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Studies of Multilayer Structure in Depth Direction by Soft X-ray Spectroscopy

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It has to be noticed that diffusion or chemical reaction of adjoining layers often occur in multilayers and their characteristics are affected. Therefore the investigation of the multilayer structure in depth direction is important. Such investigation is usually made by TEM (transmission electron microscope) observing cross sections. However this method is destructive against the samples. X-ray diffraction is a nondestructive method, but it is not easy to specify the materials at interfaces and in layers by the use of this method.

In this report, it is demonstrated that two kinds of soft X-ray spectroscopy are useful as nondestructive methods to investigate the multilayer structure in depth direction [1]. The first one is total electron yield (TEY) spectroscopy with angular dependence measurement. Using this method, it was found in the triple layers of LiF/Si/LiF that Si layers had a character of porous Si [2], and in triple layers of CaF_2/Si/CaF_2 it was found that CaF_2 segregated through Si layer [3]. The second method is soft X-ray emission (SXE) spectroscopy with spectral shape analysis. Using this method, it was found in Mo/Si X-ray multilayer that heating caused diffusion or chemical reaction giving rise to deterioration of reflectance character [4]. In antiferromagnetic Fe/Si multilayers it was confirmed that there did not exist pure Si layers, but $FeSi_2$ layers which are insulator. This suggested that the antiferromangnetic coupling is not originated from conduction electrons, but from quantum wave interference [5]. Furthermore, the application of standing wave generated in multilayers is introduced [6].

References

[1] M. Watanabe, T. Ejima, N. Miyata, T. Imazono and M. Yanagihara, *Nucl Sci Tech* (*China*) **17** (2006), 257.
[2] T. Ejima, *Jpn J Appl Phys* **42** (2003), 6459.
[3] T. Ejima, K. Ohuchi and M. Watanabe, *Jpn J Appl Phys* **44** (2005), 5171.
[4] N. Miyata, S. Ishikawa, M. Yanagihara and M. Watanabe, *Jpn J Appl Phys* **38** (1999), 6476.
[5] T. Imazono, Y. Hirayama, S. Ishikawa, O. Kitakami, M. Yanagihara and M. Watanabe, *Jpn J Appl Phys* **43** (2004), 4327.
[6] S.-H. Yang, B.S. Mun, A.W. Kay, S.-K. Kim, J.B. Kortright, J.H. Underwood, Z. Hussain and C.S. Fadley, *J Elect Spectr Rel Phenom* **114–116** (2001), 1089.

Bio-medical Imaging at the SYRMEP beamline of Elettra – First mammographic studies with patients

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On behalf of the SYRMEP Collaboration

The main purpose of the SYRMEP (SYnchrotron Radiation for MEdical Physics) research team at Elettra, the Italian Laboratory for Synchrotron Radiation (SR), is to investigate the use of innovative techniques for bio-medical imaging. In this framework, since 1997, a dedicated beamline from a bending magnet is operational. The high degree of coherence and intensity of the produced radiation has allowed us to implement novel *phase sensitive* imaging techniques, such as PHase Contrast (PHC) and Diffraction Enhanced Imaging (DEI), that can applied to different research areas, i.e. mammography, soft tissue imaging, studies of bones and cartilages, imaging of small animals, etc.

The successful results obtained by PHC mammography with *in vitro* tissue samples and test objects has led us to go ahead with the clinical validation of the technique on a restricted number of patients selected by radiologists, according to a predefined recruitment protocol. For this purpose an agreement among the local Public Hospital, the Trieste University and Elettra, has been recently established concerning the realization of a medical facility for clinical mammography at Elettra.

Patients' examinations are performed in a new radiological unit realized adjacent to the existing beamline. The safety system has been completely redesigned to guarantee the compliance with current radiation protection guidelines. Clinical trial started in March 2006.

A brief overview of the beamline highlights, the main features of the medical facility and the first studies with patients are presented.

