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SCINTILLATION TECHNIQUES AND OPTICAL DEVICES[*]

SUMMARY REPORT OF THE WORKING GROUP

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I. INTRODUCTION

Scintillation detectors have always been essential elements of high energy physics experiments, particularly for triggering, hodoscopy, and calorimetry. Several decades ago, attempts were made to utilize these devices as tracking detectors, by imaging the spatial distribution of scintillation photons with image intensifiers. Although the tests showed promise, lack of image intensifier technology and the successes of the bubble chamber technique at the time limited the extent of the effort.

However, over the last 15 years, the technological situation has changed dramatically with:

(1) sophisticated image intensification systems now available using electrostatically focussed (Gen-I), microchannel-plate (Gen-II,III), and proximity-focussed photodiode intensifier tubes;

(2) high resolution electronic cameras such as VIDICON, PLUMBICON, NEWVICON, CCD, CID, and SIT devices; and

(3) major advances in the field of fiber optics, including the capability to draw cladded fibers of glass and plastic into single strands, coherent bundles, fused multifibers, and coherent fiber-optic plates.

Additionally, recent experiments have continued to place more stringent requirements on detectors, for example:

(1) the ability to operate at high rates and in high radiation environments;

(2) to select and identify rare processes from among many interactions; and

(3) to have excellent single track and multitrack resolution.

It is expected that future experiments, particularly those which must operate successfully at the 10^{33} luminosity of the SSC, will place even greater demands on detector performance. Consequently this has forced the high energy physics community to reassess the efficacy of particle tracking in general at machines such as the SSC and of microvertex detection and high resolution tracking in particular.

Conventional choices for tracking detectors are silicon micro-strip detectors, CCDs, and gas chambers utilizing small drift cells or innovative cell structures, often with operation at elevated pressures. Each of these techniques has its strengths and weaknesses. Table I characterizes several of the important features of these devices. A critical assessment of the table would indicate that none of the conventional detectors represents a satisfactory solution to the tracking problem. This has led a number of groups to pursue an alternative approach to tracking based on scintillating optical fibers and hence to a return to the concept of scintillation imaging.

The first steps in the rebirth of this field occurred in the late 1970s with the work of Borenstein and Strand on plastic scintillation fibers and of Potter, whose NaI scintillation camera represents the modern version of the classical, bulk-scintillator imaging system developed circa 1960. A significant advance occured during the period 1982-4 with the demonstration by the Notre Dame group, first with Terbium(3+) and then with Cerium(3+) scintillating glasses, that high resolution tracking and verticizing was possible in cubic-inch-sized coherent fiber-optic plates composed of up to 10^6 cladded, optical fibers of small cross section, $>$ 15 μm. Imaging in the test system was effected by contact or proximity focussing, and the system was triggerable (gateable), hence capable of high rate operation. With the ability to record tracks in fibers and with the elimination of lens coupling, one could then entertain the possibility of using the technique for the fabrication of detectors combining simultaneously the attributes of high spatial resolution, high rate operation, and large fiducial volume. Since then, there have been important initiatives by several groups to develop tracking detectors based on glass, plastic, and liquid scintillators. It is the purpose of this summary to review the status of the current work and to suggest potentially profitable avenues for further development.

Optical fiber techniques are being considered as important components of central tracking and microvertex detectors, for high resolution calorimetric sampling and shower preconversion, and as waveshifters. As the particular interest of this working group was in particle tracking, the discussion which follows is directed principally toward this issue.

Table I

Characteristics of Current Tracking Detectors*

Detector Type	Strength	Weakness
Silicon μ-strips	Efficiency Single Track Resolution (≤ 5μm) Two Track Resolution (≥ 50μm) Fast Response	Radiation resistance of on chip amplification, etc. Power dissipation high Multiplexing of many chips Cost
CCD's	Efficiency Single Track Resolution (≤ 5μm) Two Track Resolution (≥ 25μm)	Slow readout Cost
Drift Chambers	Efficiency Single Track Resolution (≥ 80μm)	Two Track Resolution (~mm) Radiation resistance Integration time (Due to drift)
Scintillating Fiber Detectors	Single Track Resolution (≤ 20μm) Two Track Resolution (≥ 80μm) Radiation Resistance is good Large volume coverage Multiplexing simple High granularity and measurement density Inexpensive	For glass fibers attenuation length is ≤ 5 cm For plastic fibers resolution is coarse ≥ 0.5 mm Integration time (Due to phosphor screens)

*This table is meant to indicate strengths and weaknesses of current devices. It is a goal of this conference to indicate how <u>all</u> of these systems can be improved with new R & D.

