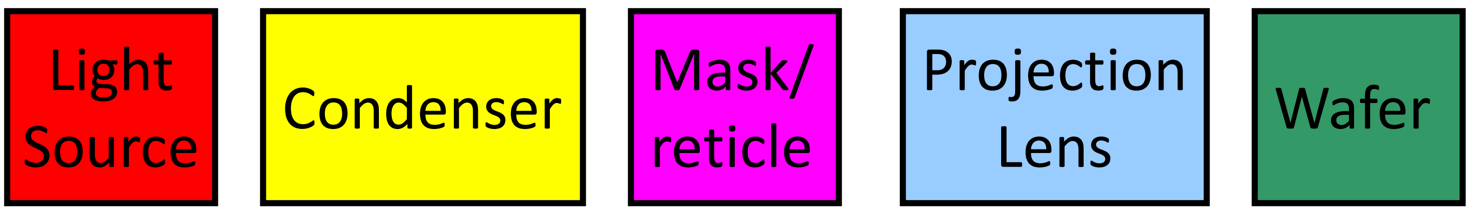
R(193 water)=110 nm

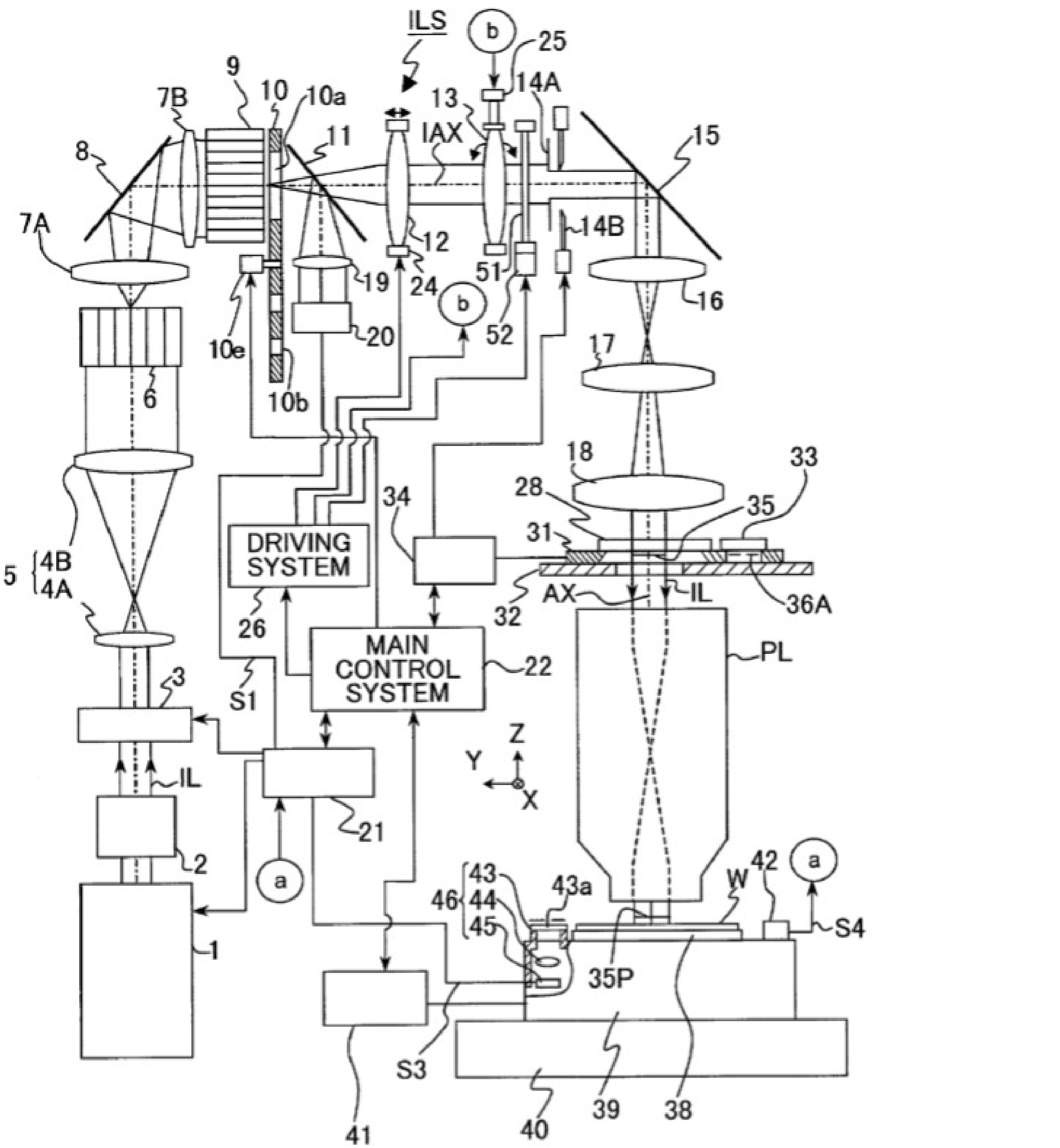
Must preserve imaging volume!
Resolution and depth of focus are critical.

Wavelength/resolution/Year

λ	Resolution	Year
G-line 436 nm	512-1024 nm	1986
I-line 365 nm	256-512 nm	1992
KrF 248 nm	128-256 nm	1998
ArF 193 nm	64-128 nm	2004
Immersion	32-64 nm	2008
EUV 13.5 nm	8-32 nm	2016

Main optical parts of a micro-lithographic system

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DRIVING SYSTEM
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AX
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MAIN CONTROL SYSTEM
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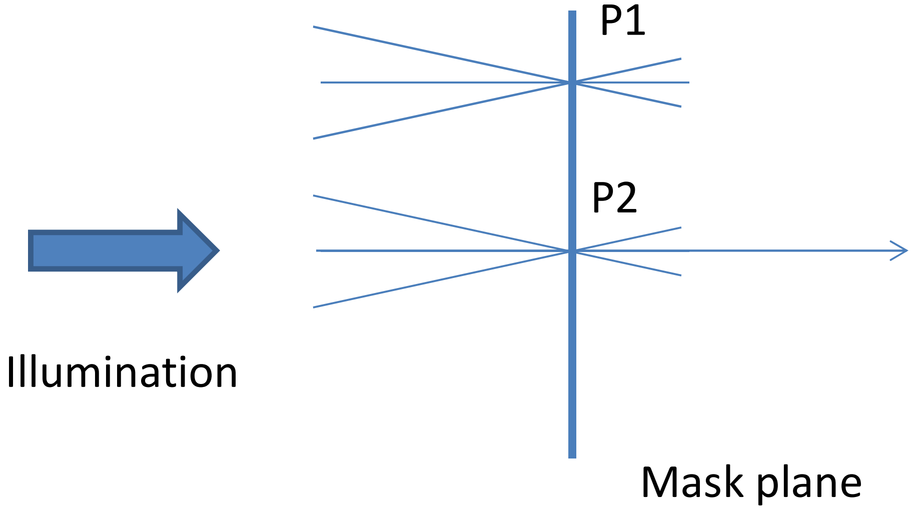
Illumination requirements

- Uniform illumination to ~1%.
- Every field point must be illuminated in the same way.



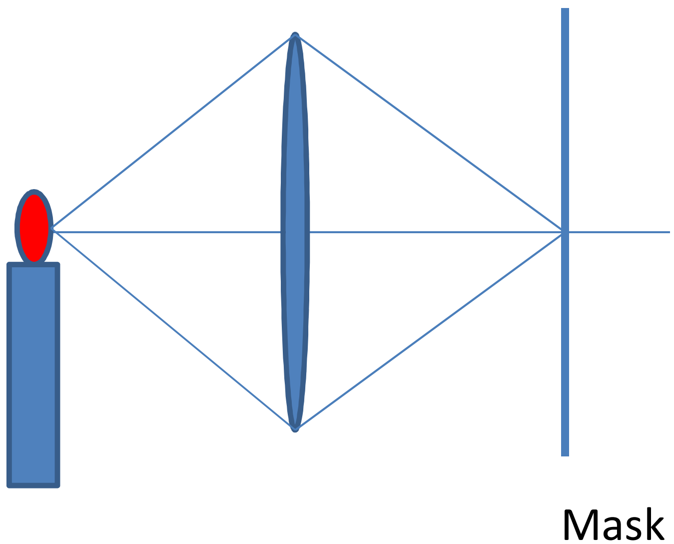
Angular ray spread is a metric for the degree of coherence. Every field point must have the same angular spread

$$\gamma_{12} = \frac{1}{\sqrt{I_1 I_2}} \int_{\Sigma} u_1 u_2^* \, \mathrm{d}\sigma,$$

$$|\gamma_{12}| \approx (1 - k^2 {\sigma_{\Delta W}}^2)^{1/2}$$

Critical illumination

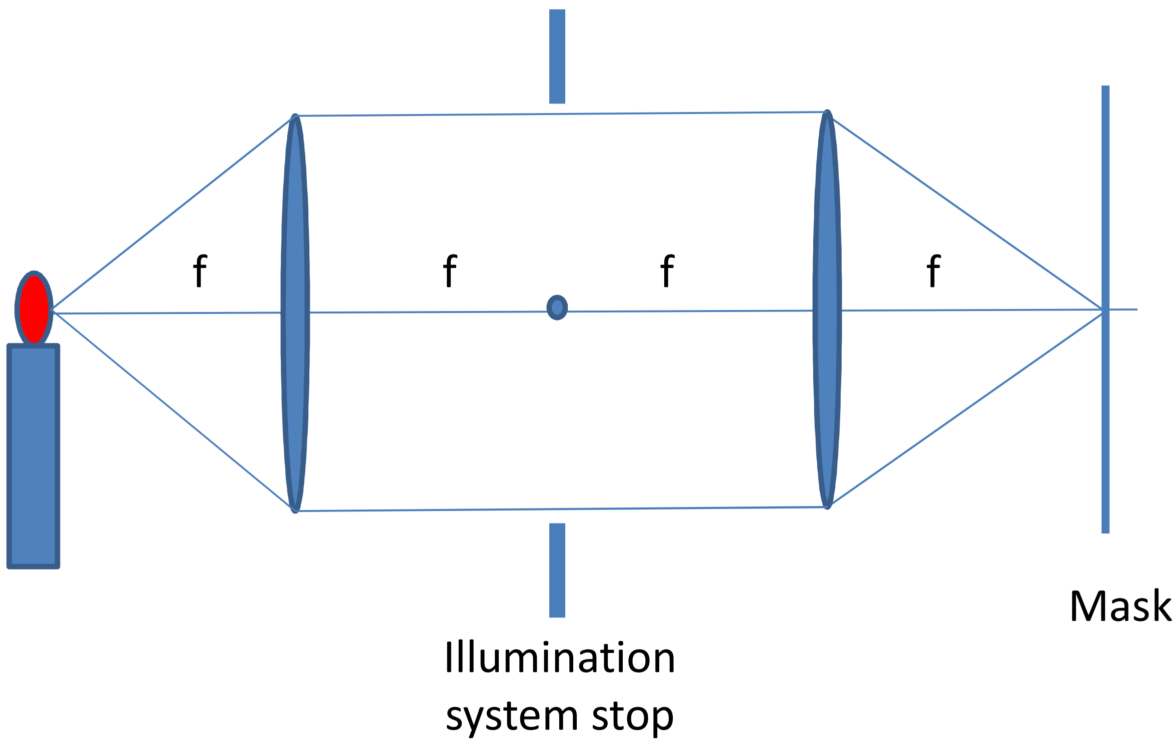
(From microscopy)



