Detector to Differentiate Gamma Rays, Thermal Neutrons, and Fast Neutrons Emitted From Radiation Sources

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Abstract

When working with a radioactive source, such as Cf-252 or a neutron generator, it is necessary to know how active the source is as well as what forms of radiation the source is emitting, in the case of Cf-252, the thermal and fast neutrons and gamma ray ratios are important. A device that detects all three of these particles is valuable to a research group working with a radioactive element or radiation generator. We have built and tested a detector that is composed of Li-6 glass, liquid scintillator and a photomultiplier tube. The Li-6 glass has a high efficiency for detecting thermal neutrons, while the liquid scintillator has a good efficiency for detecting fast neutrons and gamma rays. When these scintillators are used together, thermal neutrons, fast neutrons, and gamma rays can be differentiated by using the light decay times of the scintillator. The scintillator light decay time constant for thermal neutrons interacting in the Li-6 glass is approximately 60 ns. The scintillator light decay time constant for the fast neutrons interacting in the liquid scintillator is approximately 30 ns, and the decay constant for the gamma ray interaction is about 6 ns. Given these values, it is possible to differentiate between the three forms of radiation with good separation. This differentiation can be used to determine the radiation dose to biological systems by using the quality factors of 1 for gamma rays, 5 for thermal neutrons, and 20 for fast neutrons.

Description of the Detector

The detector is composed of a Lithium glass scintillator, a liquid scintillator, and a photomultiplier tube. The Lithium glass scintillator used in this detector was KG-2, and the liquid scintillator used was BC 501a, both are manufactured by Bicron. The liquid scintillator used has a window on each side, therefore allowing another scintillator, Li-6 glass, to be mounted on top of the liquid scintillator. These two scintillators were mounted to the photomultiplier tube XP 2230 made by Phillips Scientific.

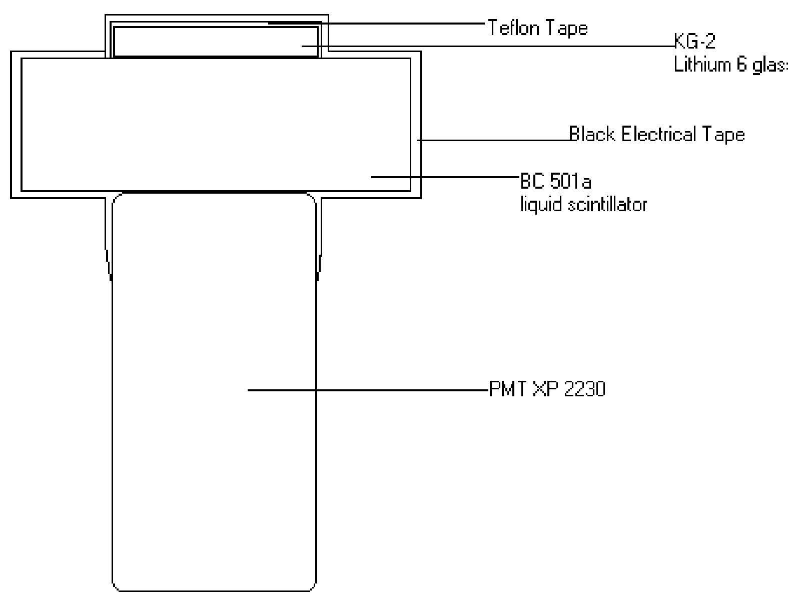


Figure 1: Diagram of the detector used. Not drawn to scale. The Li-6 scintillator was wrapped in white Teflon tape on all sides except the bottom. The entire device was then wrapped in black electrical tape. This held the device together.

The Li-6 glass scintillator, the dimensions are 2 inches in diameter and .236 inches thick, has a high efficiency for detecting thermal neutrons because of its high neutron capture absorption coefficient for thermal neutrons. The liquid scintillator, 2 inches in diameter and 1 inch thick, has a high efficiency for detecting fast neutrons because of the elastic collisions of the neutrons and protons. This scintillator emits scintillations from electrons scattered by gamma induced Compton interactions.

The photomultiplier tube XP 2230, 2 inches in diameter, detects the scintillations that occur in either one of the two scintillators.

Logic Behind the Experiment

The Li-6 scintillator emits light with a decay constant of about 60 ns. The light emitted from the liquid scintillator when the fast neutron collides with a proton is about 30 ns. The light emitted from the Compton scattering inside the liquid scintillator is about 6 ns(See graphs on pages 3 and 4 for common pulses). These differences in the light decay times make it possible for someone to differentiate between the forms of radiation.

Design and Arrangement of the Experiment

Figure 2 is the schematic used for the base of the photomultiplier tube. This base was connected to the photomultiplier tube and then the tube was fitted with a piece of high speed scintillator to determine if the photomultiplier tube was capable of detecting the gamma rays.

