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(54) Title: MAMMOGRAPHY SYSTEM AND METHOD EMPLOYING OFFSET COMPRESSION PADDLES, AUTOMATIC COLLIMATION, AND RETRACTABLE ANTI-SCATTER GRID

(57) Abstract: A mammographic imaging system is optimized for use with a single fixed size flat panel digital image receptor. It accommodates compression devices (paddles) of varying sizes, and positions them properly in the field of view of the image receptor. When a compression paddle with size smaller than the field of view of the image receptor is used, the compression paddle can be shifted laterally in the direction parallel to the chest wall, so as to facilitate different views of different size breasts, and permit the image receptor to image as much of the desired tissue as possible. An automatic x-ray collimator restricts the x-ray illumination of the breast in accordance with compression paddle size and location in the field of view. An anti-scatter grid, mounted inside the image receptor enclosure, just below the top cover of the enclosure, can be retracted out of the field of view of the image receptor for use in magnification imaging.

## **Mammography System and Method Employing Offset Compression Paddles, Automatic Collimation, and Retractable Anti-scatter Grid**

### **Field**

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This patent specification is in the field of mammography and specifically mammography employing flat panel, digital x-ray receptors rather than x-ray film.

### **Background**

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X-ray mammography machines typically use an x-ray source mounted at one end of a rotatable c-arm assembly and an image receptor at the other. Between the x-ray source and the image receptor is a device for compressing and immobilizing a breast. Until recently, the image receptor was typically a screen-film (s/f) cassette, which generated an image related to the detected transmission of x-rays through the breast. These s/f cassettes typically come in standard sizes, e.g., 18 cm × 24 cm (small) and 24 cm × 30 cm (large), with the large cassette used when the breast is too large to be uniformly compressed by the small cassette. The cassettes are easily attachable and removable from a breast support tray of a conventional mammography system. The device for compressing the breast is often called a paddle, and comes in a variety of sizes to match both the cassette size and the breast size. Such matching is desirable because the use of a small size paddle on a large breast can result in uneven and inadequate breast compression and may not allow full-breast imaging, while using a large paddle on a small breast can impede access to the breast, which is important during the compression cycle in order to optimize the amount of breast tissue brought into the field of view of the image receptor.

New mammography systems are now being developed to use digital image receptors as replacements for the screen-film cassettes. These digital image receptors, sometimes called flat panel receptors, or flat panel digital x-ray receptors, are different in many ways from s/f cassettes. They have many advantages, but also tend to be heavier and

somewhat thicker. Typically, they are not designed to be removable in normal use, so a system normally will employ only one size image receptor. These characteristics can presents challenges for some imaging procedures and breast sizes, particularly for the mediolateral oblique view (MLO) taken as a part of typical breast x-ray imaging. As  
5 with screen-film systems, it is still advantageous to use a compression paddle that matches the breast size. This typically means that the compression paddles will be removable, and there will be a selection of paddle sizes available with the system.

A number of x-ray protocols have been used for breast imaging. One common view is  
10 the cranio-caudal (CC) view, illustrates in Fig. 5, which images the breast of a standing or sitting patient from above. Another is the mediolateral oblique view (MLO), taken from an oblique or angled view, and also illustrated in Fig. 5. In screen-film mammography systems, the compression paddle typically is centered relative to the proximal edge of the screen-film cassette. In some views, such as the MLO view, and particularly for smaller  
15 breasts, this may present some difficulty as the cassette may have to be pressed against the armpit in order to approximately center the breast relative to the proximal edge of the film (the edge closest to and parallel to the chest wall). In such cases, the smaller size cassette can be used. This, plus the relative thinness of the cassette, generally allow for adequate centering. However, when a digital x-ray receptor is used usually only one size  
20 is available, and it may be the size comparable to the larger size screen-film cassette. Also, the digital receptor tends to be thicker than a screen-film cassette. Thus, centering the breast can be difficult or impossible in some cases, particularly for the MLO view and patients with smaller breasts, with the result that optimal positioning of the breast may not be possible for some views and patients.

25 To applicants' knowledge, these and other issues regarding compression paddle use with flat panel digital receptors in mammography have not been solved and perhaps have not been even addressed. In a different setting, it has been proposed to move a compression paddle laterally, relative to the proximal edge of the screen-film cassette, but for the  
30 different purpose of aligning a cutout in the paddle with a particular portion of the breast. See U.S. Patent 5,199,056. This is believed to require a paddle larger that would

normally be used for the breast size so as to maintain even compression when the cutout is off-center relative to the breast. Other earlier proposals are known for features such as collimation that adjusts to film cassette size, source-to-image distance and/or cross-sectional area to be imaged (U.S. Patents 3,502,878, 3,863,073, 5,627,869, and 5 6,149,301), moving a paddle (U.S. Patent 3,971,950), moving a cassette (U.S. Patent 4,989,227), and retracting a cassette holder (U.S. Patent 4,559,641). The cited patents are hereby incorporated by reference in this patent specification.

