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DEVELOPMENT AND INSTALLATION OF NEUTRON DETECTORS FOR ENGINEERING MATERIALS DIFFRACTOMETER AT J-PARC

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ABSTRACT

Neutron detectors for Engineering Materials Diffractometer named TAKUMI at J-PARC have been developed under international cooperation between Rutherford Appleton Laboratory (RAL) and Japan Atomic Energy Agency (JAEA), and installed successfully at the end of March 2009. The detector size was 805×1370×217mm which was about 1.5 times larger than those installed in ENGIN-X, ISIS facility, RAL. Neutrons are detected based on a nuclear reaction of $^{6}Li(n,\alpha)^{3}H$ using $ZnS/^{6}LiF$ scintillator. The data acquisition electronics and decoding module were also manufactured. The overall performances of the detectors have been tested using various sources. The results showed that the detectors had good performances such as a postion resolution of 3 mm, a neutron detection efficiency of more than 50 % at 1 Å-neutrons, and a gamma-ray sensitivity of less than 10^{-6} at 1.3 MeV-gamma-ray by ^{60}Co source, which met the requirements of TAKUMI.

1. Intorduction

The Japan Proton Accelerator Research Complex (J-PARC) is a high intensity proton accelerator facility that can promote nuclear physics, particle physics, material science, and life science. The J-PARC project has been conducted under cooperation between the Japan Atomic Energy Agency (JAEA) and the High-Energy Accelerator Research Organization (KEK). The Engineering Materials Diffractometer, named “TAKUMI” is one of neutron instruments that are installed in the Materials and Life Science Facility (MLF). TAKUMI is designed for investigations of internal stresses and crystallographic structures of industrial materials. The detailed information on TAKUMI can be found in the references [1,2]. The commissioning of TAKUMI was started in September 2008, and has been completed in March 2009 with full installation of detectors. In this paper, development and installation of the detector are described in detail.

2. Detector specifications and development

Figure 1 shows the schematic view of TAKUMI. Main detectors are installed at 90 degree. The detector requirements are as follows:

- Number of detectors: 10
- Sensitive area: 1000 mm × 200 mm
- Spatial resolution: 3mm
- 360 channel / detector
- Detection efficiency: >50%@1Å
- Gamma sensitivity: $<10^{-6}$@1.3MeV
- Secondary flight path: 2.0 m

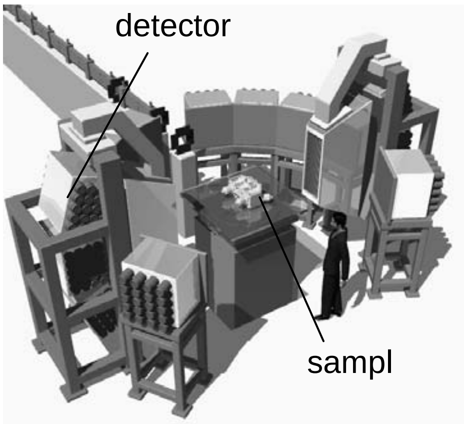

Fig.1 Schematic view of TAKUMI

As a result of international cooperation between JAEA and Rutherford Appleton Laboratory (RAL), an ENGIN-X-type linear scintillation neutron detector was developed for TAKUMI after confirmation of performances of a prototype detector [3,4], where ENGIN-X is one of the neutron instruments at ISIS in RAL. The detector head mainly consists of scintillators, reflectors, and optical fibers. The main part of the detector with photomultiplier tubes (PMTs) is shown in Fig.2. The detector has a large sensitive area of about 1000 × 196 mm that consists of 360 pixels with a position resolution of 3 mm, while that of ENGIN-X detector in ISIS facility is 744 × 196mm with 240 pixels.


Fig.2 The main part of detector

The "ventian" type head [5] originally developed by ISIS facility was adopted to improve the light collection efficiency and to increase the neutron detection efficeicy. Detailed structure of the head was desribed in Ref. [5]. The incident neutrons are detected on the basis of ZnS:Ag/^{6}LiF scintillation techniques using a nuclear reaction of ^{6}Li(n,α)^{3}H. To determine the incident neutron position and to reduce the number of PMTs, the optical fibers connected with the detector head are pair coded into the PMTs. The electric signals from the PMTs are sent to data acquisition electronics (DAE) and decoders, which were also developed at the same time. The neutron incident channel is determined in the decoders by coincidence of DAE output of any two PMTs.