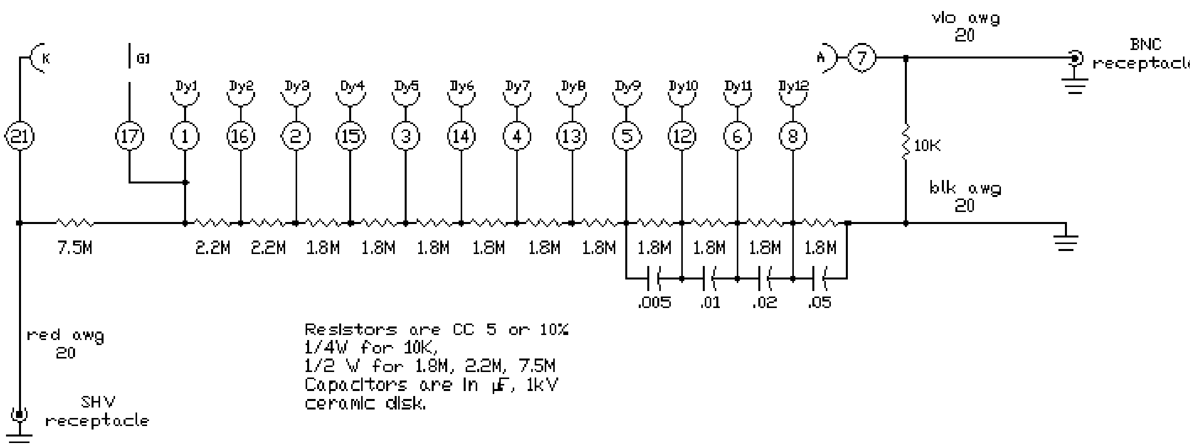


Figure 2: Schematic for the base fo the photomultiplier tube.

Figure 3 shows the setup for the experiment. The Cf-252 is placed inside the structure of wax. Cf-252 is the source of neutrons and gamma radiation used in this experiment. The Cf-252 used was 2 microcuries. A block of lead was placed between the source and the detector to inhibit the number of gamma rays. The Cf-252 source was surrounded with wax bricks to promote the production of thermal neutrons and to act as a partial neutron shield. The signal from the photomultiplier tube was then connected to a scope, Tektronix TDS 3032B. This scope was then connected via Ethernet to a computer running a labview program which found the decay time of the pulse and also the pulse integral. Figure 4 is a plot of pulse integral versus the light decay time of the liquid and Lithium glass scintillators.

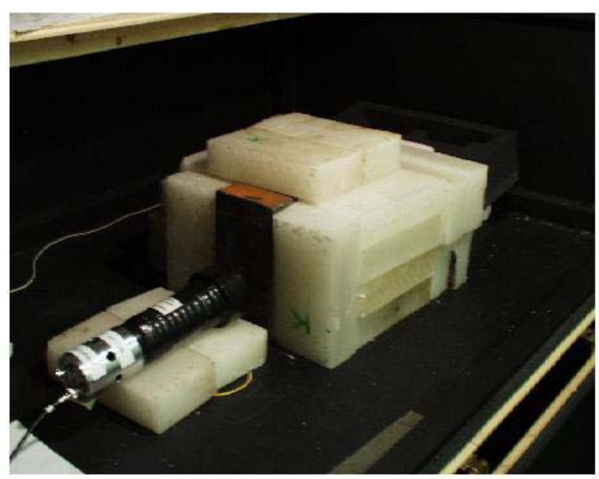


Figure 3: The Cf-252 source is housed inside the structure of wax. The signal is run from the photomultiplier tube to a scope, TDS 3032B, the scope is connected to a computer which analyzes the data and saves it into a spreadsheet format for further analysis.