### Summary

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An object of the disclosed system and method is to provide mammography that overcomes known disadvantages of proposals involving the otherwise desirable use of flat panel, digital x-ray receptors.

15 Another object is to employ compression paddles that match both the size and position of the patient's breast relative to the proximal edge of a digital x-ray image receptor so as to improve image quality, patient comfort and the ability of the health professional to position the breast optimally for imaging.

20 Another is to provide automated collimation control that changes x-ray beam collimation in accordance with one or more of the size and position of the compression paddle and of the breast, and the position of a breast platform relative to the receptor, preferably in response to information that is automatically sensed.

25 Another is to provide x-ray exposure control that is responsive to at least one of the size and position of the compression paddle, the position of the breast, and a pre-exposure x-ray measurement, preferably in response to information that is automatically sensed.

30 Another is to provide a scatter-suppression grid that is retracted for image magnification protocols, preferably automatically in response to sensing a breast position for magnification imaging.

These and other objects are met in a non-limiting example comprising a mammography system having a flat panel digital x-ray receptor, an x-ray source selectively emitting a collimated x-ray beam toward the receptor, and a compression paddle of a selectable size  
5 mounted for selective movement at least along a proximal edge of the x-ray receptor as well as along the x-ray beam. At least for selected breast x-ray protocols, a patient's breast is positioned off-center relative to the proximal edge of the x-ray receptor, and paddle of an appropriate size also is positioned off-center relative the same proximal edge to compress the breast for x-ray imaging.

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In addition, the system includes one or more of a number of other features. An exposure control can be responsive to information regarding breast thickness along the beam direction to control x-ray exposure for imaging. This information can come from a conventional auto-exposure sensor (AES) resulting from a pre-exposure, low-dose firing  
15 of the x-ray source from an output of the digital x-ray receptor during such pre-exposure firing, and/or from sensors for the relative positions of the x-ray source, the x-ray receptor, the compression paddle and/or the breast tray. The system can include a collimation control responsive to information regarding one or more of the size of the paddle, its location along the beam, its location relative to the proximal edge of the  
20 receptor, a desired field of view, magnification parameters, and the like. This information can come from appropriate sensors and/or can be input by the health professional carrying out imaging. The system can include a scatter-suppressing grid selectively movable between a position in the path of the imaging beam and a position outside that path (for magnification imaging). Again, information for controlling grid  
25 position can come from one or more different sources. And, the system can include a built-in or a separate viewing station receiving x-ray image information from the x-ray receptor and possibly from some or all of the sensors, processing it, and displaying the results as an image and/or in other forms.

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**Brief description of the drawing**

Figure 1 illustrates a partial side view of a mammography system imaging a patient's breast.

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Figure 2 illustrates the system also in side view but in more detail and in a magnification mode.

Figure 3 illustrates a lateral displacement of a small compression paddle along the proximate edge of the image receptor.

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Figure 4 shows three common positions of a small compression paddle relative to the image receptor.

Figure 5 illustrates two common x-ray protocols for breast imaging.

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**Detailed description of preferred embodiments**

Referring to Fig. 1, an x-ray source 1 is at one end of a generally C-shaped frame 7 and a flat panel digital x-ray imaging receptor 5 is at the other end. X-ray source 1 includes a collimator schematically illustrated at 40 to confine an x-ray beam 30 emitted from source 1 to a desired footprint at receptor 5, typically no larger than the area of receptor 5 and preferably just enough to image a patient's breast 3 or at least a selected part thereof, as compressed toward receptor 5 by a compression paddle 2 mounted on an arm 6 that in turn mounts to frame 7. A lower platform 11, often called a breast tray, is immediately below the breast, and a scatter-reducing grid 4 is between breast tray 11 and x-ray receptor 5 and is housed in the same enclosure 12 with the receptor. As is known in the art, frame 7 can rotate between horizontal and vertical directions of x-ray beam 30.

