



Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Development of multi-pinhole collimator for large imaging area with high spatial resolution

H. Hayashida^{*}, M. Segawa, R. Yasuda, H. Iikura, T. Sakai, M. Matsubayashi

Quantum Beam Science Directorate, Japan Atomic Energy Agency, Tokai-mura, Naka-gun, Ibaraki 319-1195, Japan

ARTICLE INFO

Available online 5 February 2009

Keywords:

Neutron radiography
Multi-pinhole
Collimator
Spatial resolution

ABSTRACT

A multi-pinhole collimator system, which is effective for enlarging imaging area with high spatial resolution, has been demonstrated on Cold Neutron Radiograph Facility at JRR-3M in JAEA. The multi-pinhole collimator system consists of a multi-pinhole aperture and an overlap-cutter. On neutron beam from the multi-pinhole aperture, neutrons from each pinhole overlap at the sample position due to beam divergence. In the overlap area, sample images from each pinhole are obtained at a detector and these images look like split images. The overlap-cutter works to cut neutrons contribute to overlap at sample position and enable us to get an image without split. Imaging area was enlarged and sharp image without split was successfully obtained by using the multi-pinhole collimator system.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

In radiography, improvement of spatial resolution is a common need in various research fields. There are two kinds of factors affecting spatial resolution. One is the detector system and the other is the beam optimization. In the beam optimization field, unsharpness of image d is given as follows:

$$d = \frac{l_{sd}D}{L} \quad (1)$$

where l_{sd} is the distance between sample and detector, D is the aperture size and L is the distance between aperture and sample. The d has to become small for sharp image. The l_{sd} is limited by a sample size and L is restricted by an instrument space. Therefore use of small aperture is effective for obtaining a sharp image.

Neutron is more sensitive to light water than X-ray and Neutron Radiography (NR) is powerful method to visualize water transportation. For example, in the research field of fuel cell, visualization of water transportation is an important study. Recently, some experiments of visualizing water in a fuel cell by NR were performed [1–11]. Imaging condition with $d < 100 \mu\text{m}$ and visible area of $50 \text{ mm} \times 50 \text{ mm}$ are required to visualize water transportation in fuel cell more clearly. Since a realistic distance of l_{sd} is about 100 mm in the case of using fuel cell as a sample, a collimator ratio $L/D > 1000$ is necessary for $d < 100 \mu\text{m}$. Using the pinhole aperture is effective for high collimator ratio. In the NR instrument installed at the National Institute of Standards and Technology, pinhole aperture is used and high collimator ratio is achieved [12].

When using pinhole aperture, an imaging area is defined by the original aperture size, the distance between the aperture and the pinhole, and the distance between pinhole and sample position. In the Thermal Neutron Radiography Facility (TNRF) which is located at 7R port at JRR-3M, the original aperture size is $40 \text{ mm} \times 40 \text{ mm}$. The pinhole collimator can be set at about 5000 mm downstream of original aperture and the distance between the pinhole aperture and the sample position L is limited to 2300 mm. Then imaging area becomes about $20 \text{ mm} \times 20 \text{ mm}$ and this is not enough to visualize whole area of the fuel cell. A multi-pinhole aperture is one of the useful methods to enlarge imaging area with high spatial resolution [13]. Test experiment using a multi-pinhole aperture was carried out at TNRF. However in TNRF, scattered neutrons from beam duct existed. These neutrons had large divergences and made overlap area at sample position. The split image made by overlapped neutrons was observed. It is, therefore, necessary for us to reduce the neutron beam contribution to overlap. An additional overlap-cutter, such as cadmium plate and so on, is necessary. In this paper, the system using multi-pinhole aperture and overlap-cutter is referred to as the “multi-pinhole collimator system”. In the TNRF, we cannot access the position setting multi-pinhole collimator system easily. Thus the system was not demonstrated in TNRF but in Cold Neutron Radiography Facility (CNRF). In Section 2, the details of the system and experimental setup are described. The results are given in Section 3.

