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Chatfield et al.

[11] **3,927,320**

[45] **Dec. 16, 1975**

[54] **METHOD AND APPARATUS FOR DERIVING FROM A SCANNING ELECTRON MICROSCOPE SIGNALS THAT CAN BE DISPLAYED STEREOSCOPICALLY**

[75] Inventors: **Eric John Chatfield; Verner Henrick Nielsen,** both of Oakville, Ontario, Canada

[73] Assignee: **Ontario Research Foundation,** Ontario, Canada

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[21] Appl. No.: **493,878**

[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **250/307;** 250/311; 250/399

[51] **Int. Cl.²** **G01N 23/00**

[58] **Field of Search** 250/307, 310, 311, 398, 250/399

[56] **References Cited**

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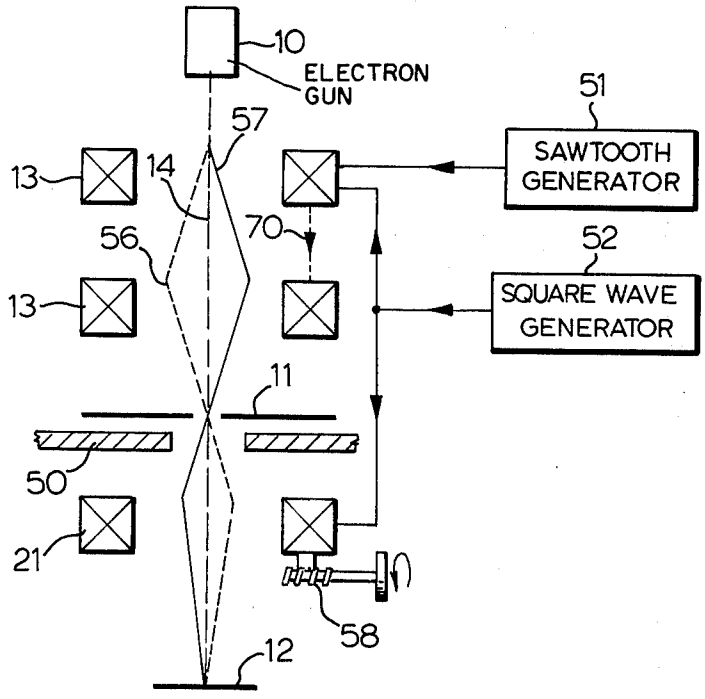
Primary Examiner—Davis L. Willis

Attorney, Agent, or Firm—Sim & McBurney

[57] **ABSTRACT**

A scanning electron microscope having line deflection coils ahead of its final aperture is modified by the addition of an ALD (after lens deflection) coil. Rectangular waveforms are supplied to these coils with the polarities of the waveforms being reversed in a predetermined fashion dependent upon the scanning sequence, thus enabling a given area on the object being scanned to be "seen" from two different angles. The derived signals may be supplied to a colour television receiver or monitor along with appropriate switching signals to enable the image of the object to be shown stereoscopically.