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In use for a CC view, paddle 2 and its supporting arm 6 are moved up, breast 3 is positioned on tray 11 and compressed by bringing paddle 2 down as needed. With suitable collimation by collimators 40 (which typically collimate in two directions, of which only one is illustrated in Fig. 1), beam 30 from source 1 images the breast onto  
5 receptor 5 and the resulting electronic image information is transmitted to a viewing station 22 (Fig. 2). The image typically is rectangular. Preferably, the collimation is such that beam 30 illuminates an area of receptor 5 just large enough to show the image of breast 3, or at least a selected part thereof. Importantly, different sizes and shapes of paddles 2 can be mounted to arm 6, and the paddle can be selectively positioned off-  
10 center relative to proximal edge 5a of receptor 5 (the left edge in Fig. 1).

Referring to Fig. 2, the system can operate in a magnification mode in which the relative positions along x-ray beam 30 of source 1, breast tray 11, and/or receptor 5 are adjusted to provide the desired image magnification. In this example, source 1 and receptor 5 stay  
15 in place but tray 11 slides up support 7 to a position spaced up from receptor 5, and the collimation of beam 30 is adjusted as needed. Note that for magnification imaging scatter-reducing grid 4 is withdrawn from the portion of receptor 5 that receives the desired breast image, because the angles of the grid septa typically are not suitable for a magnification view. If these angles can be changed to match the selected magnification,  
20 the grid can remain in place. Alternatively and if desired, a different grid that is suitable for the selected magnified view can be introduced in place of grid 4 in Fig. 1. Auto-controls 1a can include (a) an auto-exposure control coupled with an AEC sensor 24 and/or receptor 5 to receive exposure information in a pre-imaging firing of source 1, (b) an auto-collimation control to adjust the collimation of beam 30, (c) an auto-grid control  
25 to selectively withdraw grid 4, and (d) an auto-magnification control to adjust parameters for magnification imaging. AEC sensor 24 can be conventional separate sensor that helps determine imaging exposure parameters in a pre-imaging exposure of the immobilized breast at a low x-ray dosage. Alternatively, receptor 5 can be used for that purpose,  
30 eliminating the need for a separate AEC sensor, because the output of receptor 5 resulting from a low-dose pre-imaging exposure can provide the information for auto-exposure control. In addition, the output of receptor 5 in response to the pre-imaging exposure can

reveal the position of the breast relative to the receptor, and thus provide information for auto-collimation to confine beam 30 to a footprint that matches the breast even when the breast is off-center relative to proximal edge 5a. The auto-collimation control can be an arrangement sensing size and/or the position of one or more of breast 3, paddle 2, and tray 11, using respective sensors and automatically adjusting collimators 40 to confine beam 30 to the required cross-section and position. The auto-grid control can respond to a signal indicating that that magnification imaging will be carried out to withdraw grid 4, for example to the position shown in Fig. 2, using a motor 4a. This signal can come from information provided by respective sensors or it can be input by the health professional using the system. The auto-magnification control can be an arrangement responding the data entered by a health professional through viewing station 22, or in some other way, e.g., based on information from sensors to adjust the system elements involved in magnification. Information for the auto-controls can be provided in various ways. One is from sensors S that keep track of the size and position of paddle 2 along beam 30 and relative to proximal edge 5a of x-ray receptor 5, of the position of breast tray 11 along beam 30, of the position of grid 4, and the setting of collimators 40. Another is inputs from an auto-exposure sensor and/or x-ray receptor 5 resulting from a pre-exposure firing of beam 30 at low dose, with breast 3 in place for imaging. As is known in the art, the output of receptor 5 can be used to detect the position of breast 3 relative to receptor 5, or at least the approximate position of the breast relative to proximal edge 5a. Yet another possible source of information for the auto-controls is inputs from the health professional using the system, through a keyboard or other input devices in viewing station 22 or elsewhere. Information is exchanged between auto-controls 1a, sensors S, and viewing station 22 over appropriate links, shown schematically. Suitable arrangements, including encoders, motors (of which only motor M retracting and restoring grid 4 is expressly illustrated), and other control elements are included in mammography system 10 but, for clarity of the drawings, are not expressly illustrated.

Fig. 3 illustrates an example of an arrangement for positioning paddle 2 off-center relative to proximal edge 5a of receptor 5. While such off-center positioning can be used for other views as well, it is most important for views such as the MLO view. As seen in



Fig. 3, paddle 2 includes a rib 20 that has a channel slot 20a and is secured to arm 6 with a removable and adjustable lock or detent 21 that passes through channel 20a. In operation, the health professional selects a paddle 2 that is suitable in size and perhaps in shape to the breast to be imaged, removes any existing paddle 2 from arm 6 by pulling  
5 out or unscrewing detent 21, and installs the selected paddle 2 by securing it to arm 6 with detent 21 in a position relative to proximal edge 5a that matches the patient's breast's position. Any desired further lateral adjustment can be made by sliding paddle 2 along the direction of the proximal edge 5a, before or during compressing the breast for taking an image.

