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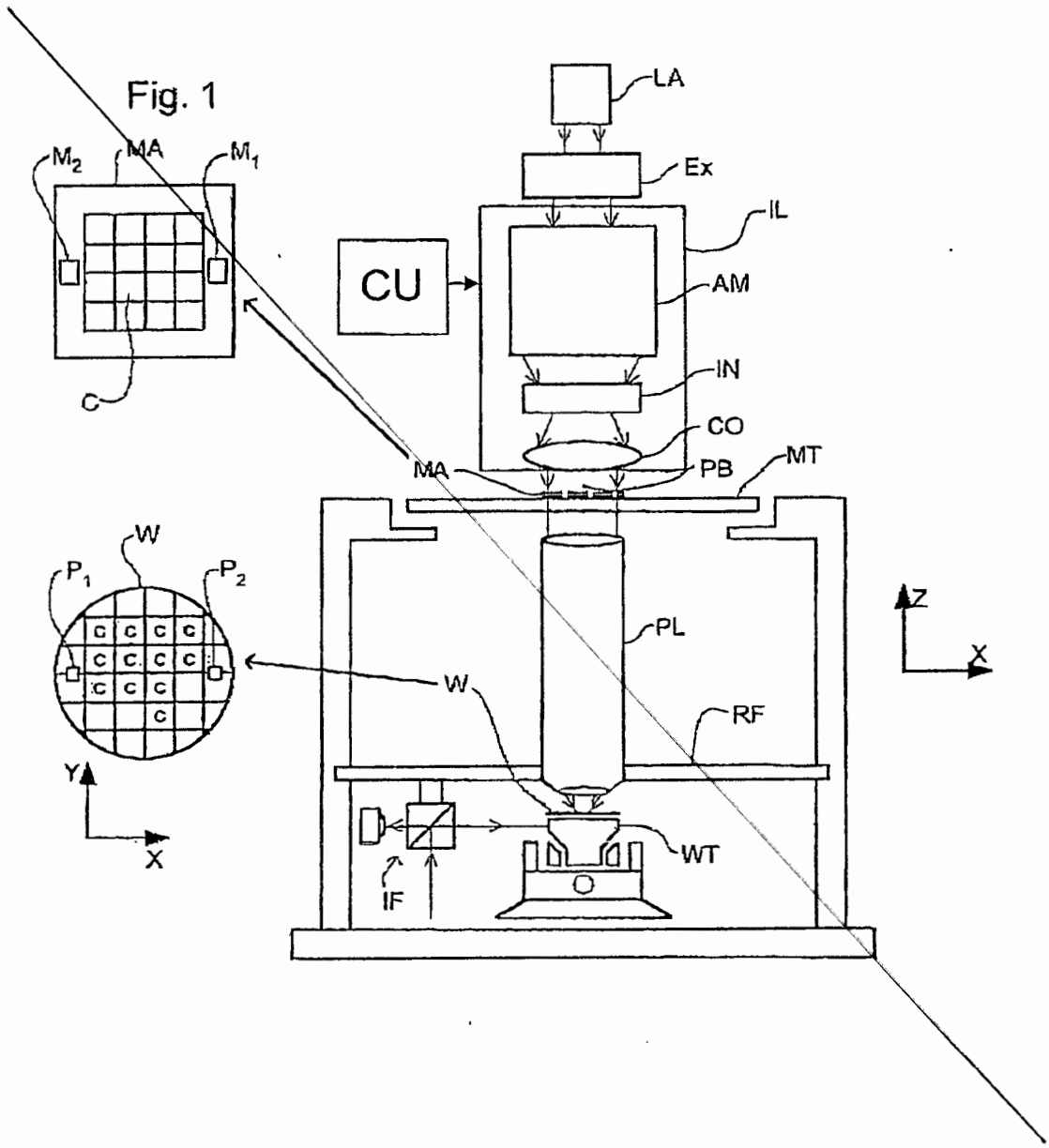
Fig. 1



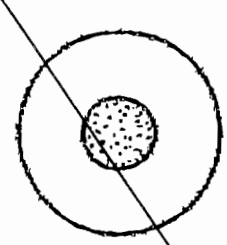


FIG. 2

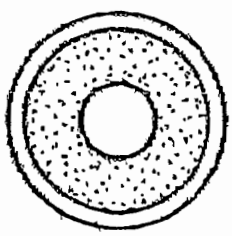


FIG. 3

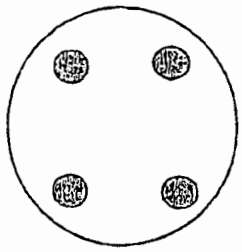


FIG. 4

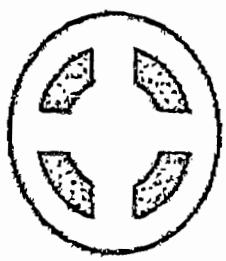


FIG. 5

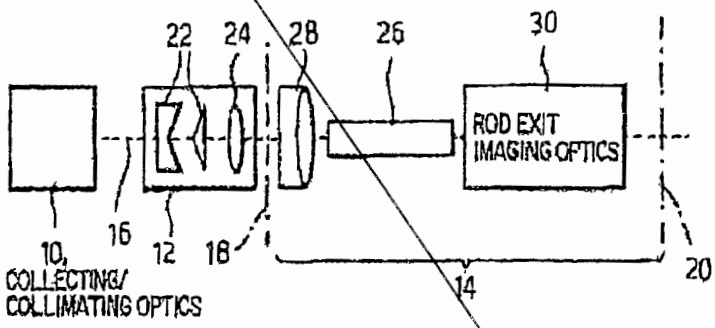


FIG. 6

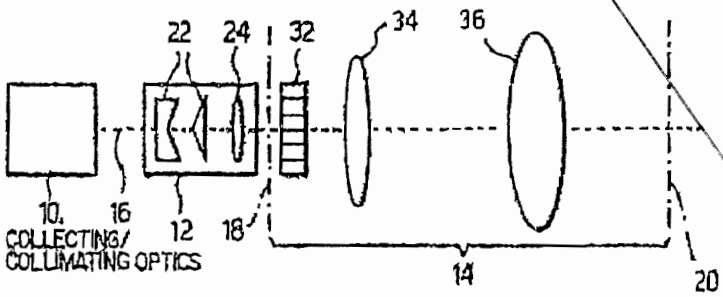


FIG. 7

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FIG. 8

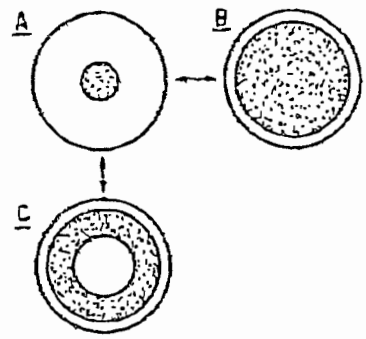
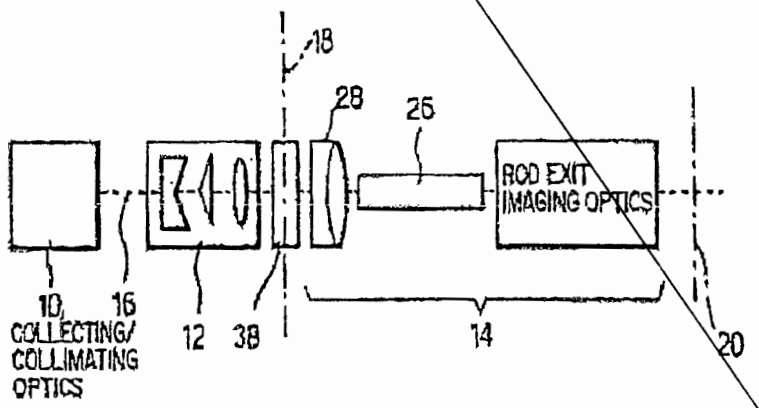


FIG. 9



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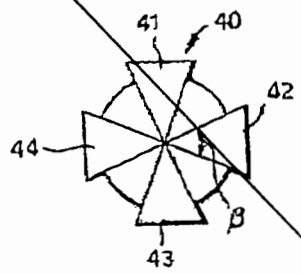

FIG. 10a

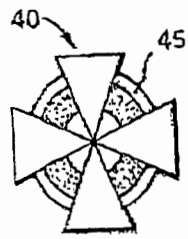

FIG. 10b

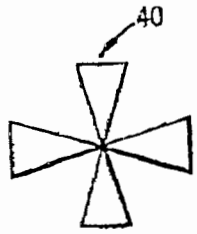

FIG. 11

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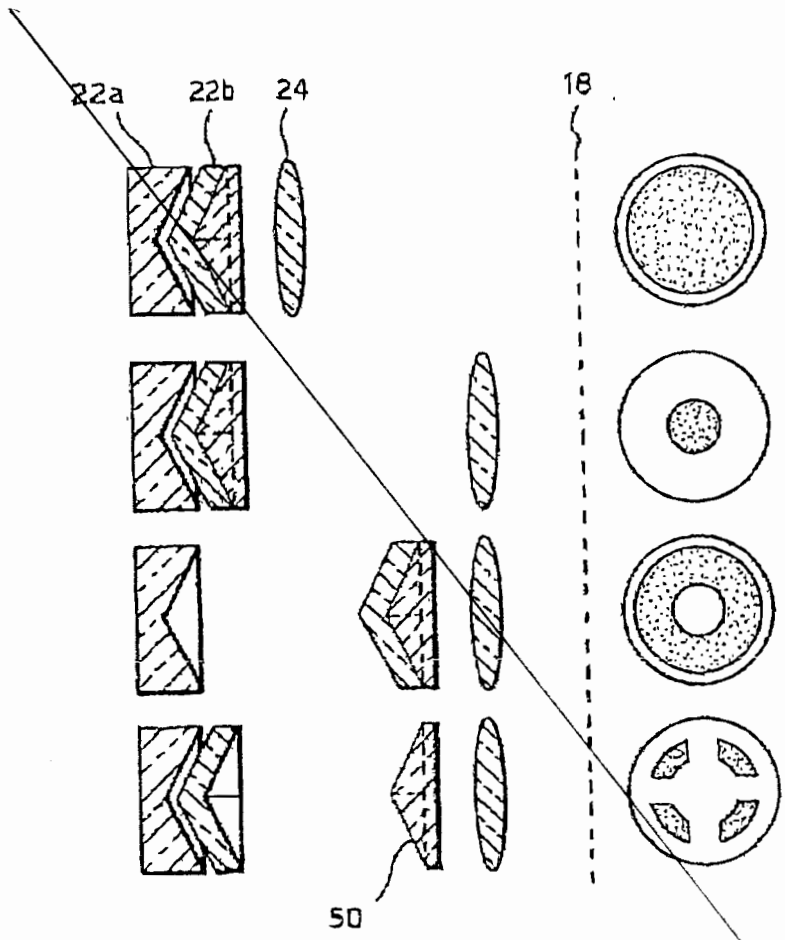

FIG. 12

06 JUN 2025

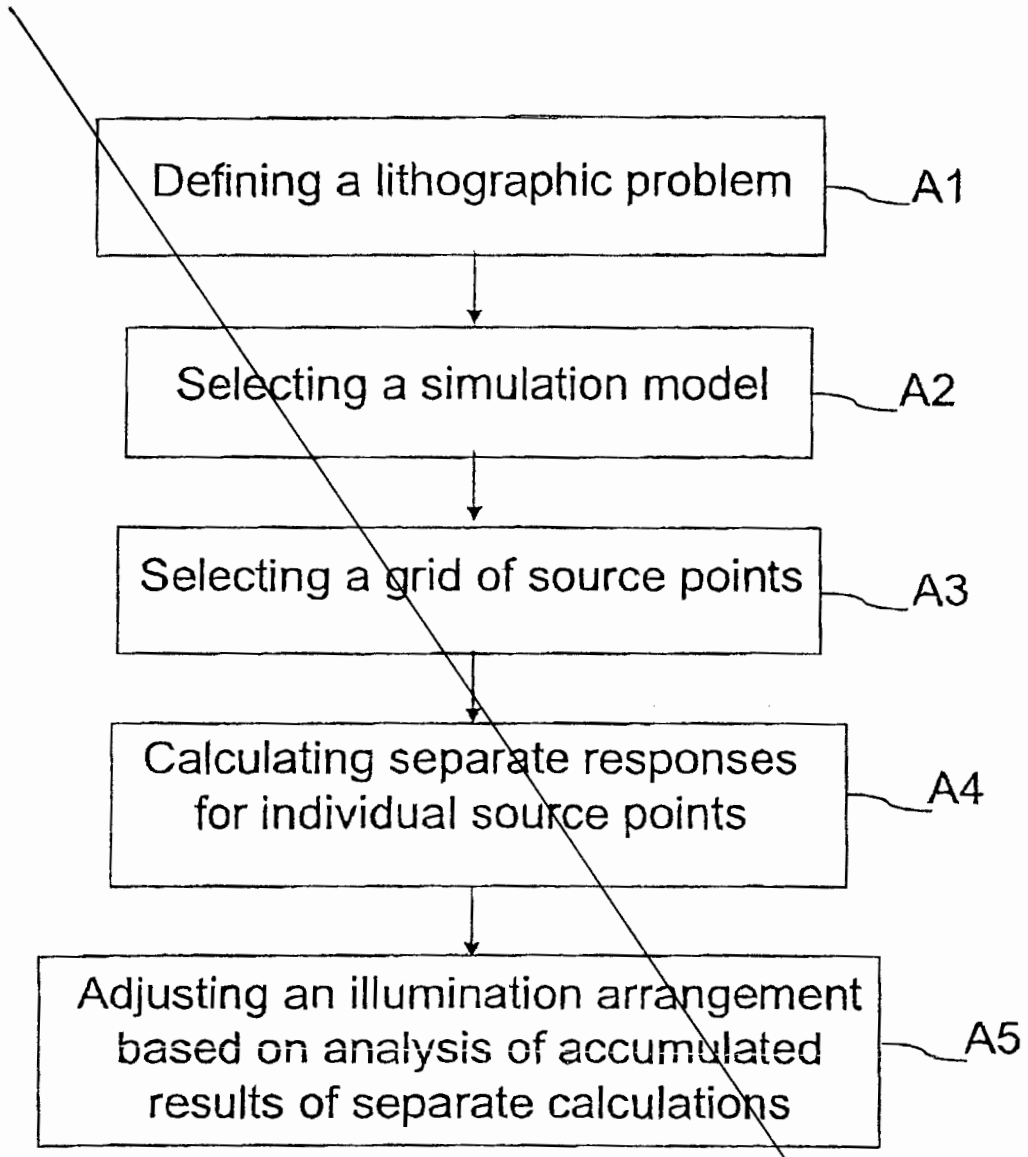

FIG. 13

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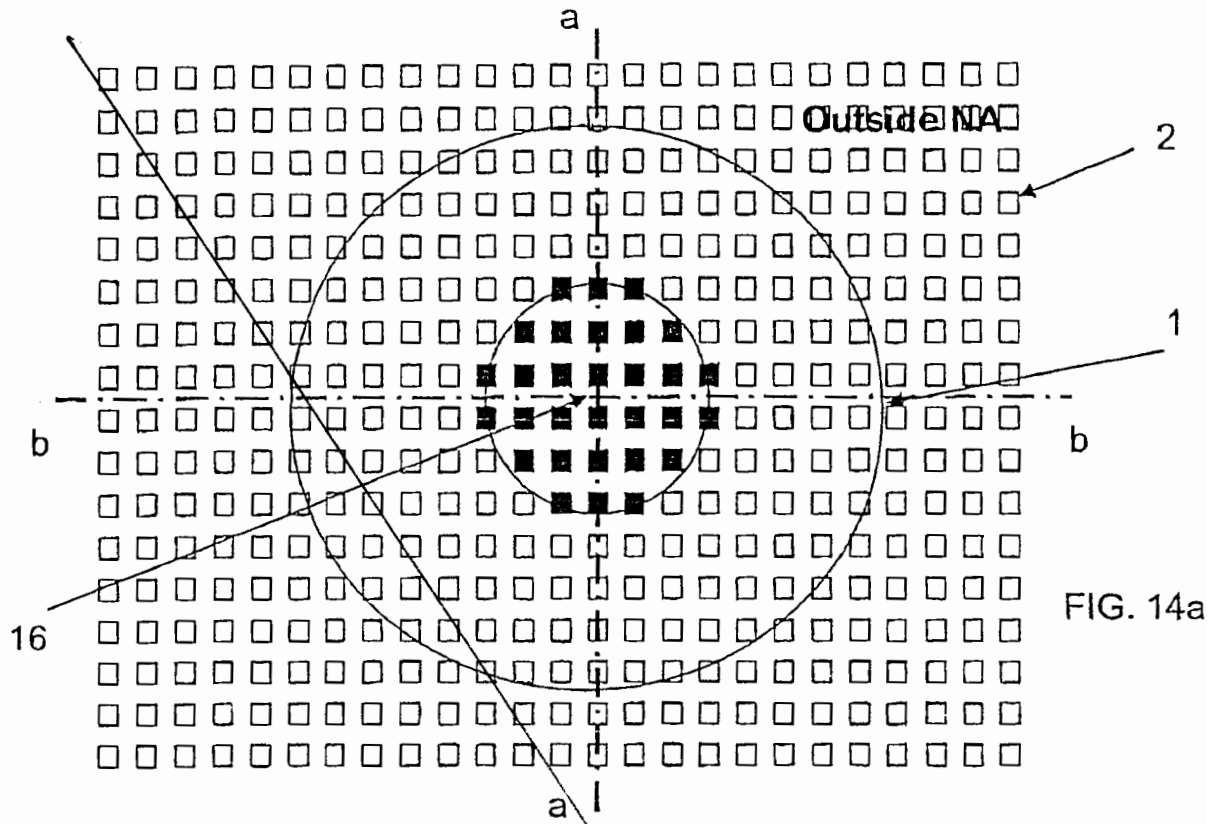

FIG. 14a

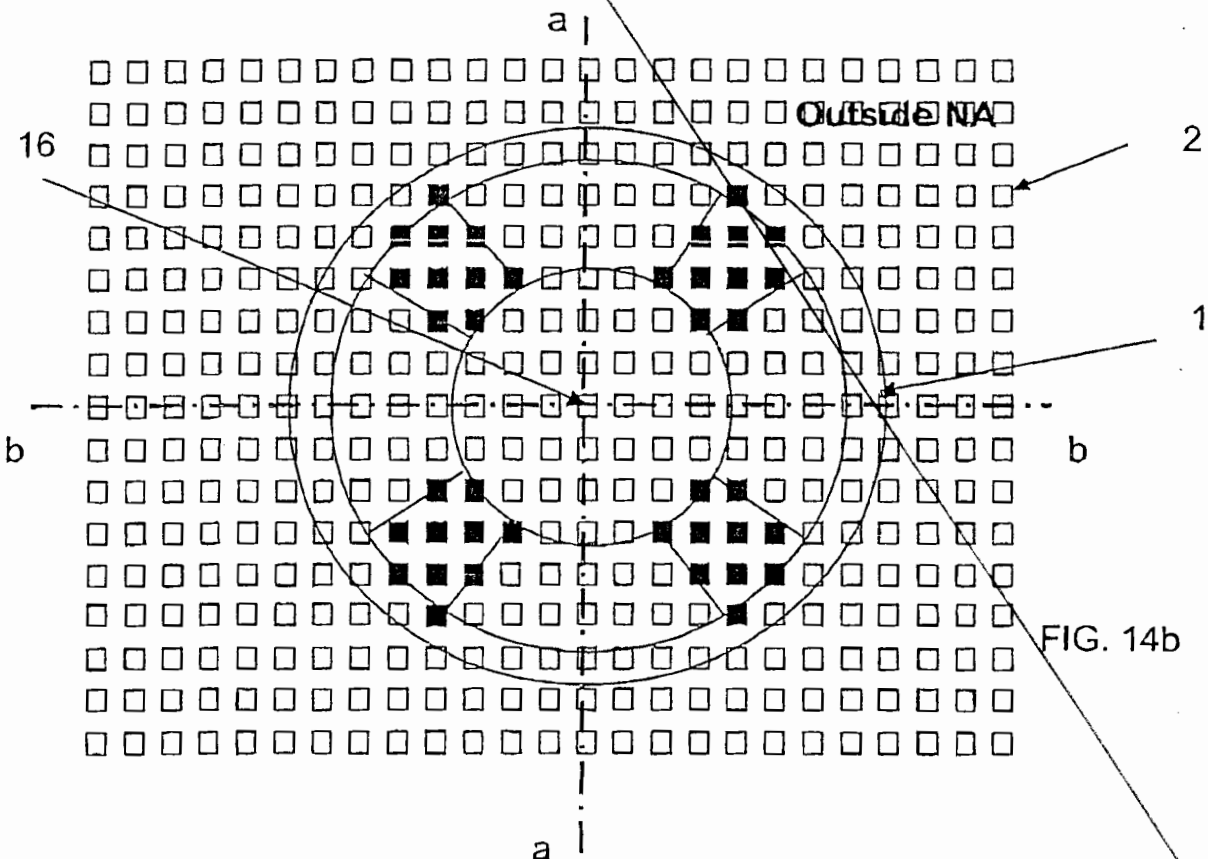

FIG. 14b

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65nm CPL isolated lines, 193nm
0.85NA, scalar aerial image simulations
0.2μm defocus

high DOF expected with appropriate Quasar

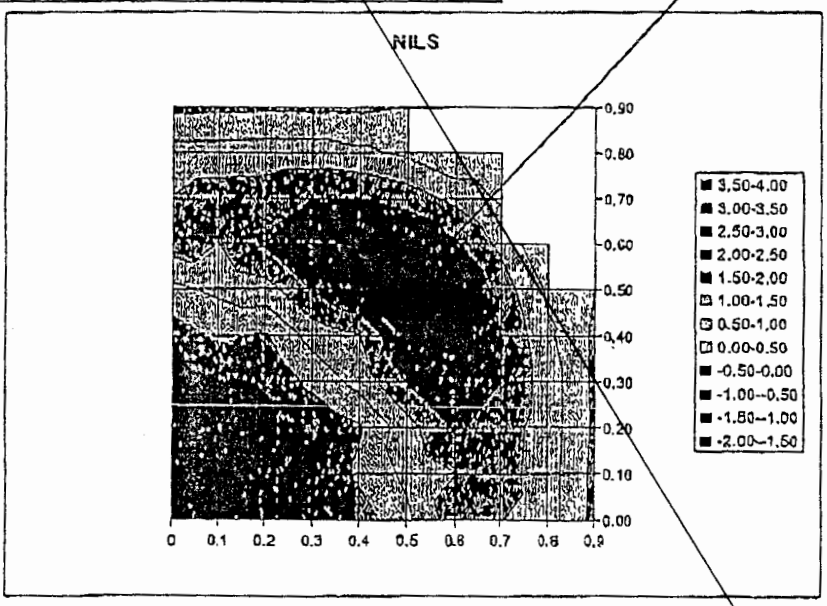

FIG. 15

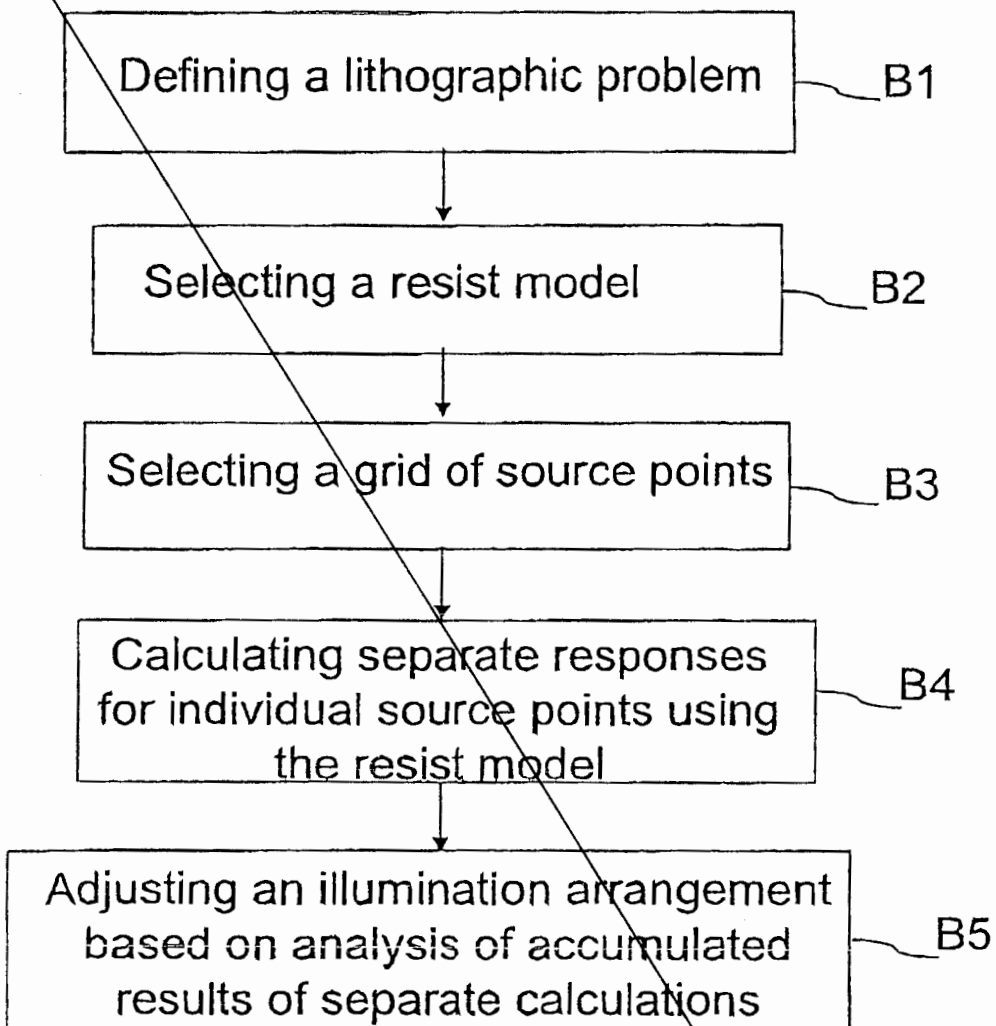
Defining a lithographic problem
B1
Selecting a resist model
B2
Selecting a grid of source points
B3
Calculating separate responses for individual source points using the resist model
B4
Adjusting an illumination arrangement based on analysis of accumulated results of separate calculations
B5

FIG. 16

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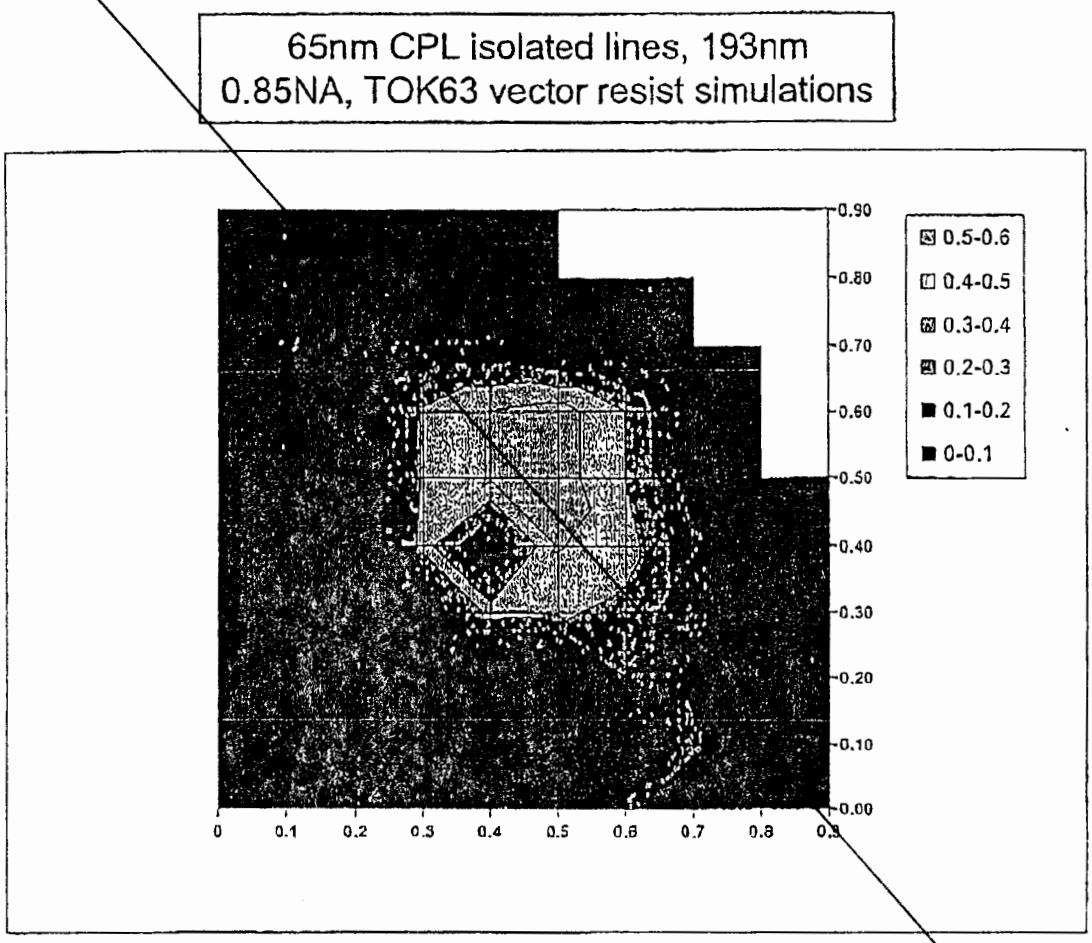

FIG. 17

REPLACEMENT SHEET
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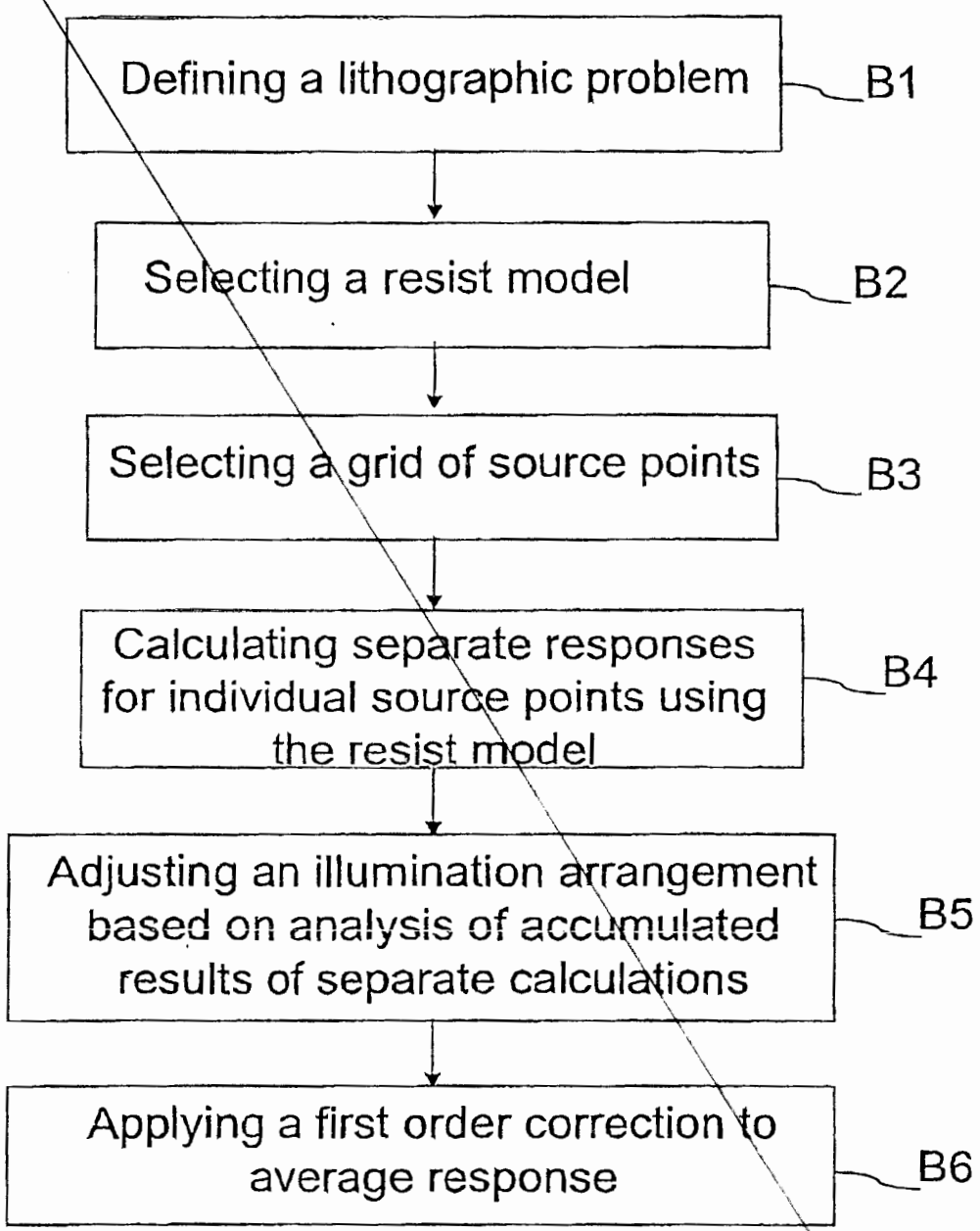

FIG. 18

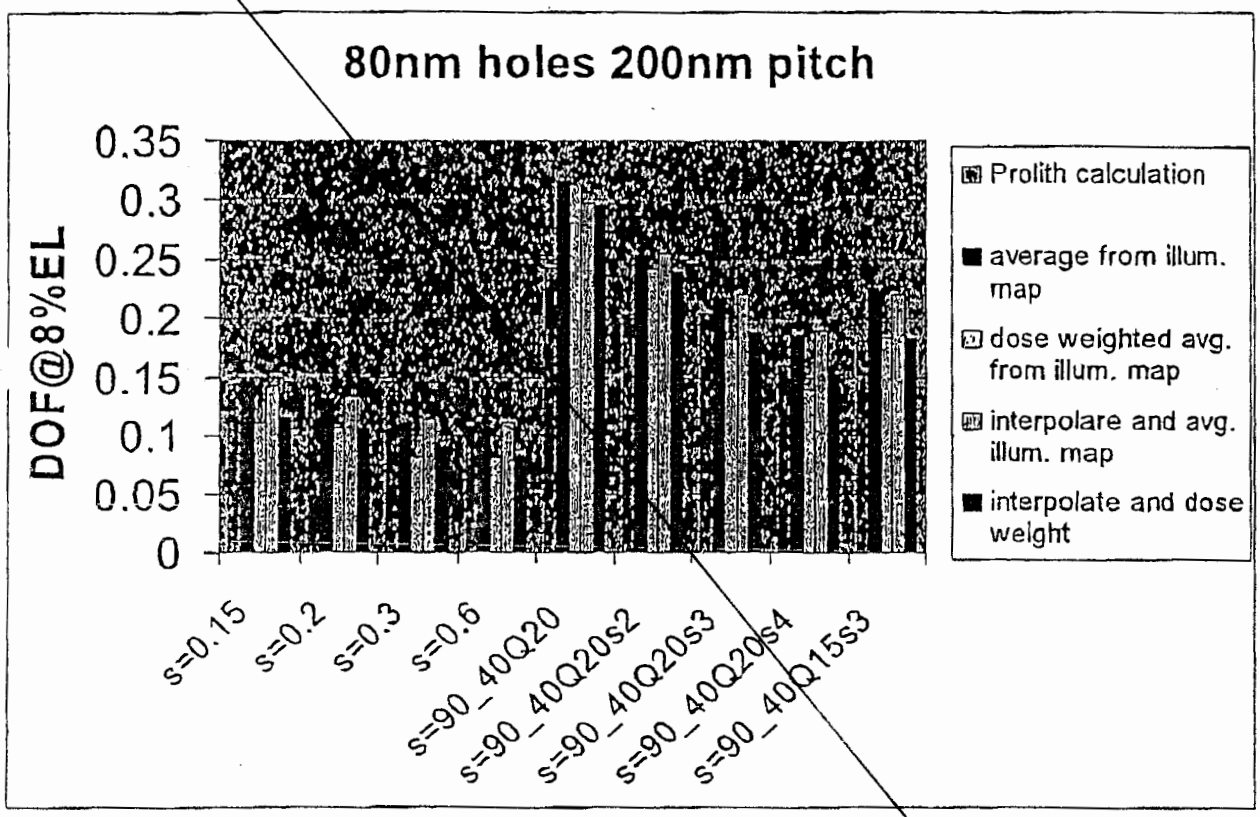
80nm holes 200nm pitch
DOF@8%EL
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
s=0.15
s=0.2
s=0.3
s=0.6
s=90_40Q20
s=90_40Q20s2
s=90_40Q20s3
s=90_40Q20s4
s=90_40Q15s3
Prolith calculation
average from illum. map
dose weighted avg. from illum. map
interpolare and avg. illum. map
interpolate and dose weight

