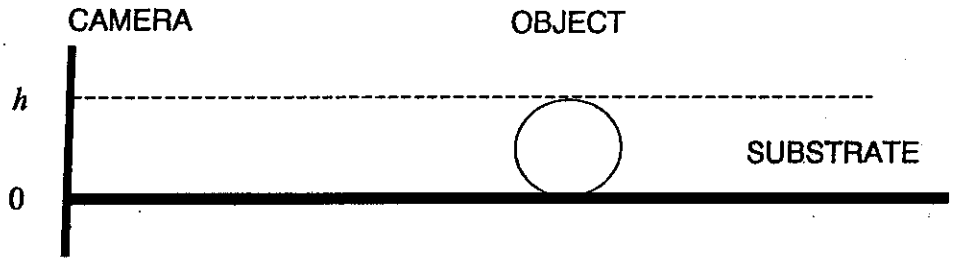


Fig. 1A

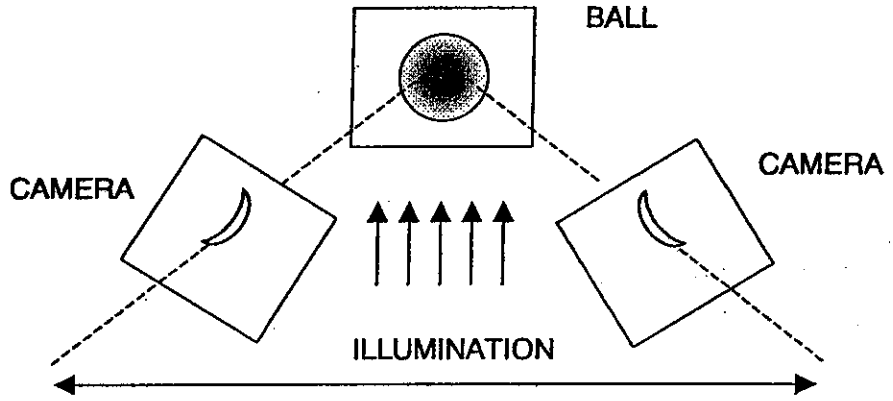


Fig. 1B

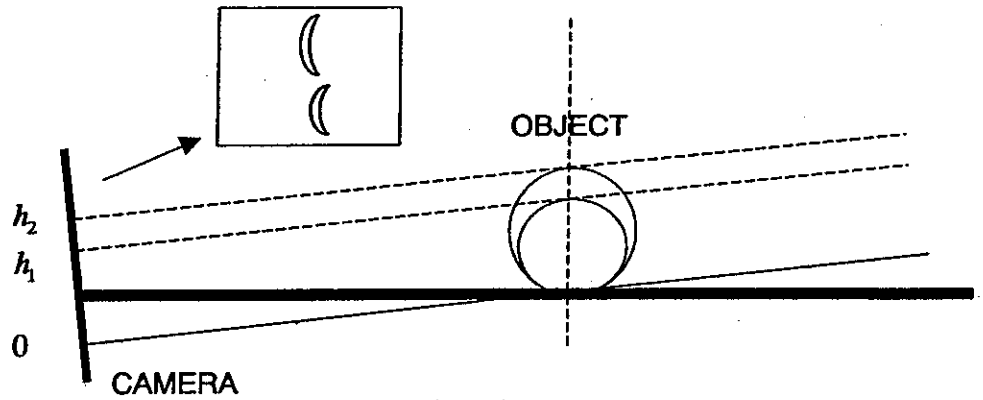


