Experiment Report Form

ESRF	**Experiment title:** Experimental validation and evaluation of x-ray phase contrast imaging simulator dedicated for breast imaging research	**Experiment number**: LS-2240
Beamline: ID17	**Date of experiment**: from: 4/09/2013 to: 10/09/2013	**Date of report**:
Shifts: 15	**Local contact(s)**: Dr Herwig Requardt	*Received at ESRF:*

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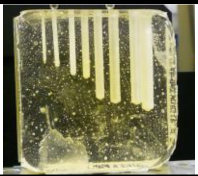
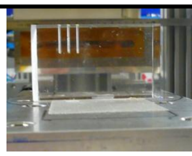
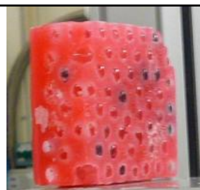
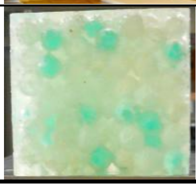
Report:

The purpose of the experiment was to acquire x-ray images in phase-contrast and absorption mode at different incident eneries and different in complexivity phantoms. Specifically, four main goals were set: 1. Validation of a developed software phlatform dedicated for simulation of phase-contrast images; 2. Measurents the characteristcs (δ and μ) for several new materials, which may be used as tissue equivalent materials when building a physical phantom dedicated for breast imaging; 3. Acquire images in phase-contrast tomosyntheis mode from different phantoms; 4. Acquire images in CT mode from different phantoms.

Prior to measurements at ID17, we prepared 16 physical phantoms from wax, PMMA, epoxy resin, polyethilene with included nylon wires, iodine and water channels, water and air spheres. Commersial phantoms dedicated for breast imaging: CIRS11A and CIRSBR3D were used as well. Some of these phantoms are shown in table 1.

Table 1. Physical phantoms used in ESRF experimentation.

Phantoms	Description	Picture	Phantoms	Description	Picture

Epoxy + air/water/iodine channels	phantom thickness: 2 cm		PMMA + air/water channels	phantom thickness: 4 cm	
Epoxy + nylon wires	phantom thickness: 2 cm		Paraffin +nylon fibers	phantom thickness: 2 cm	
Epoxy + silver powder	phantom thickness: 4.2 cm		Paraffin + water spheres	phantom thickness: 2.8 cm	
Epoxy +iodine inclusion	phantom thickness: 3.2 cm		BR3D	5 cm thick breast like phantom	
Epoxy + water spheres	phantom thickness: 3.7 cm		Polyethilene Cylinder	cylinder 10(diameter) x 20(height) cm	

1. For validation of a developed software platform for simulation of phase-contrast images, we acquired projection images at two incident energies: 25 keV and 40 keV and two distances between the object and the detector: 17cm and 11m. In this experimental task, 16 phantoms were used. Each phantom was scanned twice per energy: one image was obtained with less photon fluence, while the second one with five times greater photon fluence. All data were used in a study that included detail comparison of simulated and experimental phase-contrast images. The results of this extensive study have been included in a manuscript submitted to the journal of Computers in Biology and Medicine (CBM-D-14-00838) and is currently inder minor revision [1]. A snapshot of this experimental task is shown in Fig 1.

Fig 1. Epoxy resin phantom with air channels, scanned in absorption mode.

2. For the measurents of the characteristcs of several new materials which may be candidates for breast phantoms, we used 7 of the phantoms: epoxy resin, PMMA, epoxy resin with iodine inclusions, epoxy resin with Ag inclusions, polyethilene, silicone, CIRS 011A. Again two incident energies were used: 25 keV and 40 keV. The attenuation coefficients of these were measured. Simulation results were already published [2]. Presently, delta values are being evauated and a dedicated phantom is under development [3]. Fig. 2 shows an example of phantoms' imaging used to measure the absorption characteristics.

Fig 2. Imaging the phantom with the iodine inclusions.

3. For phase-contrast tomosynthesis we used 7 phantoms, placed at a distance of 11m away from the FReLoN CCD camera. For each phantom, four angular datasets of images were obtained at 25keV, 35 keV, 50 keV and 60 keV. Each dataset consisted of several scans (depending on the phantom size). Every one contained 90 images obtained in a ful acquisition arc of 360º, with a step of 4º. From all of these, 4 phantoms were chosen for evaluation of the phase contrast tomosynthesis, shown bellow in fig. 3. The manuscript is currently under preparation, while initial results were submitted to IMXP 2015 [4].

