THE USE OF BETATRON GAMMA-BEAM FOR DIGITAL RADIOGRAPHIC TECHNIQUE

A.R. Wagner*, A.P. Potylitsyn, V.V. Kashkovskiy, Y.N. Adishev, Tomsk Polytechnic University, Tomsk, Russia
S.A. Gorokhov, M.K. Polkovnikov, Yu.V. Rodnov, A.P. Vorobiev, R.E. Rydenko, Institute of High Energy Physics, Protvino, Moscow reg., Russia
G.I. Ayzenshtat, O.P. Tolbanov, Research Institute for Semiconductor Devices, Tomsk, Russia

Abstract

The problem of creation of the most effective high intensity x-ray radiation sources for a digital diagnostics in medicine and other fields remains actual till now.

In the work, experimental results on design of digital radiographic set-up based on the betatron MB-6 bremsstrahlung source are presented. Betatron has the following parameters: electron energy is 6 MeV, beam current is 100 nA, frequency is 50 Hz, dose rate on bunch axis is 35mG/minute at distance 1m, thickness of tantalum target is 0,6 mm. The set of 640 gallium arsenide detectors with size 0,2x0,2x2 mm^3 with sensitivity in photon energy range up to 200 keV was used. The digital images of investigated object have been received by scanning technique. The result obtained show that use of thin betatron target allows to avoid a self-absorption of bremsstrahlung photons with energy < 200 keV in a target. It will lead to increase in the detector sensitivity and reduce an exposition time to achieve high level image quality and pattern contrast.

INTRODUCTION

Wide introduction of digital radiographic diagnostic systems in medicine and non-destructing control techniques is connected firstly with development of various x-ray radiation source types, and secondly with detectors and the microelectronics development.

At present time one can use various x-ray radiation devices for the radiographic analysis purposes. The classical x-ray tubes operating at steady-state conditions are mostly widespread. For such tubes photon energy is defined by an anode voltage and the flux density depends on an x-ray tube cathode current. The most of modern x-ray tubes operates at photon energies 100-200 keV and cathode currents 10-120 mA. Radiation generation duration and tube life is defined by thermal dispersion capacity of the anode and by emission parameters of the cathode.

If one needs more intensive radiant flux for example for introscopy purposes one have to use x-ray a pulse devices which allow to receive short flashes of radiation due to formation of short high-voltage impulses or due to plasma stimulation processes at tube electrodes structure. X-ray emission duration is varied from about 10 to 500 nanoseconds. First disadvantage of such devices is high radiation energy and flux density instability. But taking into account the high value of these devices the main disadvantage is small tube life because of erosive processes [1].

Because of high flux density x-ray radiation sources needs one drew attention at compact pulse betatrons, the most suitable models possessing energy from 3 up to 15 MeV [2]. These devices generate high density fluxes and photon energy depends on a betatron design and therefore fixed. The main betatron advantages are a radiation generation duration, and setup life which is measured by tens years. However impulse operating mode and radiation flux density instability requires additional development, both of devices, and of registration and data gathering systems.

Considering the tendency of radiation sources development with the purpose of reception of greater radiation energies and flux densities, there appears a necessity of development of high effective and reliable radiation registration systems operating both steady and pulse sources.

REGISTERING MODULE

At Research Institute for Semiconductor Devices (Tomsk) the new semi-conductor materials based on material gallium arsenide (GaAs), possessing good radiation stability and high radiation registration efficiency were developed. The large atomic number and good radiation resistivity of GaAs material advantageously distinguishes these detectors by registration efficiency and by the spatial resolution from silicon semiconductor detectors. Character of these detectors is linear dependence of a detector current mean bias voltage which allows easy correction of parameters changes during dose accumulation process using electronic circuits. Detectors' response function made possible to construct the fast-acting pulse registration systems rejecting up to 95 % of noise [3]. The use of microstrip detectors, and electronic and analog microcircuits developed at Scientific Production Enterprise "Pulsar", allowed us to increase developed system registration efficiency up to 94% from general time of measurement (Fig 1). In this system detectors of direct transformation of x-ray radiation in an electric

* - BaronW@sibmail.com

signal are used. The set of 64 gallium arsenide detectors with size 0,2x0.2x2 mm^3 and with sensitivity in photon energy range up to 200 keV were used.