II. Scintillating Tracking Detectors

The fundamental structure of a scintillation tracking detector is the fiber-optic waveguide. A schematic diagram of a generic guide is shown in Fig. 1. It consists of a scintillating core material of index n_1, a non-scintillating cladding of index $n_2 < n_1$, and an optional coating called extra-mural absorber (EMA) which is typically an optically absorbing glass layer or aluminum reflective layer which resides on the external surface of the cladding.

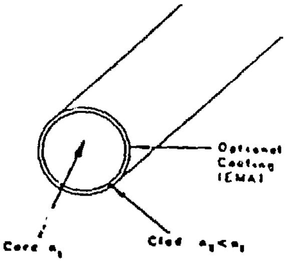

Fig. 1 Schematic of a fiber optic waveguide.

Desirable properties for this wave guide system are:

(1) the quantum efficiency of the core scintillator should be high;

(2) it should provide excellent light transmission, which requires:

- (a) the index difference $\Delta n = n_1 - n_2$ between core and cladding materials be as large as possible to optimize light collection by total internal reflection;
- (b) the cladding material should be thick enough to contain the evanescent wave (to assure wave propagation along the guide) yet sufficiently thin that most of the volume of the fiber is active material;
- (c) EMA should be incorporated as necessary to absorb untrapped light (i.e. eliminate "cross-talk");

(3) the attenuation length for the optical waveguides should be long - of order meters for large volume tracking detectors, and of order several centimeters for active targets;

(4) and radiation resistance of the materials should be good - this applies to both core and cladding materials.

A. Scintillation Materials:

Candidate core materials may be derived from glass, plastic or liquid scintillators. Table II presents a list of currently developed materials indicating scintillation efficiency relative to BGO (BGO = 10 photons per keV of deposited energy). Plastic and liquid scintillators have efficiency comparable to BGO, whereas the brightest glass scintillators are roughly 40% as efficient. The table is meant to serve as a guide only. It is hoped that more efficient materials and improvements in attenuation length can be achieved with further R and D.

Table II

Fiber Properties*

Material	Scintillation Efficiency	Attenuation Length	Diameter
Polystyrene[a]	10 Photons/Kev	120 cm	1 mm
Polystyrene[b]	10	120	1
Polystyrene[c] (PBD + .02% 3-HF)	12	90	1
Glass GS1/SC20[d]	3-4	<20 ~ 4	1 0.025
Liquids[e]			
1-Methylnapthalene +BIS/MSB	10	> 2.5	0.050
1-Phenylnapthalene +DPH +DPA	10	> 2.5	0.050

a) R. Binns, Washington University, St. Louis
b) R. Bourdinaud, SACLAY
c) A. Bross, Fermilab and R. Binns
d) R. Ruchti, Notre Dame, and A. Bross and J. Kirkby, CERN
e) D. Potter, Carnegie-Mellon University

*Please refer to contributions to these proceedings by the various authors for further details.

B. Fiber Manufacture:

Table III lists several manufacturers of plastic and glass fibers for high energy physics. In the case of scintillating liquids, it has been traditional to make your own and utilize glass capillary arrays to provide the containment for the liquid.

