Proc. Int. Symposium on Advances in Neutron Scattering Research, Tokai, 2000
J. Phys. Soc. Jpn. **70** (2001) Suppl. A pp. 468–470

A Fast Readout Method for an Imaging Plate Using CAMAC System

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A fast imaging-plate readout method using CAMAC measuring system is described. The readout system consists of a line-shaped laser system for generating photostimulated luminescence (PSL), and wavelength-shifting fibers (WSFs) for the signal transmission. The authors have carried out demonstration experiments using an alpha particle source of the size 5 mmϕ. The experimental results show that an alpha particle source image on the imaging plate of 5 mm × 16 mm can be taken within ten milliseconds. The spatial resolution of the image in laser scanning direction is estimated to be 0.5 mm, though that perpendicular to the direction is more than 1 mm, which is greatly dependent on the diameter of WSFs.

KEYWORDS: fast readout, imaging plate, CAMAC, line-shaped laser, wavelength shifting fiber

§1. Introduction

Imaging plate (IP) have been originally developed as a two-dimensional position sensitive detector for X-ray in the field of medical diagnostics.[1,2] The great advantages of the IP compared to conventional position sensitive gas detectors are, a) the wide-dynamic range, b) the high-spatial resolution, c) the large-detection area, d) the high-detection efficiency, and e) reusability. IP for neutron detection has also been developed, where the plate contains neutron sensitive materials such as Gd.[3] Neutron IP is very effective for monochromatic beam experiments in the fields of neutron powder diffraction, protein crystallography, single crystal experiments, and neutron radiography.[4]

The authors have been developing an imaging device for time-of-flight (TOF) neutron scattering experiments at pulsed neutron source. The device is required to handle a high peak counting rate and to have timing resolution to use with TOF method. The authors have chosen IP as a converter, because radiation measurement using IP is based on an integral method and it can cope with a high-counting rate required for intense pulsed neutron. However, it is well known that no timing resolution can be expected using IP. Therefore, the authors have developed a fast readout method for IP which can applicable to TOF method. Timing resolution in this case can be obtained by repeating the fast readout cycle.

In the case of conventional method, the local radiation information accumulated in the IP is read out as photostimulated luminescence (PSL) by irradiation of intense focused laser light.[5,6] Usually the stored information in local pixels are read out point by point. Therefore, it takes a relatively long time to read out the whole IP. To reduce the readout time, our method adopts a line-shaped laser to illuminate the IP. In this paper, the principle of the method and the results of preliminary experiments are presented.

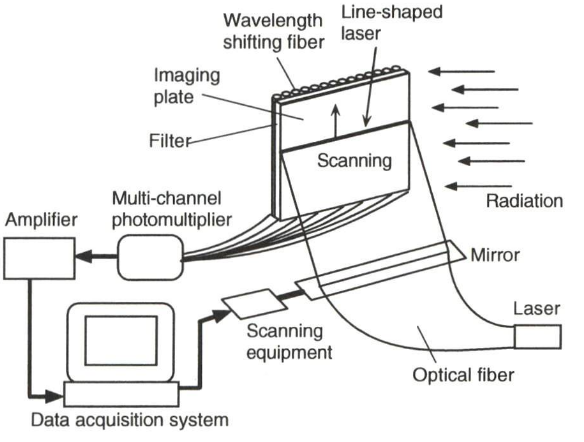

Fig. 1. The principle of readout method.

§2. Readout Method

The principle of the readout method using wavelength shifting fibers (WSFs) and line-shaped laser is schematically shown in Fig.1. The IP is scanned by a line-shaped laser beam to read out all pixels in one row simultaneously. The PSL generated by the line-shaped laser beam passes through a band pass filer and is detected from backside of the IP by the WSFs aligned in parallel perpendicular to the laser beam. The support layer of the IP, which is usually provided in case of commercially available IP, was removed to make the backside of the IP transparent to detect PSL. The luminescence detected in each WSF is converted to electric signals by a multichannel photomultiplier tube. The signals are amplified and digitized by a fast data-acquisition system.

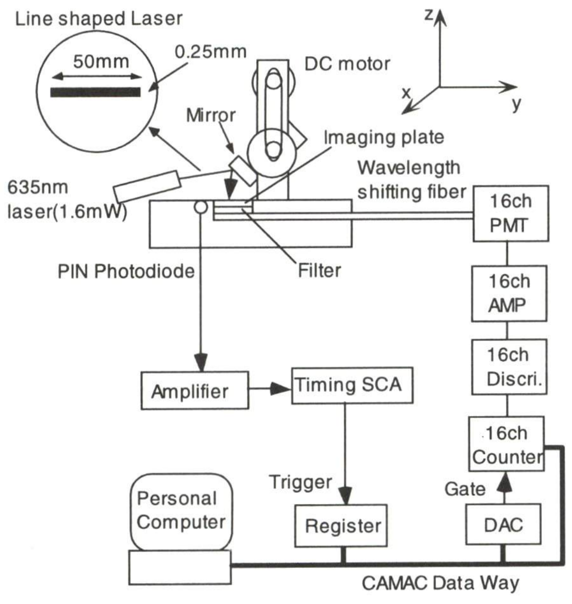

Fig. 2. The experimental setup.