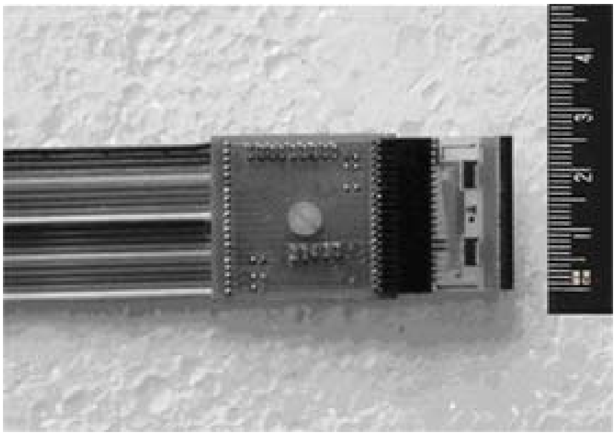

Figure 1: Image of microstrip detectors with microchip.

In recent years the Institute of High Energy Physics (IHEP, Protvino) developed digital x-ray tomography systems using semi-conductor detectors of resistive type based on gallium arsenide (GaAs) allowing to create highly effective systems of ionizing radiation registration both in pulse, and stationary modes. The advantage of these systems is received images' high resolution [4].

The gamma-quantum flux passed through an object is registered by a microstrip detectors' set which are joint into microstrip assemblage. With the purpose of increasing gamma-quantum registration efficiency microstrip detector is directed in the measuring module along gamma-quantum flux (Fig 2).

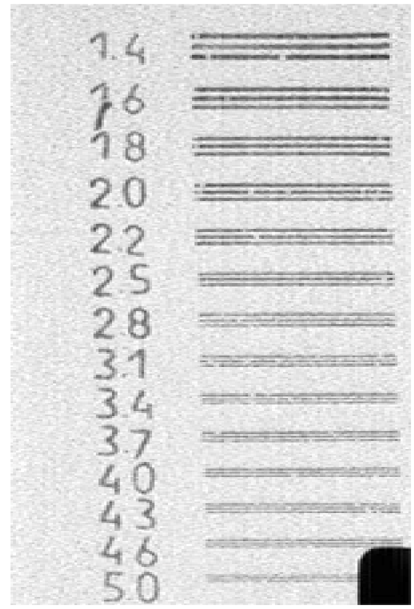

Figure 2: X-ray image of test object.

Structurally all microstrip assemblages are placed at a heat-chamber, cooled by Peltie elements up to temperature + 5 degrees centigrade. The object located between a source and the registering module, mechanically moves in a direction transversely to beam axis for fixed exposition time. Target signals from microchips are received by multiplexers then by registration module control unit, and then by inputs of ADC. The data is digitized and records at system RAM, and then at computer hard disk for the following treating (Fig 3).

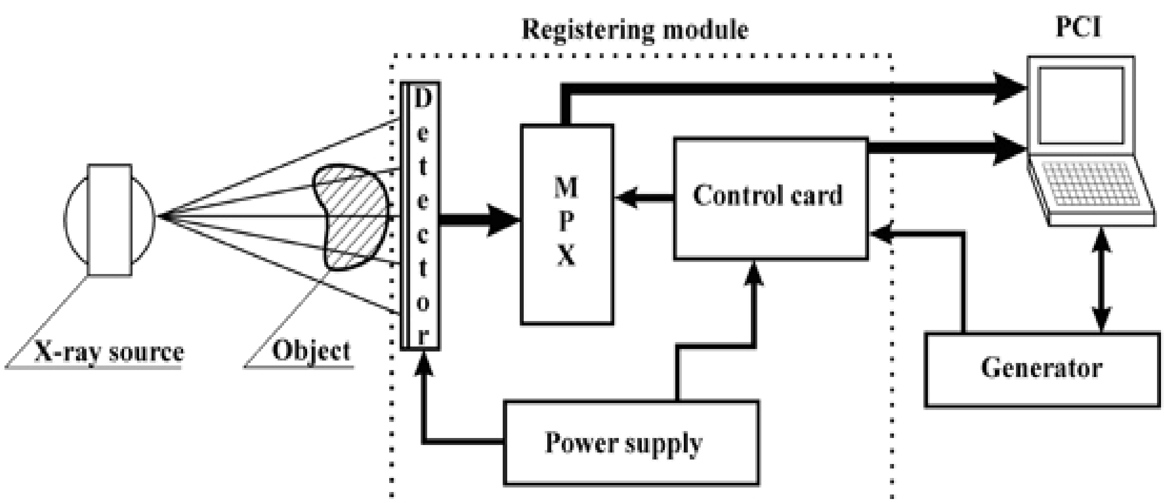

Figure 3: Flow block of system digital rontgenography.

Registration module operative control and synchronization with a radiation source is carried out by the control unit, which is capable to operate, both in stationary, and pulse modes of registration. Time of an exposition is setup by the external generator controlled by PC. Using this system images were received both in stationary, and pulse modes of radiation (fig. 4a, 4b).