Table III

Scintillating Fiber Manufacture

Plastics:	Saclay, France
	Washington University, St. Louis, MO, USA
	Fiber Optic Development Systems, Santa Barbara, USA
	Galileo, Sturbridge, MA, USA
Glasses:	Levy-Hill Laboratories, UK
	SES Technology Consultants, UK
	Collimated Holes, Inc., Campbell, CA, USA
Liquids (Capillaries):	Collimated Holes, Inc., Campbell, CA, USA
	Galileo, Sturbridge, MA, USA

C. Properties of Scintillation Materials and Waveguides:

Plastic and glass waveguides have been produced routinely with $\Delta n = n_1 - n_2 \le 0.1$. Increasing Δn further is desirable because it implies more efficient light trapping. This may be accomplished by increasing the core index and/or decreasing the cladding index.

How one sets about to achieve these adjustments in refractive indices depends upon the application. For the example of general particle tracking, where multiple scattering and bremsstrahlung are important concerns, one desires large values of n_1 in combination with low material density (long effective radiation length). For calorimetric fibers or shower preconverters, one would hope to achieve high n_1 in conjunction with high material density (and short radiation length).

Table IV indicates some initial attempts to increase the refractive index for Cerium (3+) based glasses. These efforts were successful in developing calorimetric materials: n_1 increase was associated with reduced radiation length. The quantum efficiency has also dropped indicating that further optimization of the composition is necessary.

Table IV

PROPERTIES OF SCINTILLATING GLASSES CONTAINING Ce(3+)

PROPERTY	NRL	GS1/SC20	SC20HT	SC40	SC40HT	SC56	SC61
Refractive index	1.58	1.56	1.51	1.58	1.55	1.59	--
Density (g/cc)	2.69	2.62	2.40	3.00	2.70	3.34	4.34
Efficiency(NRL=1)	1	4-5	2-3	3-4	2-3	2	0.3
Radiation Length(cm)	9	9.7	10.4	6.5	7.2	4.55	2.28
Emission maximum(nm)	395	395	403	404	--	403	458
Fluorescence decay at emission maximum(ns)	48	48	64	56	—	—	—

NRL is a radiation resistant glass which also scintillates.

The base glass composition for current scintillation fibers is GS1/SC20.

Glasses SC20HT and SC40HT have Na added to improve fluidity - high temperature properties of the glass.

SC40, SC40HT, SC56 and SC61 have Ba added to increase refractive index of the glass.

A fluoridated version of SC30 is yet to be tested.

Measurements by A. Bross and R. Ruchti.

The optimum cladding material is that with the lowest possible value of n_2. In the case of hard claddings for plastic fibers, typical values of n_2 are 1.50 for acrylics and 1.46 for vinyl acetate. For silicate cladding glasses, typical n_2 values are 1.49 for N51A, 1.47 for pyrex, and 1.46 for fused silica. These are to be taken as representative of materials for which fiber drawing is possible. Soft claddings, based on materials such as silicone, have lower index n_2 = 1.35, but are fragile and less desirable from the standpoint of handling.

Extramural absorber has been found to be necessary, in general, to minimize crosstalk in fiber lattices. In the case of scintillation materials, this is important for two reasons. First, if $\Delta n \leq 0.1$, then typically less than 10% of the scintillation light is trapped within a given optical fiber. The bulk of the light (90%) is free to propagate across fiber boundaries, and hence provides no information as to its point of origin within the fiber lattice. Second, most scintillation materials have the property of self-absorption. In the case of glass and inorganic scintillators, this is unintentional and undesirable, and is due to foreign impurities or improper valence states in the material. In the case of plastic scintillators, however, this property is not only intentional, but is exploited - to shift the wavelength of the primary (for example ~ 305nm for polystyrene) into the visible spectrum. Several solutes are used to accomplish this. While this shifting process is extremely efficient, it occurs over a spatial volume whose size is dictated by the mean free path for absorption of intermediate radiation - typically 1mm. This implies that the resultant light emission is non-local relative to the original energy deposition on a ~1mm distance scale. Thus one expects plastic fibers to become very inefficient for coherent particle tracking for fiber diameters well below 1mm unless new materials can be developed which avoid intermediate radiative transfers. One possibility is the use of 3-Hydroxyflavone (3-HF) in polystyrene (see A. Bross in these proceedings); another is the use of liquid scintillators in capillaries (see D. Potter in these proceedings). In the latter case, the energy transfer between solvent and solute is over short distance and nonradiative.

