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TECHNICAL NOTE

Development of X-ray scanning system Sowa

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Abstract. The new vehicle scanning system Sowa has been developed in the National Centre for Nuclear Research. This innovative device is equipped with a 300 kV X-ray tube, U-shape imaging detector line, transport system, and fully shielded container. Sowa allows for a detailed inspection of the car and the detection of illegal transported items. This article presents the design, applied solutions, and achieved results of Sowa scanning system.

Keywords: Cargo scanning • X-ray imaging • Dual-energy imaging

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Introduction

National Center for Nuclear Research (NCBJ) actively works on the development, production, and marketing of medical and industrial accelerators. From 2008 to 2013, a special project AiD – "Development of specialized systems using accelerators and ionizing radiation detectors for medical therapy and detection of hazardous materials and toxic waste" has been carried out at NCBJ. As a part of this project, a demo system CANIS for cargo scanning purposes was developed. CANIS consists of a linear, interlaced-energy electron accelerator, control systems, and line of detectors along with visualization software. It can be used for X-ray control of the contents of transported cargo – sea- and air-containers as well as lorries, depending on the configuration.

Since the coefficient of radiation absorption depends on the type of material and radiation energy, it is possible to identify the type of transported materials because of dual-energy X-ray scanning. This information is usually presented on the images using colour palette.

The way of fast energy switching in linear electron accelerators is based on the original solution patented by the NCBJ in 2009 [1].

Examples of achieved images are shown in Fig. 1, whereas the whole system is shown in Fig. 2 [2].

AiD project allowed to gain a lot of experience in scanning of various objects, imaging the interior of containers and vehicles, X-ray propagation in lateral or up-down configuration, and the imaging software and dual-energy identification of transported substances.

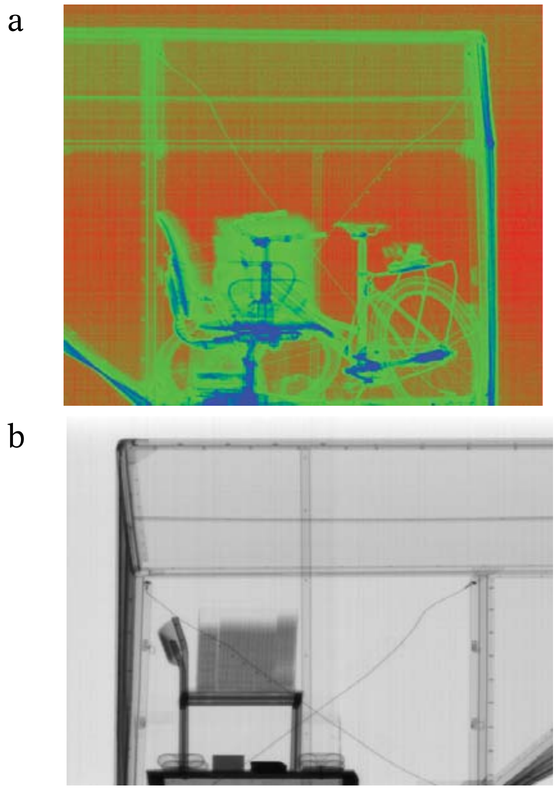

Fig. 1. Some examples of images obtained by CANIS.

Based on that a new system, called Sowa, has been built. After detailed studies of the requirements of everyday cargo scanning procedures, it appeared that the most attractive device would be much lighter scanner, fully shielded, dedicated to personal vehicles, and ready to operate not only at

Fig. 2. Design (a) and realization of the CANIS (b).

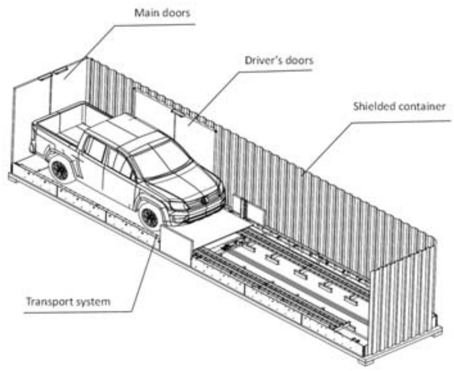

Fig. 3. Main elements of the Sowa scanning system.

the borders but also on the entire territory of the country, for example, near high-ways, sports arenas, etc. Therefore, the Sowa scanner has been designed in a closed container that equipped with all necessary subsystems inside [3].

Sowa

The general view of the Sowa system is shown in Fig. 3. Sowa scanning system is based on a sea-container. It can be easily transported by a regular truck for cargo container transport.

The control procedure is typically performed in the following way.

Before scanning, the driver should drive a car into the container through the main doors on a special, movable platform.

Since the X-ray scanning is performed without any person inside, the driver shall leave the container using the side doors. The operator of Sowa system can begin scanning when both the main and side doors are closed. Platform with the car is remotely shifted along the container, while X-rays generated from X-ray tube and formed into a fan-beam, scans the vehicle at the top–down plane in combination with linear imaging detector mounted under the floor. X-ray tube voltage can be regulated from 150 kV to 300 kV before the scanning, and it depends on the vehicle type and/or the load inside. The cars' side visualization is enhanced with a special "U" shaped detector line. In Sowa, 0.4 mm pixel size linear detector arrays are installed based on 0.5 mm thick GOS ($Gd_2O_2S:Tb$) scintillator and attached photodiodes. Detectors work in the current integration mode with 14 ms integration time.

Signals from detectors are sent to the operator's PC, where the final image is created and displayed immediately after the scanning for further analysis. Due to complete shielding, with the dose rate below 1 μSv/h in any place outside the container, no special excluding zone is required during the scanning process. The operator of the system and other people close to Sowa are completely safe at all the time.