FIG. 19

REPLACEMENT SHEET

06 JUN 2005

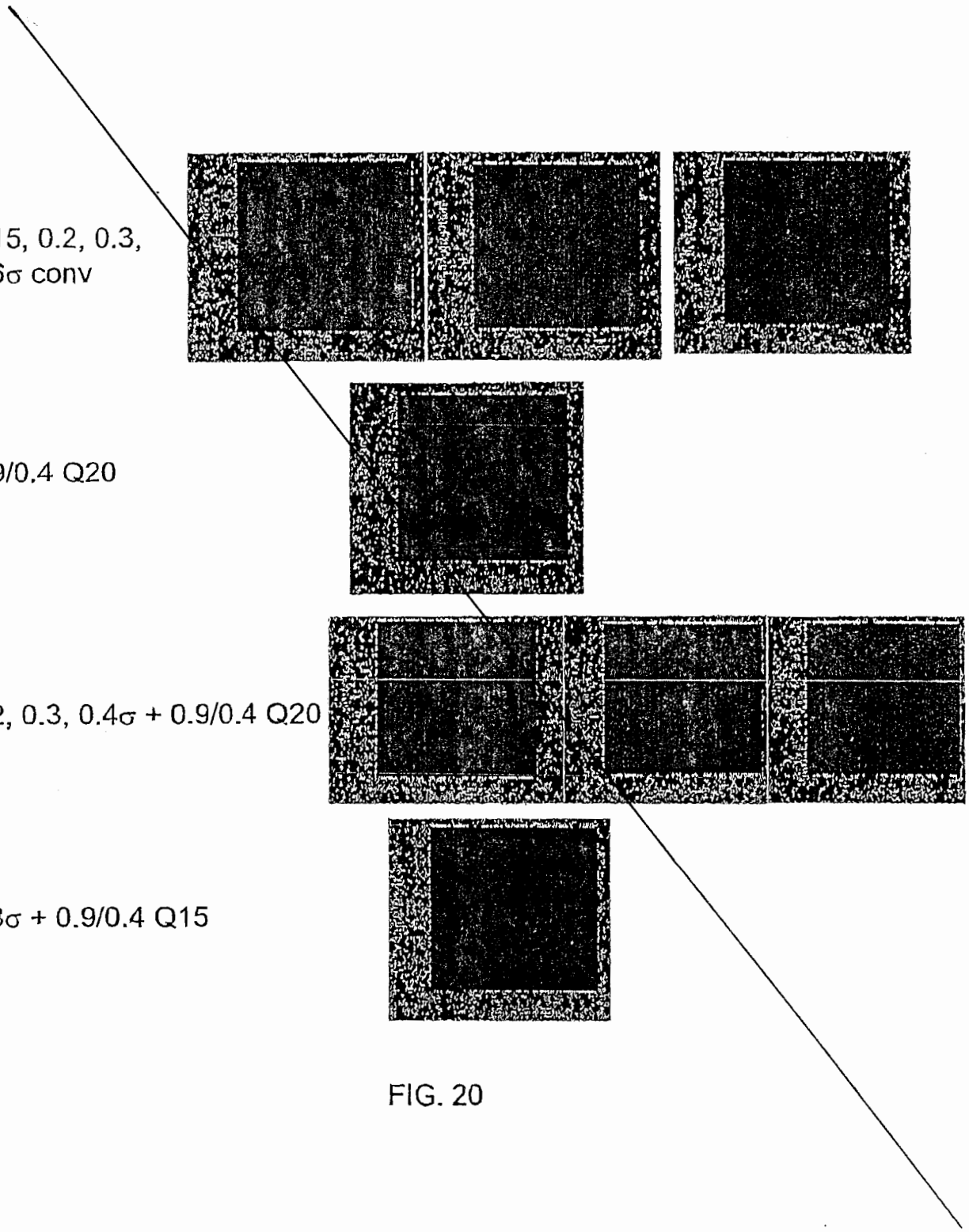

FIG. 20

REPLACEMENT SHEET
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trial illuminator	prediction based on weighted and interpolated source measurements	Prolith simulation with this illuminator
0.85_0.55Q30	0.293u	0.23u
0.75_0.55Q20	0.416	0.41
0.80_0.60Q20	0.383	0.355
0.80_0.60annular	0.110	0.10
0.75_0.55annular	0.118	0.105

FIG. 21

REPLACEMENT SHEET
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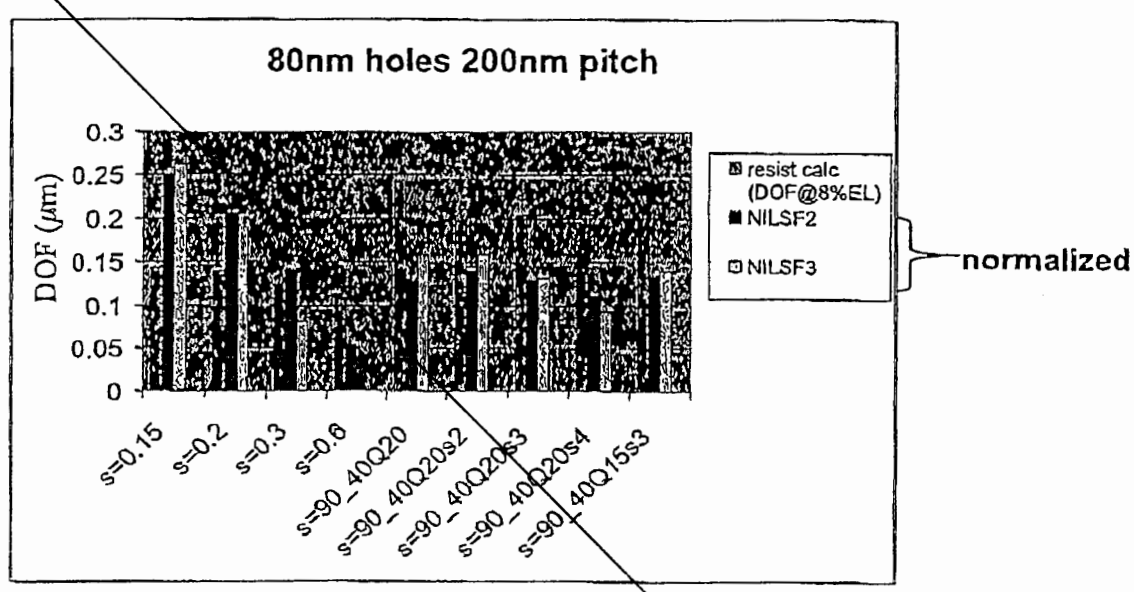

FIG. 22

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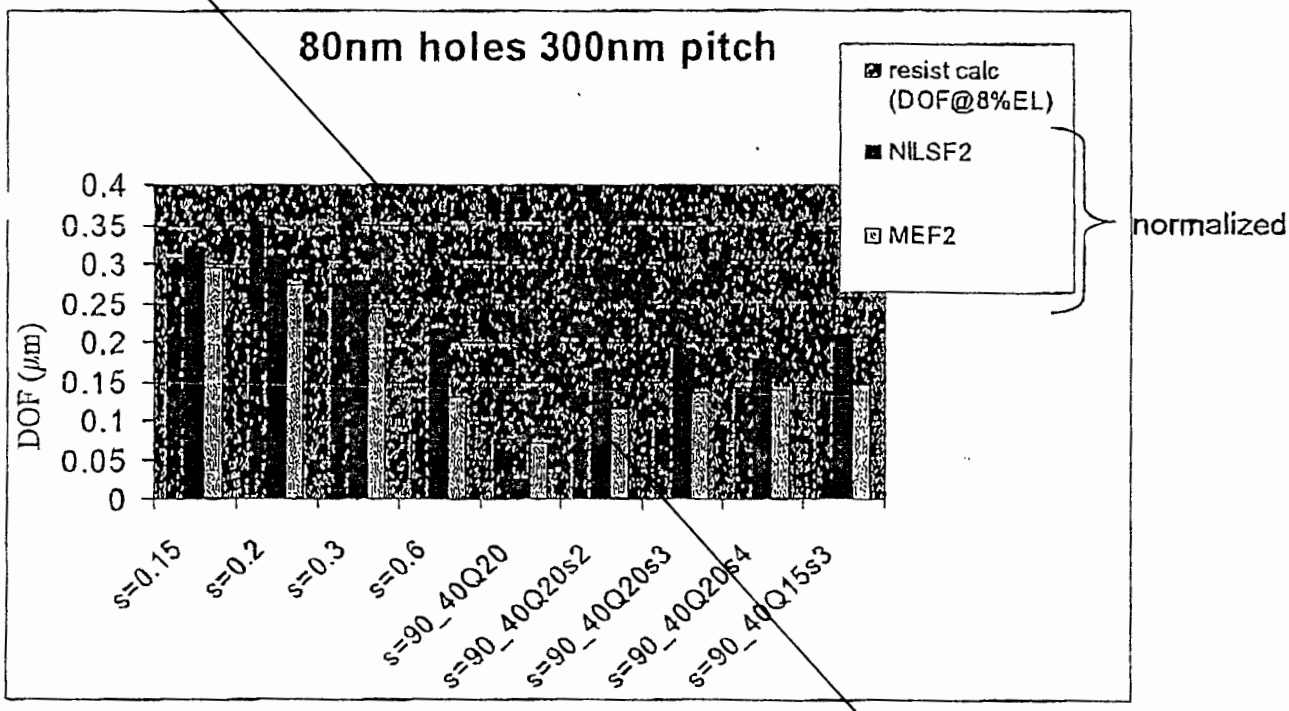

FIG. 23

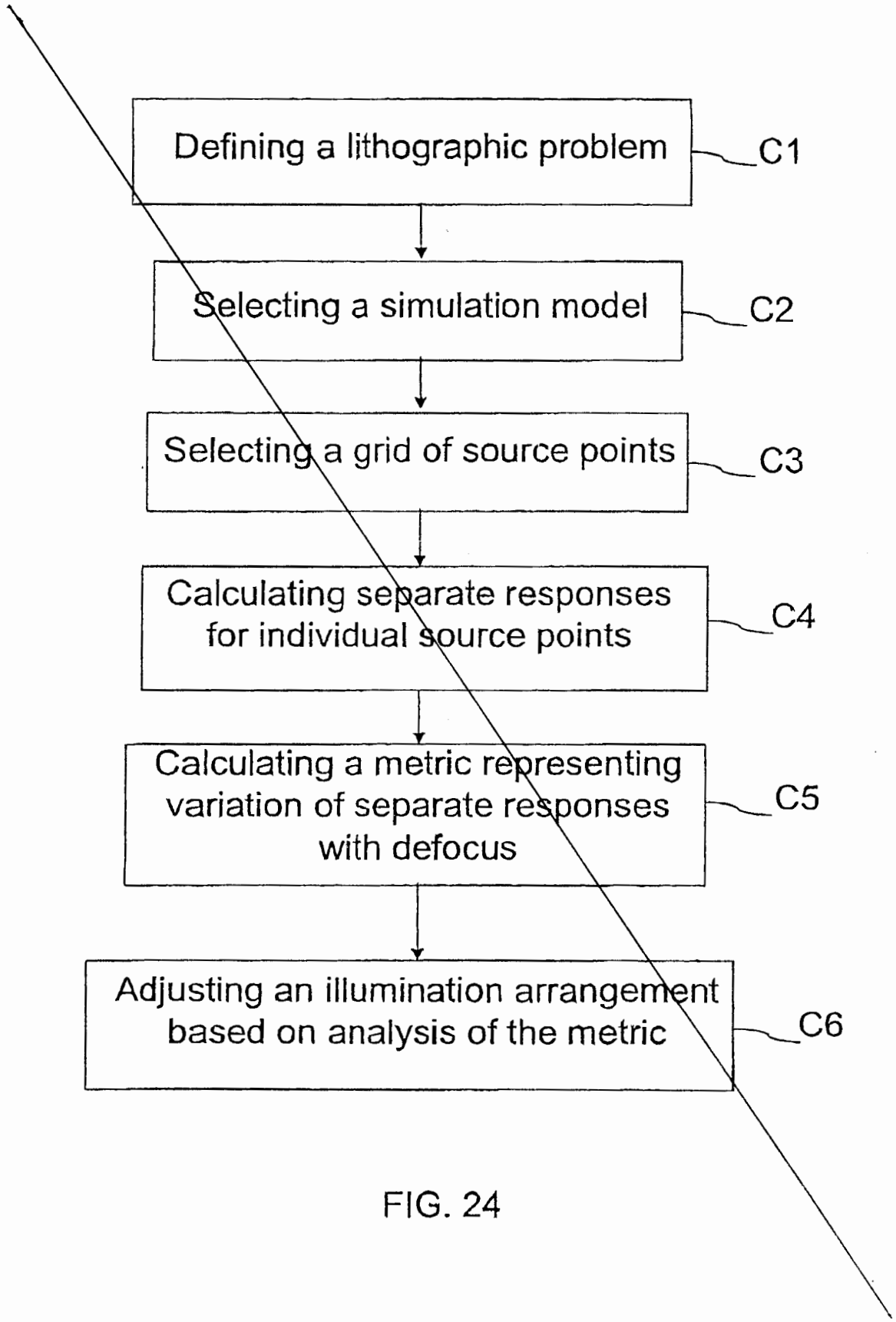
Defining a lithographic problem
C1
Selecting a simulation model
C2
Selecting a grid of source points
C3
Calculating separate responses for individual source points
C4
Calculating a metric representing variation of separate responses with defocus
C5
Adjusting an illumination arrangement based on analysis of the metric
C6

FIG. 24

REPLACEMENT SHEET
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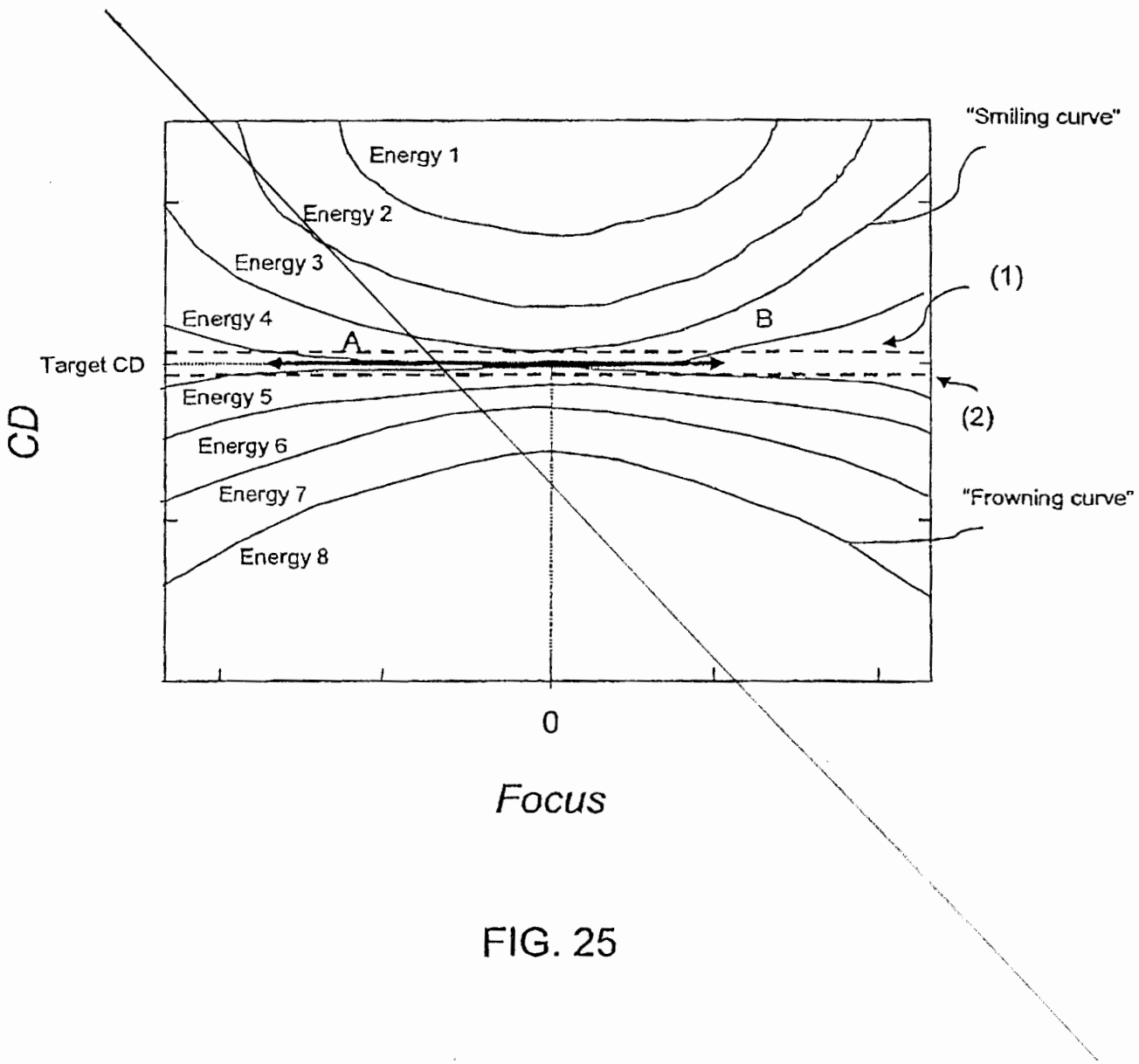


FIG. 25

FIG. 26a

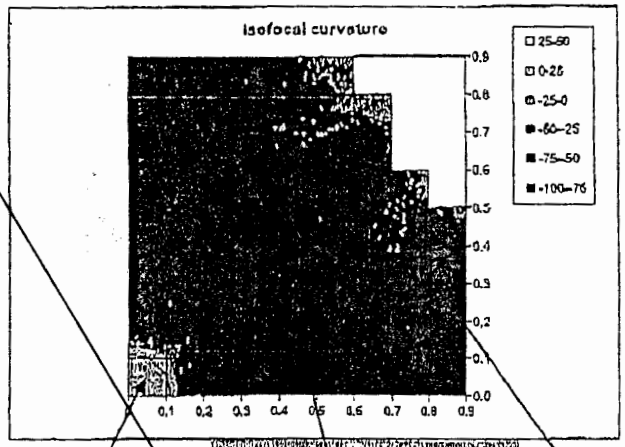


FIG. 26c

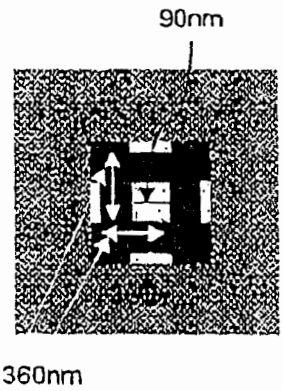
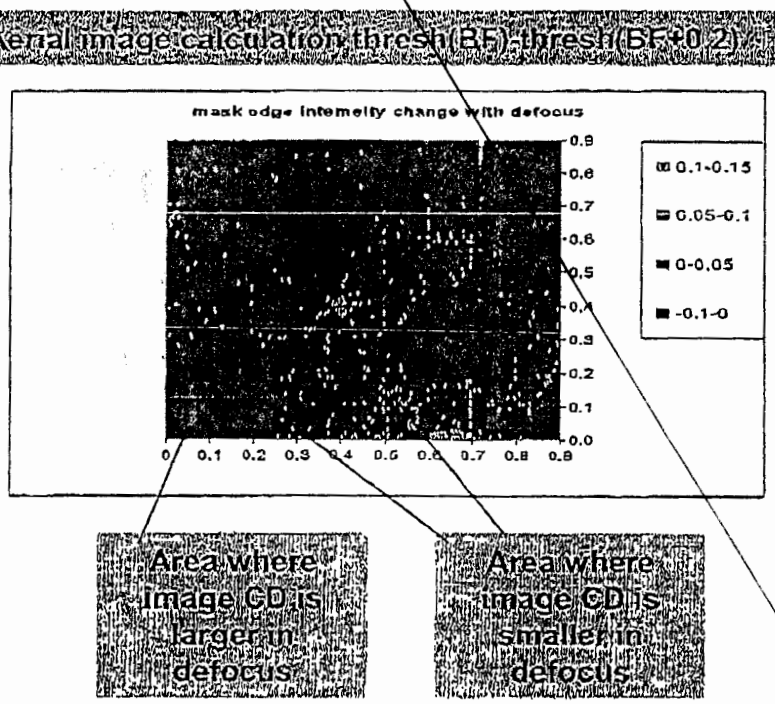


FIG. 26b



resist calculation CD(BF+0.2)-CD(BF)

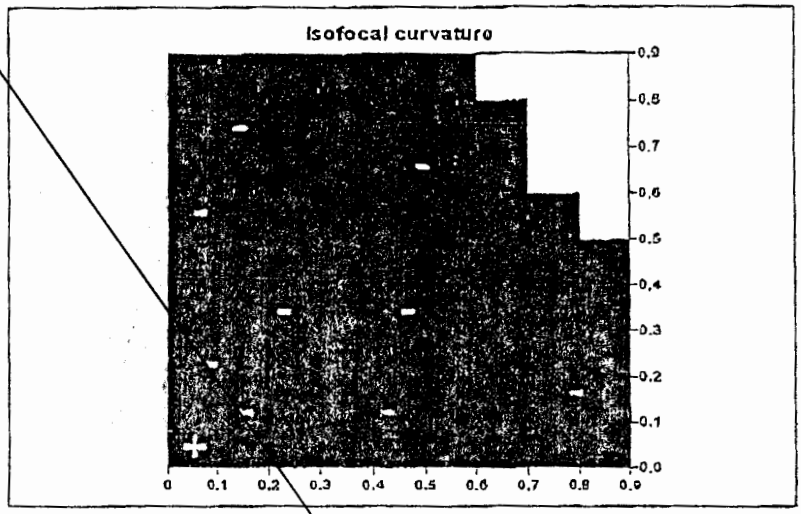


FIG. 27a

Aerial image calculation thresh(BF)-thresh(BF+0.2)

FIG. 27b

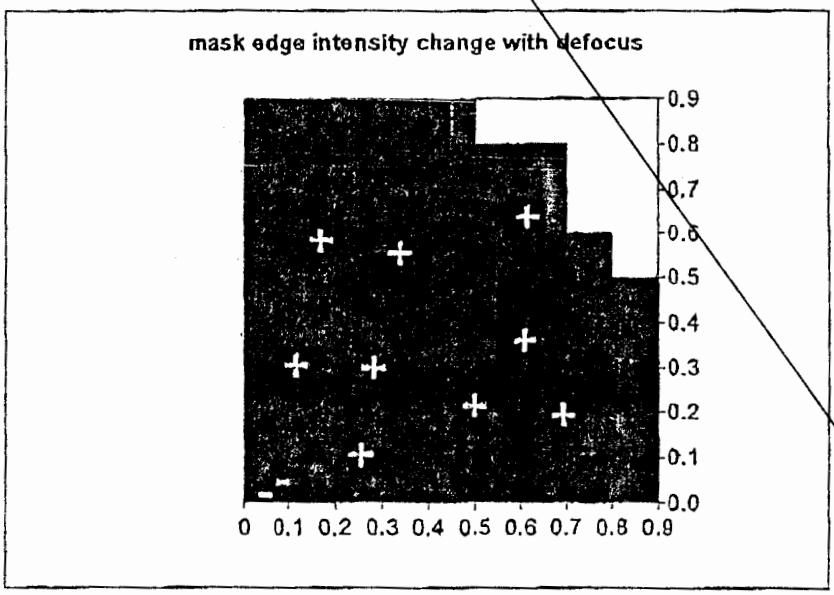
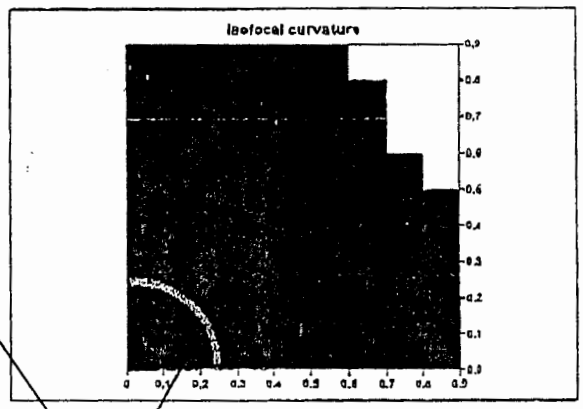


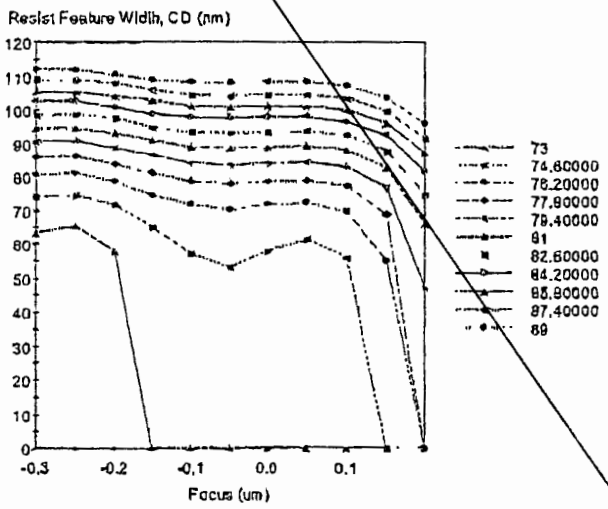
FIG. 28



σ=0.25 combines areas of + and - isofocal curvature

FIG. 29

At σ=0.25, process is approximately isofocal. DOF is good but dose latitude is low.



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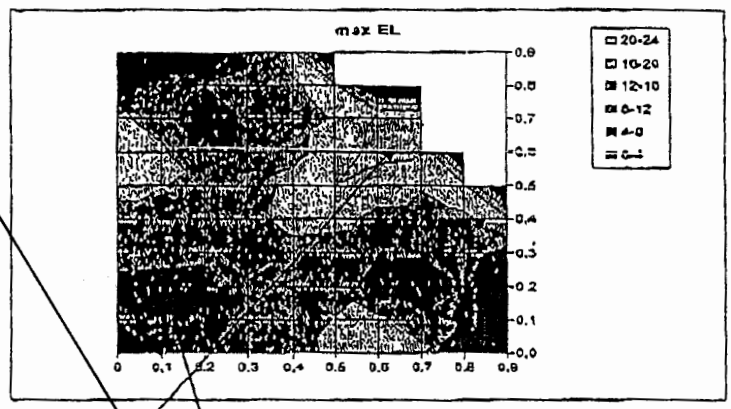


FIG. 30a

Low σ area provides poor EL and also requires high dose to print (weak aerial image)

Desirable area for high EL is wide quasar

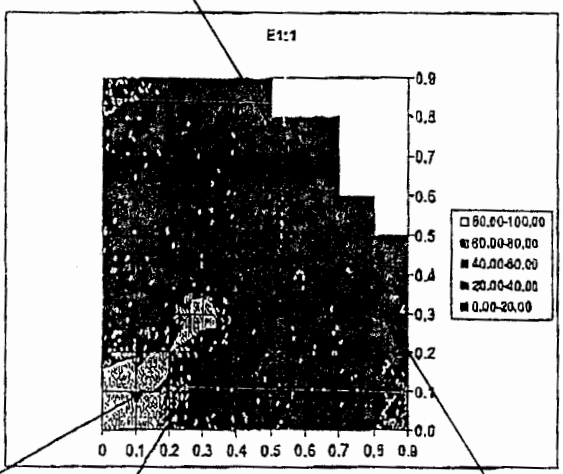


FIG. 30b

Low σ area provides poor EL and also requires high dose to print (weak aerial image)

Wide quasar also provides low E1:1 (strong aerial image)

FIG. 31

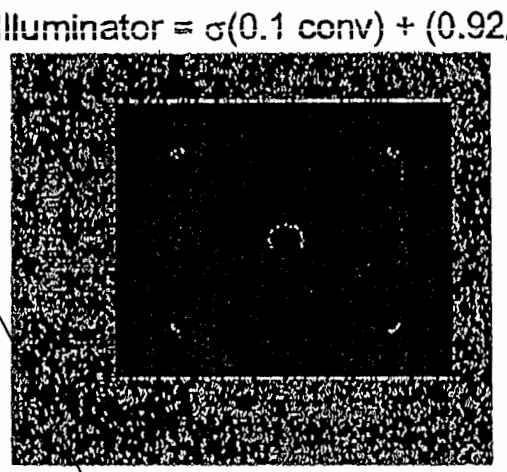


FIG. 32

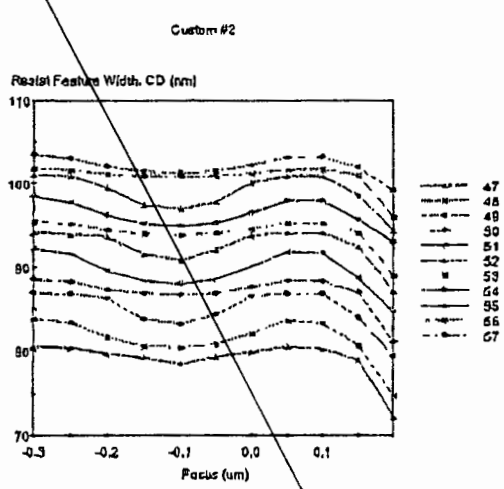
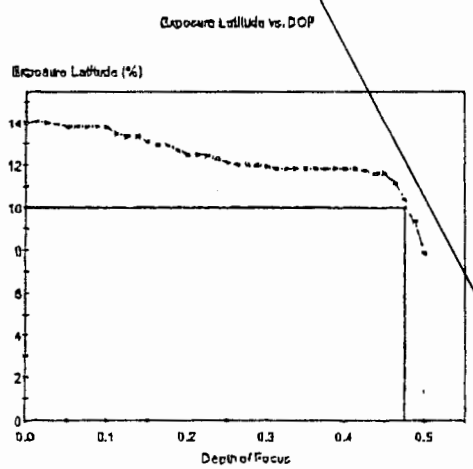
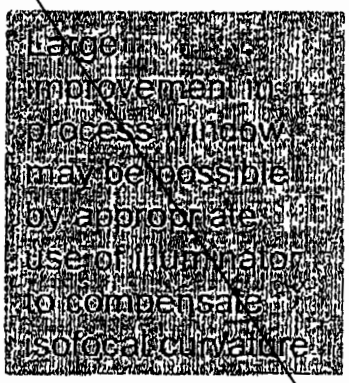


FIG. 33



optimization method	illumination	max EL	max DOF	DOF @ 10% EL	DOF @ 0% EL
standard	0.95/0.70Q30°	18%	0.3	0.18	0.24
simple isofocal compensation	0.26 conv	9%	>0.55	0	0.29
high EL isofocal compensation	0.92/0.66Q5°+0.1conv	15%	>0.85	0.57	0.83

FIG. 34



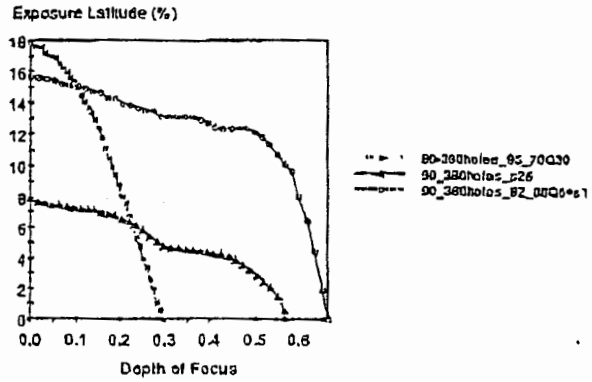


FIG. 35a

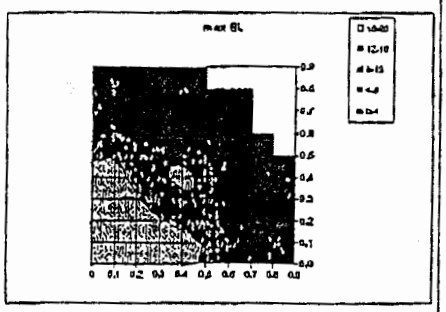


FIG. 35b

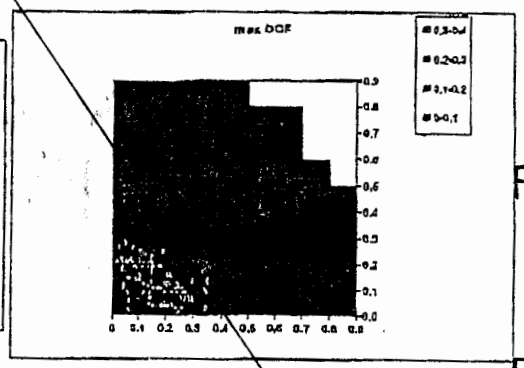
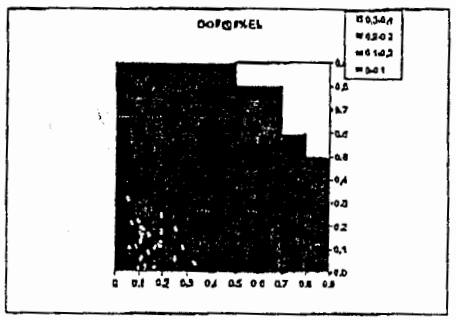
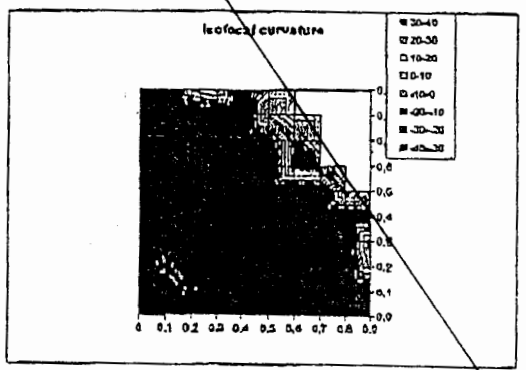


FIG. 35d

FIG. 35c





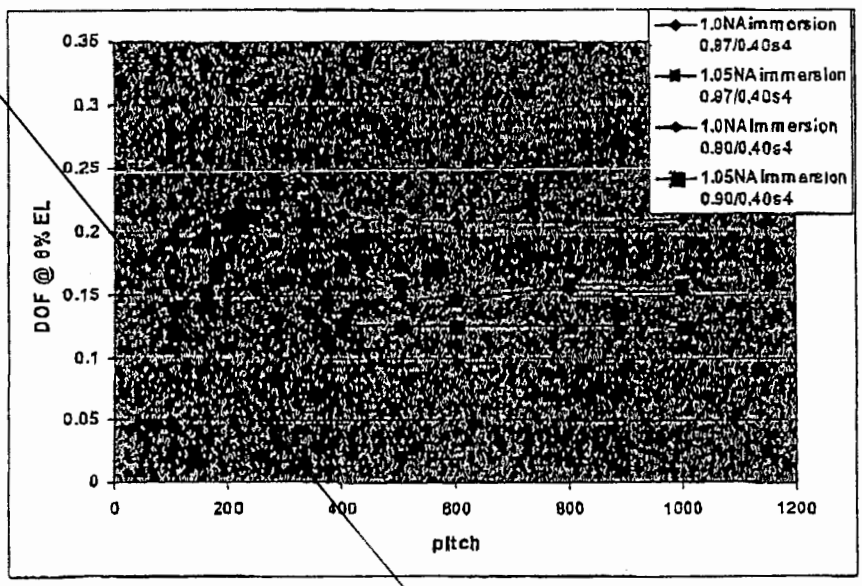
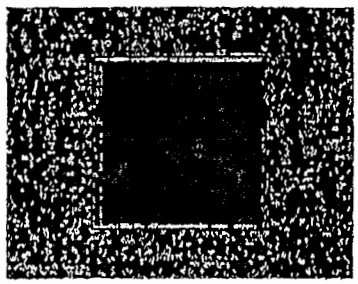


