SCINTILLATING GLASS FIBER-OPTIC IMAGING SYSTEM FOR TRACKING APPLICATIONS*

R. Ruchti, B. Baumbaugh, J. Bishop, N. Cason, S. Grenquist, V. Kenney, E. Mannel, R. Mountain, W. Shephard, and P. Wilkins
Department of Physics, University of Notre Dame, Notre Dame, IN 46556, USA
A. Kreymer
Fermi National Accelerator Laboratory, Batavia, IL 60510, USA
A. Rogers
Synergistic Detector Designs, Mountain View, CA 94043, USA
R. Mead and D. Swanson
Collimated Holes, Inc., Campbell, CA 95025, USA

ABSTRACT

Coherent, scintillating glass fiber-optic plates containing Terbium and Cerium Oxides have been developed to detect high energy particle interactions with high spatial resolution.

1. INTRODUCTION: We are developing devices which exploit the "local" fluorescence properties of trivalent Terbium and Cerium oxides in silicate glass compositions. These glasses constitute the core material of cladded-glass fibers which are formed into coherent fiber-optic plates. The combined features of "local" fluorescence and "total" internal reflection within the fibers allows the reconstruction of trajectories of ionizing particles produced in high energy reactions. The devices are suitable for both fixed target and colliding beam applications.

2. OPTICAL-IMAGING SYSTEM: The detector imaging system is shown in Fig. 1 and consists of an active detection element which is a scintillating fiber optic plate. The plates are typically 1 cm^3 in volume with constituent fibers of 10 μm - 25 μm in cross section. The volume fraction of active (core) glass is ~75%.

Details of the fluorescence properties of the scintillating glasses have been presented elsewhere[1]. For the Terbium glass, principal emission occurs at 550 nm with slow fluorescence decay $\tau \sim 3.5$ msec. For the Cerium glass, principal emission occurs at 395 nm with fast fluorescence decay $\tau \sim 40$ nsec. For our particular fiber optic plates the indices of refraction for core and clad are n = 1.58, n = 1.50 respectively. For these values, typically 10% of the produced scintillation light is trapped by total internal reflection within the fibers. Extramural absorber is incorporated on the outer surfaces of the cladding to suppress untrapped light.

The trapped light is presented to the input fiber-optic faceplate of a 3-stage image intensifier. Overall system luminescence gain is 2×10^5 which is sufficient for either film or electronic data recording using VIDICON or CCD systems. We are currently recording data using a contact-camera. Data film is held against the output fiber-optic plate of the image intensifier via vacuum pull-down, obviating the need for lenses.

Fig. 2 (a) shows an interaction of a ~600 GeV/c neutron in a Ce glass target comprised of 25 μm fibers of 0.8 cm length, and Fig. 2 (b) is a 10 GeV/c π^- interaction in a Tb glass target comprised of 15 μm fibers of 1.0 cm length. The neutron event was recorded in the P-East beam (E400) at Fermilab, the pion event at the SLAC test beam. From such data frames and others we conclude that tracks and interactions are indeed clear and distinct for both nuclear fragments (dark tracks) and minimum ionizing particles (light tracks) in fiber-optic plates containing scintillating glass fibers of very small cross section (10-25 μm) and fiber depths of ~1 cm. Spatial resolution is good $\sigma \lesssim 30$ μm per measured point, and we observe ~5 detected photoelectrons per mm of path length for minimum ionizing particles in Tb glass and $\gtrsim 2$ for Ce glass.

We are currently studying light attenuation in fibers longer than a few centimeters, the radiation resistance of the glass[2], and are exploring new glass compositions in order to improve the tracking response[3]. The immediate goal is to provide a working tracking detector for Fermilab E687 (photoproduction of high mass states at the Tevatron) and to develop large scale devices for colliding beam experiments.

We would like to thank the staffs of SLAC and Fermilab and the experimenters of Fermilab E400 for help with the beam tests.

*This work has been supported in part by grants from the U.S. National Science Foundation and the University of Notre Dame.

REFERENCES

1. R. Ruchti et al., IEEE Transactions on Nuclear Science, Vol. NS-31, No. 1 (1984), pp. 69-73.
2. Cerium glass is extremely radiation resistant. See B.D. Evens and G.H. Sigel, IEEE Transactions on Nuclear Science, Vol. NS-22, No. 6 (1975), pp. 2462-2467.
3. Present estimates indicate an improvement of a factor of ~4 in performance of Cerium targets incorporating a refined imaging system.

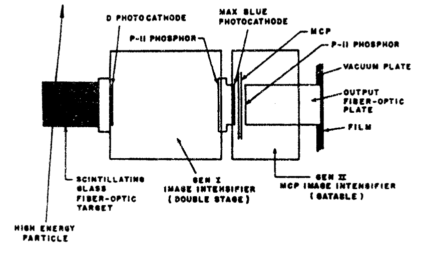

Fig. 1. Schematic of Target and Imaging System

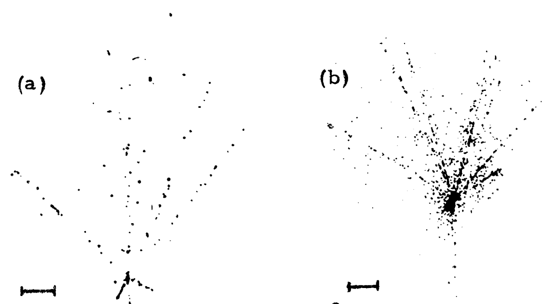

Fig. 2. Interactions recorded in scintillating glass fiber-optic targets: (a) ~600 GeV/c neutron in Ce glass; (b) 10 GeV/c π^- in Tb glass.