Journal of Physics: Conference Series

Pyroelectric neutron generator for calibration of neutrino and dark matter detectors

To cite this article: A S Chepurnov *et al* 2016 *J. Phys.: Conf. Ser.* **675** 032031

Journal of Physics: Conference Series **675** (2016) 032031 doi:10.1088/1742-6596/675/3/032031

Pyroelectric neutron generator for calibration of neutrino and dark matter detectors

A S Chepurnov[1], V Y Ionidi[1], O O Ivashchuk[2], A S Kubankin[2,3], A N Oleinik[2], A V Shchagin[2,4]
[1] Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
[2] Laboratory of Radiation Physics, Belgorod State University, Belgorod, Russia
[3]Lebedev Physical Institute, Moscow, Russia
[4] Kharkov Institute of Physics and Technology, Kharkov, Ukraine

E-mail: aschepurnov@yandex.ru

Abstract. Pyroelectric crystals, such as $LiNbO_3$ or $LiTaO_3$ being under influence of a temperature gradient can produce an electric field up to 10^5 kV/cm. It was experimentally confirmed that a crystal installed in a chamber with a residual gas pressure of about 1 mTorr could be used to generate X-Ray radiation with an energy up to 100 keV The same setup could be used to generate s 2.45 MeV neutrons if the target is deuterated and residual gas is D2. Due to such properties as On/Off mode of operation and the absence of radioactive materials, pyroelectric neutron generators seem to be a promising tool for calibration of neutrino and dark matter and other low background detectors. We propose the application of the controlled pyroelectric neutron generator for calibration of such detectors.

The pyroelectric effect consists on the generation of electric charges on the surface of the pyroelectric crystal, perpendicular to the polar z-axis, during a change of the crystal temperature. Such property is found both in crystalline and in ceramic materials. The charge polarity depends on the temperature gradient (cooling or heating) and the crystal z-axis orientation. The generated charge is compensated by free charge from air in a very short time at atmospheric pressure. However, the charge is not compensated in low pressure conditions then high electric potential up to 100 kV can be generated on the crystal surface. This is the cause of the polarization of molecules from the residual gas, as well as of the emission and acceleration of electrons from the pyroelectric crystal surface.

The possibility of X-rays generation using the Pyroelectric effect for $LiNbO_3$ and $LiTaO_3$ pyroelectric crystals was confirmed experimentally in [1] for the first time. Two different possibilities can be realized for X-rays production when a grounded target is located in front of the charged surface of the crystal in vacuum. If the pyroelectric crystal surface has a negative polarity as it is presented in figure1a, then the electrons from polarized molecules and the crystal surface are accelerated to the grounded target producing bremsstrahlung and characteristic radiation from the target. When the crystal has a positive charge polarity as it is shown in figure1b, the electrons from polarized molecules are accelerated towards the crystal surface producing bremsstrahlung and characteristic radiation from the crystal surface. It should be noted that the ions of the residual gas are also accelerated in the opposite direction relative to the electrons propagation, but the ions X-ray yield is substantially smaller in comparison with the yield produces by the electrons. Several geometries can be realized to develop pyroelectric X-ray sources [2-4].

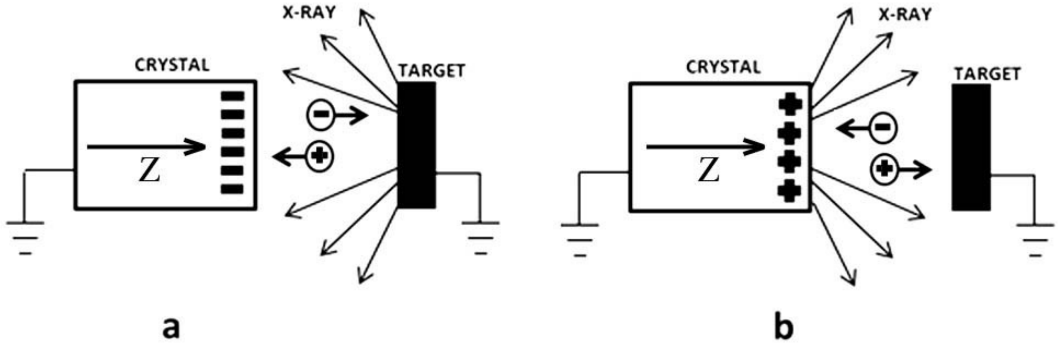

Figure 1. The two cycles of X-ray generation by pyroelectric crystal: a) crystal negative polarity; b) crystal positive polarity.