FIG. 36a

FIG. 36b



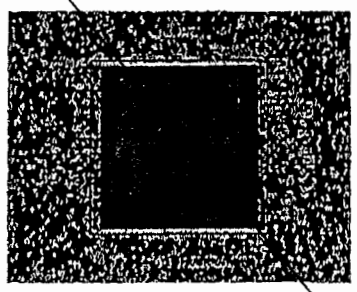


FIG. 36c

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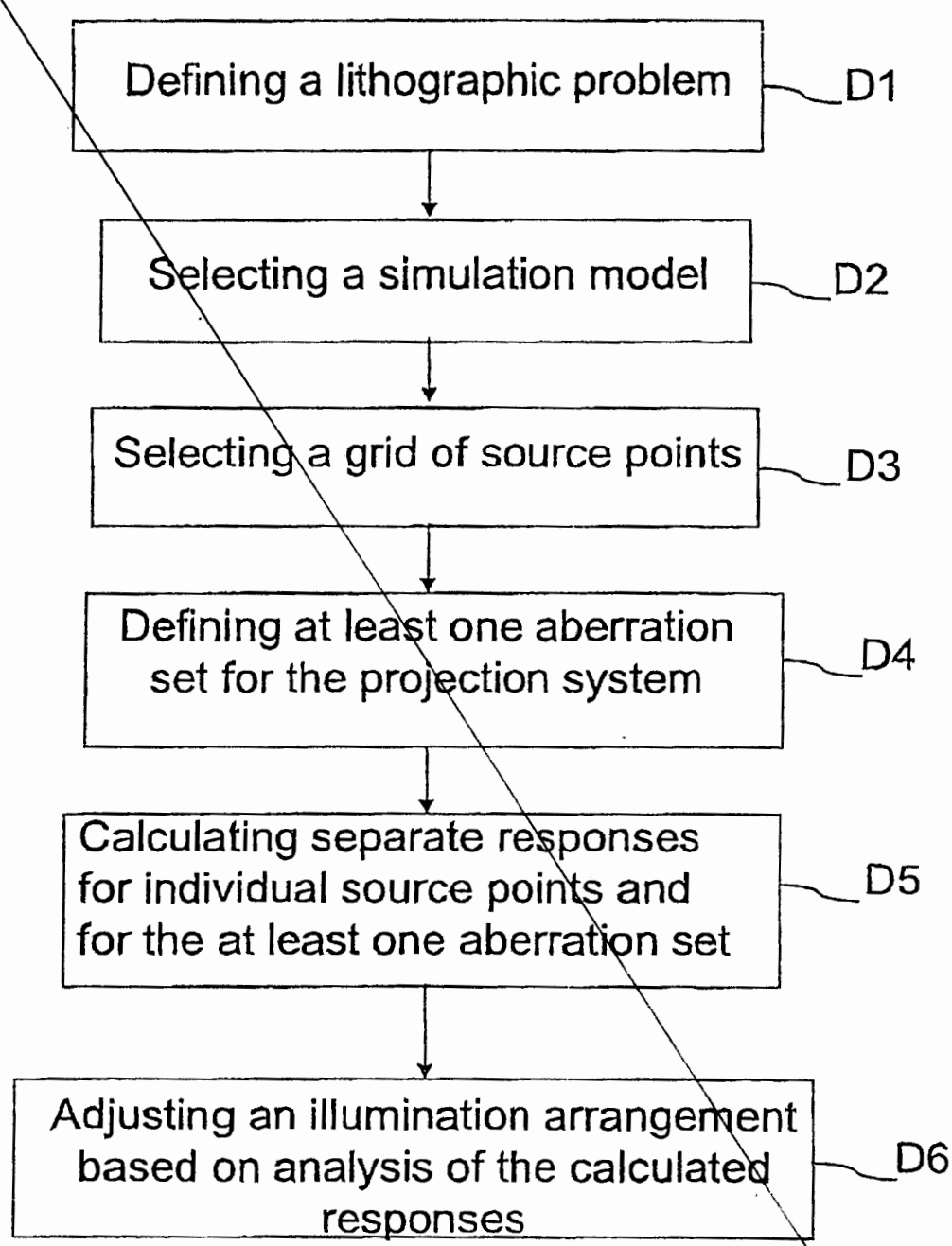

FIG. 37

REPLACEMENT SHEET

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Under these conditions, the structure is very aberration sensitive

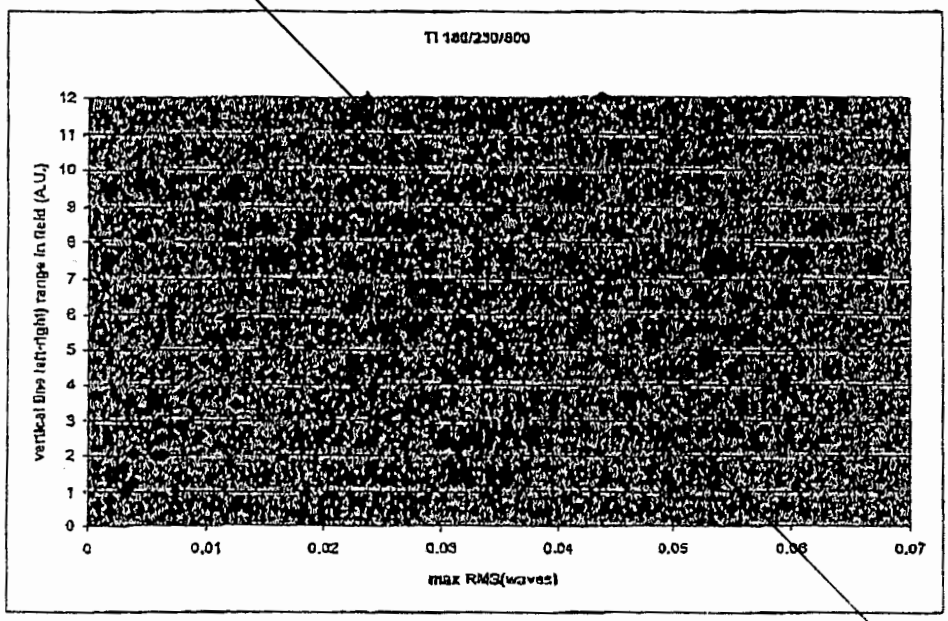
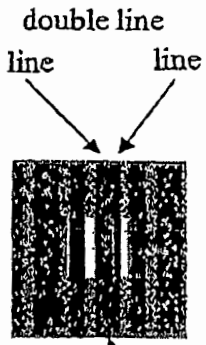


FIG. 38a



PSW
180 phase
shift window

FIG. 38b

REPLACEMENT SHEET
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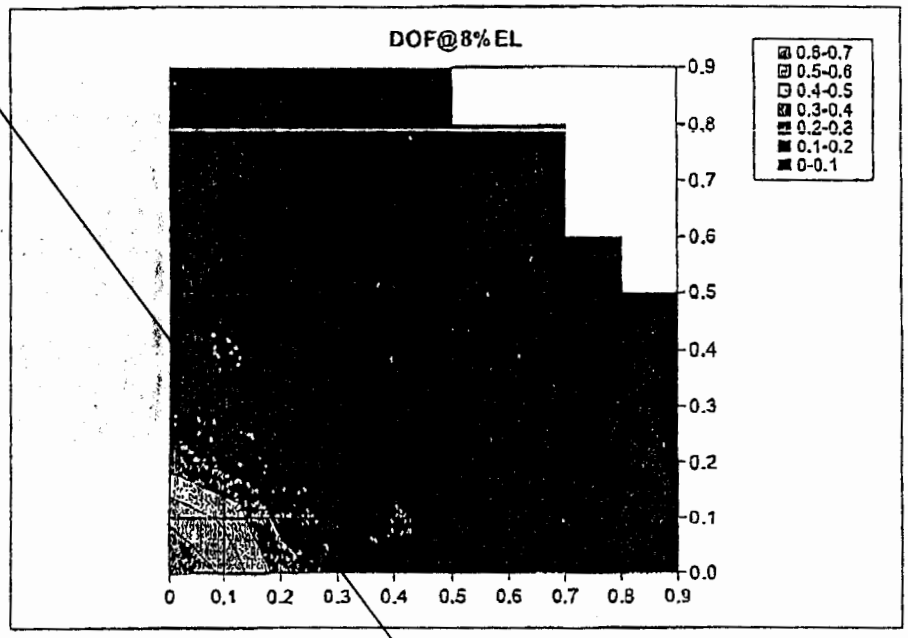


FIG. 39a

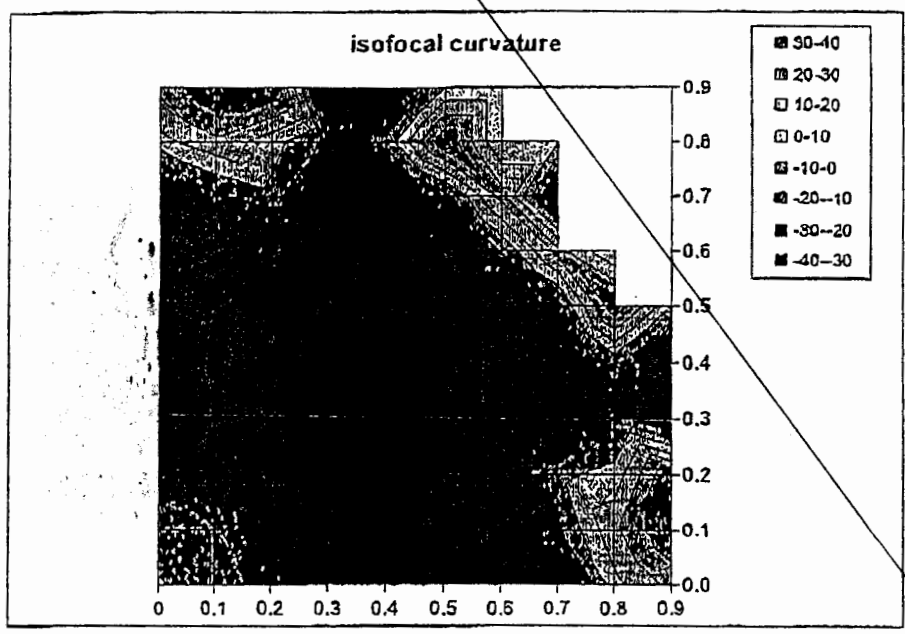
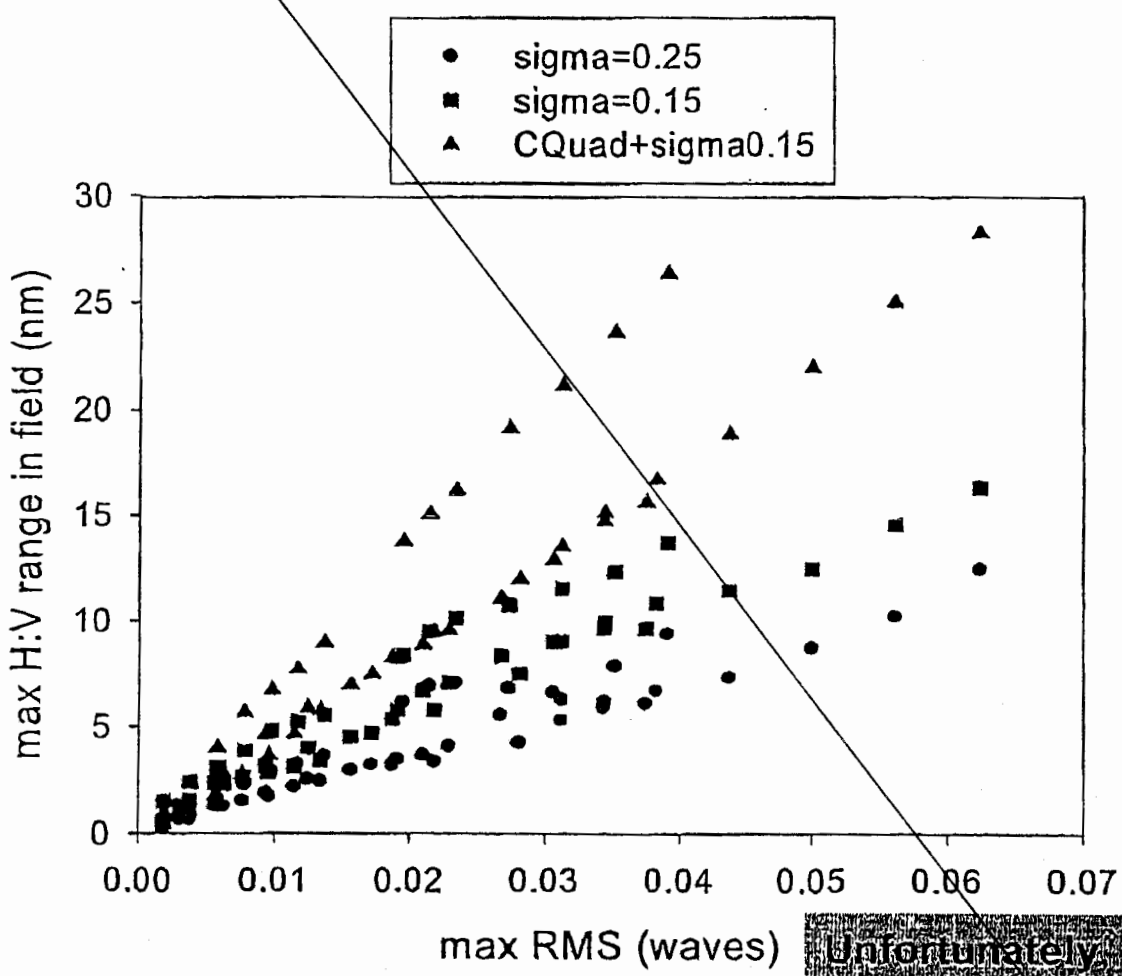


FIG. 39b



Unfortunately, the alternate settings have higher aberration sensitivity

FIG. 40

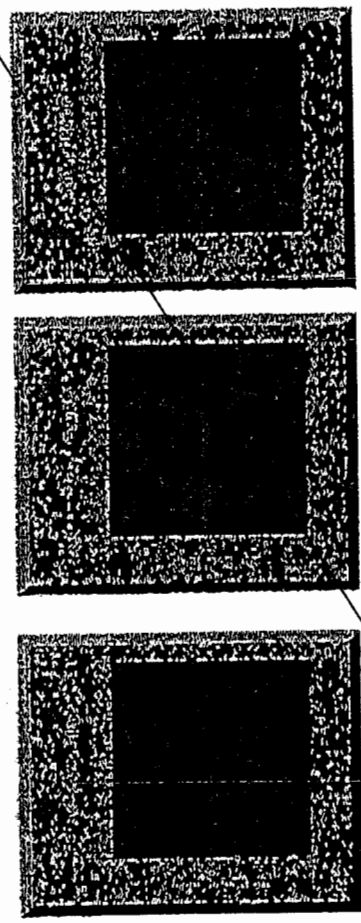


FIG. 41

REPLACEMENT SHEET
06 JUN 2005

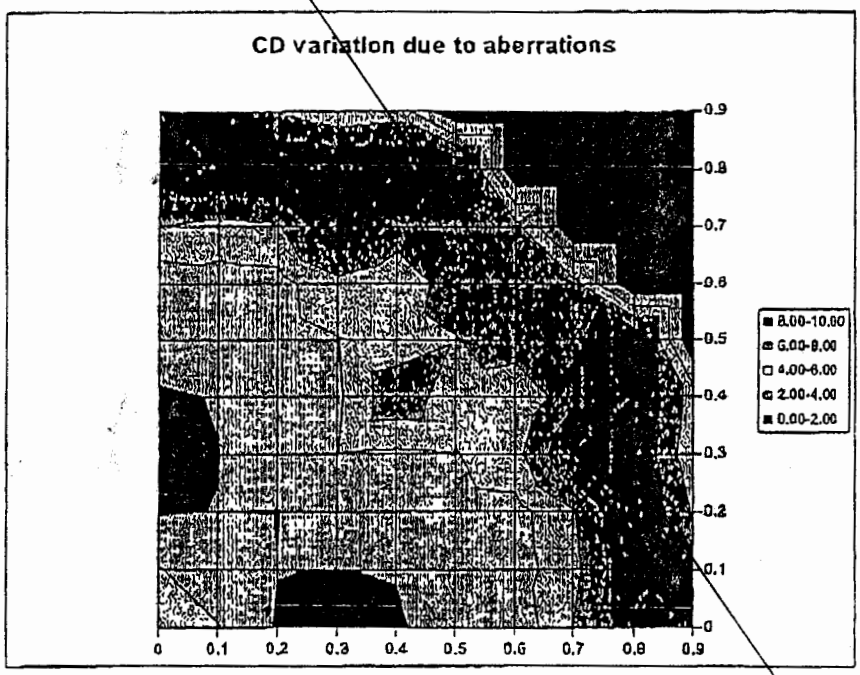
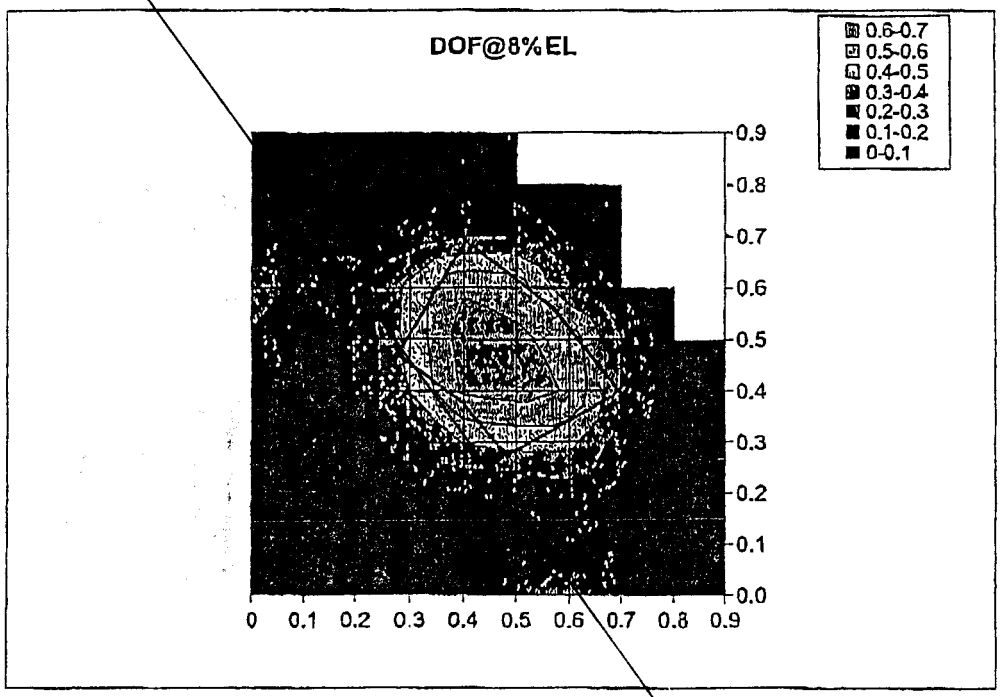


FIG. 42

REPLACEMENT SHEET
06 JUN 2005

Illum. Optimization with 0.75NA



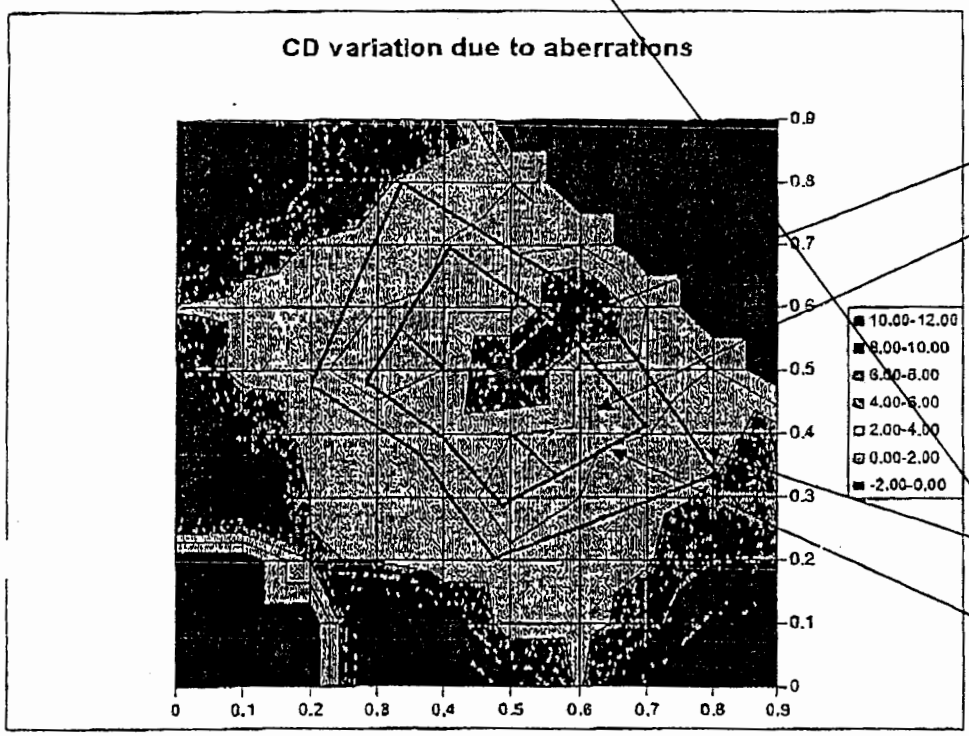
tight Quasar looks best

$\Rightarrow$ 0.80/0.55Q30°

FIG. 43

REPLACEMENT SHEET
06 JUN 2005

Source visualization of aberration sensitivity



High aberration sensitivity (6-8nm variation) for quasar 45 quasar location. Sensitivity drops (6-2nm) for different point aberration sensitivity can be reduced by enlarging poles to unfavorable off-axis sensitivity reduction in process window expected

Also consider larger poles
⇒ 0.85/0.50Q45°
in addition to tight quasar
⇒ 0.80/0.55Q30°

FIG. 44

REPLACEMENT SHEET
06 JUN 2005

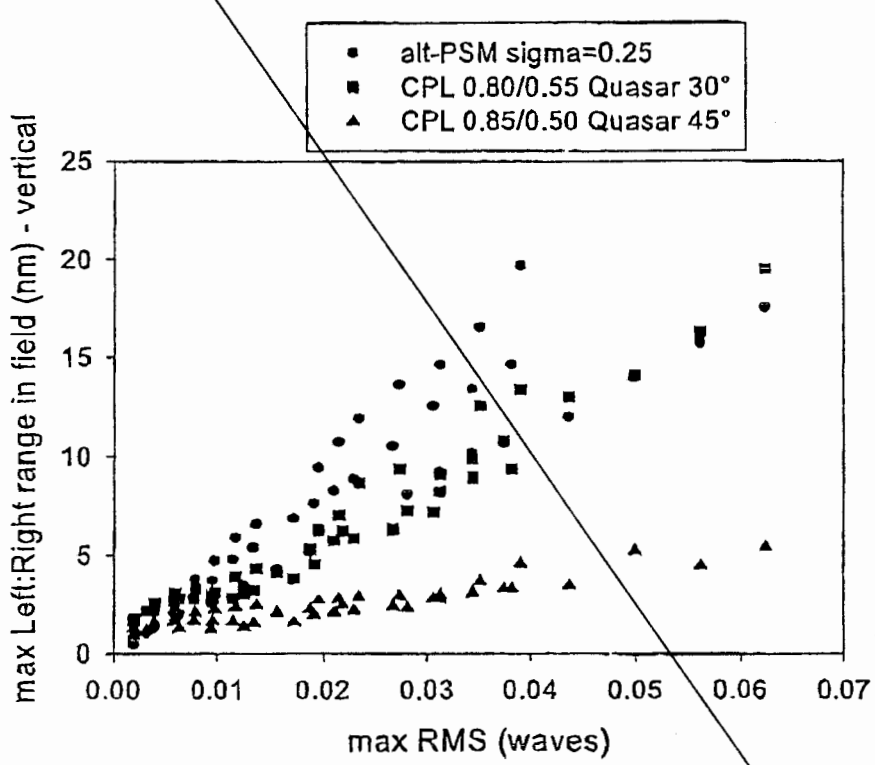


FIG. 45

REPLACEMENT SHEET
06 JUN 2005

CPL with reduced aberration sensitivity
increased pole size still gives favorable process window

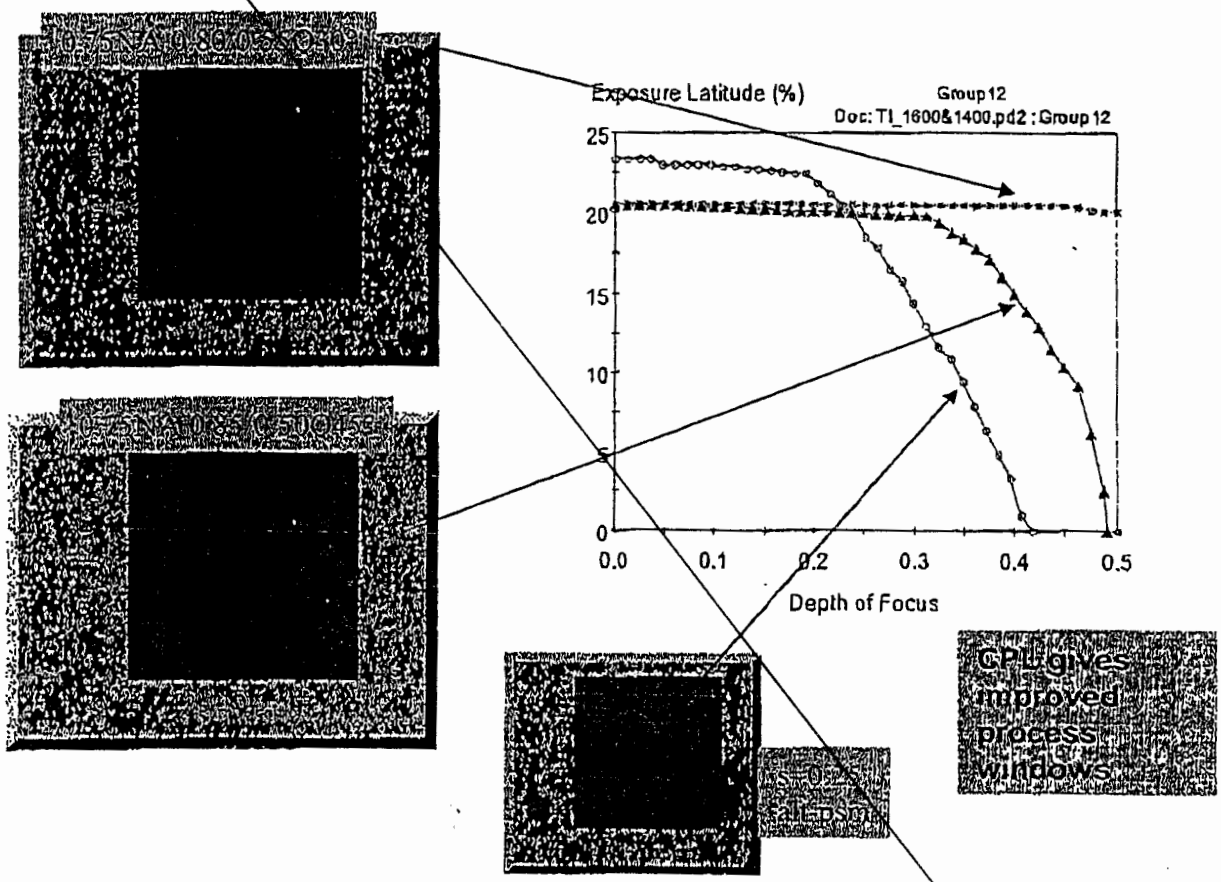


FIG. 46

REPLACEMENT SHEET
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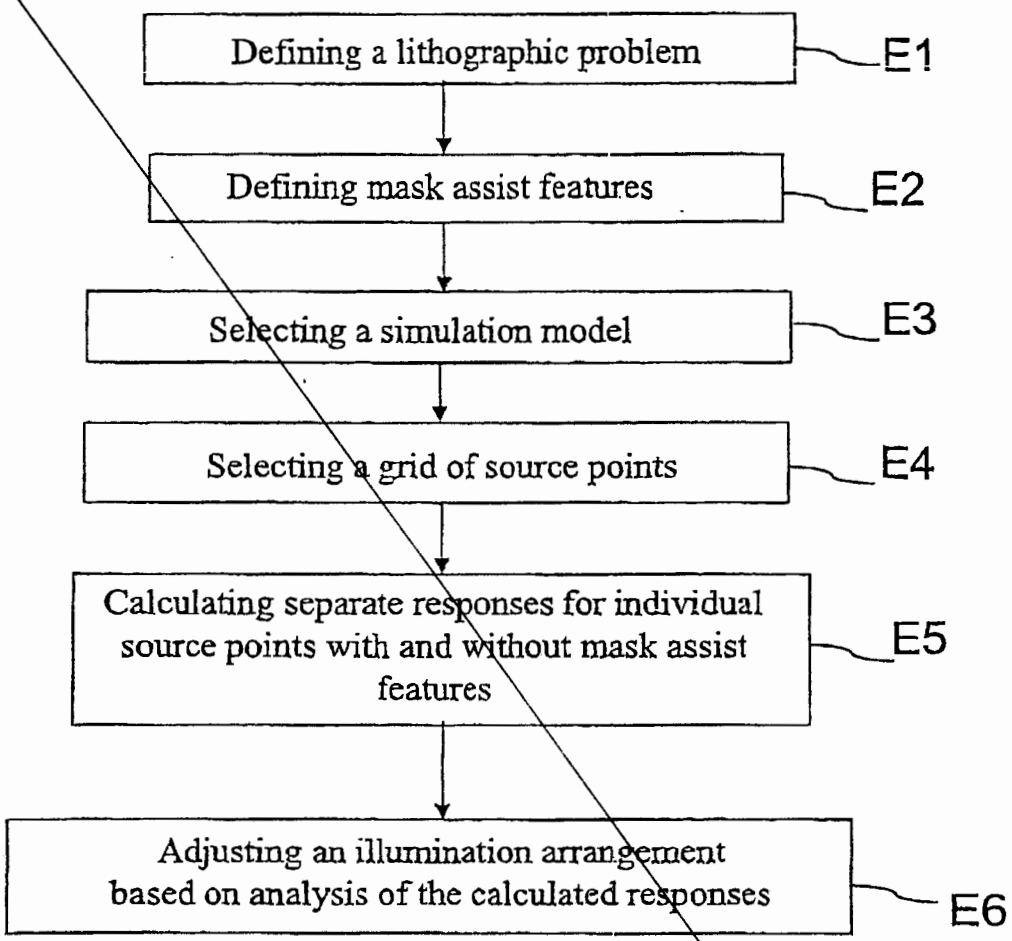


FIG. 47

6%Att-PSM, 1Anti-Scattering Bar (ASB)/side
50nm ASB, 150nm pitch

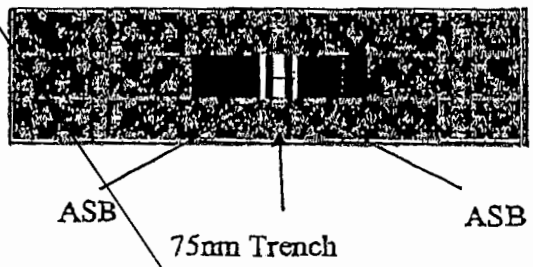
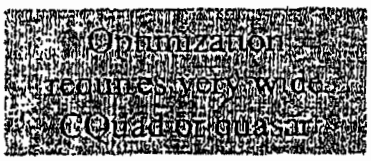
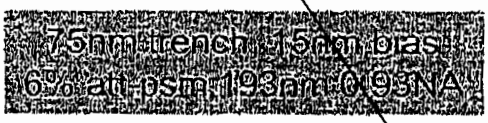


FIG. 48





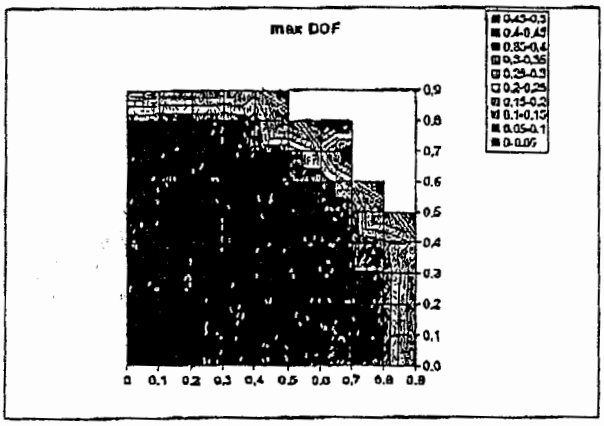


FIG. 49a

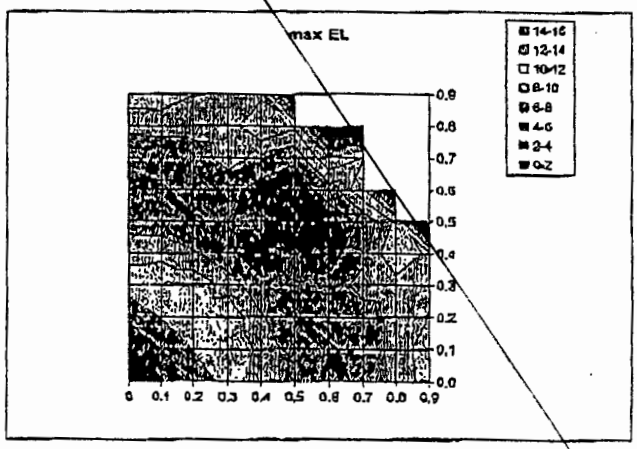


FIG. 49b

REPLACEMENT SHEET
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75nm trench, 15nm bias
6% att-psm, 193nm 0.93NA

1SB / side [redacted]

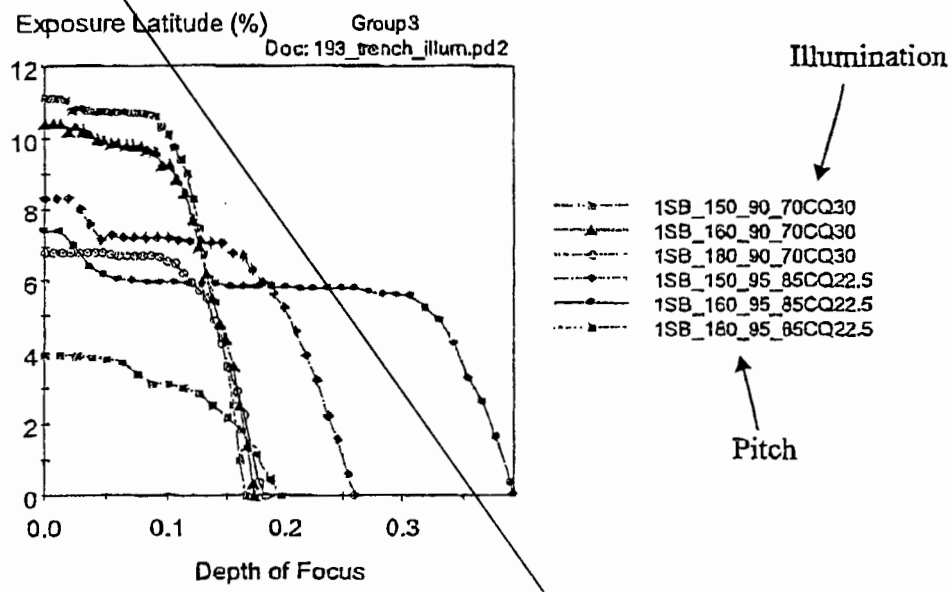
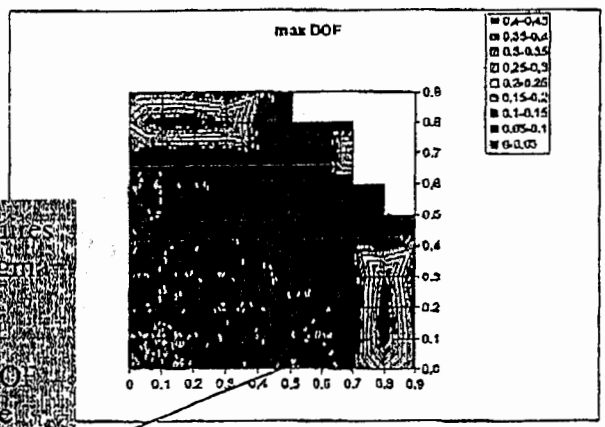
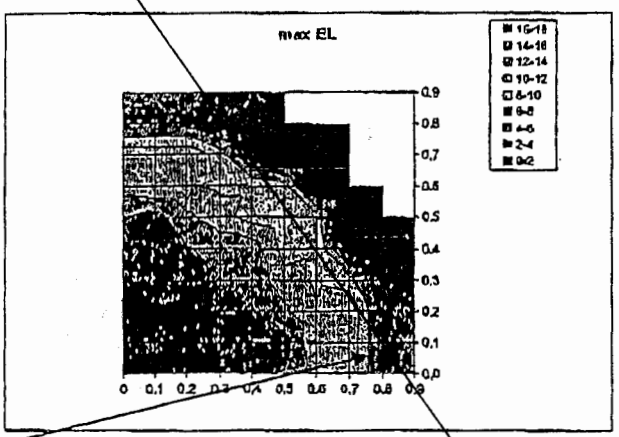


FIG. 50

6%Att-PSM





6% requires small sigma for dose latitude. Good DOF available with wide CQuad, but with poor dose latitude.