Fig. 1C

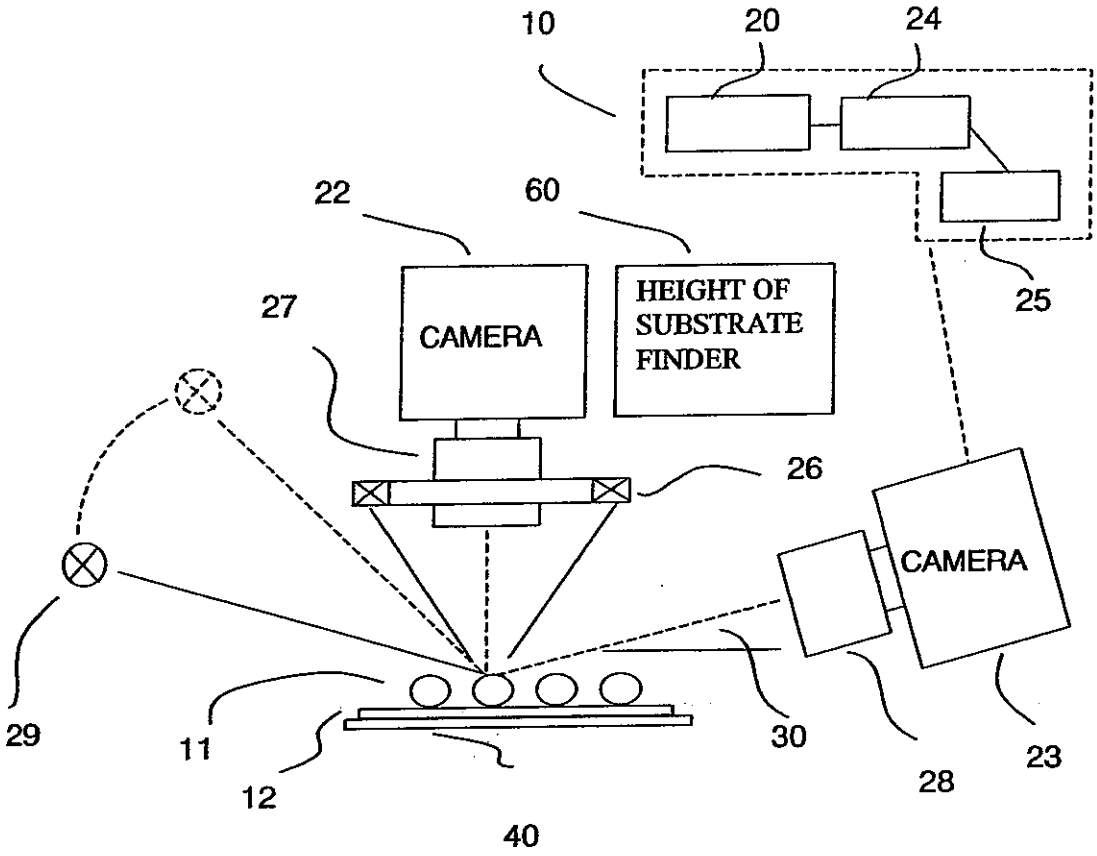
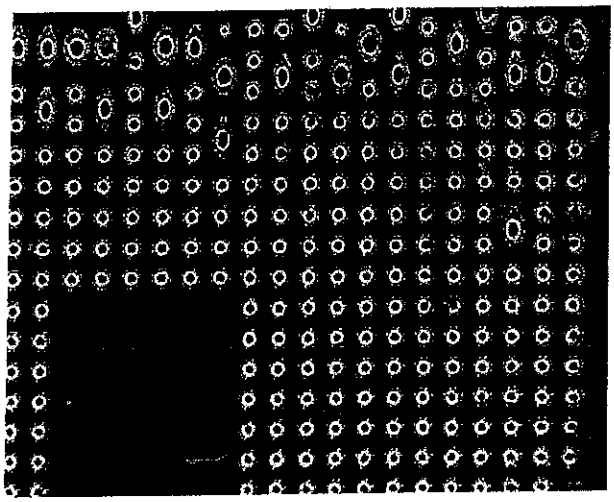
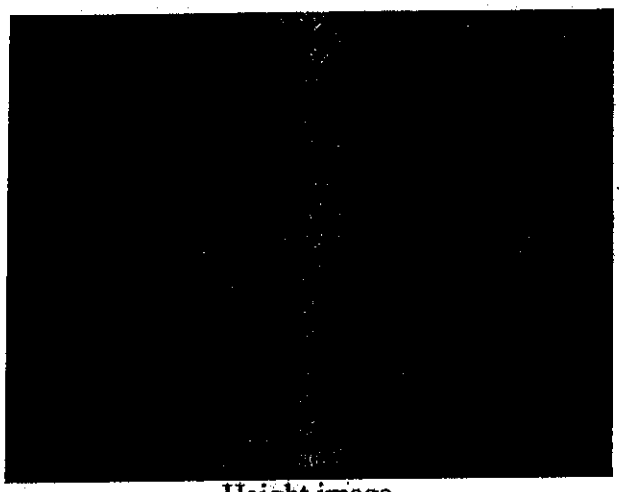