10

Figs. 4a, 4b, and 4c illustrate an alternate arrangement for lateral adjustment of paddle 2. Here a paddle 2 of a selected size and possibly shape is removably secured to arm 6, and arm 6 is in turn slidably secured to frame 6 to slide laterally, along the direction of proximal edge 5a of receptor 5. The term "lateral" is used here to designate movement  
15 parallel to, or at least generally along, the proximal edge 5a, even when the imaging plane of receptor 5 is oriented for an MLO view or is vertical. For example, Fig. 4a can illustrate a position of paddle 2 for an MLO view of the left breast, Fig. 4b can illustrate a position for a CC view, and Fig. 4c can illustrate a position for an MLO view of the right breast.

20

It should be clear than many other arrangements and variations will be apparent to persons skilled in the technology based on the disclosure in this patent specification and that the above embodiments are only some of examples embodying inventions whose scope is defined by the appended claims.

25

**CLAIMS:**

1. A method of imaging a patient's breast with x-rays comprising:  
5 providing a flat panel digital x-ray receptor having a proximal edge, and an x-ray source selectively emitting an x-ray beam toward the receptor;  
positioning a patient's breast between the source and receptor, off-center relative to said proximal edge, for imaging with said beam;  
compressing the breast toward the receptor with a compression paddle that is  
10 mounted off-center relative to said proximal edge, in accordance with the off-center position of the breast; and  
imaging the breast with x-rays emitted from the source and received by the digital receptor while the breast is compressed with said paddle.
- 15 2. A method as in claim 1 in which said paddle is removably mounted and including selecting a paddle according to the size of the breast and mounting the selected paddle before said compressing.
3. A method as in claim 2 including mounting the paddle for selective sliding  
20 movement in the direction of said proximal edge.
4. A method as in claim 3 including carrying out automatic exposure control responsive to information including information regarding a location of the compression paddle relative to said proximal edge.  
25
5. A method as in claim 4 including providing said information regarding a location of the compression paddle by automatically sensing paddle position parameters.
6. A method as in claim 1 in which the positioning of the patient breast comprises  
30 positioning the breast between said compression paddle and a breast tray that is between the paddle and the receptor and is mounted for motion relative to the receptor at least along said beam, and selectively positioning the paddle and tray

relative to the receptor for magnification imaging of at least a selected part of the breast.

- 5
7. A method as in claim 1 including collimating said x-ray beam at least in accordance a location of said compression paddle along a direction of said proximal edge.
8. A method as in claim 7 including additionally collimating said x-ray beam at least in accordance with a position of the breast for magnification imaging.
- 10
9. A method as in claim 7 including carrying out said collimating automatically in response to information provided by automatically sensing a location of said paddle along a direction of said proximal edge.
- 15
10. A method as in claim 9 including carrying out said collimating automatically in response to information provided by automatically sensing a position of the breast for magnification imaging.
- 20
11. A method as in claim 1 including positioning a scatter-suppressing grid between the breast and the receptor.
12. A method as in claim 11 including selectively withdrawing the grid for magnification imaging of the breast.
- 25
13. A method as in claim 12 including positioning a breast tray between the breast and said grid, said tray selectively movable away from the receptor toward the source for magnification imaging, and automatically withdrawing the grid in response to a selected movement of the tray away from the receptor.
- 30

14. A mammography system comprising:  
a flat panel digital x-ray receptor having a proximal edge;  
an x-ray source selectively emitting a collimated x-ray beam toward the  
5 receptor;  
a compression paddle removably mounted for selective movement at least  
along a direction of said proximal edge and along a direction of said beam;  
wherein at least for selected breast x-ray protocols a patient's breast is  
positioned off-center relative to said proximal edge and said paddle also is  
10 positioned off-center relative the proximal edge, according to said off-center  
position of the breast, to compress the breast toward the receptor for x-ray  
imaging.
15. A mammography system as in claim 14 including a slide-mounting arrangement  
supporting said paddle for selective movement along a direction of said proximal  
edge to match a position of said breast off-center relative to said proximal edge.
16. A mammography system as in claim 14 including a frame supporting said source  
and receptor, an arm supported on said frame and supporting said paddle for  
20 sliding movement at least in a direction of said beam and in a direction that is  
transverse to said beam and along said proximal edge.
17. A mammography system as in claim 14 including an exposure control responsive  
to information regarding at least a location of the compression paddle in a  
25 direction of said proximal edge.
18. A mammography system as in claim 17 in which said exposure control includes a  
controller for automatically controlling the x-ray source in accordance with said  
information.