3. Fundamental characterictcs

The fundamental characteristics such as output plateau characteristics and output linearity were measured at JRR-3 MUSASI port. The neutron flux and neutron wavelength were 1.4×10^{5} n/cm^{2}/s and 2.2Å, respectively. The Data Acquisition Electronics and the decoder were also developed at the same time. The output plateau characteristics as a function of applied voltage that were supplied to the photomultiplier tubes (PMTs) are shown in Fig.3. It can be seen that the output was almost constant and independent on

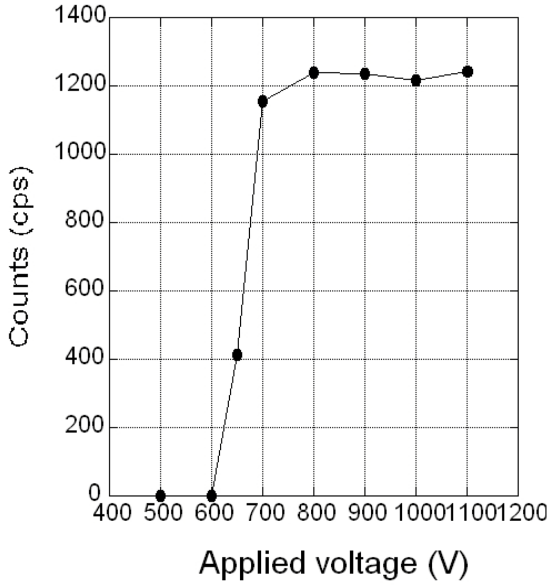

Fig.3 Plateau characteristics as a function of an applied voltage.

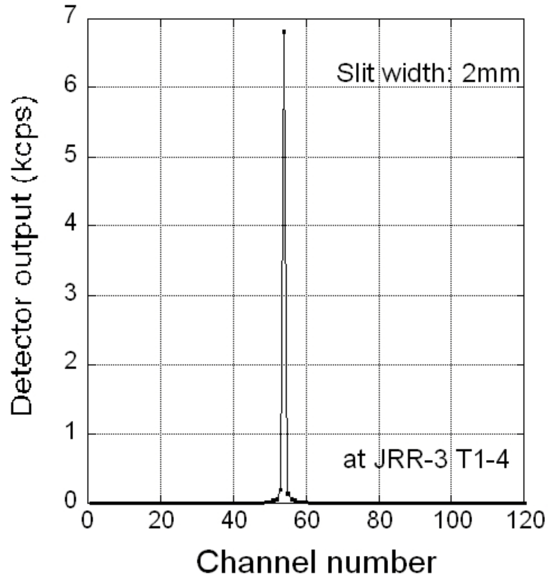

Fig.4 The detector output with a slit of 2 x 2 mm.

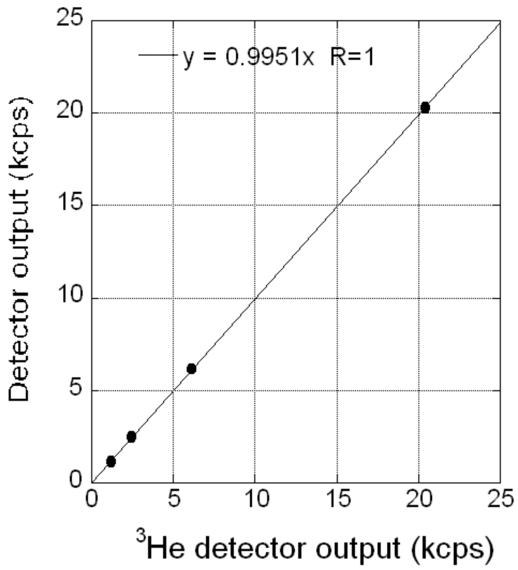

Fig.5 The output linearity of the detector.