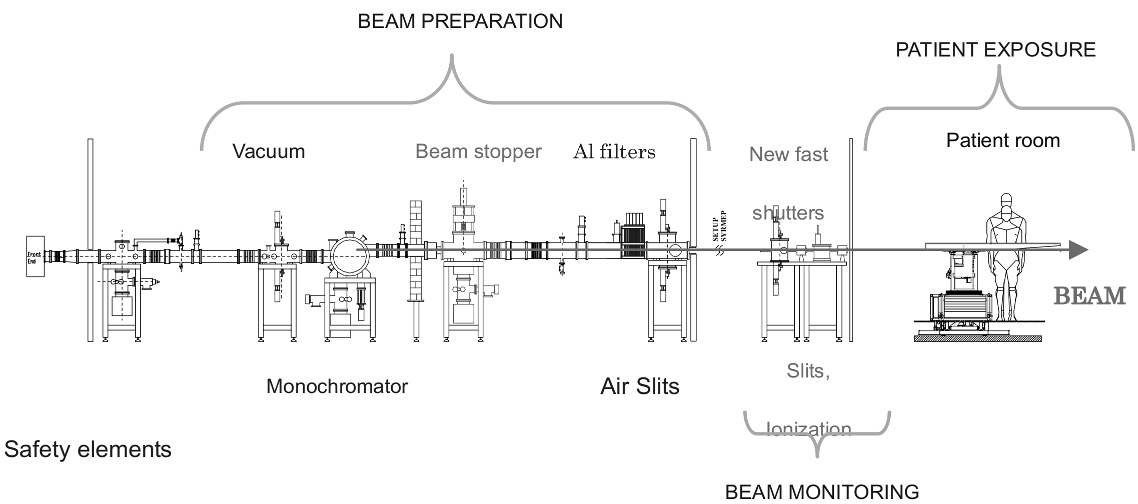

Fig. 1. Schematic view of the patient beamline.

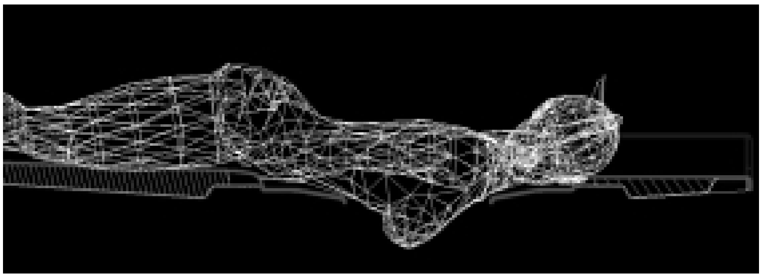

Fig. 2. Patient positioning.

Fig. 3. Patient and detector supports.

X-Ray Tomography at Beamline 2-BM of the Advanced Photon Source

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X-ray microtomography is becoming the tool of choice for three-dimensional (3D) imaging of thick structures at the 1–10 μm scale. The fast microtomography system developed at beamline 2-BM of the Advanced Photon Source (APS) offers near video-rate acquisition of tomographic data, pipelined processing and 3D visualization combined with fully automated and remotely controlled capability. At its maximum throughput, the system can image hundreds of specimens a day.

The entire instrument, including the tomography setup, beamline and a dedicated 32-node computer cluster for data analysis, is remotely accessible via Access Grid technology giving a user full remote control of every aspect of the experiment.

In this presentation we will describe the implementation of the tomography system at beamline 2-BM and present the major scientific applications in material and life science research.

