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Laser-Based Calibration System For the CLAS-TOF Scintillators

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Introduction

The construction of a proposed calibration system for the TOF scintillators is described. Components, costs, time scales and expected characteristics are given in some detail. An informal proposal to supply such a system is included.

Attributes of the Proposed System

The CLAS TOF system will be composed of almost 300 scintillators of lengths varying from less than 1 m to greater than 4m. The system will have hexagonal symmetry. The support structure will divide the system into three "carriages" which include a single forward carriage and two side carriages. The forward carriage will support all scintillators from 0 to 48 degrees. Each of the six sectors will have 23 scintillators mounted on the forward carriage for a total of 138. The two side carriages will each support three sectors extending from 48 to 144 degrees with 34 scintillators in that region of each sector. Thus each side carriage will carry 102 scintillators.

It is intended to bring one optical fiber to each of the scintillators (each of which are viewed by two photomultiplier tubes). Thus, one needs 138 or more available fibers at the front carriage and 102 or more, at each of the two side carriages. The goals of such a system include uniformity (no more that X3 to X5 variation in light output among fibers), stability (both from pulse to pulse and over long time periods), variability (ideally from about 1 MeV to about 50 MeV light equivalent delivered to each scintillator), modular, interchangeable components, control of the light source from outside the experimental hall and reasonable cost.

The basic units proposed include a commercially available 330nm gaseous nitrogen laser, locally fabricated distribution boxes based on commercially available fiber bundles and silica fibers of rugged design and moderate cost for distribution of light. The laser can be placed outside the experimental area in a location accessible during beam periods. The distribution units will be easily replaced and of a modular design which can limit the number of components used. Interchangeability of spare assemblies will be relatively easy. This design provides extra output channels in the event that some should fail or additional channels are needed for other devices.

Preliminary Results on Test Units

The design described here is based in part on suggestions by K. Giovanetti who has made similar studies for the EGN detectors. In tests carried out at William and Mary(1,2), two stages of signal division were tested in cascade with the goal of a signal output of approximately 50-100 MeV equivalent light after two stages of division, the first by 20 and a second stage of division by 30. Such a system would provide 600 output signals exceeding the needs of the TOF system by about a factor of two. In this test two fiber bundles were used in series. Both were produced by Fiberguide Industries and were composed of 20 (or 30) 100μ graded index fibers at the output coupled to an 800μ step index fiber as input. The fibers were polished and connectors were mounted on this system at William and Mary by T. Pavey and R. Perez. Details of this work can be found in references 1 and 2.

Connection of Test System

The tests at William and Mary made use of the system shown in Fig. 1. A 330nm nitrogen laser (Laser Photonics Model LN120) was used in the tests. As no optical power meter was available to measure absolute power at each stage the goal of the tests was set to coincide with the needs of the TOF system namely, delivery of light equivalent to 50 MeV to a plastic scintillator coupled to a photomultiplier tube. A calibration source was placed near the scintillator in order to calibrate the equivalent light output.

Results

For the fiber bundles tested in this work, each output fiber was polished by hand and an ST connector attached in the laboratory. The range of output signals was well within the x5 goal mentioned above but the light output from a signal derived from the laser and divided first by 20 and then by 30 was shown to be about three times the light induced by a ^{137}Cs gamma ray source. Thus, only about 2 MeV (equivalent light output) was delivered to the scintillator from the test scheme used in these studies.

Suggested Improvements

A number of improvements as proposed in refs 1 and 2, would allow the final system proposed here to achieve the desired 50-100 MeV signal when installed on the CLAS-TOF system. First, commercially polished fiber ends should permit an improvement in output of possibly 10 Db (3) over the hand-polished ends used in the tests at Williamsburg. A high-output laser, with 1.4 Mj energy per pulse and pulse width comparable to the laser used in these tests, is available from the same manufacturer. (Laser Photonics LN1000). The increase in pulse output of x20 should provide additional signal strength needed to reach the goal of 50-100 MeV. The fibers proposed here can withstand pulses of far higher energy and thus should not be a limiting factor.

Attenuation

The fiber lengths used in the tests described here were kept to about 5 m or less. The fibers needed in the CLAS system may be as long as 50-100 m in total length. Typical attenuation of 330 nm signals in these fused silica fibers are 0.2 Db/m. One must therefore expect 10 - 20 Db of attenuation in the fibers employed in the CLAS system and the system must be designed accordingly. Of possible importance is the attenuation one may find in graded-index fibers. Those fibers will reduce the time spread of propagated signals but the dopants used to achieve gradations in index may be more absorbent in the wavelength region needed here. These considerations will be considered further below.

Details of Proposed System

Division of the laser signal will be based on modular components. Most of the optical fanouts can be 1 input, 12 output devices which should reduce costs and will allow several extra output lines at each location in the event that failures occur or additional signals are desired.