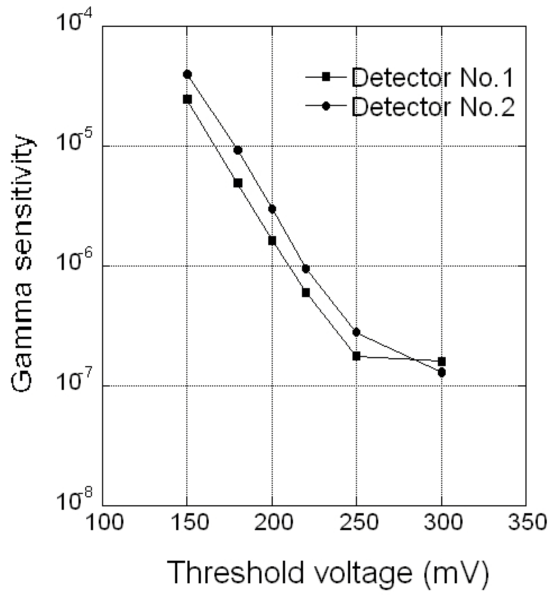

Fig.6 Gamma sensivity with ^{60}Co.

the applied voltage when the voltages was more than 800 V, although this value is dependent on the indivisual characteristics of PMTs used. The output plateau characteristics are obtained because light from both surfacesof the scintillator can be collected in the venetian-type detector head. This feature is very favable for setting the voltage. Figure 4 shows the detector output when the collimated neutron beam (2 × 2 mm) was irradiated on the detector. One can see that an intense signal was observed only in the incident neutron channel. This means that there was no coding misses in the detector and decoder manufacturing. Next the output linearity was measured by changing the beam size. In this experiment, neutron intensity was also measured by one-dimensional ^{3}He neutron detector (ORDELA, 1150N). The output of the prototype detector as a function of the ^{3}He detector output is shown in Fig.5. The relationship between both outputs was linear and the coefficient was almost unity. One can also see that the detector has good output linearity up to 2×10^4 cps. Finally the gamma sensitivity was measured using ^{60}Co source as shown in Fig.6. The figure shows detector output per gamma-ray as a function of a threshold voltage of DAE. The gamma sensitivity was less than 10^{-6} with a threshold voltage of more than 250 mV. At a threshold level of 250 mV, neutron detection efficiency was estimated using a calibrated detector. The detection efficiency of detectors No.1 and No.2 were about 53 % at a neutron wavelength of 1 Å.

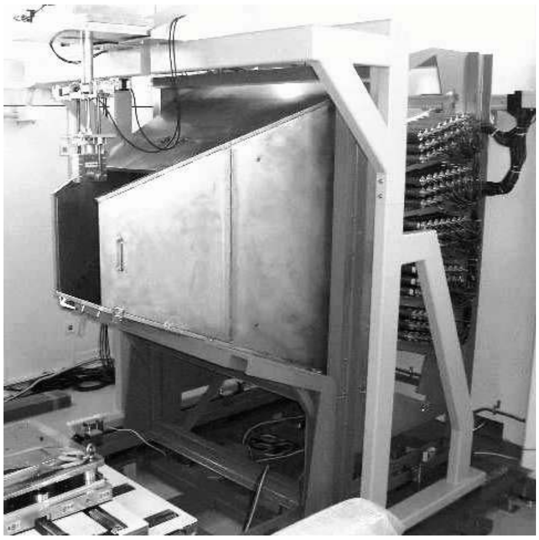

Fig.7 Detectors installed at the south bank.

4. Installation and Commisioning

The commissioning of TAKUMI was started in September 2008 and completed by the end of March 2009. At this time all ten detectors were intalled at a scattering angle 2θ of 90 degree after confirmation of fundamental detector performances using a ^{252}Cf source and a ^{60}Co source The coverage angle of 2θ was $75^\circ < 2\theta < 105^\circ$. Fig.7 shows