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19. A mammography system as in claim 14 including an automatic exposure control sensor responsive to x-rays from said source illuminating the receptor to provide said information.
- 5 20. A mammography system as in claim 19 in which said automatic exposure control sensor comprises at least a portion of said receptor.
21. A mammography system as in claim 19 in which said automatic exposure control sensor is in addition to said receptor.
- 10 22. A mammography system as in claim 14 including a collimation control responsive at least to a location of said paddle in a direction of said proximal edge to control collimation of said x-ray beam.
- 15 23. A mammography system as in claim 22 in which said collimation control includes an offset position sensor providing information relating to location of said paddle in a direction of said proximal edge and a circuit responsive at least to said information from the offset position sensor to automatically control collimation of said beam in accordance with a location of the paddle to cause a footprint of the
- 20 beam on the receptor to be off-center in a direction of said proximal edge.
24. A mammography system as in claim 22 including a breast platform between said receptor and the patient's breast during imaging, and wherein said collimation control includes a magnification sensor sensing a position of said breast for
- 25 magnification imaging, and circuits responsive at least to the information from the magnification sensor to automatically control collimation of said beam in accordance therewith.
25. A mammography system as in claim 14 including a breast platform between the
- 30 receptor and a patient's breast positioned for imaging, and a scatter-suppressing grid movable between a position between the platform and the receptor and in the

path of at least a portion of the beam imaging the breast and a position outside said path.

- 5 26. A mammography system as in claim 25 including a magnification sensor sensing at least a location of one of said paddle and platform along the beam and a grid position control for moving the grid between said positions thereof in response at least to information from said magnification sensor.
- 10 27. A mammography system as in claim 14 including a viewing station receiving x-ray image information from said receptor and processing said information and displaying results of said processing.
- 15 28. A method of carrying out x-ray breast imaging comprising:  
providing a single-size, flat panel, digital x-ray receptor, said receptor having a proximal edge that is nearest a chest wall of a patient during x-ray imaging of a patient's breast;  
compressing a patient's breast between the receptor and a compression paddle such that the compressed breast is at a position selected to be offset from a center of said proximal edge; and  
20 imaging the compressed breast with x-rays collimated in accordance with said offset position of the breast such that a center plane of the x-rays that is perpendicular to said proximal edge is at a position selected to be offset from the center of the edge.
- 25 29. An x-ray mammography system comprising:  
a flat panel, digital x-ray receptor having a proximal edge that is nearest a chest wall of a patient during x-ray imaging of a patient's breast;  
an x-ray source selectively emitting a collimated x-ray beam toward the receptor;  
a compression paddle and a mounting arrangement for said paddle selectively  
30 moving the paddle generally along a centerline of said x-ray beam and

also along a said proximal edge, including to positions selected to be offset from a center of said proximal edge;  
said x-ray source collimating said x-ray beam such that said centerline of the beam is oriented in a direction related to a selected position of the paddle, including at paddle positions selected to be offset from a center of said proximal edge; and  
said collimation changing with changes in position of the paddle along said proximal edge.

- 10 30. A system comprising:  
an x-ray source selectively emitting an x-ray beam;  
a flat panel, digital x-ray receptor positioned to receive x-rays emitted from said source;  
said receptor having a proximal edge that is closest to a patient's chest wall during  
15 x-ray imaging of a patient's breast;  
a compression paddle mounted to selectively compress a patient's breast toward the receptor for imaging with said x-ray beam;  
said paddle being selectively positioned with a centerline thereof that is transverse to said proximal edge being offset from a center of the proximal edge; and  
20 said x-ray source collimating said x-ray beam to direct the beam in a direction related to the offset of the paddle centerline from the center of said proximal edge.