2. Experimental system

Fig. 1(a) shows a typical NR setup using multi-pinhole aperture where D is the aperture size, L is the distance between multi-pinhole aperture and sample position and l_{sd} is the distance

^{*} Corresponding author. Tel.: +81 292843911; fax: +81 292843909.
E-mail address: hayashida.hiroto@jaea.go.jp (H. Hayashida).

between sample position and detector position. Two pinholes are shown in Fig. 1 and beam paths from each pinhole are indicated by solid and dashed lines. A beam overlap area exists due to beam divergence. In other words, the overlap area has two light sources. At a sample position, an object of star shape is placed in beam overlap area and objects of circle shape are placed in non-overlap area as shown in Fig. 1(a). The image of star-shaped object will be split at the detector position due to two light sources. Neutron beam contributes to overlap which has to be cut in order to get image without split. Fig. 1(b) shows a schematic diagram using overlap-cutter and also a setup without overlap area at the sample position. In this case, a little overlap remains but imaging area without overlap will be expected to be enlarged compared to the setup without overlap-cutter. Fig. 1(c) shows a setup without overlap area at the detector position. In this case, a little blank area exists but imaging area without overlap will be expected to be enlarged too. The size of remaining overlap area shown in Fig. 1(b) and that of blank area shown in Fig. 1(c) depend on l_{sd} and beam divergence.

A demonstration was performed at CNRF and the multi-pinhole collimator system was set to CNRF. Photograph of the setup is shown in Fig. 2(a) where $l_{12} = 255$ mm, $L = 900$ mm, $l_{sd} = 100$ mm. The overlap-cutter was set to the condition without overlap at detector position (Fig. 1(c)). An imaging plate (IP) was used as a detector of resolution $50\mu\text{m}$. The pictures of the multi-pinhole aperture and of the overlap-cutter are shown in Figs. 2(b) and (c), respectively. The multi-pinhole collimator and the overlap-cutter were fabricated by cadmium plate. All pinhole size on the multi-pinhole aperture is 2 mm in diameter and distance between two pinholes is 10 mm. The size of each part of an overlap-cutter is indicated in Fig. 2(c). Neutron beam contributes to overlap from pinhole (1) and (2), indicated in Fig. 2(b), is cut by (4) part on overlap-cutter, indicated in Fig. 2(c). And neutron beam contributes to overlap from pinhole (1) and (3) is cut by (5) part on overlap-cutter. All the neutron beam contributions to overlap from each pinhole are cut by overlap-cutter with the same principle.

3. Experimental result

A plastic model mainly fabricated by polystyrene was used as a sample. The size of the sample was about 100 mm in height,

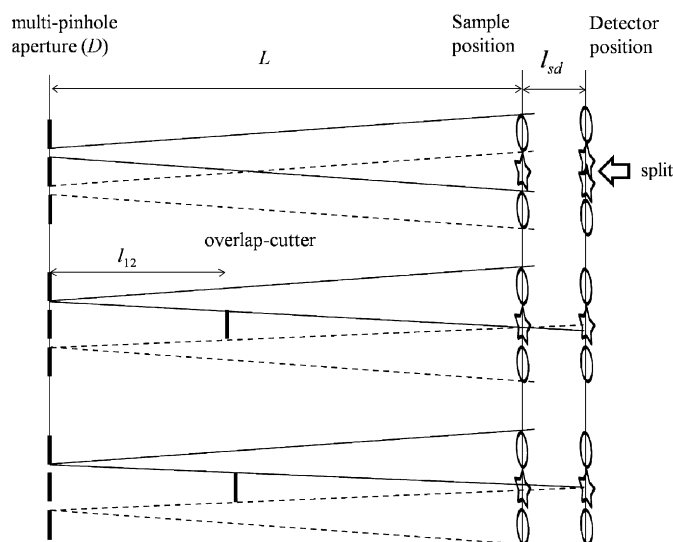


Fig. 1. (a) Typical NR setup using multi-pinhole aperture. (b) and (c) show a typical setup using an additional overlap-cutter. (b) shows the setup without overlap at the sample position and (c) shows the setup without overlap at the detector position.

