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Kanatake

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(54) **HIGH RESOLUTION POINT ARRAY**

(75) Inventor: **Takashi Kanatake**, Torokozawa (JP)

(73) Assignee: **Ball Semiconductor, Inc.**, Allen, TX (US)

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(51) **Int. Cl.**[7] **G03B 27/32**; G03B 27/42

(52) **U.S. Cl.** **355/77**; 355/53

(58) **Field of Search** 355/53, 77; 430/5, 430/22, 30

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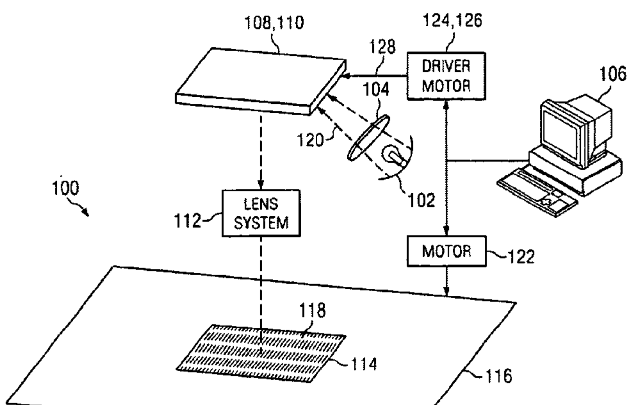
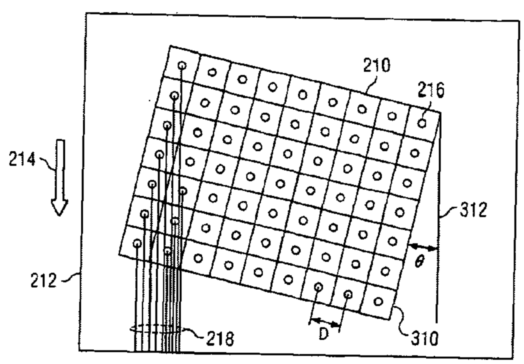
Primary Examiner—Rodney Fuller
(74) *Attorney, Agent, or Firm*—Haynes and Boone, LLP

(57) **ABSTRACT**

A method for increasing a scan rate in a photolithography system by increasing a unit travel length while maintaining a minimum resolution is provided. The method includes determining the minimum resolution and a pixel spacing distance equal to the unit travel length. The method also includes calculating a window size based on the minimum resolution and the pixel spacing distance. A plurality of windows of the calculated size are established so that a pixel in a first window is offset from a pixel in a second window by the minimum resolution in a first dimension and the pixel spacing distance in a second dimension, and one of the plurality of windows is selected for projection onto a subject.

13 Claims, 14 Drawing Sheets





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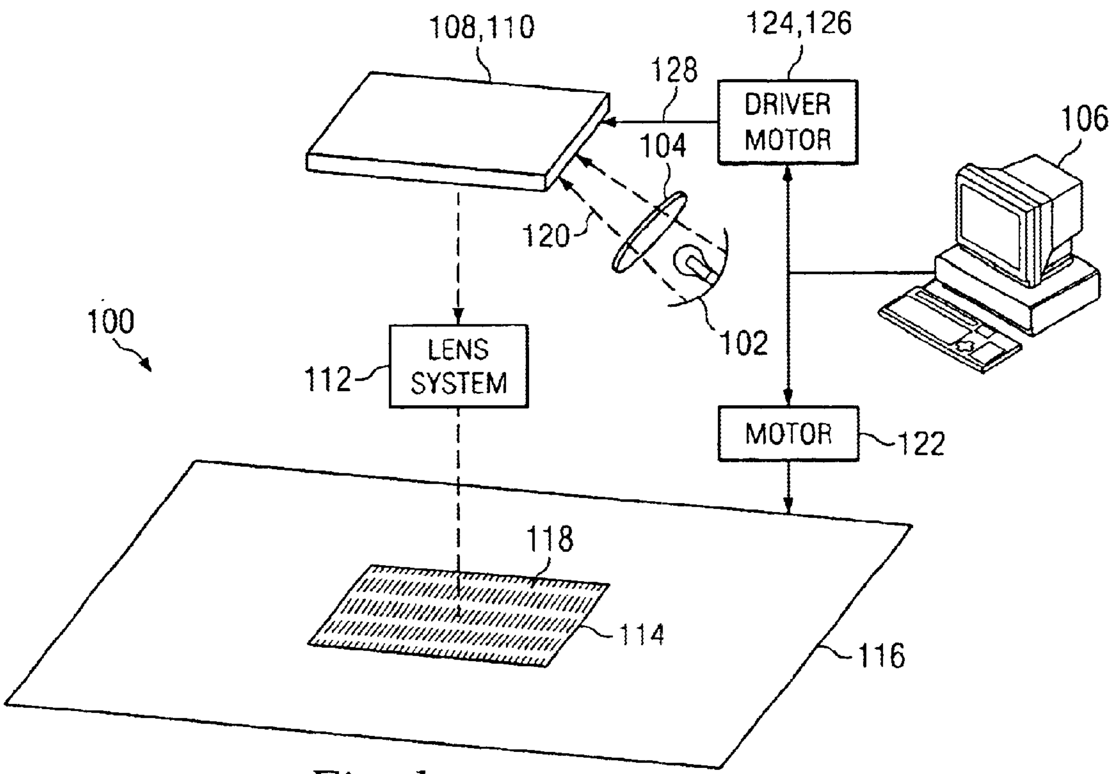