FIG. 51a

FIG. 51b

REPLACEMENT SHEET
06 JUN 2005

35°Cquad + 0.10σ

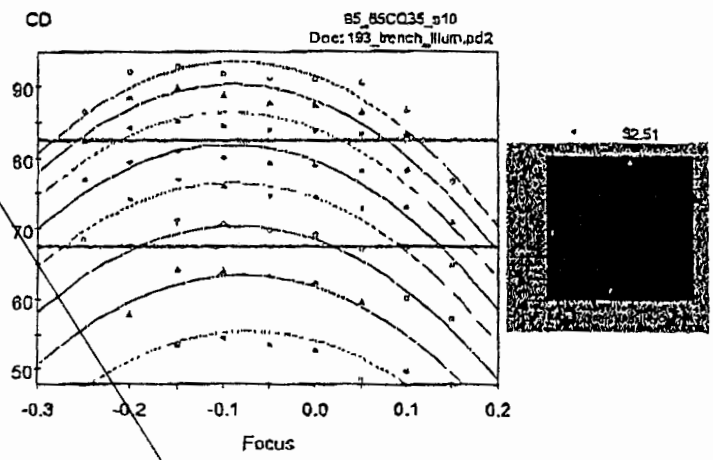
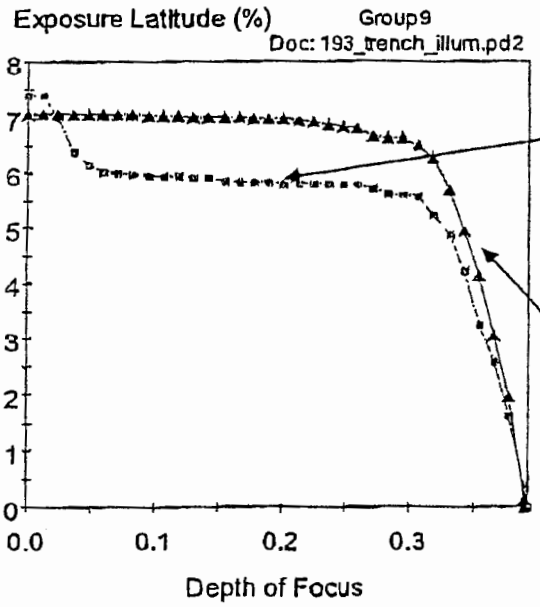


FIG. 52

Comparison of "mask assist" and "illuminator assist" for high DOF

- similar results



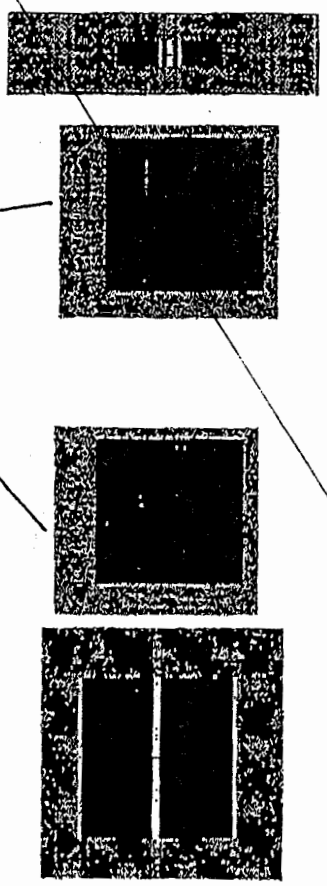


FIG. 53

REPLACEMENT SHEET
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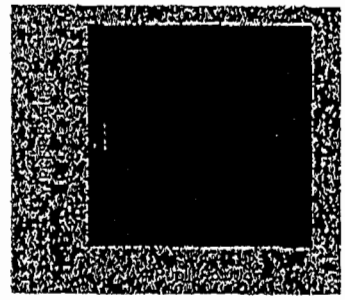
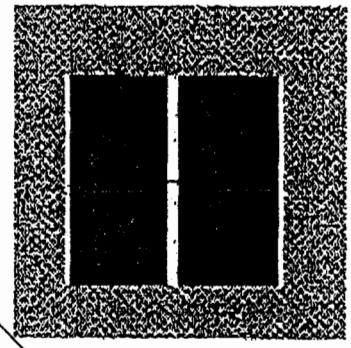
Effect of bias



• Lower bias increases DOF. This is an advantage for the "simple mask, complex illuminator" case because there are no assist features to print when using low biases / high exposures.





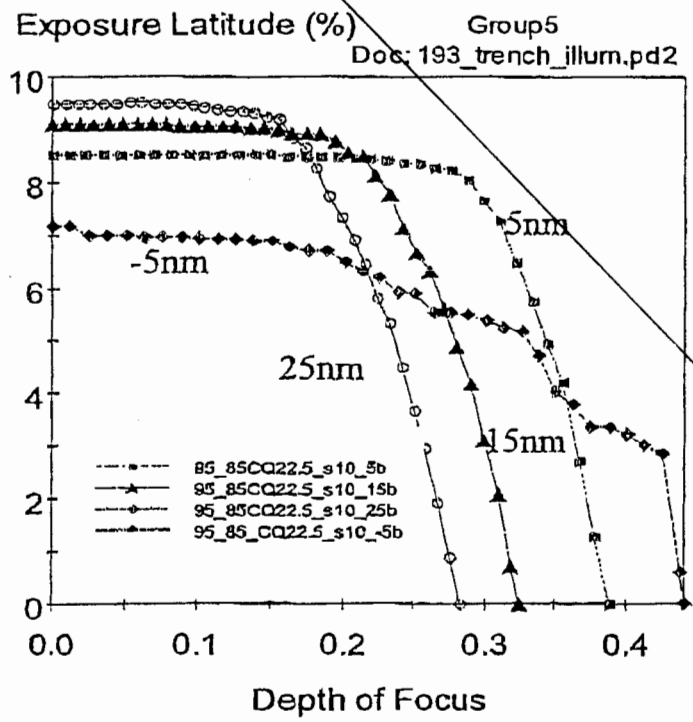


FIG.54

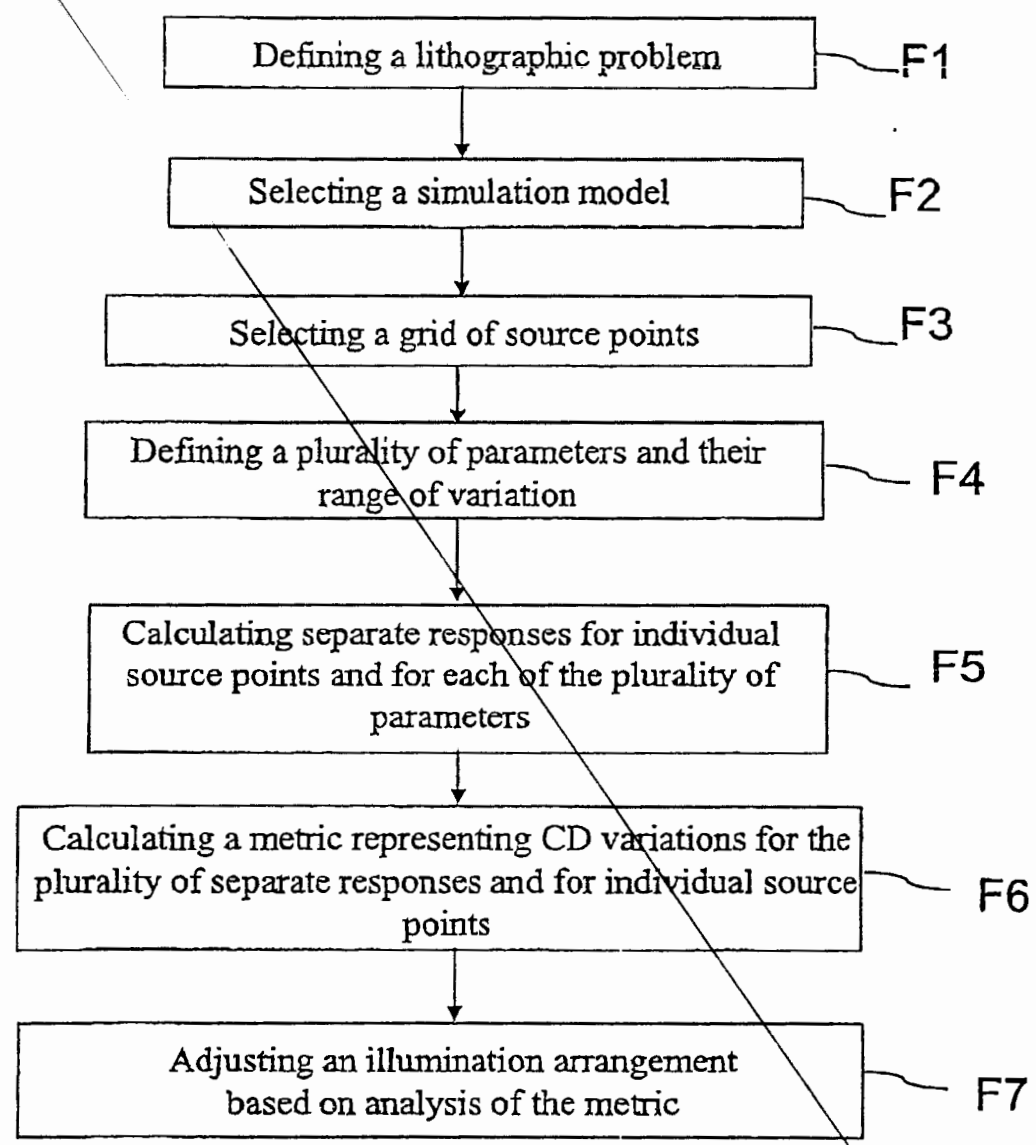
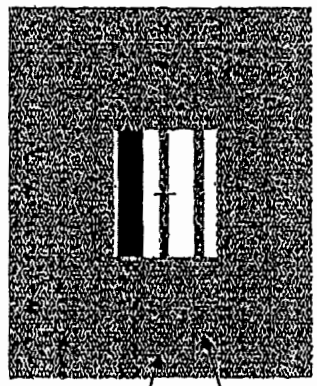

Defining a lithographic problem
F1
Selecting a simulation model
F2
Selecting a grid of source points
F3
Defining a plurality of parameters and their range of variation
F4
Calculating separate responses for individual source points and for each of the plurality of parameters
F5
Calculating a metric representing CD variations for the plurality of separate responses and for individual source points
F6
Adjusting an illumination arrangement based on analysis of the metric
F7

FIG. 55

06 JUN 2005

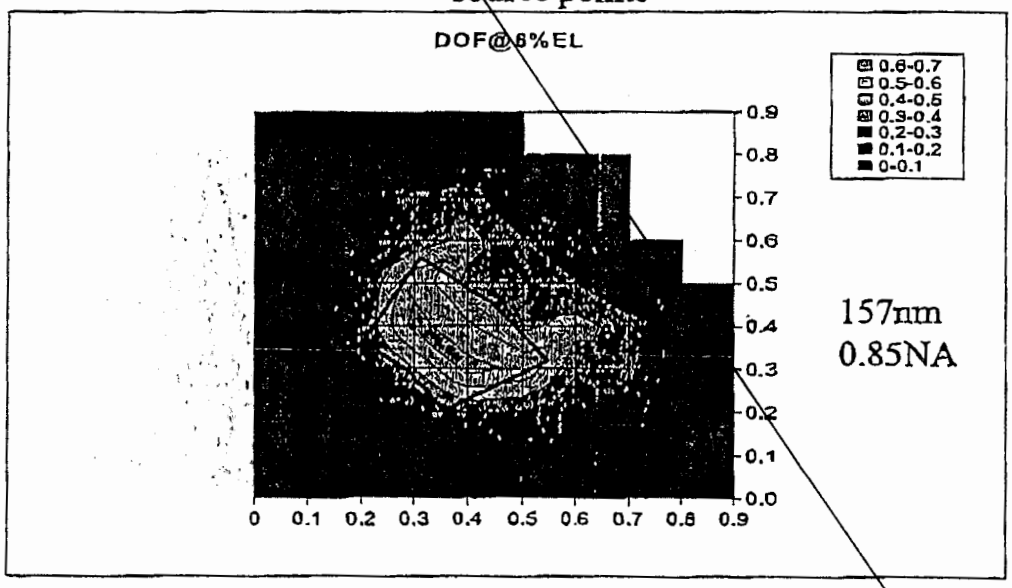
CPL for double line



Print 50nm lines

FIG. 56

Source visualization map
based on resist simulations for a grid of
source points



Best choice for illumination based on process window merit as the indicated
0.6+0.42Quasar30
Note, smaller poles centered at the same location expected to give better process
window - larger worse

FIG. 57

REPLACEMENT SHEET
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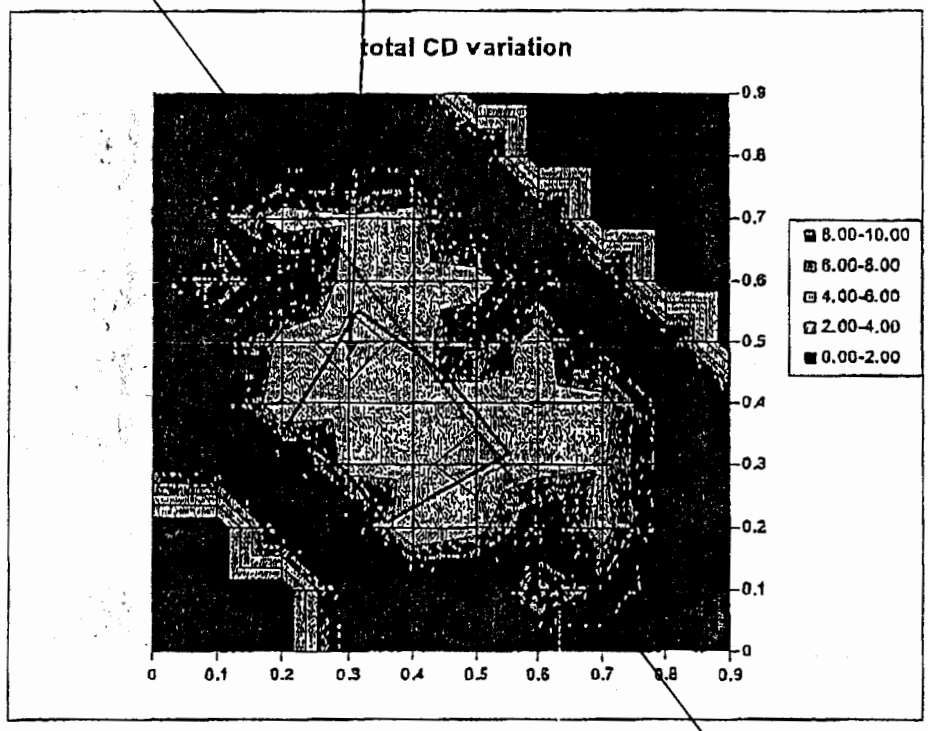

FIG. 58

REPLACEMENT SHEET
06 JUN 2005

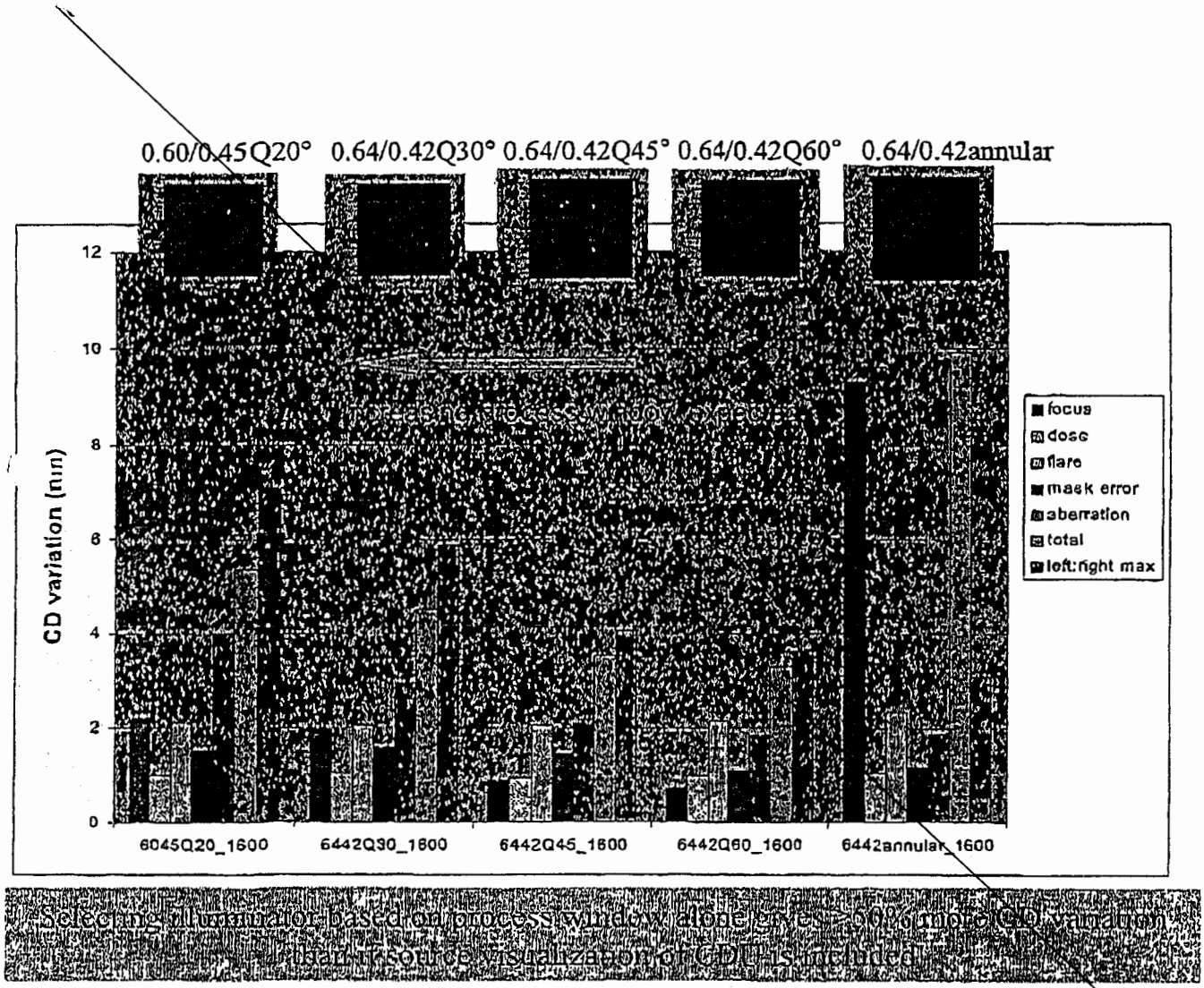

FIG. 59

REPLACEMENT SHEET
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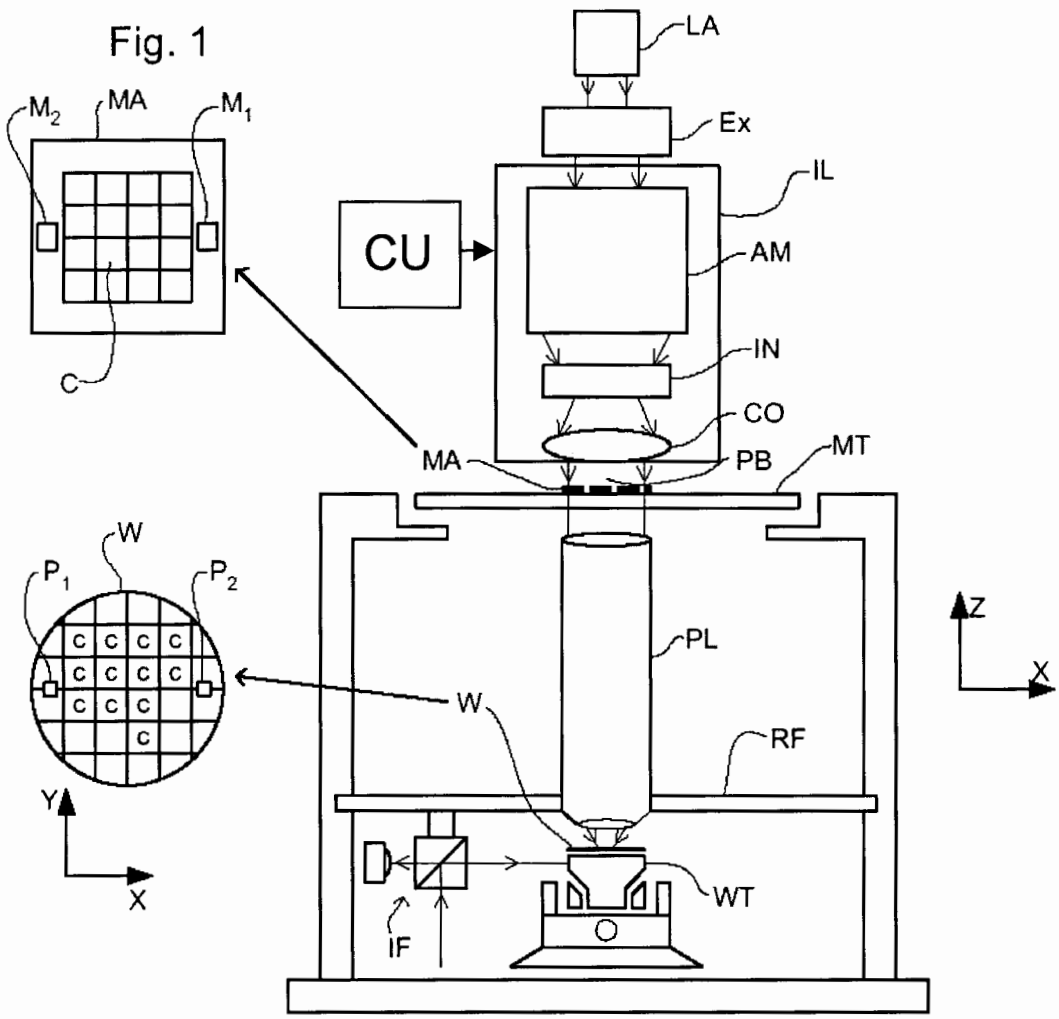
Fig. 1



REPLACEMENT SHEET
06 JUN 2005

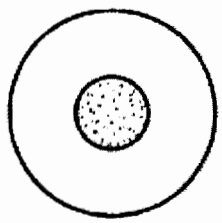


FIG. 2

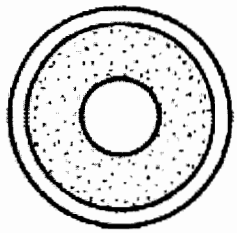


FIG. 3

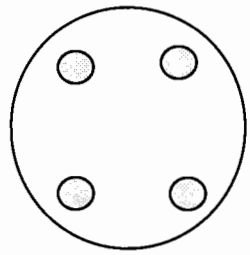


FIG. 4

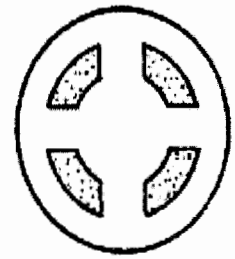


FIG. 5

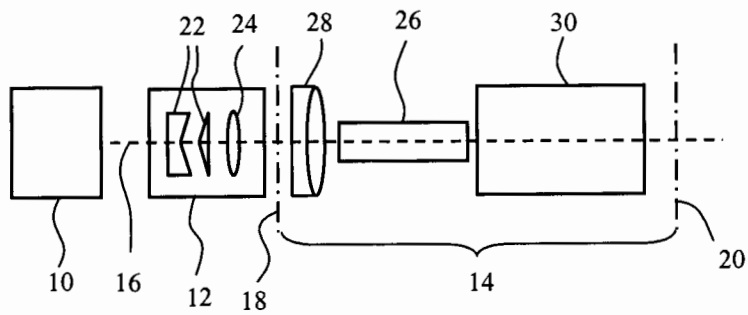


FIG. 6

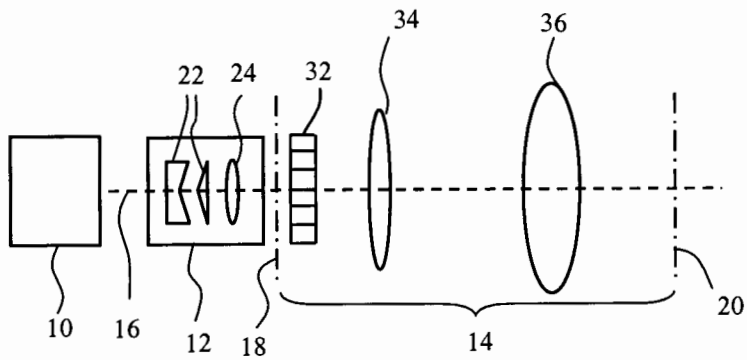


FIG. 7

FIG. 8

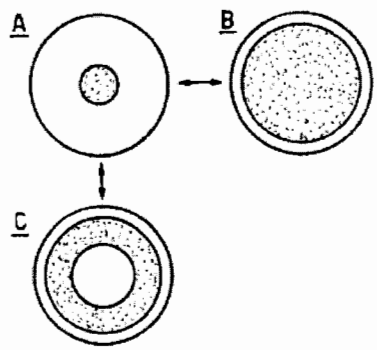
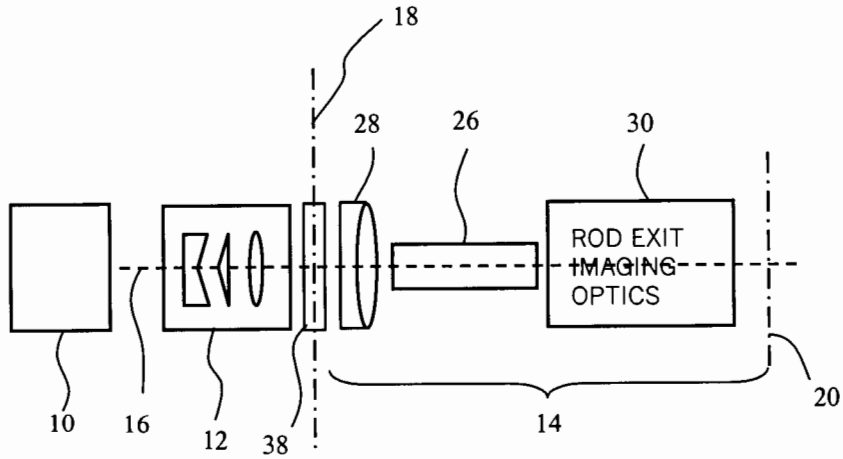


FIG. 9



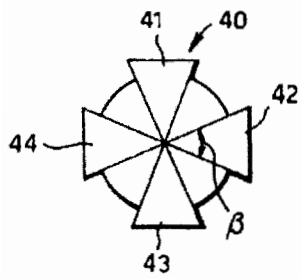


FIG. 10a

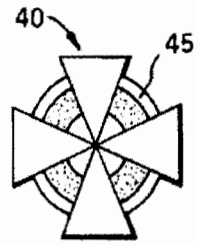


FIG. 10b

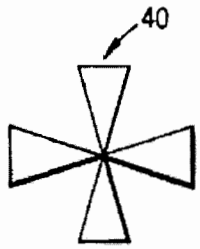


FIG. 11

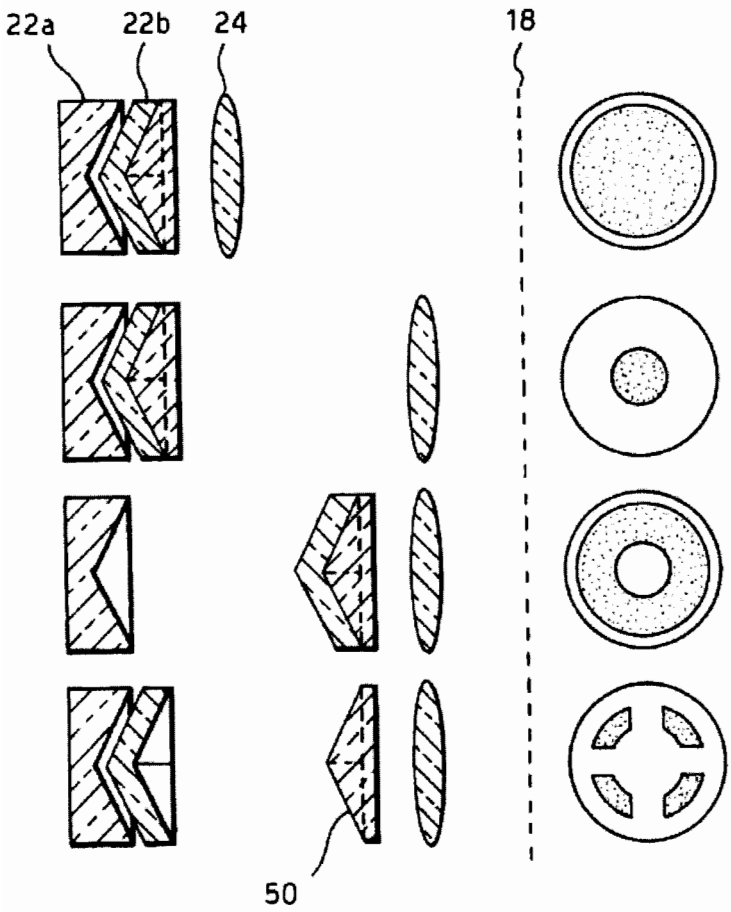


FIG. 12

REPLACEMENT SHEET
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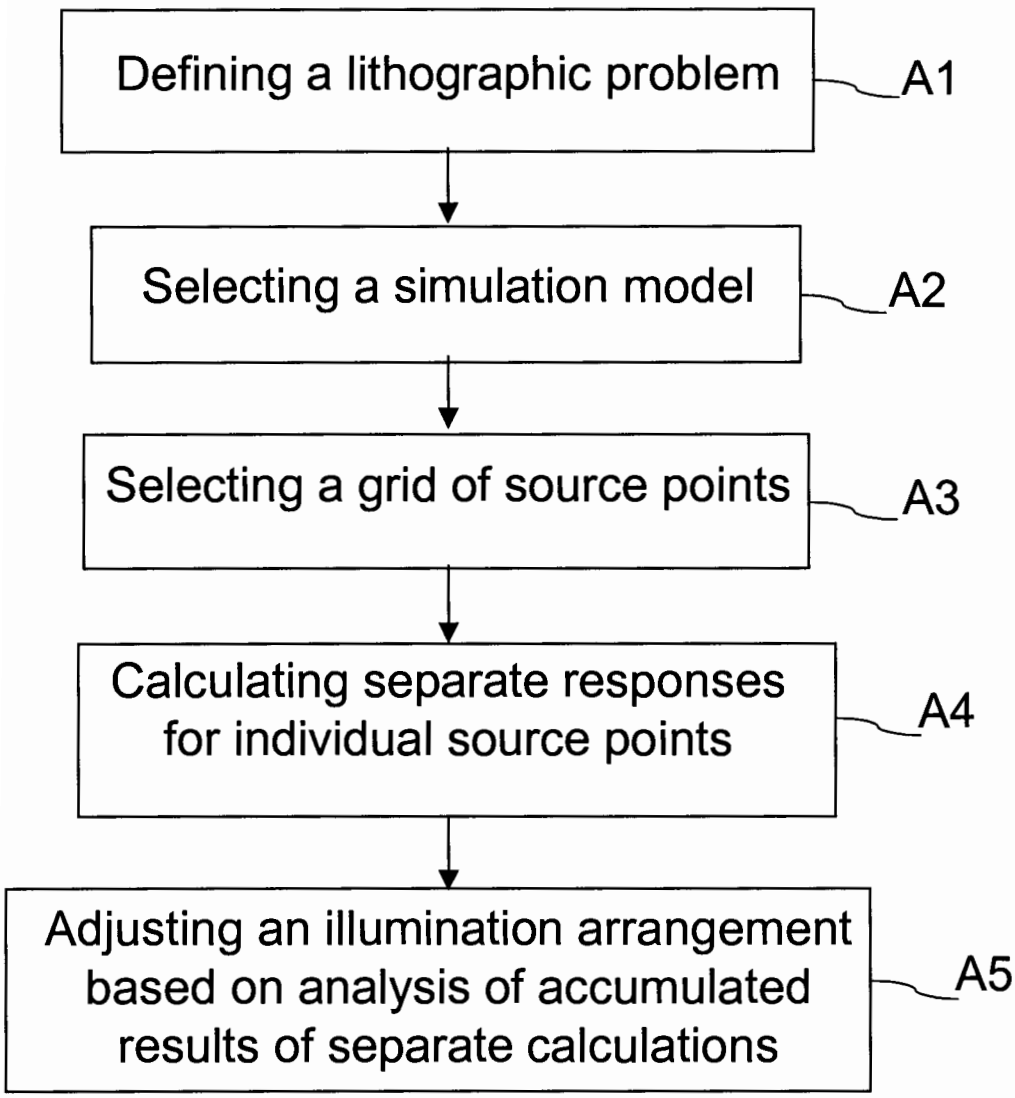