22 Claims, 12 Drawing Figures



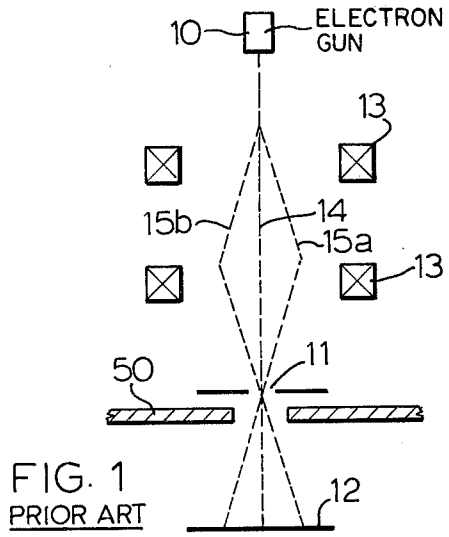


FIG. 1
PRIOR ART

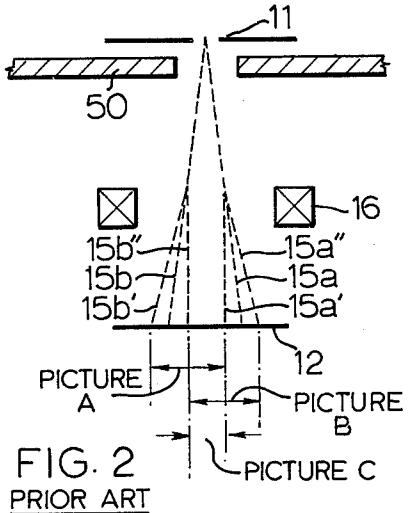


FIG. 2
PRIOR ART

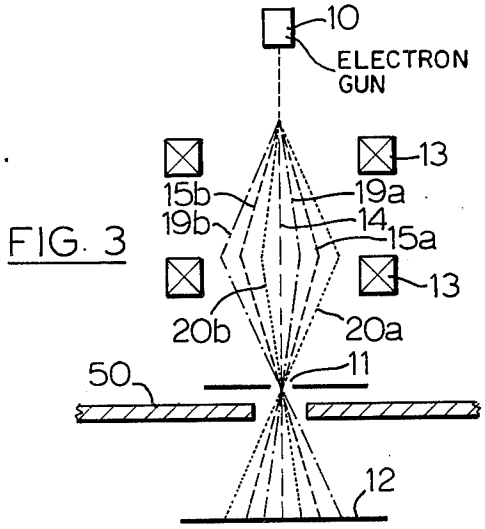


FIG. 3

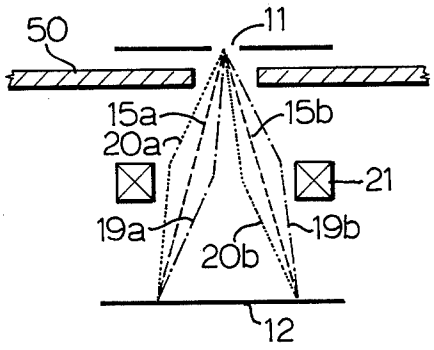


FIG. 4

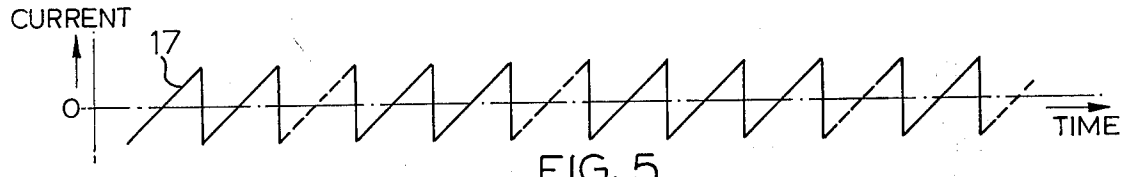


FIG. 5

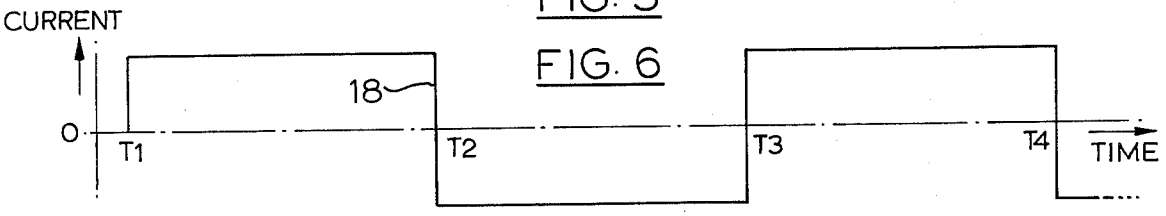


FIG. 6

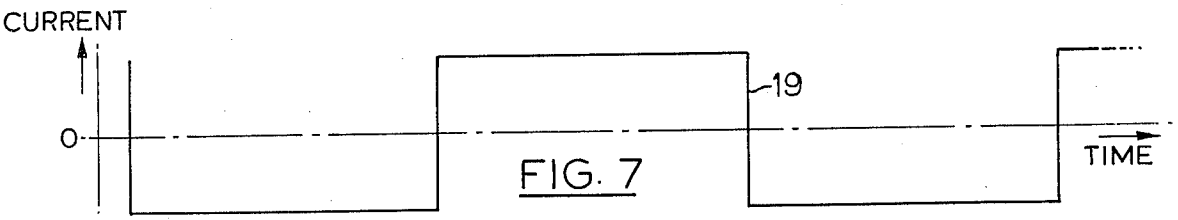


FIG. 7

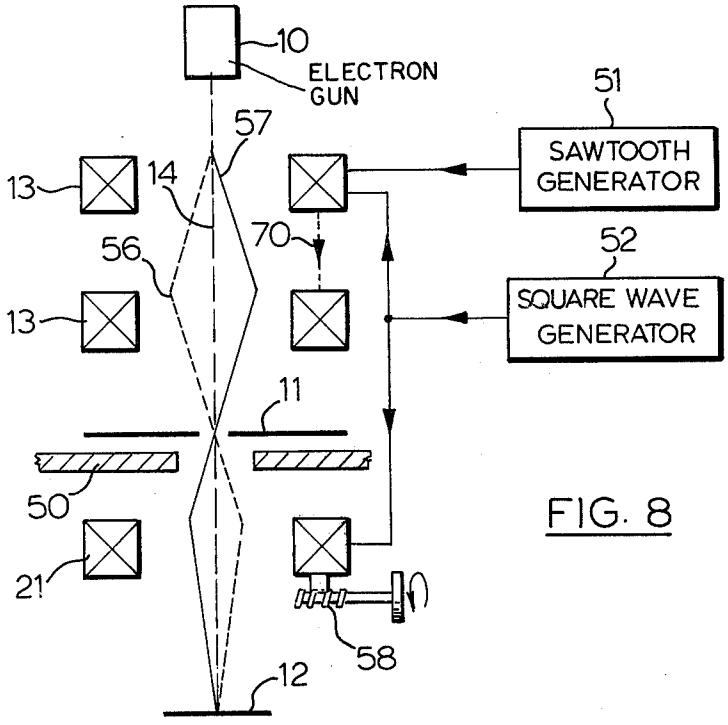

10
ELECTRON GUN
51
SAWTOOTH GENERATOR
57
13
14
70
52
56
SQUARE WAVE GENERATOR
13
11
50
21
58
12

FIG. 8

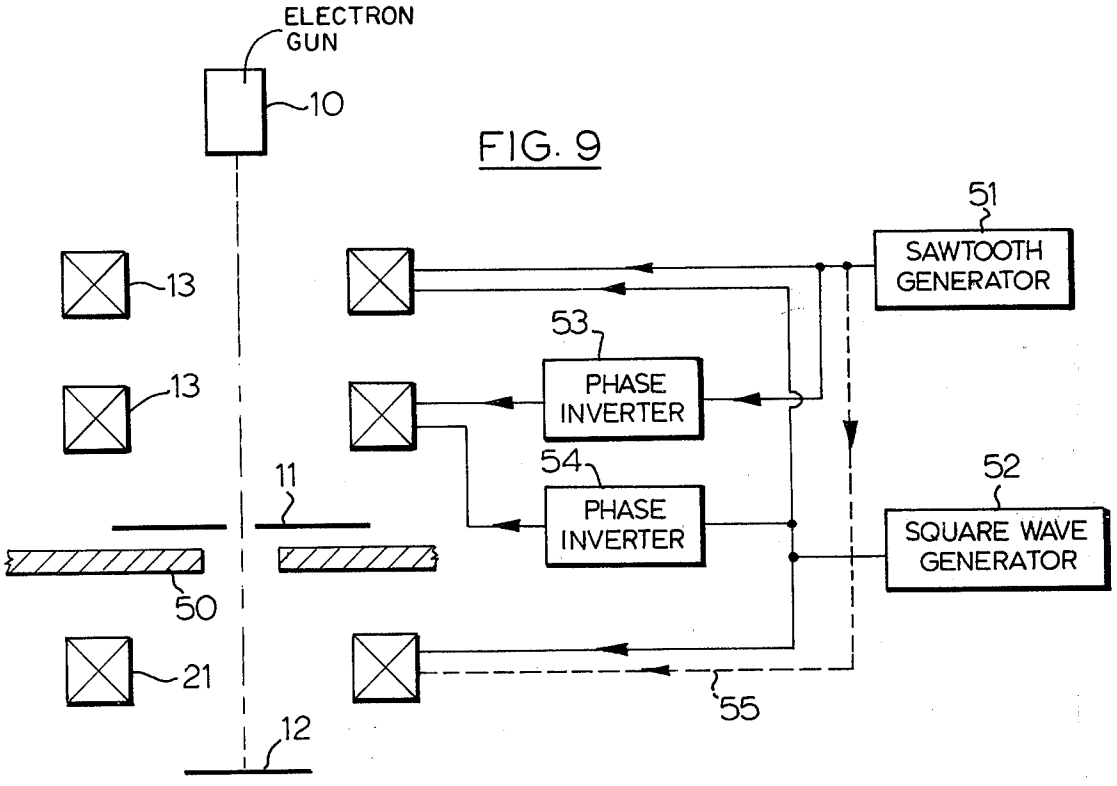

ELECTRON GUN
10
51
SAWTOOTH GENERATOR
13