Forward Carriage

The forward carriage carries six sectors, each with 23 scintillators. This carriage will be served by twelve 1→12 optical fanouts, each fed by a (13th) single 1→12 fanout.

Side Carriages

Each of the two side carriages will hold 102 scintillators. (34 in each of three sectors) Each side carriage will be served by 9 fanouts, each also 1→12 and each fed from a single (10th) 1→12 optical fanout. The three primary fanouts can be fed from a single 1→3 optical fanout or, should it prove desirable, three single fibers can be brought to the laser focus point and fed as a group. The costs should prove comparable if separation of the laser from the CLAS is 50m or less. It may prove desirable, at additional cost, to use three lasers, one at each carriage. Such an arrangement would permit individual selection of right, left or forward scintillators. In addition, the signal supplied to each scintillator would be increased owing to the elimination of the 1→3 optical fanout and the fibers to and from that fanout. One would then be able to trigger only about one-third of the TOF scintillators at once, should it be useful to compare that to the effect of a global TOF trigger.

Materials Required/Estimated Cost

1. Laser; Laser Photonics LN-1000 1.4 Mj	$12,000
2. Fiber; 150m 800μm Superguide G @40$	$ 6,000
3. Fiber; 60m 500μm Superguide G	$ 1,800
4. Fibers; 350 100μm fibers; Superguide GI w/ connectors	$14,000
5. Splitter Bundles(35), 1→12; 500 μm→100μm w/ connectors	$35,000
6. Splitter; 1->3; 800->500μm, w/ connectors	$ 500
7. Mounting Boxes, Hardware, Labor	$13,000

ESTIMATED TOTAL $82,300

Proposed Test System

Prior to committing funds to a complete system as described above, a simple test system made of such components can be obtained for considerably lower cost. We propose that CEBAF obtain two 1 ->12 splitter bundles from Fiberguide Industries and a single 1 ->3 bundle. Each of these bundles should have factory polished fiber ends and connectors mounted. In addition, several typical lengths of fused silica fiber should be obtained both to test the fibers for suitability and to measure attenuation as a function of fiber length while in use. Tests carried out by one of us (KLG) suggest that time dispersion of pulses in long, step-index fibers may be excessive for TOF calibration purposes. In that case, use of graded-index fibers may be necessary. The laser presently owned, a Laser Photonics Model LN 120 70 uJ laser, can then be used to send test pulses through the simulated distribution network. A simple scaling of a factor 20 will allow a reasonable prediction of the equivalent light output to be expected from the more powerful LN 1000 laser. As in the tests described here, a radiation source coupled to a scintillator-photomultiplier combination should provide accurate means of calibrating the equivalent light provided by a fiber coupled to the same scintillator.

Controlled Variation of Light Output From System

The test system described above utilized a short-focus quartz lens (Oriel 41329) to maximize the light delivered from the laser to the input fiber. The input fiber was held in position by a movable microscope stage (Edmund Scientific A30,058) which permitted careful positioning of the input fiber for signal maximization. This arrangement permits an open region of about 30 mm between lens and input fiber. A translucent quartz crystal can be positioned in this region to serve as a defocussing device for the laser light. In this fashion, it should be possible to vary the light delivered to the input fiber by more than a factor of 10 while maintaining relative equality of light among several output fibers. The system should thus be able to be reproducibly changed in output from the maximum to about 0.1 x maximum either continuously or in steps as may be necessary.

Maintaining Long-Term Stability of the System

The simplest system for checking absolute magnitude of the output signals over a long period of time should be provided by a small radioactive source imbedded in a small scintillator with one or more fibers imbedded in similar fashion in the same fiber and the scintillator coupled to a photomultiplier tube. Although the strength of the radioactive source will diminish with time, the pulse height it provides will not. Thus, changes in the scintillator, phototube, tube base electronics, glue joints etc will affect fiber and source alike and the relative comparison between the two should hold constant. Coupling more than one fiber (and, perhaps, more than one source type) should insure a check on long-term stability.

Time Scale

The system described here can be in place within six months of initial orders for equipment. Tests of light transmission through two or three fiber bundles in cascade would be possible within six weeks of a decision on component specification.
It is recommended that all fibers be cleaved and polished at the factory and that the bundles and fibers so obtained be enclosed and installed locally.

Alternatives to a Laser as Light Source

A gaseous flash tube with light output of sufficiently short wavelength to stimulate scintillator light can provide an alternative to the laser(s) discussed above. In such a system, three flash tubes would be employed, one on each carriage. The optical fanout boxes would then be dispensed with. Instead, approximately 140 fibers would be brought to the face of each of the three flash tubes. One important advantage to such a system would be the use of sliding shutters with different hole patterns arranged to slide in front of the fibers and to expose all or a few to the tube light. Such a technique would permit the simulation of a wide variety of trigger coincidences. The utility of such an alternative is presently being studied.

