Nuclear Instruments and Methods in Physics Research A 616 (2010) 59–64

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

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

The FastGas detector

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ARTICLE INFO

Article history:
Received 14 December 2009
Received in revised form
3 February 2010
Accepted 9 February 2010
Available online 11 February 2010

Keywords:
MSGC
^{3}He
Gas detector
Neutron detector
Reflectometry

ABSTRACT

The development and testing of the FastGas neutron detector is described. Based on a Gas Microstrip Chamber the aim of the project was to produce a high counting rate detector capable of replacing the existing ^{3}He tubes for specular reflectometry, currently in use on the ISIS reflectometer instruments. The detector system is described together with results of neutron beam tests carried out at the ISIS spallation neutron source.

1. Introduction

Following the successful testing of a 2D imaging detector based on the gas microstrip detector (MSGC) technology [1] on the ROTAX beamline at ISIS [2], it became clear that this technology could offer significant detection capabilities for further experiments on ISIS beamlines. The CRISP reflectometer [3,4] is an instrument which is primarily used for time of flight neutron reflection experiments from surfaces and interfaces. In its specular reflection mode the instrument uses a single, 1 in. diameter wire detector filled with 3.5 bar of neutron sensitive ^{3}He, which is used to measure the intensity of the reflected neutron beam.

The FastGas project was a development programme aimed at demonstrating that MSGC technology could successfully be applied to the field of neutron detection in order to replace the ^{3}He tubes, the count rate performance of which has been shown to deteriorate quite rapidly at relatively modest neutron fluxes. Based on the same ^{3}He neutron converter with added quencher, this technology can offer a high rate capability with good timing resolution and low gamma sensitivity at high neutron detection efficiencies in the 1–10 Å wavelength range.

2. FastGas detector design

The FastGas MSGC glass plates are of the same basic design as those described previously [5]. The MSGC pattern is etched into 0.5 μm chromium and comprises of 10 μm wide anodes interleaved with 90 μm wide cathodes on a 300 μm pitch. The plates are produced at IMT [6] on Schott S8900 conducting glass [7]. The glass plate consists of eight sections, each of which has 10 anodes connected together with an active length of 60 mm, and can be seen in Fig. 1(a). The plates themselves are glued to a printed circuit board (PCB) and are ultrasonically wire bonded to pads on the PCB. The cathodes are biased via a filter network on the reverse of the PCB and the anodes are tracked to a 15 way D connector. The PCB is then mated to a 15 way vacuum feed-through flange at one end and supported on spacers at the other end to keep the plate level. This flange is welded into the stainless steel detector vessel along with two high voltage feed-throughs. An aluminium window, 3.5 mm thick, is bolted to the vessel and the gas seal is made by using a Garlock seal [8]. The drift plane is mounted on the inside of this window and is insulated from the window by using solid ceramic spacers of thickness 2 mm which cover the whole active window (hence leaving no "dead" gas space). A high voltage connection is made to the drift plane by means of a spring loaded contact and the drift depth is defined as 25 mm. A gas inlet pipe is also welded into the vessel and is sealed off with a swagelok valve [9] thus enabling the vessel to be pressurised. The vessel has been designed and pressure tested to operate at 14 bar gauge pressure and can be seen in Fig. 1(b).

The signals from each group of anodes are input to a module containing 16 channels of a charge preamplifier plus shaping amplifier chain [10] (eight channels of which are redundant). This is mounted on the reverse of the 15 way D feed-through in a custom built external housing. The differential analogue output pulse is then sent via a 15 m cable to a signal converter unit,

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doi:10.1016/j.nima.2010.02.071

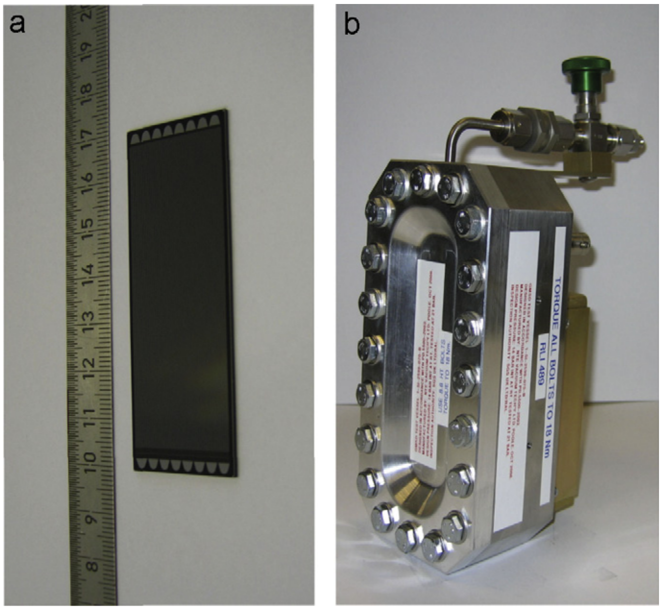

Fig. 1. (a) The MSGC plate and (b) The assembled FastGas vessel.

which in turn feeds the signals to an eight channel NIM based discriminator. From here the signals can then be fed to the ISIS Data Acquisition Electronics system (DAE) [11]. Alternatively, the fast analogue pulses from the signal converter unit can be stretched in time (by a simple RC circuit) before being amplified by a standard Ortec 575 post-amplifier, where they can then be fed to a Pulse Height Analyser (PHA) to give the corresponding pulse height spectrum. Each section of the plate can be operated independently, albeit with the same operating characteristics (and the same biasing supplies), or the digital output pulses of all eight sections can be summed together externally giving an active detector area of 60 mm by 24 mm.