Source must be uniform to achieve Uniform object illumination

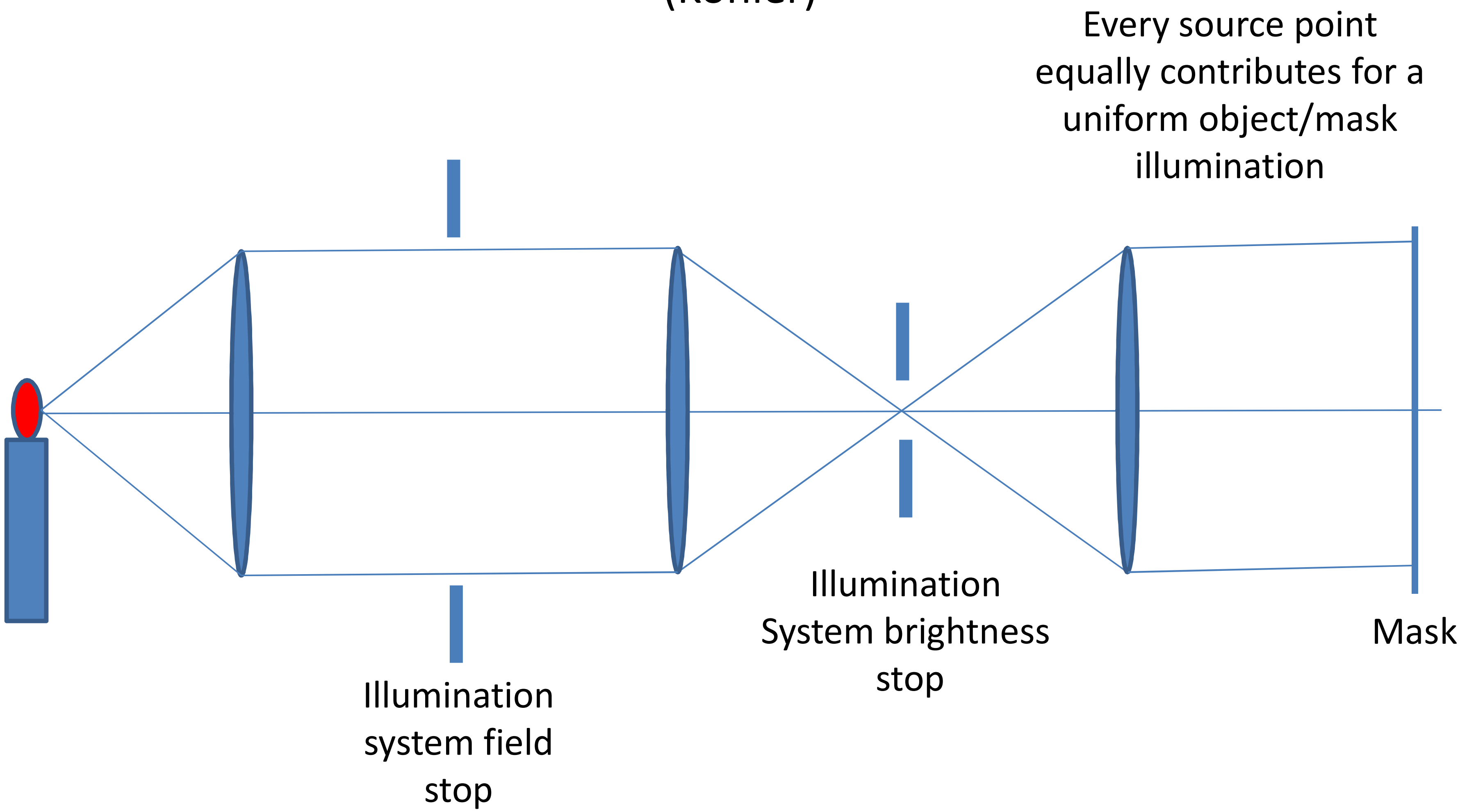
Critical illumination

(4-f relay)

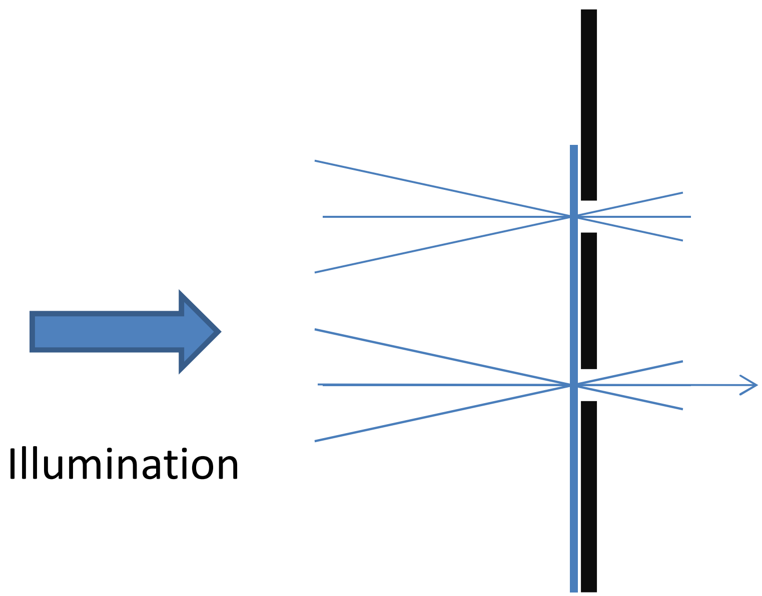


Uniform illumination

(Kohler)

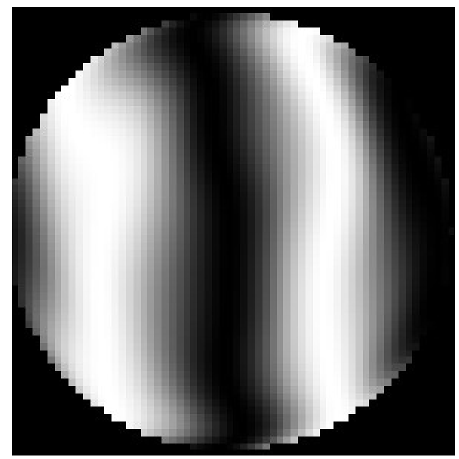


Young's double slit (pin-hole) experiment



The smaller the ray spread the more coherent the illumination would be as it will come more from a single source point.

$$|\gamma_{12}| \approx (1 - k^2 {\sigma_{\Delta W}}^2)^{1/2}$$

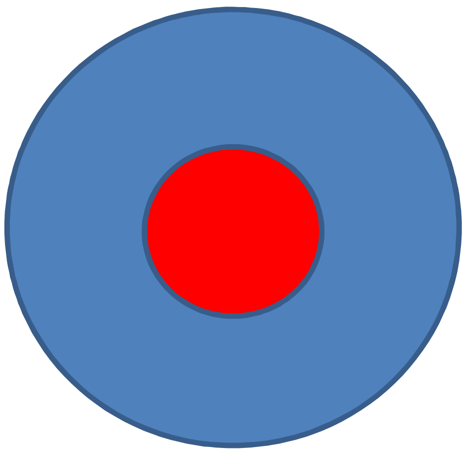


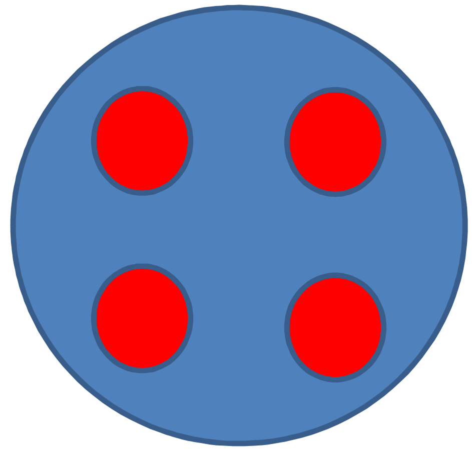
Fringe contrast will
Depend on degree
Of coherence between
the light from the two
Pin holes.

