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Development, creation and producing of the automatic systems for the radioscopic testing of the materials and components

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The investigations of the X-ray introscop on base of the CCD-camera and luminescent screens - X-radiation converters CsI(Tl) for the nondestructive testing in energy range up to 6 MeV were done.

The problem of development of high-efficient systems of digital radiography (SDR) for the wide X-radiation energy ranges is primarily conditioned by the problems of radiation detecting and converting it into a visible image for the subsequent digital processing. The principal difficulty here is the comparatively high penetration rate of X-radiation in the energy range up to 6 MeV. On the one hand it must be possible to test objects of large thickness and on the other hand the radiation converter – scintillation screen should be relatively thin in order to perform the effective detection.

Most of the existing and developing SDR employ the classic layout (Fig.1). It consists of the X-radiation source, betatron, the luminescent screen, the radiation converter, turning mirror, lens, CCD-camera, controller, and computer with software for image processing.

Since X-radiation with energy up to 6 Mev has high penetrability and produces rather weak radiation contrast, the development of SDR with digital image processing and with high contrast sensitivity presents a relatively complicated scientific and technical problem. For successful solution of this problem the all elements of SDR should provide the maximum detection efficiency, radiation and light image contrast, and the minimal level of scattered radiation.

Usually the SDR is considered to consist of two principal units. The first is the X-Ray image detector and the second is an image processing unit. The former is located in the irradiated region and includes a scintillation screen, mirror, lens, shielded CCD-camera, and controller. The latter is located in a radiation safe room and includes a digital interface and a computer with software for image processing.

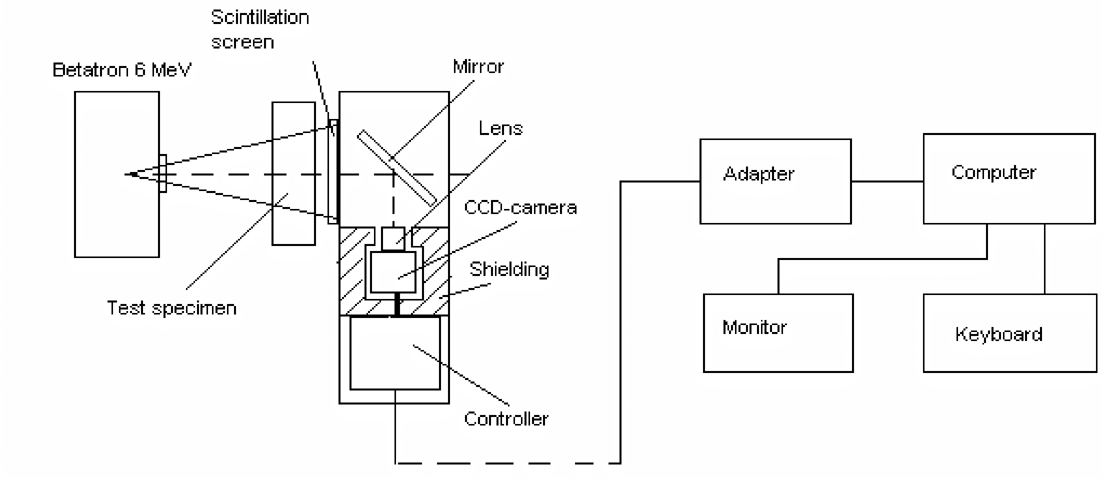

Fig. 1. Scheme of the SDR on base of CCD-camera

Currently three types of screens are used for conversion of high-energy radiation to visible image. There are scintillation screens based on single crystal CsI(Tl), polycrystalline luminescent screens on various phosphor compositions, and fiber screens made from luminescent glass doped with Tl. However, according to [1] fiber screens have no advantages over other types of screens for energies above 1 MeV. Besides, the high-energy X-rays cause radiation damage of the fiber scintillation material.

To determine the conversion efficiency of screens having various compositions the dependence of the fraction of X-ray quantum energy F deposited in a luminescent screen versus the incident quantum energy E was calculated according to the technique described in Ref. [2]. All calculations were made for the phosphor screen thickness of 500 μm and CsI-Tl single crystal screen thickness of 5 mm. The results are given in Table 1.

From the table it follows that phosphor compositions which are most efficient in terms of deposited energy are CsI-Tl, Gd_2O_2S-Tb and $PbW0_4$. For the quantum energy range 5-20 MeV the energy deposited in $PbW0_4$ being twice as large as that in CsI-Tl. However, taking into account that the phosphor $PbW0_4$ is still under development and has relatively low luminescent yield, the screens which are in most common use are those based on Cs-Tl and Gd_20_2S-Tb.