Glass scintillators, like inorganic scintillators, fluoresce by energy transfer to activation centers - for Cerium based glasses, these are Cerium (3+) sites. This energy transfer process is of short range and is non-radiative, with subsequent Ce light emission local to the original energy deposition. This permits track imaging in fibers of very small cross section, $\leq 15\mu m$. However, Cerium-based glasses present a different and fundamental complication: self-absorption due to the presence of the valence state Cerium (4+) in the glass. Ce(3+) and Ce(4+) are produced in oxidation reactions which occur during the melting process. Unfortunately, Ce(4+) has a broad absorption band which completely overlaps the emission from Ce(3+). If present in sufficient concentration, the 4+ state will effectively absorb away the desired scintillation light. It is believed that the short attenuation length of current Cerium glasses such as GS1/SC20 is due to the presence of Ce(4+) at the few percent level. Elimination of this undesirable valence state requires careful control of the glass production process, with special attention to the use of reducing or inert atmosphere throughout. Studies of Cerium concentration are currently in progress (see J. Kirkby, these proceedings).

D. Attenuation Length

Attenuation lengths of currently used materials are presented in Table II, and are in the meter range for plastic fibers of 1mm diameter, and in the 4-5 cm range for glass fibers of ~ 25μm diameter and for liquid scintillator capillary arrays of ~50μm diameter. These values are thought to be dominated in the case of plastics and glasses by irregularities in the core/cladding interface and additionally by self-absorption and local density variations, such as crystallization, in the case of glasses.

Current experience also indicates that as the diameter of plastic fibers is reduced, so also is the attenuation length. For acrylic plastic multifibers of the type fabricated by Washington University St. Louis (see W. Binns, these proceedings), the attenuation length is found to be ~60cm for fibers of 100μm cross section and with no EMA between fibers. One expects the attenuation length to deteriorate further with smaller diameter and EMA usage, at least for conventional plastic materials.

It is hoped that new developments in glasses and plastics, many of which are now underway, will solve these problems.

E. Radiation Resistance

Cerium glasses and polystyrene plastic scintillators have both been shown to have remarkable resistance to radiation damage. Cerium samples of 4mm thickness can tolerate dosages in excess of 10^7 rads with ~20% light transmission loss at peak fluorescence (395 nm). In fact Cerium is a common additive to many glasses to enhance radiation resistance. Polystyrene scintillation fibers of the Saclay type, after an exposure of 3 x 10^6 rads, are found to have a factor of 2 reduction in attenuation length. This is significantly better than current experience with acrylic scintillators.

One further and equally important consideration is that the radiation resistance of cladding materials is also essential. In a fiber-optic guide, energy propagates within the cladding as well as the core, and attenuation in either medium can lead to loss of the propagating wave. The radiation resistance studies discussed above included the effects of cladding damage for plastic fibers; the glass measurements were for the bulk core material only.

III. Imaging Systems

The general consensus of the group was that most of the basic building blocks needed for fiber detector readout exist at this time, but require optimization.

A. Image Intensifiers

Image intensifiers now exist which are capable of single photon counting when used in cascade, including GEN-I (electrostatically focussed), GEN-II (containing microchannel plates), and proximity-focussed photodiodes. Of these devices, the GEN-II tubes provide the highest average gain but at the expense of signal uniformity, due to the exponential nature of the gain distribution. This can create havoc if one is attempting to image single photoelectrons. On the other hand, GEN-I tubes have substantially less average gain, but better uniformity of response - ascribable to a more Poisson-like gain distribution.

A prototypical system which provides reasonable uniformity and high gain is that employed by the Notre Dame group for active target imaging. In their system, two GEN-I intensifiers are used as a preamplifier to provide moderate initial gain and good uniformity, followed by a GEN-II device which provides very high gain with generally acceptable uniformity because this tube is no longer looking at single photoelectrons at its input. Utilizing such a cascade technique, one can image single photoelectrons with film or electronic cameras.