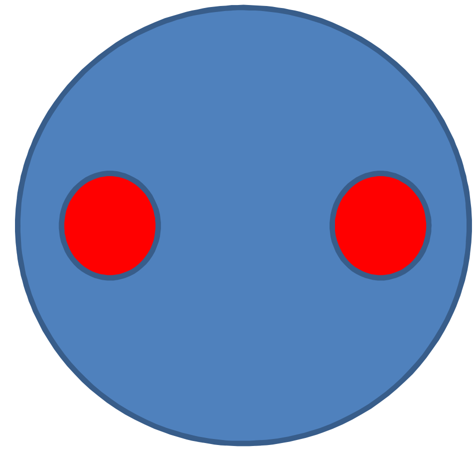
Illumination

Entrance pupil

Power efficiency is critical



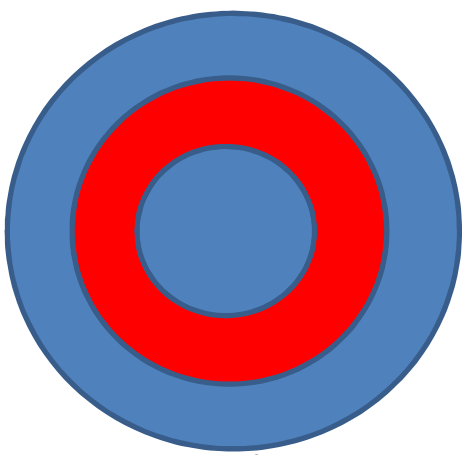




Sigma factor = d/D

Quadrupole

Dipole



Annular

FIG. 9

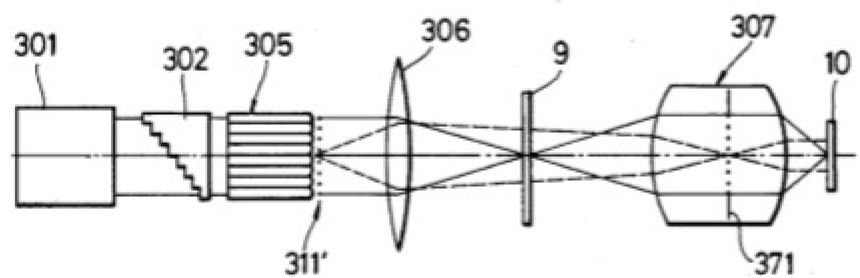


Fig. 6A

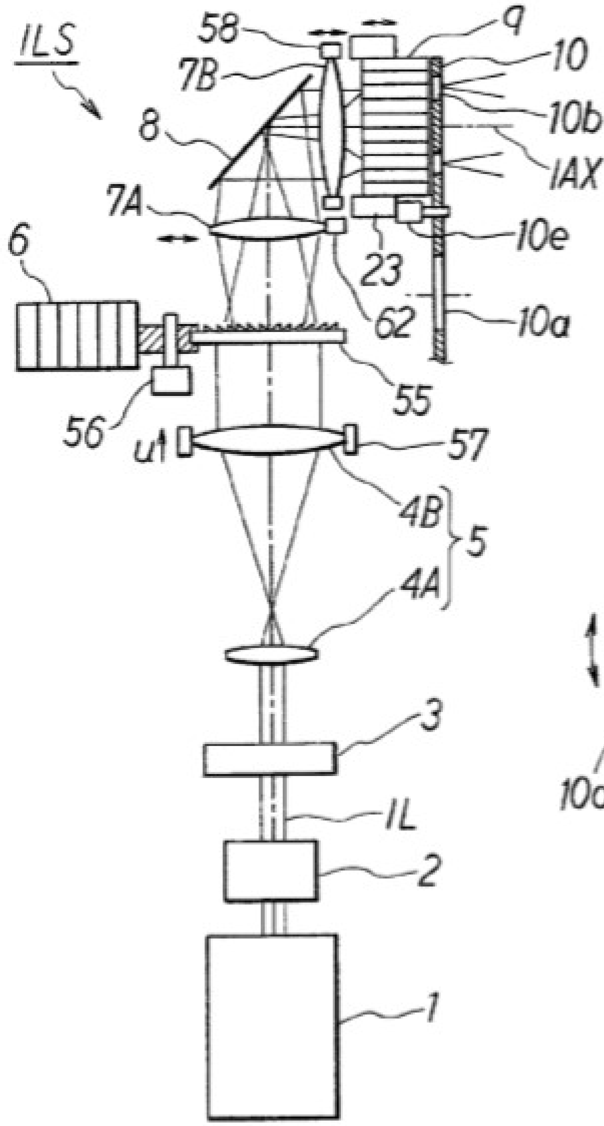

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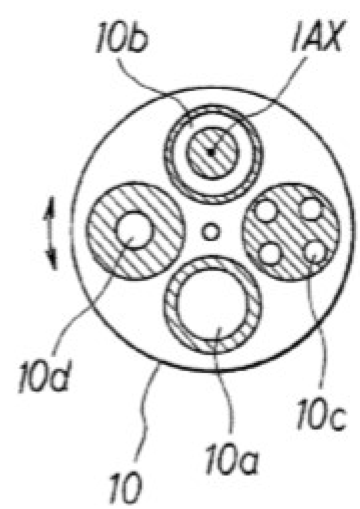
Fig. 6B


10b
IAX
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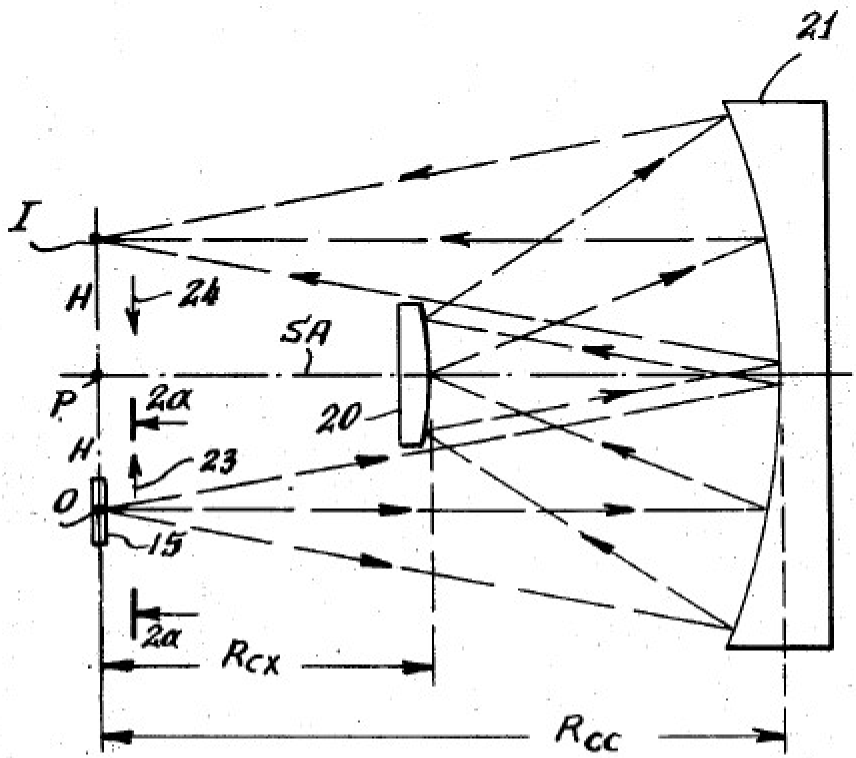
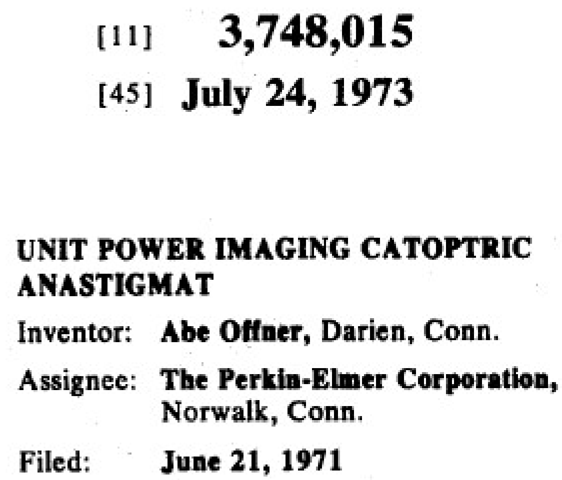
Projection lenses

Ring field system





[11] **3,748,015**

[45] **July 24, 1973**

UNIT POWER IMAGING CATOPTRIC ANASTIGMAT

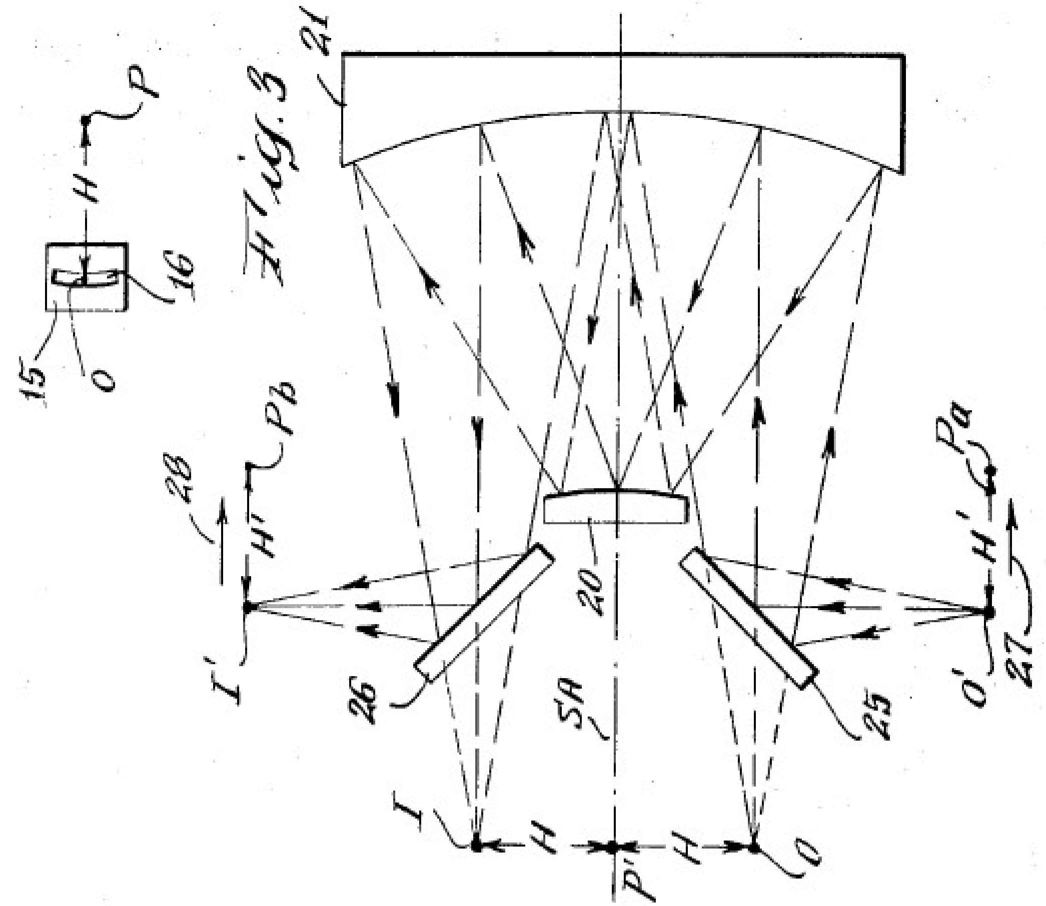
Inventor: **Abe Offner,** Darien, Conn.

Assignee: **The Perkin-Elmer Corporation,** Norwalk, Conn.

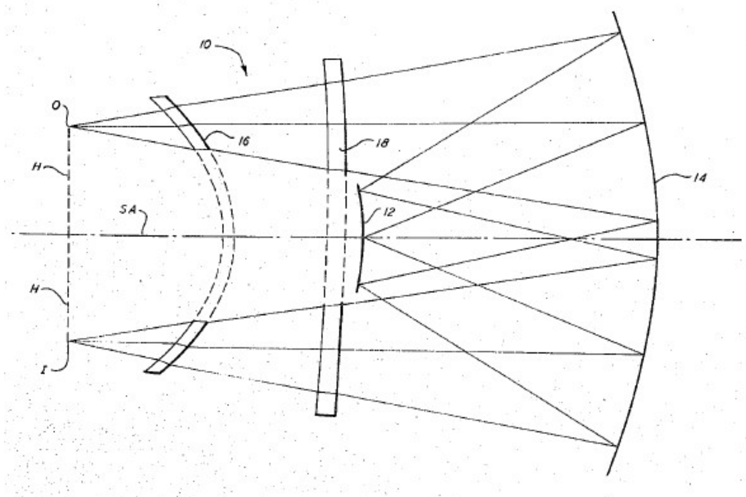
Filed: **June 21, 1971**

Doubly telecentric
No primary aberrations

Unit power imaging catoptric anastigmatic



Restricted off-axis field system



RESTRICTED OFF-AXIS FIELD OPTICAL SYSTEM

Inventor: **Abe Offner**, Darien, Conn.

Assignee: **The Perkin-Elmer Corporation,** Norwalk, Conn.