53
PHASE INVERTER
13
54
52
11
PHASE INVERTER
SQUARE WAVE GENERATOR
50
21
55
12

FIG. 9

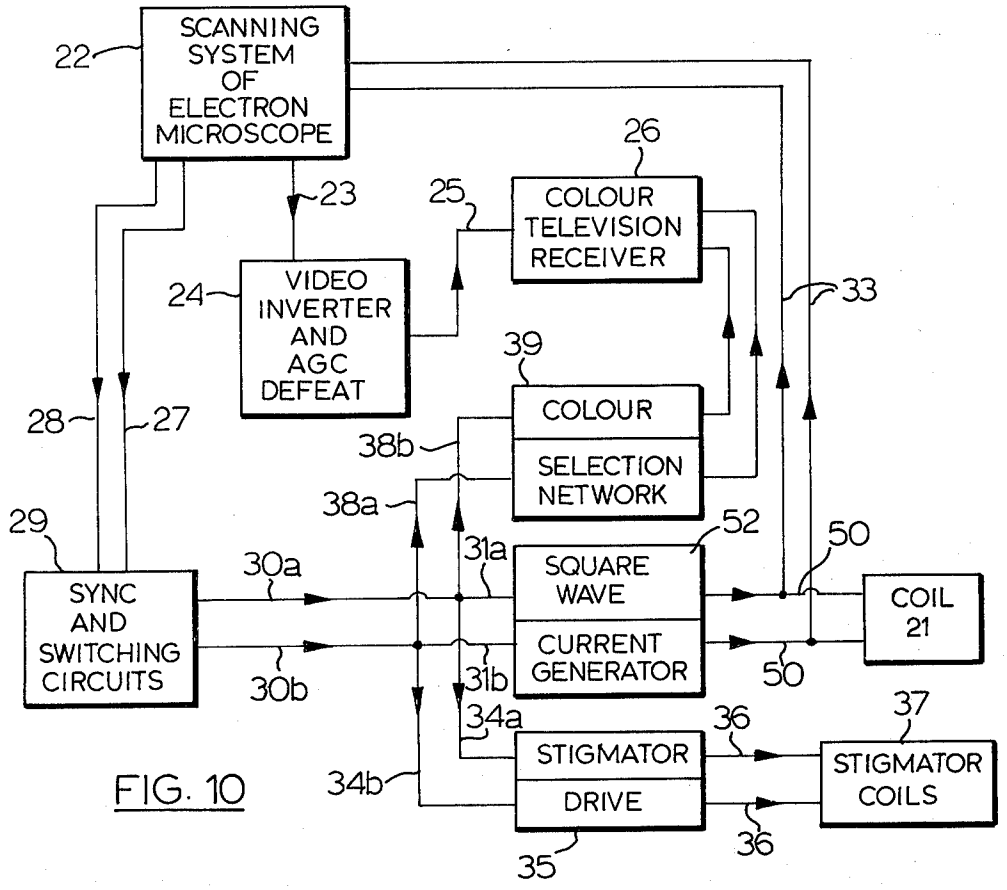

SCANNING SYSTEM OF ELECTRON MICROSCOPE
22
23
26
25
COLOUR TELEVISION RECEIVER
24
VIDEO INVERTER AND AGC DEFEAT
33
39
COLOUR
SELECTION NETWORK
38b
38a
28
27
29
SYNC AND SWITCHING CIRCUITS
30a
30b
31a
31b
SQUARE WAVE
CURRENT GENERATOR
52
50
COIL 21
34a
34b
STIGMATOR DRIVE
36
37
STIGMATOR COILS
35

FIG. 10

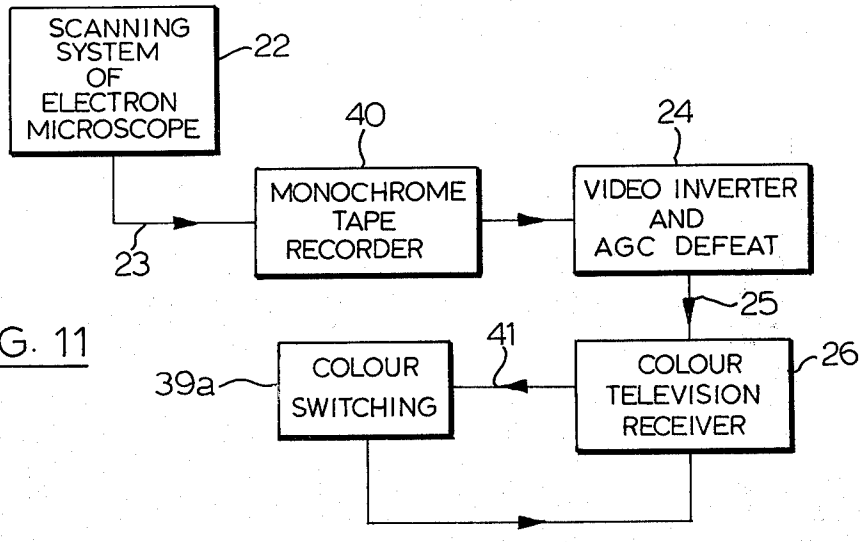

SCANNING SYSTEM OF ELECTRON MICROSCOPE
22
40
MONOCHROME TAPE RECORDER
24
VIDEO INVERTER AND AGC DEFEAT
23
25
41
39a
COLOUR SWITCHING
COLOUR TELEVISION RECEIVER
26