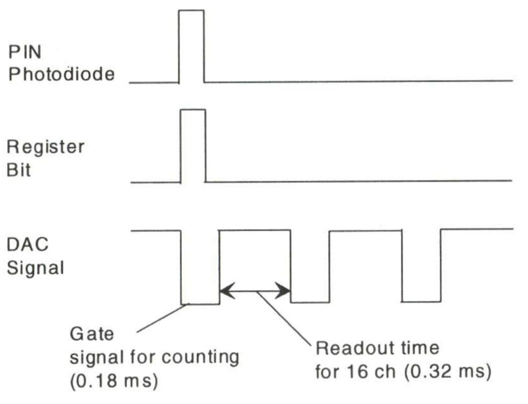

Fig. 3. Readout timing of PIN photodiode, Resister and DAC. The gate time for counting pulses and readout time for all 16 channels are 0.18 ms and 0.32 ms, respectively.

If the plate is supposed to have $10^3 \times 10^3$ pixels, the scanning time for full readout of the plate is reduced by a factor of 10^3 compared with a conventional readout method, in principle. If it is a few minutes with a normal readout method, the readout time should become less than a few 10 ms.

§3. Experiments

The authors have carried out fundamental experiments to test the readout method. The experimental setup is schematically shown in Fig.2. The front-end of the readout part mainly consists of WSFs, a semiconductor laser (635nm, 1.6 mW), and a rotating mirror. The IP was prepared by cutting out from a BAS-ND sheet (Fuji Film Co. Ltd.). A support layer of the IP was removed to detect signals from the backside of the IP. The size of the prepared IP was 44 mm × 50 mm × 0.1 mm. An optical filter (Hoya, B-390) was set between the IP and the WSFs to eliminate incident laser light when PSL was measured. The WSF (Bicron Inc., BCF-92, 1 mmϕ) was used for wavelength shifting and signal transmission. The WSF absorbs about 390 nm photons from the side and emits about 490 nm photons from the core. The one end of the WSFs were optically connected to a 16-channel photomultiplier tube (Hamatasu Co. Ltd., H6568). The red light from the semiconductor laser was converted to a line-shaped laser by an optical element. The length and width of the laser beam were 50 mm and 0.25 mm, respectively. The IP was scanned with the line-shaped laser beam by using the rotating mirror. A PIN photodiode was used for generating a trigger signal to start readout sequence of the CAMAC system.

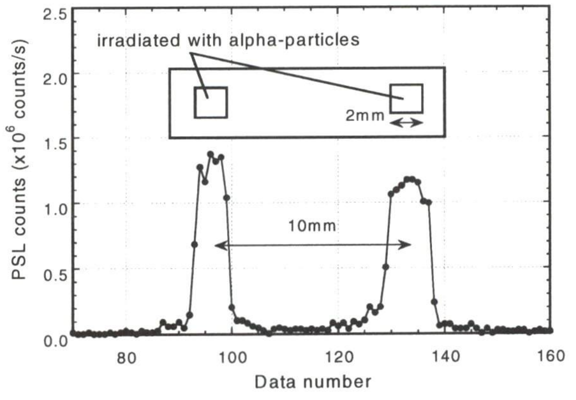

Fig. 4. The results of preliminary experiment. Two square areas irradiated with alpha particle were made on the IP.

Figure 3 shows the readout timing in this system. The readout cycle is triggered by the output of the PIN photodiode. The trigger signal makes the register (Kaizuworks Co. Ltd., KC3411) on. The on-off status of the register is monitored by the personal computer (PC, Pentium II 333 MHz). When the register becomes on, the PC sends a signal immediately to the DAC (Kinetic Systems Inc., 3112) for generating a gate signal to a 16 input 120-MHz-24-bit fast counter (Hoshin Co. Ltd., C026). On the other hand, the PSL signals from the IP are detected with a 16-channel photomultiplier tube and amplified with a 16-channel amplifier (Hoshin Co. Ltd., N018). The signal are discriminated from noise with a 16-channel discriminator (Hoshin Co. Ltd., N019). The discriminator sends counting pulses to the 16-channel counter. It counts the input pulses while the gate signal is on and converts them to digital data. The digital data are stored in the counter memory until they are read by the PC. The PC, the register, the DAC, and the counter are connected with CAMAC data way. These CAMAC modules are controlled by an 8-bit crate controller (Hoshin Ltd., CCP-F). The readout time of the digital data stored in the ADC is about 0.32 ms for all the 16 channels. The duration of the gate signal was fixed to be 0.18 ms throughout the experiments.

