APPARATUS AND METHOD FOR DETECTING SLOW NEUTRONS BY LYMAN ALPHA RADIATION

CROSS-REFERENCE TO PROVISIONAL APPLICATION

This patent application claims priority under 35 U.S.C. §119(e) to provisional patent application Ser. No. 60/956,943, entitled "Far Ultraviolet Dosimeter for Slow Neutron Detection," which was filed on Aug. 21, 2007, the disclosure of which is incorporated herein by reference.

TECHNICAL FIELD

Embodiments are generally related to neutron detecting devices and methodologies. Embodiments are also related to detection of single neutrons, high spatial resolution position sensitive detection of neutrons, and thermal neutron imaging. Embodiments are additionally related to neutron detecting sensors and components thereof. Embodiments are specifically related to the detection of slow neutrons.

BACKGROUND OF THE INVENTION

The two most routinely used thermal neutron detectors, the fission detector and proportional Geiger mode detector, are based on technologies that are more than 30 years old. The fission detector is based on the reaction of thermal neutrons with fissionable material (generally isotopes of uranium or plutonium) with the high energy reaction products detected with conventional solid state particle detectors. The proportional detector is based on the reaction of neutrons with either ^{3}He or BF_3. Fission detectors have low sensitivity, limited dynamic range and sensitivities are not stable with use.

The majority of neutron detectors in use today are either BF_3 or ^{3}He gas proportional tubes. ^{3}He and BF_3 detectors have efficiencies similar to the proposed new technique, but require high voltages (1300 V to 2000 V), are susceptible to microphonics and have a dead time of approximately 1 μs limiting their maximum counting rate. The tubes also require an ultra-pure quench gas to achieve sufficient signal-to-noise ratios and suffer from wall effects when particle energy is lost by absorption at the tube walls. In addition, BF_3 is a toxic and corrosive gas. While there are many instruments that employ BF_3 in the field, manufacturers are moving away from its use.

There are a small number of detectors using a lithium doped scintillator (e.g., lithium glass, lithium iodide, or lithium-loaded plastic). The utility of such devices is limited by gamma ray backgrounds. A need, therefore, exists for an improved method and/or apparatus for neutron detection that has high sensitivity, wide dynamic range, stability and the capability of being calibrated absolutely. The disclosed embodiments have these advantages.

The disclosed embodiments involve phenomena of nuclear physics and of atomic, molecular and optical (AMO) physics, associated with atomic electron excitation as a result of the ^{3}He(n,tp) reaction. This reaction generates a quantity of Lyman alpha radiation that is easily detectable in ^{3}He gas targets. Lyman alpha radiation, at a wavelength of approximately 122 nm in the far-ultraviolet region of the electromagnetic spectrum, is produced by the 2p-1s optical transition in atomic hydrogen isotopes. Such radiation serves as a useful signature for precise neutron dosimetry, leading to single-neutron detection capabilities and compact neutron detectors that can operate over a wide dynamic range without high voltages. Backgrounds from gamma radiation are very low.

The ^{3}He(n,tp) reaction has long been studied in nuclear physics and now is the basis of most thermal neutron detectors used at the National Institute of Standards and Technology (NIST). The small uncertainty in the reaction cross section (0.12%) suggests this reaction as a candidate for the primary standard detector for accurate determination of thermal neutron fluence, but the operational uncertainty of ^{3}He proportional tubes is more than an order of magnitude larger than the uncertainty in the cross section. The disclosed embodiments provide a method for substantially reducing the operational uncertainty of a neutron detector based on the ^{3}He(n,tp) reaction.

The ^{3}He(n,tp) reaction is exothermic at zero incident neutron energy, where it yields (from the nuclear perspective alone) a triton and a proton with combined escape energy of 764 keV. The reaction yields, with unknown branching ratios, hydrogen atoms (H), tritium atoms (T) protons (p), and tritons (t) in a number of final state configurations, including the 2p excited states of hydrogen and tritium, respectively H(2p) and T(2p).

In an ambient environment of ^{3}He gas, Lyman alpha radiation is generated by the following mechanisms: H(2p) and/or T(2p) produced in the initial reaction; higher excited states of H and/or T produced in the initial reaction, followed by radiative or collisional relaxation to 2p states; ground states of H and/or T from the initial reaction followed by subsequent collisions with ^{3}He to produce H(2p) and/or T (2p); and direct production of protons and tritons followed by charge exchange collisions with ^{3}He, leading to both ground and excited states of H and T that then undergo subsequent collisions resulting in H(2p) and/or T(2p). The local ^{3}He environment is transparent to Lyman alpha radiation, which thus allows for its efficient detection by optical techniques. In addition, radiation at the Lyman alpha wavelength is produced by a transition between two excited states of the He^+ ion.

BRIEF SUMMARY OF THE INVENTION

The following summary of the invention is provided to facilitate an understanding of some of the innovative features unique to the present invention and is not intended to be a full description. A full appreciation of the various aspects of the invention can be gained by taking the entire abstract specifications, claims, and drawings, as a whole.

It is, therefore, one aspect of the present invention to provide for an improved neutron detector apparatus.

It is another aspect of the present invention to provide for a neutron detector apparatus that uses Lyman alpha radiation in the far-ultraviolet region of the electromagnetic spectrum as a signature of the ^{3}He(n,tp) reaction.

The aforementioned aspects of the invention and other objectives and advantages can now be achieved as described herein. A method and system is disclosed for detecting slow neutrons by monitoring Lyman alpha radiation produced by a ^{3}He(n,tp) nuclear reaction induced by neutrons incident on a gas cell containing ^{3}He with or without other gases.

Lyman alpha radiation is produced with high efficiency when a ^{3}He cell is irradiated with neutrons. Several mechanisms contribute to Lyman alpha production, as described herein. When the gas cell contains only helium atoms, Lyman alpha radiation is spectrally isolated and the gas medium is transparent to it. The Lyman alpha radiation can be detected with high efficiency using a photo-detector sensitive to Lyman alpha radiation, or alternatively it can be converted to visible radiation by scintillator materials, with the visible radiation channeled to a suitable photo-detector.