Appl. No.: **106,415**

Filed: **Dec. 21, 1979**

4,293,186

;, 1981

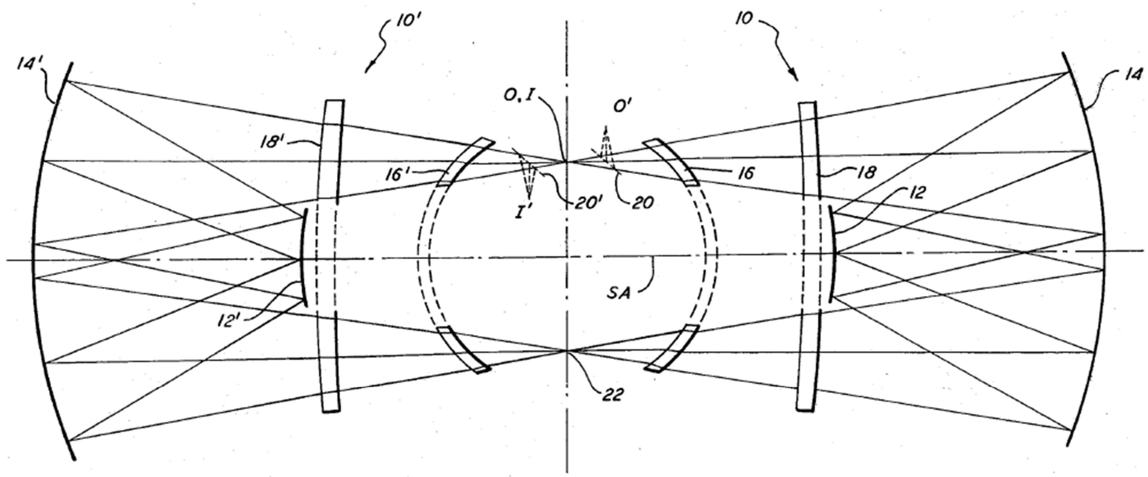


FIG. 2

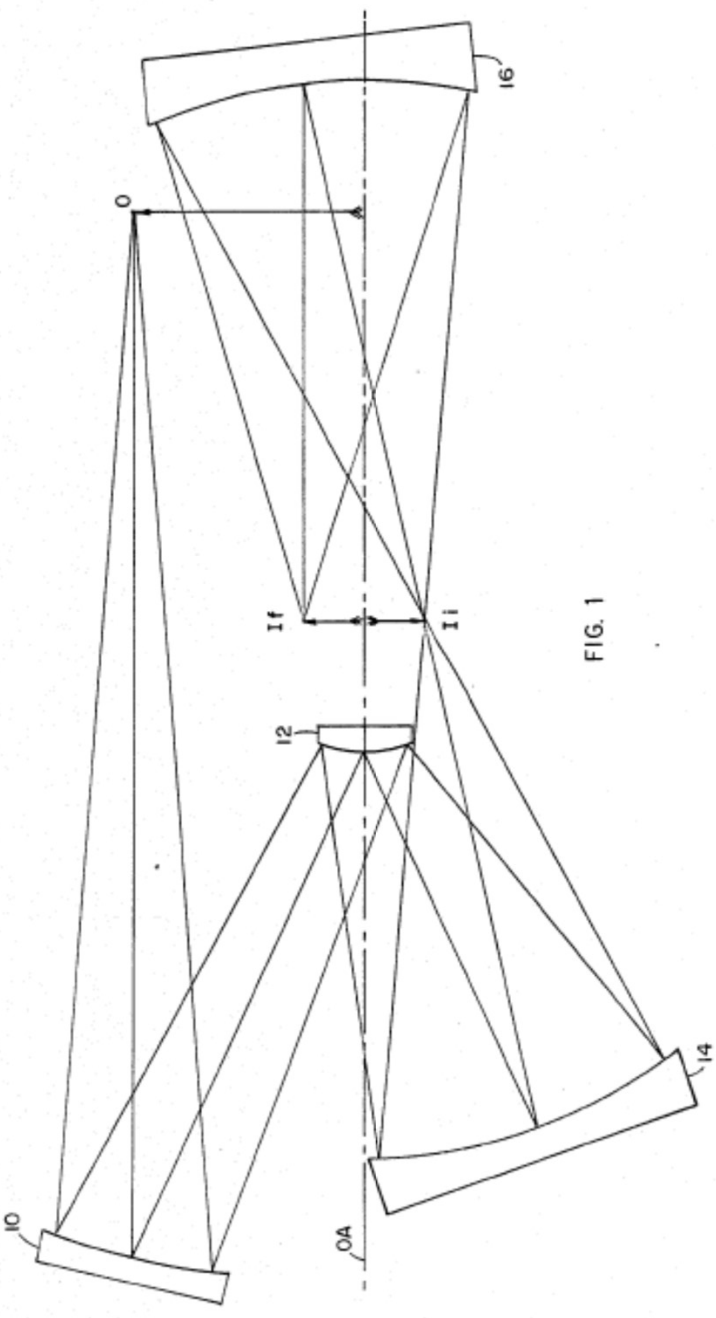
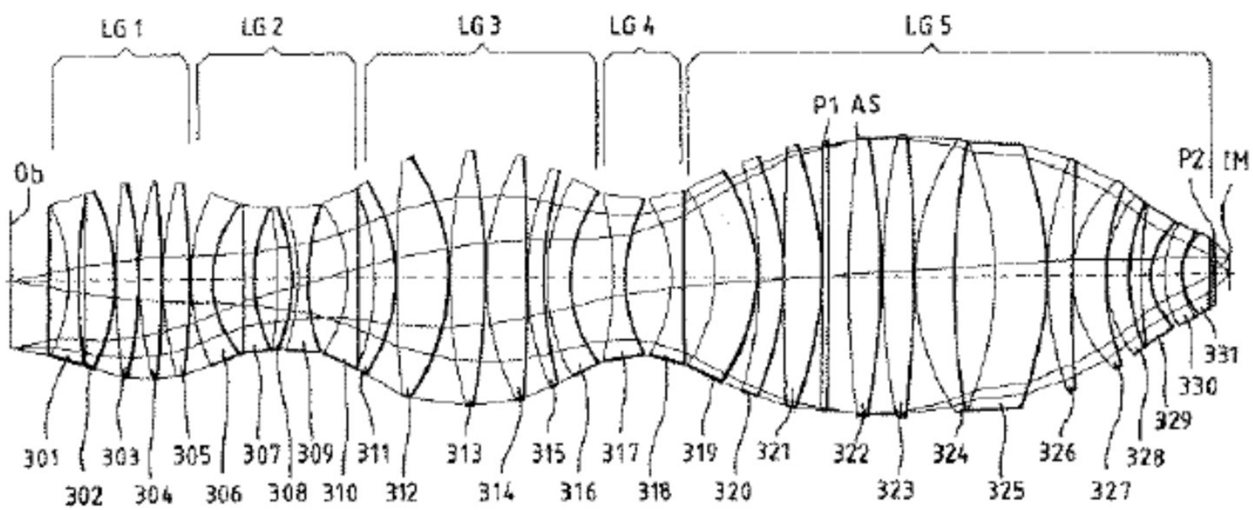