The long path towards radiology with coherent x-rays

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The evolution from absorption-based radiology to techniques based on the (real part of the) refractive index is a fascinating topic. The history of synchrotron source began with a heavy emphasis on flux that only impacted longitudinal coherence in an indirect way. Then, the focus shifted towards brightness and emittance. The impact on lateral coherence was automatic but unnoticed by most synchrotron radiation scientists. Even the first results of refractive-index radiology were not identified as such. And, when refractive-index radiology became visible in the 1990s, it was invariantly stated that it was made possible by the characteristics of 3rd-generation sources – which in fact is wrong. The situation was further complicated by great difficulty in explaining the techniques to medical radiologists and therefore to the obstacles against an effective cross-fertilization. We will complete this historical overview by presenting simple modelling approaches that made it possible to understand the imaging mechanisms in elementary terms, and their practical impact such as the use of limited longitudinal coherence that opened the door to real-time experiments.

Digital and Phase Mammography

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X-ray imaging is an important modality in medical diagnosis. For over 100 years, diagnostic x-ray imaging is principally based on x-ray tissue attenuation. However, x-ray tissue contrast can also be acquired from phase-changes. Among several methods of x-ray phase imaging currently under investigation, the in-line phase-contrast technique can be implemented with polychromatic x-ray sources; it holds potentials for clinical applications including mammography. This presentation discuss the current analog and digital mammography systems, analyze the impact of phase x-ray imaging to breast cancer screening and diagnosis; and present the results of developing and characterizing prototype phase x-ray imaging systems under clinical conditions.

A Step Forward to a Clinical and Pathological Diagnosis of Breast Carcinoma Using 2D and 3D Refraction-based Visualization

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Following a clinical trial of intravenous coronary angiography we have been developing 2-dimensional (2-D) and 3-dimesional (3-D) x-ray imaging of breast cancer due to x-ray refraction. X-ray dark-field imaging (XDFI) [1] using a transmission type of angle analyzer (AA) with thickness of 2.124 mm for the field view of 90 mm x 90 mm [2] in a 2-D mode has been achieved for micro-papillary carcinoma [3] with the spatial resolution of 30 microns. Thinning of thickness of AA down to 125 microns can achieve the spatial resolution of 10 microns to provide views of isolated breast cancer cells and stroma of the same specimen [4]. That this contrast is based on Ca concentration was confirmed by x-ray fluorescence [5]. Furthermore a 3-D extension of breast cancer of ductal carcinoma has been successfully achieved [6] by the algorithm newly developed by us [7].

References

[1] M. Ando et al., *Jpn J Appl Phys* **41** (2002), L1016–L1018.
[2] M. Ando et al., *Jpn J Appl Phys* **43** (2004), L1175–L1177.
[3] M. Ando et al., *Jpn J Appl Phys* **44** (2005), L528–L531.
[4] M. Ando et al., submitted.
[5] M. Ando et al., *Jpn J Appl Phys* **44** (2005), L998–L1001.
[6] M. Ando et al., *Bioimages* **13** (2005), 1–6.
[7] A. Maksimenko et al., *Appl Phys Lett* **86** (2005), 124105-1∼124105-3.

From Coherent X-ray Phase-Contrast Imaging towards Incoherent X-ray Ghost Imaging

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Coherence is generally being considered necessary for phase contrast and diffraction imaging techniques. Recently, it was found that imaging and interference in a second-order correlation can be obtained with incoherent light, and this may found applications in the context of X-ray diffraction [1–4]. In the presentation, recent progress on X-ray phase contrast imaging study in SIOM [5,6] which now focus on eliminating incoherent scattering in clinic applications will be reported, and the preliminary experimental results on lensless ghost diffraction with incoherent light will also be introduced.

References

[1] J Cheng and S.S. Han, *Phys Rev Letters* **92** (2004), 093903.
[2] A. Gatti et al., *Phys Rev Letters* **93** (2004), 093602.
[3] G. Scarcelli, V. Berardi and Y.H. Shih, *Phys Rev Letters* **PRL 96** (2006), 063602.
[4] D. Zhang et al., *Opt Lett* **30** (2005), 2354.
[5] J. Cheng and S.S. Han, *Opt Lett* **24** (1999), 175.
[6] S.S. Han, H. Yu, J. Cheng, C. Gao and Z.L. Luo, *Review of Scientific Instruments* **75** (Oct. 2004), 3146.