FIG. 11

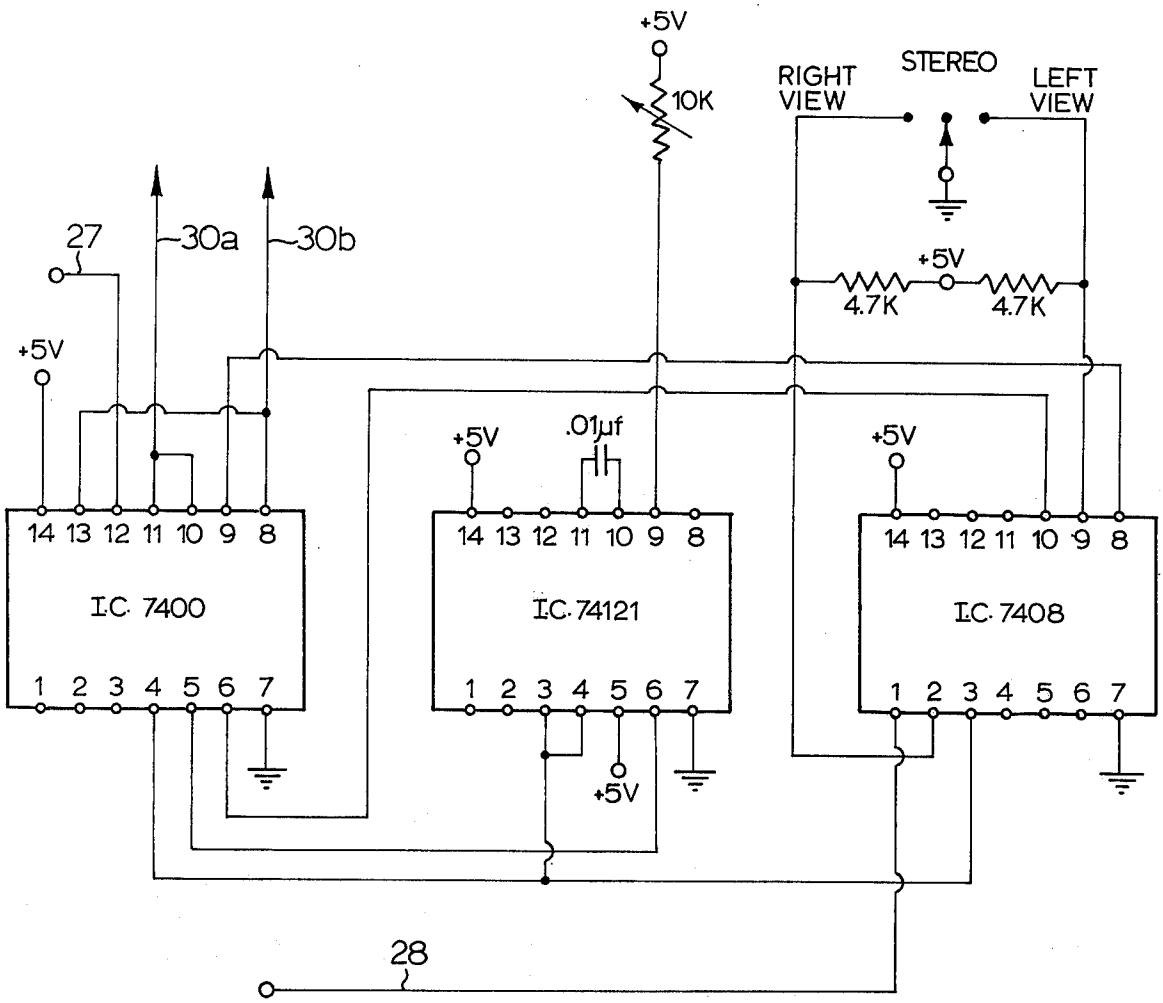

+5V
10K
RIGHT VIEW
STEREO
LEFT VIEW
+5V
4.7K
4.7K
27
30a
30b
+5V
+5V
.01μf
+5V
14 13 12 11 10 9 8
IC. 7400
1 2 3 4 5 6 7
14 13 12 11 10 9 8
IC. 74121
1 2 3 4 5 6 7
+5V
14 13 12 11 10 9 8
IC. 7408
1 2 3 4 5 6 7
28

FIG. 12

METHOD AND APPARATUS FOR DERIVING FROM A SCANNING ELECTRON MICROSCOPE SIGNALS THAT CAN BE DISPLAYED STEREOSCOPICALLY

This invention relates to improvements in scanning electron microscopes of the type having deflection coils located or deflector plates located ahead of the final aperature. By the practice of this invention signals can be derived from such scanning electron mocroscopes that can be translated to permit the object under examination to be seen in three dimensions, i.e., stereoscopically.

The production of stereo pictures using a scanning electron microscope (SEM) has been achieved in the past. One technique that has been employed is to mechanically tilt the specimen, make two exposures thereof at two different viewing angles, photograph the images for each exposure (these photographs being referred to as stereo pairs), and view the stereo pairs through a conventional stereo viewer. This technique is very slow, and only one person at a time can look at a stereo pair through a viewer.

It is also known to modify an SEM by adding to it what is called an after lens deflection (ALD) coil and applying a deflection signal thereto to deflect the electron beam after it has passed through the final aperture so that it impinges on the specimen from two different angles. In this manner stereo pairs can be made without mechanically tilting the specimen. This system has a number of inherent disadvantages that will be discussed at a later point herein.

Further, it is known to employ a double ALD system to permit viewing in stereo of a specimen being examined by an SEM. The major problem with a double ALD system is the poor resolution that results from the necessarily larger working distance between the final aperature and the specimen as compared with a single ALD system where only one ALD coil is required, or the system where there are no ALD coils and the specimen is tilted mechanically. In addition, a double ALD system has its own inherent astigmatism problems.

In accordance with one aspect of this invention there is provided, in a scanning electron microscope of the type having an electron gun for producing an electron beam, a final aperture through which at least a part of said electron beam passes prior to impingement on an object being scanned by said electron beam, a longitudinal axis extneding from said electron gun through said final aperture and through the object being scanned by said electron beam, and an electron beam deflecting system for scanning said electron beam across the object being scanned in adjacent parallel lines, said electron beam deflecting system including a plurality of electron beam line deflection devices and means for supplying a scanning waveform to at least one of said electron beam line deflection devices to scan said electron beam in a line across the object being scanned by said electron beam, said plurality of electron beam line deflection devices including at least two electron beam line deflection devices located between said electron gun and said final aperture and a third electron beam line deflection device located between said final aperture and the object being scanned by said electron beam; the improvement comprising apparatus for enabling said scanning electron microscope to generate signals that enable an image of the

object being scannned by said electron beam to be viewed in three dimensions, said apparatus comprising means for supplying to at least two of said electron beam line deflection devices located between said electron gun and said final aperture a waveform which (a) during the scanning of a first set of said lines, and in addition to any deflection of said electron beam caused by said scanning waveform, creates a field which deflects an electron beam that is travelling from said electron gun through said final aperture on said longitudinal axis in a first path firstly away from said longitudinal axis and to one side of said longitudinal axis and lastly towards said longitudinal axis to intersect said longitudinal axis in the immediate vincity of said final aperture and then to proceed away from said longitudinal axis but on the opposite side thereof and (b) during the scanning of a second set of said lines, and in addition to any deflection of said electron beam caused by said scanning waveform, creates a field which deflects an electron beam that is traveling from said electron gun through said final aperture on said longitudinal axis in a second path firstly away from said longitudinal axis and to said opposite side thereof and lastly towards said longitudinal axis to intersect said longitudinal axis in the immediate vicinity of said final aperture and then to proceed away from said longitudinal axis but on said one side thereof, and means for supplying to said third electron beam line deflection device an electron beam deflecting waveform, said electron beam deflecting waveform being applied to said third electron beam deflection device during the scanning of said respective sets of lines and deflecting said electron beam in addition to any deflection thereof caused by said scanning waveform, the nature of said electron beam deflecting waveform being such that said electron beam deflecting waveform creates a field which, when acting on an electron beam travelling in the portions of said first and second paths that are beyond said final aperture, deflects an electron beam travelling in the portions of said first and second paths respectively that are beyind said final aperture back towards said longitudinal axis to intersect said longitudinaal axis at the object being scanned by said electron beam from both said one and said opposite sides thereof.

In accordance with another aspect of this invention there is provided a method for operating a scanning electron microscope of the type having an electron gun, a final aperture through which at least a part of said beam passes prior to impingement on an object being scanned by said electron beam and a longitudinal axis extending from said electron gun through said final aperture and through the object being scanned by said electron beam to enable said scanning electron microscope to generate signals that enable an image of the object being scanned by said electron beam to be viewed in three dimensions, said method comprising: (a) scanning said electron beam across the object being scanned in adjacent parallel lines, (b) between said electron gun and said final aperture and in addition to any deflection of said electron beam by said scanning (i) providing a field during the scanning of a first set of said lines which deflects an electron beam that is travelling from said electron gun through said final aperture on said longitudinal axis in a first path firstly away from said longitudinal axis and to one side of said longitudinal axis and lastly towards said longitudinal axis to intersect said longitudinal axis in the immediate vicinity of said final aperture and then to proceed away from

said longitudinal axis but on the opposite side thereof and (ii) providing a field during the scanning of a second set of said lines which deflects an electron beam that is travelling from said electron gun through said final aperture on said longitudinal axis in a second path firstly away from said longitudinal axis and to said opposite side thereof and lastly toward said longitudinal axis to intersect said longitudinal axis in the immediate vicinity of said final aperture and then to proceed away from said longitudinal axis but on said one side thereof, and (c) between said final aperture and the object being scanned by said electron beam, and in addition to any deflection of said electron beam by said scanning, during said scanning of said respective sets of lines providing fields which are of such a nature that, when acting upon electron beams travelling in the portions of said first and second paths that are beyond said final aperture, deflect electron beams travelling in the portions of said first and second paths respectively that are beyond said final aperture back towards said longitudinal axis to intersect said longitudinal axis at the object being scanned by said electron beam from both said one and said opposite sides thereof.