FIG. 1

Double-triple bulge full field



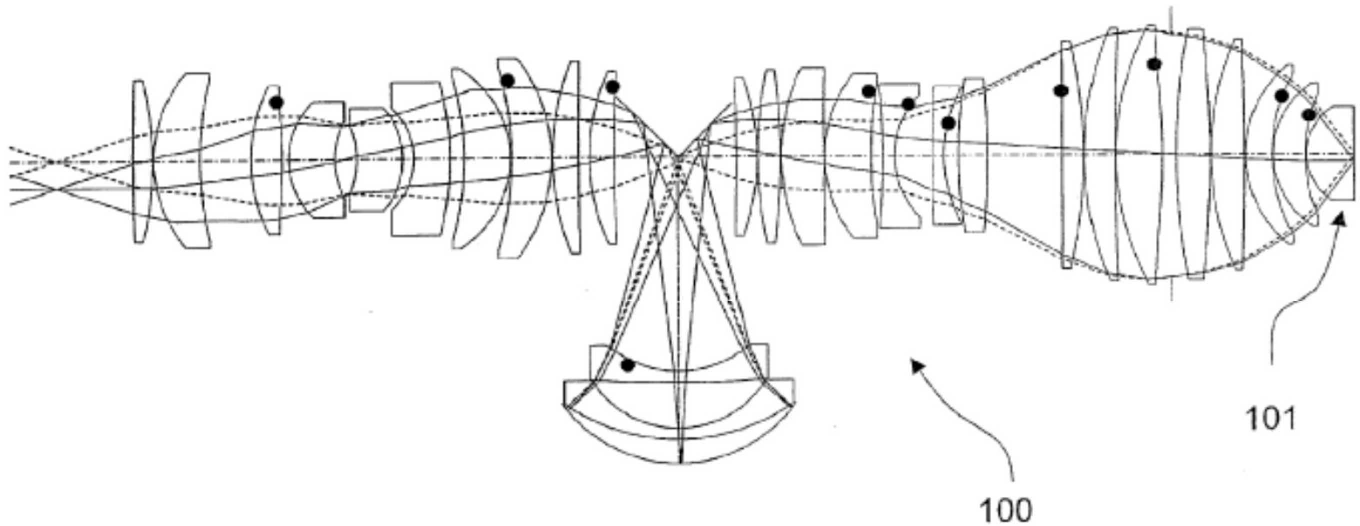


Fig. 5

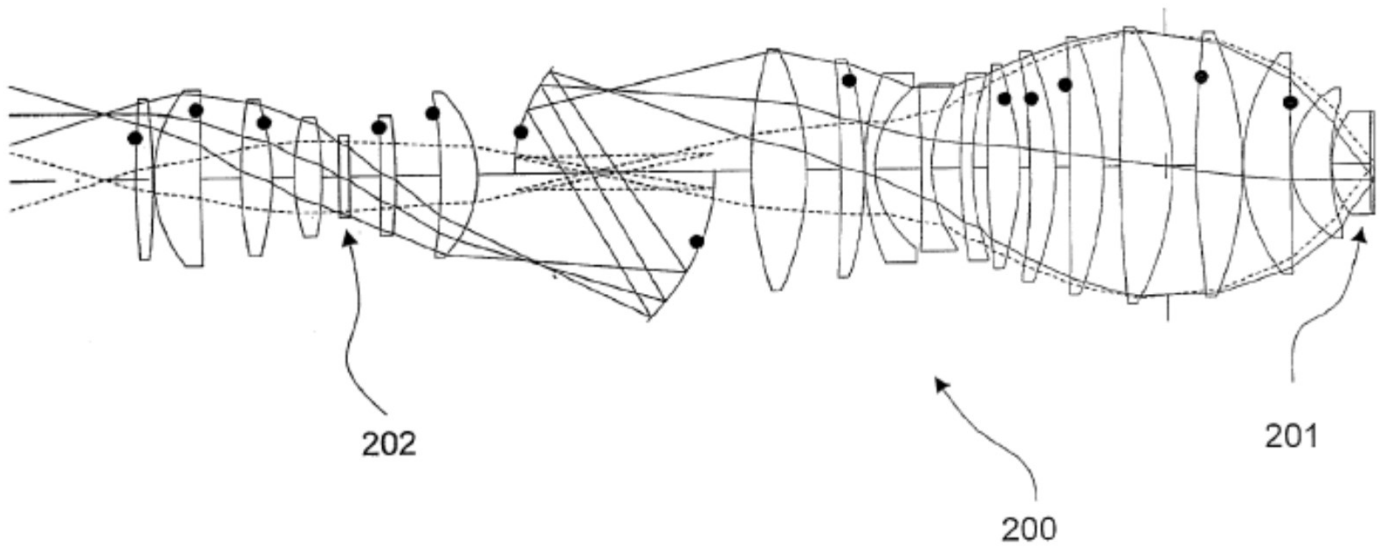
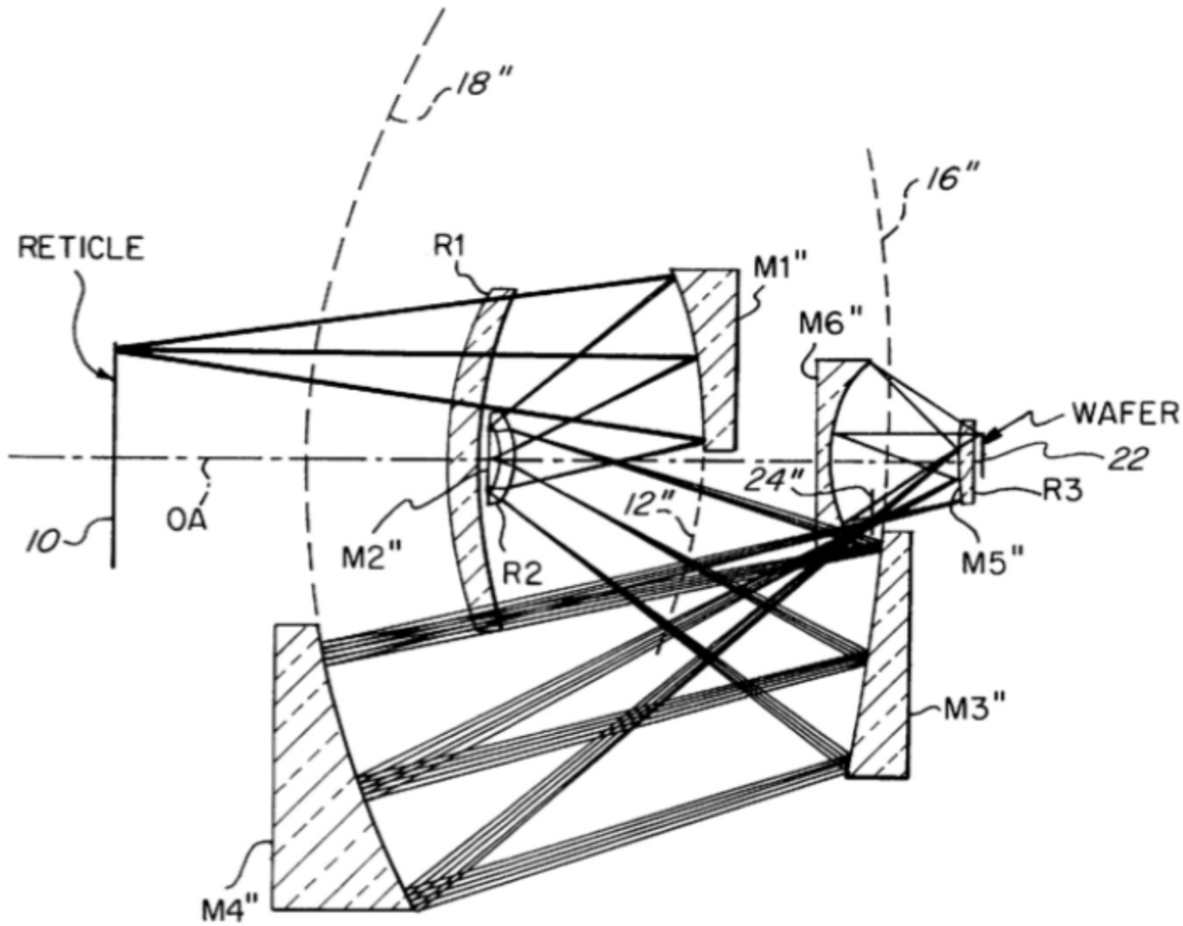
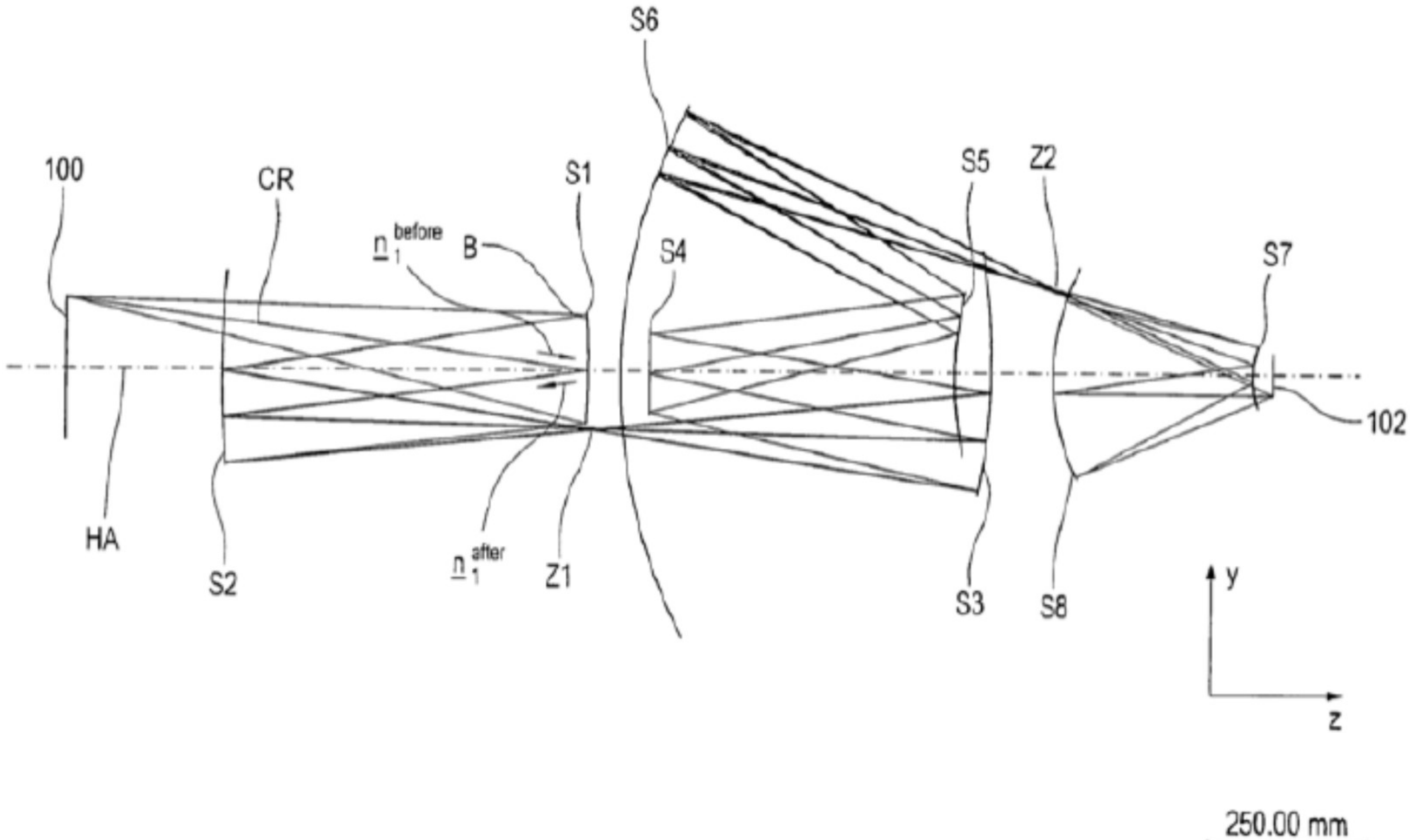


Fig. 6

U.S. Pat. No. 5,815,310 (1998)



U. S. Pat. No. 7,508,580 (2009)



Fly-eye integrators

Jan. 31, 1967 P. M. LARRABURU 3,302,016

OPTICAL COLLIMATING SYSTEM

Filed Aug. 21, 1964

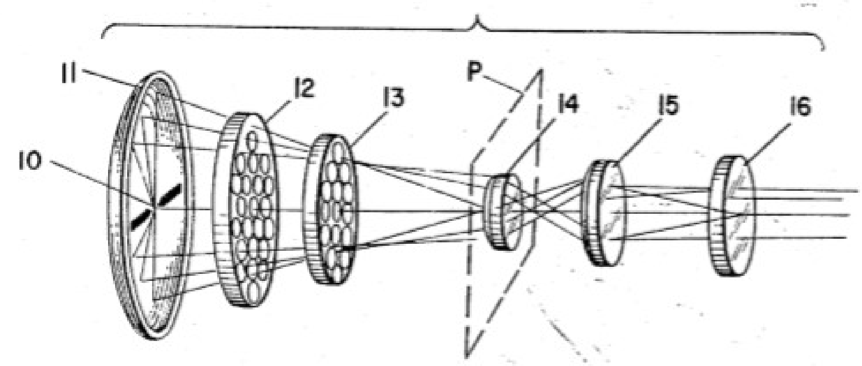
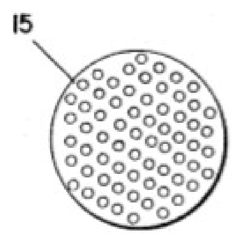
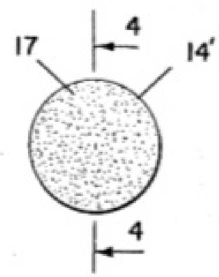


FIG. 1.

diffusing coating





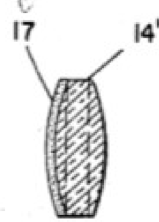
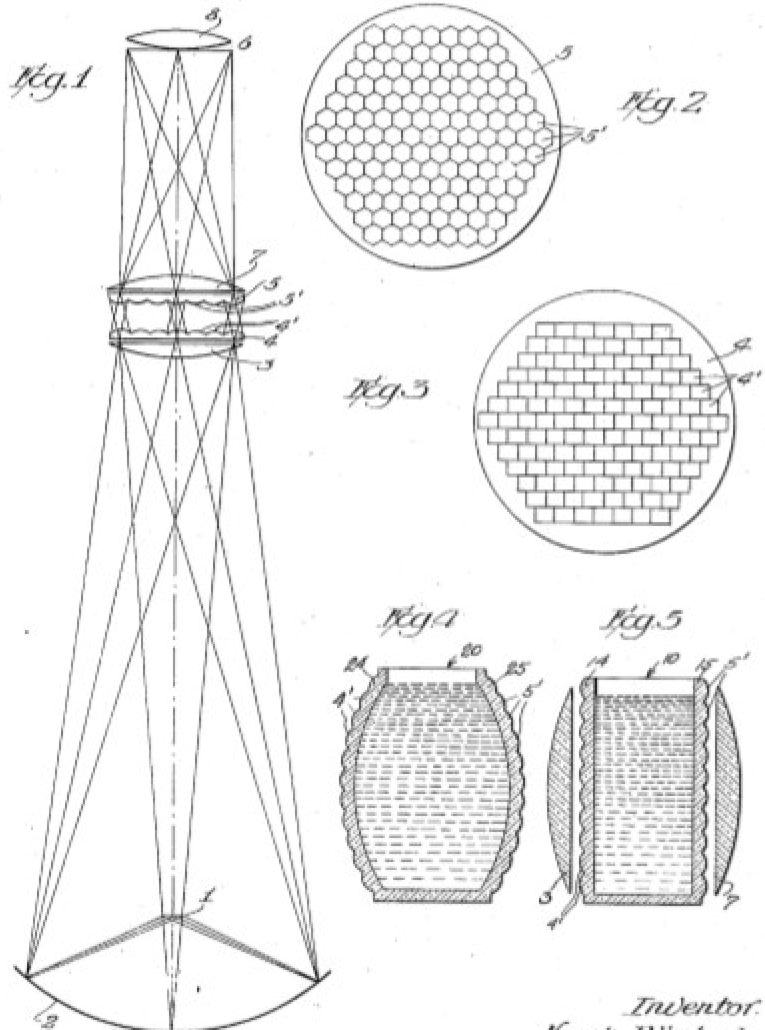


FIG. 2. FIG. 3. FIG. 4.