3. System performance

The performance of the FastGas detector was characterised using two sets of facilities. The basic characterisation and long-term stability was measured using a moderated ^{241}Am:Be source which was capable of inducing a counting rate of ~140 Hz in a single section of the detector—adequate for these purposes. For the high rate tests, exposures were arranged on various ISIS beam lines (ROTAX [12], CRISP, SURF [13]) as limited time slots became available, and in this case the fast signals were fed directly from the discriminator to the ISIS DAE system. For the results presented in Sections 3.1 and 3.2 the analogue signals from the preamp are stretched (by integration) and amplified before being fed to the PHA, but for Section 3.3 the fast preamp signals are discriminated and then sent directly to the ISIS DAE.

As one of the putative applications of the FastGas detector is to replace the 1 in. diameter single wire counters installed on the CRISP reflectometer, the detector was designed to operate with a filling of 10 bar ^{3}He to achieve a nominal neutron stopping efficiency of 87% at a neutron wavelength of 1 Å. For the measurements reported here, 4 bar of CO_2 were used as the quench gas.

3.1. Basic properties

Typical pulse height spectra obtained from a single section of the detector are shown in Fig. 2 at normal operating conditions.

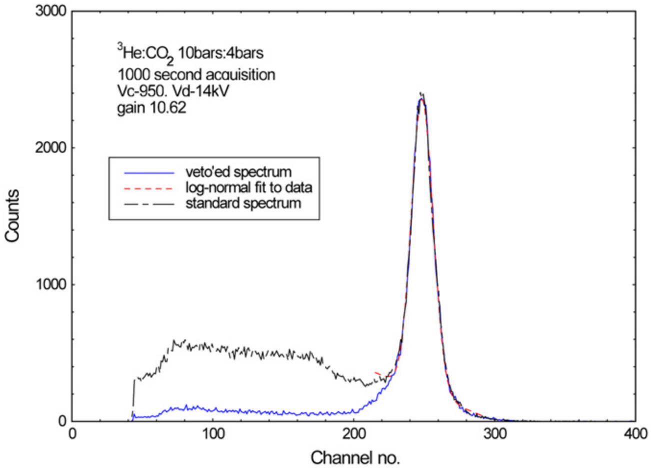

Fig. 2. Pulse height distribution from ^{241}Am:Be source with CO_2 quencher.

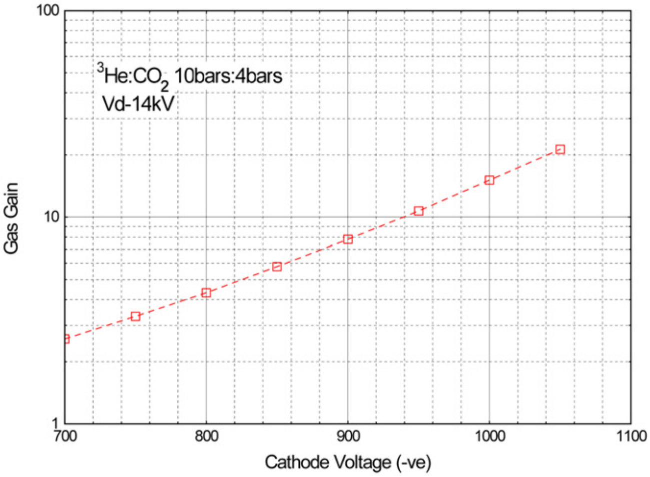

Fig. 3. FastGas gain curve in ^{3}He:CO_2 gas mixture.

A clear peak is observed corresponding to the full deposit of the 764 keV energy deposit from the Q of the detection nuclear reaction. (Since the pulses for the PHA are stretched by integration, the spectrum does not strictly represent the pulse height distribution encountered by the fast discriminators). From this peak, pulse gain curve can be calculated as seen in Fig. 3. The gain obtainable is low by the standards of X-ray detectors. This is unimportant because the initial charge signal from the ^{3}He (n,p) t reaction is ×100 greater than the typical X-ray signal so that a gain of ×10 is adequate to bring the charge signal into the comfortable working range of $2–3\times10^5$ electrons. It is only required to obtain adequate gain to ensure that the temporal pulse formation is kept stable and short. A gain of ×10 seems more than adequate to assure this with the small dimensions of the MSGC section.

An option available with the FastGas detector is to use adjacent sections to veto the events where serious proton leakage out of the section occurs. Fig. 2 shows the effect on the pulse height spectrum of vetoing events in a section with triggers from its neighbours (trigger threshold set to 200 keV). Almost all the small pulses disappear (MSGC plate and window end effects are inevitably still present). This process costs some detection efficiency and would in general not be used; however, in a high-gamma background environment it may well be very useful.

At the high pressures required for efficient operation, the drift field must be sufficient to ensure effective charge collection onto