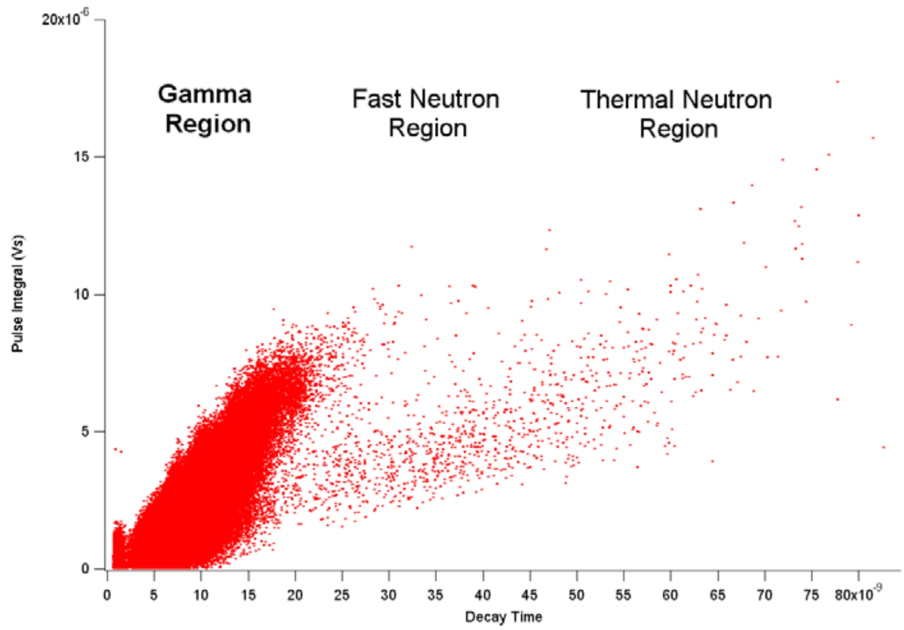
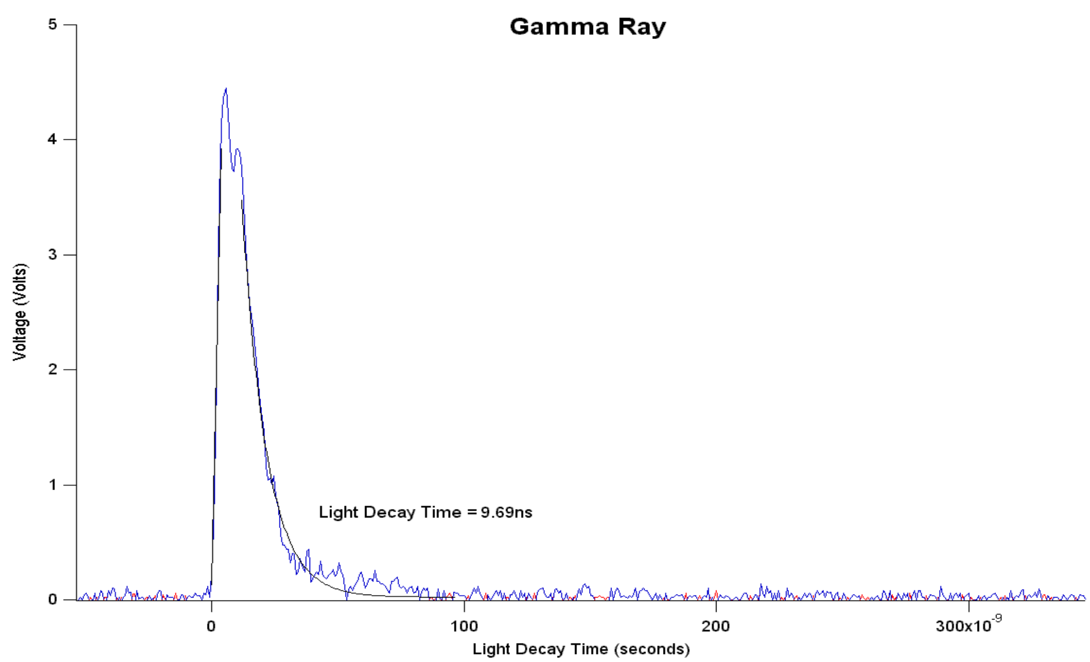
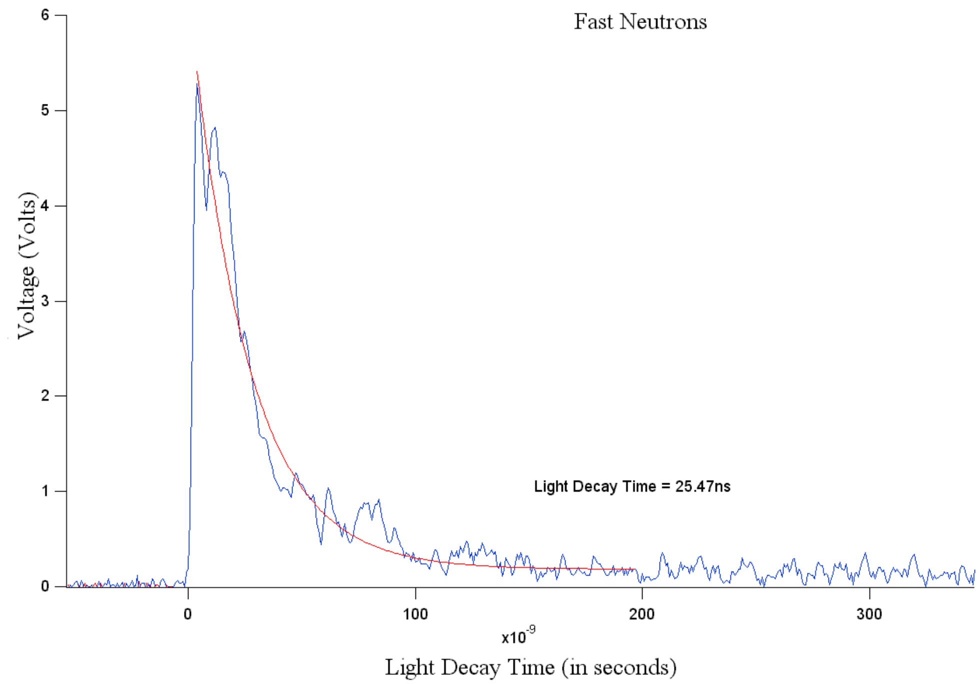