108,110
124,126
128
DRIVER
MOTOR
104
106
120
102
100
LENS
SYSTEM
112
MOTOR
122
118
114
116

Fig. 1

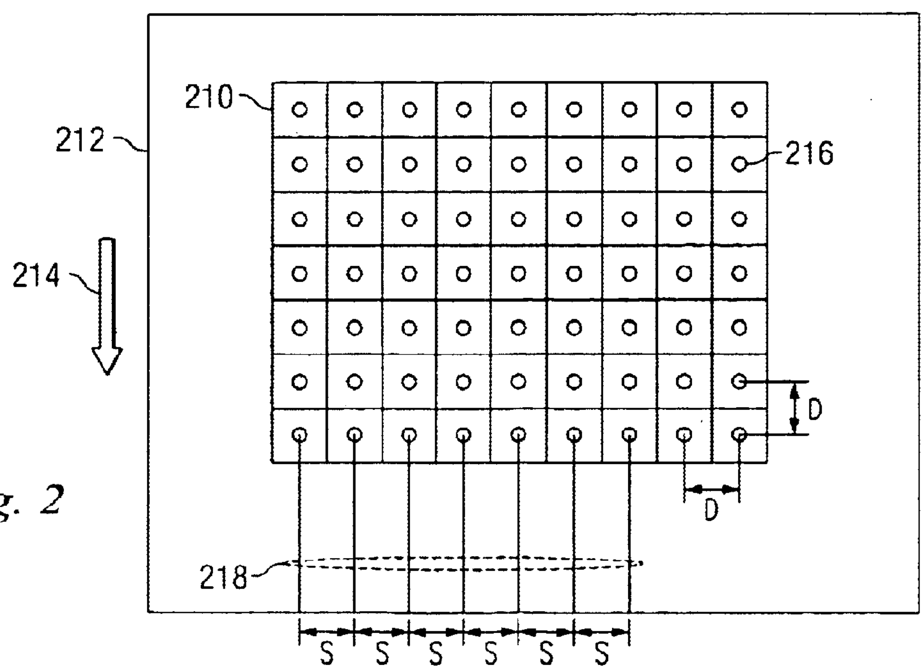

210
212
216
214
D
D
218
S S S S S S

Fig. 2

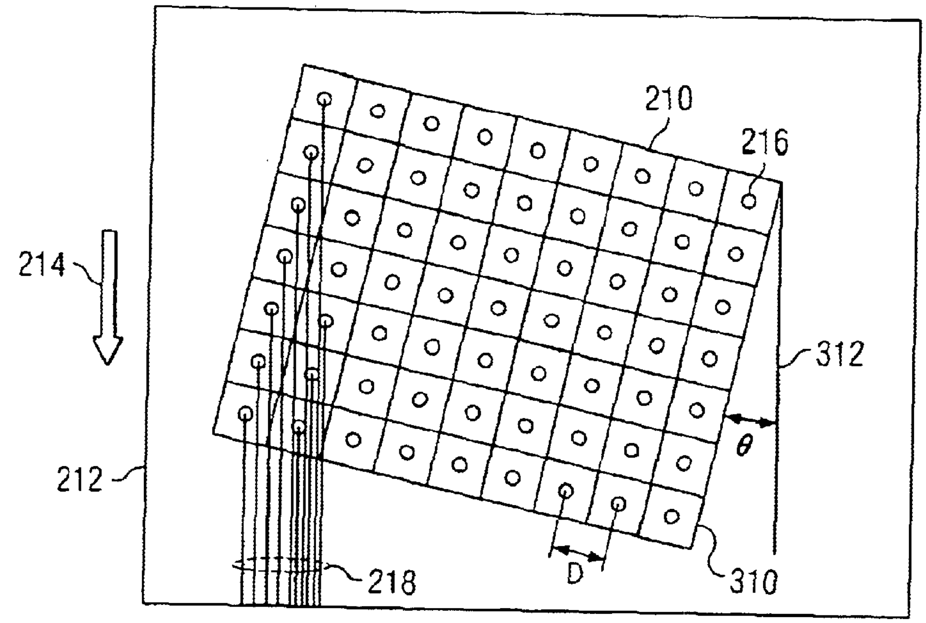

210
216
214
312
θ
212
218
D
310

Fig. 3

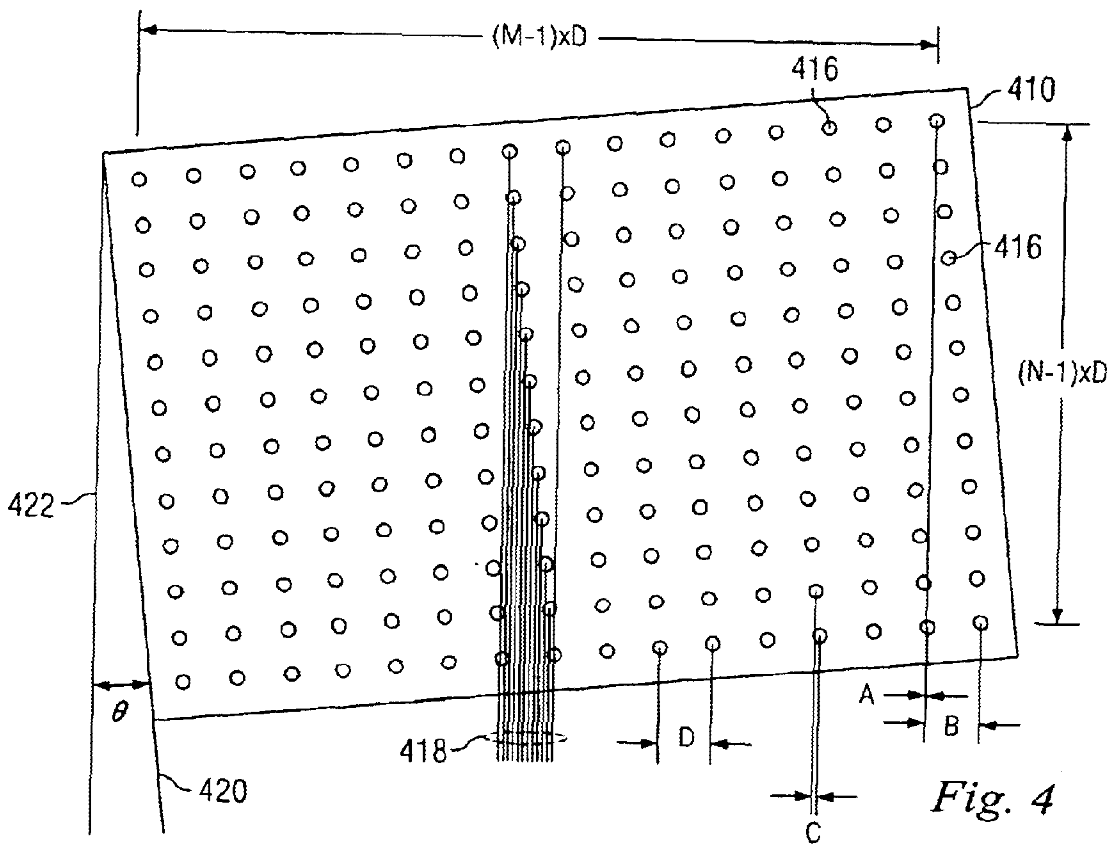

(M-1)xD
416
410
416
(N-1)xD
422
A
B
θ
418
D
420
C

Fig. 4

Fig. 5

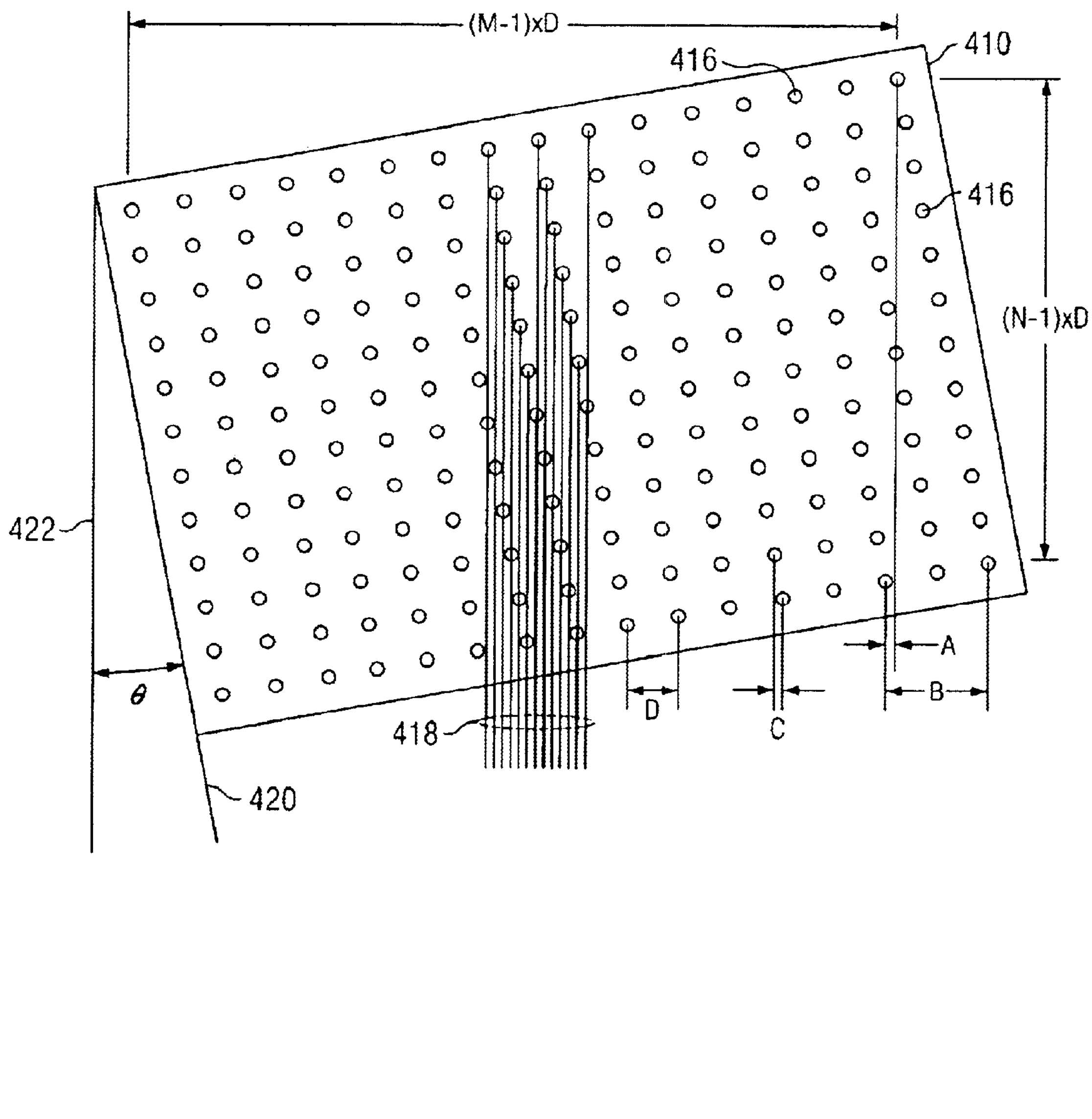
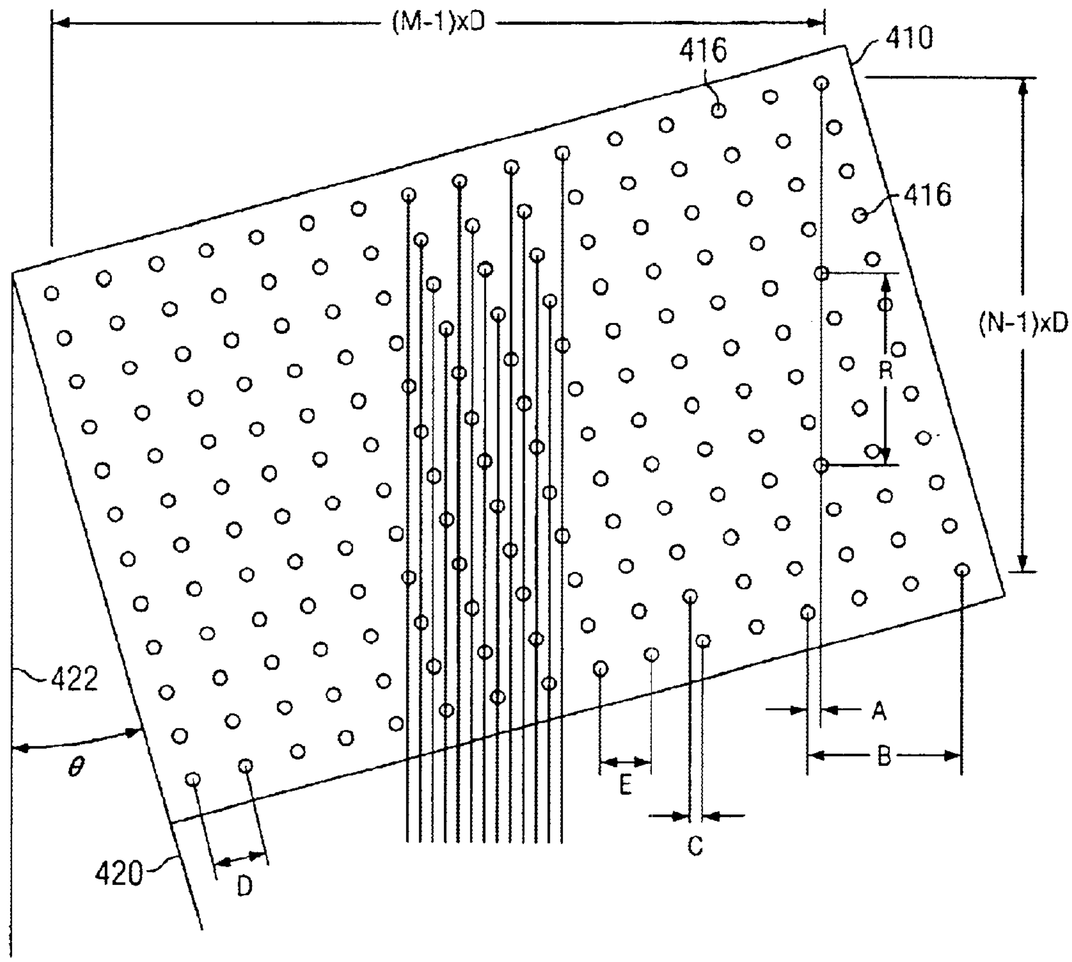


Fig. 6



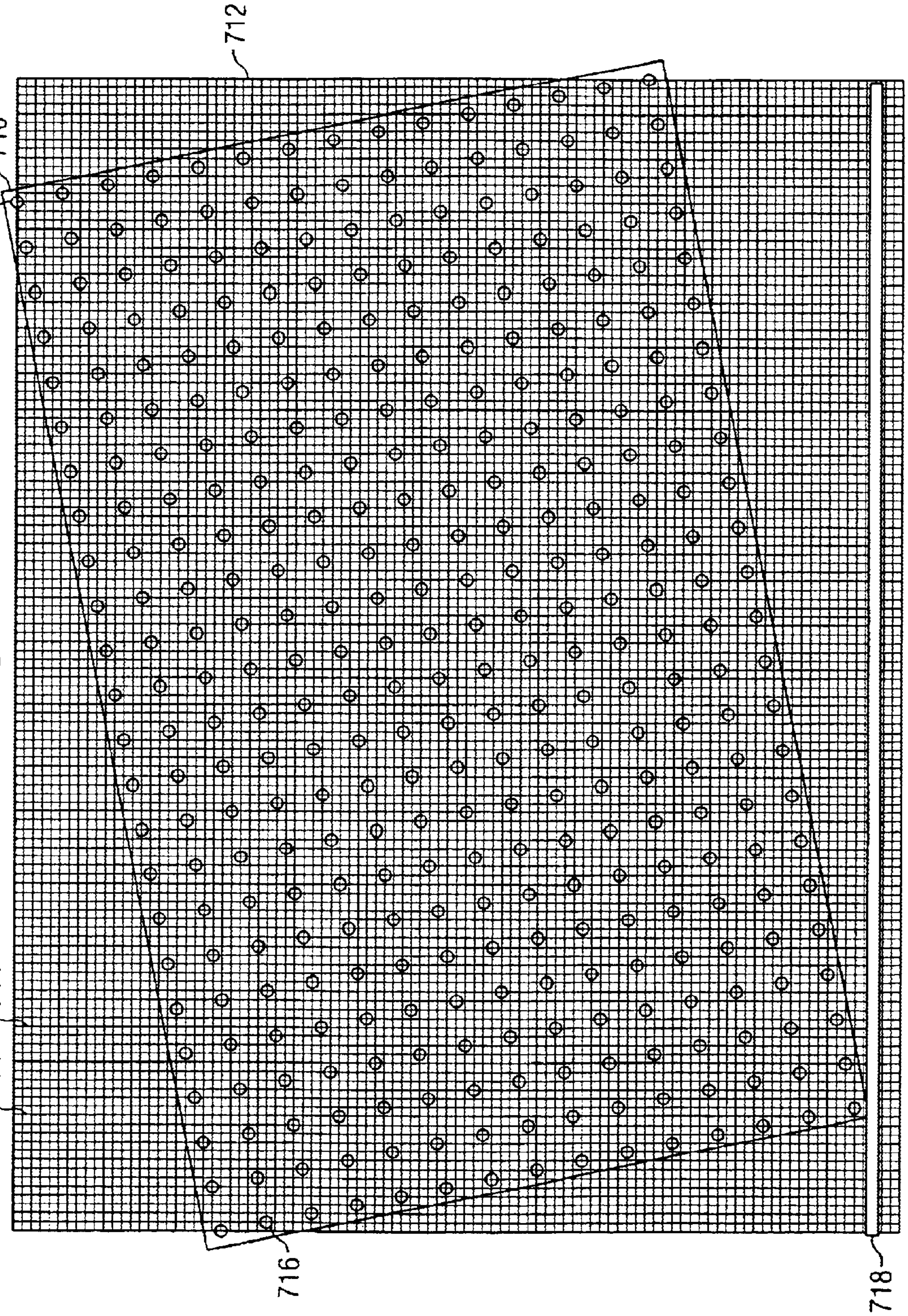


Fig. 7

Fig. 8

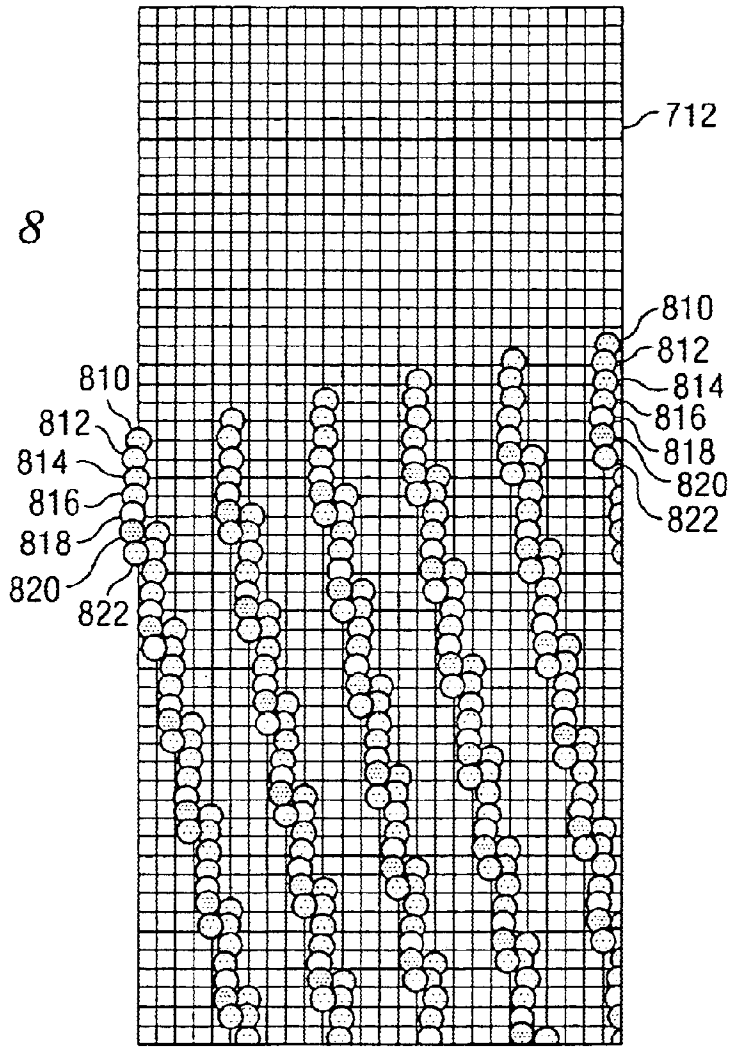
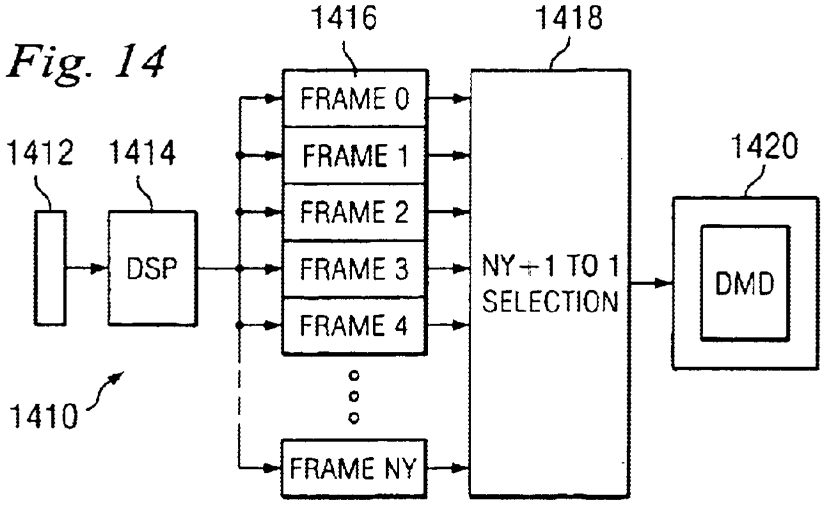