10
20
24
22
60
CAMERA
HEIGHT OF SUBSTRATE FINDER
25
27
26
CAMERA
29
11
12
40
30
28
23

Fig.2



2D image



Height image

Fig.3

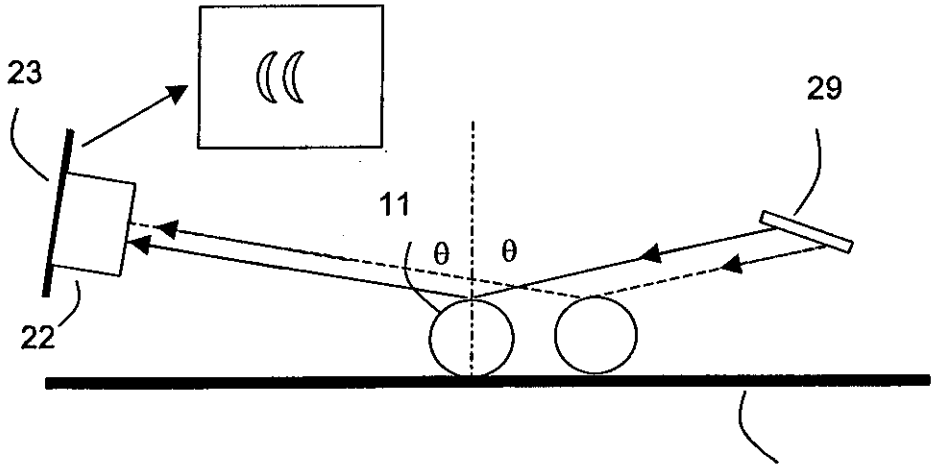
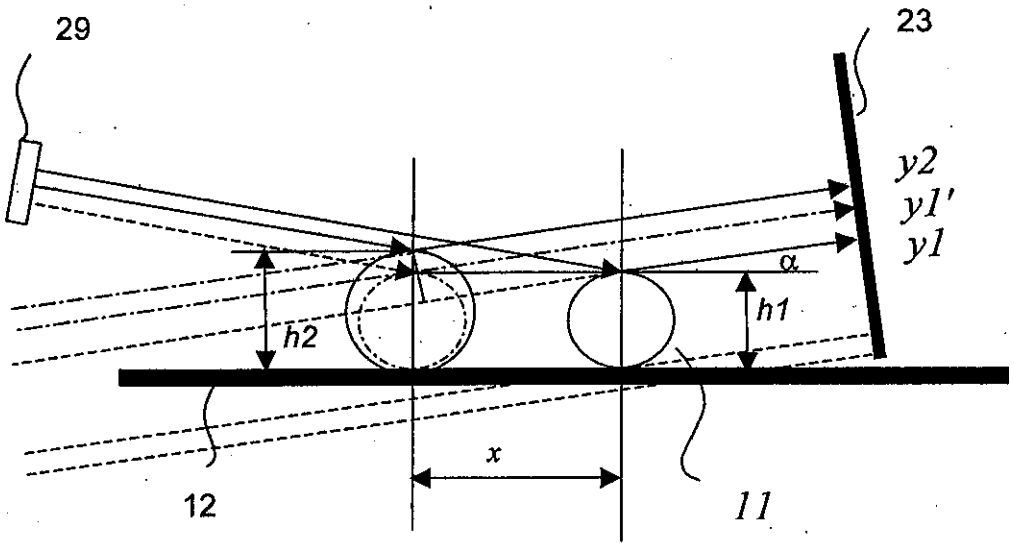


Fig. 4A



$$\Delta h_{21} = (y2 - y1')/M\cos\alpha = [(y2 - y1) - (y1' - y1)]/M\cos\alpha$$
$$= [(y2 - y1) - x\sin\alpha]/M\cos\alpha$$