After the scanning, the controlled car returns to the entrance gate on the platform, thus the system does not require any road behind the container. The whole process, i.e., scanning and returning to the platform, takes about 120 s.

Mechanical design

During the scanning process, the controlled vehicle is placed on the platform made up of low X-ray absorption material, while the platform is moved along roller lines. There are three sets of rollers: main, left, and right. Side rollers can be adjusted to provide platform alignment against the driving belt and clearance elimination. The platform was specially designed to avoid any metallic elements like screws or fittings that could be visible on the final image. Only the platform's base material is moved through the scanning area by an electric motor with a toothed belt.

To avoid overloading the belt, the electromagnetic lock is fixed in the platform in the initial position when the car is driven-in or driven-out of the container. There are two limit switches on each of the marginal platform positions. By using two switches on each side, it is possible to provide a soft start and soft finish of the working move. Main and side doors are equipped with electromagnetic locks, and limit switches protect the container against the opening when scanning is in progress.

To keep radiation level below 1 μSv/h at any point around the container, Monte Carlo calculations were performed for optimal shielding design.

The example of radiation calculations is shown in Fig. 4.

As one can see there is a lot of scattering radiation (green) that can affect the final image by lowering the contrast. Thus, special attention was given to design a proper collimating system. It consists of two collimators. The first one is located close to the X-ray tube, to form a fan-shape beam and irradiate only a narrow part of the scanning vehicle, while the second one limits the angle acceptance for radiation hitting the detector.

The maximum dimensions of the scanned vehicle are 5000 mm (length) × 2105 mm (width) × 2500 mm (height) for standard sea-container.

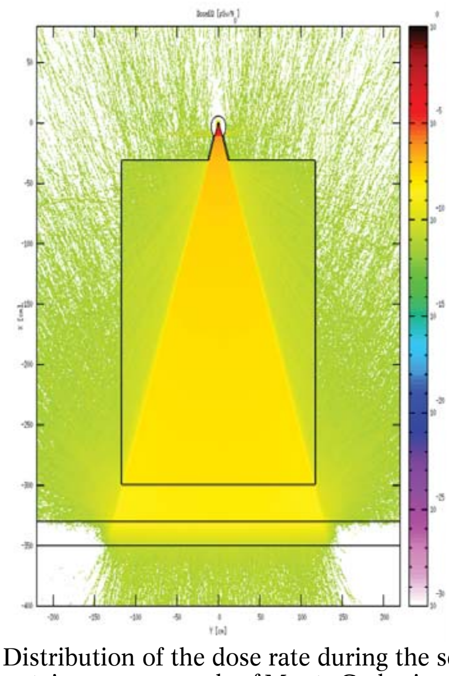

Fig. 4. Distribution of the dose rate during the scanning of the container – an example of Monte Carlo simulations.

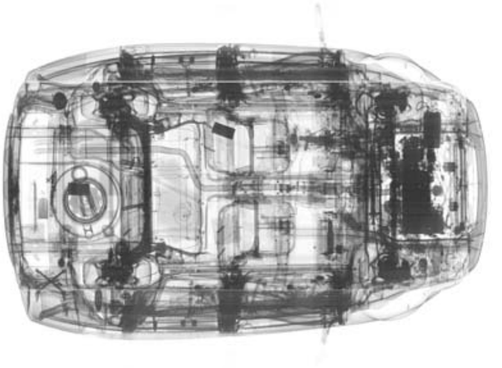

Fig. 5. X-ray image generated by the Sowa.

Imaging software

Specially designed software is equipped with digital image processing functions, such as auto-brightness and contrast, pseudo-colour, differential filter, sharpening, and others. The software also allows us to zoom some interesting elements and saves scans with comments for efficient archiving and uploading the data.

Achieved results

Sowa delivers an excellent image of controlled cars with a 0.4 mm resolution. An example is shown in Fig. 5.

Such quality allows for the detection of smuggling materials or other illegal items, such as weapons, drugs, alcohol, cigarettes, and modifications of vehicle's construction. The system can also perform dual-energy scanning, which helps in the identification of organic materials. Two different energy spectra have been obtained using Sn or Cu filtering directly on the detector line. No significant difference was found between these two filters, and the exact identification of the material was not possible due to the presence of metal in any place of the scanned vehicle. Example of coloured dual-energy scan is shown in Fig. 6 with the following colour-coding: orange – lowest Z range, green – middle Z range, and blue – high Z materials.

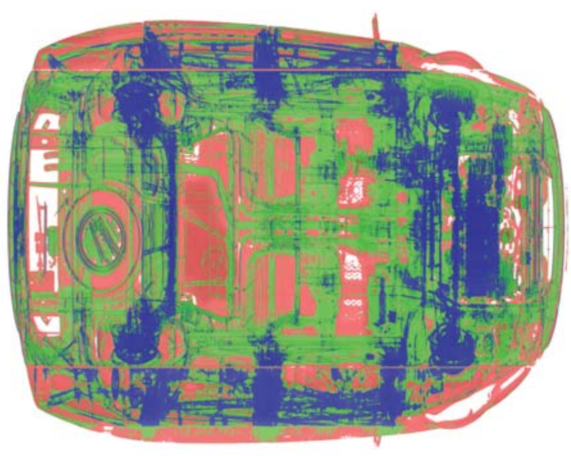

Fig. 6. Colour image generated during a dual-energy scan.

Summary

The new vehicle scanning system Sowa has been developed, built, and tested in the National Centre for Nuclear Research. Clear X-ray images of the vehicles have been obtained. Thanks to proper radiation shielding, Sowa can operate in standard public localizations. Presented development is a continuation of an electron linac-based cargo scanning system, but designed for lighter vehicles, thus operates at lower X-ray energies.

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