B. Electronic Cameras

There are currently available a great variety of electronic imaging systems including devices based on VIDICON, PLUMBICON, NEWVICON, CCD, CID, and SIT cameras. The spectral response, resolution, and intrinsic gain (if any) of these devices vary markedly. The latter three are perhaps the best suited for high energy physics imaging applications.

CCD arrays are commercially available in sizes which are typically 1cm^2 in area. Readout times are in the 1-30 msec range depending upon the specific architecture employed. Larger area devices (with much slower readout speeds) are also available. Most of the commercial architectures are not particularly well matched to high energy physics requirements, and often those which hold promise are dropped from production. (A notable example of the latter is the RCA ICCD tube, which utilizes back-thinned CCDs. A management decision ended production and further development of such devices just prior to this conference). Nevertheless, large area devices and special applications devices are expected to become available shortly, particularly from Tektronix. CCDs made by Fairchild and Thomson/CSF are capable of fast clearing on microsecond time scales – a factor of 10^3-10^4 faster than it takes to read them. This feature is particularly useful for dumping unwanted data, or eliminating accumulated dark current. Development and refinement of CCD structures is clearly an area which needs substantive input from the high energy physics community.

CID arrays, like CCD arrays, are two dimensional area sensors capable of detecting photons. They are structurally different from CCDs in terms of accessing the charge in a given photosite (pixel) and are architecturally more closely related to memory. In general CID cameras are less expensive than CCD cameras, a fact which may be important for a large volume detector which would require many such devices.

The SIT tube is potentially important because of its fast and flexible beam scan capability (due to electrostatic deflection) and because of its high intrinsic gain (~1000). Typically, a 20mm x 20mm area can be scanned in a few milliseconds with a component pixel size of 30μm x 30μm. Because of its intrinsic gain, less image intensification is required in front of the SIT than would be required for a CCD. Improved overall system resolution is therefore a possibility. One drawback of the SIT is the tube lag, the latent charge remaining after the silicon target is read out. For the SIT the lag is ~20%. Hence several read cycles must be performed to effectively erase the target surface.

A comparison of the electron gain for CCD and SIT devices, utilizing various combinations of image intensifiers, indicates that either of these cameras is suitable for single photon imaging. (See R. Ruchti, these proceedings.)

C. Digitizing Systems

A typical electronic camera system such as a CCD or SIT has in excess of 10^5 photosites, each of which contain potential information for a given event. It is essential to digitize this information and store it rapidly and compactly in a memory, where it can reside until a high level trigger decision initiates transfer of the data to a storage medium. Commercial devices which can perform such tasks are called frame grabbers. These devices are usually capable of holding only a single frame and digitization is achieved at conventional television rates – characteristics which are not particularly well suited to high rate data acquisition.

A prototype of a more sophisticated system for data management has been developed by Fermilab and Notre Dame for use with the Scintillating Glass Active Target for Tevatron experiment E687 (R. Ruchti, these proceedings). The system, known as VDAS (for Video Data Acquisition System), features up to 100 MHz operation, 6 Bit A/D and fast sparsification to eliminate zero pixels - pixels below minimum threshold. This latter feature is particularly important for data handling: in a typical fixed target event only 10% of pixels are active; for a collider detector, which does not see the primary interaction directly but rather emerging secondaries, the number of active pixels is even further reduced. This is still true at SSC luminosities, where numerous events (~10) can occur in a typical integration time of ~100 ns. For temporary data storage VDAS utilizes an 8 MByte FI/FO (expandable to 256 MBytes). The data is successively shifted through the FI/FO, providing ample time for the formation of a high level trigger to decide whether to write the data to tape or optical disk.

The VDAS system represents an important initial step in data handling and processing. Nevertheless, further effort is definitely required to understand how to accomodate data from the ~1000 CCDs needed to image a large scintillating fiber detector such as the SCIFID device considered at Snowmass '84.

IV. Triggering

The ability of scintillating fiber detectors to handle high rates is due to their granularity. Several levels of triggering are required in order to extract information efficiently. Table V indicates important time intervals of relevance to an SSC scintillating fiber detector.