Time-resolved in-line phase-contrast imaging

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The availability of partially coherent x-ray beams at synchrotron facilities or new micro-focus laboratory x-ray sources has enabled in-line x-ray phase-contrast imaging. Phase-contrast imaging have allowed for dramatic improvements in image contrast for samples that have negligible absorption contrast. While in-line phase contrast imaging is less sensitive than diffraction-enhanced-imaging or interferometry, it has the significant advantage in its simplicity and its ability to use wide-bandpass beams. This has allowed in-line phase-contrast imaging to be used for time-resolved measurements. At the 10 ms scale, this technique has opened up a new avenue of research for small animal physiologists. The internal biomechanics and dynamics of insect respiration and feeding have, for the first time, been directly visualized. These measurements have brought new insight to the field. At the 10????s level, this technique has been used to study the dynamics of automobile fuel injectors. Unprecedented time-resolved images of the plunger motion within the steel injector have been seen for the first time. At the 300 ns level, snapshots of cavitation and bubble implosion within the fuel spray itself have been seen. The present push is to capture images at the 100 ps time-scale.

Evaluation of the X-ray diffraction enhanced imaging in diagnosis of breast cancer

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The significance of the X-ray diffraction enhanced imaging (DEI) technique in diagnosis of breast cancer, and its feasibility in clinical medical imaging are evaluated. Different massive specimens including normal breast tissue, benign breast tumor tissues and breast cancer tissues are imaged with DEI method. The images were recorded respectively by CCD or X-ray film at different positions of rocking curve and processed with pixel-by-pixel algorithm. The characters of the DEI images of the normal and diseased breast tissues are comparatively analyzed. The rocking curves of double-crystal diffractometer with various tissues are also studied.

The differences in DEI images and their rocking curves are evaluated in early diagnosing breast cancers. DEI images can show the inside microstructures of various breast tissues but not need a large number of pathology slices. The refraction images show the microstructures of normal, benign and malignant breast tissues with the best clearness. The diffraction images have higher contrast than the absorption images and can show also microstructures inside the breast tissues. There are more abundant microstructures in the diffraction image recorded by X-ray films and magnified by optical microscope, but its imaging process is not as convenient as use of CCD. The differences of the integrated intensity of rocking curves are also possible to distinguish the normal, benign or malignant breast tissues. The DEI method might be valuable in diagnosing breast cancers in their early stage.

Tissue Phase-Retrieval Based on Phase-Attenuation Duality in X-Ray Imaging

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The propagation-based x-ray phase-contrast imaging has great potentials for sensitive and quantitative imaging of soft-tissue body-parts such as breast and brain. The phase-retrieval is the key to quantitative x-ray imaging. In order to retrieve a tissue phase-map, multiple phase-contrast images are needed in general. The limited stability of this retrieval-approach requires low noise-level for accurate retrieval. Moreover, it is desirable to find a way to retrieve the tissue phase-map from a single phase-contrast image for reducing the radiation dose and the artifacts associated with patient's involuntary motions. In addition phase-retrieval from a single acquired image will facilitate the 3-D phase-tomography and dynamic imaging.

Based on a new concept of the phase-attenuation duality, we show how only a single acquired image can be used for a successful phase-retrieval for inhomogeneous soft-tissues. In this talk the duality-based phase-retrieval formulas will be discussed in details. In addition we show how to extend the phase-retrieval formulas into cases of polychromatic and incoherent x-ray sources encountered in clinical imaging. The high robustness of these new retrieval algorithms will be rigorously established. Taking the mammography as an example, we show that this new phase-retrieval approach may result in striking enhancement of mammography contrast-noise ratio. The duality-based reconstruction formulas for 3-D phase-tomography will be presented as well.