APPLICATION OF ACCELERATED PARTICLES FOR EXPLOSIVES IDENTIFICATION

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At the present time the problem of an explosive detection independent on outer shell presence or its composition, including a plastic explosive, is urgent in context of terrorism and enormous quantity of minefields that are left after wars and local armed conflicts. Explosive detection in the passenger luggage, cargo, and demining is an acute global problem that requires elaboration of new detection principles.

A distinctive feature of all kinds of powerful chemical explosives is an anomalous nitrogen content (from 18% to 43%). There is a some correlation of nitrogen, carbon and oxygen content. These features can be useful to identification of explosives.

Currently many physical methods of an explosive detection are known. For instance:

The improved X-ray methods:

Two beams method allows one to determine the absorption coefficients.

Compton back scattering together with conventional X-ray method allows one to detect the light materials.

Detecting the explosive evaporation.

Nuclear quadrupole resonance (NQR) is a technique in RF spectroscopy, which is based on the observation of RF signals from nitrogen [1]. It allows to identify some explosives, but now it is insufficiently advanced.

Visualization of the hidden subjects by X-rays scanning was proposed by authors [2, 3]. This method is similar to positron annihilation tomography. It uses X-rays with the energy lower than thresholds of nuclear reactions.

The nuclear elemental analysis is more promising for explosive detection. The neutrons and high energy photons are used for excitation of nuclear reactions on explosive elements. This in turn leads to the generation of characteristic γ-rays, that allow one to identify these elements.

There is a simple method based on an electron accelerator. The accelerated electrons strike a heavy metal target producing bremsstrahlung radiation with endpoint energy equal to the electron beam energy. The gamma-beam interacts with the explosive nitrogen and excites a photonuclear reaction $^{14}N(\gamma,n)\,^{13}N$. The stable nitrogen isotope ^{14}N converts to radioactive isotope ^{13}N, which then decays with a 10 min half-life via positron emission to ^{13}C. The positron immediately annihilates producing two 511 keV photons that are easily detected using standard scintillation detectors. A threshold of the $^{14}N(\gamma,n)\,^{13}N$ reaction is about 10.6 MeV. Other elements in explosives and soil have photonuclear reaction thresholds above 13 MeV, as shown in Fig.1, produce no positrons, or have very short half-lives. Table lists the reaction thresholds for any elements and half-life of corresponding daughter nuclei (β^+ decay).

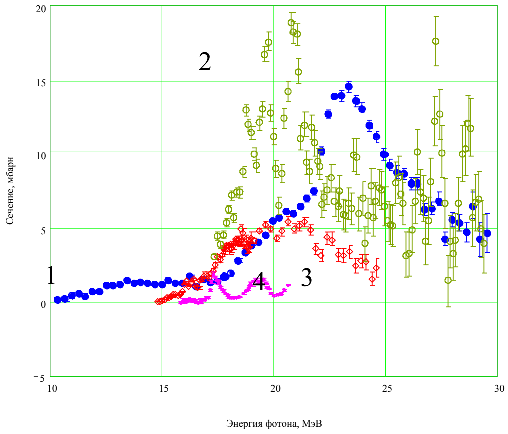

Fig. 1. Cross sections of (γ,n) reactions in ^{14}N - 1, ^{28}Si - 2, ^{27}Al - 3, ^{16}O - 4.

Element	Threshold	Daughter nucleus	Half-life (β^+ decay)
^{14}N	10.6	^{13}N	10.1 min
^{16}O	15.7	^{15}O	Stable
^{27}Al	13.1	^{26}Al	6.7 sec
^{28}Si	17.2	^{27}Si	4 sec

Thus, an optimal accelerator for this method is the RF linac with electron energies of 13.5-14 MeV for the gamma-beam producing. A portable linac can be mounted on a remotely controlled vehicle for demining [4] or placed in airports for inspection of the baggage.

The bremsstrahlung spectrum is very broad and is distributed from small energies up to energy of an electron, but only energies, that are higher than a threshold of the photonuclear reaction $^{14}N(\gamma,n)\,^{13}N$, are useful. An electron penetrating in a target dissipates its energy, and eventually riches a threshold energy.