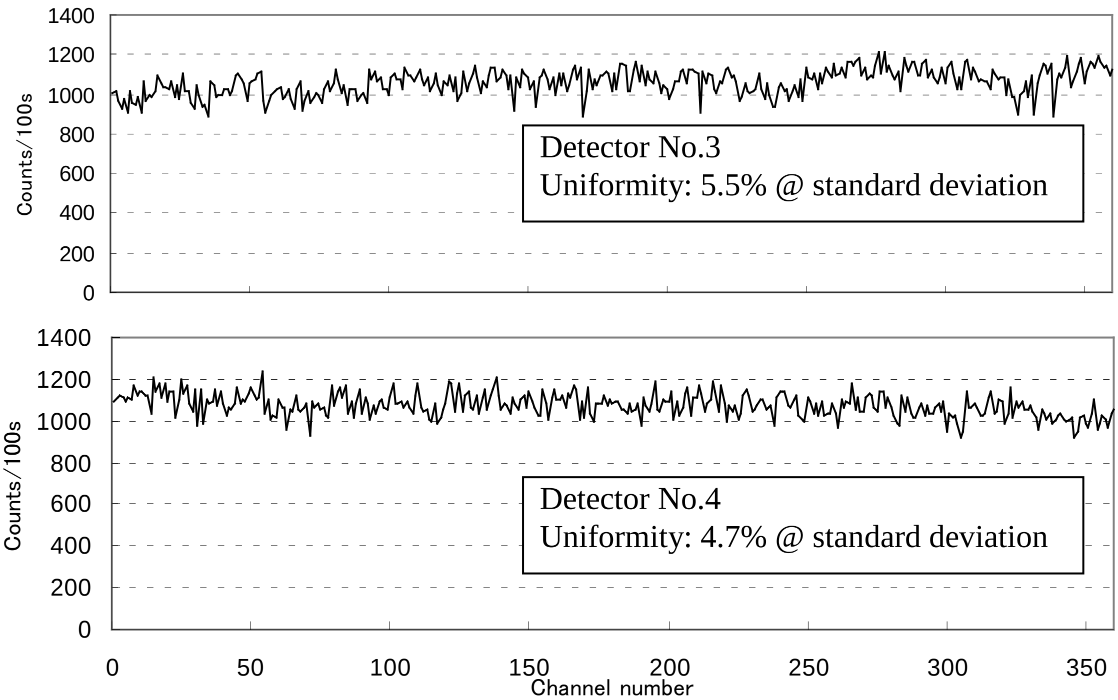

Fig.8 Results of uniformity measurement

installed five detectors at the south bank. Other five detectors were installed at the north bank. As an example of the commissioning test, Fig.8 shows a uniformity measurement of detectors No.3 and No.4 using a polyethyrene rod with a diameter of 10 mm. The detectors had a very good uniformity with a standard deviation of 5.5 % for detector No.3 and 4.7 % for detector No.4. The TOF characteristics were also measured with a bcc-Fe sample by changing a slit width. The results with a slit of 5 mm after time foucusing were shown in Fig.9. Sharp peaks originated from d-spacings were clearly observed. The resolution defined by Δd/d of the 110 peak was about 0.15% which was almost the same as the designed value.

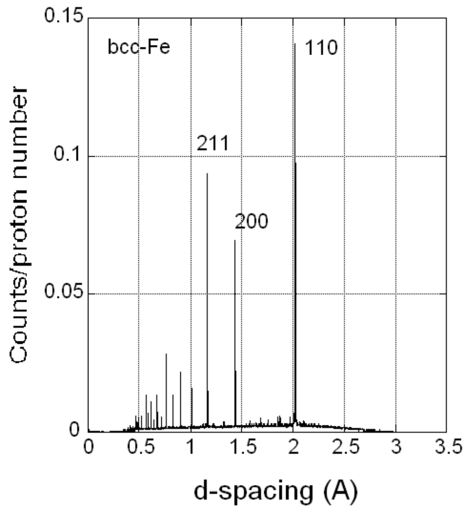

Fig.9 TOF measurement with a Fe sample.

5. Summary

We have developed linear scintillation detectors with a position resolution of 3mm for the Engneering Materials Diffractormater, TAKUMI, at MLF in J-PARC under international collaboration between RAL and JAEA. The neutron detection efficiency and gamma-ray sensitivity were more than 50 %@ 1 Å and less than 10^{-6}, respectively, which met the requirements. The installation of all ten detectors was completed by the end of March 2009. The detectors are installed in two banks of five modules. The active area of the detector was 2.0 m^2. TAKUMI is now open for users. Detailed current status of TAKUMI will be described in this proceedings [6].

6. References

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