712
810
812
814
816
818
820
822
810
812
814
816
818
820
822

Fig. 14


1416
1418
1412
1414
DSP
FRAME 0
FRAME 1
FRAME 2
FRAME 3
FRAME 4
FRAME NY
NY÷1 TO 1 SELECTION
1420
DMD
1410

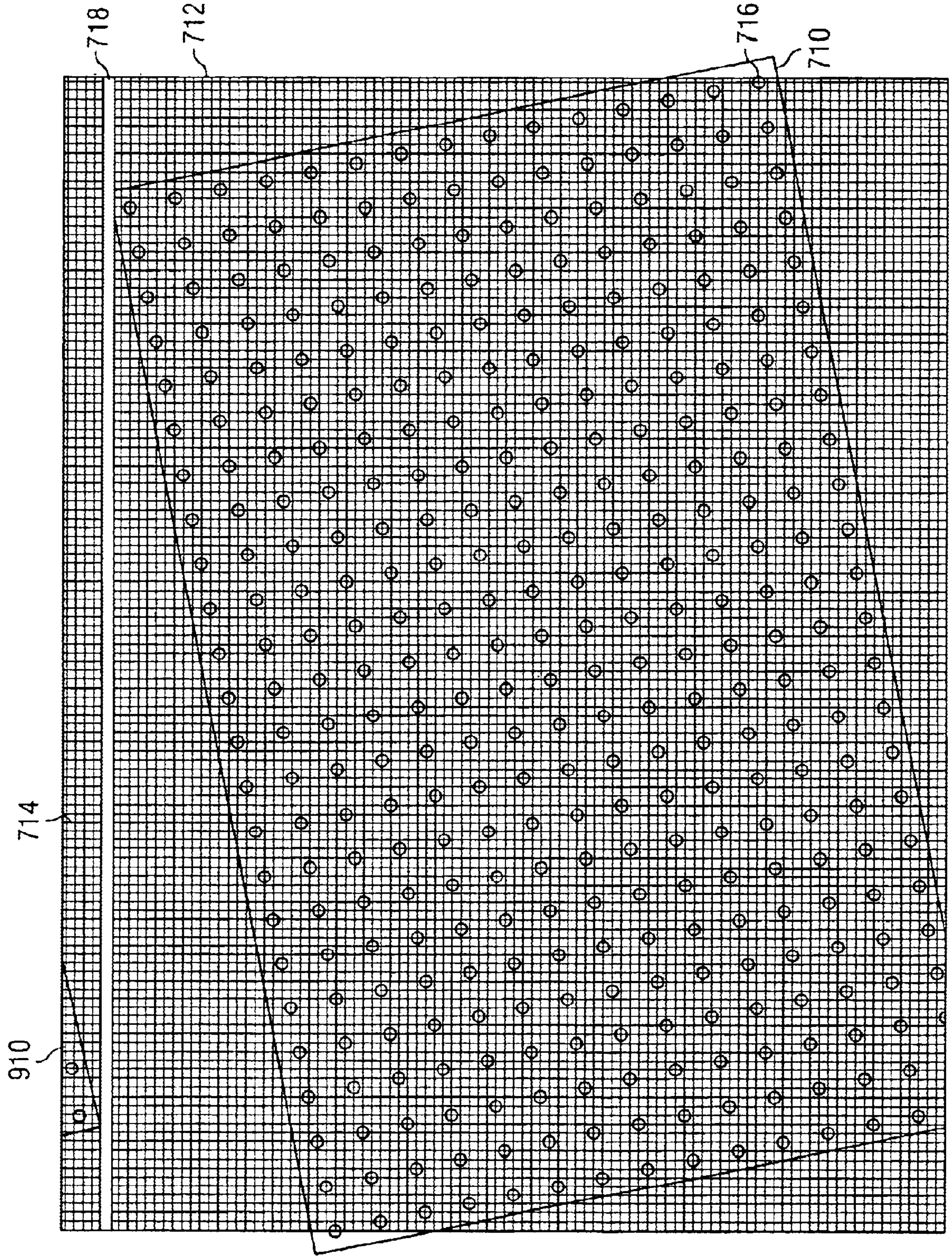


Fig. 9

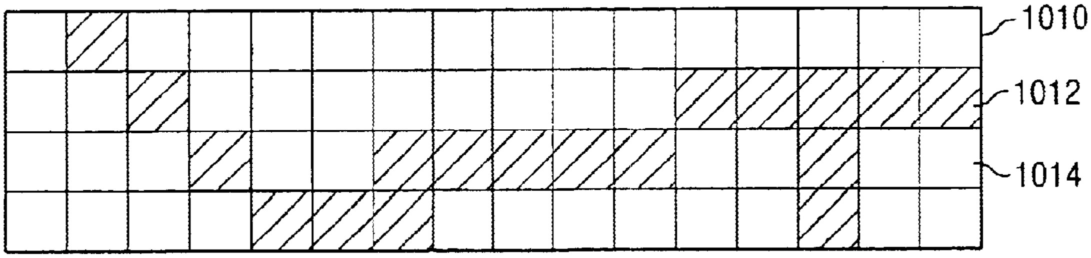


Fig. 10a

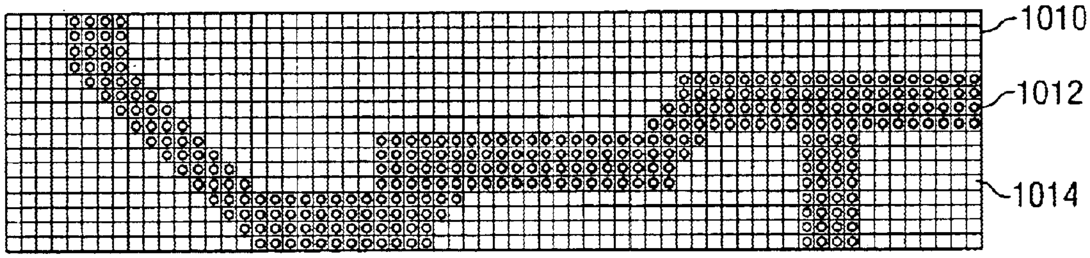


Fig. 10b

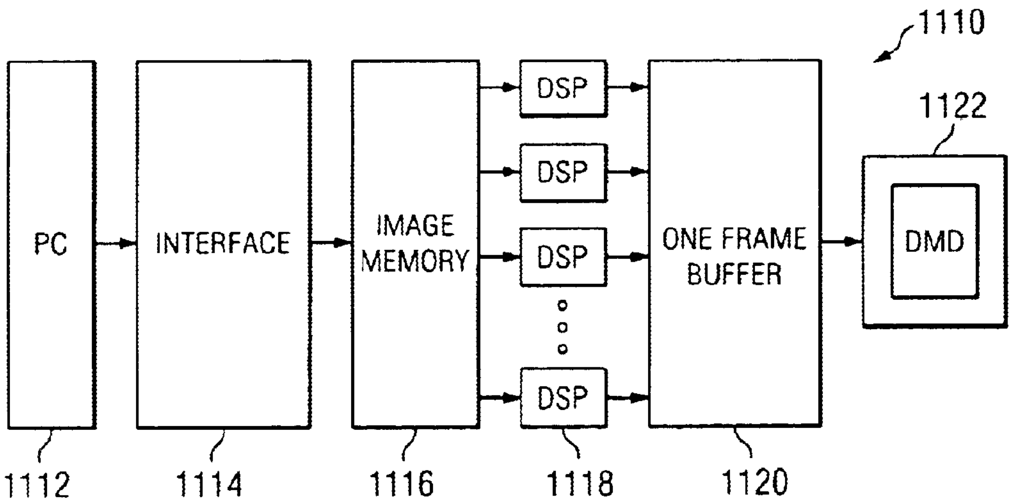
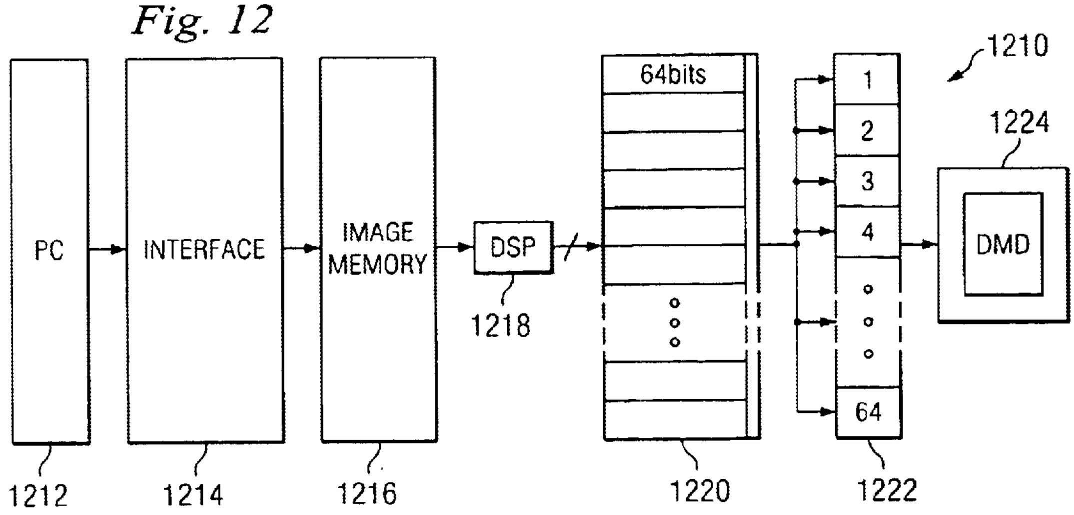