Acknowledgements

We gratefully acknowledge the continued assistance of the William and Mary Physics Machine Shop.

References

1. T. G. Pavey, Senior Honors Thesis, May, 1993, Williamsburg Va. (unpublished)
2. R. Perez, Senior Research thesis, May, 1993, Williamsburg, Va. (unpublished)
3. One notes that the variation in output magnitudes shown in Ref 1. Table 5, for a 20-fiber splitter box, indicates uniformity better than ±30%. One may conclude from those data that the fibers polished as described in Refs 1 and 2 may be as good as those available with commercial polishing. If such proves to be the case, commercial polishing may not provide as much additional signal as suggested here.

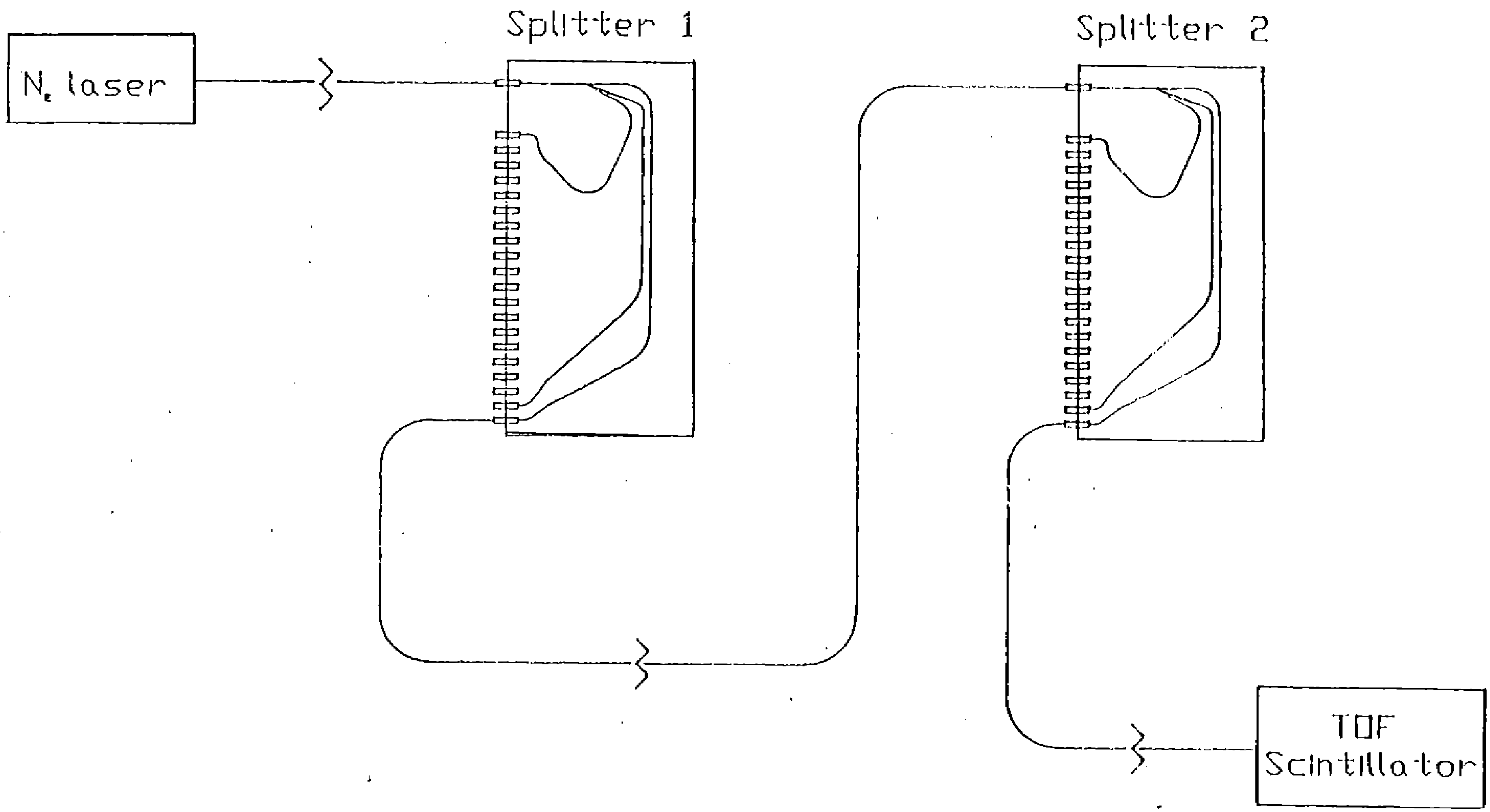

Figure 1. Schematic of Test System