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Design optimization, manufacture and response measurements for fast-neutron radiography converters made of scintillator and wavelength-shifting fibers

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ABSTRACT

In order to improve the image quality of fast neutron radiography, a converter made of scintillator and wavelength-shifting fibers has been developed. The appropriate parameters of the converter such as fibers arrangement, distance between fibers are optimized theoretically, and manufacture of the converter are also optimized. Fast neutron radiography experiments by 14 MeV neutrons are used to test this converter and kinds of traditional converters. The experiments' results matched the calculations. The novel converter's resolution is better than 1 mm and the light output is high.

Contents

1. Introduction

Fast-neutron radiography (FNR) is a nondestructive testing technology using fast neutrons as probes. This method can be complimentary to existing technologies such as X-ray radiography. Compared with low-energy neutron, fast-neutron could penetrate thicker samples, but its detection is difficult. The key problem of improving the quality of fast-neutron radiography is developing a suitable detector, which can convert the invisible fast-neutron image into a visible light image effectively and distinguishably.

The common fast neutron converters such as ZnS(Ag)-based scintillator [1,2] and plastic scintillator [2] have been developed for several years. A thick plastic scintillator could be used to improve the detection efficiency because its transparent characteristic benefits for light transmission. Unfortunately, this converter is sensitive to gamma ray and resolution is low. ZnS(Ag)-based

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scintillator has higher light output with low sensitivity to gamma ray but ZnS(Ag) powder is opaque, which limits the thickness of scintillator and makes the detection efficiency poor for an appropriate resolution.

A converter made of scintillator and wavelength-shifting fibers (WSF) is a new scintillator which may have both high detection efficiency and high resolution. Matsubayashi et al. [4] firstly developed this scintillator, which was piled up with 0.1 mm thick polypropylene (PP) scintillator sheets and WSF sheets with diameter of 0.5 mm alternatively. Zou et al. [5] improved the performance of WSF converter and optimized the converter design primarily. The preliminary experiment results of the WSF converter pointed out that this converter has higher light output and lower gamma sensitivity.

In this work, an academic method is developed to optimize parameters of the converter. The process is also improved to obtain large size WSF converter. An experiment based on an accelerator neutron source with 14 MeV neutrons has been carried out to test the WSF converters.

2. Method

The WSF converter includes the neutron detecting process and light transmission process, which is corresponding to the detection efficiency and resolution. Fig. 1 shows the structure of WSF converter. Scintillator is made of ZnS(Ag) powder used to give out light, and hydrogen enriched materials such as polypropylene and resin are used to detect fast neutrons. Fast neutron would induce recoil proton in the hydrogen enriched materials, then the recoil proton would excite the ZnS(Ag) powder and generate primary light photos. WSF is the light transmission path which light photons impenetrate from the scintillator. The primary light photons would access the nearby fiber and deliver to secondary light photons. Then secondary photons would be guided by the fiber and formed image on the converter surface. This separation solved the conflicting goals of detection efficiency and resolution.

2.1. Fibers arrangement

The fibers should be arranged in the scintillator regularly. There are two typical arrangements shown in Fig. 2. Assume that the primary light photons attenuate exponential in the scintillator, and each fiber would guide the primary light photons in its own nearby area (the shadow area in Fig. 2). When the distance between fibers in the two arrangements is the same, the nearby area is the same, triangle arrangement has larger fiber density

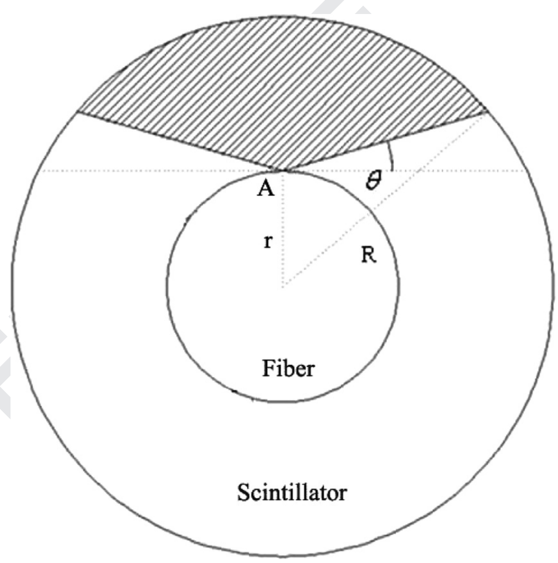

Fig. 3. Calculation model.

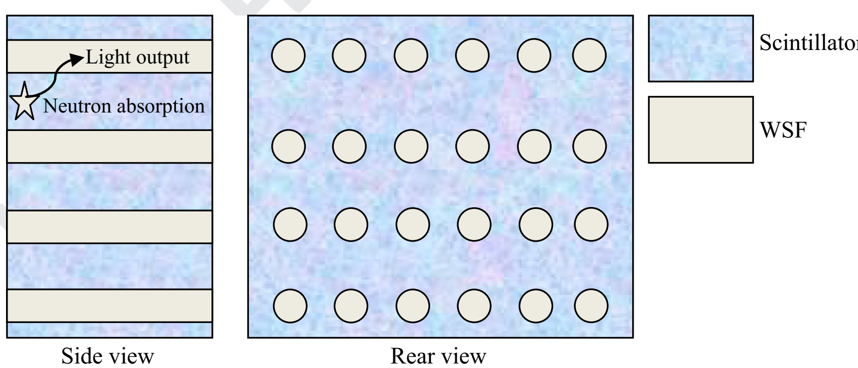

Fig. 1. Sketch map of WSF converter.

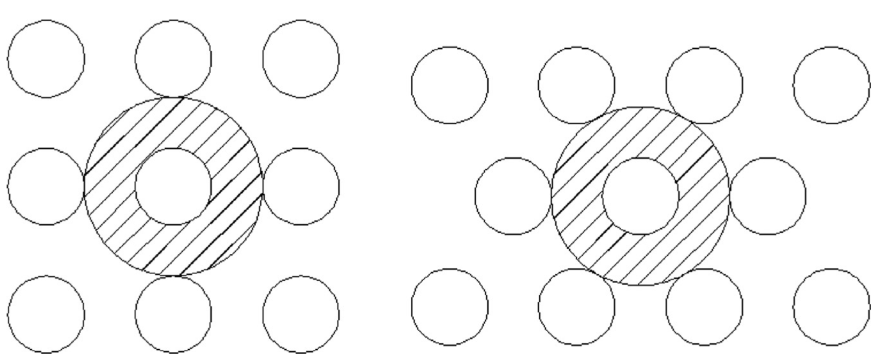

Fig. 2. Arrangements of fibers (left: square arrangement; right: triangle arrangement).

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