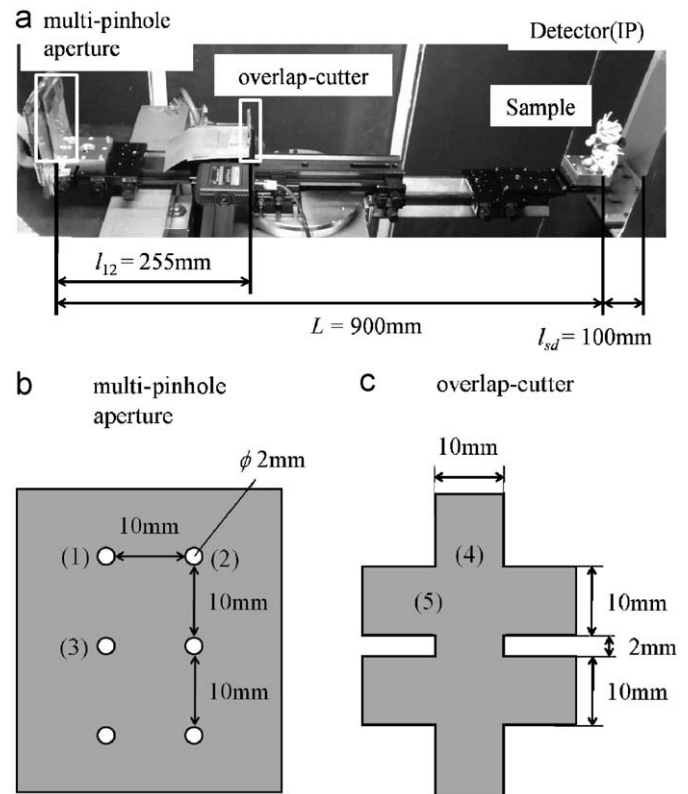


Fig. 2. (a) The photograph of multi-pinhole collimator setup at CNRF. (b) The picture of multi-pinhole aperture and (c) picture of an overlap-cutter.

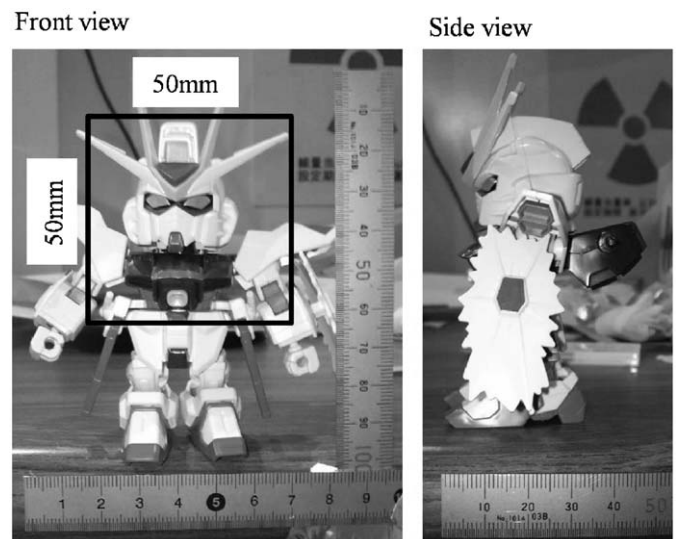


Fig. 3. The photograph of sample.

80 mm in width and 40 mm in thickness as shown in Fig. 3(a). The demonstration was performed with three conditions as written below in order to verify the effect of multi-pinhole collimator system.

3.1. Using large single pinhole

A large size aperture with a size of 35 mm in vertical and 17 mm in horizontal was setup. The result in this condition is shown in Fig. 4(a) and an unsharp image was obtained. The size of

Download English Version:

<https://daneshyari.com/en/article/1828537>

Download Persian Version:

<https://daneshyari.com/article/1828537>

[Daneshyari.com](https://daneshyari.com)