Fig. 4B

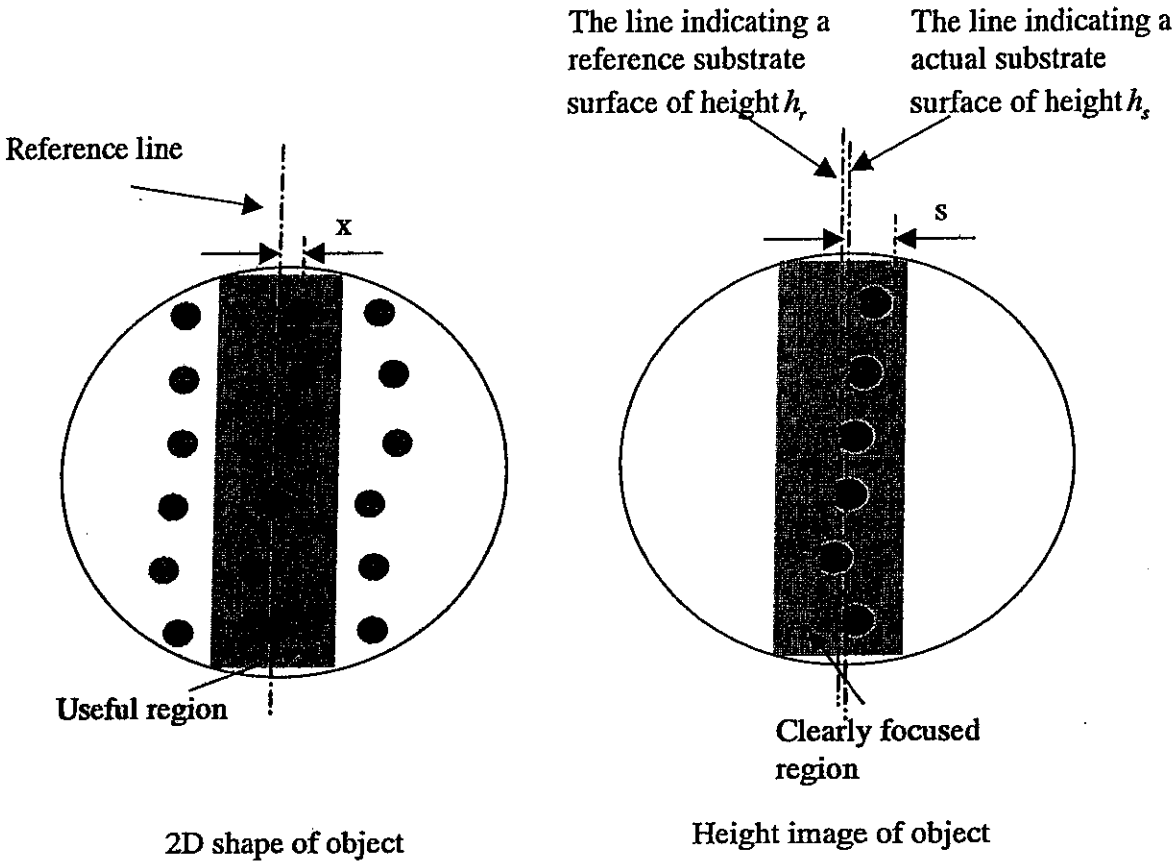
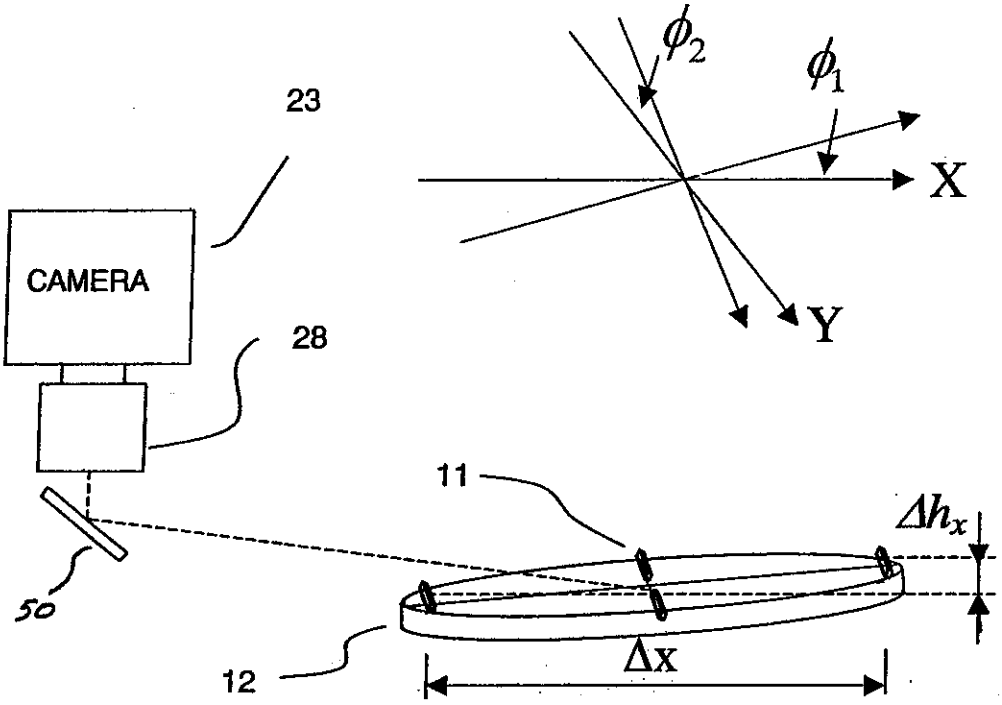