Table V

Time Intervals of Relevance to a Scintillation Tracking Detectors at the SSC

(1)	Interval between successive beam interactions	~10 ns
(2)	Phosphor decay time on image intensifier preamp stages	$\lesssim$ 100 ns
(3)	Formation of a level 0 trigger (fast calorimetry; E_T)	1 μs
(4)	Time to perform a fast clear of a CCD	1 μs
(5)	Time to read CCD ($\gtrsim 10^5$ pixels)	$\gtrsim$ 1 ms

A major difficulty in running at the highest luminosities projected for the SSC is that an optical delay line would be required to "pipeline" events during the 0.5-1.0 μsec formation time of a level "0" trigger. The only solution arrived at during the workshop was a long (250m) coherent fiber bundle to introduce the required delay. An additional difficulty is the effective 100ns integration time introduced by available phosphors (P-46 and P-47). The development of faster (yet efficient) phosphors is essential to minimize event pileup.

One can conceive of incorporating the tracking information from the CCDs directly into a high level trigger at the 10 Hz level.

V. Tracking

There is now impressive evidence that particle tracking is indeed possible in fiber detectors. Tracks and interactions have been recorded using glass fiber-optic detectors and plastic fibers. Figures 2-5 show examples and Table VI summarizes the current results. In general, the quantum efficiency and attenuation length properties of plastic fibers are superior to glass fibers, whereas the glass fibers provide substantially better track resolution.

Tracks and Interactions Recorded in Scintillating Fiber Detectors

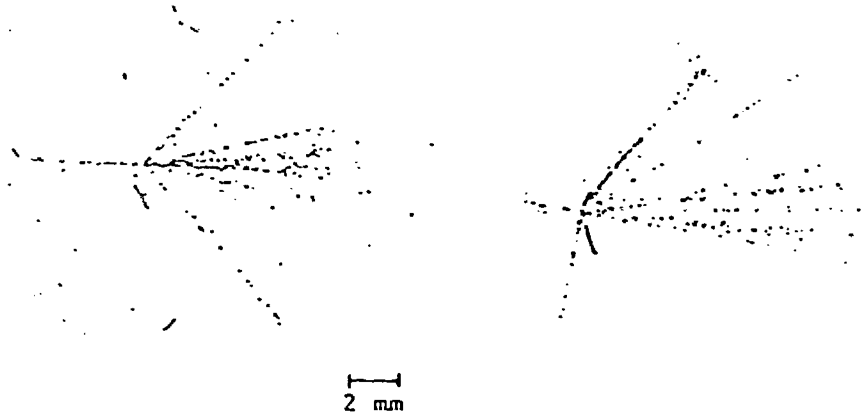

Fig. 2 Interactions of 50 GeV/c pions recorded in GSl glass using the Fermilab NH beam: left, 40 μm fibers with EMA; right, 25 μm fibers with EMA. (Ruchti, et al.)

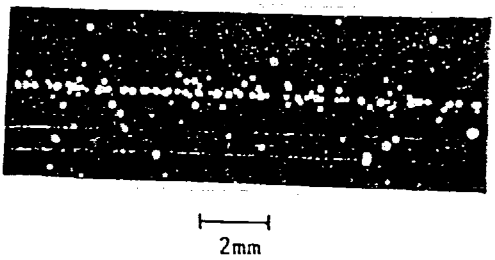

Fig. 3a Minimum ionizing track recorded in a GSI target with EMA, at CERN/PS test beam. (Kirkby, _et al_.)