FIG. 13

REPLACEMENT SHEET
06 JUN 2005

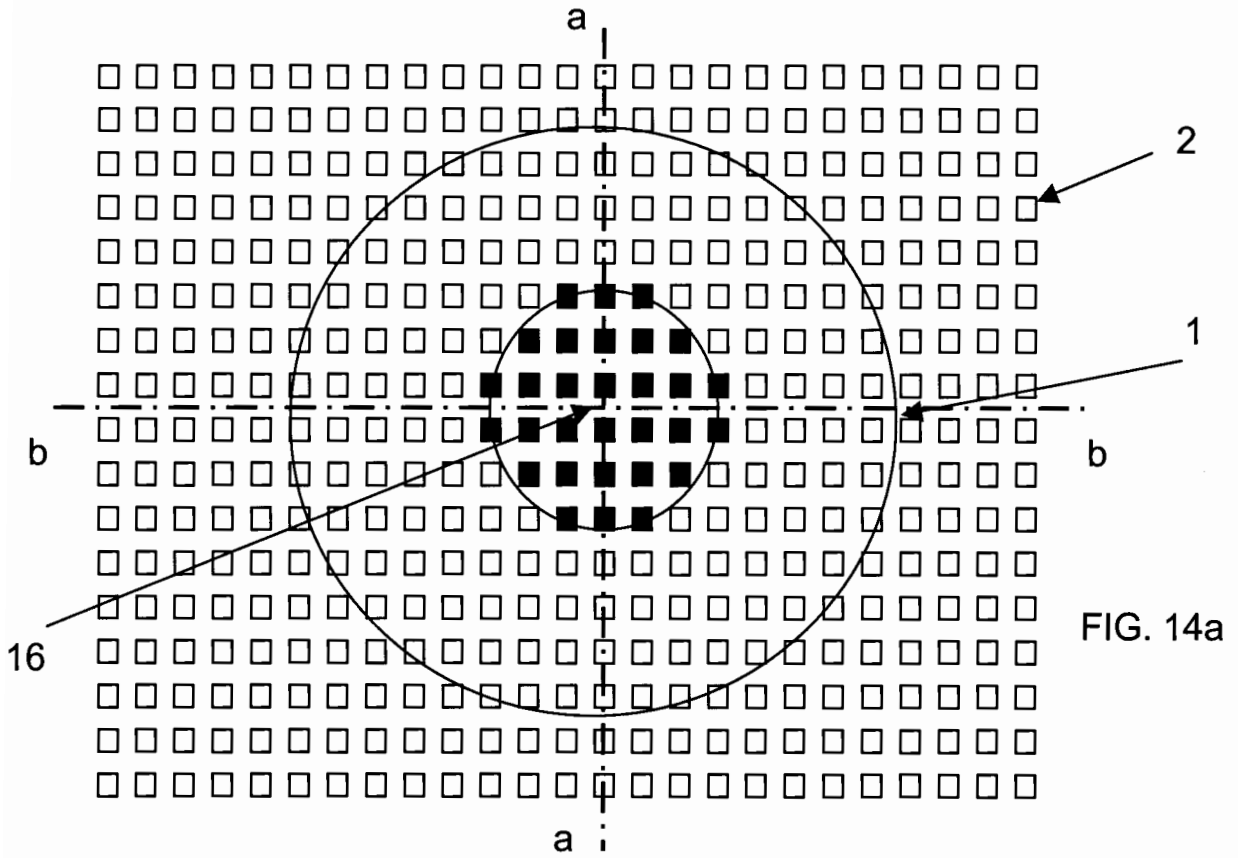

FIG. 14a

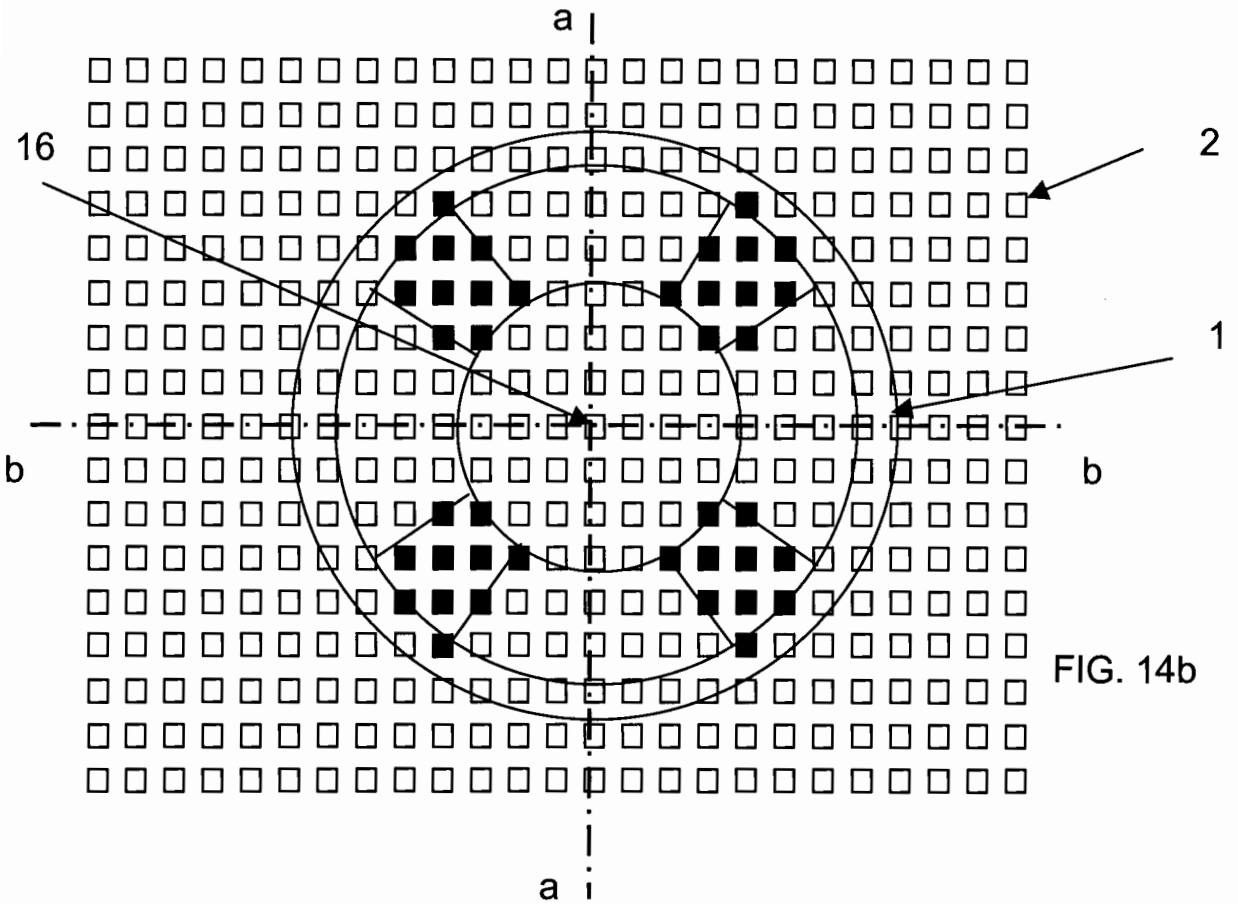

FIG. 14b

REPLACEMENT SHEET
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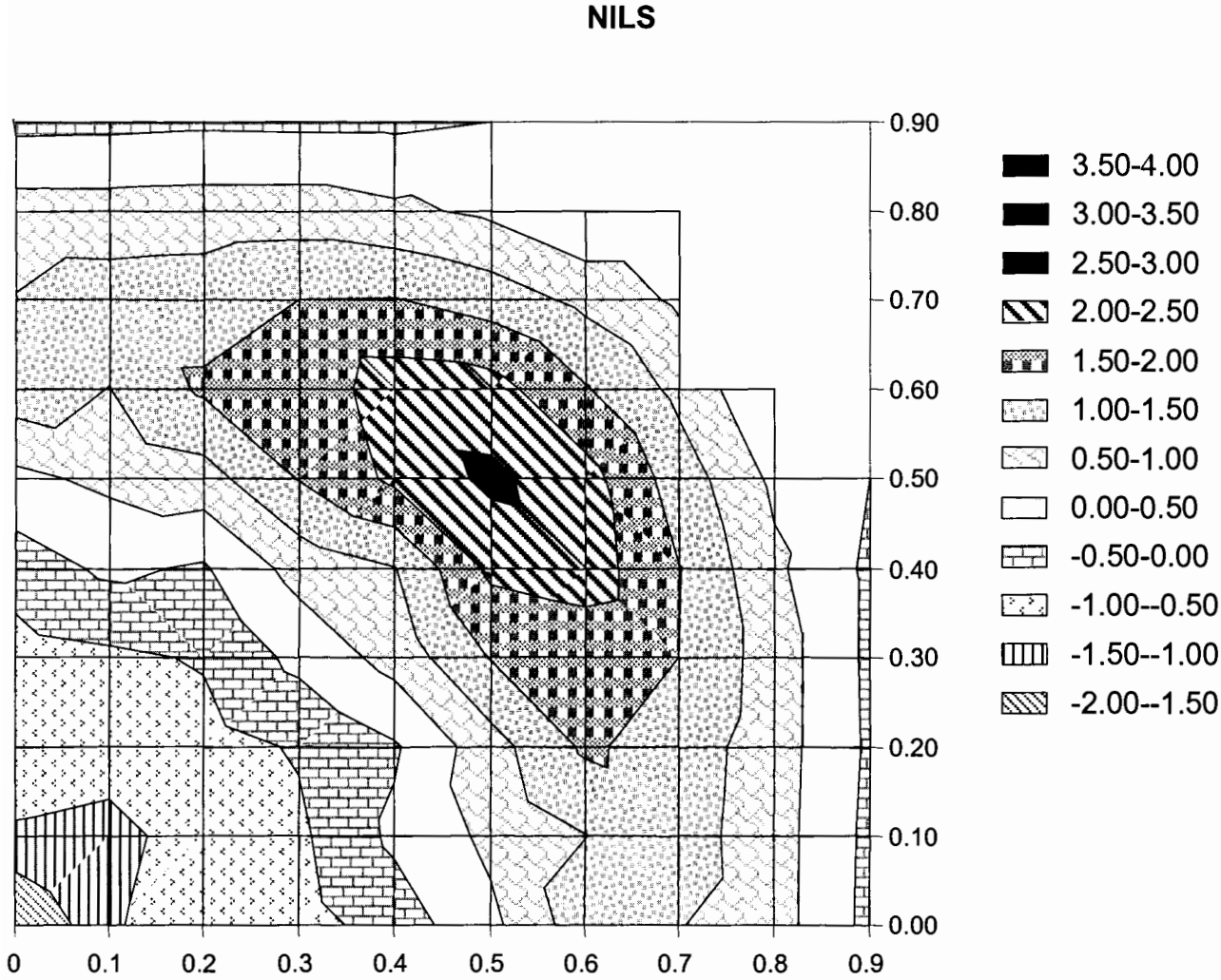


FIG. 15

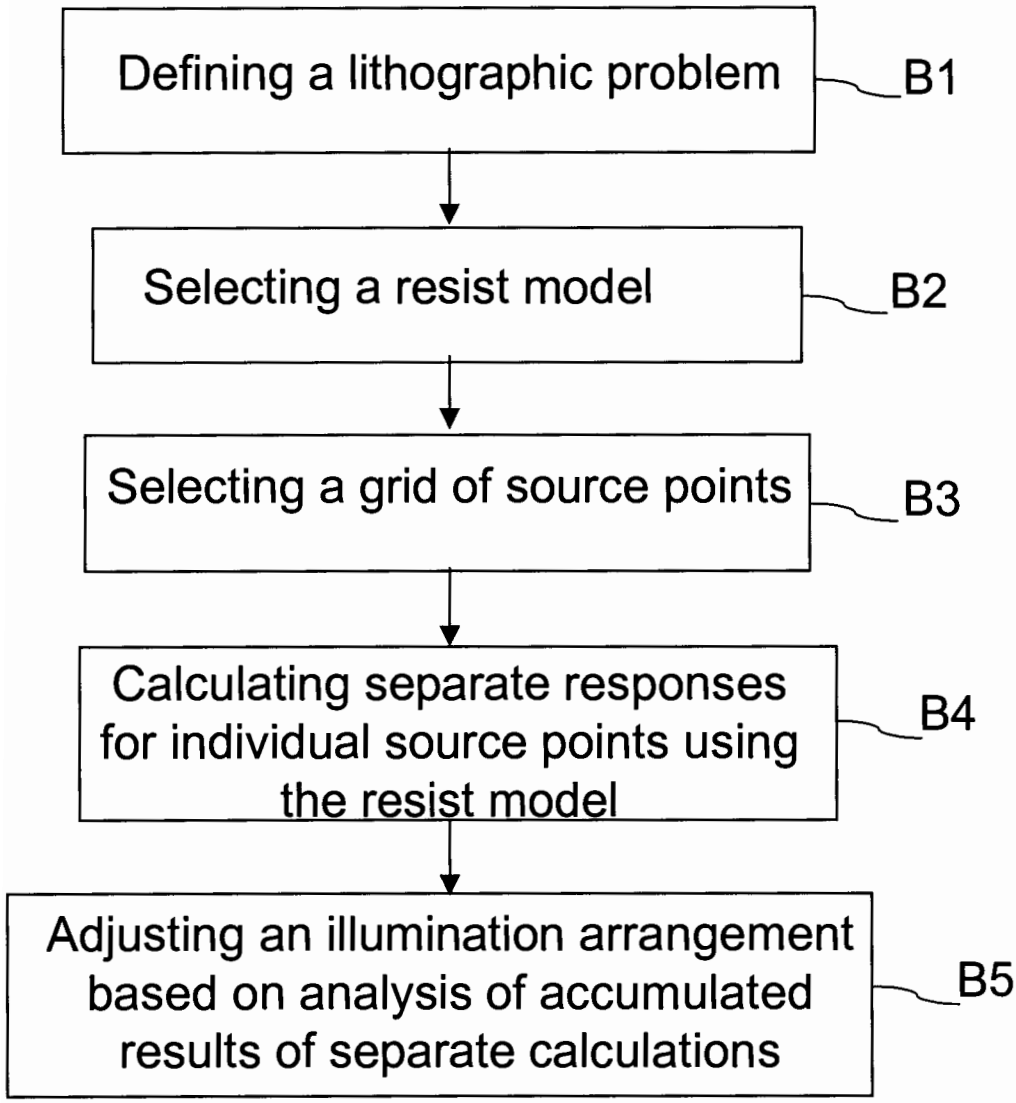

Defining a lithographic problem
B1
Selecting a resist model
B2
Selecting a grid of source points
B3
Calculating separate responses for individual source points using the resist model
B4
Adjusting an illumination arrangement based on analysis of accumulated results of separate calculations
B5

FIG. 16

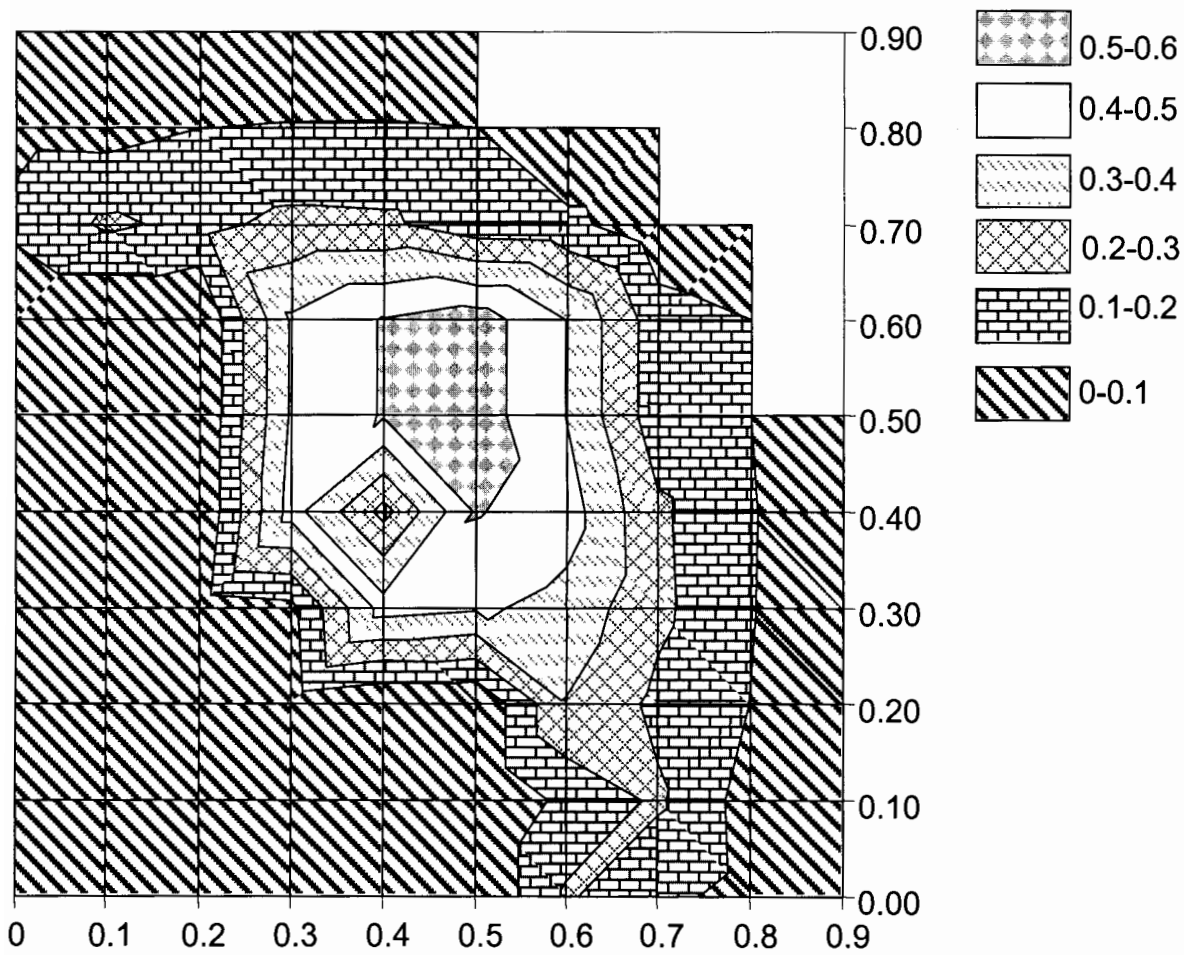

0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.5-0.6
0.4-0.5
0.3-0.4
0.2-0.3
0.1-0.2
0-0.1

FIG. 17

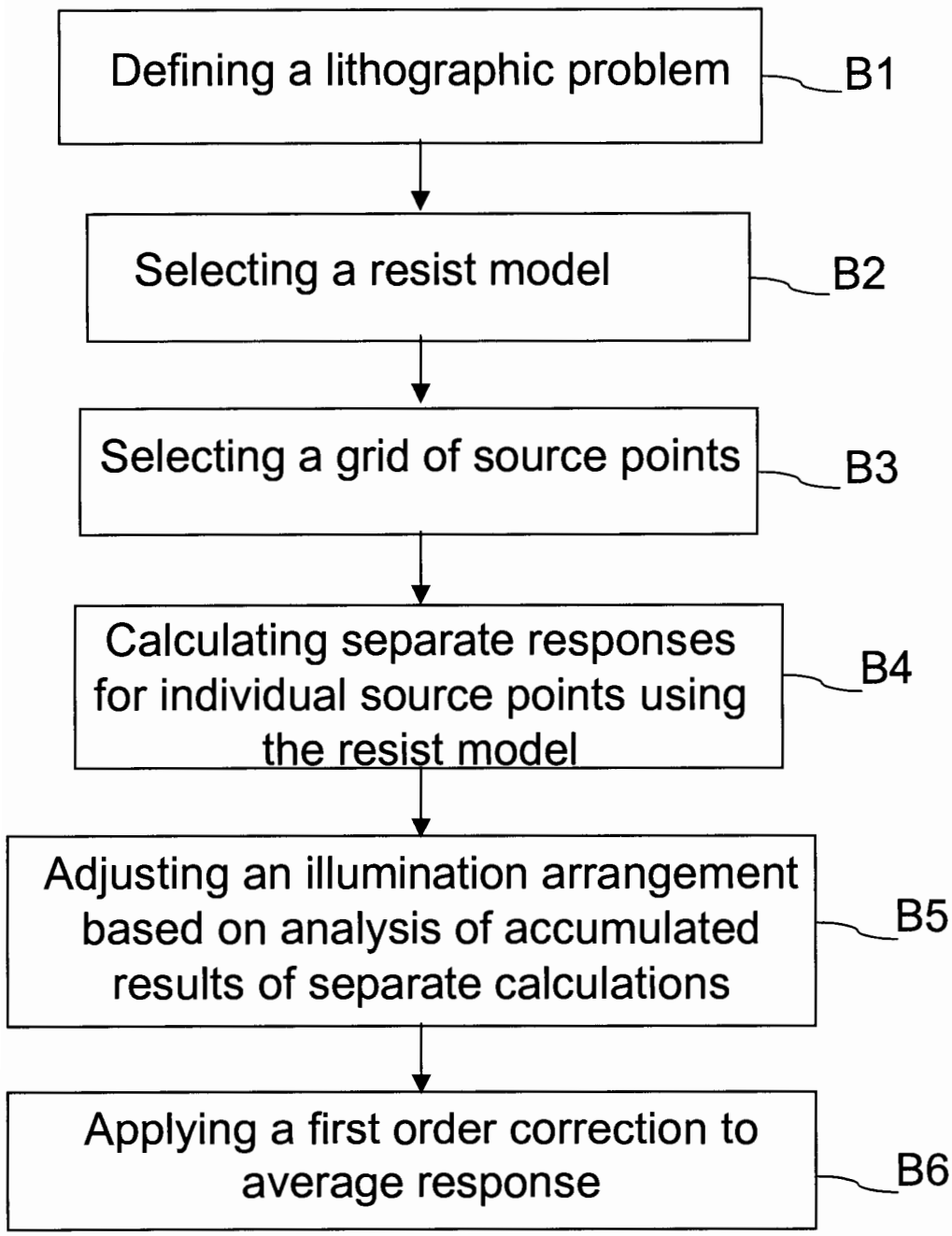

Defining a lithographic problem
B1
Selecting a resist model
B2
Selecting a grid of source points
B3
Calculating separate responses for individual source points using the resist model
B4
Adjusting an illumination arrangement based on analysis of accumulated results of separate calculations
B5
Applying a first order correction to average response
B6

FIG. 18

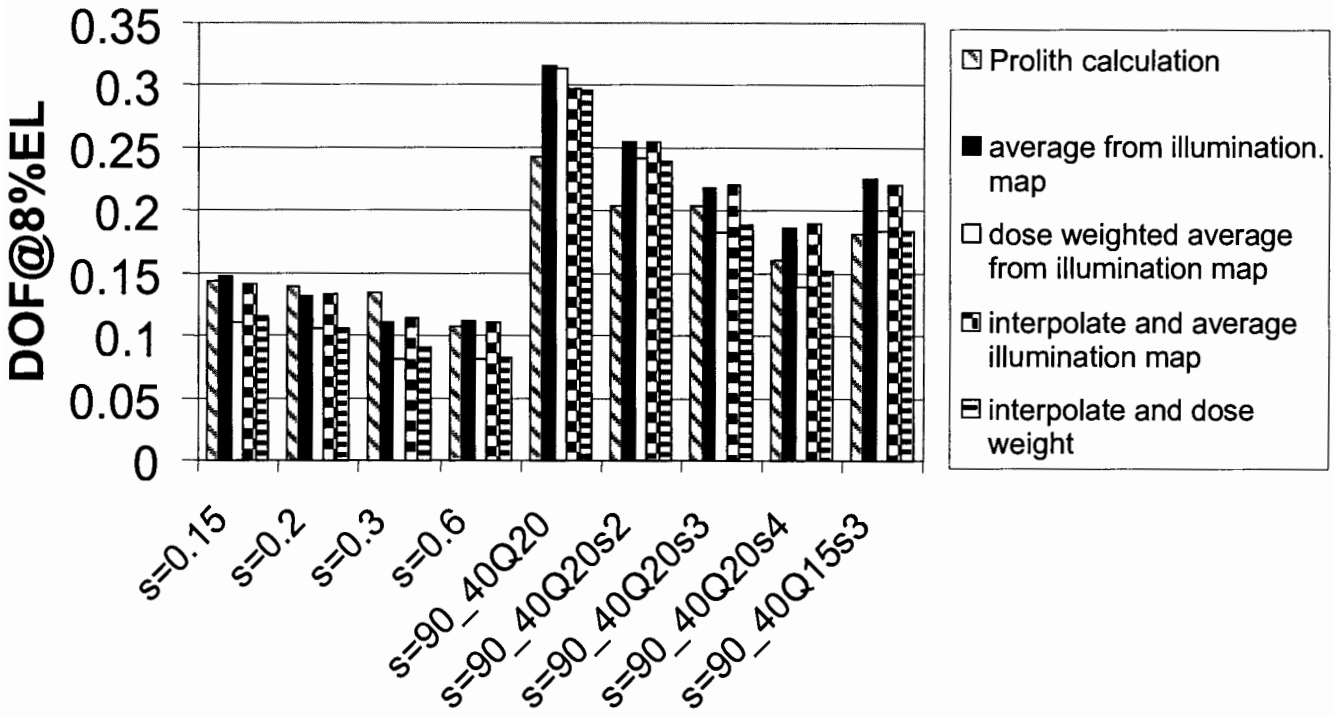
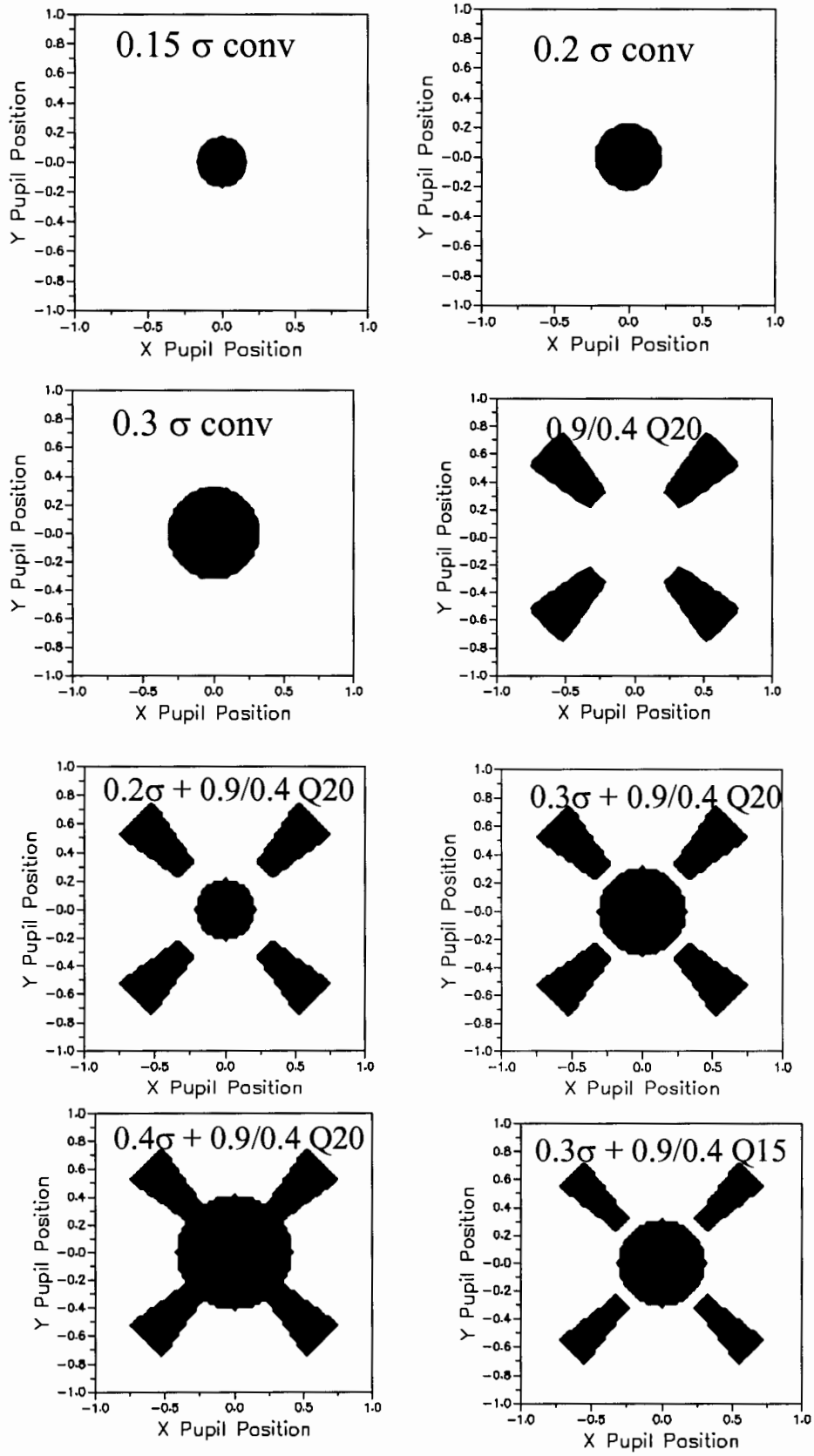

DOF@8%EL
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
s=0.15
s=0.2
s=0.3
s=0.6
s=90_40Q20
s=90_40Q20s2
s=90_40Q20s3
s=90_40Q20s4
s=90_40Q15s3
Prolith calculation
average from illumination. map
dose weighted average from illumination map
interpolate and average illumination map
interpolate and dose weight

FIG. 19

FIG. 20


0.15 σ conv
0.2 σ conv
0.3 σ conv
0.9/0.4 Q20
0.2σ + 0.9/0.4 Q20
0.3σ + 0.9/0.4 Q20
0.4σ + 0.9/0.4 Q20
0.3σ + 0.9/0.4 Q15
Y Pupil Position
X Pupil Position

REPLACEMENT SHEET
06 JUN 2005

trial illuminator	prediction based on weighted and interpolated source measurements	Prolith simulation with this illuminator
0.85_0.55Q30	0.293u	0.23u
0.75_0.55Q20	0.416	0.41
0.80_0.60Q20	0.383	0.355
0.80_0.60annular	0.110	0.10
0.75_0.55annular	0.118	0.105

FIG. 21

REPLACEMENT SHEET
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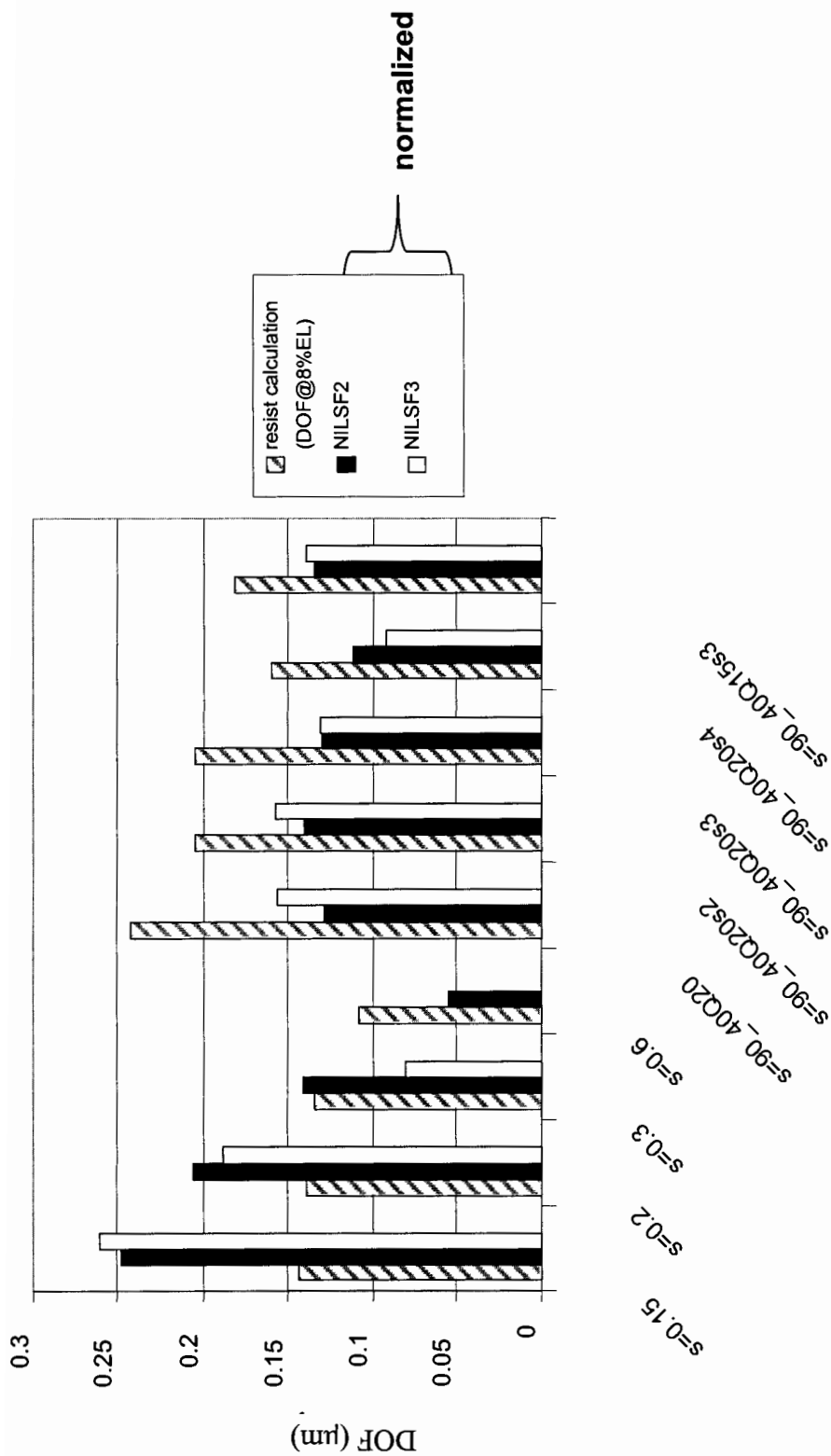

FIG. 22

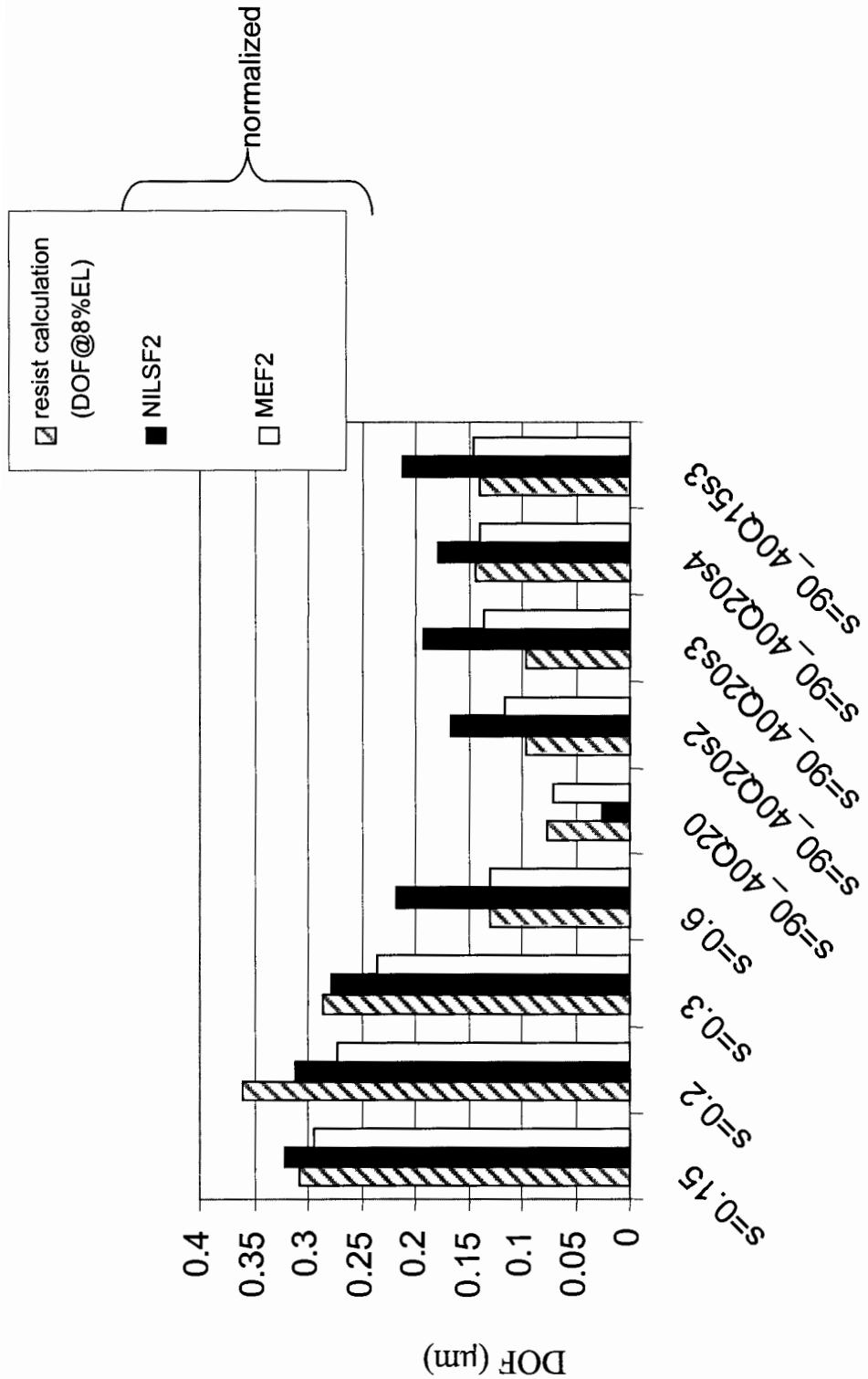
normalized
resist calculation (DOF@8%EL)
NILSF2
MEF2
DOF (μm)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
s=0.15
s=0.2
s=0.3
s=0.6
s=90_40Q20
s=90_40Q20S2
s=90_40Q20S3
s=90_40Q20S4
s=90_40Q15S3