Aug. 17, 1943. K. RÄNTSCH 2,326,970

ILLUMINATING SYSTEM, PARTICULARLY FOR PROJECTION PURPOSES

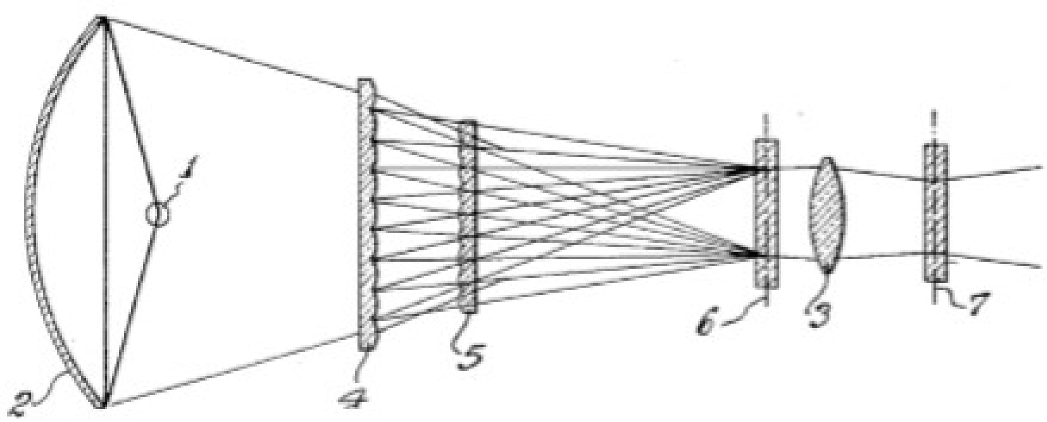
Filed July 1, 1940



Inventor:
Kurt Räntsch
By Singer, Ehlert, Stern & Carlberg
Attys.

ILLUMINATING SYSTEM FOR PICTURE PROJECTORS

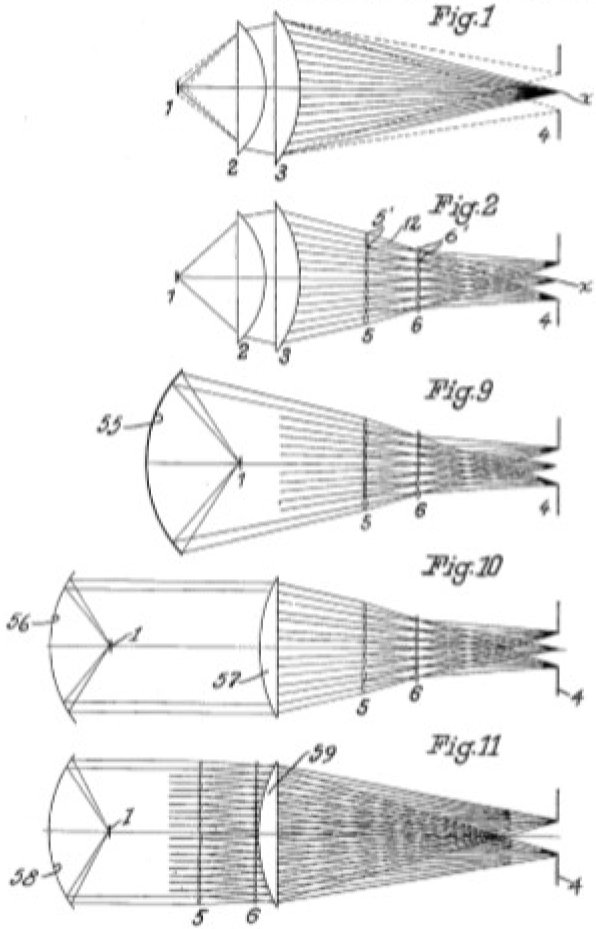
Filed May 18, 1953



Jan. 9, 1940. K. RÄNTSCH ET AL 2,186,123

ILLUMINATING SYSTEM

Filed Feb. 21, 1938 5 Sheets-Sheet 1



Inventors

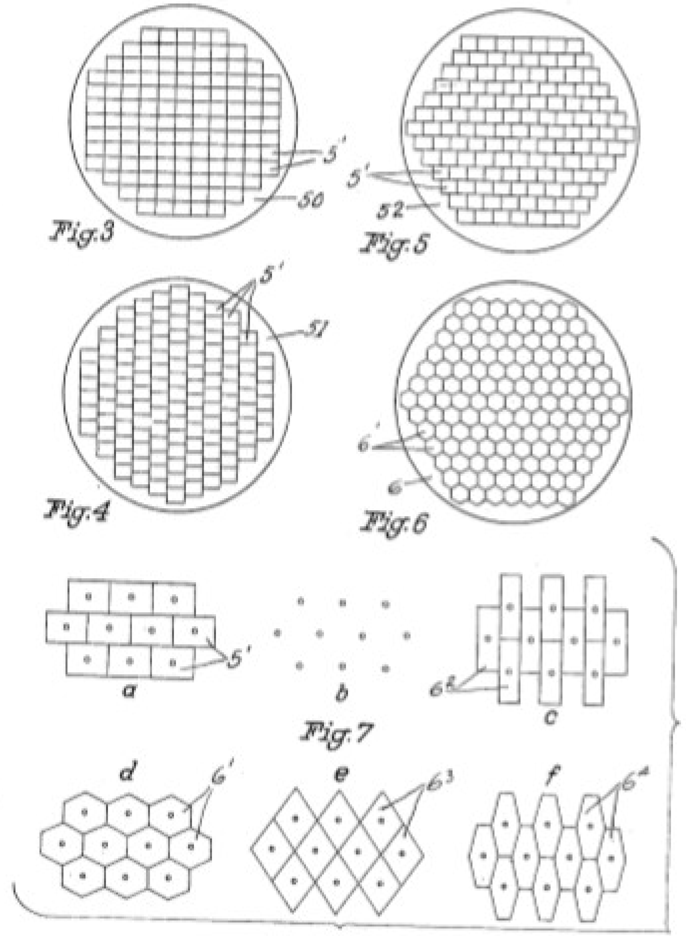
Kurt Räntsch Hans Lauer Ludwig Bertele and Alfred Maier