Figure 4: This is a plot of pulse integral (measured in V*s) versus the Exponential Decay Time of the liquid scintillator light and the Li-6 glass scintillator light. In this case, there is no definitive separation between the thermal and fast neutrons because Cf-252 produces a wide variety of neutrons ranging from 0-10MeV.

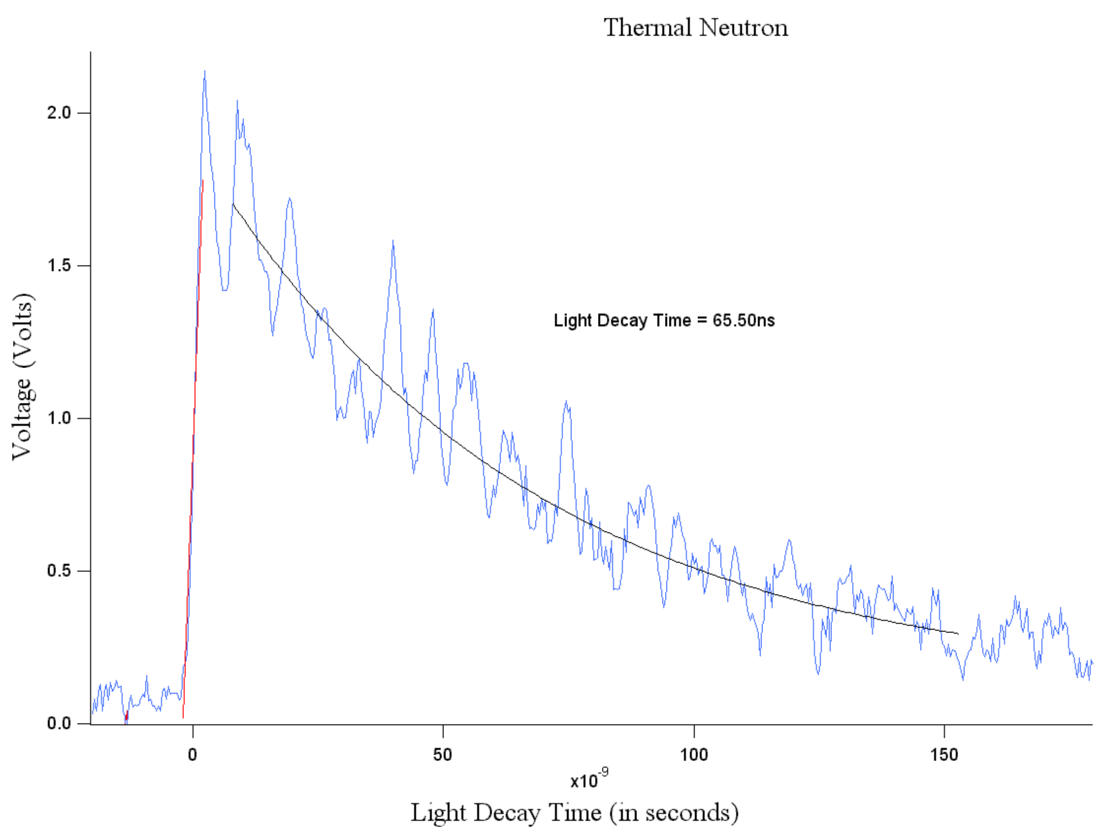
Conclusion

Using this two scintillator detector, we were nearly able to distinguish between the three separate forms of radiation emitted from the Cf-252. The thermal and fast neutron region were not easily differentiated. But, it is certain the detector can differentiate between gammas and neutrons, and it also can detect thermal neutrons as seen from Figure 4. Since the device can detect all three forms of radiation, the device does have value to research, biological, or other such groups which work with a radioactive source or generator.





Fast Neutrons
Voltage (Volts)
6
5
4
3
2
1
0
Light Decay Time = 25.47ns
0
100
200
300
x10-9
Light Decay Time (in seconds)



Thermal Neutron
Voltage (Volts)
2.0
1.5
1.0
0.5
0.0
Light Decay Time = 65.50ns
0
50
100
150
x10-9
Light Decay Time (in seconds)