In this work the SDR with 5-mm-thick single crystal CsI-Tl screens with diameter of 200 mm and also polycrystalline CsI-Tl screens with dimensions of 200x400 mm^2 and a 1-mm-thick Pb substrate has been developed.

Table 1.
Conversion efficiency of screens with various compositions

Screen material	$F(E)\cdot 10^{-4}$		
	5 MeV	10 MeV	20 MeV
ZnCdS-Ag	0,32	0,26	0,2
$BaSO_4$-Eu	0,37	0,3	0,22
CsI-Tl	0,5	0,4	0,3
Gd_2O_2S-Tb	0,8	0,65	0,5
$PbWO_4$	1,1	0,9	0,7
CsI-Tl Single crystal 5 mm	46	38	29

To obtain the maximum image contrast and a low background rate of scattered X-rays a radiation sensitive unit with the following design features has been developed. The mirror consisted of a plastic substrate on which a layer of Al was sputtered. The objective ‘Avenir’ 75/1.3 was employed. The CCD-camera was shielded with 20-mm-thick Pb layer. The CCD-camera controller was mounted inside of an X-ray sensitive unit. The photo-sensitive array of the sensor consists of 1160×1040 pixels with dimensions of 16×16 μm. The sensor is installed inside of a gas-filled metal housing of the DIP type with Peltier micro-cooler, that enables one to maintain the temperature -35°C. The controller sets the accumulation mode for the low contrast images, maintain the present temperature of the sensor, reads the accumulated charge, and transmit the obtained signal to the adapter via a 20-m-length cable. The adapter consequently receives the signals from every sensitive cell, convert them into 12-bit code and provides its input into the computer via a parallel port using the EPP-protocol. The control for the scanning process, as well as correction and digital image storage is performed using the DIADA software.

The experiments in which the 50-mm-thick steel specimen X-rayed with 6 MeV betatron radiation have shown that the usage of SDR with 5-mm-thick single crystal CsI-Tl screen allows the detection of a 0.2-mm-deep groove standard #2 (according to Russia State Standard GOST-7512-82). Grooves with deep of 0.4 and 1.0 mm can be detected in steel specimens having thickness of 100 mm and 150 mm, respectively, yielding the sensitivity of the SDR of 0.4 to 0.7% in steel thickness range of 50 to 150 mm.

Thus, the usage of SDR can completely replace the X-ray film during testing specimens with big thickness.

Also in Introscopy Institute of Tomsk Polytechnical University a radioscopic testing system has been developed for the on-line quality inspection and a technical diagnostics of the listed products of the most crucial objects of the gas-and-oil producing industry both in shop and field environments. It permits defect's detection directly at place of welding and other manufacturing works, marks its positions and produces repeated control after repair and reconditioning of the gas-and-oil producing equipment.

The diagnostic system is a X-ray TV-unit, mounted on a lorry. The unit consists of the three parts: the remote X-ray sensitive module (X-module), image visualization, processing and storage module (IP-module), mount and moving mechanism (MMM).

The system working principle based on conversion of the X-radiation energy to the visible image on a luminescent screen of X-module during the testing object irradiation. The system is compatible with any type of X-ray unit.

The X-raying of a weld is realized with the stepwise movement the X-ray source and X-module, which are fixed on the testing pipe. The weld image is observed by operator on the video monitor. The documentation of the inspection results is made by a videotape recorder or computer, which are in IP-module package. The digital video-processor from the IP-module package is meant for numeralization and averaging from 4 to 256 TV-frames. It permits to reject irregular interferences and increases a signal-to-noise merit.

The transformed to analog representation, processed video-signal from the video processor is sent to monitor where the operator makes a visual analysis of the weld image and conclude about its quality. If it is necessary, the testing results are documented by recording the images to video cassette or by computer to a digital storage media.

During radiogram analysis the operator detects an existing defects and a weld quality. After 5-15-seconds-duration exposure the next part of a testing weld is fixed by moving mechanism. During one exposure the 90-150 mm length of weld is checked for various diameter pipes. X-module is able to work under temperature range (-20...+40)° C.

The future improvement of SDR permits to check quality of the variety objects like pipeline welds, pressure vessels, composite materials and also a different objects of double functionality at place of its production and storage.

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