By B. Singer and F. Stern, Attys

Jan. 9, 1940. K. RÄNTSCH ET AL 2,186,123

ILLUMINATING SYSTEM

Filed Feb. 21, 1938 5 Sheets-Sheet 2



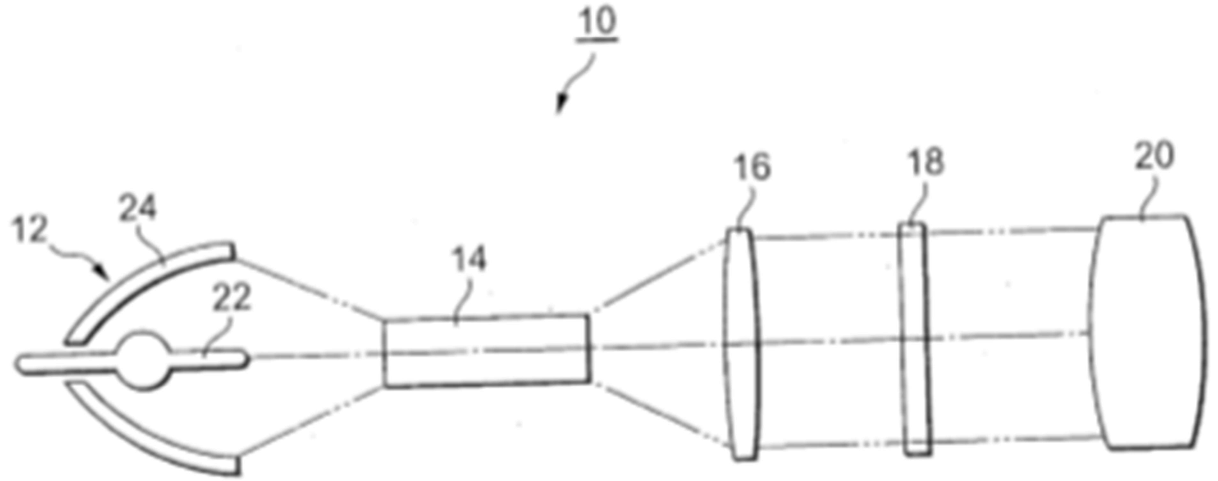
Inventors

Kurt Räntsch Hans Lauer Ludwig Bertele and Alfred Maier

By B. Singer and F. Stern, Attys

Rod integrators

Fig.1



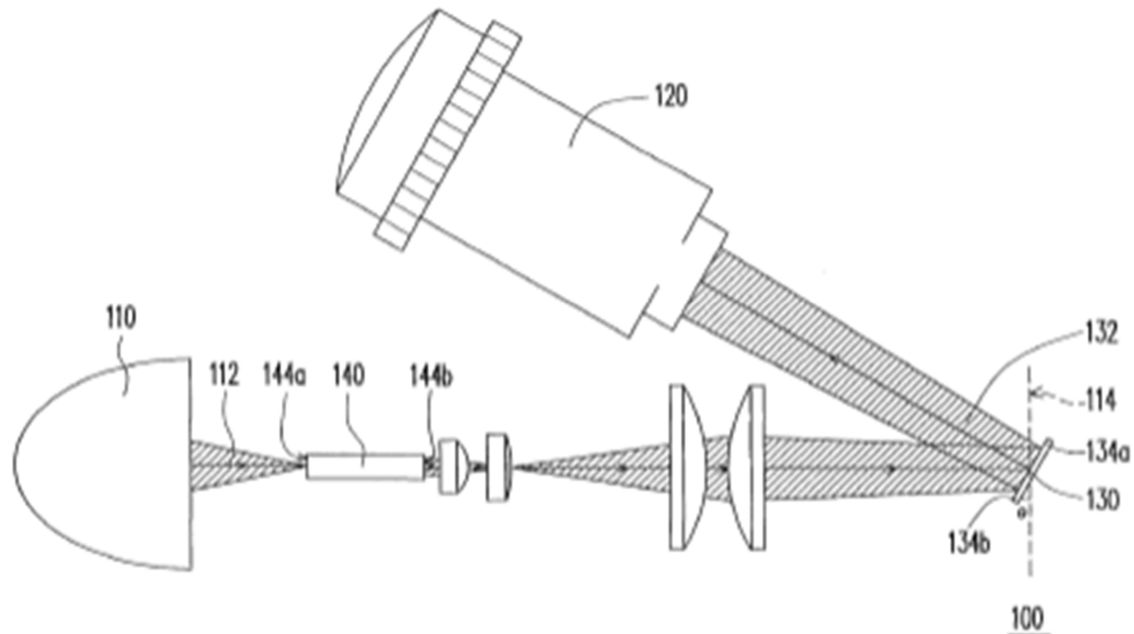
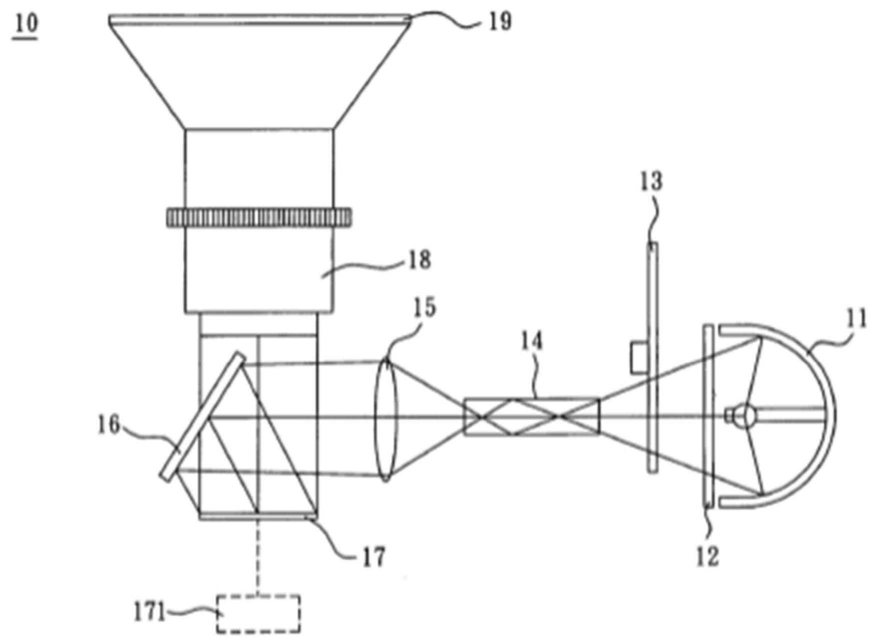


FIG. 1A (PRIOR ART)



PRIOR ART
FIG. 1

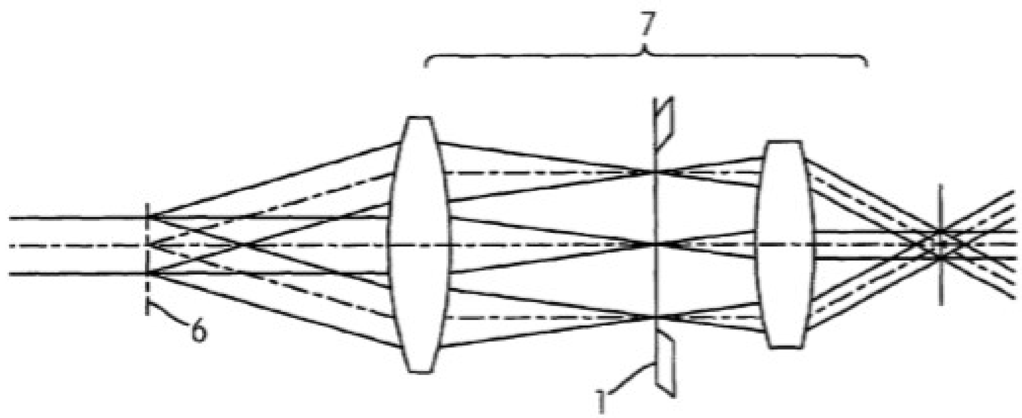
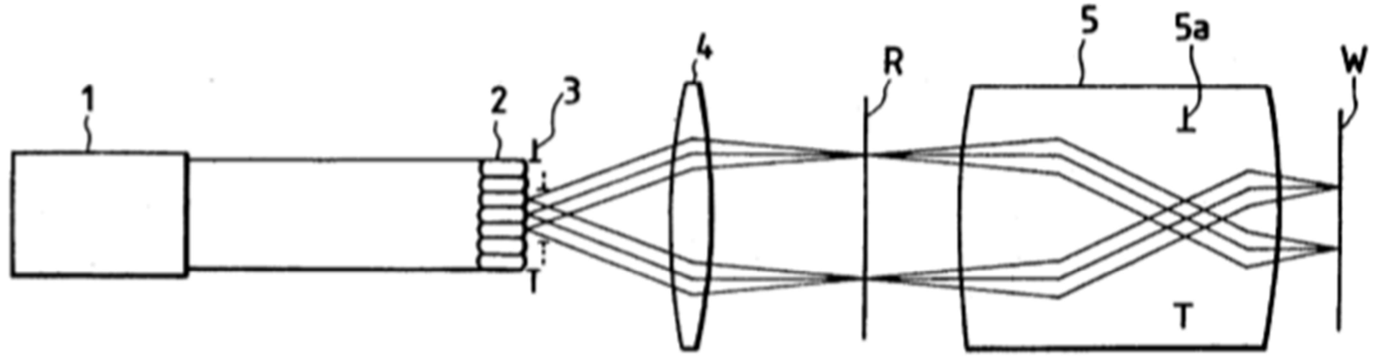


FIG. 1a

FIG. 3



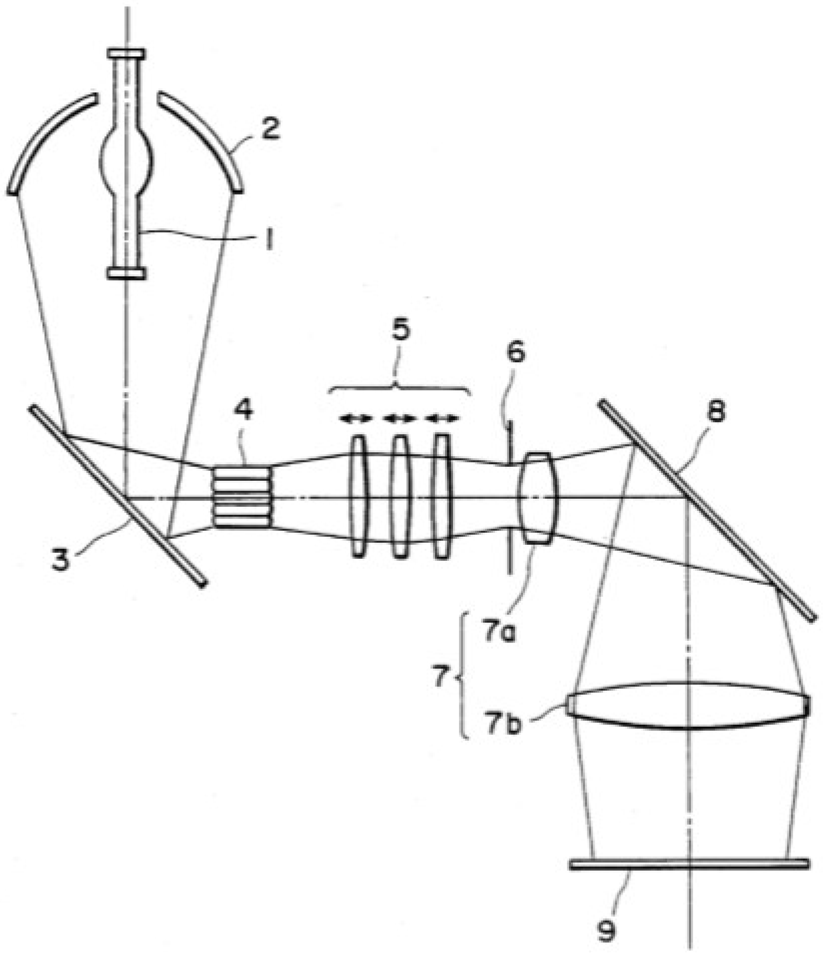


FIG. 1

FIG. 8

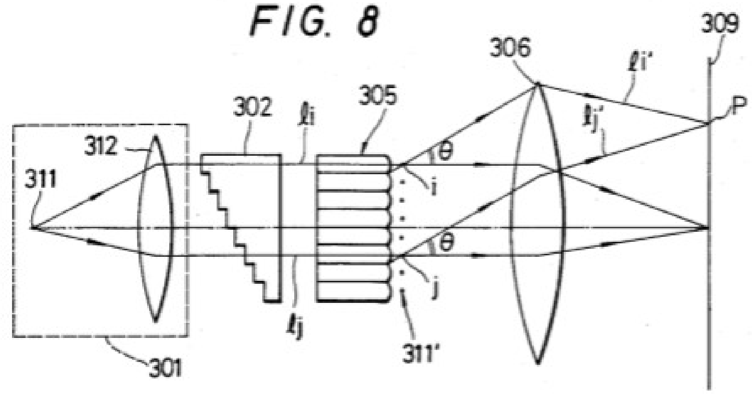


FIG. 9

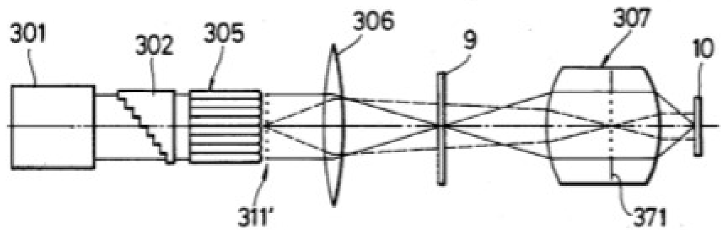
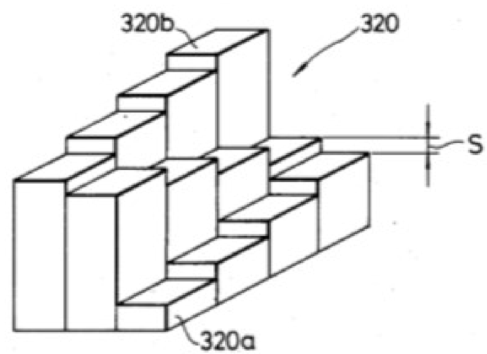
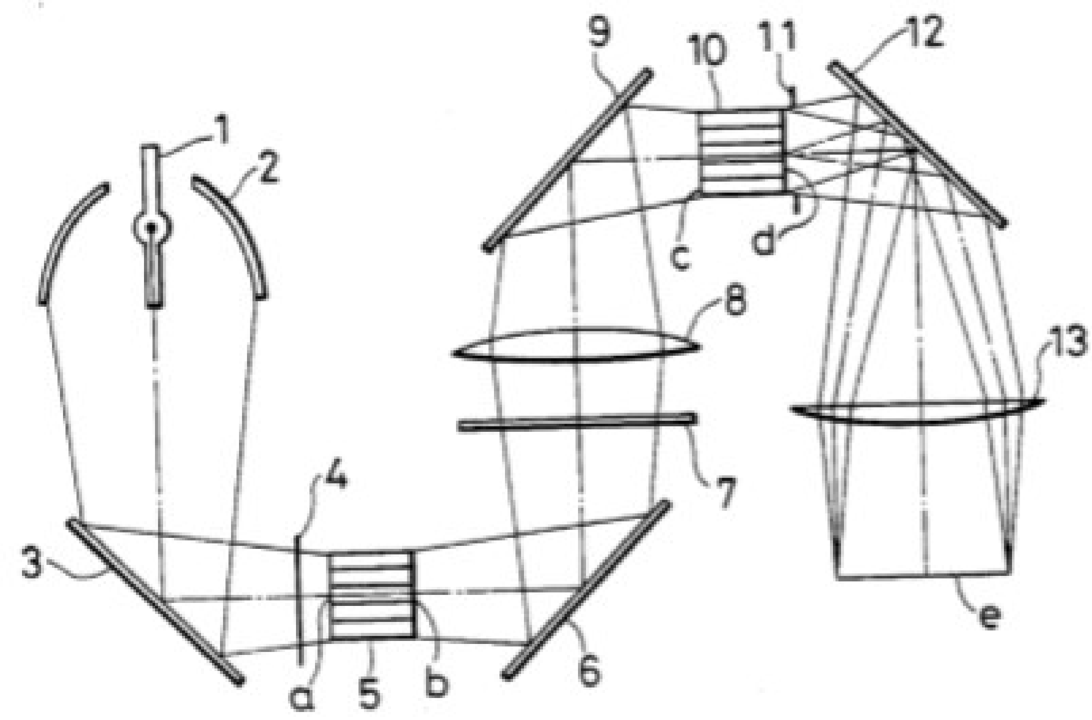