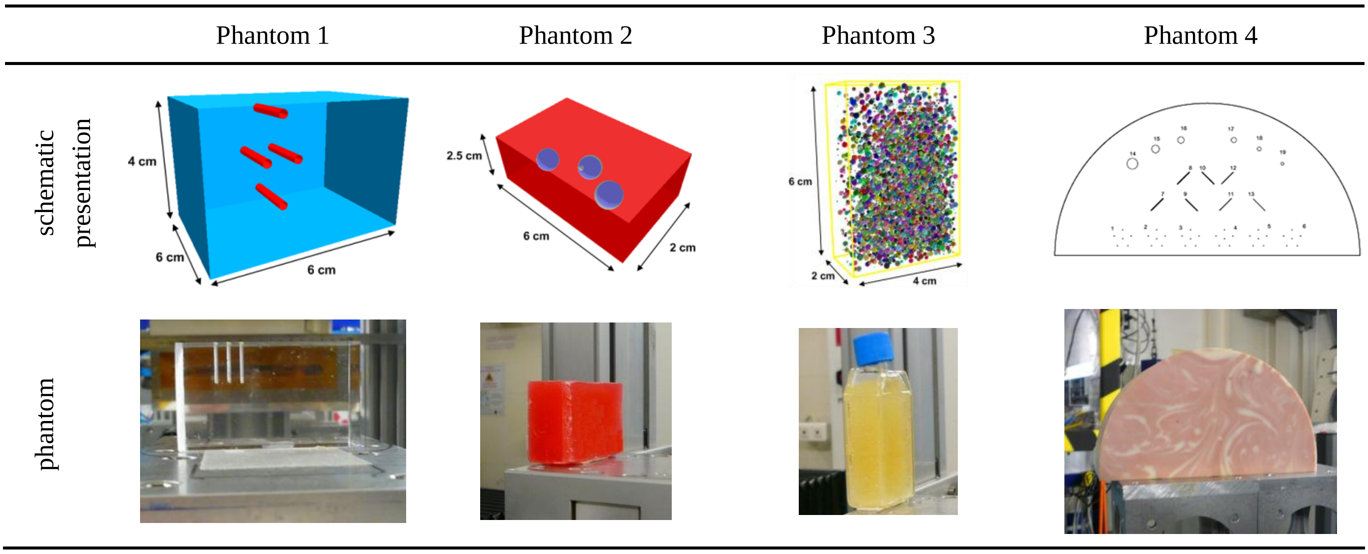


Fig. 3: Phantoms used in the research study. Phantoms 1 and 2 represent simple homogeneous phantoms with test objects inserted at different places as shown in the first row. Phantoms 3 and 4 represent complex objects used to test the phase contrast tomosynthesis.

4. For testing algorithms for in-line phase contrast CT breast imaging, we used three phantoms: CIRS BR3D, epoxy resin with introduced nylon wires, and polyethilene cylinder. The phantoms were placed on the rotational stage at a distance of 11m away from the detector (fig. 4). Two incident energies were used: 35 keV and 50 keV. The CT mode was realised with 2000 projection images per scan. Incident dose exposure was 1.4 mGy per image. The very first results demonstrated satisfactory outcomes as shown in the picture bellow. Further processing is still ongoing. The results will be used in a comparative study with phase contrast tomosynthesis.

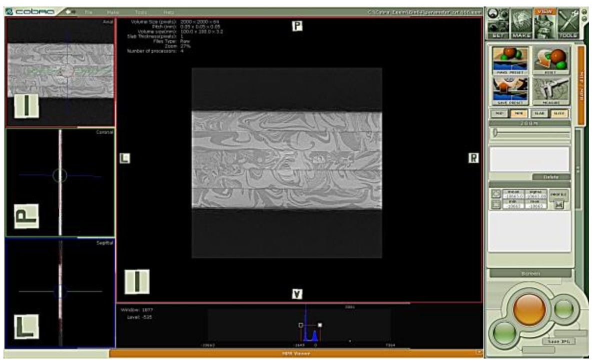


Fig 4: A screenshot from the software used in the Department of Physics, University of Napoli for reconstructions of CT images from CIRS BR3D.

References:

[1] Bliznakova K, Giovanni M, Paolo R, Requardt H, Popov P, Bravin A, and Buliev I, *A software platform for phase contrast breast imaging research*, Computers in Biology and Medicine, CBM-D-14-00838, under minor revision

Abstract:

Purpose: To present and validate a computer-based simulation platform dedicated for two- and three-dimensional phase contrast x-ray breast imaging research.

Methods: The software platform, developed at the Technical University of Varna on the basis of a previously validated x-ray imaging software simulator, comprises the modules for object creation and for x-ray image formation. These modules were updated to take into account the refractive index for phase contrast imaging as well as implementation of the Fresnel-Kirchhoff diffraction theory of the propagating x-ray waves. Projection images are generated in an in-line acquisition geometry. To test and validate the platform, several phantoms differing in their complexity were constructed and imaged at 25 keV at the beamline ID17 of the European Synchrotron Radiation Facility. The software platform was used to design computational phantoms that mimic those used in the experimental study and to generate x-ray images in absorption and phase contrast modes.

Results: The visual and quantitative results of the validation process showed an overall good correlation between simulated and experimental images and show the potential of this platform for research in phase contrast x-ray imaging of the breast. The application of the platform is demonstrated in a feasibility study for phase contrast images of complex inhomogeneous and anthropomorphic breast phantoms, compared to x-ray images generated in absorption mode.

Conclusions: The improved visibility of mammographic structures suggests further investigation and optimisation of phase contrast x-ray breast imaging, especially when abnormalities are present. The software platform can be exploited also for educational purposes.

[2] Bliznakova K, Buliev I, Bliznakov Z, Kolev N, Kolev J *Study of suitability of new materials for use with physical breast phantoms*, EHB 2013, IEEE Conference , 21-23 November 2013, Iasi.

[3] Bliznakova K, Giovanni M, Paolo R, Requardt H, Popov P, Bravin A, and Buliev I, *Comparative study of using three x-ray based techniques to image thick objects with application in mammography*, to be submitted to the Journal of x-ray science and technology.

[4] Bliznakova K, Requardt H, and Buliev I *Phase Contrast Breast Tomosynthesis at ESRF: A Phantom study*, submitted to the IXMP 2015.