25

Fig 1

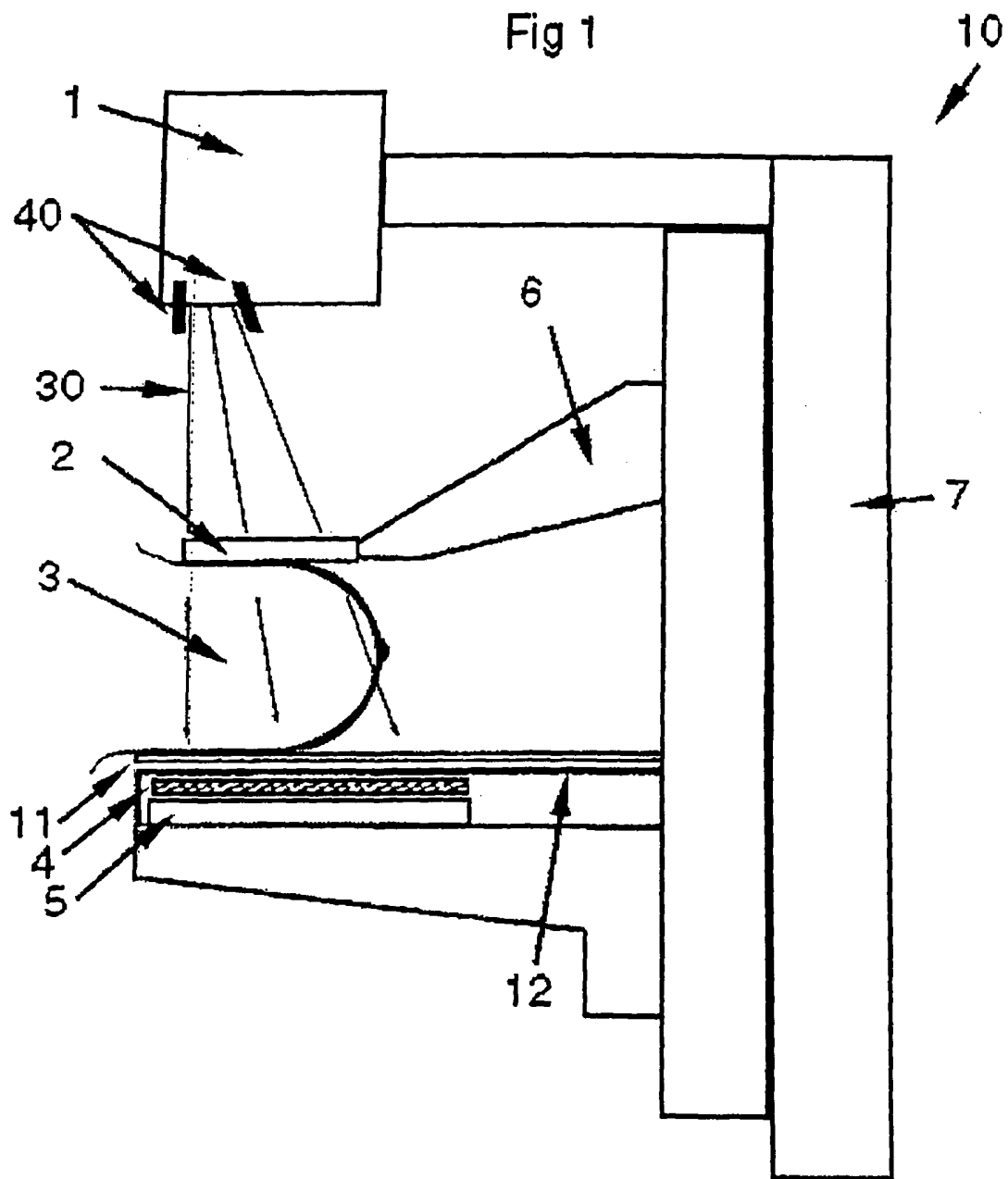
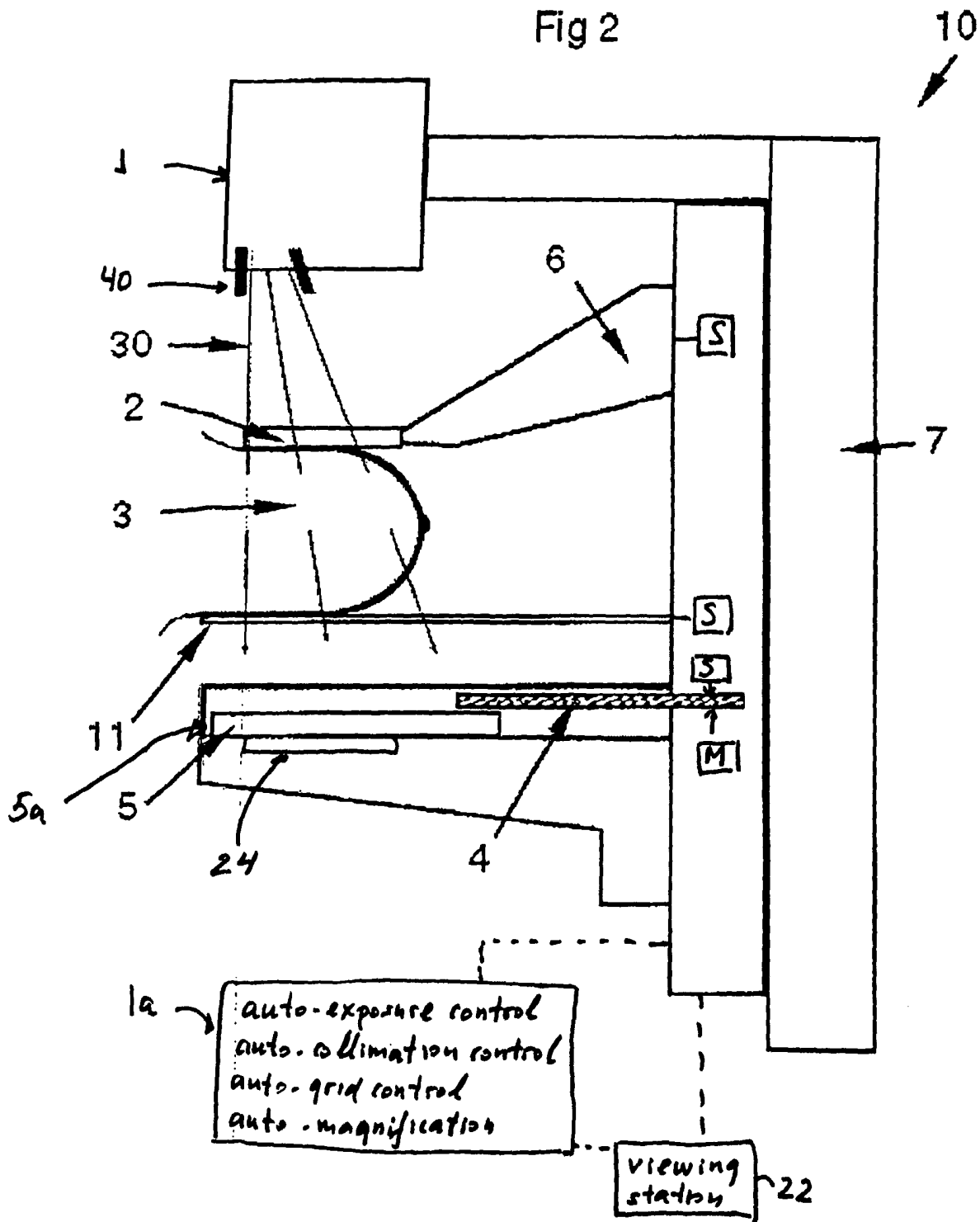