The considered pyroelectric effect can be used for neutron generation also. If deuterium gas is used instead of air as the residual gas and the target contains deuterium, then 2.45 MeV neutrons can be generated during a nuclear D-D reaction [5]. The neutrons yield depends on the energy and current of accelerated deuterium ions, which interact with the deuterated target. The tungsten tip installed on the crystal surface is usually applied to increase the probability of the deuterium ionization. Figure 2 schematically illustrates the mechanisms of neutron generation using the pyroelectric effect. Neutron generation using the pyroelectric effect was widely investigated in recent years [6-7].

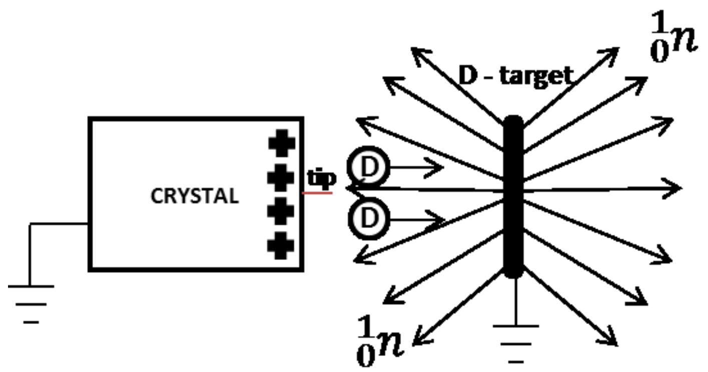

Figure 2. The neutrons generation using the pyroelectric effect.

Neutron calibration is one of the critical procedure performed time to time for most of neutrino and dark matter search experiments [8]. One of the main reason is that neutrons are main backgrounds for such experiments which fake expected physical events. The sources for calibration should have an ultra-low background, a compact size and the possibility to control the intensity. Radioactive materials and high-voltage power supplies should be avoided in such sources.

Our proposal consists in the application of neutron sources based on the pyroelectric effect described above for calibration of low-background detectors. Such sources will have a typical size of several cubic centimeters, they do not contain any radioactive substances and could be manufactured low background and they don’t need external high voltage power supply. It is also important that the output neutron intensity can be controlled.

The pyroelectric neutron source can be installed stationary into a neutrino or dark matter detector. When the source is tuned off, it does not produce any radiation and does not hamper operation of the detector. The source can be tuned on by connecting of a low voltage power supply that should provide variation of the temperature of the pyroelectric crystal. The tuned on source produces 2.45 MeV neutrons. The scattering of the neutrons on atomic nuclei of the detector produces recoil nuclei that can be used for calibration of the detector. Besides of neutrons, the source can produce X-rays that can hamper the calibration. The X-rays should be absorbed by walls of the chamber of the source.

The neutrons source intensity is of several thousand neutrons per thermal cycle. These values are enough for low background detector calibration. At the moment, the work on improving the pyroelectric source characteristics is being performed.

Acknowledgments
A.V. Shchagin is thankful to F. Goennenwein for preliminary discussions about applicability of the pyroelectric neutron source for calibration of neutrino and dark matter detectors. Also, authors are thankful to S.I. Bashko and his team from ISSP RAS for production of tungsten tips. This study was supported financially by the Russian Foundation for Basic Research, projects 14-22-0301 ofi_m and the Ministry of Education and Science of the Russian Federation, project 3.2009.2014/K.

References

[1] Brownridge J D 1992 Pyroelectric x-ray generator *Nature* **358** 277–8
[2] Nagaychenko V I *et al.* 2007 (In Russian) Journal of Surface Investigation. X-ray, Synchrotron and Neutron Techniques **3** 81 (Original Russian title: Poverkhnost'. Rentgenovskie, Sinkhrotronnye i Neitronnye Issledovaniya)
[3] Brownridge J D and Shafroth S M 2007 *New Research on Lasers and Elecrooptics,* ed. by William T Arkin (New York: Nova Science Publishers) p 37
[4] URL: www.amptek.com/coolx.html
[5] Naranjo B, Gimzewski J K and Putterman S 2005 *Nature* **434** 1115
[6] Geuther J, Danon Y and Saglime F 2006 *Phys. Rev. Lett.* **96** 054803
[7] Gillich D *et al.* 2009 *Nucl. Instrum. Meth.* A **602** 306
[8] Bondar A E *et al.* 2013 (in Russian) Proposal for neutron scattering systems for calibration of dark matter search and low-energy neutrino detectors *Vestnik of NSU: Physics Series* **8** 27