High Resolution Scintillating Fiber Gamma Ray Detectors For Medical Imaging[1]

M. Atac and D. B. Cline
University of California, Los Angeles
405 Hilgard Avenue, Los Angeles, CA 90024

R. C. Chaney, E. J. Fenyves and G. Hademenos
University of Texas at Dallas
P. O. Box 830688, Richardson, TX 75083-0688

P. P. Antich
University of Texas Southwestern Medical Center at Dallas
5323 Harry Hines, Dallas, TX 75235-9058

M. D. Petroff
Rockwell International Science Center at Anaheim
3370 Miraloma Avenue, Anaheim, CA 92803-3105

Abstract

High spatial and time resolution gamma ray detectors have been developed using plastic scintillating fibers coupled to position sensitive vacuum photomultipliers under development. These detectors can significantly improve the spatial resolution, time resolution, and efficiency of both SPECT and PET, extend the application of these technologies into new fields of medical research, and improve currently existing methods of medical diagnosis. Initial results of testing these detectors showed a better than 1 mm position accuracy and better than 10 nsec time resolution.

I. INTRODUCTION

This collaboration has recently developed high resolution gamma ray telescope designs for gamma ray astronomy using scintillating fibers as detectors [1,2]. A prototype Compton telescope composed of bundles of 1 mm diameter fibers of polysterene scintillator doped with Butyl-PBD and DPOPOP producing $\lambda = 420$ nm wave length photons, with an acrylic cladding of 25 μm thickness, and viewed by Hamamatsu R 2486 position sensitive photomultipliers was built[2]. The initial testing of this prototype Compton telescope with 1.2 MeV gamma rays from a ^{60}Co source resulted in a $\sigma_{rms} \leq 1$ mm position resolution of the Compton conversion point of gammas, and in a better than 10 nsec time resolution of the conversion events detected[2]. The time resolution of the scintillating fiber detectors can be further improved to better than 2 nsec by using Solid State Photomultipliers (SSPMs) under development at Rockwell International Science Center at Anaheim, California[3].

II. CONSTRUCTION OF PROTOTYPE GAMMA DETECTORS FOR MEDICAL IMAGING

Based on the experience obtained in constructing the prototype Compton telescope we have built two 10 x 10 x 5 cm^3 stacks of 0.5 mm diameter scintillating fibers of the same specifications, each viewed by 4 Hamamutsu R 2486 position sensitive photomultipliers (Figs. 1-2). The X and Y fiber planes are rotated by 90° angle relative to each other, and directly coupled to the position sensitive photomultipliers. The scintillating fiber planes are adjacent to each other, and the electron conversion points are reconstructed in the scintillating fiber stack in a 3-dimensional way with a spatial resolution better than the $\sigma_{rms} \leq 1$ mm obtained earlier for the 1 mm diameter fiber[4].

[1] This work was supported by the Texas Coordinating Board Advanced Technology Program.

Fig. 2 illustrates the application of the two scintillating fiber stacks in a PET configuration. The outputs of the 4 photomultipliers of each stack are coupled to two-stage preamplifier units, which are further connected to double buffered Flash-ADC units. The buffers are emptied by a VME computer. The image reconstruction and graphics display is carried out by an additional fast VME computer.

When applying the above gamma ray detectors in Single Photon Emission Computer Tomography (SPECT), parallax becomes very small and application of specially designed collimators optimized for scintillation fiber technology will improve the efficiency of SPECT very significantly. The spatial resolution depends on the fiber size and can increase the resolution of SPECT by at least one order of magnitude. This technique also provides an excellent time resolution due to the less than 2 sec rise time of plastic scintillating fibers combined with the SSPM's. The good time resolution will minimize accidentals and pileups at high count rates.

Similarly, the application of these detectors in Position Emission Tomography (PET) improves the spatial resolution of the method, and significantly represses the background using the excellent spatial and time resolution of the plastic scintillating fiber gamma detectors[4]. With this advancement, both SPECT and PET technology can be extended further into new fields of medical research and significantly improve currently existing methods of medical diagnoses.

III. REFERENCES

[1] M. Atac, D. B. Cline, D. Chrisman, J. J. Kolonko, J. Park, E. J. Fenyves and R. C. Chaney, "High Resolution Gamma Ray Telescope Using Scintillation Fibers and Position Sensitive Photomultipliers", Nucl. Phys. B (Proc. Suppl.) 10 B (1989) pp. 139-142.

[2] P. Antich, M. Atac, R.Chaney, D. Chrisman, D. Cline, E. Fenyves and J. Park, "Development of a High Resolution Scintillating Fiber Gamma Ray Telescope", Nuclear Instruments and Methods in Phys. Res. (1990) (in press).

