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Abstract

Recent advancements in the ultra-wide band Radio Frequency Identification (RFID) technology and solid state pillar type neutron detectors have enabled us to move forward in combining both technologies for advanced neutron monitoring. The LLNL RFID tag is totally passive and will operate indefinitely without the need for batteries. The tag is compact, can be directly mounted on metal, and has high performance in dense and cluttered environments. The LLNL coin-sized pillar solid state neutron detector has achieved a thermal neutron detection efficiency of 20% and neutron/gamma discrimination of 1E5. These performance values are comparable to a fieldable ^{3}He based detector. In this paper we will discuss features about the two technologies and some potential applications for the advanced safeguarding of nuclear materials.

Introduction

Continuous remote monitoring of sensitive materials and timely detection of their loss is a powerful method for preventing any diversion activity. In a recent paper on the testing of RFID tags presented in the 31th ESARDA meeting, Hori et al. (Ref. 1) from Japan-Atomic Energy Agency (JAEA) pointed out the possibility of performing near real-time nuclear materials tracking and location in both uranium and plutonium nuclear fuel cycles. Most of the RFID tags tested in the paper do not perform as well as expected. At LLNL, we plan to combine the two technologies still under development: ultra-wide band (UWB) RFID tags and pillar type thermal neutron detectors for possible future robust near real time tracking. With the combination of both systems, it is possible to provide close to real time tracking of sensitive nuclear materials so that significant improvement in the continuity of knowledge can be realized. The UWB neutron tags can also reduce maintenance requirements and human factor-related errors as well as effectively verifying on-site inventories. Moreover, measurements at key points with these tags will provide a new capability to detect processing of undeclared activities.

LLNL UWB passive tags

Prototypes of current UWB reader and passive tag are shown in Figure 1. Figure 2 also demonstrates excellent signal-to-noise ratio from long range signal detection using a UWB passive tag. The LLNL UWB tags possess several unique features: high performance around metallic surfaces; resistant to signal jamming and vulnerability to be tampered; good penetration properties; omni-directional antennas; no spectrum licensing required; and no limitation to worldwide operation.

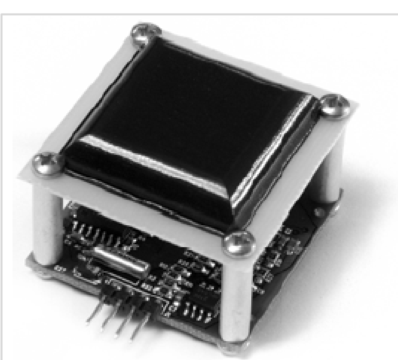

Figure 1. LLNL passive UWB RFID reader (left) and tag (right), the passive tags basically using the RF signals sending from the reader as the energy source.

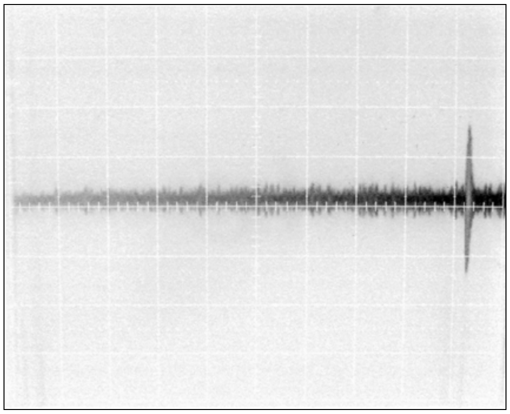

Figure 2. Excellent signal to noise ratio is achieved from a test of the LLNL UWB tag at 20ft

LLNL solid state thermal neutron detectors

Thermal neutrons can be detected using ^{10}B coated Si detectors via recoil charged-particle detection from the n+ ^{10}B reaction. Basically, the ^{10}B layer serves as a conversion material for its high thermal neutron capture cross sections. However, the efficiency of such device is limited to 2-4% due to limited range in the recoil ^{7}Li and alphas. To overcome traditional planar geometry for the ^{10}B coated Si detectors, we have invented the pillar type geometry (Figure 3). In such geometry, the detection efficiency can be as high as 90% (Figure 4) depending on the pillar size, pitch, and pillar height (Ref 2). At present we have achieved a detection efficiency of ~ 20% and neutron/gamma discrimination of 1E5. These performance values are comparable to a fieldable ^{3}He based detector.

