

1.4.3. FEASIBILITY STUDY OF X-RAY DIFFRACTION FOR A PORTABLE INSPECTION SYSTEM

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The work we present has been performed in the frame of a multi-partners research project, whose aim is the validation of a novel portable imaging system for the characterization of dangerous/illicit materials inside objects. The system combines two X-ray techniques: the dual-energy tomosynthesis and the energy-dispersive diffraction. The latter has been chosen for its utility in the detection of narcotics and a wide range of explosives as pointed out elsewhere [1 – 6]. In the diffraction modality, measurements are performed by translating the source and the sub-system output collimator/detector. The detector is based on CdZnTe semiconductors, which can provide energy resolution (DE / E) of about 3% @ 90 keV [7] at room temperature.

We report here the optimization study for the system specifications in the diffraction modality. In order to select the experimental conditions (the high voltage of X-ray source, the “diffraction” angle q , the angular resolution Dq / q , the collimators design, ...) best suited for the system purposes, a multi-parametric simulation study has been performed.

A model based on the kinematic theory of diffraction has been defined. The model considers the geometry of fig. 1, where a “suspected object” is positioned in the middle of a 40 cm deep baggage. The latter is irradiated with a collimated beam and the diffraction profile is measured at a fixed angle q by a CdZnTe detector. In the model we take account of : the angular resolution of both incident and diffracted beams, the X-ray tube spectrum, the detector energy resolution, the collimators geometry and the beam attenuation introduced by the baggage. Several simulations for different materials have been carried out. As an example, fig. 2 shows the diffraction spectra of Tetryl ($C_7H_5N_5O_8$) obtained in the ideal and real conditions. The real spectra are characterized by a finite resolution Dx / x which, in the small angle approximation, can be written as

$$Dx / x = ((\lambda E / E)^2 + (\lambda \theta / \theta)^2)^{0.5} \quad (1)$$

where x , the momentum transfer parameter, is given by

$$x = \sin(\theta / 2),$$

with λ the wavelength of the diffracted beam. In computing the fig. 2 spectra, two cases were considered: the angular resolution (Dq / q) corresponds respectively to a proportion of 0.30 (a) and 1.70 (b) of the detector energy resolution (DE / E). In the second case, the material principal characteristics peaks start to melt together rendering the material identification a more difficult task (note that no noise has been added to fig. 2 spectra). This part of the simulation study was devoted to the system angular resolution identification. A possible interval comprised between 2% and 5% has been retained.

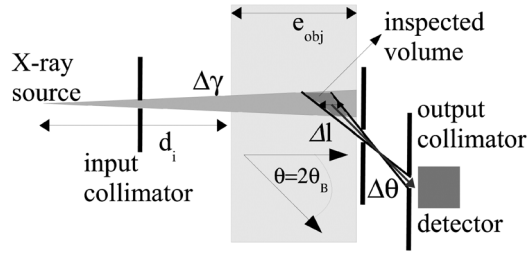
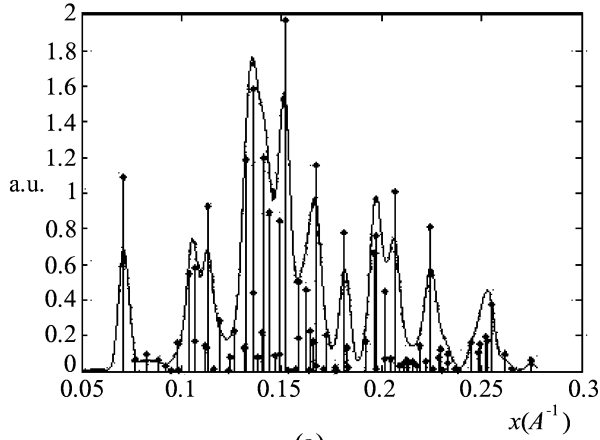
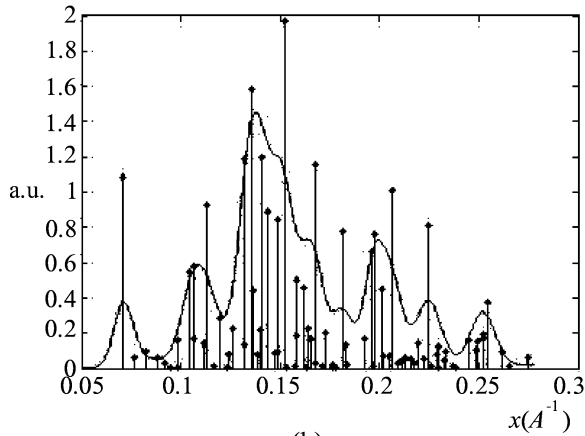


Fig. 1. Geometry for the diffraction modality



(a)



(b)

Fig. 2. Tetryl diffraction spectra. The ideal spectra (blu line) are compared with the real (red line) ones for two cases: the angular resolution (Dq/q) corresponds respectively to a proportion of 0.30 (a) and 1.70 (b) of the detector energy resolution

Some of the other most relevant results can be summarized as follows: (i) a small working angle ($\sim 3^\circ$) is necessary in order to investigate big/attenuating objects. (ii) The number of detected X-rays will be improved if the total angular resolution is equally shared out between the source and detector collimators. (iii) The choice of the collimation length is a compromise between the desire of a compact system and the spatial resolution of the inspected volume.

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