Underwater threats detection with neutrons: the SABAT project

M. Silarski[1]* for the SABAT collaboration
[1] Institute of Physics, Jagiellonian University, Łojasiewicza 11, 30-348 Kraków, Poland
* email: michal.silarski@uj.edu.pl

Introduction

In twenty-first century the risk of terrorist attacks is constantly growing around the world. This situation put us in a need to develop more effective methods to detect potential threats and smuggling of illicit materials, e.g. explosives or drugs. New methods are needed particularly for shores and ports protection and monitoring [1]. They are very important also in view of environmental protection of sea areas of intensive warfare, e.g. Baltic Sea, where over 250 kilotons of munition were sunk after the World War II, mostly explosives, but also many chemical agents. High economic and environmental costs have been preventing so far any activities aiming at extraction of these hazardous substances, but it is clear that we are about to face a very serious problem, especially in the Baltic Sea [1].

Presently used methods for underwater munition detection are based on sonars which show only a shape of underwater objects, like e.g. sunk ships or depth charges. To estimate the amount of dangerous substances and to determine the exact location of sunk munition it is still necessary that people are diving and searching the bottom of the sea. This operation is always very dangerous for divers since the corrosion state of the shells is usually not known. Moreover, these methods are very expensive and slow, thus they cannot be used in practice to search big sea areas [1]. One of the methods which has a big potential to substitute or support sonars is the Neutron Activation Analysis (NAA). It is based on fast or thermal neutron beams which excite nuclei of an investigated substance. Detection of characteristic gamma quanta emitted in de-excitation of the nuclei allows one to identify the stoichiometry of the substance and determine if it is dangerous. There are several designed and produced devices utilizing the NAA for detecting dangerous substances on the ground, e.g. [2-3], but in the water one needs to overcome many difficulties connected to neutron attenuation and huge background from oxygen and hydrogen [4]. This background can be reduced for example by using neutron generators with associated α particle measurement and by decreasing the distance between the inspected object and the detector [5]. There are also solutions based on low energy neutrons which are moderated in water before reaching the tested object. The detector is then registering gamma quanta originating from thermal neutron capture [1].

An alternative design of a NAA-based device for underwater threats detection was proposed at the Jagiellonian University in the SABAT project, where we use guides for the neutron beam and gamma quanta emitted towards the detector. This method not only reduces the background from water but also may provide detection of dangerous substances hidden deep in the bottom of the sea and may allow determination of the density distribution of the dangerous substance in the tested object.

Design of the SABAT system

Scheme of the proposed device is presented in Fig 1. Neutron generator collides deuterium ions with a tritium target producing a neutron and an α particle. Because of the much higher energy released in this reaction compared to the energy of deuterium, both particles are produced almost isotropically and move back-to-back. The α particle is detected by a system of position sensitive detectors, e.g. silicon pads or scintillation hodoscope, disposed on the walls of the generator. Neutrons emitted towards the subject of interrogation fly inside a guide built out of a stainless steel pipe filled with low pressure air or some other gas having low cross section for neutron interaction. Neutrons after leaving the guide may be scattered inelastically on atomic nuclei in the tested substance.

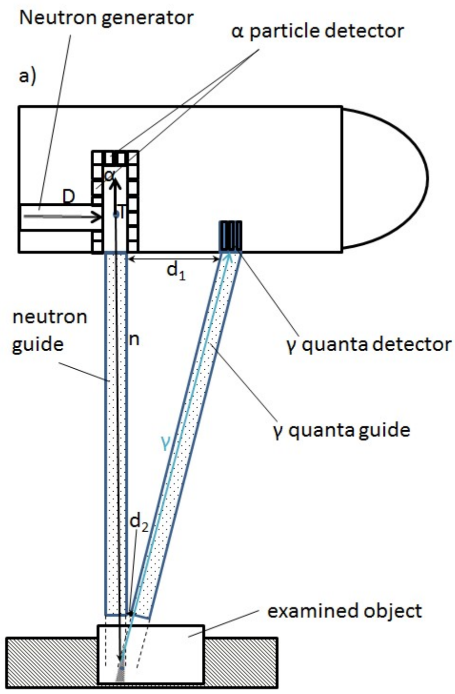

Fig. 1 Schematic view of the SABAT system for underwater detection of hazardous substances.

The nuclei deexcite and emit gamma quanta with energy specific to the element. Part of the emitted γ quanta fly towards a dedicated detector within an analogous guide which decrease their absorption and scattering with respect to gamma quanta flying in water. The γ ray detector could be again a position sensitive detector measuring the energy, time and impact point of impinging particles. If the diameter-to-length ratio of both guides is small the depth at which γ quanta excite nuclei can be determined by measuring the time elapsed from the α particle registration until the time of the γ quantum registration [6]. Changing the distance between the guides provides registration of gamma quanta emitted from different parts of the object. This allows one to determine the density distribution of elements building the suspected object. In order to remove background resulting from interaction of neutrons emitted in other directions only signals registered by the γ quanta detector in coincidence with signals from α particle detectors mounted in-line with the neutron guide are saved, while the other coincidences are discarded [10].

Status of the project

To design and optimize the SABAT detector in terms of high sensitivity and interrogation time we have performed Monte Carlo simulations using the general Monte Carlo N-Particle Transport Code (MCNP) package [7]. We studied geometry of the system including the relative positions of gamma quanta detector and the neutron generator, and the optimal guides dimensions. The first feasibility studies revealed that the mustard gas detection is possible in the aquatic environment even without the associated α particle measurement. We have concluded that the separate detection of prompt γ-quanta and radiation from the delayed neutron capture gives the best performance of the detection system [8].

References

[1] M. Silarski, D. Hunik, M. Smolis, S. Tadeja, P. Moskal, Acta Phys. Polon. B47, 497 (2016).
[2] B. C. Maglich, *AIP Conf. Proc.* **796**, 431 (2005)
[3] L. Kaźmierczak et. al., *Acta Phys. Polon. A* **127**, 1540 (2015)
[4] M. Silarski, P. Sibczyński, Sz. Niedźwiecki, S. Sharma, J. Raj, P. Moskal, Acta hys. Polon. B 48, 1675 (2017)
[5] V. Valkovic, D. Sudac, K. Nad, J. Obhodas, D. Matika, R. Kollar (2010). "'Surveyor"': An Underwater System for Threat Material Detection. International Atomic Energy Agency (IAEA): IAEA
[6] M. Silarski, D. Hunik, P. Moskal, M. Smolis, S. Tadeja, Acta Phys. Pol A127, 1543 (2015)
[7] T. Goorley et al., Nuclear Technology 180, 298 (2012).
[8] P. Sibczyński, M. Silarski, O. Bezshyyko, V. Ivanian, E. Kubicz, Sz. Niedźwiecki,
[9] P. Moskal, J. Raj, S. Sharma, O. Trofimiuk, Journal of Instrumentation, submitted