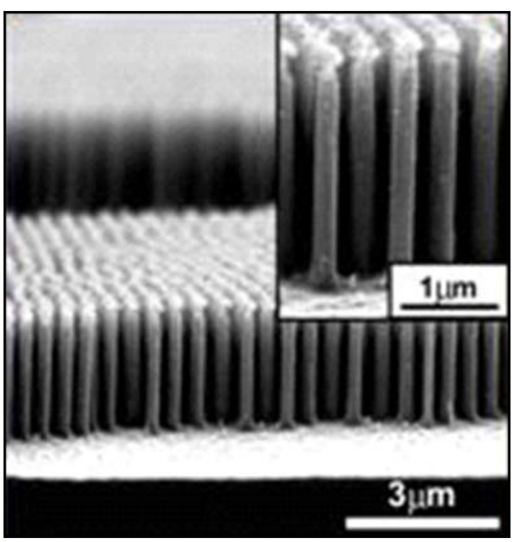

Figure 3. Si pillars prior to the chemical vapor deposition of the ^{10}B

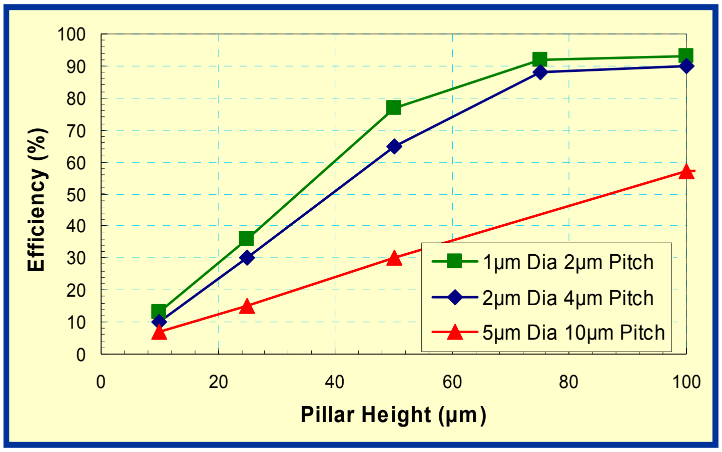

Figure 4 Monte Carlo simulations of the thermal neutron detection efficiency w.r.t. pillar height, and pitch under ideal situations. More realistic detection efficiency that involve pillar transport properties can be found in Ref. 2

The LLNL solid state neutron detectors provide: real-time neutron monitoring; user configurable; small footprint; scalable; solid state replacement of ^{3}He tubes; easily transportable; and, low voltage, low power.

Proposed Combination of the two technologies

Figure 5 illustrates the idea of combining the two technologies with a design of mW electronics for the neutron detection. The neutron detectors required constant power for neutron detection, the power can be from the RF signals that were provided by the reader or may be provided by solar energy. In either case, low power consumption is a must. It is possible to achieve low power consumption by slightly trading off the efficiency of the neutron detection. LLNL is currently optimizing the detection efficiency with the power consumption.

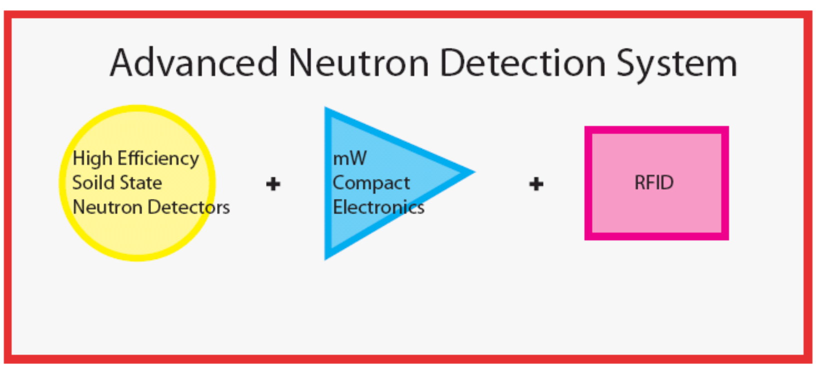

Figure 5 Combination of the two technologies with low power consumption electronics

Combination of the two technologies (UWB smart tags) can be used in environments such as container monitoring -- the UWB mart tag can be placed on containers to monitor neutrons emitted from special nuclear materials. Continuous unchanged neutron detection helps establish continuity of knowledge and validity.

Future work and conclusions

Both technologies are still at least two years from maturing. There are several improvements needed. For example, in the UWB tags development one can envision improvements such as multiple tag detection capability through unique identification; real-time geo-location; more efficient antenna design for improved range as well as read/write capability. In the neutron detectors, further advancements include: neutron chip design/fabrication, how to integrate with UWB tags; and encapsulation design. We would also like to be able to find a facility for field testing of the smart tags.

References

1) "Feasibility of using RFID in the material accountancy and safeguards verification in the nuclear cycle facilities," Masato Hori, Yoko Kawakubo and Masauki Mizui, Presented in the 31th ESARDA meeting
2) "Numerical Simulations of Pillar Structured Solid State Thermal Neutron Detector: Efficiency and Gamma Discrimination,"Adam M. Conway, Tzu F. Wang, Nimanlendu Deo, Chin L. Cheung, and Rebecca J. Nikolic, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 56, NO. 5, OCTOBER 2009

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