The electrons with energies lower than 10.6 MeV are useless because the radiation, generated by them, creates only unnecessary background. This in turn leads to the restriction of the target thickness. This thickness is determined by energy losses in the target. Calculations show that for tantalum target it is equal approximately 0.18 of the radiation length. Actually this thickness can be less because multiple electron scattering in target leads to small increasing of a gamma flux density with increasing of the target thickness. In addition to this, near threshold cross-sections is very small, and the reaction yields are negligible at this energy region (near to 10.6 MeV).

We propose an elaboration of this method both for demining and for airport inspection purposes in Ukraine on the base of advanced acceleration technique at the National Scientific Center “Kharkov Institute of Physics and Tecnology”.

The possible version of the demining system similar to [5] is shown in Fig. 2.

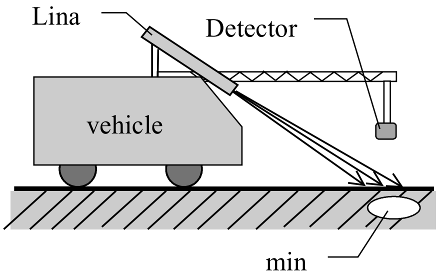

Fig. 2. The proposed remotely controlled system for a mine detection.

Irradiation expositions are carried out periodically. The detection of the annihilation gamma-quanta from ^{13}N is carried out during the pauses, therefore immediate gamma-quanta from processes of electron-positron pair production are not detected.

This system with sliding detectors can provide a detection of explosives at the distance. Instead of local metal target we consider a possibility to use air as target too. The required beam power depends on a distance to a mine and an explosive amount, and it can be equal 1-10 kW.

The possible version of the airport inspection system is shown in Fig. 3.

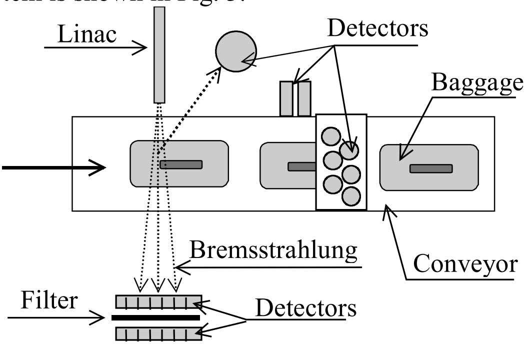

Fig.3. The airport inspection system.

This system can provide simultaneously several images of luggage contents. A sensitive detector array provides a three-dimensional image of activity concentration of the nitrogen. Detectors, which have high efficiency in a soft X-ray region but low efficiency for a high-energy X-ray, can map a distribution of the physical density similar to a conventional method. The use of two detectors, which have different sensitivities in different spectral regions, allows us to realize a two-ray method for measurements of absorption coefficients. An image in a back-scattered radiation can be obtained too.

Three-dimension nitrogen distributions can be obtained similarly to a positron emission tomography in the medicine. In this method two oppositely directed coincident 0.511 MeV photons are counted simultaneously by the detector array.

The high-energy photons from the accelerator easily penetrate through thick materials and are capable to detect nitrogen containing materials in large containers as shown in Fig. 4.

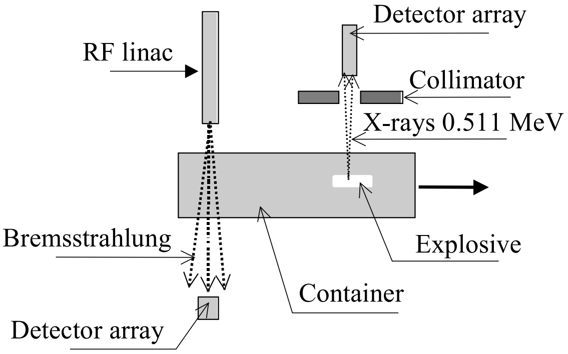

Fig.4. The container inspection system.

Thus the linac concept appears to be a very attractive candidate for both the detection of explosives in cargo and buried land mines.

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