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Low efficiency 2-dimensional position-sensitive neutron detector for beam profile measurement

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Abstract

A gas-filled position-sensitive wire detector has been developed for monitoring thermal neutron beams with flux up to 10^7 n/cm^2/s over an area $\approx 80\,cm^2$. It is filled with CF_4(4 atm) and a small quantity of ^3He, has 1.2 mm spatial resolution, 0.1% efficiency (at 0.18 nm) and can achieve a count rate of 350 kHz. Experiments at the 30 MW HANARO reactor showed that the fabricated PSD is a very useful and convenient tool for adjusting neutron monochromators, especially focusing monochromators, and for monitoring monochromatic beams. It can be used for various neutron optics experiments.

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1. Introduction

In experiments with neutron beams, a photographic method is usually used for localization of a neutron beam and determination of its sectional size. In particular, the method is used in experiments with focusing neutron monochromators to measure beam size at different distances from a single bent graphite monochromator [1]. The photographic method is quick, simple and cheap but because of a low dynamic range it cannot provide accurate information of the intensity profile across the beam. Such information is important for many neutron scattering instruments because a homogeneous neutron beam is desirable.

Position-sensitive detectors (PSD) can solve the problem of measuring a beam intensity profile. However, commercially available PSDs are

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designed to have high detection efficiency and because of the limitation in count rate they cannot measure neutron fluxes of more than $10^4\,n/cm^2/s$. A high-resolution ($\sigma = 0.1\,mm$), low-efficiency ($\approx 1\%$) PSD using gas micro-strip technology (MSGD) was developed recently in RAL to monitor beam lines with a mean flux of $\sim 10^7\,n/cm^2/s$ over an area of $\approx 30\,cm^2$ at the ISIS spallation neutron source [2].

A number of gas-filled multi-wire position-sensitive detectors (MWPC) with high detection efficiency (~60% at 0.18 nm) were developed in the Neutron Physics Department (NPD) of KAERI for application in various neutron scattering instruments at the 30 MW stationary HANARO reactor [3–5]. The aim of this work is to develop a comparatively cheap and simple MWPC-type PSD to monitor monochromatic neutron beams reflected from the monochromators and delivered to the instruments. Existing electronics for high-efficiency PSDs, a N110 TDC developed by the European Synchrotron Radiation Facility, could be used for the detector [6].

The intensity of a monochromatic thermal neutron beam in the reactor hall is 10^5–$10^7\,n/cm^2/s$. Beam size varies from several to several tens of square centimeters and usually does not exceed $30\,cm^2$. For an achievable count rate $\approx 300\,kHz$ the efficiency of the PSD should be about 0.1%. Sectional linear sizes of the beams are usually more than 10 mm. Therefore a PSD with a spatial resolution of about 1 mm is sufficient to estimate the uniformity of the beam.

A gas-filled MWPC detector with low detection efficiency (~0.1%) was fabricated. The detector is based on delay-line readout [7], has a $90 \times 90\,mm^2$ active window, 1.2 mm spatial resolution and can achieve a count rate of 350 kHz. The detector was used for adjusting monochromators and measuring intensity profiles of monochromatic beams at the four-circle diffractometer (FCD), the high-resolution powder diffractometer (HRPD) and in experiments with focusing monochromators from bent perfect Si crystals (BPC).

2. Description of the detector

The detector was designed for small-angle X-ray scattering and as such it has a 0.5 mm thick carbon fiber window. The effective size of the window is $90 \times 90\,mm^2$. With the carbon fiber window the detector can be filled up to 5 atm pressures.

The anode plane is made of 90 thin $\varnothing 6\,\mu m$ gold-plated tungsten wires stretched over and soldered on a printed circuit board. The board was made from polyimide which is a very good material for gas-filled detectors [8]. There are two $\varnothing 30\,\mu m$ gold-plated tungsten guard wires, one on each side of the anode wires. The spacing between the wires is 1 mm. The cathode plane is made of 90 thin $\varnothing 30\,\mu m$ gold-plated tungsten wires. Both the cathode wires are connected to a tap of lumped delay line (56 pF capacitor, 145 nH inductor, $Z_0 = 50\,\Omega$, delay of 2.9 ns/tap). The total thickness of the active volume is 20 mm. The X and Y coordinates of detected neutrons are read from cathode wires, and anode signals are used as starting pulses of the TDC in delay line readout method.

Since the spatial resolution of the detector is proportional to the charged particle range in the neutron converter and quenching gases, CF_4, which has a high stopping power for protons, is used. The range of a 573 keV proton from the $^3He(n,p)^3H$ reaction is less than 1 mm for more than 4 atm of CF_4 [9]. The detector was filled with a small quantity of ^3He and 4 atm of CF_4. For this gas mixture the detection efficiency was around 0.1% for 0.18 nm neutrons.

The differential non-linearity of the detector filled with these gases was about 3% over the detection area. To evaluate the spatial resolution and linearity the detector was installed in the monochromatic beam of FCD, at sample position. A cadmium hole of 0.5 mm diameter was used to test the spatial resolution. The separation between peaks in this case was 10.0 mm. The average of the full-width at half-maximum (FWHM) for the peaks is 1.2 mm. The point spread function of the detector is shown in Fig. 1. The resolution is the same in vertical and horizontal directions across the detector.