Reference line
x
Useful region
2D shape of object
The line indicating a reference substrate surface of height h_r
The line indicating a actual substrate surface of height h_s
s
Clearly focused region
Height image of object

Fig. 5



$$\phi_1 = \frac{\Delta h_x}{\Delta x} \qquad \phi_2 = \frac{\Delta h_y}{\Delta y}$$

Fig. 6

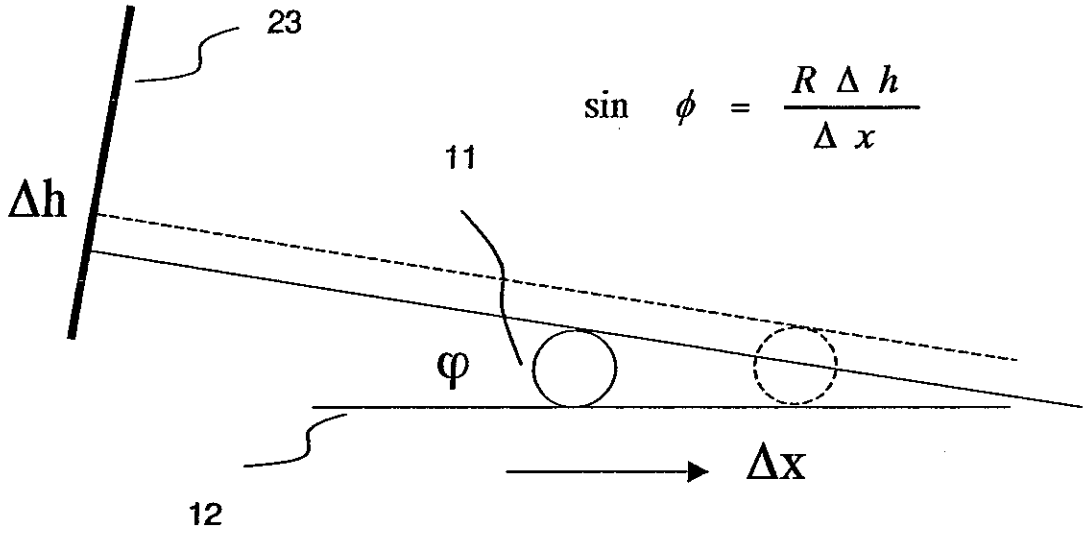


Fig. 7

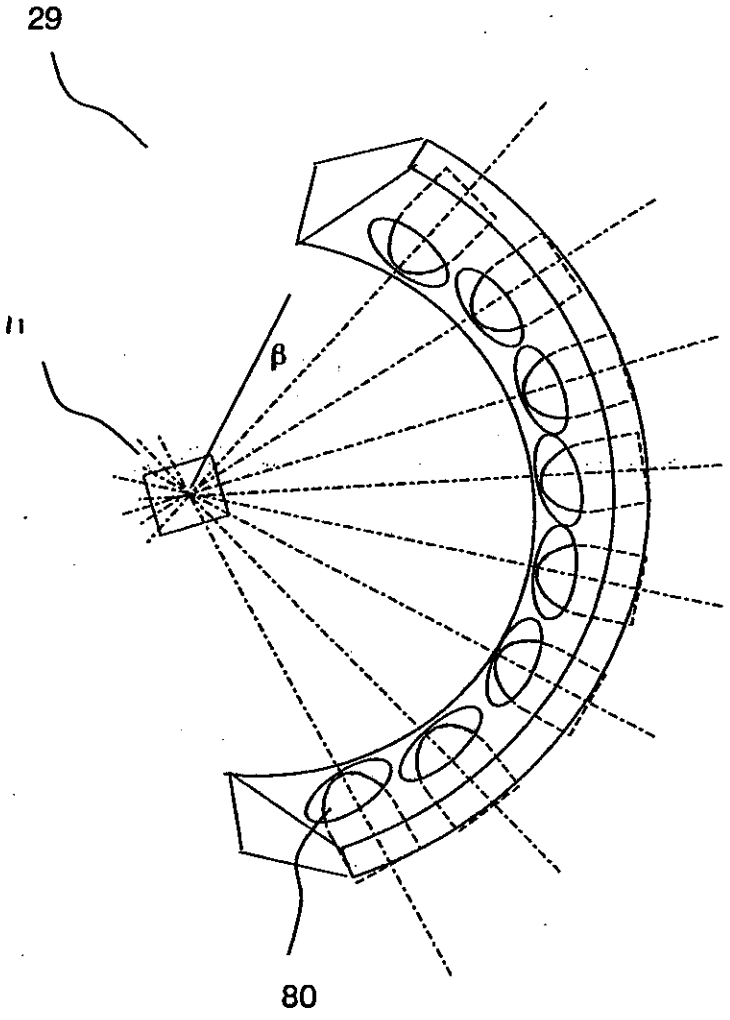


Fig. 8

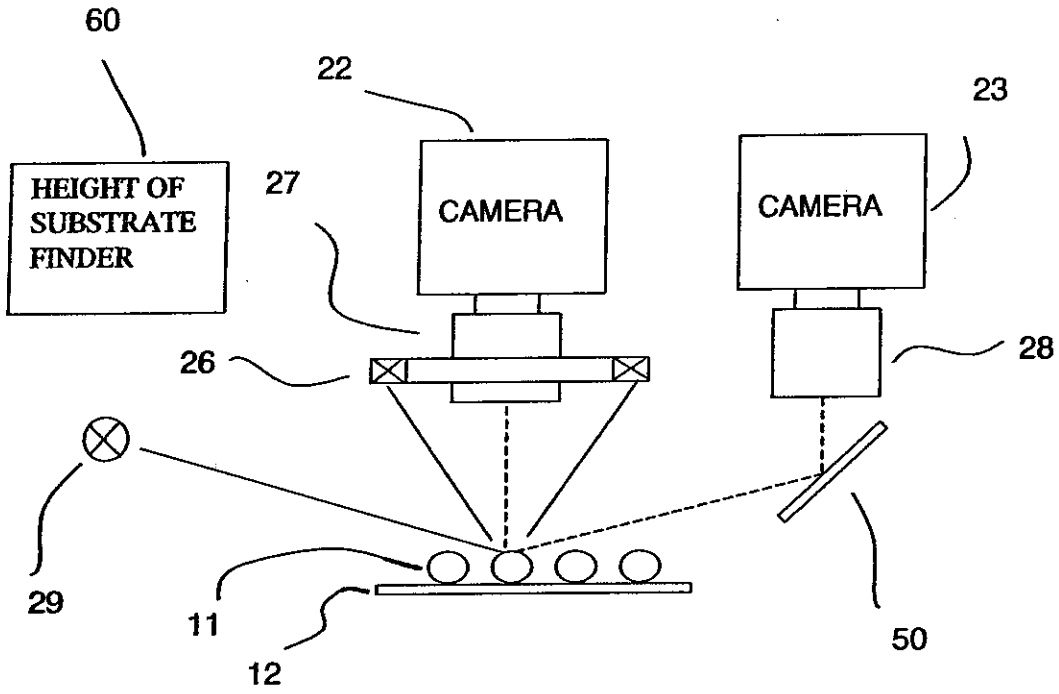

60
HEIGHT OF SUBSTRATE FINDER
22
CAMERA
23
CAMERA
27
26
28
29
11
12
50

Fig.9

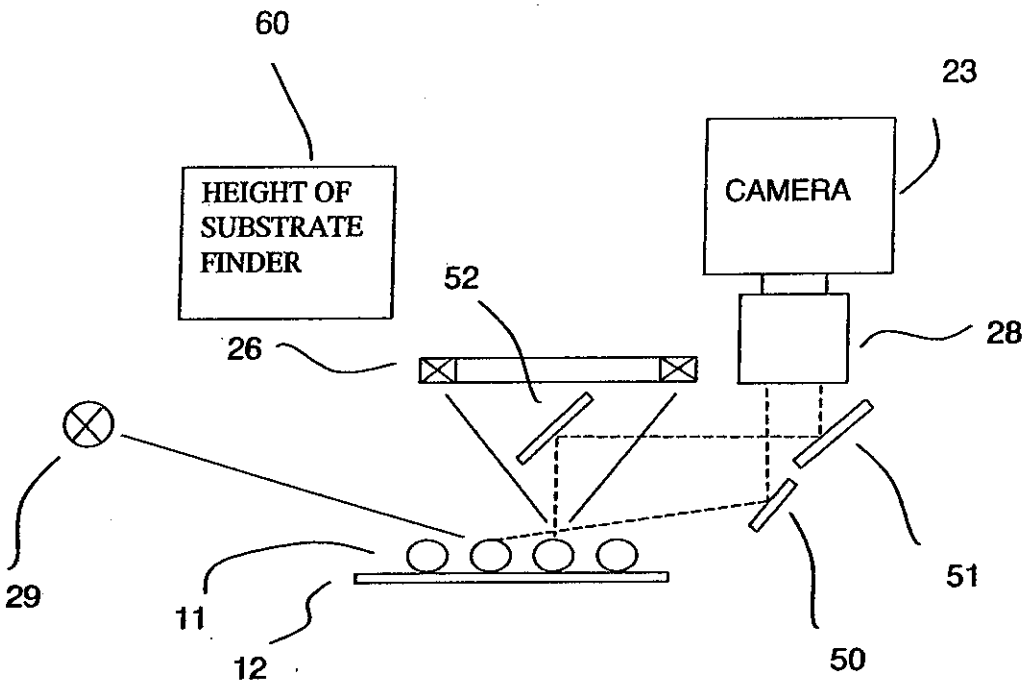


Fig. 10

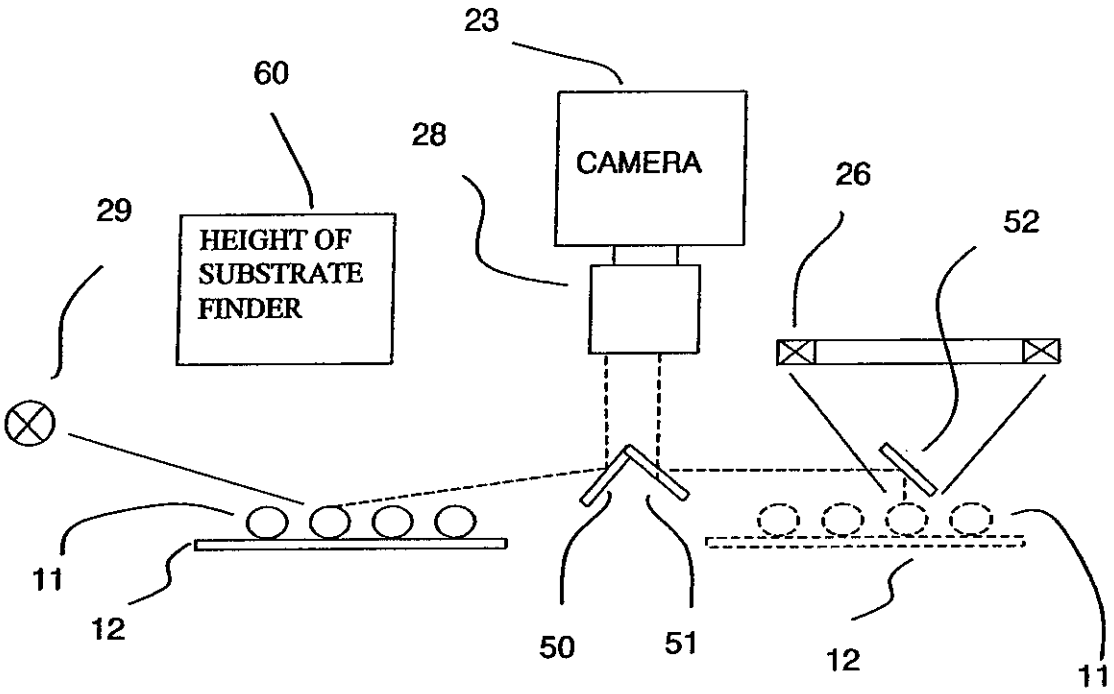

23