FIG. 23

REPLACEMENT SHEET
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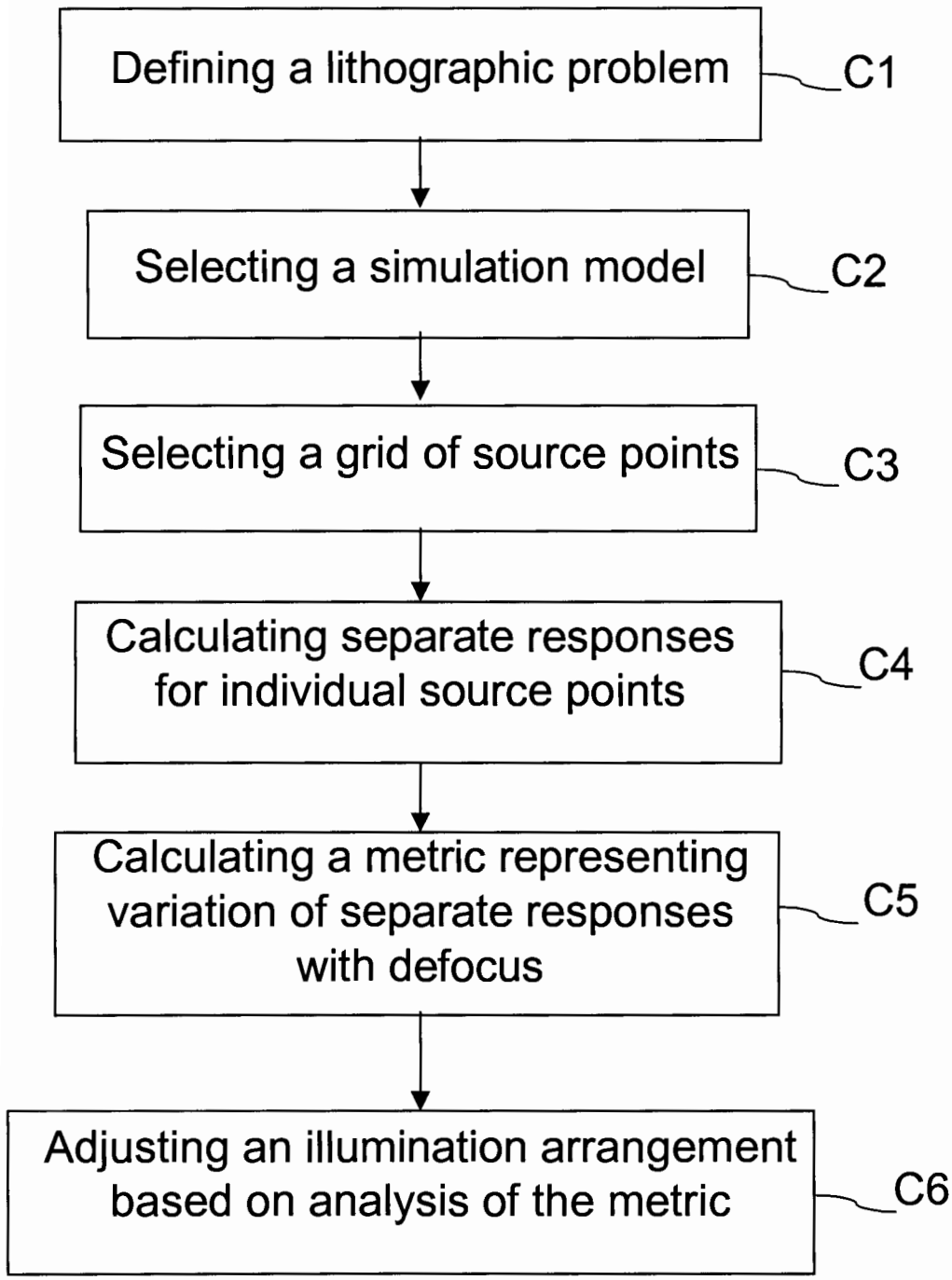


FIG. 24

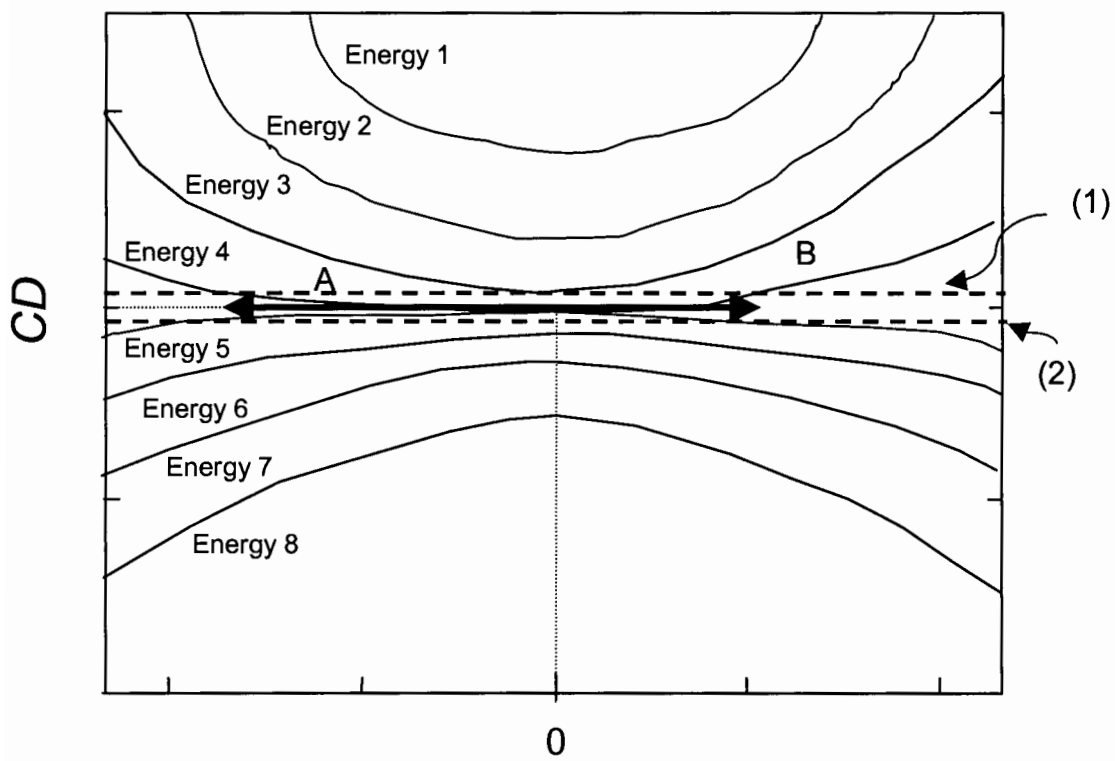

Energy 1
Energy 2
Energy 3
Energy 4
Energy 5
Energy 6
Energy 7
Energy 8
A
B
(1)
(2)
CD
0
Focus

FIG. 25

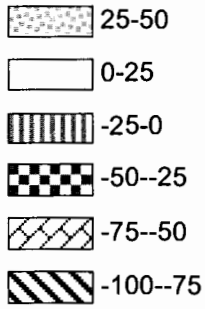
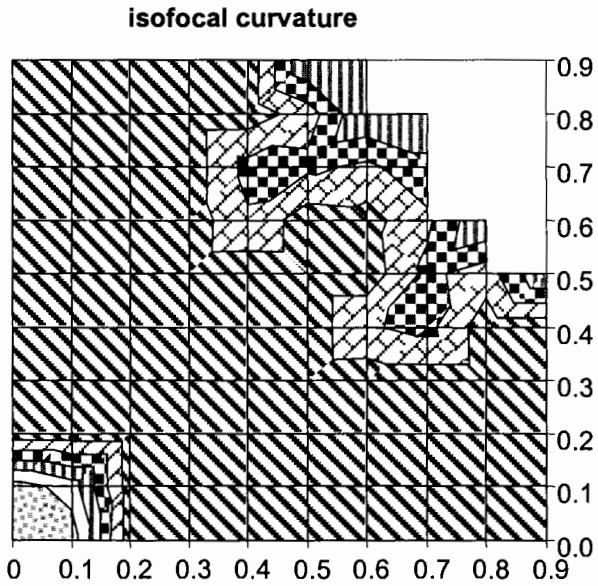


FIG. 26a



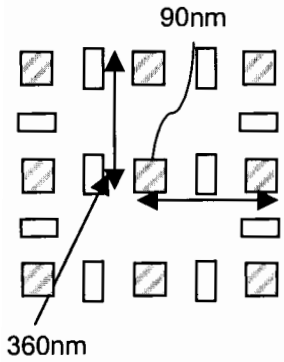


FIG. 26c

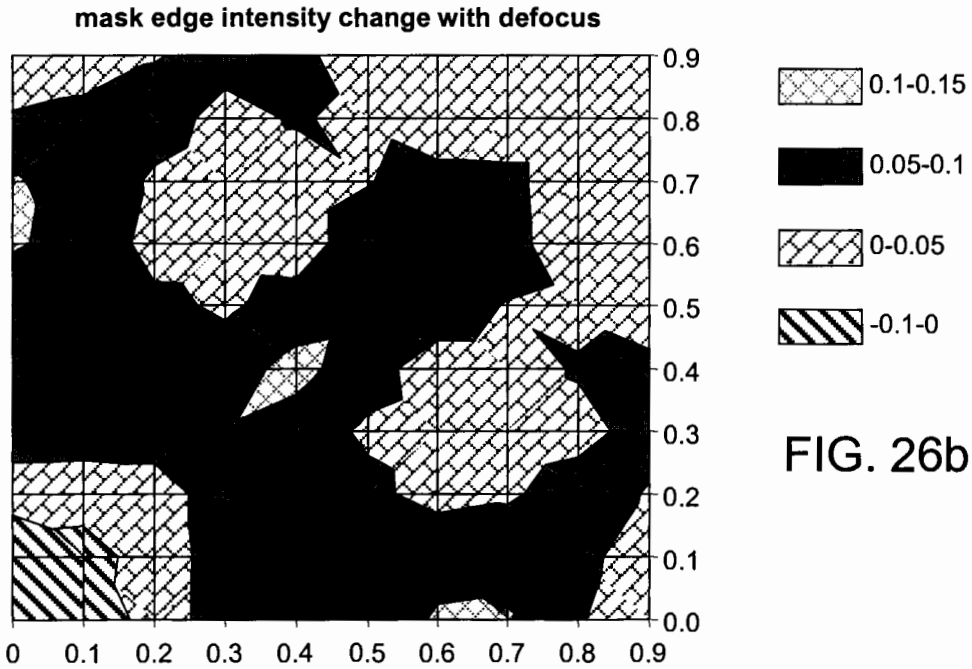


FIG. 26b

FIG. 27a

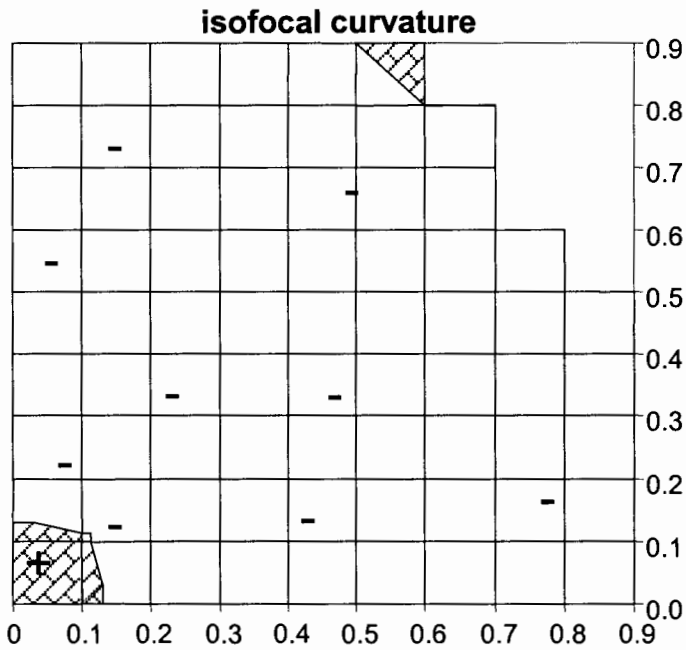


FIG. 27b

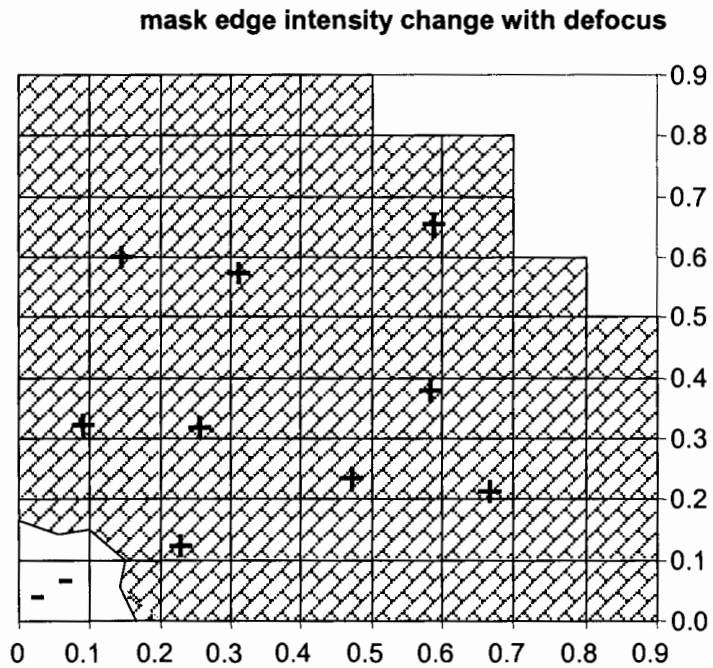


FIG. 28

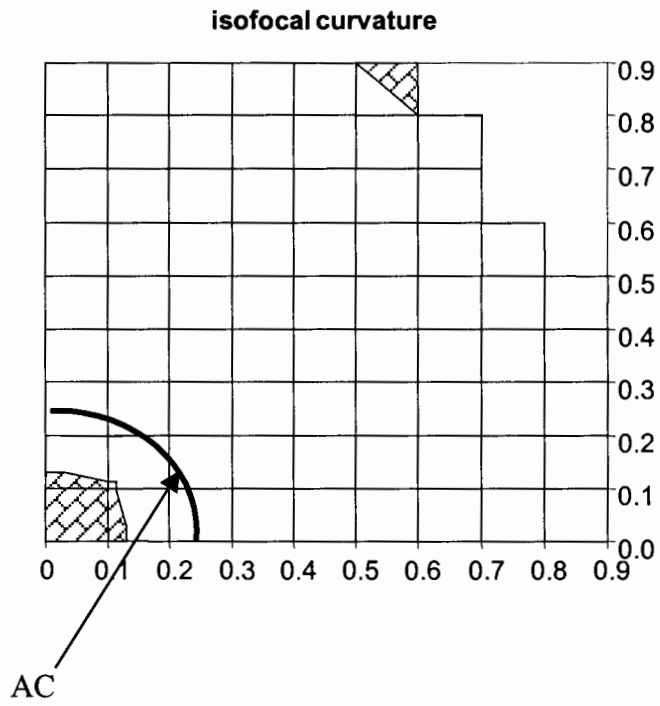

isofocal curvature
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
AC

FIG. 29

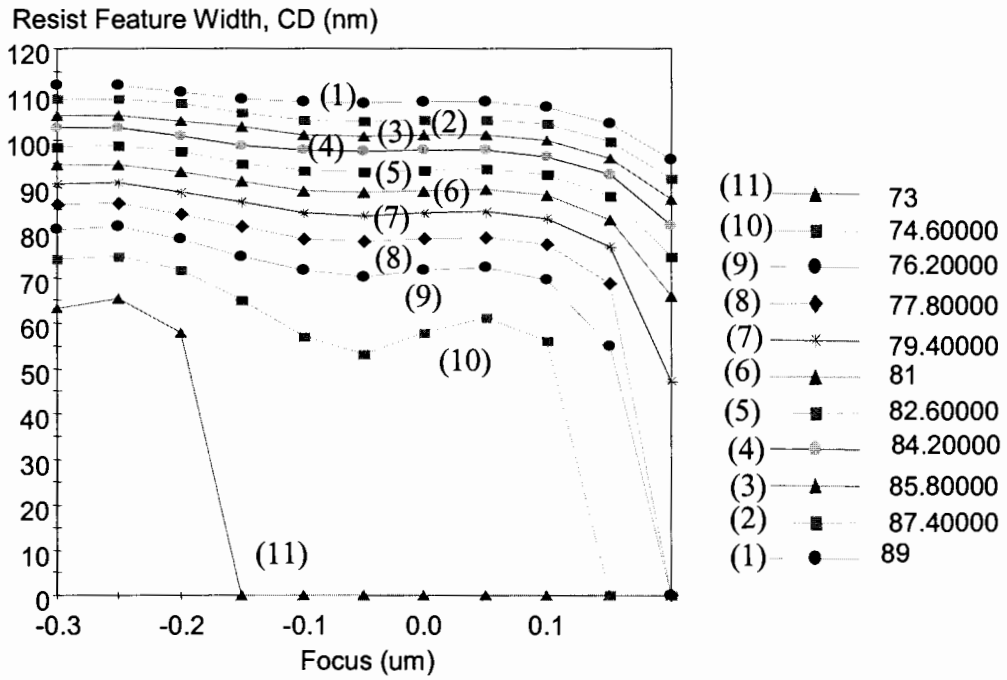

Resist Feature Width, CD (nm)
120
110
100
90
80
70
60
50
40
30
20
10
0
-0.3
-0.2
-0.1
0.0
0.1
Focus (um)
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(11) 73
(10) 74.60000
(9) 76.20000
(8) 77.80000
(7) 79.40000
(6) 81
(5) 82.60000
(4) 84.20000
(3) 85.80000
(2) 87.40000
(1) 89

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FIG. 30a

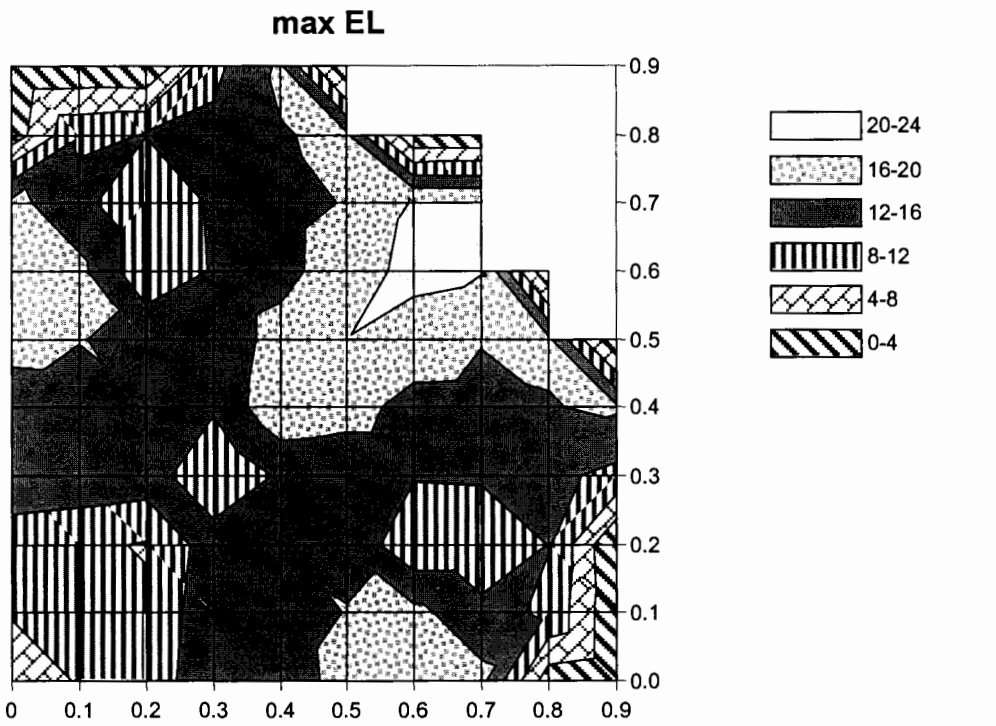


FIG. 30b

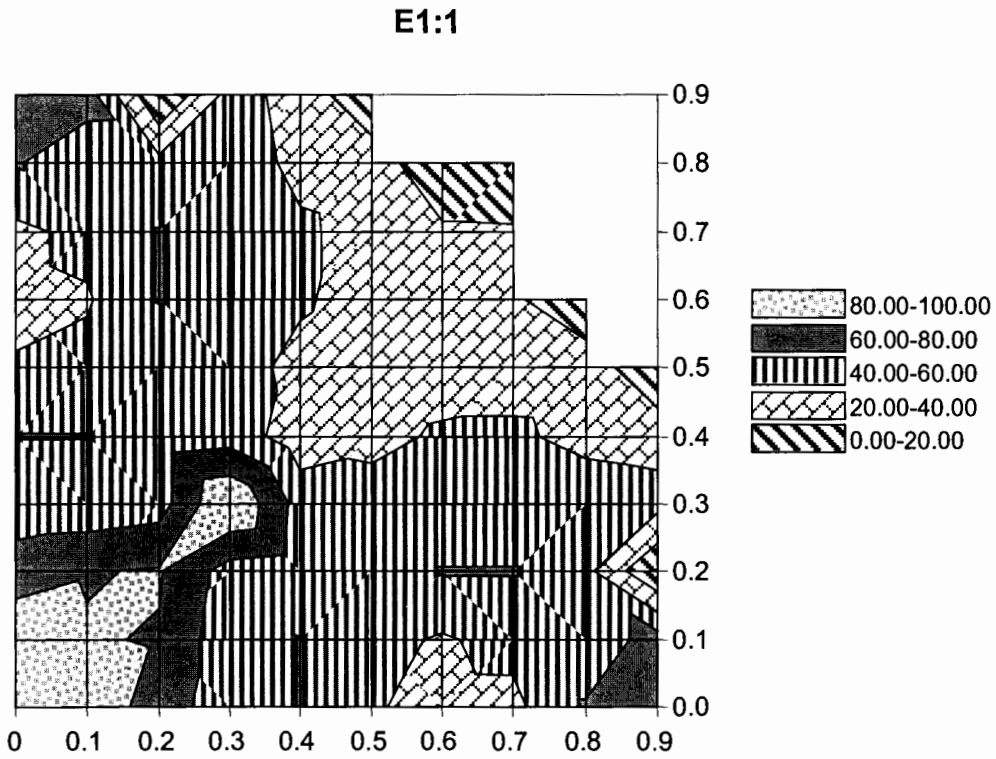


FIG. 31

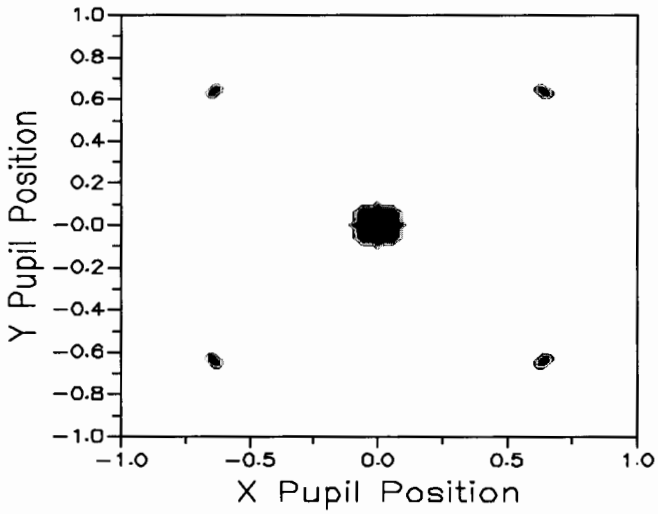


FIG. 32

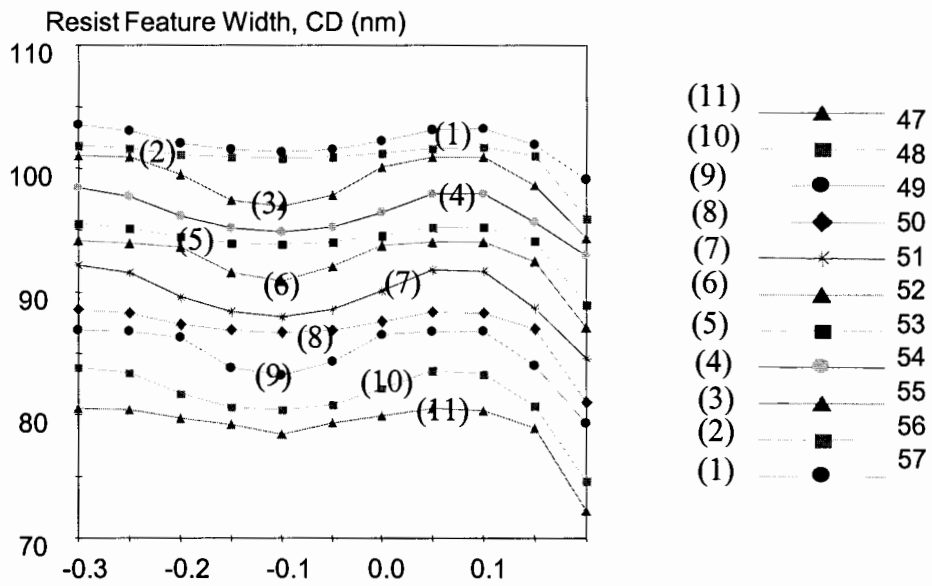
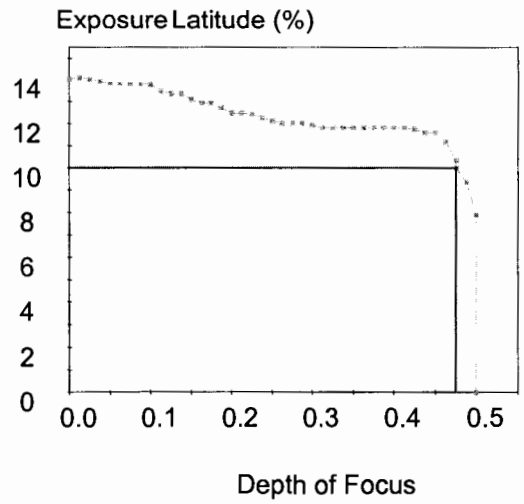


FIG. 33



REPLACEMENT SHEET
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FIG. 34

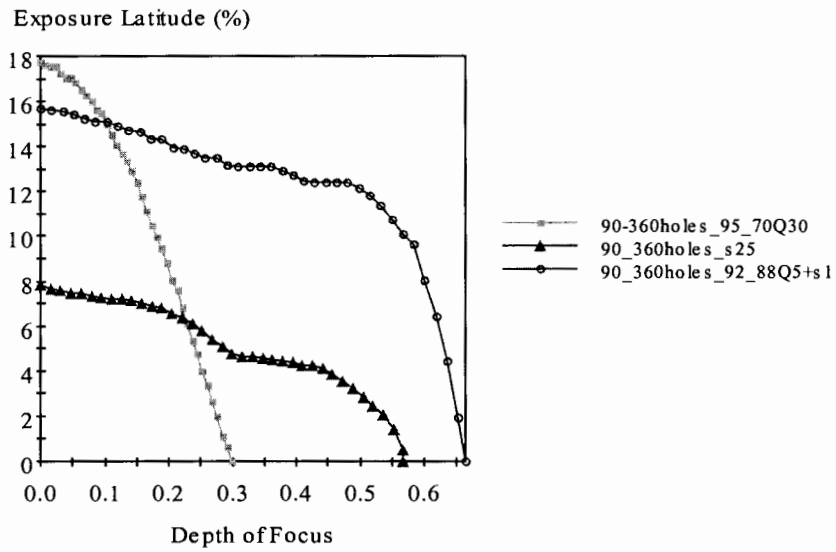


FIG. 35a

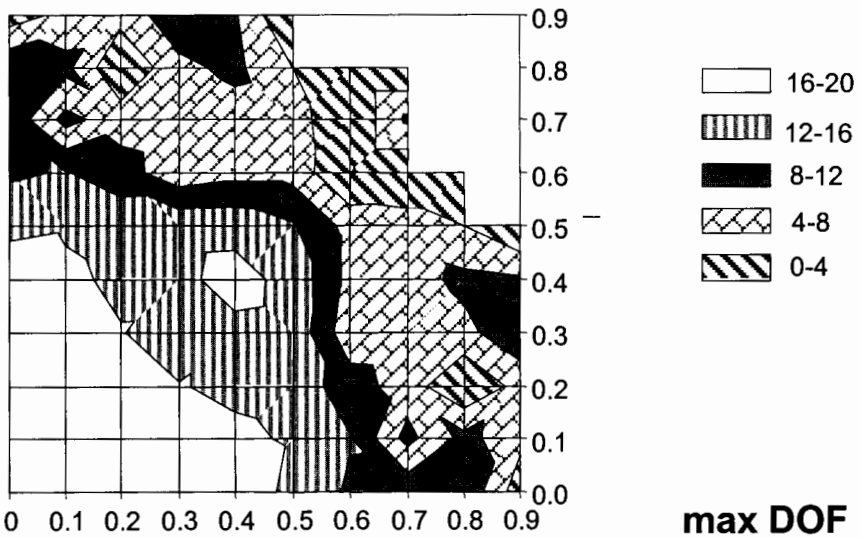
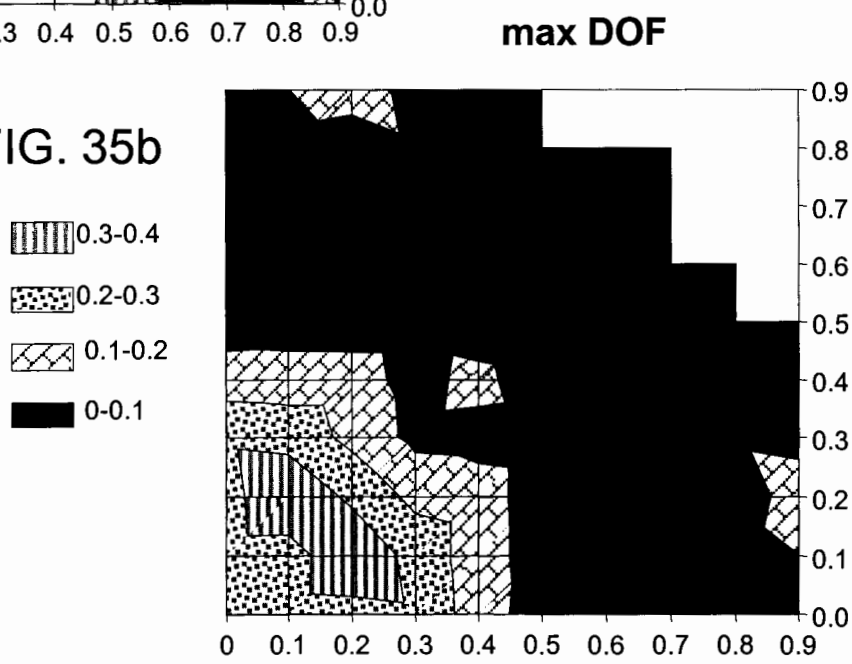


FIG. 35b



REPLACEMENT SHEET
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FIG. 35c

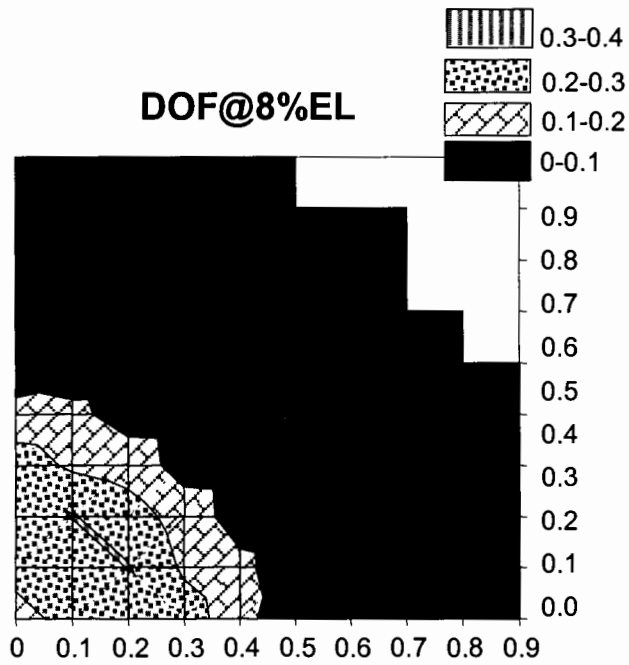
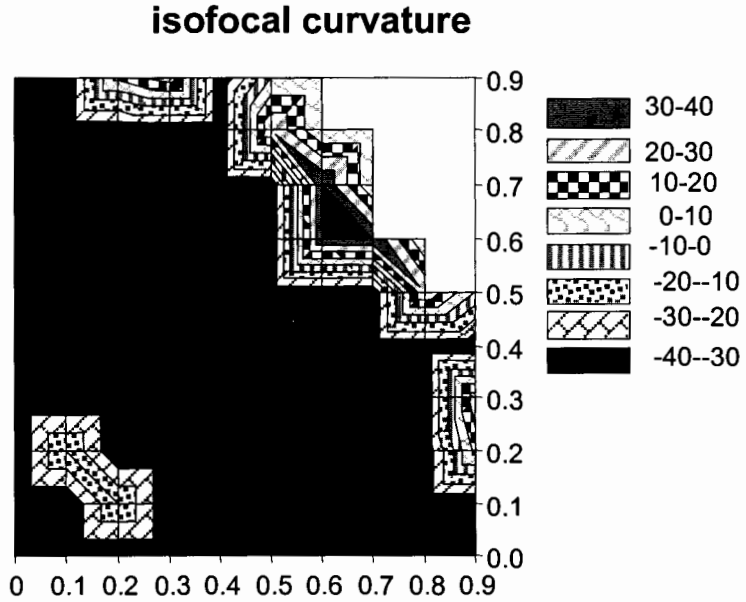