[3] M. D. Petroff and M. G. Stapelbroek, IEEE Trans. Nucl. Sci. NS-36, 158 (1989); and M. D. Petroff and M. Atac, IEEE Trans. Nucl. Sci. NS-36, 163 (1989).

[4] R. C. Chaney, E. J. Fenyves and P. P. Antich, "Simulation of Scintillating Fiber Gamma Ray Detectors for Medical Imaging", (this meeting, paper 5M8).

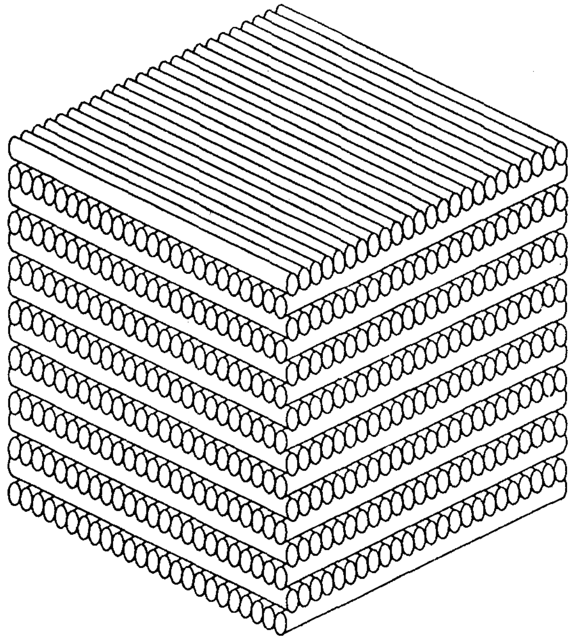

Fig. 1 The schematical view of the 10 x 10 x 5 cm³ fiber stack with the X and Y fiber planes rotated by 90° relative to each other.

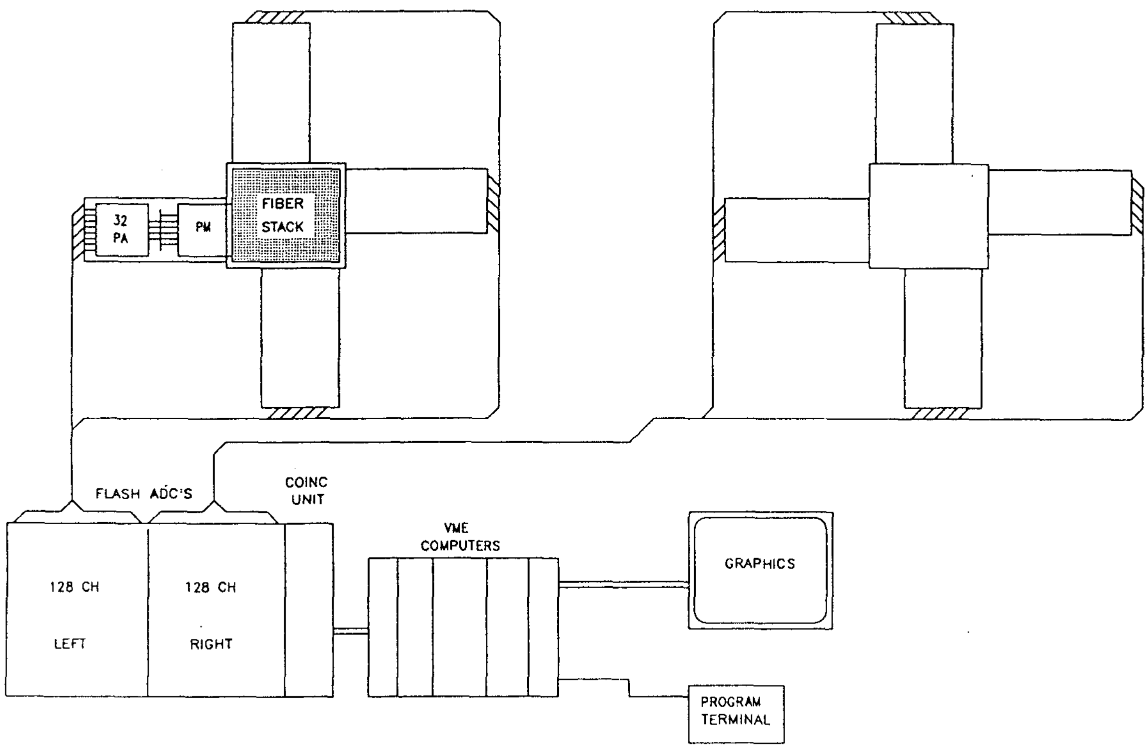

Fig. 2 Application of two scintillating fibers stacks in a PET configuration.