This invention will become more apparent from the following detailed description of a preferred embodiment and other embodiments, taken in conjunction with the appended drawings, in which:

FIG. 1 is a schematic diagram of a conventional SEM of a type that may be modified in accordance with this invention,

FIG. 2 is a schematic diagram of a prior art system that enables a specimen in an SEM to be viewed stereoscopically,

FIGS. 3 and 4 are schematic diagrams of an SEM modified in accordance with this invention,

FIGS. 5–7 show the waveforms of signals that are applied to an SEM modified in accordance with this invention,

FIGS. 8 and 9 are other schematic diagrams of an SEM modified in accordance with this invention,

FIG. 10 shows, in block form, circuitry useful in practising this invention,

FIG. 11 shows, in block form, another system embodying this invention, and

FIG. 12 shows one of the blocks of FIG. 10 in greater detail.

It will be understood, of course, that FIGS. 1–4 do not purport to show a complete scanning electron microscope. Scanning electron microscopes are well known and are commercially available, so only those components thereof that are necessary for an understanding of this invention are shown and will be discussed. In fact FIG. 1 is intended to be a schematic representation of a Cambridge STEREOSCAN (trade mark) S4 scanning electron microscope that is particularly suited for use in the practice of this invention.

Referring to FIG. 1, the electron gun of an SEM is shown at 10, while 11 is the final aperture, 12 the specimen and 13 the normal line deflection coils of the SEM. In TV parlance the line deflection coils are the horizontal deflection coils. The vertical or field deflection coils are not shown. In the particular SEM illustrated there are two line deflection coils 13. The two line deflection coils may be connected together in series circuit to form an integral double deflection system. In this case coils 13 are oppositely wound to provide the required opposite polarity deflection fields. Alternatively, coils 13 may be electrically independent and wound in the same way. In this case they are supplied from the same sawtooth generator but with 180° out of phase sawtooth waveforms to provide the required opposite polarity deflection fields. In any event, the field magnitudes of coils 13 always are adjusted so that the electron beam passes through final aperture 11. Reference numeral 50 designates the lens plate of the final lens of the SEM. Not shown is the detector which detects secondary electrons emitted by specimen 12 to provide the output signal of the SEM.

The path of the undeflected electron beam is shown at 14 in FIG. 1, which also designates the longitudinal axis of the SEM, the latter extending from gun 10 through aperture 11 and specimen 12. By applying a conventional sawtooth sweep signal at TV scan rate to coils 13, the electron beam is caused to scan across specimen 12 in parallel lines. Odd numbered lines are scanned to create one field. Even numbered lines then are scanned to create another field. This is known as interlaced scanning. The two fields together make a frame or picture, all as is well known. The odd and even lines are interlaced, i.e. even lines occur between odd lines and vice versa. The extreme limits of the paths of the electron beam (the beginnings and ends of the lines) are shown at 15a and 15b in FIG. 1. Double deflection is required because it is necessary for the beam to pass through final aperture 11.

Referring now to FIG. 2, shown therein is what is believed to be a system described by A. R. Dinnis in a paper delivered at the Fourth Annual Scanning Electron Microscope Symposium in Chicago in April, 1971 for obtaining stereo pairs from an SEM. In this system there is added between final aperture 11 and specimen 12 a deflection or ALD coil 16. The paths 15*a* and 15*b* of the electron beam corresponding to those paths shown in FIG. 1 and which the electron beam would follow were it not for deflection coil 16 are also shown in FIG. 2. During, say, the scanning of odd numbered lines, Dinnis applied a positive deflection current to coil 16 to deflect the electron beam along paths having the extreme limits 15*a*′ and 15*b*′ creating what can be referred to as picture A. During the scanning of even numbered lines Dinnis applied a negative deflection current to deflection coil 16 to deflect the electron beam along paths having the extreme limits 15*a*″ and 15*b*″ creating what can be referred to as picture B. Where pictures A and B overlap, picture C is created, and by photographing picture C during the scanning of odd numbered lines and again during the scanning of even numbered lines, stereo pairs are created. The limitations of this system are obvious from FIG. 2. Only a very small portion of specimen 12 can be seen in stereo. Moreover, Dinnis reported "serious aberrations which cannot be adequately corrected" and rejected this system in favour of one employing a double deflection arrangement between final aperture 11 and specimen 12. The disadvantages of such a double deflection arrangement have been previously discussed.

Referring now to FIG. 3, the same SEM as is illustrated in FIG. 1 is shown. However, in addition to the normal sawtooth waveform 17 (FIG. 5) which is applied to deflection coils 13, there is additionally applied to deflection coils 13 the rectangular waveform 18 shown in FIG. 6. It should be understood, however, that in this embodiment coils 13 are considered to be series connected and oppositely wound. Thus the rectangular waveform 18 shown in FIG. 6 is supplied to the upper one of coils 13 and, in effect, the waveform that is

supplied to lower coil 13 thus is 180° out of phase with waveform 18. It is shown at 19 in FIG. 7. Referring to FIG. 6, the interval T1–T2 and the interval T3–T4 represent the periods of time taken to scan, say, the odd numbered lines of a field, while the interval T2–T3 represents the period of time taken to scan the even numbered lines of a field. The result of applying waveform 18 to deflection coils 13 is that the electron beam which otherwise would follow paths within the area bounded by paths 15*a* and 15*b* is caused to follow paths within the area bounded by paths 19*a* and 19*b* during intervals T1–T2 and T3–T4 and paths within the area bounded by paths 20*a* and 20*b* during the interval T2–T3. In other words, the electron beam is deflected to the left and to the right of the paths that it normally would follow if only waveform 17 were applied to coils 13. This modification alone does not permit stereo pictures to be obtained because, as is readily apparent from FIG. 3, neither the electron beams 19*b* and 20*b* nor the electron beams 19*a* and 20*a* converge at the same point on specimen 12. It is well known that to produce stereo pictures it is necessary for the same points on specimen 12 to be viewed from two slightly different angles. This result is achieved by the addition of a deflection coil 21 between final aperture 11 and specimen 12, as shown in FIG. 4, and the application thereto of a waveform of the same general configuration, i.e. rectangular, as waveform 18. As shown in FIG. 4, the application of this rectangular waveform to coil 21 causes electron beams 19*a* and 20*a* to impinge on specimen 12 at the same point but from two slightly different angles. The same is true of electron beams 19*b* and 20*b*. Consequently the condition for providing stereo images has been achieved. In fact, beams 19*a* and 20*a* do not converge at precisely the same point on specimen 12, but rather one line apart. This does not materially detract from the quality of the stereo picture that can be obtained.