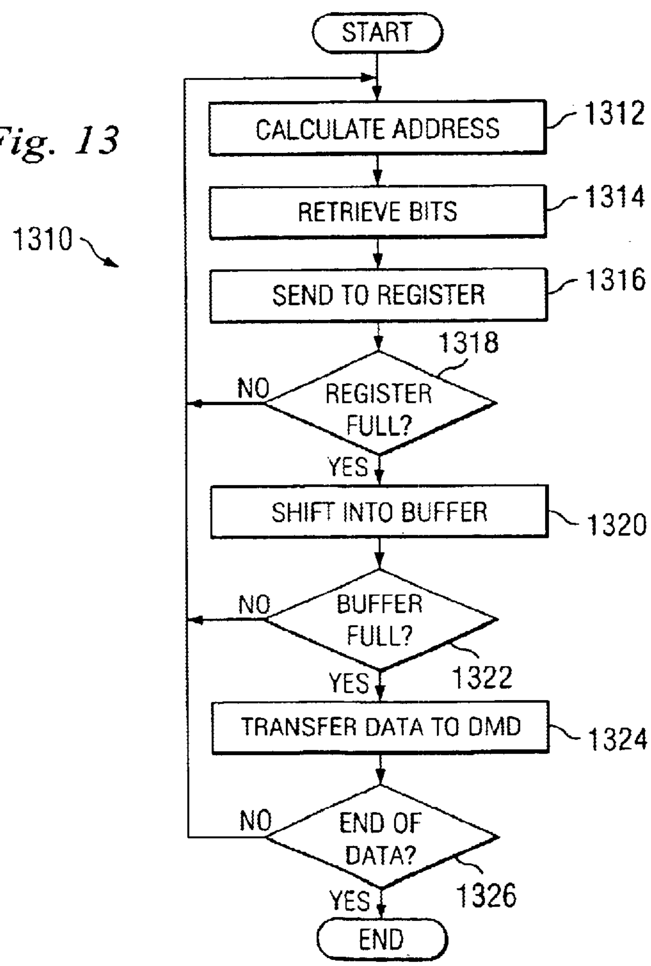
Fig. 11

Fig. 12



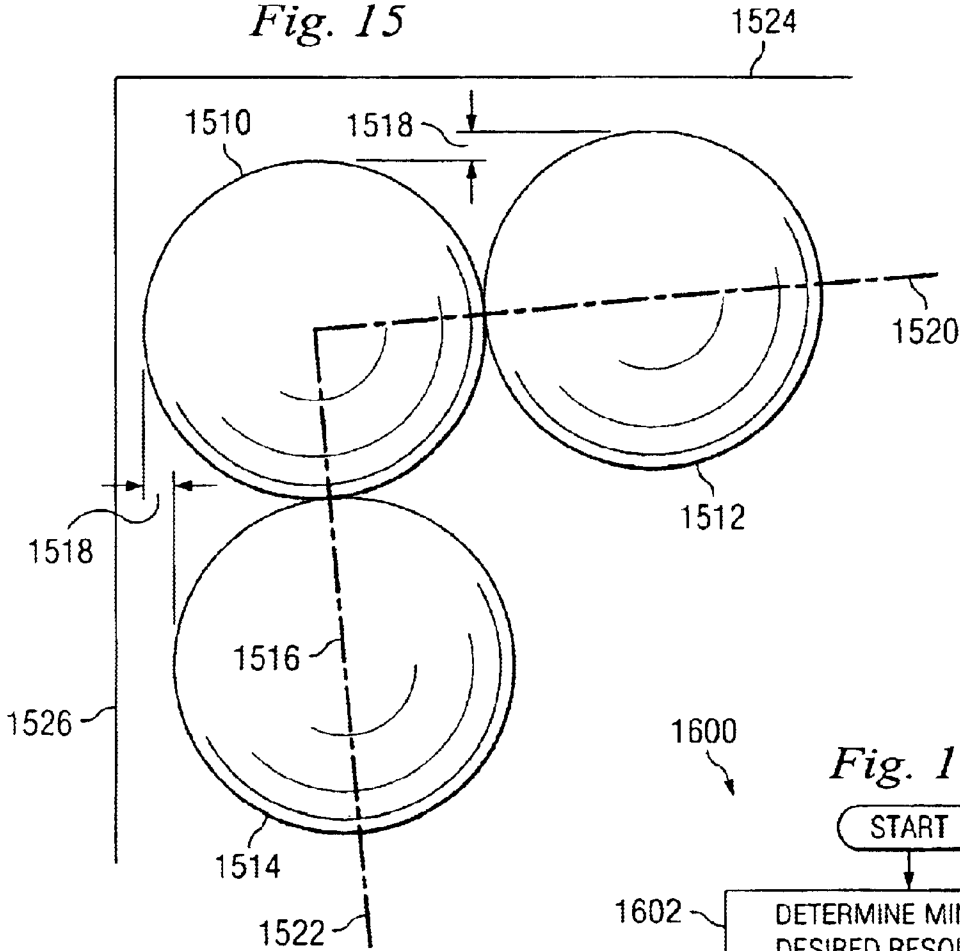
1210
PC
INTERFACE
IMAGE MEMORY
DSP
64bits
1
2
3
4
64
1224
DMD
1218
1212
1214
1216
1220
1222

Fig. 13



1310
START
CALCULATE ADDRESS
1312
RETRIEVE BITS
1314
SEND TO REGISTER
1316
1318
NO
REGISTER FULL?
YES
SHIFT INTO BUFFER
1320
NO
BUFFER FULL?
YES
1322
TRANSFER DATA TO DMD
1324
NO
END OF DATA?
YES
1326
END

Fig. 15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1510
1518
1520
1512
1518
1516
1526
1514
1522

Fig. 16

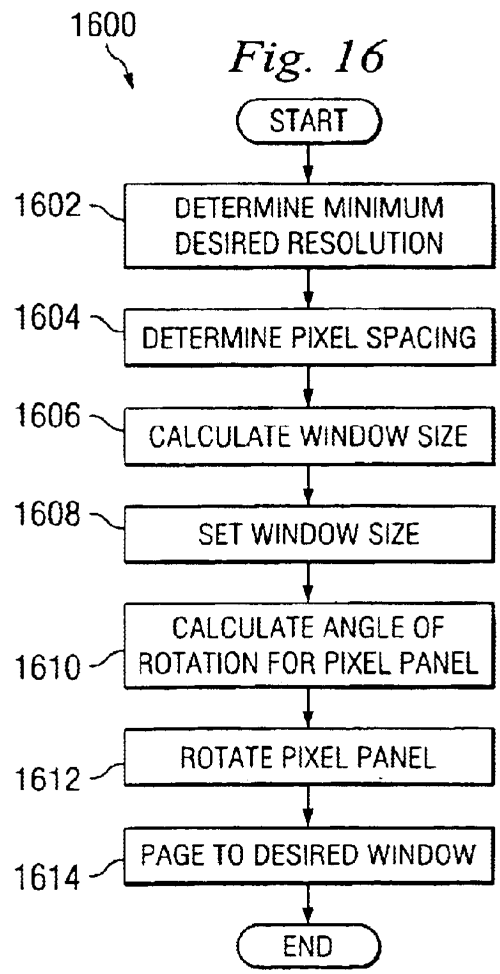
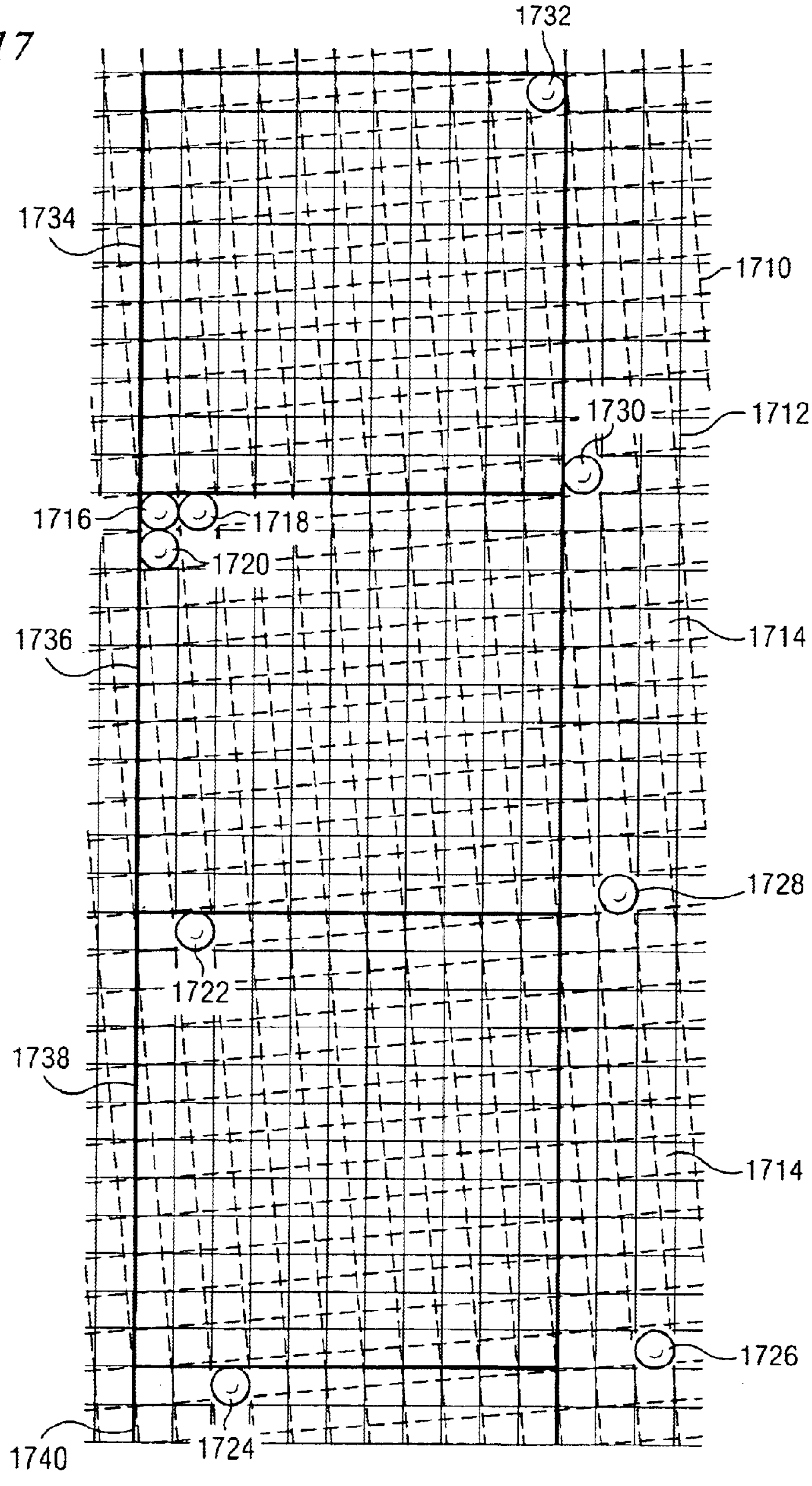

1600
START
1602
DETERMINE MINIMUM DESIRED RESOLUTION
1604
DETERMINE PIXEL SPACING
1606
CALCULATE WINDOW SIZE
1608
SET WINDOW SIZE
1610
CALCULATE ANGLE OF ROTATION FOR PIXEL PANEL
1612
ROTATE PIXEL PANEL
1614
PAGE TO DESIRED WINDOW
END

Fig. 17



1732
1734
1710
1730
1712
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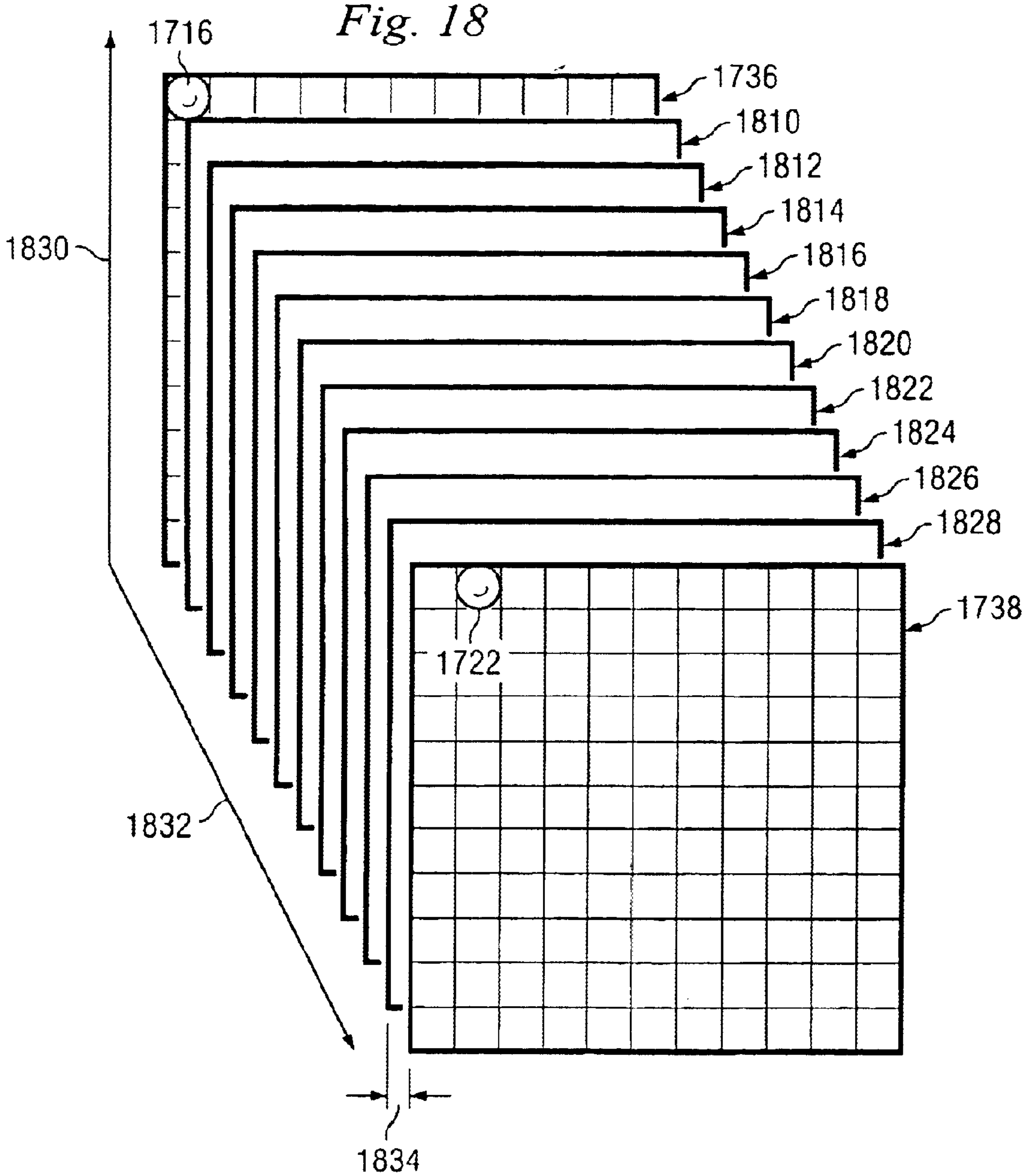
1736
1714
1728
1722
1738
1714
1726
1740
1724

