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Approaches to Ultrafast Neutron Detectors*

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Abstract

We discuss two approaches to obtain neutron detectors of very high temporal resolution. In the first approach, uranium-coated cathode is used in a streak tube configuration. Secondary electrons accompanying the fission fragments from a neutron-uranium reaction are accelerated, focussed and energy analyzed through a pinhole and streaked. Calculations show that 20 ps time-resolution can be obtained. In the second approach, a uranium-coated cathode is integrated into a transmission line. State-of-the-art technology indicates that time resolution of 20 ps can be obtained by gating the cathode with a fast electric pulse.

Introduction

In laser fusion, such as with the Nova laser which will soon be completed, the fusion is expected to last only 50-100 ps. In order to understand how the fusion reaction progresses, it is important to measure the time-dependence of the neutron production. We discuss here two possible approaches to obtain neutron detectors of 20 ps resolution and of adequate sensitivity.

Neutron Streak Camera

A possibility of obtaining a 20 ps resolution neutron detector based on the streak tube technic, has been described in an earlier publication. For details, the reader is referred to Ref. 1. Only a brief description is presented here.

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The neutron streak camera is essentially the same as the optical or x-ray streak camera, except that (1) the cathode is sensitive to neutrons, and (2) the cathode is shaped such that the difference in the neutron path lengths from a point source to various parts of the cathode is compensated by electron transit times within the streak tube. In this way the cathode can be made large (several cm^2) for high sensitivity, without sacrificing the time resolution. Time compensation is thus a key element to the development of a high sensitivity neutron streak camera.

A possible configuration of the neutron streak camera is shown in Fig. 1. The 2 cm diameter cathode of 2.5 cm radius of curvature is coated with $1 \mu\text{m}$ UO_2 and placed at 30 cm from the neutron source. Large number (~ 400) of secondary electrons accompanying the fission fragments from the cathode are focused at the first pinhole with the 10 kV extractor and 30 kV anode. Detailed calculation with electron beam optics code shows that the 14 MeV neutron arrival time difference at various parts of the cathode can be cancelled to within 5 ps by the corresponding electron transit time difference to the pinhole. The overall time resolution of the streak tube is estimated to be ≈ 20 ps, taking into account the effect of the 6 eV secondary electron energy spread and the electron transit-time spread in the cathode material. Using the geometry described above, for 10^{11} neutrons emitted isotropically from a point source ≈ 100 neutrons can be recorded. The current design, for the cathode to be placed at 8 cm from the neutron source, indicates that good neutron and electron transit time compensation can be obtained with a parabolic cathode.² In this case, only 10^{10} neutrons are required to produce 100 events.

Gated Transmission Line Diode

A newer approach to 20 ps neutron detector is by extending the gated intensifier technique being developed for x-rays. Time resolution of 50 ps or less have been reported for the x-ray framing camera.^{3,4}

Figure 2 depicts the conceptual design of our ultrafast gated stripline neutron diode. A short pulse derived from the charge line propagates down the transmission line when the Auston switch is closed with a fast-rising laser. The neutron-sensitive U coated cathode, designed as a matched stripline, is activated during the passage of the pulse thus sampling the neutron flux during the pulse duration. Note that unlike the x-ray framing cameras which require high spacial resolution for image preservation, our neutron diode need only signal counting on the phosphor screen, making it easier to attain higher time resolution. We estimate that ≈ 20 ps resolution can be achieved with a 6 mm wide stripline.

Two possible configurations are shown in Fig. 3 and 4. Figure 3 shows an equidistance configuration in which the stripline is at the same distance from the neutron source. Different part of the stripline samples the neutron flux at different times. This scheme is useful when the neutron yield is high. When the neutron yield is low, the velocity-matched configuration of Fig. 4 is preferred. Here the stripline is so arranged that the whole cathode samples the neutron flux

at the same instance by matching the pulse propagation time with the neutron arrival time. Four such striplines can sample the entire neutron pulse at four different times. With 10 μm U coating, four 5 cm long striplines can yield 100 events for 3×10^8 neutron source at 8 cm. This is a useful sensitivity even for Omega and Gekko lasers.

Figure 5 shows a possible configuration with a mesh anode stripline if the background due to neutron-phosphor screen interaction were a problem. A simple static test should suffice to determine whether the shield is required for the phosphor screen.

Discussion

The neutron streak camera was the only known possibility to obtain a 20 ps neutron detector of adequate sensitivity up to a year ago. However with the advancement of the ultrafast gating technology, the stripline neutron diode approach appears to have advantages. It does not require as critical shaping of the cathode to achieve velocity matching as the neutron streak camera. For the latter, the cathode shape has to be changed whenever the cathode to source distance is changed. For the stripline, the velocity matching can be achieved by simply tilting the angle. The striplines are cheaper to make and the sensitivity can be considerably higher. Finally, the need for ultrafast gating is common to the x-ray framing so that the development cost can be shared.

References

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2. E. R. Close and J. S. Colonias, accompanying paper in this proceeding.
3. R. H. Price et al., IEEE 1983 Nuclear Science Symposium, San Francisco, California (1983).
4. A. K. L. Dymoke Bradshaw et al., 16th European Conference on Laser Interaction with Matter, London (1983).

Figure Captions

- Fig. 1. A possible configuration of the neutron streak camera.
- Fig. 2. Conceptual design of a ultrafast gated stripline neutron diode.
- Fig. 3. Equidistance configuration of the neutron diode stripline.
- Fig. 4. Velocity matched configuration of the neutron diode stripline.
- Fig. 5. A possible configuration with a mesh anode stripline to shield the phosphor screen for background reduction.

A NEUTRON STREAK CAMERA

Fig. 1

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Gated transmission line neutron diode

Fig. 2

Equidistance configuration

Velocity-matched configuration

Fig. 4

Shielded phosphor screen