Reference may be made to FIG. 8 which illustrates the system described in the preceding paragraph in greated detail. In this Figure the sawtooth generator which provides waveform 17 is shown at 51 and is connected to upper coil 13. The internal connection of oppositely wound coils 13 is shown by the dotted line 70. Reference numeral 52 designates a "square" wave generator that provides the rectangular waveform shown at 18. Generator 52 is connected to upper coil 13 and to ALD coil 21. Lines 56 and 57 schematically indicate the paths followed by the electron beam during times T1 to T2 and T2–T3 respectively due solely to the output of generator 52.

In another embodiment shown in FIG. 9 coils 13 are not connected in series and are wound in the same direction. In this case both generators 51 and 52 are connected via phase inverters 53 and 54 respectively to lower coil 13.

In another embodiment of the invention also shown in FIG. 9, sawtooth generator 51 also may be connected to ALD coil 21, as shown by the dotted line 55. This connection may be made via an amplifying or attenuating device, neither of which is shown, so as to permit the amplitude of the sawtooth signal supplied to coil 21 to be varied.

In a less preferred embodiment of the invention which is not illustrated, sawtooth generator 51 may be connected only to ALD coil 21. This embodiment is not preferred because of the increased angle of scan that necessarily results when scanning a line of a given length as the scanning coil, i.e., the coil furthest from specimen 12 to which waveform 17 is applied, moves closer to specimen 12.

Those skilled in the art will understand that the times T1, T2, T3 and T4 etc. are one-sixtieth of a second apart and that during these one-sixtieth second intervals there occur sufficient cycles of sawtooth waveform 17 to scan first the odd numbered lines, then the even numbered lines etc. While this is the preferred embodiment of the invention, since the derived signal can be displayed using a conventional colour television receiver or monitor, as will be outlined in greater detail hereafter, it also would be possible for the switching to take place after each frame. Another alternative would be to scan in a non-interlaced fashion with switching taking place after each line. Other types of systems could be used to meet the requirement that any given area on the specimen be viewed from two different angles.

It will be seen from the foregoing that in practising this invention a biasing signal is supplied to coils 13 that has the effect, during the scanning of certain lines, and in addition to the scan, of deflecting the electron beam from gun 10 in a first path, say 56 (FIG. 8), that is firstly away from longitudinal axis 14 and to the left side thereof and lastly towards axis 14 to intersect axis 14 in the immediate vicinity of final aperture 11, the beam then proceeding away from axis 14 on the right hand side thereof. The biasing signal supplied to coils 13 also has the effect, during the scanning of certain lines, which may or may not be the same lines as previously mentioned, depending on the scanning sequence which is used, and in addition to deflection caused by the scan, of deflecting the electron beam from gun 10 in a second path 57 that is firstly away from longitudinal axis 14 and to the right side thereof and lastly towards axis 14 to intersect axis 14 in the immediate vicinity of final aperture 11, the beam then proceeding away from axis 14 on the left side thereof. While there may be more than two deflections of the beam ahead of final aperture 11, it is essential that the final deflection ahead of final aperture 11 be towards axis 14 and that the beam intersect axis 14 at or substantially at final aperture 11. In addition a biasing signal is supplied to coil 21 that, in addition to the deflection resulting from scanning, deflects the electron beams travelling in the portions of paths 56 and 57 that are beyond aperture 11 back towards axis 14 to intersect axis 14 at specimen 12 from both the right and left hand sides thereof. Finally, a scanning waveform is provided. It may be supplied to both coils 13 and not to coils 21 or to coil 21 only or to all three coils. If desired the scanning waveform could be applied to coils that are completely independent of coils 13 and 21 and the latter used solely for stereo deflection.

It also should be noted that in practising this invention electrostatic rather than electromagnetic deflection may be used. Consequently coils 13 and 21 could be replaced by plates and generators 51 and 52 by generators of suitable voltage waveforms for electrostatic deflection.

The lens of an SEM commonly is electromagnetic in nature, but electrostatic lenses also are known. In the case where an electromagnetic lens is employed, an important feature of the instant invention is the fact that the field of ALD coil 21 is rotatable relative to the fields of coils 13. This is schematically shown in FIG. 8 by a worm gear 58 that can be manually turned to

rotate coil **21** about axis **14.** The field rotation is necessitated by the fact that the electron beam emerging from final aperture **11** moves in a spiral path, rather than in the *x* plane, the actual path being determined by the degree of final lens excitation. Under these circumstances, if the fields of coils **13** and **21** lay in the same plane, vertical convergence would not be possible. It is achieved by rotating coil **21** until vertical convergence is obtained. Generally only a slight rotation of the order of 2° or 3° is required.

It should be noted that ALD coil **21** can be mechanically rotated or its field electrically rotated. In the latter case a quadrupole deflection coil system could be used, for example. Likewise, if electrostatic deflection is employed together with electromagnetic focussing, provision should be made for electrical field rotation or mechanical plate rotation. It also would be possible to achieve the same effect by electrical field rotation or mechanical rotation of coils **13.**

An important feature of the invention is the fact that only the ALD coil for *x* deflection is required. In this respect, the greater the number of ALD coils that are required, the greater is the astigmatism problem.

If desired, in any embodiment of the invention an amplifying or attenuating device may be connected between generator **52** and ALD coil **21.** By varying the setting of this device and hence the drive to ALD coil **21,** convergence of beams **56** and **57** on specimen **12** can be accomplished. If, as previously noted in connection with FIG. **9,** an amplifying or attenuating device is connected between generator **51** and ALD coil **21,** it may be varied so that during scanning the electron beam impinging on specimen **12** at various points from an angle upwardly and to the right follows parallel paths in moving towards axis **14** and likewise for the beam coming in at various points from an angle upwardly and to the left. In other words, the angle of view can be kept constant.

In the embodiment of the invention shown in FIG. **8,** coils **13** may be properly called electron beam line deflection devices as a scanning waveform which deflects the beam in a line across specimen **12** is applied thereto. No such scanning waveform is applied to coil **21** in FIG. **8.** Notwithstanding this, it still may be termed an electron beam line deflection device as it does deflect the beam in the same plane (below lens **50**) as the one in which it is scanned. Thus, where herein and in the claims reference is made to an electron beam line scanning device, coil or plate, this is intended to include both such a device to which a line scanning waveform is supplied and one that is adapted to deflect an electron beam that is being line scanned in the plane in which such scanning is taking place.

Referring now to FIG. **10,** the TV scanning system of the SEM modified in accordance with FIGS. **3** and **4** is shown at **22.** A composite video output signal is derived in a conventional manner and is supplied by a line **23** to a network **24** that incorporates a video signal inverter and an AGC defeat circuit. The composite video signal is like any normal transmitted TV signal and contains video information and sync pulses. The video information, of course, constitutes the information derived from the SEM by scanning specimen **12.** Thus, during time intervals T1–T2 and T3–T4, the electron beam scans the lines of an odd field and moves between extreme positions **19***a* and **19***b* (FIG. **4**), the lines of the even field of the frame being scanned during time interval T2–T3 while the electron beam moves between the extreme positions **20***a* and **20***b*, and the resultant field information constitutes the video information of the composite video signal. The composite video signal is inverted by the video inverter and supplied via a line **25** to a conventional colour television receiver **26.** This colour television receiver is of a type that accepts positive-going video, whereas the output of network **22** is a composite video signal having negative-going polarity. This is the reason, of course, for the video inverter. If the scanning system of the SEM were to produce a composite video signal having positive-going polarity, the video inverter would not need to be employed.