Fig. 18


1716
1736
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1812
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1816
1818
1820
1822
1824
1826
1828
1830
1738
1722
1832
1834

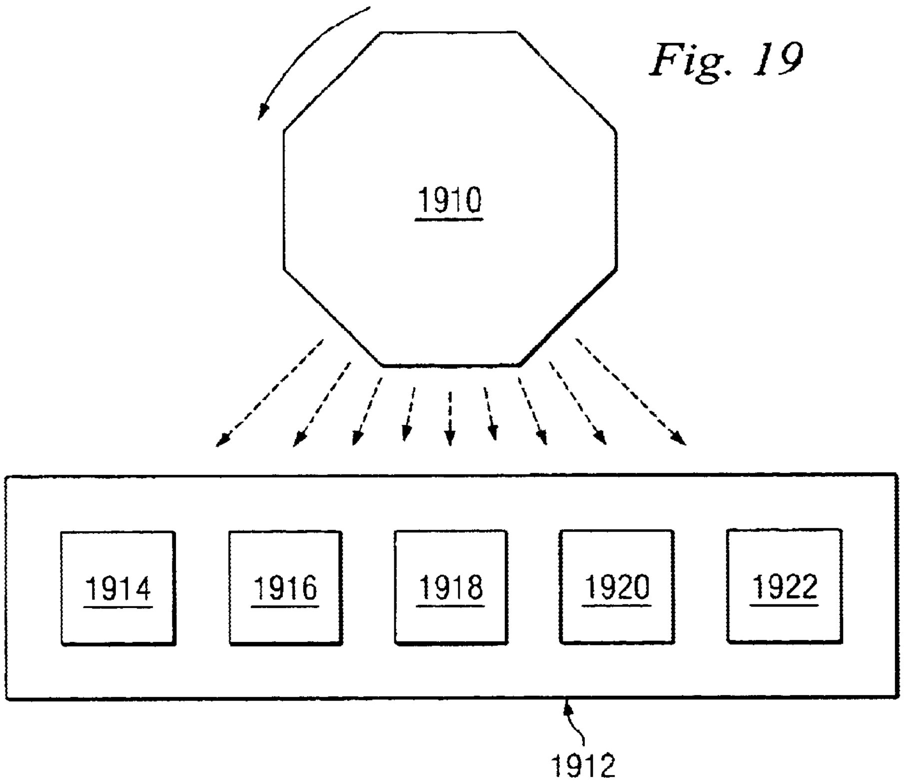

1910
1914
1916
1918
1920
1922
1912

Fig. 19

Fig. 20

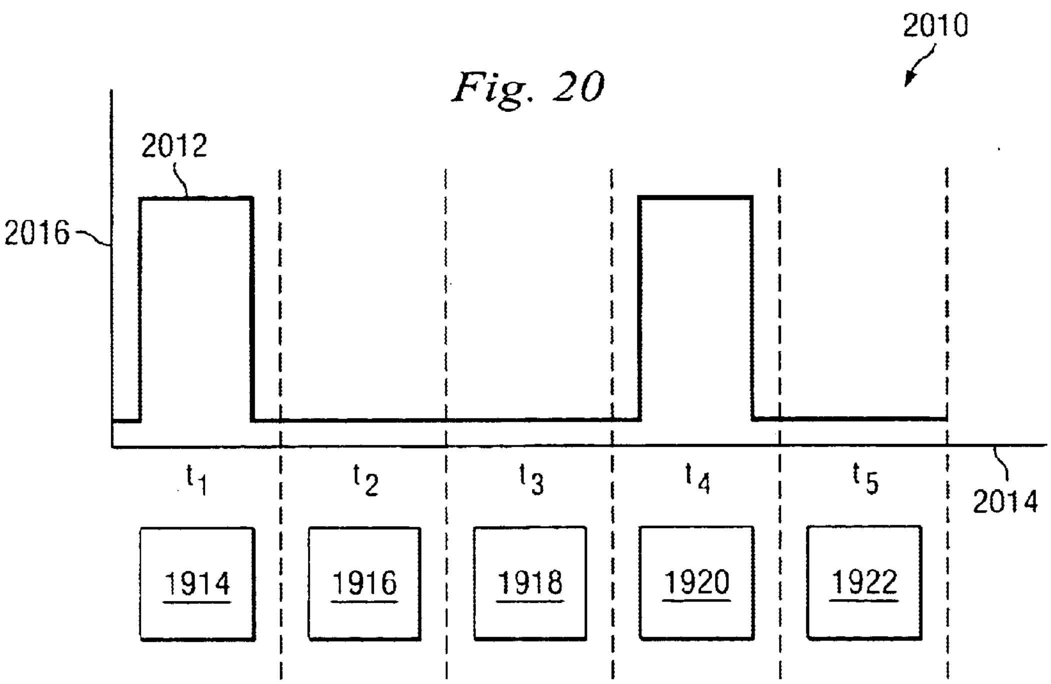

2010
2012
2016
2014
t_1
t_2
t_3
t_4
t_5
1914
1916
1918
1920
1922

Fig. 21

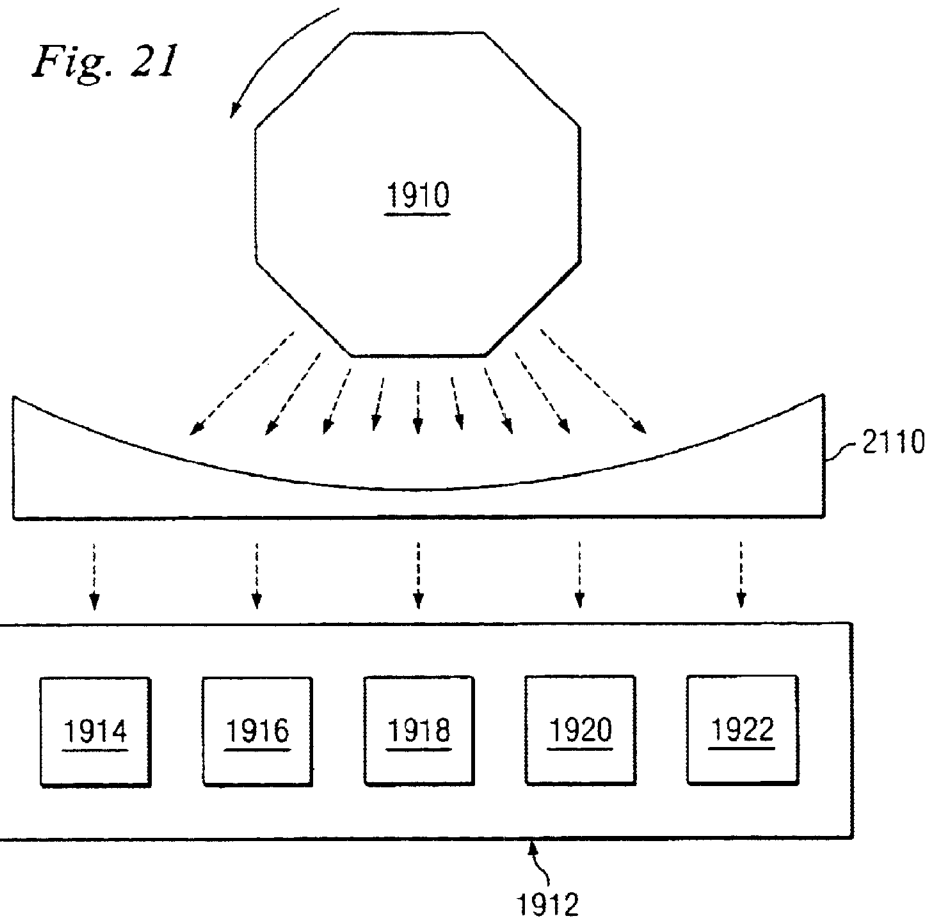
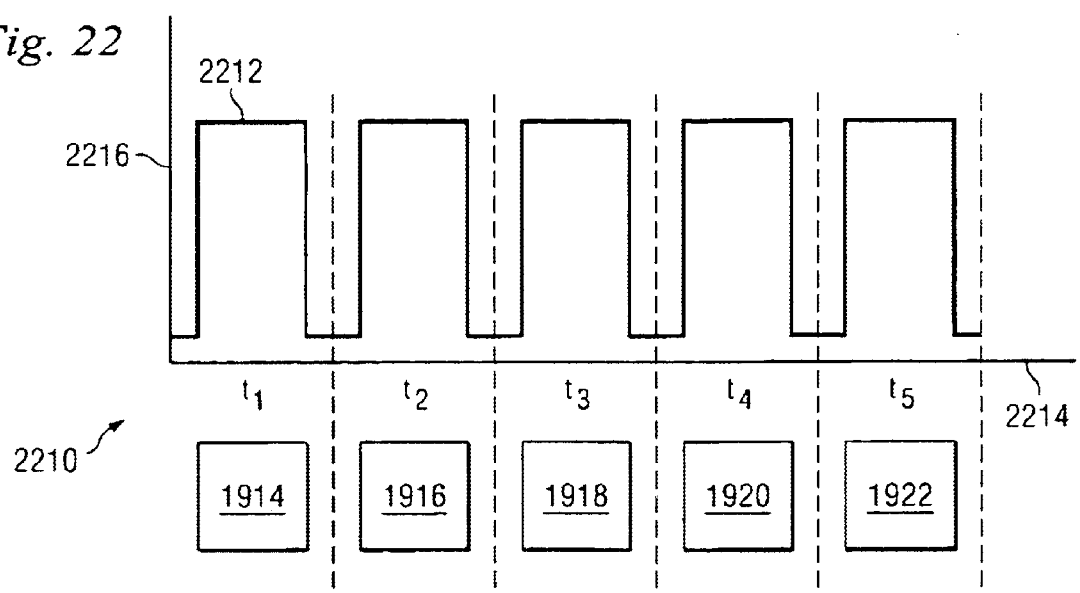

1910
2110
1914
1916
1918
1920
1922
1912

Fig. 22


2212
2216
t_1
t_2
t_3
t_4
t_5
2214
2210
1914
1916
1918
1920
1922

HIGH RESOLUTION POINT ARRAY

CROSS REFERENCE

This application claims priority to U.S. Provisional Patent Application Ser. No. 60/319,201, filed on Apr. 23, 2002.

BACKGROUND

The present invention relates generally to optical scanning systems, and more particularly, to a system and method for increasing a scan rate while maintaining a minimum resolution.

Digital scanning systems, such as those used in maskless photolithographic processing, require image data to be scanned onto a subject. The scanning may occur at a defined scan rate, which may be based on factors such as mechanical limitations and the speed with which data is processed and projected onto the subject. A system may also controllably alter the scan rate to achieve different objectives.

The amount of image data that must be processed in a digital scanning system is generally relatively large, and generally increases when higher resolutions are desired. Higher resolution may be desirable for a number of reasons. For example, a line may have a minimum width when projected at a certain resolution. This minimum width may be undesirable, for instance, because it limits the number of lines which may be projected onto the subject. Using a higher resolution may allow the line to be projected using a smaller minimum width, and so more lines may be projected onto the subject. In photolithography, the subject may be a substrate and the projected image may be a mask. Therefore, a higher resolution enables a more detailed mask to be projected onto the substrate without altering the size of the substrate.

Although sometimes desirable, higher resolutions may decrease the scan rate of a scanning system because of the amount of data that must be transferred. This is especially true if the scanning system has a fixed data rate which is operable to transfer a limited amount of data.

Therefore, certain improvements are needed in digital imaging systems. For example, it is desirable to increase the scan rate of a system while maintaining a desired minimum level of resolution. It is also desirable to maintain high light intensity, to provide high productivity, and to be more flexible and reliable.

SUMMARY

A technical advance is provided by a novel system and method for increasing a scan rate while maintaining a minimum resolution in an optical imaging system. In one embodiment, the method comprises determining a minimum resolution and a spacing distance for a first discrete element and a second discrete element. A window size is calculated based on the minimum resolution and the spacing distance and the window size is set equal to the calculated size. An angle of rotation is calculated for the projection device relative to a subject based on the window size, where angle of rotation operable to offset the first discrete element from the second discrete element by the minimum resolution.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic view of an improved digital photolithography system for implementing various embodiments of the present invention.

FIG. **2** illustrates an exemplary point array aligned with a subject.

FIG. **3** illustrates the point array of FIG. **2** after being rotated relative to the subject.

FIG. **4** illustrates a point array rotated so that only one point falls on a single vertical line.

FIG. **5** illustrates the point array of FIG. **4** rotated so that two points fall on a single vertical line.

FIG. **6** illustrates the point array of FIG. **5** rotated so that three points fall on a single vertical line.

FIG. **7** illustrates a point array overlaid on an exemplary memory grid.

FIG. **8** is an exploded view of a portion of the point array of FIG. **7** illustrating individual points in a series of frames.

FIG. **9** illustrates the point array of FIG. **7**, with a portion of a second point array overlay visible.