§4. Results and Discussions

First of all, the authors have checked the scanning performance by a preliminary experiment. The IP was irradiated with an alpha particle source through a mask which has two square-shaped (2 mm × 2 mm) openings.

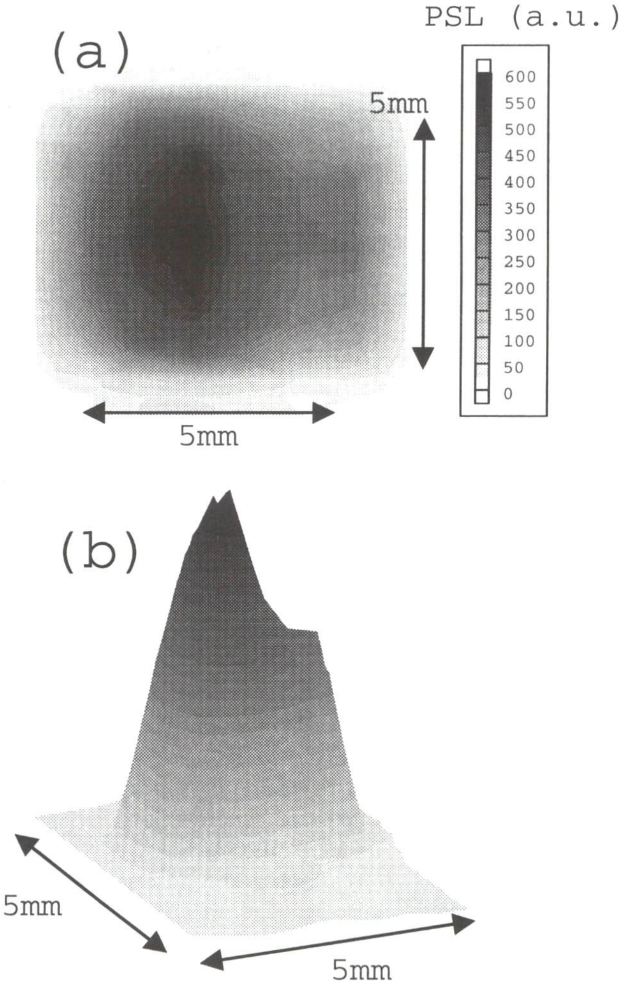

Fig. 5. The image of an alpha particle source taken by the system. (a) Intensity map and (b) 3D plot.

The distance between the two openings was 10 mm. After the irradiation, the PSL signal was measured with the system. Figure 4 shows one of the outputs from the 16-channel counter. Since the number of measured data channels was 38 between the centers of the two peaks and the full readout time for all the 16 channels was 0.5 ms, the scanning speed on the IP was 0.53 mm/ms and the radiation information in the IP was read out in every 0.26 mm. It means that an area of 5 mm $\times$ 16 mm of the IP can be scanned in less than 10 ms. Also the position resolution in scanning direction is estimated to be 0.5 mm, and that in perpendicular direction is more than 1 mm, which is greatly dependent on the diameter of the WSFs.

Next the authors have tried to take a radiation image irradiated by an alpha particle source (^{241}Am, 25 μCi, 5mmϕ). After the IP was irradiated with the source for 40 minutes, the IP was scanned and the image was taken with the system. The result is shown in Fig.5. The image shows local dose distribution by the source, though the spatial resolution in the horizontal direction in Fig.5 (a) is more than 1 mm. The spatial resolution in this direction that is perpendicular to the scanning direction depends on the diameter of WSF and the thickness of the filter. In this experiment, because of the low power of the laser system, only a small fraction of stored information was read out. This may result in degradation of the dynamic range. However, the stored information would be able to read out with a better dynamic range if a high-power laser system is employed and the thickness of the IP is optimized.[7)]

§5. Conclusions

The authors have developed a fast readout method for an IP using CAMAC system. The principle mechanism of the method was confirmed through the fundamental experiments, namely, intense neutron flux can well be measured with a time resolution by repeating the fast readout cycle. This method adopts WSFs for signal transmission and a line-shaped laser for reading out all pixels in one row simultaneiusly to reduce the readout time. The demonstration experiments show that an alpha particle source image of 5 mm $\times$ 16 mm can be taken in 10 ms with a spatial resolution of 0.5 mm in the scanning direction. Although the spatial resolution perpendicular to the scanning direction greatly depends on the diameter of the WSFs and thickness of the filter, it is easily possible to obtain better spatial resolution (for example, 0.5 mm) using those with a smaller diameter and a thin filter. The spatial resolution of 0.5 mm well suits for most neutron scattering experiments. The readout time can also be reduced with a faster CAMAC readout system using a 16-bit or 32-bit crate controller. The obtained image can be improved by adopting an intense laser and optimizing the thickness of the IP.

Acknowledgements

The authors thank to Professor, Nanto, Kanazawa Insitute Technology, for his helpful discussion. They are also grateful to Dr. Niimura, Japan Atomic Energy Research Institute, for his encouragement.

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