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Experiment report

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Introduction

Beam time has been allocated on BM5 in September 1998, in order to check if mammography with synchrotron radiation is feasible on this beamline. These tests are connected with the experiments **MI** - 163 and LS - 884 performed on ID17 and called: “Effect of synchrotron radiation on image quality and dose in mammography”.

Beam time has already been requested on BM5 for the first semester of 1999.

The results obtained during these tests show that the beam on BM5 is homogeneous enough to obtain mammographic images. Moreover, enhancement of contrast and global image quality with lower surface dose compared with standard mammography have been demonstrated.

Phase contrast images of a 51 mm thick PMMA test object have been obtained, opening interesting possibilities of using this technique for mammography.

Material and method

Test object

The test object used in these tests is a 51 mm thick PMMA block with inserted objects. Its surface is 10 x 15 cm^2. There are objects used for subjective assessment of image quality, like pieces of marble simulating microcalcifications or acetate beads simulating masses, for example. The central part of the test object is used for the objective assessment of image quality. It contains a sharp edge for the resolution measurement, a sheet of 200 μm thick pure aluminium for the contrast measurement and an homogeneous region for the noise measurement. Figure 1 shows a schematic image of the test object.

Detector

The detector used is a standard mammographic screen film system. The screen is a Kodak Min R 2190 fluorescent plate and the film is a Kodak Mm R 2000. The films have been processed in a Kodak M6 processor, respecting the manufacturers prescriptions.

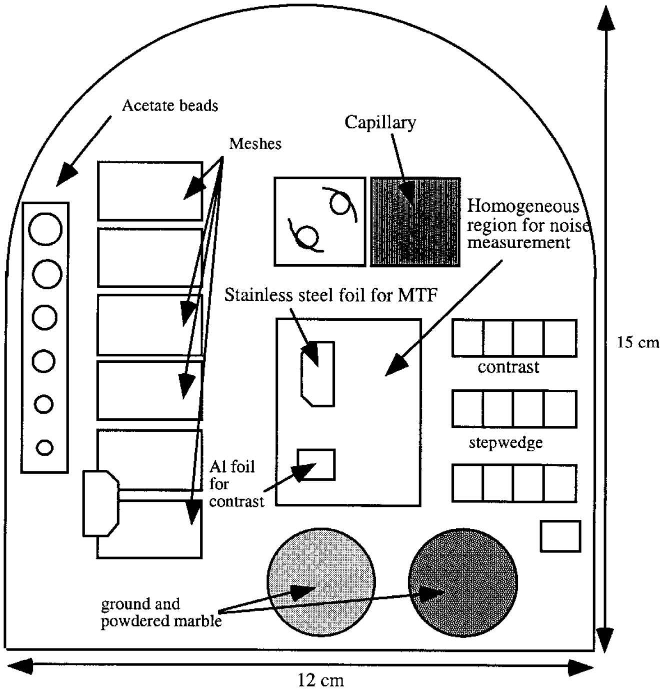

Figure 1: Schematic upper view of the test object used in these tests.

Experimental conditions

The beam was 0.3 mm height and 10 cm wide. Monochromatic beams of 16,20 and 22 keV were used. The test object and the screen film system were scanned vertically during the irradiation. Typical scanning duration were about 10 seconds. The distance between the test object and the detector could be varied from 0 to 115 cm. A slit of 5 mm height and 12 cm wide in 3 mm copper could be placed between the test object and the detector.

Dosimetry

The dosimetry was performed with LiF thermoluminescent dosimeter (TLD) of 0.38 mm thickness. The TLD were calibrated in our institute according to the DIN norm 6809, Tei14.

Two TLDs were placed on the surface of the test object for each irradiation. Most of the images were obtained twice. The measured surface dose is then an average of the response of four TLDs.

Image quality assessment

The image quality assessment of the mammograms obtained with our test-object is based on the statistical decision theory. It calculates the size of the smallest spherical calcification detectable at 99.7 % on the mammogram by a non-prewhitening matched filter observer. This quantity is given in millimetres and called IQI which stands for

Image Quality Index. According to its definition, the smaller the IQI computed the better the image quality. The precision on the IQI measurements is in the order ± 0.005 mm. This method is fully objective and has been described elsewhere [1, 2]. To obtain the IQI, three parameters of image quality must be calculated. First the contrast, which is obtained by measuring the difference between the average density of the film and the optical density due to an aluminium sheet inserted in the beam. Second, the resolution is evaluated by the way of the modulation transfer function, which is calculated in analysing the ability of the system to transfer the information from a sharp edge. Third, the noise is calculated in evaluating the Wiener spectrum, which is the noise power spectrum of the system.

Conventional images

Mammographic images were obtained on a conventional installation in order to compare the synchrotron radiation images with them. They have been performed on a General Electric CGR DMR mammographic unit, with a Molybdenum anode and a 30 μm thick Molybdenum filtration. Films have been obtained at 28 kV with a 5:l antiscatter grid.

Digitisation

In order to obtain the data needed for the objective assessment of image quality, the films must be digitised. The scanner we used is a Tango device from Heidelberg. The scanners resolution was set to 100 pixels per millimetre. The output image is obtained in a 16 bits TIFF format. The relation between optical density and grey levels is performed for each scan.

Results

The results concerning the standard technique of imaging (no phase contrast) were obtained always in the same experimental configuration: the test object and the detector were in contact, only separated by the copper slit.

The phase contrast images have been obtained with a gap of 1.15 meters between the detector and the test object.