60
28
CAMERA
26
29
52
HEIGHT OF SUBSTRATE FINDER
11
12
50
51
12
11

Fig. 11

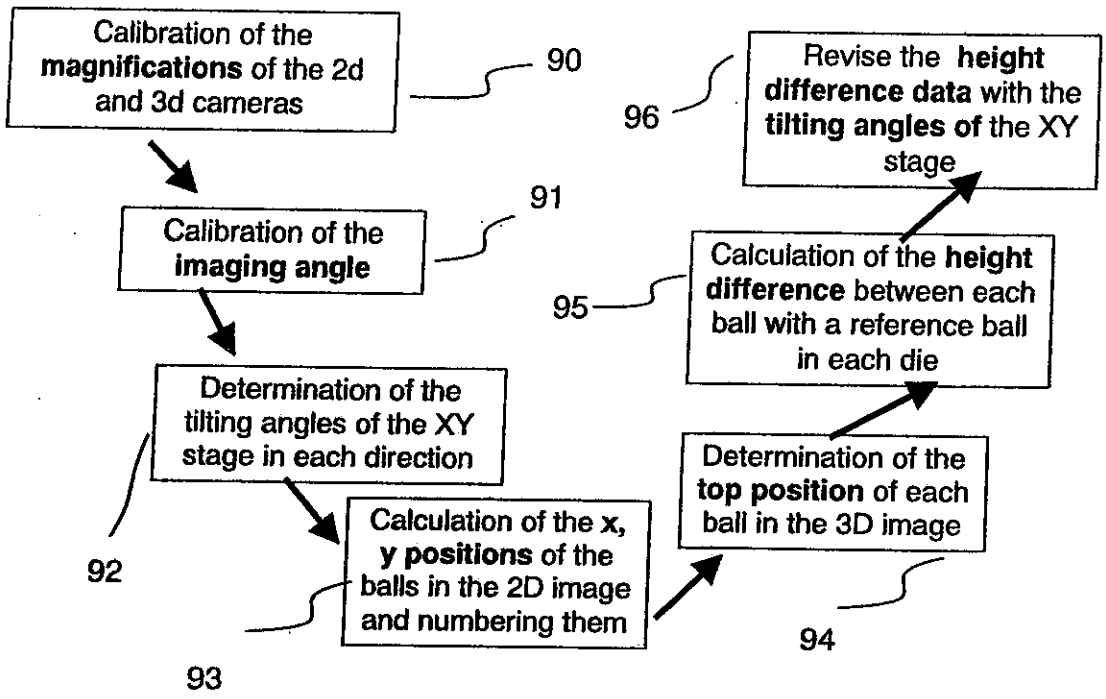

Calibration of the **magnifications** of the 2d and 3d cameras
90
Calibration of the **imaging angle**
91
Determination of the tilting angles of the XY stage in each direction
92
Calculation of the **x, y positions** of the balls in the 2D image and numbering them
93
Determination of the **top position** of each ball in the 3D image
94
Calculation of the **height difference** between each ball with a reference ball in each die
95
Revise the **height difference data** with the **tilting angles of** the XY stage
96

Fig. 12