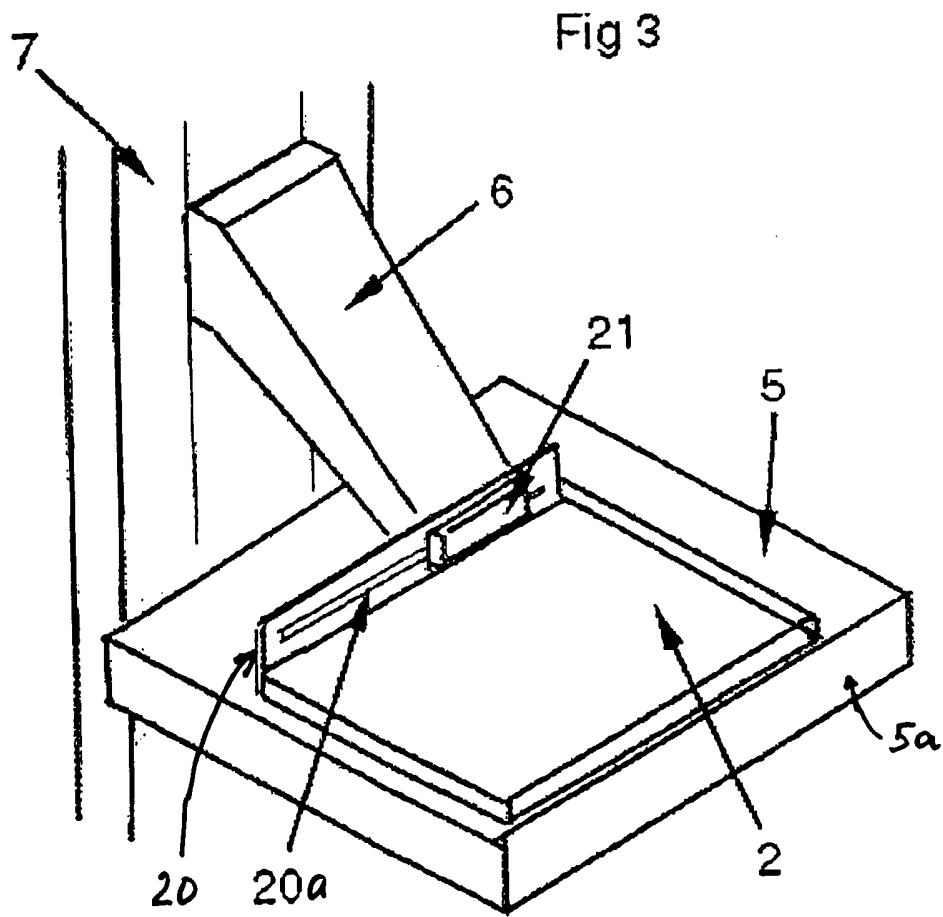
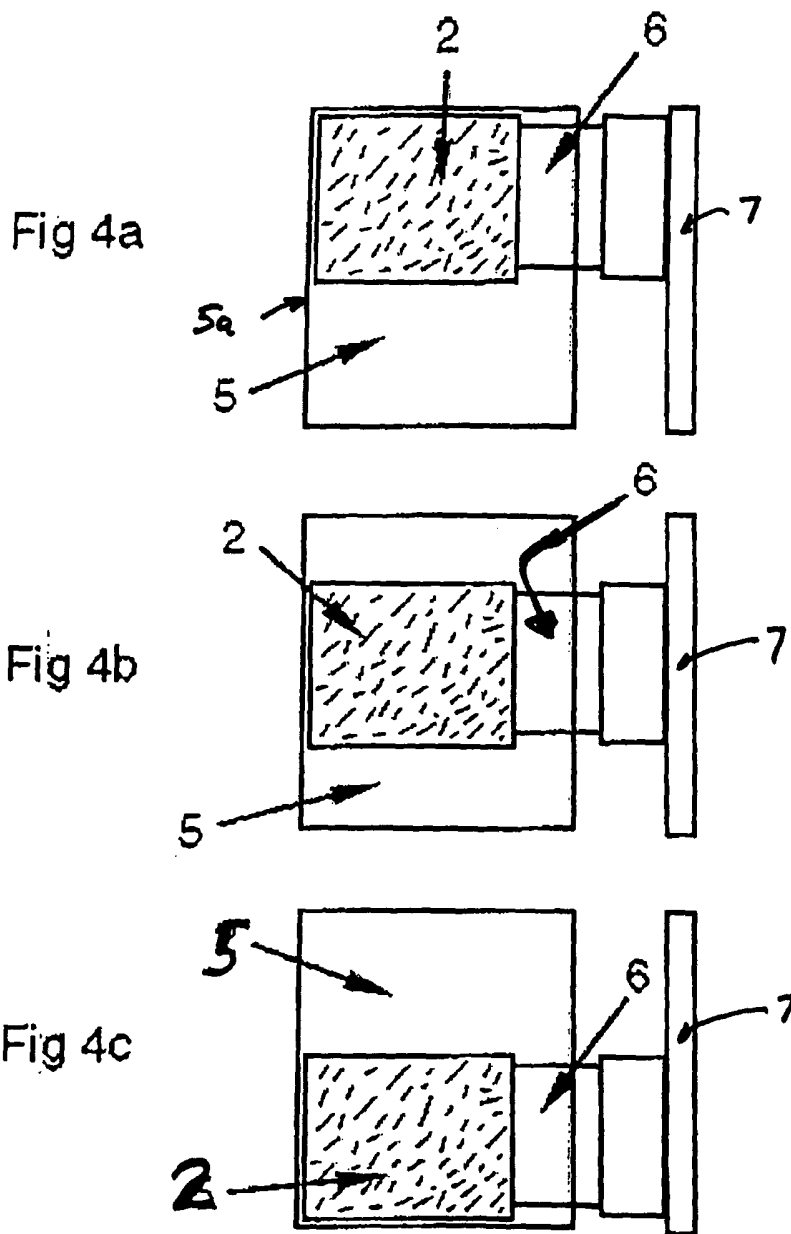




Fig 2







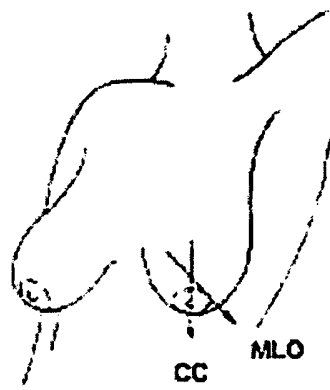


FIG. 5