FIG. **10** is an example of an image portion projected at two different resolutions.

FIG. **11** is a diagrammatic view of one embodiment of an exemplary system for converting image data for display on a rotated pixel panel.

FIG. **12** is a diagrammatic view of another embodiment of an exemplary system for converting image data for display on a rotated pixel panel.

FIG. **13** is a flow chart illustrating a process for retrieving image data from memory and projecting it on a rotated pixel panel.

FIG. **14** is a diagrammatic view of yet another embodiment of an exemplary system for converting image data for display on a rotated pixel panel.

FIG. **15** illustrates three pixels that have been rotated relative to a subject to create an offset.

FIG. **16** is a flow chart illustrating a process for creating windows using the rotation illustrated in FIG. **15** and selecting one of the windows for projection onto the subject.

FIG. **17** illustrates a plurality of windows overlaid on a point array and memory grid.

FIG. **18** illustrates some of the windows of FIG. **17** viewed from a different perspective.

FIG. **19** illustrates an illumination device directing light towards a plurality of exposure areas on a subject.

FIG. **20** is a graph illustrating levels of light intensity received by the exposure areas in FIG. **19** over a period of time.

FIG. **21** illustrates the illumination device and exposure areas of FIG. **19** with the addition of a lens.

FIG. **22** is a graph illustrating levels of light intensity received by the exposure areas in FIG. **21** over a period of time.

DETAILED DESCRIPTION

The present invention relates generally to optical scanning systems, and more particularly, to a system and method for increasing a scan rate while maintaining a minimum resolution. It is understood, however, that the following disclosure provides many different embodiments, or examples, for implementing different features of the invention. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to limit the invention from that described in the claims. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

Referring now to FIG. **1**, a maskless photolithography system **100** is one example of a system that can benefit from the present invention. In the present example, the maskless photolithography system **100** includes a light source **102**, a first lens system **104**, a computer aided pattern design system **106**, a pixel panel **108**, a panel alignment stage **110**, a second lens system **112**, a subject **114**, and a subject stage **116**. A resist layer or coating **118** may be disposed on the subject **114**. The light source **102** may be an incoherent light source (e.g., a Mercury lamp) that provides a collimated beam of light **120** which is projected through the first lens system **104** and onto the pixel panel **108**.

The pixel panel **108**, which may be a digital mirror device (DMD), is provided with digital data via suitable signal line(s) **128** from the computer aided pattern design system **106** to create a desired pixel pattern (the pixel-mask pattern). The pixel-mask pattern may be available and resident at the pixel panel **108** for a desired, specific duration. Light emanating from (or through) the pixel-mask pattern of the pixel panel **108** then passes through the second lens system **112** and onto the subject **114**. In this manner, the pixel-mask pattern is projected onto the resist coating **118** of the subject **114**.

The computer aided mask design system **106** can be used for the creation of the digital data for the pixel-mask pattern. The computer aided pattern design system **106** may include computer aided design (CAD) software similar to that which is currently used for the creation of mask data for use in the manufacture of a conventional printed mask. Any modifications and/or changes required in the pixel-mask pattern can be made using the computer aided pattern design system **106**. Therefore, any given pixel-mask pattern can be changed, as needed, almost instantly with the use of an appropriate instruction from the computer aided pattern design system **106**. The computer aided mask design system **106** can also be used for adjusting a scale of the image or for correcting image distortion.

In some embodiments, the computer aided mask design system **106** is connected to a first motor **122** for moving the stage **116**, and a driver **124** for providing digital data to the pixel panel **108**. In some embodiments, an additional motor **126** may be included for moving the pixel panel. The system **106** can thereby control the data provided to the pixel panel **108** in conjunction with the relative movement between the pixel panel **108** and the subject **114**.

Efficient data transfer may be one aspect of the system **106**. Data transfer techniques, such as those described in U.S. provisional patent application Ser. No. 60/278,276, filed on Mar. 22, 2001, and also assigned to Ball Semiconductor, Inc., entitled "SYSTEM AND METHOD FOR LOSSLESS DATA TRANSMISSION" and hereby incorporated by reference as if reproduced in its entirety, may be utilized to increase the throughput of data while maintaining reliability. Some data, such as high resolution images, may present a challenge due in part to the amount of information needing to be transferred.

Referring now to FIG. **2**, a pixel panel **210** comprising a DMD, which may be present in a system such as that described above with reference to FIG. **1**, is illustrated. The pixel panel **210**, which is shown as a point array for purposes of clarification, projects an image (not shown) upon a substrate **212**. The substrate is moving in a direction indicated by an arrow **214**. Alternatively, the point array **210** could be in motion while the substrate **212** is stationary, or both the substrate **212** and the point array **210** could be moving simultaneously. The point array **210** is aligned with both the substrate **212** and the direction of movement **214** as shown. A distance, denoted for purposes of illustration as "D", separates individual points **216** of the point array **210**. In the present illustration, the point distribution that is projected onto the subject **212** is uniform, which means that each point **216** is separated from each adjacent point **216** both vertically and horizontally by the distance D.

As the substrate **212** moves in the direction **214**, a series of scan lines **218** indicate where the points **216** may be projected onto the substrate **212**. The scan lines are separated by a distance "S". Because of the alignment of the point array **210** with the substrate **212** and the scanning direction **214**, the distance S between the scan lines **218** equals the distance D between the points **216**. In addition, both S and D remain relatively constant during the scanning process. Achieving a higher resolution using this alignment typically requires that the point array **210** embodying the DMD be constructed so that the points **216** are closer together. Therefore, the construction of the point array **210** and its alignment in relation to the substrate **212** limits the resolution which may be achieved.

Referring now to FIG. **3**, a higher resolution may be achieved with the point array **210** of FIG. **2** by rotating the DMD embodying the point array **210** in relation to the substrate **212**. As illustrated in FIG. **3**, although the distance D between the points **216** remains constant, such a rotation may reduce the distance S between the scan lines **218**, which effectively increases the resolution of the point array **210**. The image data that is to be projected by the point array **210** may be manipulated so as to account for the rotation of the point array **210**. The manipulation can include an angle θ between an axis **310** of the rotated point array **210** and a corresponding axis **312** of the substrate.

The magnitude of the angle θ may be altered to vary the distance S between the scan lines **218**. If the angle θ is relatively small, the resolution increase may be minimal as the points **216** will remain in an alignment approximately equal to the alignment illustrated in FIG. **2**. As the angle θ increases, the alignment of the points **216** relative to the substrate **212** will increasingly resemble that illustrated in FIG. **3**. If the angle θ is increased to certain magnitudes, various points **216** will be aligned in a redundant manner and so fall onto the same scan line **218**. Therefore, manipulation of the angle θ permits manipulation of the distance S between the scan lines **218**, which affects the resolution of the point array **210**. It is noted that the distance S may not be the same between different pairs of scan lines as the angle θ is altered.

Referring now to FIG. **4**, a pixel panel **410** (again shown as a point array) comprising M columns by N rows is illustrated. In the present example, M=16 and N=12. The point array **410** may represent an image, such as an image used in a maskless photolithography system. Each column and row includes a plurality of individual points **416**. For purposes of illustration, each point **416** will be referenced by its column/row position in the point array **410** when it is important to identify a particular point. For example, the point **416** located in the second column, fourth row, will be referred to as point **(2,4)**. Each point **416** is separated by a distance "D" from the corresponding point in the adjacent columns and rows. For example, the point **(10,11)** is a distance D from point **(9,11)**, point **(11,11)**, point **(10,10)**, and point **(10,12)**. Therefore, the total distance between the first and last points **416** in each row is equal to $(M-1)*D$, while the total distance between the first and last points **416** in each column is $(N-1)*D$.

An angle θ represents the angle between an axis **420** of the point array **410** and a corresponding axis **422** of a subject

412 (not shown). A series of scan lines **418** indicate where the points **416** may be projected onto the subject **412**. Depending on the angle θ, the scan lines **418** may be separated by a constant distance or by varying distances, as described below. When no redundancy occurs (i.e., no two points **416** from the array **410** may fall on the same scan line **418**), a variable "K" is equal to one, signifying a one to one correspondence between a point **416** and a scan line **418**. A series of relationships may be developed using the values M, N, K, D and θ. The relationships enable various aspects of the rotation of the array **410** to be calculated in order to achieve a desired result.

A distance "B", which designates the distance between the scan lines **418** of two adjacent points **416** in a row when the array **410** is rotated to angle θ, may be calculated by setting B equal to D*cos(θ). A distance "C" represents the distance between the scan lines **418** of two adjacent points **416** in a column when the array **410** is rotated to angle θ, and may be calculated by setting C equal to D*sin(θ). A distance "A" represents the distance between the scan lines **418** of the point **416** in the bottom row of a column and the point **416** in the top row of the next column when the array **410** is rotated to angle θ. For example, the scan lines associated with the point **(15,12)** and the point **(16,1)** are separated by the distance A, which may be calculated as B−(N−1)*D*sin (θ).

In the present example, the points **416** are uniformly distributed (i.e., the same distance separates each point **416** from the adjacent points **416** when projected onto the subject). When this uniformity occurs, A=C=D*sin(θ) and tan(θ)=K/N.

Using one or more of these relationships, the angle θ can be calculated to achieve a desired distance between the scan lines **418**. For example, when N=600 and K=1, then $\theta=\tan^{-1}(1/600)\approx 0.0955$ degrees. Therefore, rotating the point array **410** by 0.0955 degrees will enable the array **410** to be projected with the desired characteristics of A, B, C and D.

It should be noted that choosing a uniform distribution of points **416** may simplify the calculation of θ and its effect on the resolution provided by the spacing of the scan lines **418**. This may be accomplished by selecting a desired resolution so that A=C=D*sin(θ).

Referring now to FIG. **5**, the point array **410** of FIG. **4** is illustrated with a larger angle θ. In contrast to FIG. **4**, the present figure depicts an example where K=2. This means that there is redundancy such that two points **416** from the array **410** fall on the same scan line **418** (i.e., there is a two to one correspondence between two points **416** and a scan line **418**). For example, the point **(8,1)** and the point **(7,7)** are associated with the same scan line **418**. Such redundancy may be desirable if, among other reasons, the DMD includes a faulty mirror. If the mirror associated with one of the points on a scan line fails, a redundant mirror may be utilized to ensure the point is properly projected.

The distance "D" separates each point **416** from the adjacent points **416**. The total distance between the first and last points **416** in each row is equal to (M−1)*D, while the total distance between the first and last points **416** in each column is (N−1)*D. Using M, N, K, D and θ, a series of relationships may be developed for K=2. As in FIG. **4**, the relationships may enable various aspects of the rotation of the array **410** to be calculated in order to achieve a desired result.

The distance "B" designates the distance between the scan lines **418** of two points in a row separated by another point **416** when the array **410** is rotated to angle θ. For example, the point **(14,12)** is separated from the point **(16,12)** by the distance b, which may be calculated as B=K*D*cos(θ). The distance "C" may be calculated as C=D*sin(θ). The distance "A" may be calculated as A=B−(N−1)*D*sin(θ).

When the points **416** are uniformly distributed (i.e., the same distance separates each point **416** from the adjacent points **416** when projected onto the subject), then A=C=D*sin(θ) and tan(θ)=K/N.

Using one or more of these relationships, the angle θ can be calculated to achieve a desired distance between the scan lines **418**. For example, when N (the number of rows) is equal to 600 and K=2, then $\theta=\tan^{-1}(2/600)\approx 0.19098$ degrees.

Referring now to FIG. **6**, the point array **410** of FIG. **5** is illustrated with a larger angle θ. In contrast to FIG. **5**, the present figure depicts an example where K=3. This means that there is redundancy such that three points **416** from the array **410** fall on the same scan line **418** (i.e., there is a three to one correspondence between three points **416** and a scan line **418**). For example, the points **(8,1)**, **(7,5)**, and **(6,9)** are associated with the same scan line **418**.

The distance "D" separates each point **416** from the adjacent points **416**. As in FIG. **5**, the total distance between the first and last points **416** in each row is equal to (M−1)*D, while the total distance between the first and last points **416** in each column is (N−1)*D. Using M, N, K, D and θ, a series of relationships may be developed for K=3. As in FIG. **5**, the relationships enable various aspects of the rotation of the array **410** to be calculated in order to achieve a desired result.

The distance "B" designates the distance between the scan lines **418** of two points in a row separated by two other points **416** when the array **410** is rotated to angle θ. For example, the point **(13,12)** is separated from the point **(16,12)** by the distance B, which may be calculated as B=K*D*cos(θ). The distance "C" may be calculated as C=D*sin(θ). The distance "A" may be calculated as A=B−(N−1)*D*sin(θ). A distance "R" represents the distance between redundant points **416** on a scan line **418**. For example, the point **(15,5)** is separated from the point **(14,9)** by the distance R. A distance "E" designates the distance between the scan lines **418** of two adjacent points in a row when the array **410** is rotated to angle θ, and may be calculated as E=C*N/K.

When the points **416** are uniformly distributed (i.e., the same distance separates each point **416** from the adjacent points **416** when projected onto the subject), then A=C=D*sin(θ), N/K is an integer, and tan(θ)=K/N.