The function served by the AGC defeat network is to turn off the tuner of television receiver **26** so that no external signal transmitted on the channel to which the television receiver is tuned can be picked up to interfere with the stereo display of an image of specimen **12.** It is not required if a colour monitor is used.

Also derived from network **22** are certain sync signals. Thus, vertical sync signals signifying the start of a new field are obtained on line **27,** while a composite sync signal containing both horizontal and vertical sync pulses is obtained on line **28.** From the latter signal information can be obtained as to whether the field is an even field or an odd field. The two sync signals are supplied to a network **29** designated sync and switching circuits which incorporates a monostable multivibrator and a set-reset flip flop. Network **29** produces pulses at each time T1, T2, T3 etc. These pulses are supplied via lines **30***a*, **30***b* and **31***a*, **31***b* to square wave generator **52** that provides the waveform **18** shown in FIG. **6** and which is supplied to coil **21** via lines **50.** The output of square wave generator **52** also is supplied via lines **33** to network **22** where it is supplied to line deflection coils **13.**

The pulse output signal of network **29** also is supplied via lines **30***a*, **30***b* and **34***a*, **34***b* to the stigmator drive network **35** of the SEM, the output of this network being supplied via lines **36** to the stigmator coils **37** of the SEM. In this manner additional dynamic correction for astigmatism resulting from the additional deflection of the electron beam in accordance with this invention is applied to stigmator coils **37.** For proper correction it has been found that about ten times the current normally used for astigmatism correction in the S4 SEM should be used. Of course the astigmatism correction is switched to allow correction of both left and right images.

The output pulses of network **29** also are supplied via lines **30***a*, **30***b* and **38***a*, **38***b* to a colour selection network **39.** The colour selection network performs the necessary switching of the electron guns of the colour picture tube of television receiver **26.** The blue gun is turned off permanently. During scanning of odd numbered fields the output signal of network **39** turns off the red gun of the television receiver, so that the odd fields appear as green images on the screen of the television receiver picture tube. During the scanning of even fields the signal from network **39** turns off the green gun, so that even fields appear as red images on the screen of the colour picture tube. Of course, this arrangement could be completely reversed without departing from the invention. In other words, the green gun could be turned off during the scanning of odd fields and the red gun turned off during the scanning of even fields. When the picture appearing on the screen of the television receiver is viewed by an observer wearing glasses having a red filter in front of one eye

and a green filter in front of the other eye, an image of specimen **12** in three dimensions will be seen.

Referring to FIG. **12,** block **29** shown in FIG. **10** may be seen in greater detail. It is composed of three integrated circuits I.C. **7400,** I.C. **74121** and I.C. **7408.** Incorporated in block **22** of FIG. **8** is a ZENITH (trade mark) TV module sync board that is sold as an accessory with a Stereoscan S4 SEM. Line **27** is connected to pin number **1** of module Z**319** on this board, while line **28** is connected to pin D on the sync board.

Those skilled in the art will understand that the selection of red and green is not essential to the obtaining of stereo images. Thus, the green gun could be permanently turned off and even and odd fields displayed in red and blue respectively, in which event stereo images will be seen when using glasses having a red filter and a blue filter. It also would be possible, although rather impractical, considering the other alternative which is available namely the system just disclosed, to place on the screen of the picture tube alternate strips of vertically and horizontally polarized material corresponding to and in registry with the odd and even numbered lines and then view the screen of the picture tube through glasses having one lens vertically polarized and the other lens horizontally polarized. It also would be possible to supply the odd field information to a first picture tube, which may be a black and white picture tube, and the even field information to a second picture tube, also of the monochrome type, and a stereo image will be seen when the two picture tubes are viewed through a stereo viewer. Of course, this system suffers the disadvantage that only one person at a time can look through the stereo viewer.

While an embodiment of the invention has been disclosed in which odd field information is displayed in one colour and even field information is displayed in another colour, those skilled in the art will appreciate that the whole of one frame may be displayed in one colour, the whole of the next frame being displayed in a different colour. This simply involves altering the waveform **18** so that switching occurs at intervals T**1,** T3 etc. rather than at intervals T**1,** T**2,** T3 etc. The switching speed in this case is half as fast, and the net result is that a flicker appears on the screen of the colour picture tube, but this flicker is tolerable.

An important advantage of the system disclosed herein is that the composite video signal which is derived from network **22** can be recorded on a monochrome tape recorder, since only one image is transmitted at any time. A colour tape recorder is not required. Referring to FIG. **11,** the composite video signal on line **23** is supplied to a monochrome tape recorder **40** and recorded for subsequent playback. During playback the composite video signal is supplied to network **24** and then to colour television receiver **26** in the same manner as has been disclosed in connection with FIG. **10.** By utilizing the sync circuits of the television receiver itself, composite sync pulses (containing both the vertical and horizontal pulses) signifying the start of a new field are supplied via line **41** to a colour switching network **39***a* that performs the same function as colour selection network **39** of FIG. **10.** Thus, colour switching network **39***a* turns off the red gun during one field and then turns off the green gun during the next field. The network **39***a* determines whether any given vertical sync pulse on line **41** signifies the start of an odd field or an even field, and eliminates an ambiguity which otherwise might require reversal of the coloured viewing lenses.

Important advantages of the preferred embodiment of this invention are that the display is continuous, is seen in real time, i.e., while the specimen is in the microscope, and can be viewed by several people simultaneously.

Notwithstanding the foregoing, while for the sake of completeness systems have been disclosed whereby the stereo signals that are derived in accordance with the instant invention can be displayed, and while both together constitute a preferred embodiment of the invention, the essence of this invention is the system and method for deriving the stereo signals, and other display systems may be employed as desired without departing from the basis of this invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In a scanning electron microscope of the type having an electron gun for producing an electron beam, a final aperture through which at least a part of said electron beam passes prior to impingement on an object being scanned by said electron beam, a longitudinal axis extending from said electron gun through said final aperture and through the object being scanned by said electron beam, and an electron beam deflecting system for scanning said electron beam across the object being scanned in adjacent parallel lines, said electron beam deflecting system including a plurality of electron beam line deflection devices and means for supplying a scanning waveform to at least one of said electron beam line deflection devices to scan said electron beam in a line across the object being scanned by said electron beam, said plurality of electron beam line deflection devices including at least two electron beam line deflection devices located between said electron gun and said final aperture and a third electron beam line deflection device located between said final aperture and the object being scanned by said electron beam; the improvement comprising apparatus for enabling said scanning electron microscope to generate signals that enable an image of the object being scanned by said electron beam to be viewed in three dimensions, said apparatus comprising means for supplying to at least two of said electron beam line deflection devices located between said electron gun and said final aperture a waveform which (a) during the scanning of a first set of said lines, and in addition to any deflection of said electron beam caused by said scanning waveform, creates a field which deflects an electron beam that is travelling from said electron gun through said final aperture on said longitudinal axis in a first path firstly away from said longitudinal axis and to one side of said longitudinal axis and lastly towards said longitudinal axis to intersect said longitudinal axis in the immediate vicinity of said final aperture and then to proceed away from said longitudinal axis but on the opposite side thereof and (b) during the scanning of a second set of said lines, and in addition to any deflection of said electron beam caused by said scanning waveform, creates a field which deflects an electron beam that is travelling from said electron gun through said final aperture on said longitudinal axis in a second path firstly away from said longitudinal axis and to said opposite side thereof and lastly towards said longitudinal axis to intersect said longitudinal axis in the immediate vicinity of said final aperture and then to proceed