FIG. 35d



REPLACEMENT SHEET
06 JUN 2005

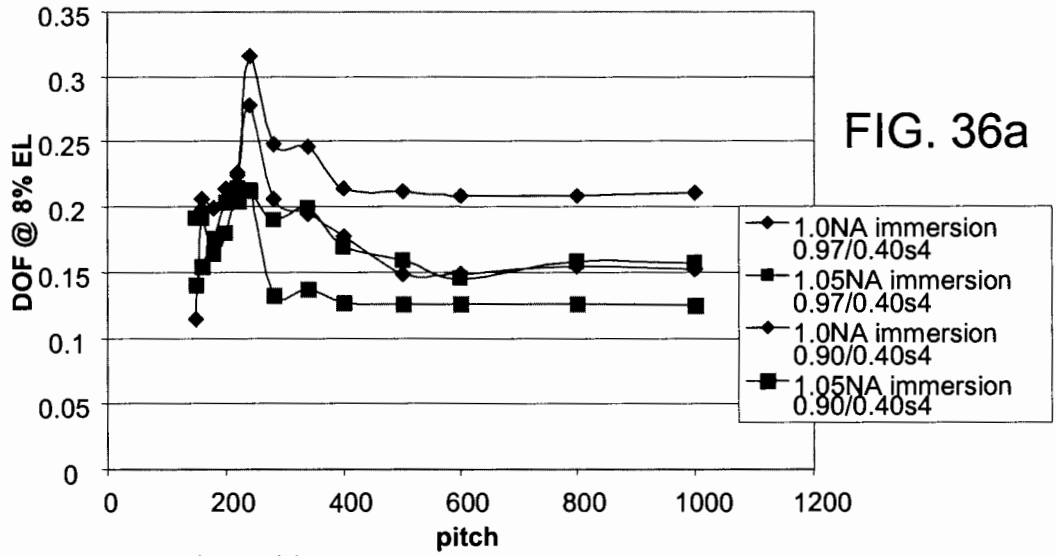


FIG. 36a

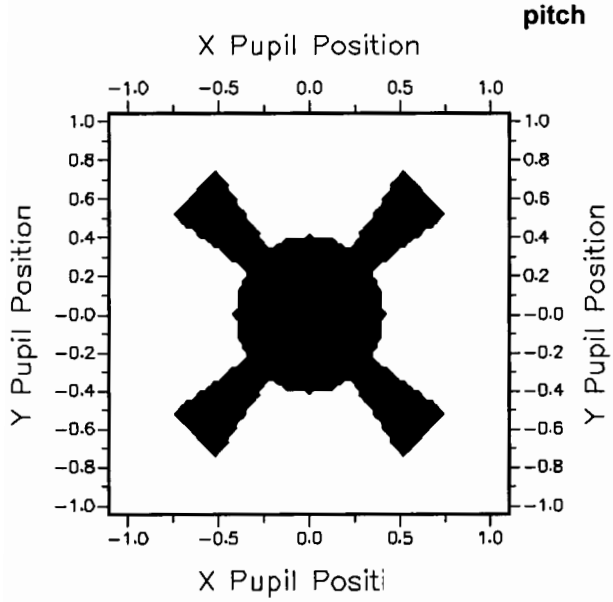


FIG. 36b

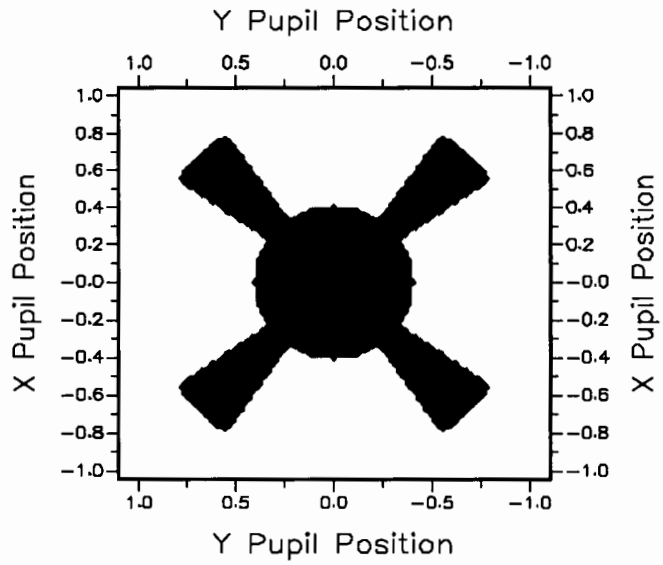


FIG. 36c

REPLACEMENT SHEET
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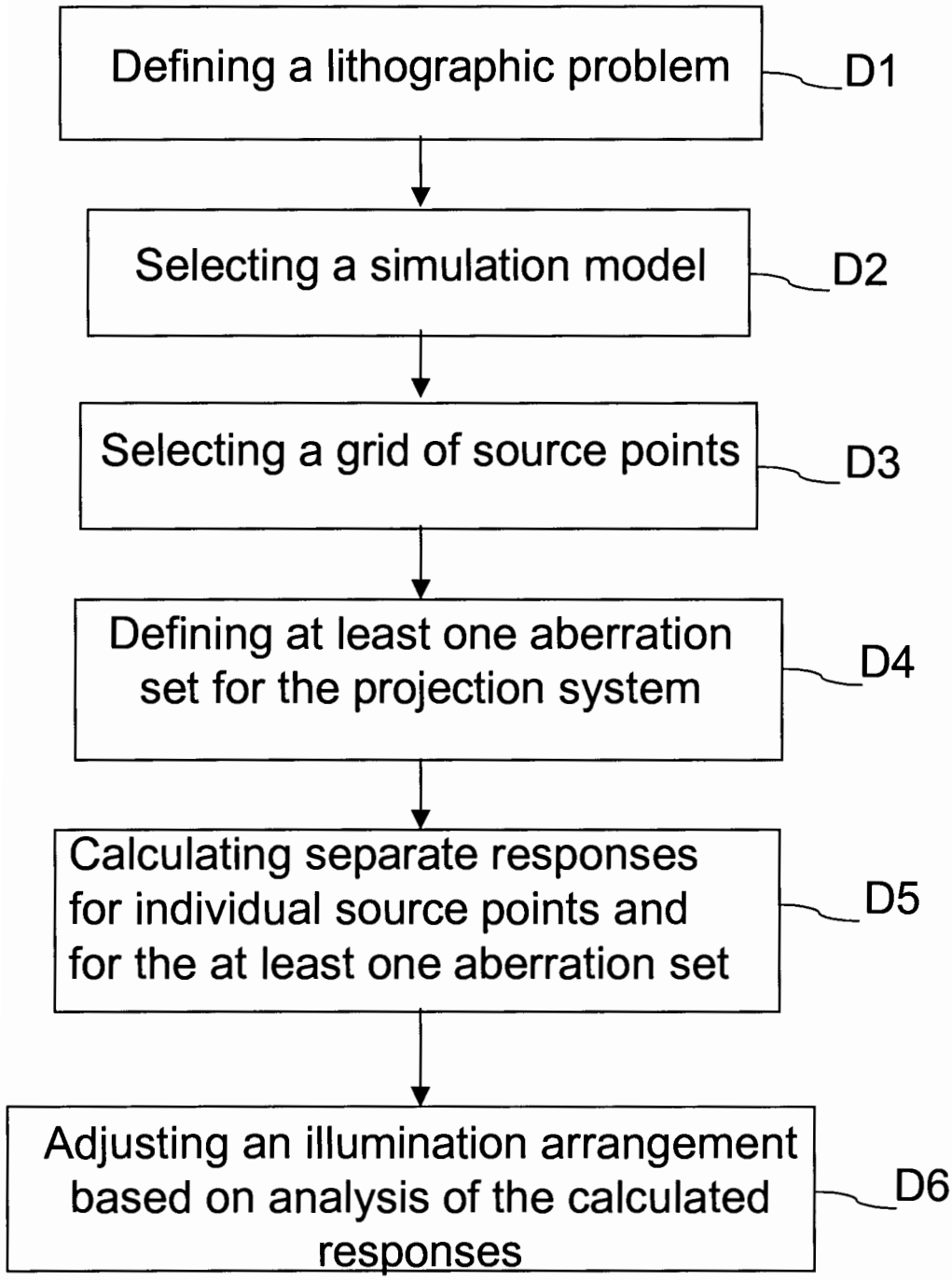

FIG. 37

REPLACEMENT SHEET
06 JUN 2005

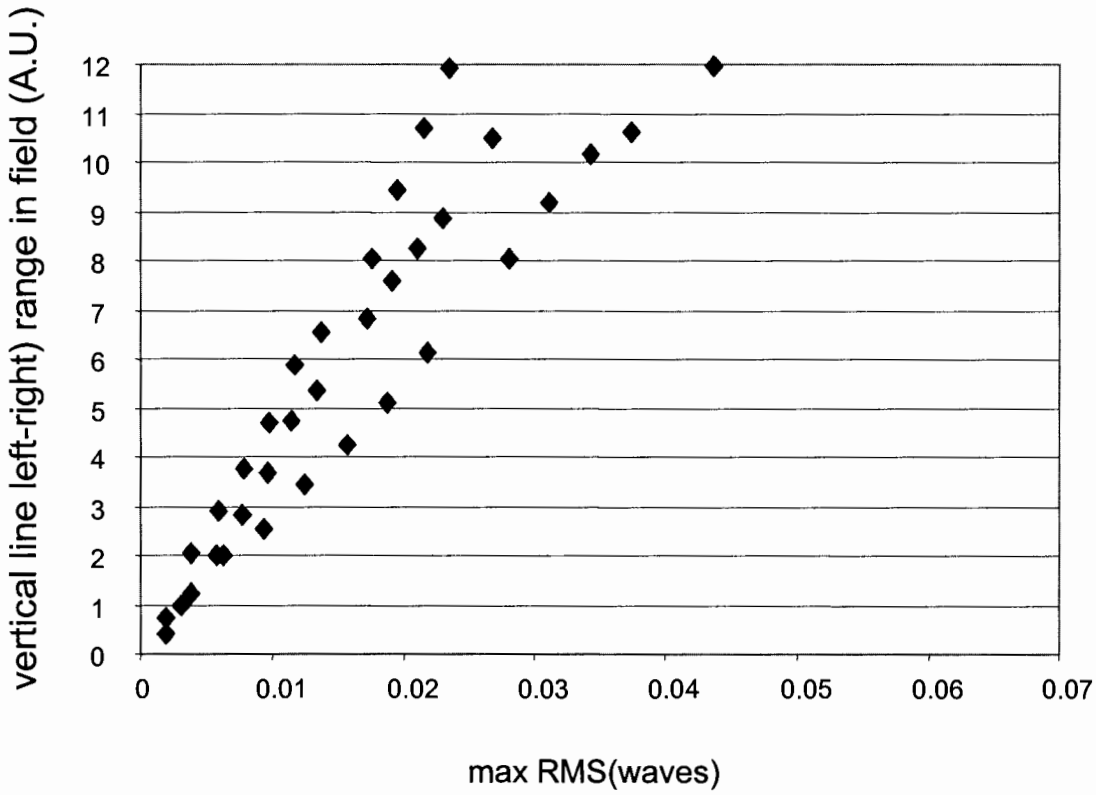

FIG. 38a

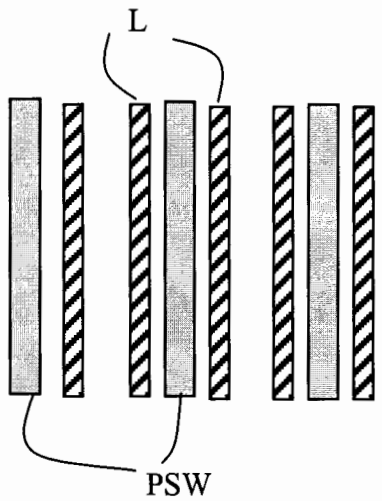

FIG. 38b

REPLACEMENT SHEET
06 JUN 2005

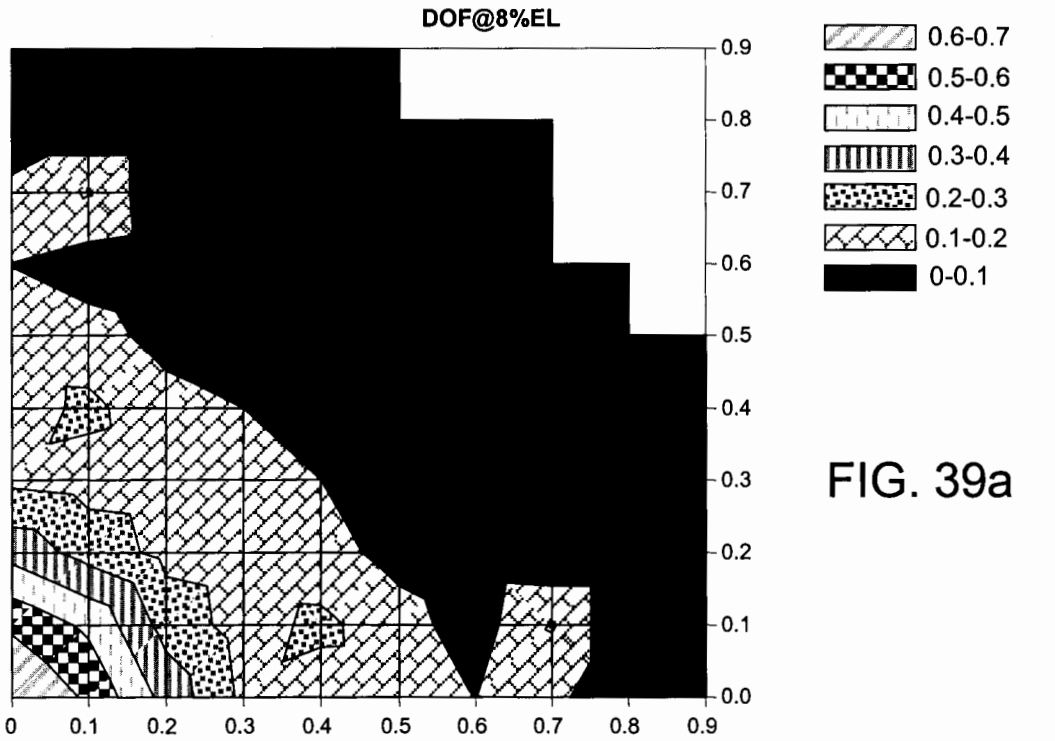

FIG. 39a

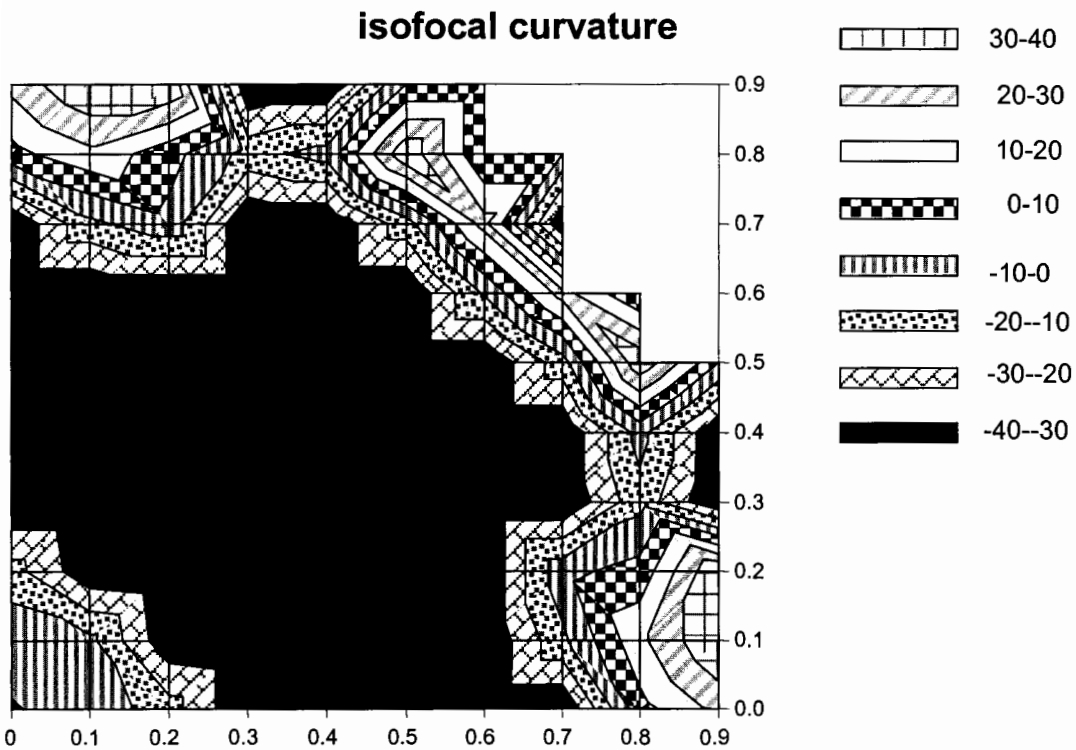

FIG. 39b

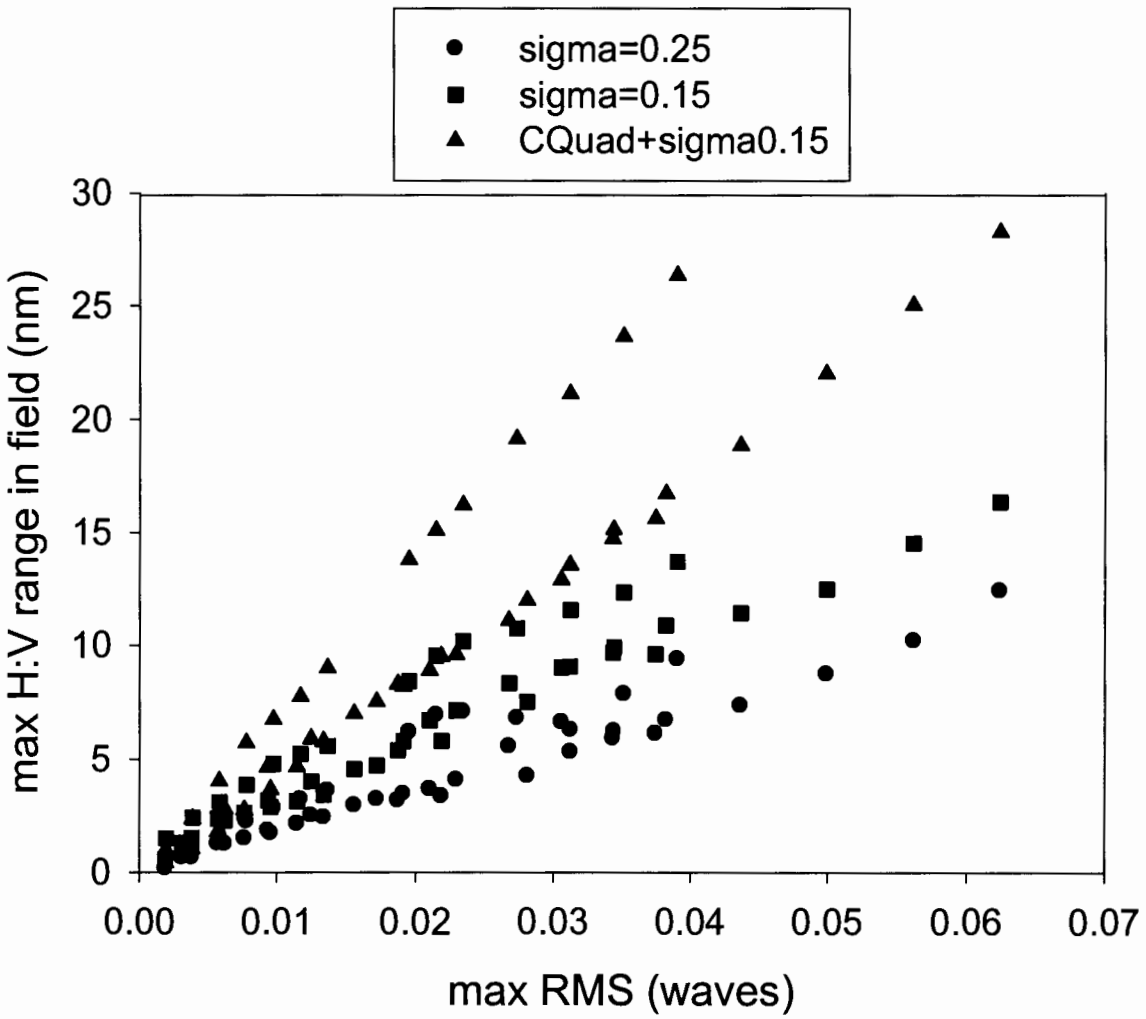
sigma=0.25
sigma=0.15
CQuad+sigma0.15
max H:V range in field (nm)
0
5
10
15
20
25
30
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
max RMS (waves)

FIG. 40

REPLACEMENT SHEET
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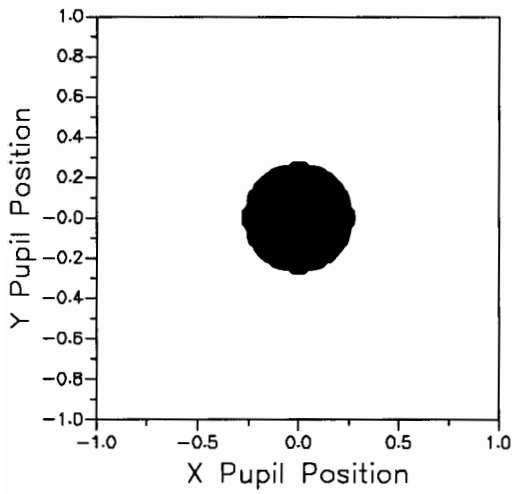
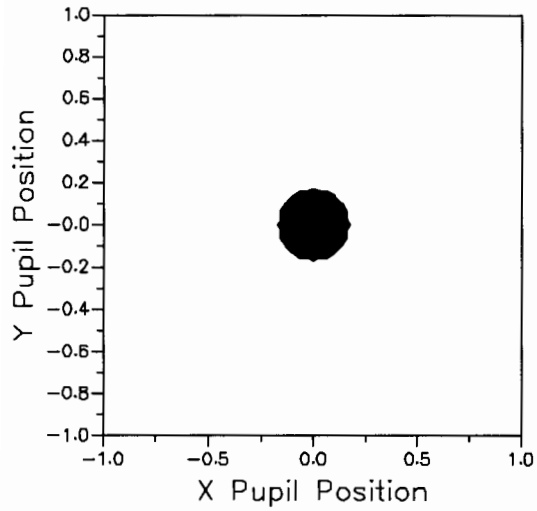
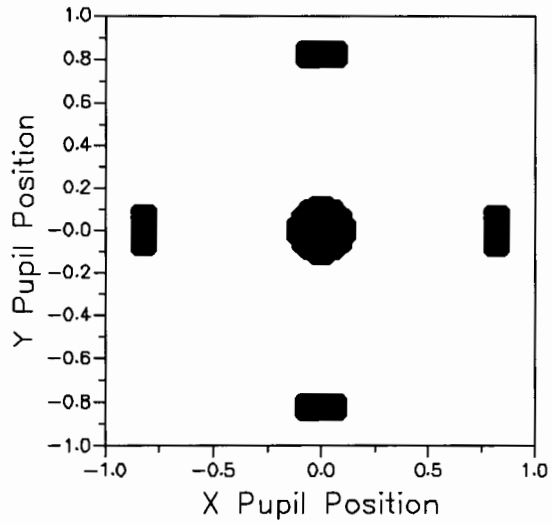


(a)



(b)

FIG. 41



(c)

REPLACEMENT SHEET
06 JUN 2005

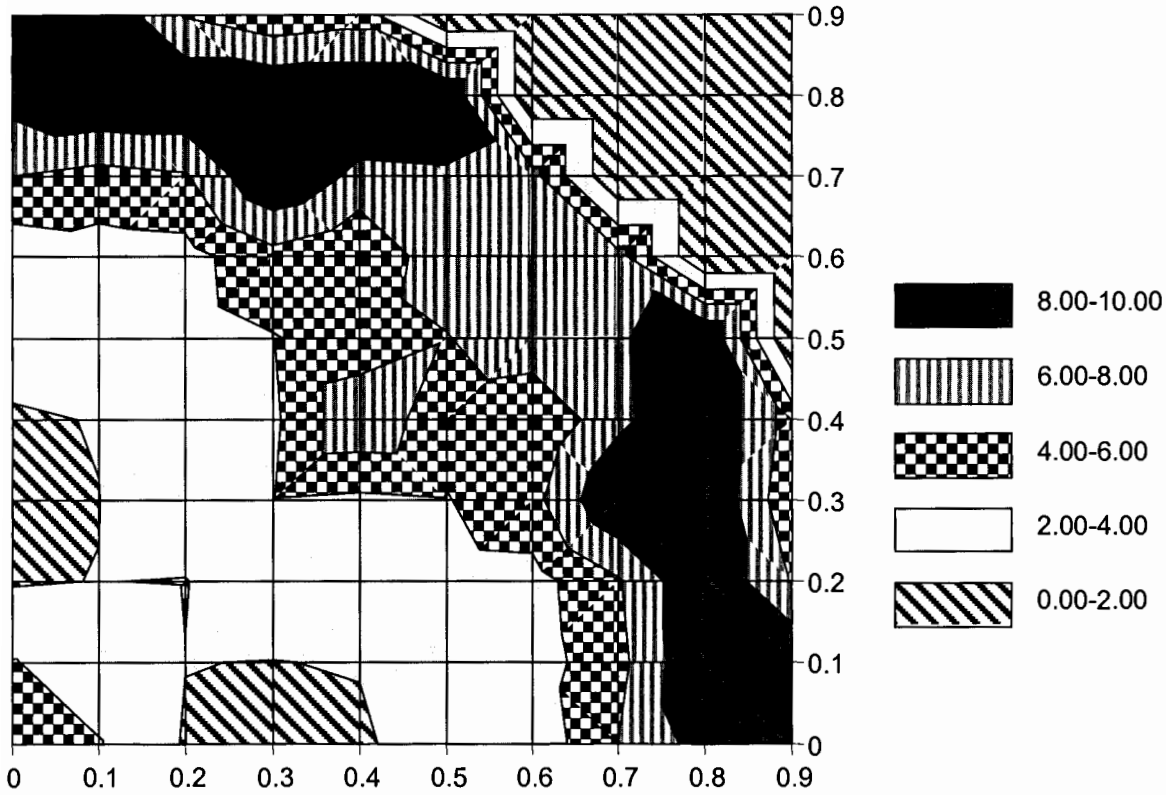


FIG. 42

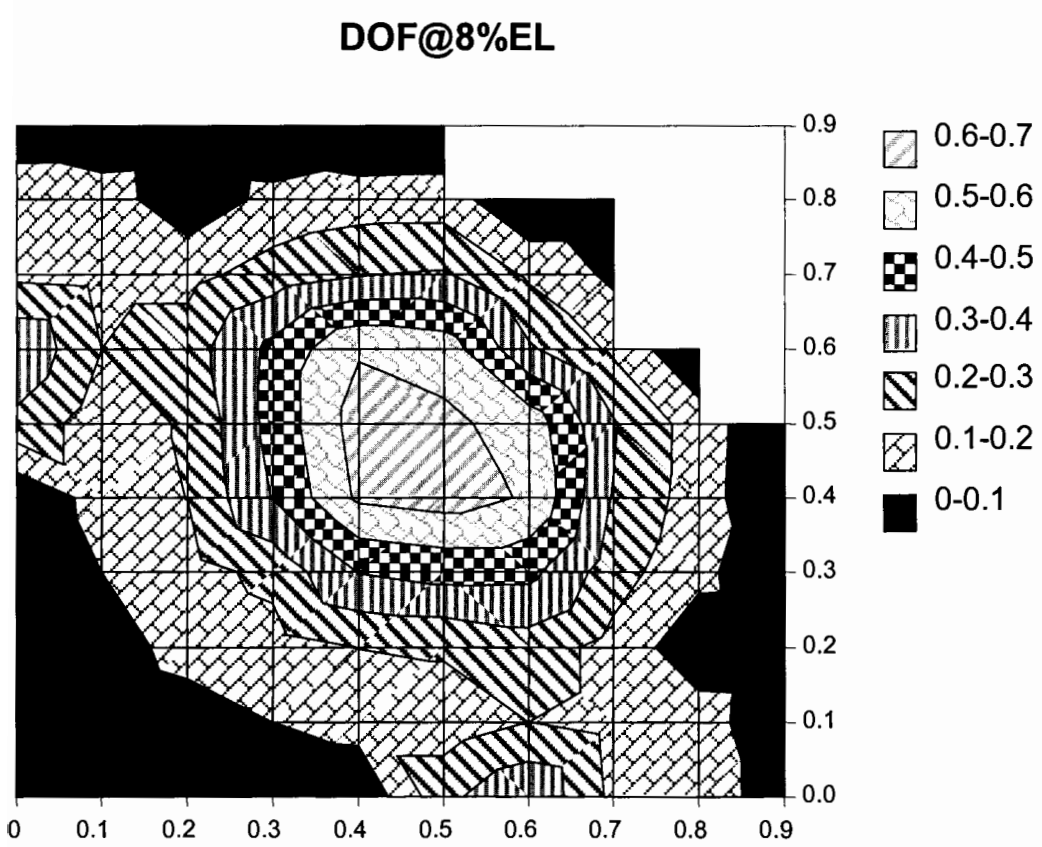

DOF@8%EL
0.6-0.7
0.5-0.6
0.4-0.5
0.3-0.4
0.2-0.3
0.1-0.2
0-0.1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

FIG. 43

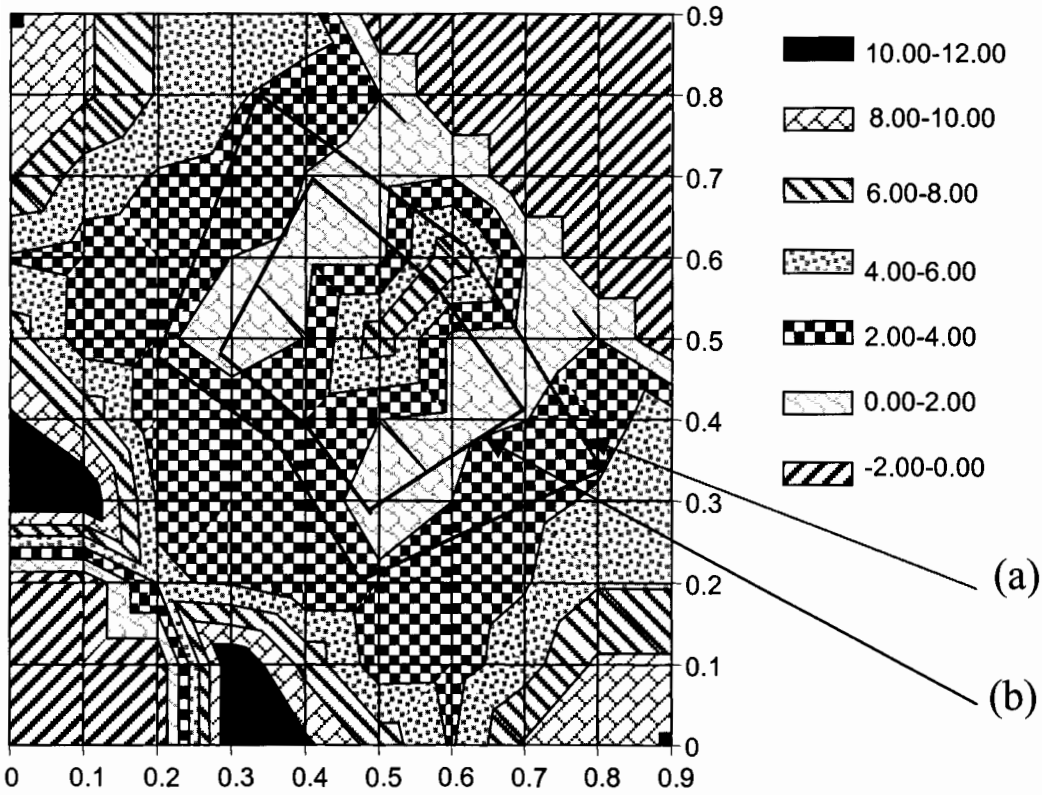

0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
10.00-12.00
8.00-10.00
6.00-8.00
4.00-6.00
2.00-4.00
0.00-2.00
-2.00-0.00
(a)
(b)

FIG. 44

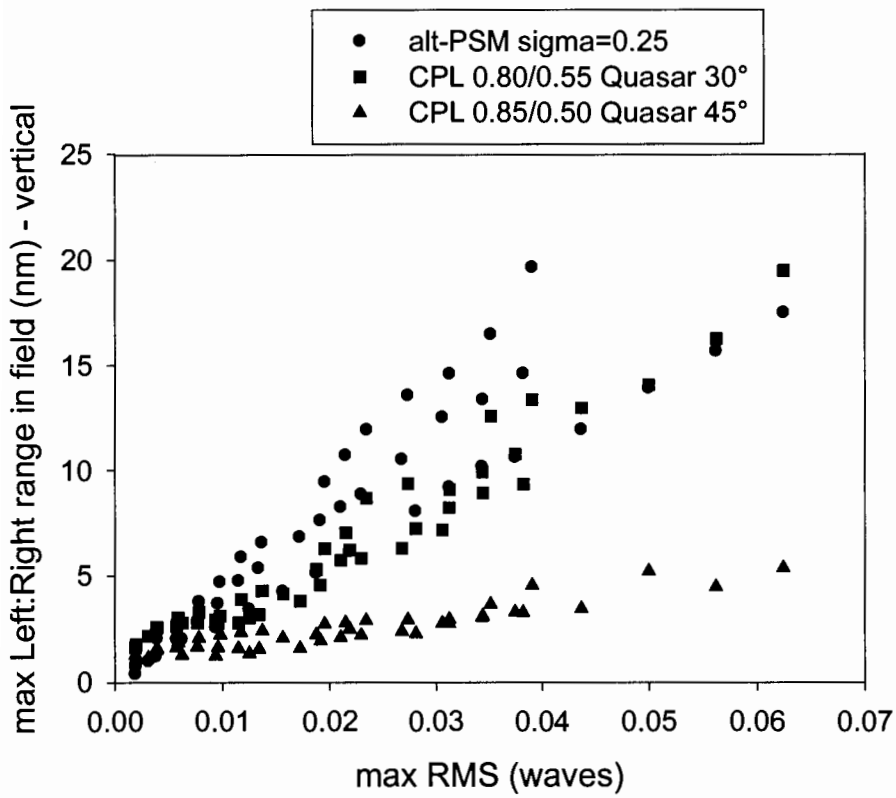
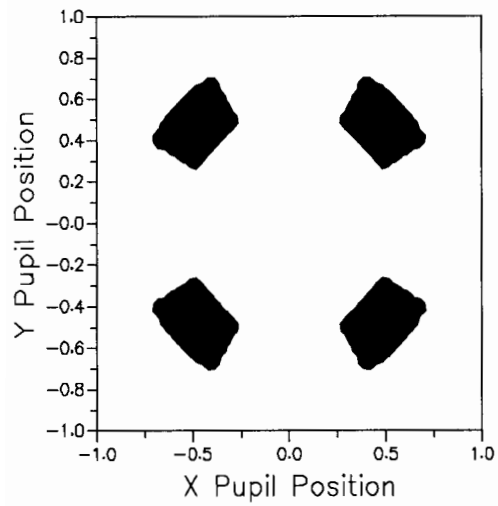
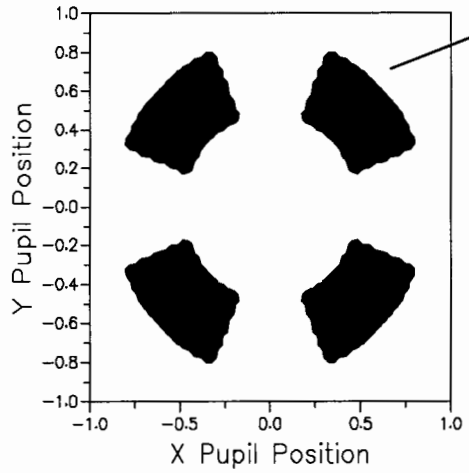

alt-PSM sigma=0.25
CPL 0.80/0.55 Quasar 30°
CPL 0.85/0.50 Quasar 45°
max Left:Right range in field (nm) - vertical
0
5
10
15
20
25
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
max RMS (waves)

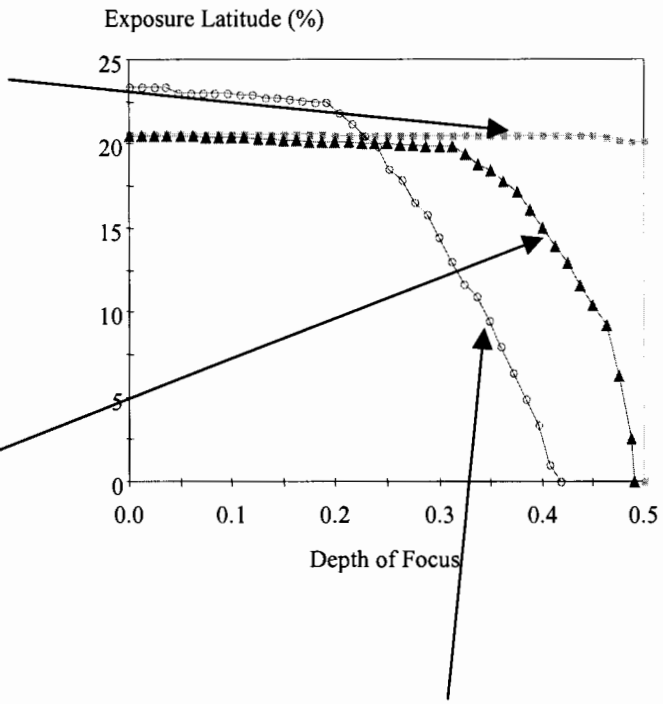
FIG. 45


Y Pupil Position
X Pupil Position

(b)


Y Pupil Position
X Pupil Position

(a)


Exposure Latitude (%)
Depth of Focus

(c)

