A Li-6 DIODE BASED, MODERATING DETECTOR FOR NEUTRON DETECTION

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INTRODUCTION

This paper discusses a new neutron detection system that allows local volumetric identification of fast neutron thermalization in the context of forming a solid state, Bonner-like neutron spectrometer [1]. The shortage of He-3 as a thermal neutron detection medium is leading to the development of B-10 and Li-6 based diodes [2] with high efficiency (>22%)for thermal neutron detection. The relatively smaller size of these diodes compared to He-3 gas-filled detectorsresults in increased spatial resolution. Such volumetric resolution is possible through the layering of these weakly perturbing and pixilated high thermal efficiency diodes into a neutron moderating volume. The resulting departure and subsequent improvement from the classical Bonner spectrometer is that the entire moderating volume is sampled locally for thermal neutrons. This information can be used to infer information on incident neutron energy spectra anddirection, which provides capabilities not available in current systems[1, 3-19].

NEUTRON DOSIMETER IMPLEMENTATION

It is desirable to accurately resolve the absorbed dose equivalent resulting from neutron sources spanning a wide range of incident kinetic energies (thermal to tens of MeV). One implementation of the new system described here utilizes multiple Li-6 based, thermal neutron diode detectors[2]along the axial length of a right cylinder polyethylene moderator, resulting ina lightweight, highly efficient, versatile, neutron dosimeter. It utilizes real-time, simultaneous sampling of thermalized neutronsas a function of axial position in the dosimeter volume. Each neutron detector (30 total) exhibits a unique, energy-dependent, Bonner-like response curve, the collection of which can be used in conjunction with a weighted least squares method to identify a set of coefficients to create a dose equivalent curve. This curve (seen in dark green in Figure 1) closely matches the ICRP/ICRU neutron-to-dose response curve(shown as the smooth black curve [20]) needed for accurate neutron dosimetry. Thus, unfolding of the neutron spectrum is not required. MCNPX has been used to calculate these response functions which have been combined to provide a response function with less than 10% percent error in neutron-to-dose conversion. The system exhibits >10% total detection efficiency over the entire energy range.

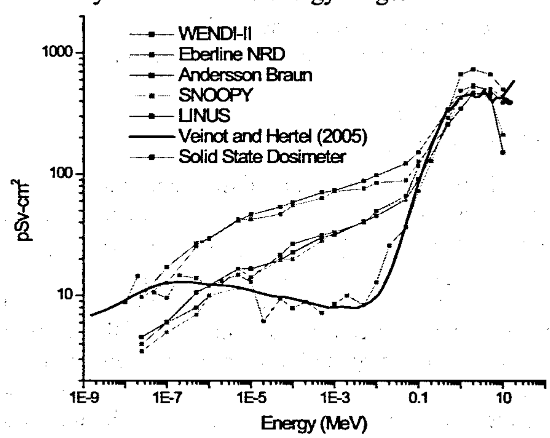

FIGURE 1 Dose per unit fluence for the proposed system compared to currently available dosimeters

NEUTRON SOURCE IDENTIFICATION

Neutron spectrometers can be used to identify a source of unmoderatedfast neutrons (Cf-252, AmBe, Pu spontaneous fission, etc.). A Bonner Sphere system utilizes the difference in the response of the system to various sized moderators as a function of incident neutron energy. This information is used to subsequently deduce incident neutron energyby unfolding the acquired responses with previously determined response functions. This requires unfolding of multiple, independent measurements for different sized moderators.

This same dosimeter geometry discussed above enhances the ability of a moderating system to discriminate between and accurately measure different neutron spectra. Layering and pixilating the individual detection elements in the moderator allows for binning in axial and polar coordinates such that energy resolution of parallel and/or omnidirectional incident neutrons can be determined. The characteristics of thissystem have also been modeled with MCNPX. Figure 2 shows the response to a Pu spontaneous fission spectrum incident on the face of the moderating cylinder in the presence of an omni-directional background cosmic spectrum.

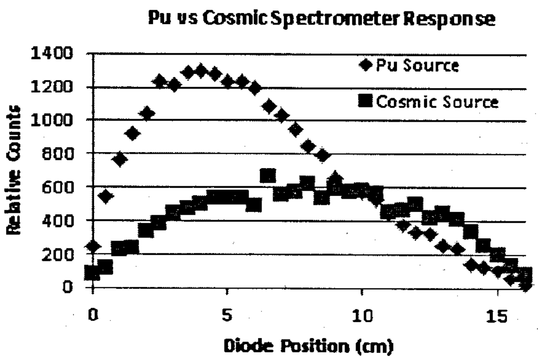

FIGURE 2 Results of the depth dependence of plutonium and cosmic-ray induced neutrons

APPLICATION TO NEUTRON PHYSICS MEASUREMENTS

Fission multiplicity and fission neutron spectrum measurements as a function of incident neutron energy are of interest to the nuclear physics community. The solid state spectrometer system described above is capable of resolving a fission neutron energy spectrum as a function of the neutron fission multiplicity and on-target incident neutron energy. Such a concept is different than measuring the mean energy of the multiplicity distribution as a function of the on-target incident energy as has been completed previously.

The main implications of such a spectrometer system on nuclear data needs, in the context of transmutation, include real time flux analysis, which is advantageous for optimizing burnup of unknown material composition in addition to excellent gamma discrimination and EMI protection.

CONCLUSIONS

A new Bonner Sphere like system has been designed which utilizes high efficiency, Li-6 based, pixilated diodes distributed throughout a moderating medium. Through MNCPX modeling of this system, its utility for a number of important neutron measuring systems has been studied. Current work involves the assembly of this system for experimental testing.

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