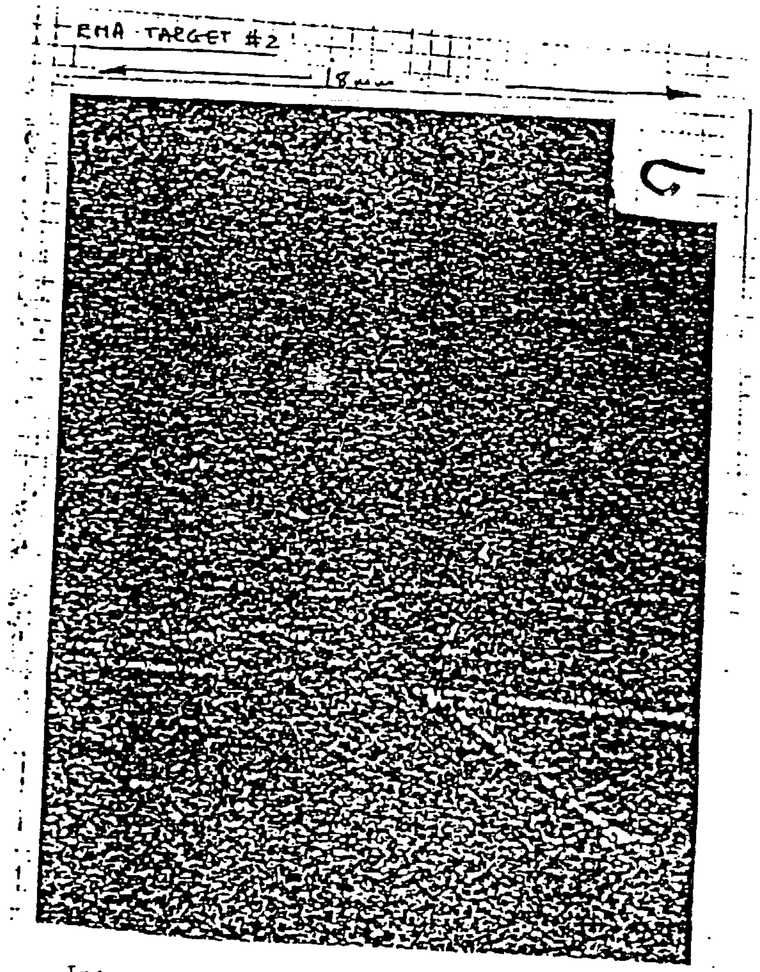

Fig. 3b Interaction recorded in a GSI target with EMA, at CERN/PS test beam (Kirkby, et al.).

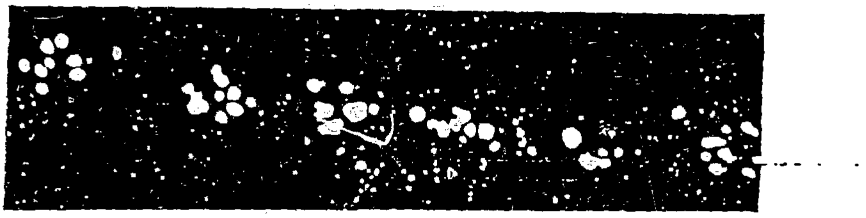

Fig. 4 Track recorded in a bundle of 1 mm diameter Saclay fibers of 1 m length. (Bourdinaud, *et al.*)

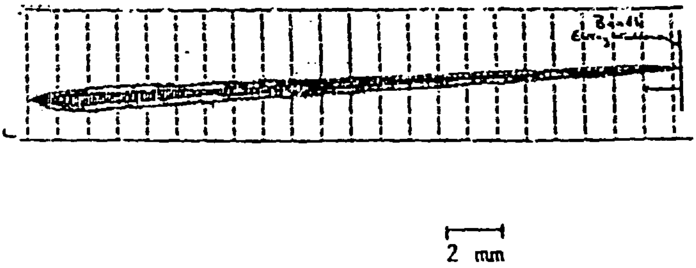

Fig. 5 Stopping Fe fragment in a bundle of polystyrene multifibers of 100 μm diameter. (Binns, *et al.*)

VI. Photodiode Devices

Photodiode devices, APD's, were discussed. Although some of these detectors offered impressive performance in some areas: gain = 10^8 - 10^9 for Geiger-mode APD's, high QE (40 - 60%), and 20 psec response time, the likelihood for producing useful arrays was very small making this type of technology an unlikely candidate for the readout of a many fiber system.

VII. Calorimetry

There was also some limited discussion of optical scintillation techniques for calorimetry. A prototype system consisting of laminated sheets of 8 mm thick Pb interspersed with layers of scintillation fibers 1 mm thick was presented by A. Klovning. (The fibers were made by Saclay). The prototype modules gave $\Delta E/E$ of approximately 2% for 30 Gev electrons.