Additional relationships may be developed using the above described equations.

$$\cos(\theta)^2=N^2/(N^2+K^2)$$

$$\sin(\theta)^2=k^2/(N^2+K^2)$$

$$R/C=1+(N/K)^2$$

$$R=C*(1+(N/K)^2)$$

Using one or more of these relationships, the angle θ can be calculated to achieve a desired distance between the scan lines **418**. For example, when N (the number of rows) is equal to 600 and K=3, then $\theta=\tan^{-1}(3/600)\approx 0.286$ degrees.

Angles for different relationships may be calculated by applying the above described equations. For example, if N=600 and K=20, then N/K=30, which is an integer. Therefore, there is a uniform distribution of points on the substrate surface and the angle θ may be calculated from tan(θ)=K/N. In this instance, θ≈1.91 degrees.

Referring now to FIG. **7**, in one embodiment, a point array **710** (such as is embodied by a rotated DMD) is illustrated as an overlay on a memory **712** (shown as an exemplary memory grid). The point array **710** comprises M columns and N rows, where M=24 and N=15. For purposes of illustration, the memory **712** comprises an S column by T row grid **718** of memory locations **714**. The memory **712** may be contiguous (as illustrated) or non-contiguous.

The memory **712** includes an image (not shown) such as may be used for a photolithographic mask. Therefore, portions of the image are located at appropriate S,T locations **714** in the memory **712**. Individual points **716** of the array **710** are illustrated overlaying memory locations **714** so as to reflect the rotation of the array **710** (i.e., located in such a way that each point **716** can be identified by a set of S,T coordinates). The rotation of the array **710** is such that K=3, which means that three points **714** from the array **710** are in the same memory column S.

The size of the memory grid **712** is 130×94, which may be calculated as follows:

$$S=N+(M-1)*N/K=15+(24-1)*15/3=130$$

$$T=M+(N-1)*N/K=24+(15-1)*15/3=94.$$

Image data for the point array **710** may be retrieved memory row T by memory row T from the memory **712** and projected onto a subject (not shown). It is noted that a memory row T may not be equivalent to a point array row N, as the point array **710** has been rotated. As each memory row T is retrieved, a pointer **718** representing a starting address for the retrieved memory row T is updated to the address for the next memory row T to be retrieved. It is apparent that alternate retrieval strategies may be implemented to achieve the same result. For example, it may be preferable to retrieve multiple rows simultaneously, or it may be advantageous to retrieve the point array from memory on a column by column basis.

The point array **710** with its respective points **716**, as illustrated in FIG. **7**, may be viewed as a single "frame" in a scanning process. Each point **716** would then represent a corresponding pixel in the image stored in the underlying memory location **714**. Therefore, each memory location **714** would appear in its respective position when the frame is projected onto a subject. This process is described in further detail with respect to FIG. **8**.

Referring now to FIG. **8**, an exploded view of a portion of the point array **710** overlay of FIG. **7** is now illustrated. The view illustrates an exemplary frame sequence for the point array **710**. The points **716** of point array **710** are illustrated as a series of frames **810–822**. Although the exploded view does not show each point **716**, the frames **810–822** each include a set of 24×15 points **716** having a similar shading. Therefore, FIG. **8** illustrates seven frames **810–822**. Each frame **810–822** includes the points **716**, but the location of the points relative to the underlying image is altered as the point array **710** is scanned. For example, the frame **810** includes the topmost set of points in each group of seven, while the frame **812** includes the second set of points, and so on.

Referring now to FIG. **9**, a final row of memory overlaid by the array **710** of FIG. **7** is illustrated as the current address of the pointer **718**. A portion of memory for a second array **910** is visible and will be retrieved next starting with the bottom row. It is noted that a single point array may utilize a large amount of memory, and multiple arrays utilize increasingly large amounts of memory. In addition, a high rate of retrieval may be maintained for optimal projection results.

Referring now to FIGS. **10***a–b*, an example of a benefit afforded by the higher resolution provided by the present invention is illustrated. Referring now specifically to FIG. **10***a*, a pixel panel (not shown) is operable to project a point array **1010** at a resolution of 3.4 micrometers (μm). The point array includes "full" pixels **1012** which may represent pixels for circuit components and "empty" pixels **1014** which represent empty space in which no circuit component is present. This may be accomplished with a frame rate of approximately 5000 frames per second (5 Kfps) at a data rate of approximately 450 KB per pixel panel. As previously described, the resolution of the projected image is typically limited by the resolution of the pixel panel.

Referring now specifically to FIG. **10***b*, rotating the pixel panel such that K=30 enables the same portion of the point array **1010** to be projected at a higher resolution of 0.85 μm. Therefore, in the present example, rotating the point array **1010** provides a level of resolution that is four times greater than the native resolution of the pixel panel. This means that each pixel **1012**, **1014** of FIG. **10***a* is now represented by sixteen pixels in FIG. **10***b*. This may allow edges to be smoothed and similar desirable refinements to be made to the circuit.

Referring now to FIG. **11**, one embodiment of a system **1110** for real time data extraction and manipulation is illustrated. The system **1110** may be incorporated in another system, such as the system **100** of FIG. **1**, or it may be a stand alone system. In the present embodiment, the system **1110** includes a personal computer (PC) **1112**, an interface **1114**, an image memory **1116**, a plurality of digital signal processing (DSP) devices **1118**, a frame buffer **1120**, and a DMD **1122**. The PC, utilizing the interface **1114**, may interact with and/or control aspects of the system **1110**.

For purposes of illustration, the system **1110** utilizes point arrays **1124** (not shown) of M=848 columns and N=600 rows, such as are described in relation to FIGS. **4–9**. The point arrays **1124** may be combined to form an image **1126** (not shown), and so each point array **1124** may be viewed as a single frame of the image **1126**. Each point array **1124** includes a plurality of points **1128**. Each DSP device **1118** operates in a similar manner, and so a single exemplary DSP device **1118** is described below. In the present embodiment, the DMD **1122** is rotated so that K=30, as has been previously described and has a native resolution of 848 pixels by 600 pixels.

The memory size needed to store an 848×600 point array (a frame) may be calculated by inserting the values for M, N, and K into the previously described equations. Doing so results in a memory size of:

$$S=N+(M-1)*N/K=600+(848-1)*600/30=17540$$

$$T=M+(N-1)*N/K=848+(600-1)*600/30=12828$$

or 17540×12828. This can be viewed in terms of storage as approximately twenty-eight megabytes (MB).

In operation, the DSP device **1118** extracts a discrete unit, such as a frame embodied in one of the point arrays **1124**, from the image **1126**. The DSP device **1118** then calculates a position on the DMD **1122** for each point **1128** of the point array **1124**. Because the DMD **1122** is rotated in relation to a subject **1130** (not shown), the position of each point **1128** enables proper projection of the associated point array **1126**.

After the DSP device **1118** has calculated the DMD positions of the points **1128**, the frame is transferred to the frame buffer **1120**. In the current embodiment, the frame buffer **1120** is capable of storing a single 848×600 frame, which is approximately 62.1 kilobytes (KB) of data. The frame buffer **1120** then transfers the frame to the DMD **1122**, where the frame is projected onto a subject. It is noted that a plurality of frame buffers **1120** may be utilized for increased efficiency and throughput. For example, dual frame buffers **1120** may be utilized so that, while one frame buffer is receiving data from the DSP device **1118**, the other frame buffer is transferring its data to the DMD **1122**.

Referring now to FIG. **12**, another embodiment of a system **1210** for real time data extraction is illustrated. The system **1210** may be incorporated in another system, such as the system **100** of FIG. **1**, or it may be a stand alone system. In the present embodiment, the system **1210** includes a PC **1212**, an interface **1214**, an image memory **1216**, a DSP device **1218**, a shift register **1220**, a frame buffer **1222**, and a DMD **1224**.

The PC, utilizing the interface **1214**, may interact with and/or control aspects of the system **1210**. The shift register **1220** may be a single shift register or may be a plurality of shift registers suitable for a desired operation. For purposes of illustration, the shift register **1220** is a 64×53 bit register (i.e., it includes 53 registers operable to store 64 bits each). The DMD **1224** in the system **1210** includes a 53 bit data path, although other data path sizes may be used as desired, and has a native resolution of 848×600. The frame buffer **1222** includes a capacity for sixty-four 848×600 frames.

As in FIG. **11**, the system **1210** utilizes point arrays **1226** (not shown) of M=848 columns and N=600 rows. The point arrays **1226** may be combined to form an image **1228** (not shown), and so each point array **1226** may be viewed as a single frame of the image **1228**. Each point array **1226** includes a plurality of points **1230**. In the present embodiment, the DMD **1224** is rotated so that K=30, as has been previously described.

The memory size needed to store an 848×600 point array (a frame) may be calculated by inserting the values for M, N, and K into the previously described equations. Doing so results in a memory size of:

$$S=N+(M-1)*N/K=600+(848-1)*600/30=17540$$

$$T=M+(N-1)*N/K=848+(600-1)*600/30=12828$$

or 17540×12828. This can be viewed in terms of storage as approximately 28 megabytes (MB).

In the present embodiment, the DSP device **1218** selects and extracts 64 bits of data from the memory **1216**. The selection and extraction of data may be done by row or column, or by some other method. The DSP device **1218** then calculates the location for each of the 64 bits on the DMD **1224**, and transfers the data into one of the 64 bit registers of the shift register **1220**. The DSP device **1218** continues with this selection, extraction, calculation, and transfer process until all 53 of the 64 bit registers of the shift register **1220** are full.

The contents of the shift register **1220** are then transferred to the frame buffer **1222**. Since each of the 64 frames included in the frame buffer **1222** is 848×600, the contents of the shift register **1220** may not be sufficient to fill a frame. Therefore, the process involving the DSP device **1216**, the shift register **1220**, and the frame buffer **1222** may be repeated until each frame of the frame buffer **1222** is filled. After 64 frames (or less, if 64 frames are not available) are stored in the frame buffer **1222**, the frames are transferred to the DMD **1224** and projected onto a subject. The process then begins again in order to retrieve more data for the DMD **1224** as is illustrated in FIG. **13**.

Referring now to FIG. **13**, a method **1310** suitable for application to the system **1210** of FIG. **12** is illustrated. In step **1312**, the method calculates an address for 64 bits, which determines the location of each bit on the DMD **1224**. The 64 bits are then retrieved from the memory **1216** in step **1314** and sent to the register **1220** in step **1316**. Once this process occurs 53 times, as determined in step **1318**, the data is shifted into the frame buffer by column (i.e., 53 bits at a time) in step **1320**. For example, the most significant digit (or least, depending on the endian ordering) of all 53 registers are shifted in the first frame, while the second most (or least) significant digits of all 53 registers are shifted into the second frame and so on, until all 64 bits have been shifted into an appropriate frame. Therefore, a total of 64 shifts will be utilized to fully clear the shift register **1220**.

If the frames of the frame buffer **1222** are not full as determined in step **1322**, the process returns to step **1312**. This continues until the frames are full or until all the data has been transferred from the memory **1216**. When the frames are full, the data is transferred for each frame in sequential order to the DMD **1224** in step **1324**. If image data remains to be transferred as determined in step **1326**, the process returns to step **1312**. It is noted that the ordering of some steps of the method **1310** may be altered and that certain steps may be modified or removed. For example, it may be preferable to retrieve the 64 bits from the memory before calculating the addresses. In addition, it may be preferable to calculate a single address for each retrieved set of bits, rather than for each bit. These and other alterations may depend on a particular implementation of the system **1210**, and so the described system and method are merely exemplary.

Referring again to FIG. **12**, it is noted that a plurality of frame buffers **1222** may be utilized for increased efficiency and throughput. For example, dual frame buffers **1222** may be utilized so that, while one frame buffer is receiving data from the shift register **1220**, the other frame buffer is transferring its data to the DMD **1224**. The system **1210** utilizes a relatively small amount of memory, but certain steps may be repeated in order to retrieve all of the frames.

Referring now to FIG. **14**, yet another embodiment of a system **1410** for real time data extraction is illustrated. The system **1410** may be incorporated in another system, such as the system **100** of FIG. **1**, or it may be a stand alone system. In the present embodiment, the system **1410** includes a line buffer **1412**, a DSP device **1414**, a frame buffer **1416**, a selector **1418**, and a DMD **1420**. The DMD **1420** in the system **1410** includes a 53 bit data path, although other data path sizes may be used as desired, and has a native resolution of 848×600. The frame buffer **1416** is operable to hold a plurality of 848×600 frames for an image **1422** (not shown).

As in FIG. **11**, the system **1410** utilizes point arrays **1424** (not shown) of M=848 columns and N=600 rows. The point arrays **1424** may be combined to form the image **1422** (not shown), and so each point array **1424** may be viewed as a single frame of the image **1422**. Each point array **1424** includes a plurality of points **1426**. In the present embodiment, the DMD **1420** is rotated so that K=30, as has been previously described.