away from said longitudinal axis but on said one side thereof, and means for supplying to said third electron beam line deflection device an electron beam deflecting waveform, said electron beam deflecting waveform being applied to said third electron beam deflection device during the scanning of said respective sets of lines and deflecting said electron beam in addition to any deflection thereof caused by said scanning waveform, the nature of said electron beam deflecting waveform being such that said electron beam deflecting waveform creates a field which, when acting on an electron beam travelling in the portions of said first and second paths that are beyond said final aperture, deflects an electron beam travelling in the portions of said first and second paths respectively that are beyond said final aperture back towards said longitudinal axis to intersect said longitudinal axis at the object being scanned by said electron beam from both said one and said opposite sides thereof.

2. The invention according to claim **1** wherein said scanning electron microscope employs interlaced scanning and said first and second sets of lines are interlaced.

3. The invention according to claim **1** wherein said electron beam is scanned across the object following each adjacent line in sequence and said first and second sets of lines are the same sets of lines.

4. The invention according to claim **1** wherein said scanning electron microscope includes a final electromagnetic lens, said third electron beam line deflection device also being located between said final electromagnetic lens and the object being scanned by said electron beam, and means for rotating the electron beam deflecting field of said third electron beam line deflection device relative to the electron beam deflecting fields of said electron beam line deflection devices located between said electron gun and said final aperture.

5. The invention according to claim **1** wherein said scanning waveform is a sawtooth waveform, said means for supplying said scanning waveform to at least one of said electron beam line deflection devices comprising means for supplying said scanning waveform to at least two electron beam line deflection devices.

6. The invention according to claim **1** wherein said scanning waveform is a sawtooth waveform, said means for supplying said scanning waveform to at least one of said electron beam line deflection devices comprising means for supplying said scanning waveform to at least said third electron beam line deflection device.

7. The invention according to claim **1** wherein said scanning waveform is a sawtooth waveform, said means for supplying said scanning waveform to at least one of said electron beam line deflection devices comprising means for supplying said scanning waveform to said two and said third electron beam line deflection devices.

8. The invention according to claim **1** wherein said electron beam line deflection devices comprise electromagnetic devices for deflecting said electron beam.

9. The invention according to claim **1** wherein said supplying means comprise a rectangular waveform generator and means connecting said rectangular waveform generator to supply a rectangular waveform to said two and said third electron beam line deflection devices.

10. The invention according to claim **9** wherein said scanning electron microscope employs interlaced scanning and said first and second sets of lines are interlaced.

11. The invention according to claim **10** wherein said scanning waveform is a sawtooth waveform, said means for supplying said scanning waveform to at least one of said electron beam line deflection devices comprising means for supplying said scanning waveform to at least said two electron beam line deflection devices.

12. The invention according to claim **11** wherein said scanning electron microscope includes a final electromagnetic lens, said third electron beam line deflection device also being located between said final electromagnetic lens and the object being scanned by said electron beam, and means for rotating the electron beam deflecting field of said third electron beam line deflection device relative to the electron beam deflecting fields of said two electron beam line deflection devices.

13. The invention according to claim **12** wherein said electron beam line deflection devices comprise electromagnetic devices for deflecting said electron beam.

14. The invention according to claim **12** wherein said third electron beam line deflection device is the only electron beam line deflection device between said final aperture and the object being scanned by said electron beam.

15. The invention according to claim **1** wherein said third electron beam line deflection device is the only electron beam line deflection device between said final aperture and the object being scanned by said electron beam.

16. A method for operating a scanning electron microscope of the type having an electron gun, a final aperture through which at least a part of said beam passes prior to impingement on an object being scanned by said electron beam and a longitudinal axis extending from said electron gun through said final aperture and through the object being scanned by said electron beam to enable said scanning electron microscope to generate signals that enable an image of the object being scanned by said electron beam to be viewed in three dimensions, said method comprising: (a) scanning said electron beam across the object being scanned in adjacent parallel lines, (b) between said electron gun and said final aperture and in addition to any deflection of said electron beam by said scanning (i) providing a field during the scanning of a first set of said lines which deflects an electron beam that is travelling from said electron gun through said final aperture on said longitudinal axis in a first path firstly away from said longitudinal axis and to one side of said longitudinal axis and lastly towards said longitudinal axis to intersect said longitudinal axis in the immediate vicinity of said final aperture and then to proceed away from said longitudinal axis but on the opposite side thereof and (ii) providing a field during the scanning of a second set of said lines which deflects an electron beam that is travelling from said electron gun through said final aperture on said longitudinal axis in a second path firstly away from said longitudinal axis and to said opposite side thereof and lastly toward said longitudinal axis to intersect said longitudinal axis in the immediate vicinity of said final aperture and then to proceed away from said longitudinal axis but on said one side thereof, and (c) between said final aperture and the object being scanned by said electron beam, and in addition to any deflection of said electron beam by said scanning, during said scanning of said respective sets of lines

providing fields which are of such a nature that, when acting upon electron beams travelling in the portions of said first and second paths that are beyond said final aperture, deflect electron beams travelling in the portions of said first and second paths respectively that are beyond said final aperture back towards said longitudinal axis to intersect said longitudinal axis at the object being scanned by said electron beam from both said one and said opposite sides thereof.

17. A method according to claim **16** wherein said scanning is interlaced and said first and second sets of lines are interlaced.

18. A method according to claim **16** wherein said scanning electron microscope includes at least one electron beam line deflection device and said scanning is accomplished by applying a sawtooth waveform thereto.

19. A method according to claim **16** wherein said scanning electron microscope includes a plurality of electron beam line deflection devices, at least a first and a second of said devices being located between said electron gun and said final aperture and a third of said devices being located between said final aperture and the object being scanned by said electron beam, said fields being provided by applying rectangular waveforms to said first, second and third electron beam line deflection devices.

20. A method according to claim **19** wherein said scanning is accomplished by applying a sawtooth waveform to at least said first and second electron beam line deflection devices.

21. A method according to claim **19** wherein said scanning is accomplished by applying a sawtooth waveform to at least said first and second electron beam line deflection devices by applying a sawtooth waveform to at least said third electron beam line deflection device.

22. A method according to claim **19** wherein said scanning is accomplished by applying a sawtooth waveform to at least said first and second electron beam line deflection devices by applying a sawtooth waveform to said first, second and third electron beam line deflection devices.

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