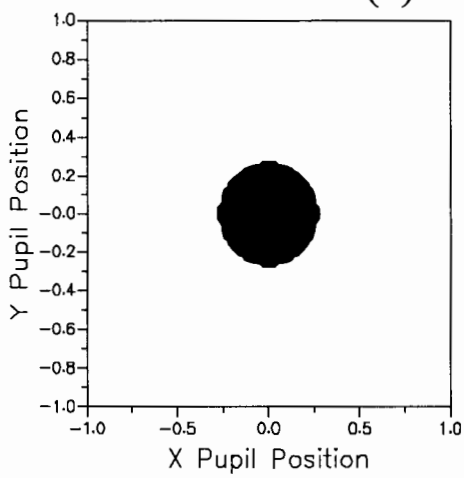

Y Pupil Position
X Pupil Position

FIG. 46

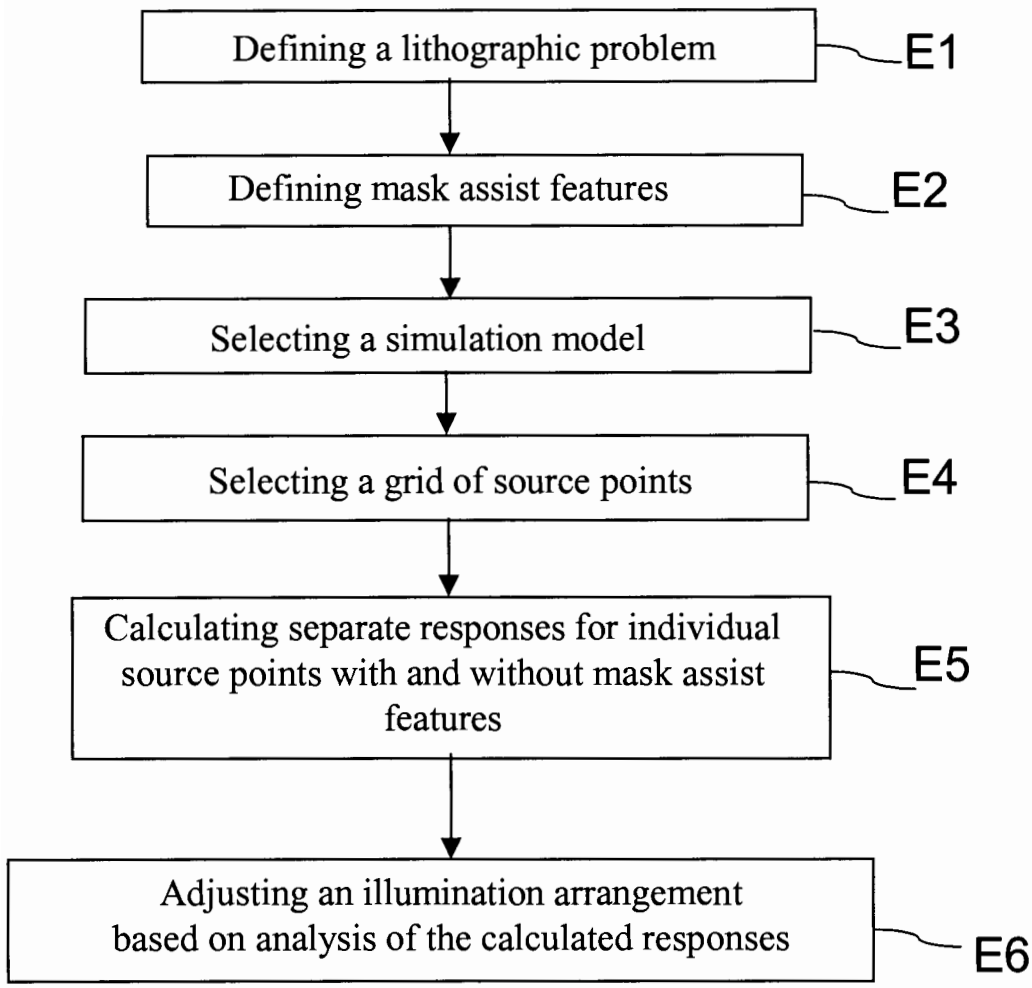

Defining a lithographic problem
E1
Defining mask assist features
E2
Selecting a simulation model
E3
Selecting a grid of source points
E4
Calculating separate responses for individual source points with and without mask assist features
E5
Adjusting an illumination arrangement based on analysis of the calculated responses
E6

FIG. 47

FIG. 48

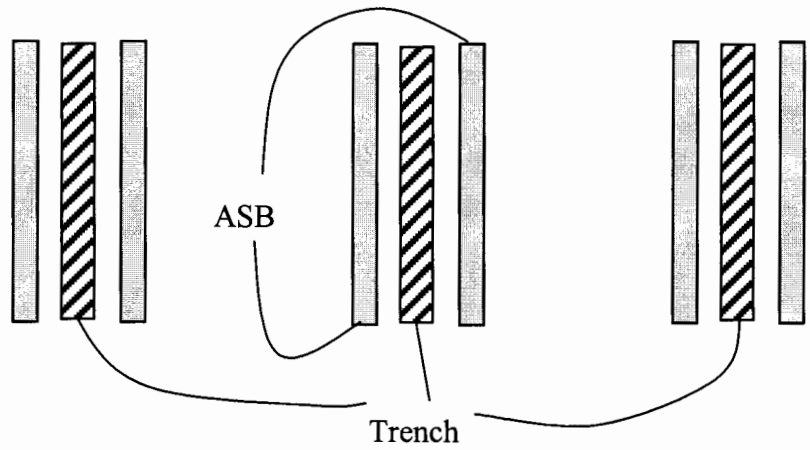


FIG. 49a

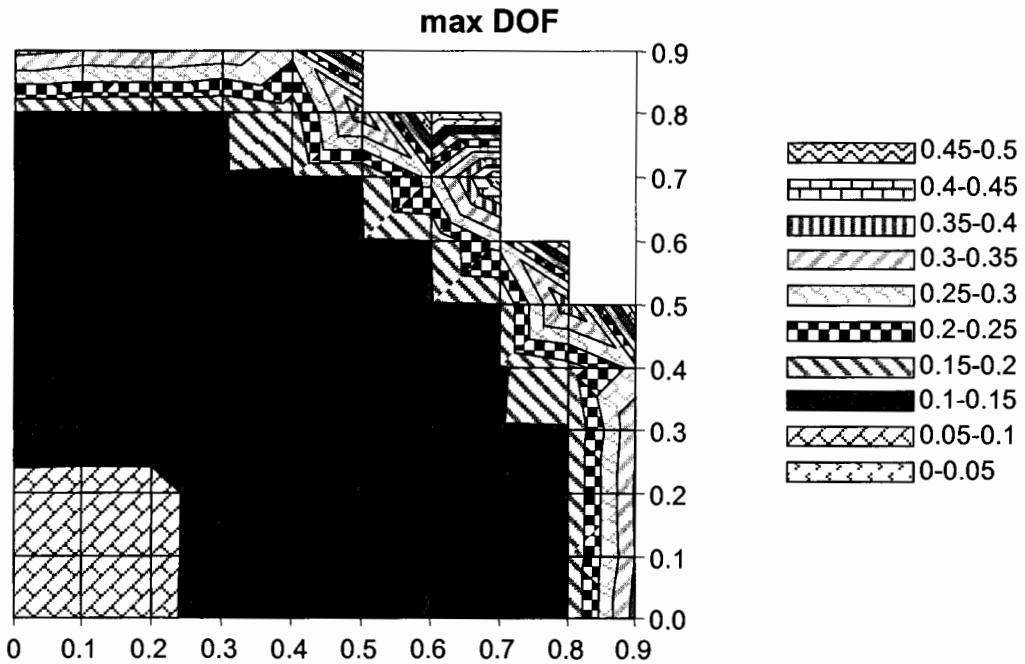
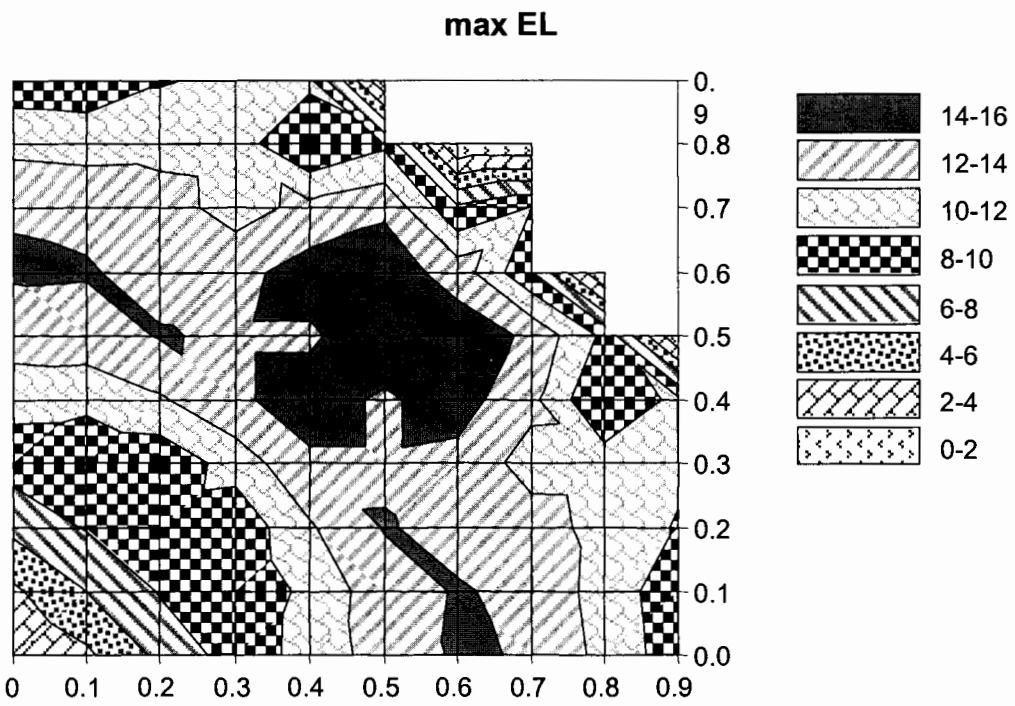


FIG. 49b


max EL
0.
9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
14-16
12-14
10-12
8-10
6-8
4-6
2-4
0-2

REPLACEMENT SHEET
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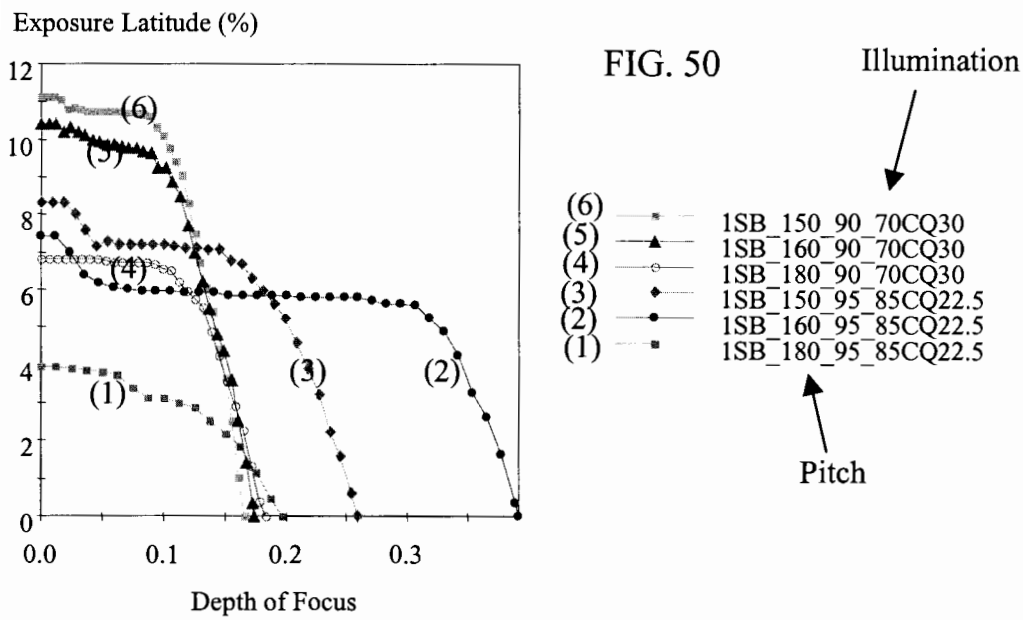


FIG. 50

FIG. 51a

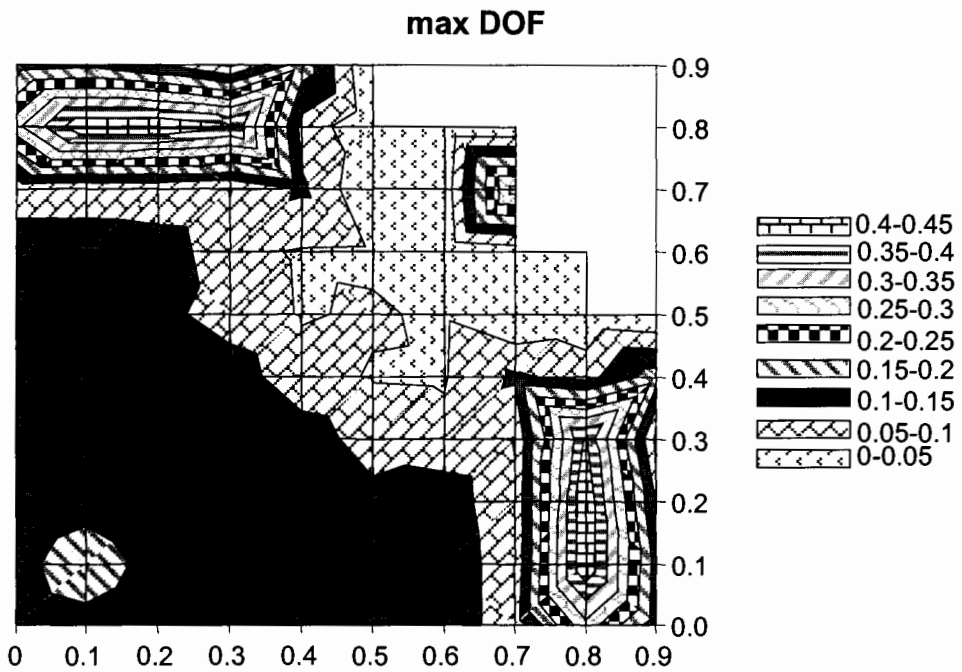
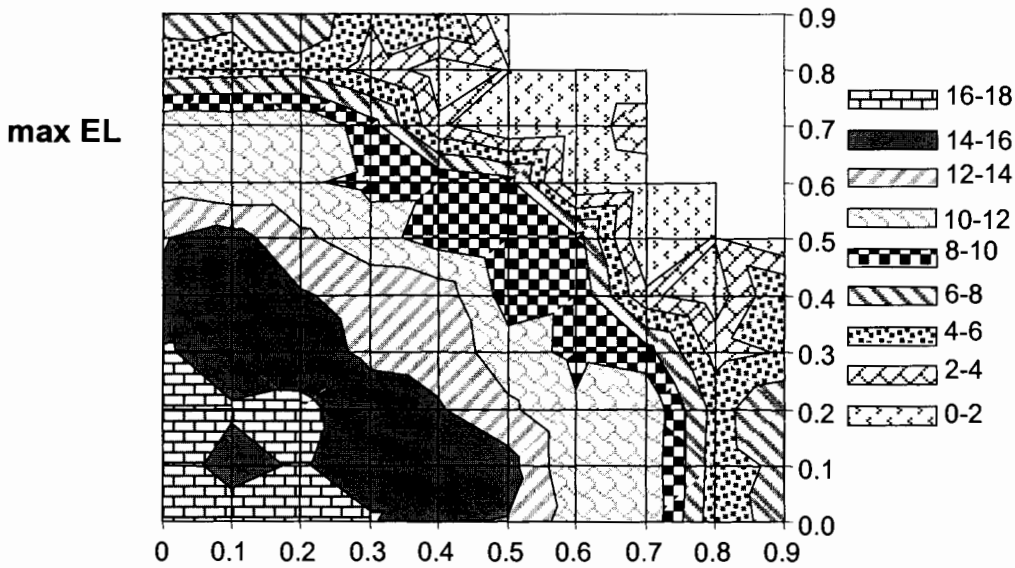


FIG. 51b


max EL
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
16-18
14-16
12-14
10-12
8-10
6-8
4-6
2-4
0-2

REPLACEMENT SHEET
06 JUN 2005

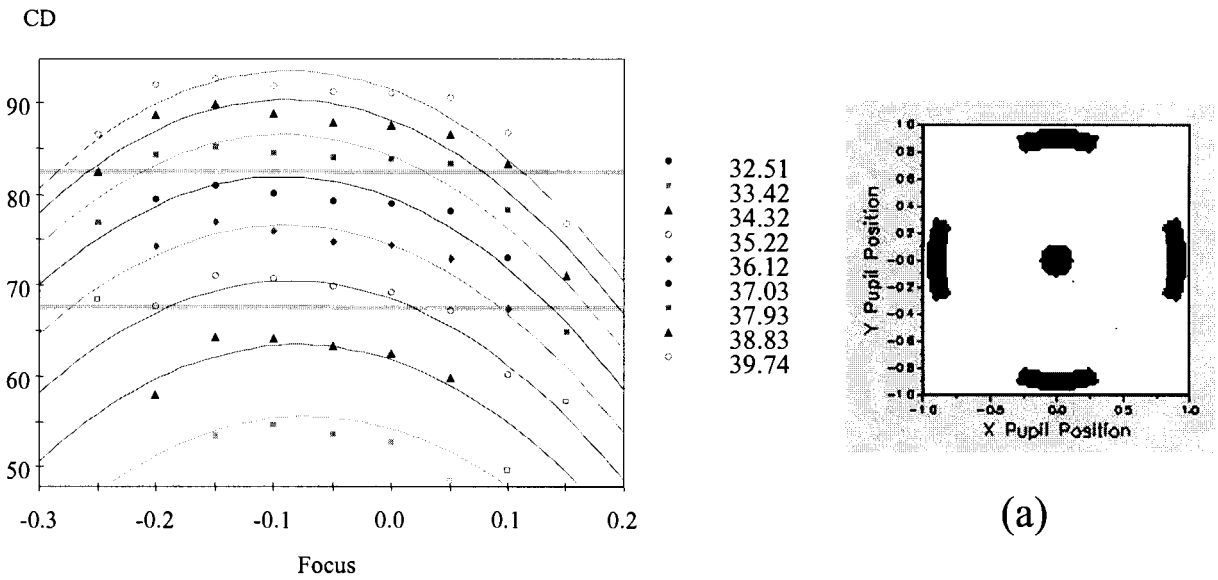


FIG. 52

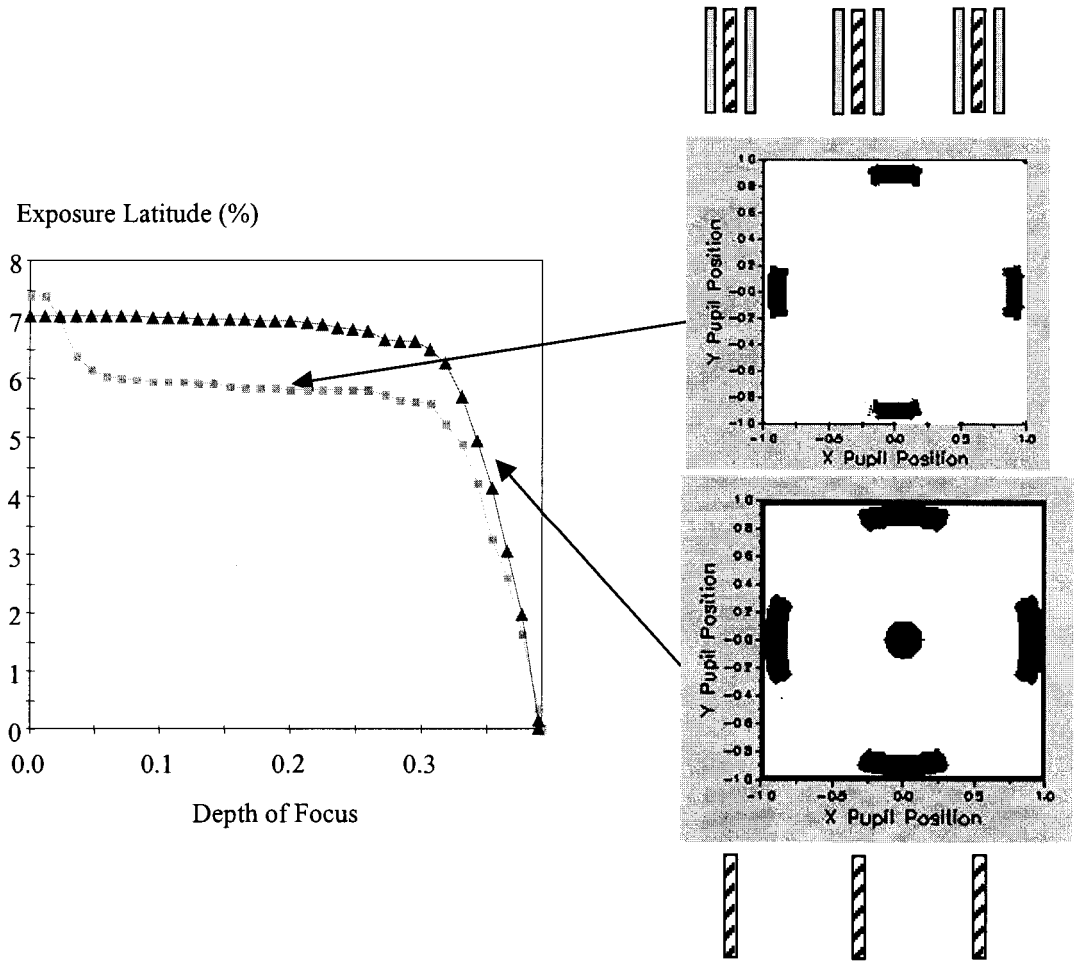
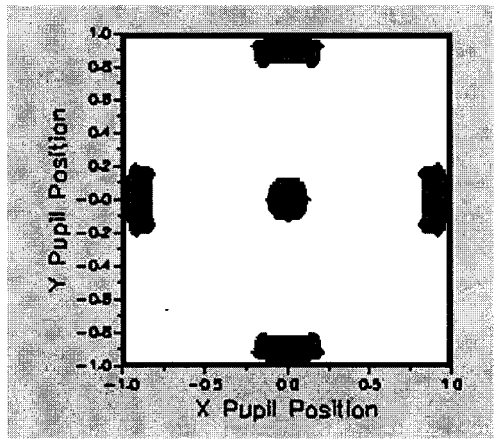
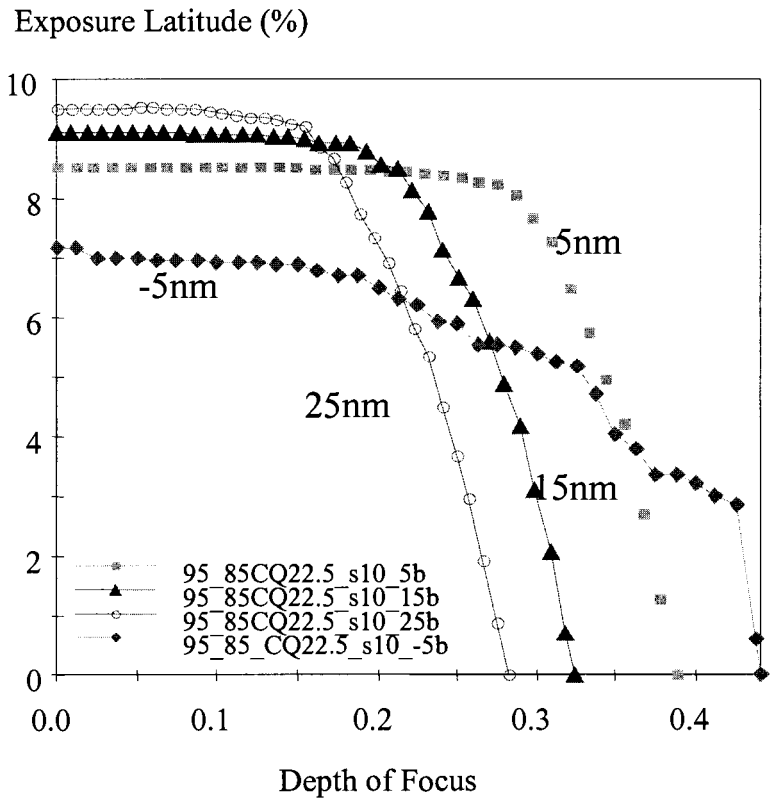


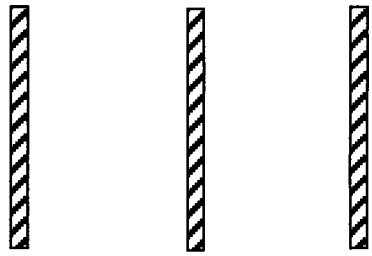
FIG. 53

REPLACEMENT SHEET
06 JUN 2005

(b)







(a)

FIG.54

REPLACEMENT SHEET
06 JUN 2005

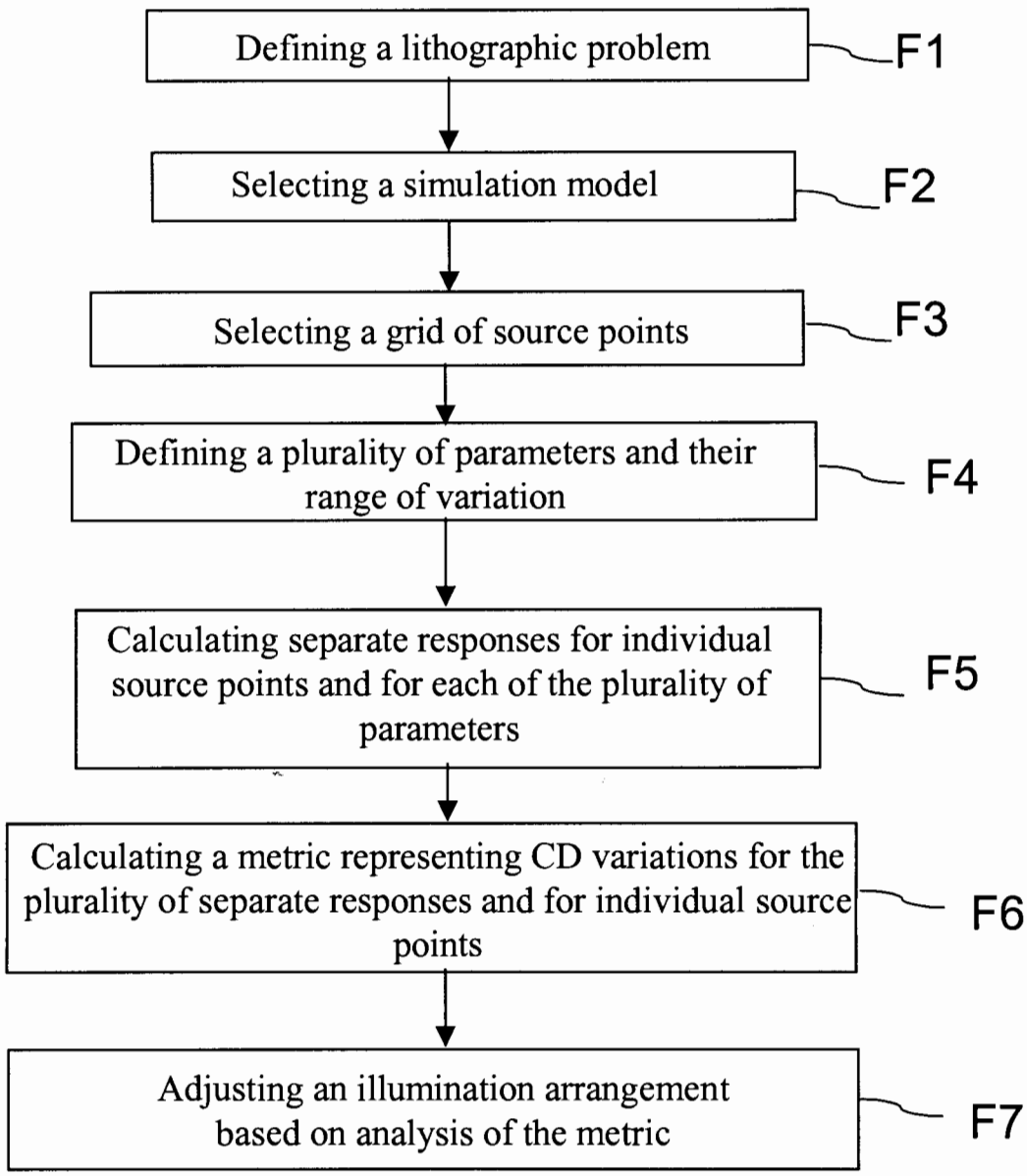
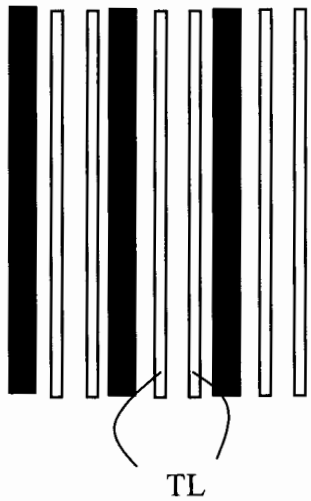


FIG. 55

REPLACEMENT SHEET
06 JUN 2006

FIG. 56



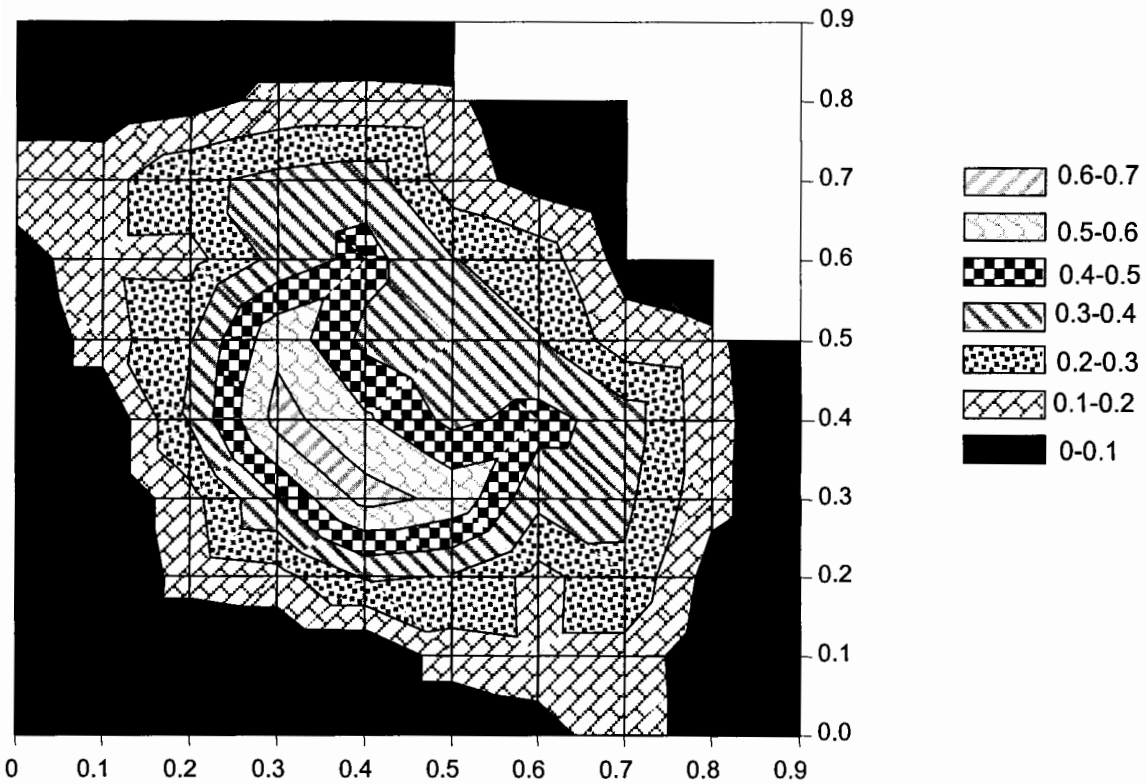
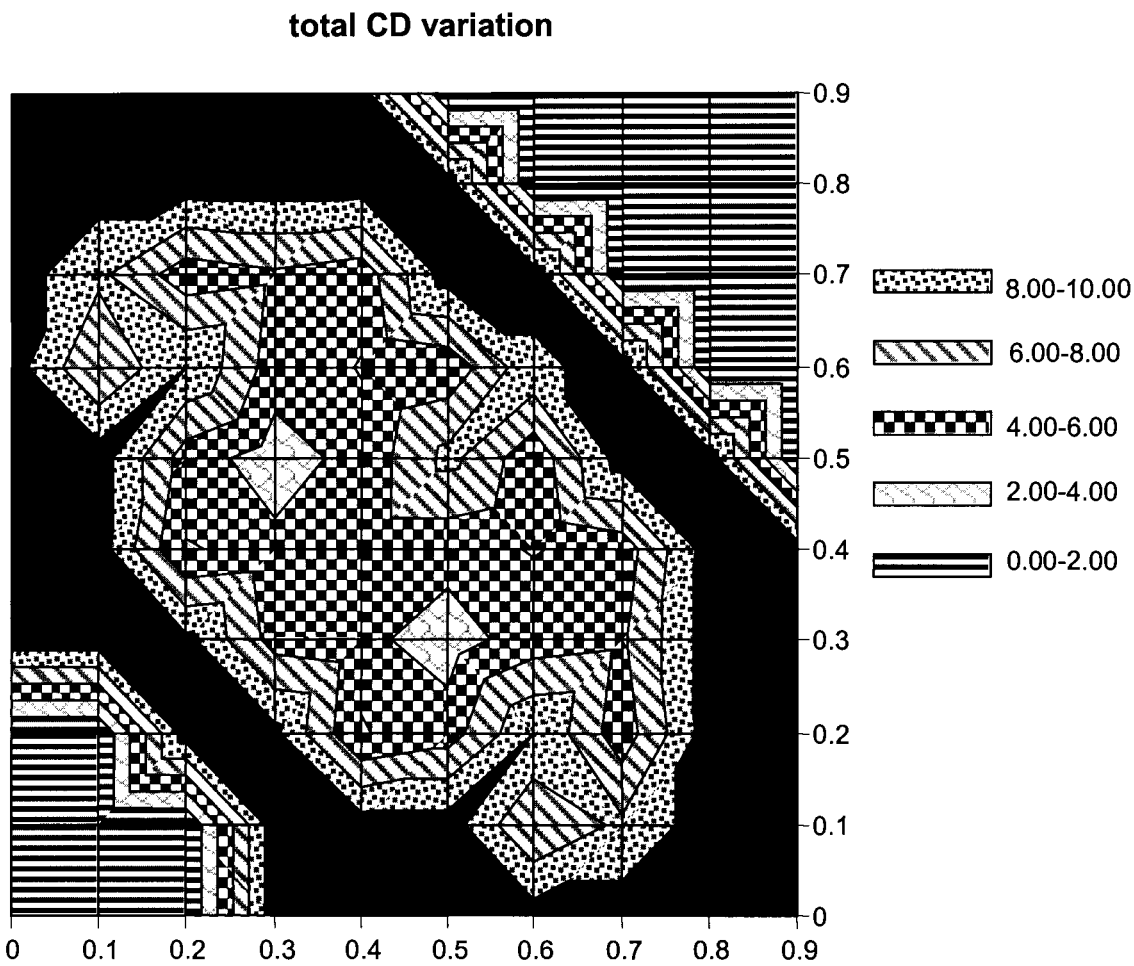


FIG. 57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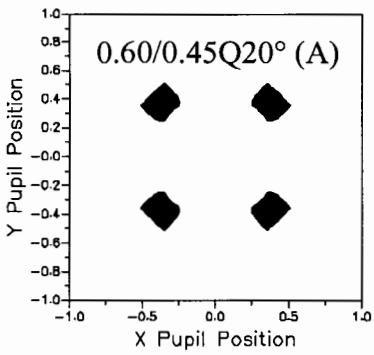
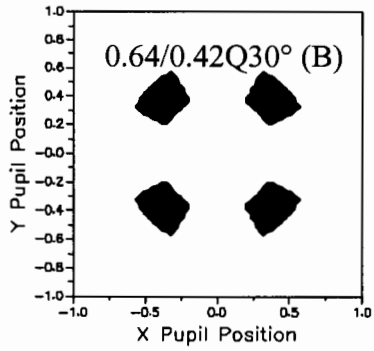
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
8.00-10.00
6.00-8.00
4.00-6.00
2.00-4.00
0.00-2.00

FIG. 58

REPLACEMENT SHEET
06 JUN 2005





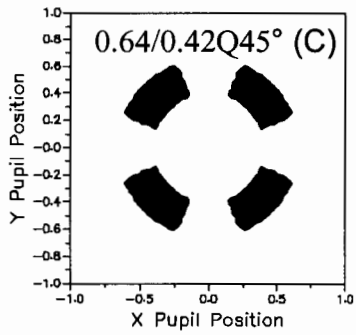


FIG. 59