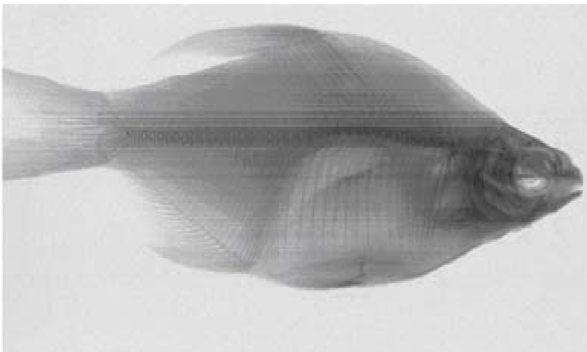

Figure 4.a: X-ray image of fish, exposition time is 40 sec, stationary mode, size image 125x315 mm.

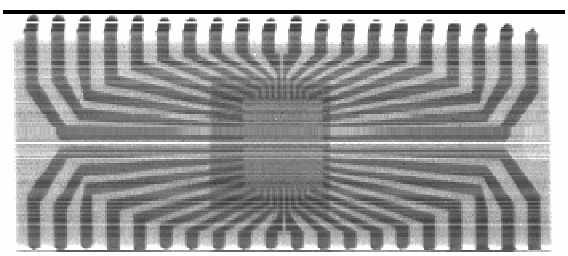

Figure 4.b: X-ray image of integrated circuit, exposition time is 20 sec, pulse mode, size image 25x75 mm.

At the Tomsk Polytechnic University with collaboration of IHEP scientists the digital images' registration system using x-ray source of high density was created. As an ionizing radiation source one choosed small-sized pulse betatron MB - 6 with electron energy 6 MeV, constructed at a Research Institute for Introscopy (Tomsk) [2].

Table 1: Betatron has following parameters

Electron energy	6	MeV
Beam current	100	ηA
Frequency	50	Hz
Dose rate on beam axis at distance 1m	35	mG/min.
Thickness of tantalum target	0,6	mm

Betatron is used as a source of bremsstrahlung. The registering module with a vertical arrangement of slit is located on the beam axis at the distance of 50 cm from the betatron target.

The remote controller allows to move the object fixed on it in a horizontal plane. The system of digital registration of the image is launched in a pulse mode synchronously with the betatron. Exposition time of one picture area makes 13 μs.

For first measurement 5 microstrip assemblages with 640 channels were used as the registration module. Using this system the image of the lead plate in the sizes 20x100 mm and 1.5 mm thickness was received (fig. 5).

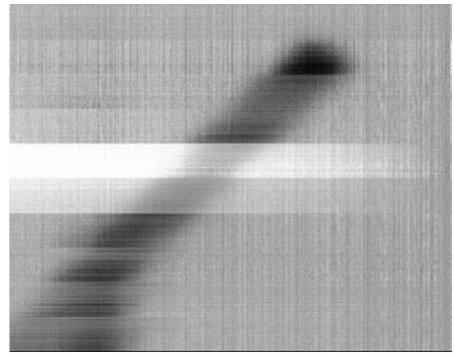

Figure 5: The X-ray image of lead plate, exposition time is 1 minute, pulse mode, X-ray source is betatron, size image 125x200mm.

CONCLUSION

We tested the x-ray image system on the bremsstrahlung beam of X-ray tube and betatron in a pulse mode. In case of using betatron as radiation source unsatisfying quality of the received roentgenogram is determined by the lack of the collimation and voltage stabilization systems, and by using full gamma-quantum spectrum. For image quality improvement and for opportunity of receiving complex objects' images one planes to lead a number of actions:

1. Update of registering module and betatron synchronization control electronic elements.
2 Stabilization of the betatron power supply for suppression of pulsing constituent of radiation intensity.
3. Installation of betatron radiation field collimating system.
4. Replacement of a target (bremsstrahlung converter) by more thins one what allows to increase soft x-ray part in a bremsstrahlung spectrum.

It is obvious, that realizing these actions the quality of x-ray image will improves and this allows to carry out further experiments of digital rontgenography system development for purposes of this technique application for medicine and introscopy.

REFERENCE

[1] H. Aichinger, J. Dierker, M. Sabel, S. Joite-Barfub "Radiation Exposure and Image Quality in X-Ray Diagnostic Radiology", Springer, 2001, p. 270

[2] http://inri.tpu.ru

[3] G.I.Ayzenshtat, E.A.Babichev, S.E.Baru,V.R.Groshev, G.A.Simonov, O.P.Tolbanov, A.P.Vorobiev, Nucl. Instrum. and Meth. in Phys. Res. A 509 (2003) p 268-273.

[4] http://www.ihep.su