Table VI

Fiber Performance

Property	Glass	Plastic
Information density	6 Hits/mm (in 25 μm fibers)	12 Hits/mm (in 1 mm fibers)
X_o	1%/mm	0.25%/mm
Optical Attenuation Length	$\leq$ 20 cm	120 cm
Decay time	50 ns	a few ns
Radiation Hardness	10^6 rad Co^{60} 1 inch length	10^6 rad Co^{60} reduces Att. Len. by factor of 2
Usable in vacuum	yes	yes (probably)
Power consumption in detector volume	0	0

CONCLUSIONS AND COMMENTS

Scintillating fiber detectors represent a particularly elegant solution to the SSC tracking problem. The first important step has been taken - demonstration that tracking is feasible in glass, liquid capillary and plastic fiber devices. Detection efficiency is excellent, with glass providing high spatial resolution ($\leq 20\mu m$) and plastic fibers providing long attenuation length ($\lambda \sim 1.2m$)

However, to realize a useful detector based upon these materials, it is now essential to extend the R and D effort in the following areas:

1. Optimization of basic scintillating glasses and plastics for incorporation into fibers.
2. Optimization of cladding materials for fiber-optic transmission.
3. Once scintillator and cladding are identified, industrial expertise should be enlisted to produce high quality optical fibers using these materials.
4. Work on image intensifier systems is needed, particularly in the development of fast efficient phosphor screens with $\tau \leq 100nsec$ and green or longer output wavelength, and for high quantum efficiency photocathodes (~20%).
5. High resolution, fast readout CCD cameras are essential - ICCD tubes could be particularly useful. Readout times of ≤ 1 msec and clear times of ≤ 1 μsec are reasonable objectives.
6. Finally optical delay lines will probably be necessary for active event storage during intermediate triggering. Industrial assistance in this area would be useful.

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It is expected that future experiments, particularly those which must operate successfully at the 10^{33} luminosity of the SSC, will place even greater demands on detector performance. Consequently this has forced the high energy physics community to reassess the efficacy of particle tracking in general at machines such as the SSC and of microvertex detection and high resolution tracking in particular.

Conventional choices for tracking detectors are silicon micro-strip detectors, CCDs, and gas chambers utilizing small drift cells or innovative cell structures, often with operation at elevated pressures. Each of these techniques has its strengths and weaknesses. Table I characterizes several of the important features of these devices. A critical assessment of the table would indicate that none of the conventional detectors represents a satisfactory solution to the tracking problem. This has led a number of groups to pursue an alternative approach to tracking based on scintillating optical fibers and hence to a return to the concept of scintillation imaging.

The first steps in the rebirth of this field occurred in the late 1970s with the work of Borenstein and Strand on plastic scintillation fibers and of Potter, whose NaI scintillation camera represents the modern version of the classical, bulk-scintillator imaging system developed circa 1960. A significant advance occured during the period 1982-4 with the demonstration by the Notre Dame group, first with Terbium(3+) and then with Cerium(3+) scintillating glasses, that high resolution tracking and verticizing was possible in cubic-inch-sized coherent fiber-optic plates composed of up to 10^6 cladded, optical fibers of small cross section, > 15 μm. Imaging in the test system was effected by contact or proximity focussing, and the system was triggerable (gateable), hence capable of high rate operation. With the ability to record tracks in fibers and with the elimination of lens coupling, one could then entertain the possibility of using the technique for the fabrication of detectors combining simultaneously the attributes of high spatial resolution, high rate operation, and large fiducial volume. Since then, there have been important initiatives by several groups to develop tracking detectors based on glass, plastic, and liquid scintillators. It is the purpose of this summary to review the status of the current work and to suggest potentially profitable avenues for further development.

Optical fiber techniques are being considered as important components of central tracking and microvertex detectors, for high resolution calorimetry sampling and shower preconversion, and as waveshifters. As the particular interest of this working group was in particle tracking, the discussion which follows is directed principally toward this issue.