FIG. 10

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Rod and fly-eye integrators

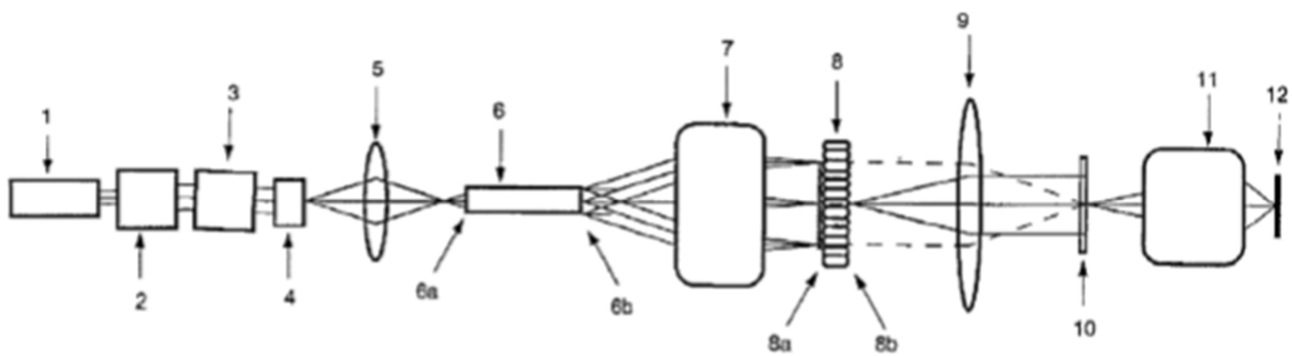

FIG. 5

FIG. 1A

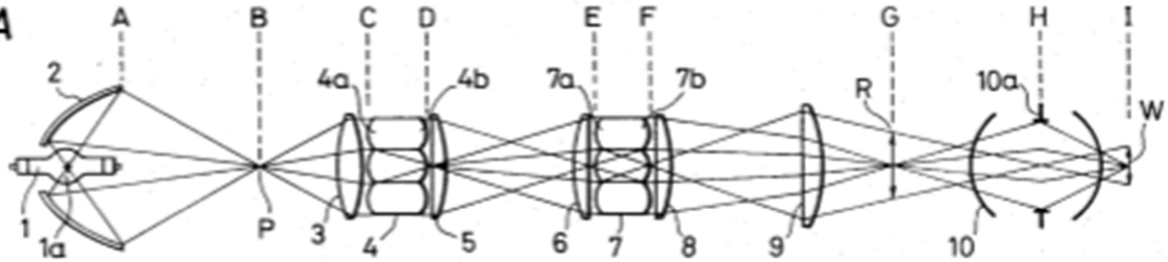
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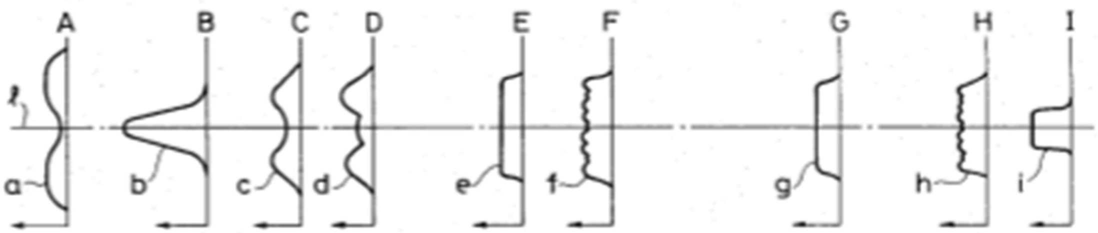
FIG. 1B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Feb. 23, 1965 D. E. PRITCHARD 3,170,980

OPTICAL TUNNEL SYSTEM

Filed May 9, 1962

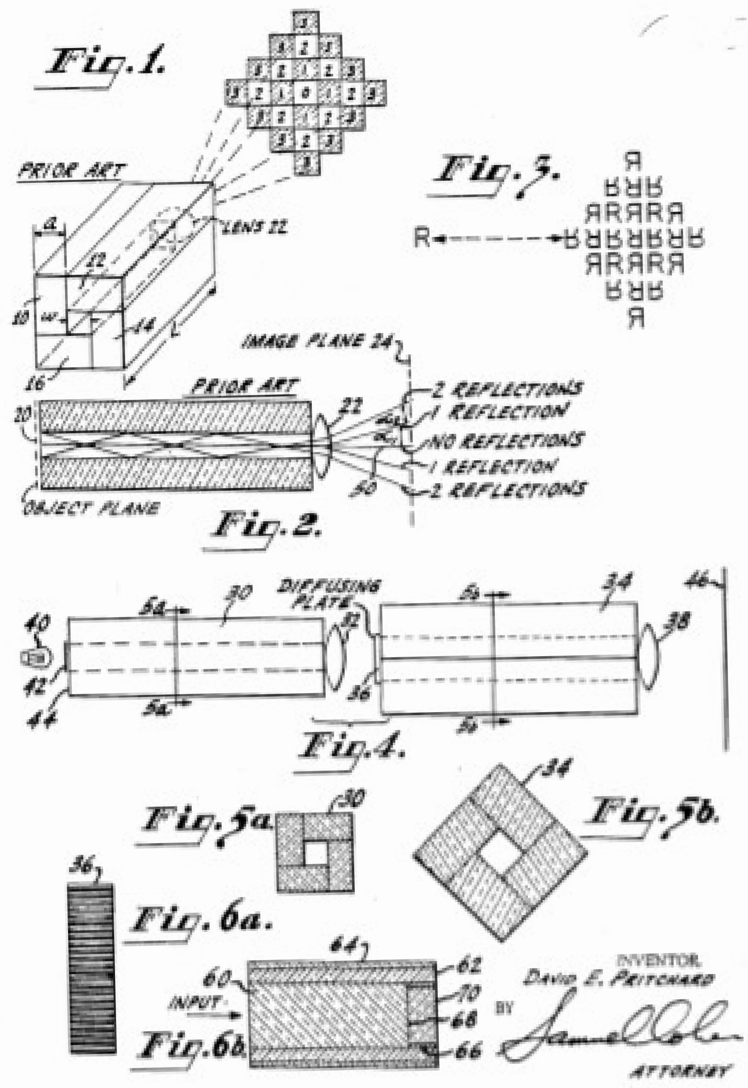
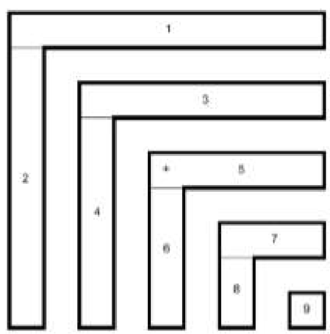


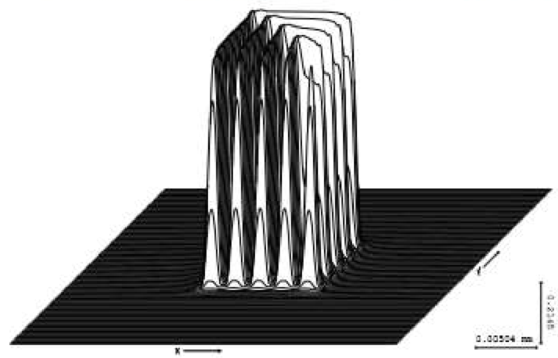
Image simulation

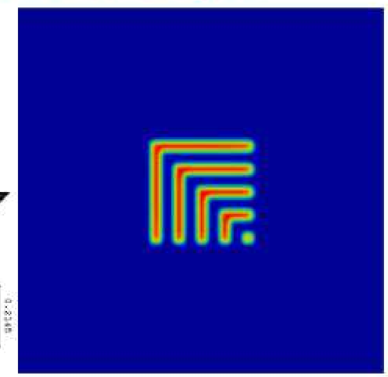
H. H. Hopkins equation

$$I(x,y)=\left(\frac{1}{f\lambda}\right)^2\iint_{\infty}\sigma(x_0,y_0)\left|s(x,y)t(x,y)**psf(x,y)\right|^2dx_0dy_0$$

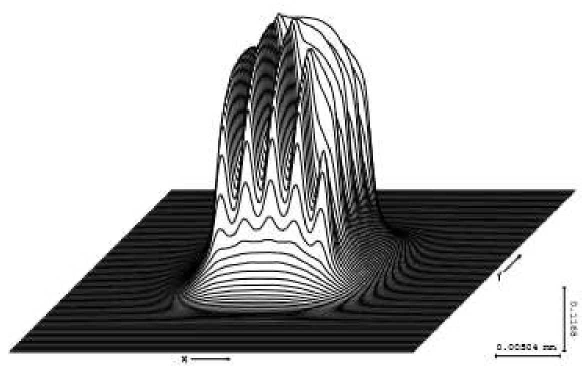
Example of Elbows Imaged in Partially Coherent Light

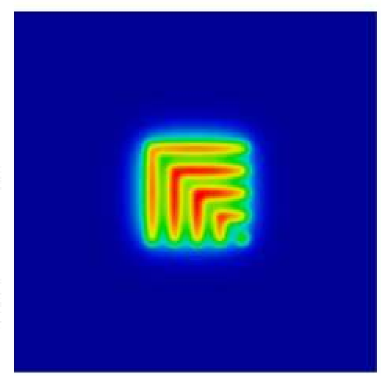






With 1 wave of spherical aberration





Effect of partial coherence on imaging an edge