In the present embodiment, the line buffer **1412** receives lines of data from a memory (not shown). For example, the line may be a row of memory such was described in relation to FIG. **7**. The data line is retrieved from the line buffer **1412** by the DSP device **1420**. The DSP device **1414** calculates the address for the line data so that its location on the DMD **1420** is known. The DSP device **1414** then transfers the line data into the frame buffer **1416**. This process continues until all the line data has been placed into the appropriate frames. Therefore, the frame buffer **1416** includes a total number of frames for the image **1422**.

After the line data is stored in the frame buffer **1416**, the selector **1418** selects a frame and transfers the selected frame to the DMD **1420** for projection. This selection may be sequential or may use some other criteria for the order in which frames are selected and transferred.

It is noted that modifications to the system **1410** may be made as desired. For example, it may be desirable for the selector to transfer frames as they are filled, rather than waiting for the frame buffer **1416** to completely fill before beginning the selection and transfer process. In addition, the DSP device **1414** may insert the line data into the frames in a variety of ways. For example, the DSP device **1414** may insert the entire line into a single frame, or it may insert individual bits of the line data into appropriate but different frames.

The system **1410** may utilize more memory than some systems (for example, the system **1210** if FIG. **12**), but is operable to prepare all the frames of an image for transfer at one time. Therefore, different systems may be used to accomplish different goals. In addition, systems or portions of systems may be combined so as to gain particular benefits as desired.

It is noted that memory usage may be effected by the value selected for K. As is illustrated below, a smaller K generally results in higher memory consumption, while a higher K results in a lower memory consumption.

For example, a point array of 848×600 with K=30 may have a memory array of 17540×12828, as calculated previously. A line buffer operable to buffer a complete line of data will need memory for 17540 bits, or approximately 3.3 KB. A frame buffer operable to hold all the frames may have a memory allowance for 12828×848×600 bits, or 816 MB.

In contrast, the same point array of 848×600, but with K=20, may have a memory array of 26010×18818. A line buffer operable to buffer a complete line of data will need memory for 26010 bits, or approximately 3.3 KB. A frame buffer operable to hold all the frames may have a memory allowance for 18818×848×600 bits, or 1.2 gigabytes (GB).

Referring now to FIG. **15**, in another embodiment, high resolutions may slow scanning speeds undesirably in some applications. This negative impact on speed may be caused in part by the size of the unit travel length, which is represented in FIG. **6** and the associated text by the distance "C". A DMD (not shown) may receive a frame update for each unit travel length as described above in reference to FIGS. **11**, **12**, and **14**. Therefore, a relatively small unit travel length may result in a large number of DMD updates, which in turn may negatively impact the scan speed because the DMD frame rate is fixed.

To increase the scan rate, it may be desirable to alter the unit travel length. However, while altering the unit travel length increases the scanning speed and may remove a certain amount of the redundancy previously represented by "K", it may decrease the resolution to an undesirable level.

As illustrated in FIG. **15**, a particular resolution may be achieved without the need for a particular line width. Consider three pixels **1510–1514**, each having a diameter **1516** that may be relatively large in comparison to a desired resolution defined by a distance **1518**. For example, the diameter **1516** may be 2.2 μm while the desired resolution **1518** may be 0.2 μm. Assuming that the line width of 2.2 μm is acceptable for an intended application, there is no need for an actual line width of 0.2 μm to achieve the desired resolution of 0.2 μm. This may be beneficial because achieving a particularly narrow line width, as described above, can slow the scan speed to undesirable levels.

The resolution of 0.2 μm may be realized by providing an offset distance (e.g., the distance **1518**). The offset distance may be provided by rotating the pixels **1510–1514** in relation to a subject (not shown). For example, the rotation may be accomplished by rotating an x-axis **1520** and y-axis **1522** (fixed on the pixels **1510–1514**) relative to an x-axis **1524** and y-axis **1526** defining the subject. By defining the unit travel length as the spacing of the pixels **1510–1514**, rather than the distance **1518**, the unit travel length may be increased from 0.2 μm to 2.2 μm. As described below in greater detail, this increase achieves the resolution of 0.2 μm while also maintaining a relatively high scan rate.

Referring now to FIG. **16**, a method **1600** utilizes the pixel panel rotation, pixel offset, and increased unit travel length described above to increase a scan rate while maintaining a desired minimum resolution. The minimum resolution and a pixel spacing are determined in steps **1602** and **1604**. In **1606**, a window size is calculated using the minimum resolution and pixel spacing. The window size is set in step **1608** based on the calculation of step **1606**. An angle of rotation θ for a pixel panel is calculated in step **1610** as described previously and the pixel panel is rotated to that angle in step **1612**. The desired window may then be paged in step **1614** to position a pixel at a desired location for projection onto a subject. The method **1600** may be accomplished as described in reference to FIG. **17**.

Referring now to FIG. **17**, a point array **1710** (such as may be embodied by a rotated DMD) is illustrated as an overlay on a design grid **1712** (which may be a memory as previously described). In the present example, the design grid **1712** comprises a grid of 2.2 μm squares and a desired resolution of 0.2 μm is to be achieved. The design grid **1712** may include data points (e.g., pixels) **1716–1732** in one or more of locations **1714**. The pixels **1716–1720** are arranged in a manner similar to the pixels **1510–1514** of FIG. **15**.

Portions of the design grid **1712** are illustrated as "windows" **1734–1740**. The size of a single window is calculated based on the pixel spacing (e.g., 2.2 μm) and the minimum desired resolution (e.g., 0.2 μm), which results in a window size of 2.2 μm/0.2 μm=11. Accordingly, each window is 11×11 pixels, with each pixel representing a 2.2 μm area. As described in reference to FIG. **18** below, the windows **1734–1740** represent every eleventh window.

Referring now to FIG. **18**, the windows **1736** and **1738** are illustrated with a plurality of similar 11×11 pixel intermediate windows **1810–1828**. As described previously, each pixel is 2.2 μm. The windows **1736**, **1810–1828**, and **1738** are aligned on a y-axis **1830**. However, each window is offset from the preceding and succeeding windows in the direction of an x-axis **1832** by a distance **1834**, which in the present example is 0.2 μm. Accordingly, the pixel **1722** in the window **1738** is horizontally offset from pixel **1716** in the window **1736** by 2.2 μm.

Referring again to FIG. **17**, the windows **1734–1740** are projected by the rotated point array **1710**. Due to the rotation of the point array **1710**, the location of the pixel **1716** may vary incrementally depending on the particular window in which it may be found. For example, the window **1736** includes the three points **1716–1720**. Due to the rotation of the point array **1710**, the points **1716–1720** are positioned so that there exists a 0.2 μm offset between each pixel in a single column of the windows **1734–1740** as described previously in reference to FIG. **15**.

Therefore, each pixel in one of the windows **1734–1740** is offset by 0.2 μm in the succeeding window when the rotated pixel panel projects the pixels. Accordingly, a pixel will be completely shifted by 2.2 μm in every eleventh window.

Referring still to FIG. **17**, the unit travel length of the pixel panel **1710** may be set at 2.2 μm, while allowing for a minimum resolution of 0.2 μm. Accordingly, a shift of 0.2 μm in the positive x direction may be accomplished by paging forward one page. Likewise, a shift of 0.4 μm may be accomplished by paging forward two pages. Similar incremental shifts may be accomplished by paging forward the desired number of pages. A shift of one pixel (e.g., 2.2 μm) may be accomplished by paging forward eleven pages. Therefore, a desired shift may be achieved by paging to a window having a corresponding pixel position.

Referring now to FIG. **19**, in another embodiment, an illumination device **1910**, such as a polygon mirror, may be used to project or reflect light towards a subject **1912**. In the present example, the subject **1912** includes five exposure areas **1914**, **1916**, **1918**, **1920**, and **1922**. As the subject **1912** moves relative to the polygon mirror **1910**, the polygon mirror **1910** may rotate to reflect light towards one or more of the exposure areas **1914**–**1922** (e.g., only one of the exposure areas may be a "target" exposure area at any given time). However, the light reflected towards the exposure areas **1914**–**1922** may be "scattered" and not focused on a particular one of the exposure areas (e.g., the target area). Furthermore, the rotation of the polygon mirror **1910** and the movement of the subject **1912** may be such that one or more exposure areas are not illuminated by the most intense light from the polygon mirror **1910** and so may not be properly exposed.

Referring now to FIG. **20**, a graph **2010** illustrates a level of light intensity **2012** (reflected by the polygon mirror **1910**) in relation to the particular exposure area **1914**–**1922** being exposed. The graph **2010** includes an x-axis **2014** representing time (divided into five time zones t**1**–t**5**) and a y-axis **2016** representing light intensity. It should noted that the upper and lower levels of light intensity may be adjusted as desired. Below the graph are the five exposure areas **1914**–**1922**, which are arranged sequentially in the time zones t**1**–t**5**, respectively. In the present example, the light intensity **2012** reaches a maximum at times t**1** and t**4**, and is at a minimum at times t**2**, t**3**, and t**5**. Accordingly, exposure areas **1914** and **1920** receive more intense light than the exposure areas **1916**, **1918**, and **1922**. In the present example, this signifies that the exposure areas **1916**, **1918**, and **1922** are not fully exposed.

Referring now to FIG. **21**, in still another embodiment, a lens **2110** may be positioned between the polygon mirror **1910** and the subject **1912** of FIG. **19**. The lens **2110** may be designed to direct a relatively large portion of the light reflected by the polygon mirror **1910** onto a single one of the exposure areas **1914**–**1922**. As the polygon mirror **1910** rotates and the subject **1912** moves relative to the polygon mirror **1910**, the light may be focused onto another of the exposure areas **1914**–**1922**.

Referring now to FIG. **22**, a graph **2210** illustrates a level of light intensity **2212** (reflected by the polygon mirror **1910**) in relation to the particular exposure area **1914**–**1922** being exposed in a manner similar to that of the graph **2010** of FIG. **20**. In the present example, unlike that of FIG. **20**, the light is directed through the lens **2110** of FIG. **21**. The graph **2210** includes an x-axis **2214** representing time (divided into five time zones t**1**–t**5**) and a y-axis **2216** representing light intensity. Below the graph are the five exposure areas **1914**–**1922**, which are arranged sequentially in the time zones t**1**–t**5**, respectively. In the present example, the light intensity **2212** reaches a maximum in each time zone t**1**–t**5**, rather than only during particular time zones. Accordingly, each exposure area **1914**–**1922** receive a relatively equal amount of light.

While the invention has been particularly shown and described with reference to the preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention. Therefore, the claims should be interpreted in a broad manner, consistent with the present invention.

What is claimed is:

1. A method for increasing a scan rate while maintaining a minimum resolution in an optical imaging system, the optical imaging system including a projection device, the method comprising:

determining a minimum resolution and a spacing distance for a first discrete element and a second discrete element;

calculating a window size based on the minimum resolution and the spacing distance and setting a window equal to the calculated size; and

calculating an angle of rotation for the projection device relative to a subject based on the window size, the angle of rotation operable to offset the first discrete element from the second discrete element by the minimum resolution.

2. The method of claim **1** further comprising associating the first discrete element with a first window and the second discrete element with a second window.

3. The method of claim **2** further comprising:

identifying a position for each of the first and second discrete elements in their respective windows; and

associating each of the first and second discrete elements with their respective position.

4. The method of claim **2** further comprising determining whether to select the first discrete element or the second discrete element for projection onto the subject at a predefined location, wherein the determination includes identifying which of the first and second discrete elements will match the predefined location when projected.

5. The method of claim **4** further comprising selecting the first or second discrete element by paging to the first or second window, respectively.

6. The method of claim **1** further comprising rotating the projection device relative to the subject in accordance with the angle of rotation.

7. The method of claim **1** further comprising:

defining a unit travel length as the spacing distance; and

adjusting the scan rate based on the unit travel length.

8. The method of claim **1** wherein calculating the window size based on the minimum resolution and the spacing distance includes calculating a number 'N' by dividing the spacing distance by the minimum resolution, wherein the window comprises a two dimensional matrix of size N×N.

9. A method for increasing a scan rate in a photolithography system by increasing a unit travel length while maintaining a minimum resolution, the method comprising:

determining the minimum resolution;

determining a pixel spacing distance equal to the unit travel length;

calculating a window size based on the minimum resolution and the pixel spacing distance;

establishing a plurality of windows of the calculated size so that a first pixel in a first window is offset from a second pixel in a second window by the pixel spacing distance in a first dimension; and

selecting one of the plurality of windows for projection onto a subject.

10. The method of claim **9** further comprising:

calculating an angle of rotation for a pixel panel, wherein the pixel panel is used to project the window onto the subject; and

rotating the pixel panel to the calculated angle, wherein the rotation enables the first and second pixels to be projected onto the subject at the minimum resolution or a greater resolution.

11. The method of claim **10** further comprising using a digital mirror device for the pixel panel, wherein the window is reproduced using the digital mirror device.

12. The method of claim **9** further comprising repeatedly selecting and projecting the first and second pixels to form a straight line on the subject.

13. The method of claim **9** further comprising determining whether to select the first or second pixel for projection onto the subject, wherein the determination includes identifying which of the first and second discrete elements will match a desired exposure area when projected.

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