Beam quality

The beam fluence was not totally homogeneous along the fan beam. This variation caused a change of the optical density along the image and it was taken into account when calculating the Wiener spectrum. However, the shape of the beam was not a critical problem. The flatness of the beam can be enhanced by adjusting the secondary slits of the beamline.

Lines of higher or lower optical density appeared along the scanning direction. They were due to the fact that the slits limiting the beam in height were not sharp edges. That problem was taken into account when calculating the Wiener spectrum, because it added high amplitudes at low frequencies in the spectrum. These lines can be eliminated by using other slits or by enlarging the height of the beam.

The harmonics of the beam were eliminated by slightly tuning the second crystal of the monochromator. The remaining proportion of harmonics in the beam were less than 3 % for the 20 keV beam and less than 6 % for the 16 keV beam.

Dose

The measured surface doses are presented in table 1.

Beam condition	Surface dose [mGy]
16 keV	11
20 keV	1.1
22 keV	**0.4**
28 kV with grid	**9.5**

Table 1: Surface dose for different beam conditions

These results show that a 16 keV synchrotron irradiation leads to a surface dose equivalent to a standard irradiation at 28 kV with an antiscatter grid. When the energy is set to 20 keV, the dose is lowered by a factor of 10. The results are consistent with absorption calculation and show that the surface dose can be greatly lowered when using synchrotron radiation.

Contrast

The contrasts obtained in the same experimental conditions than for the dose measurements are presented in table 2.

Beam condition	Contrast [mm^{-1}]
16 keV	1.85
20 keV	1.20
22 keV	**0.80**
28 kV with grid	1.30

Table 2: contrast measured with different beam conditions.

The contrast obtained at 20 keV is of the same order than the one obtain with a conventional mammographic X-ray tube. The contrast is enhanced by a factor of 1.5 when the energy of the beam is lowered to 16 keV. These results show that the contrast can be greatly enhanced when using synchrotron radiation.

Resolution and noise

No enhancement has been observed for the resolution and the noise measurements. However, the inhomogeneities of the beam could mask some improvement of these image quality factors.

Image quality index

The image quality index of different configurations have been calculated. They are presented in table 3.

Beam condition	IQI [mm]
16 keV	0.165
20 keV	0.190
22 keV	0.250
28 kV with grid	0.195

Table 3: Image quality index for different configurations. The lower the IQI, the better the global image quality.

The global image quality is much better with a 16 keV synchrotron beam than with a conventional X-ray tube. It is equivalent for a 20 keV beam.

Figure 2 show the IQI - dose relationship. At equivalent surface dose, the IQI is greatly improved when using synchrotron radiation. Conversely, at equivalent IQI, the surface dose is lowered by a factor of about 10. These are very promising results in the context of optimisation in the mammographic techniques [3].

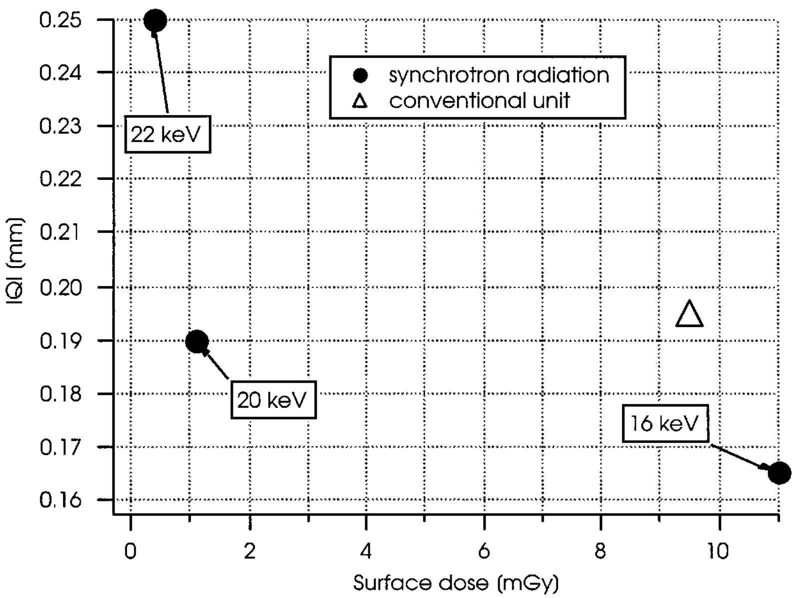

Figure 2: IQ1 versus surface dose for conventional and synchrotron radiation mammographic images.

Phase contrast

Phase contrast images of the test object have been obtained by placing the detector 1.15 metre away from the test object. These images demonstrate the feasibility of phase contrast imaging in mammography on BM5. Further developments, like the creation of a dedicated test object and an objective assessment method for phase contrast imaging, could lead to a new possibility of breast investigation method.

Conclusion

The possibility of lowering the entrance dose in mammography in using synchrotron radiation is demonstrated by these preliminary measurements,

The surface dose obtained at 16 keV is comparable to the dose obtained with a standard mammography unit with an antiscatter grid. In this case, the contrast is 1.5 times higher with synchrotron radiation. The surface dose can be lowered by a factor of 10 when passing from 16 to 20 keV, conducting to an equivalent contrast.

A much higher global image quality is achievable for the same surface dose with synchrotron radiation. Conversely, the same image quality index is achieved for a surface dose about 10 times lower when using synchrotron radiation.

Phase contrast images have been obtained. That open the possibility of further development on a phase contrast technique in mammography.

These preliminary tests clearly show the feasibility of mammographic imaging on BMS. They justify the demand of beam time allocation for the first semester of 1999.

References

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