Notes on a Visit by T. Hiruma and R. Fisher of Hamamatsu Corp.

by

A. Roberts, Hawaii DUMAND Center.

On May 12 - 13, 1981, President T. Hiruma and Western Sales Representative R. Fisher of Hamamatsu visited the Hawaii DUMAND Center. Discussions with them on DUMAND problems, and DUMAND phototube requirements occupied two days. Following is a summary of the discussions and related work.

On the first day, DUMAND members discussed recent DUMAND progress, emphasizing those aspects of DUMAND relating to PMT requirments. V. Z. Peterson described the DUMAND organization and program; V. J. Stenger discussed briefly various arrays now under consideration; A. Roberts discussed deployment requirements and how they affected sensor design; and J. G. Learned described the proposed muon string experiment, and discussed possible improvements. Throughout this discussion, the fact that Hamamatsu had produced a working 20" PMT was kept in mind. (Tests at Irvine on a smaple 20" tube by JGL indicate it is an excellent tube.)

On the next day, a long and fruitful discussion was held on what Hamamatsu might be able to provide for DUMAND, to meet our present requirements. These include the MICRO array, still several years away; and the muon string, whose performance could be improved by more sensitive PMT's.

<u>K^{40} Background.</u> -- For DUMAND, one of the major problems with all PMT's is the need to discriminate against the K^{40} background, which consists almost entirely of single photoelectron pulses, with a few large pulses due to tube noise and afterpulses. Two methods of accomplishing this discrimination have heretofore been studied: the use of a high-gain first dynode[1,2], and the use of several PMT's in coincidence[3]. Just before the meeting, a third method which appears to show promise was considered by JGL and AR: the segmented anode.

<u>Segmented Anode PMT's.</u> -- An adaptation of the coincidence method, this technique is based on the hypothesis (whose validity is presently being examined) that tubes can be so designed that the cascade produced by a single photoelectron at the first dynode can be geometrically confined to a small area on the anode. According to B. Leskovar, as we discovered later, many tube designs are careful to avoid this, in order to prevent high current densities on the last dynode and anode. For channel multipliers, such isolation is obviously feasible; for conventional PMT structures, each case must be individually examined. We have since been informed by Leskovar that in conventional structures such imaging does not occur; in venetian blind structures it would be even less likely.

In tubes in which such imaging does occur, a signal producing, say, two independent photoelectrons would produce two photoelectron cascades at uncorrelated positions on the anode. If the anode positions are thus correlated with the impact points on the first dynode, we can then distinguish multiple- from single-electron pulses by segmenting the anode into, say, a 3x3 array.

If all electrons are then uncorrelated, the chance that two simultaneous electrons strike the same anode segment is only one in 9. A requirement that at least two segments be simultaneously fired then suppresses the background by the same amount as a two-fold majority logic coincidence circuit for nine independent PMT's. But only one sensor is required; and the chief drawback seems to be the loss in sensitivity of 1/9 or 11%, when two photoelectrons produced signals in the same anode segment.

Calculation of Random Coincidence Rate. - - Let the total single-electron noise rate be N, and divide the anode into m segments. The random coincidence rate C is then:

$$C = [m(m-1)/2] \times [2 (N/m)^2 \tau]$$

$$\approx N^2 \tau$$

Thus the number of segments is to a first approximation unimportant; the most important parameter is the total counting rate.

Progress at Hamamatsu. - - Dr. Hiruma mentioned several projects at Hamamatsu that interest us. They are still working on high-gain first dynodes. They are also working on spherical tubes, containing two hemispherical PMT's back to back, with the cathode directly deposited on the inside surface of the glass pressure envelope, but the backside required to hold atmospheric pressure only (as first suggested by Sternglass, in DUMAND 1975![4]). Such tubes may use channel-plate structures. Hiruma is moderately optimistic about lifetimes for channel-plate tubes.

Quasi-channel structures of lower resolution (e.g. like the Bendix channeltron) were briefly discussed as an alternative to channel plates, whose resolution is greater than necessary for our purposes.

Pressure Containers. - - The problem of obtaining pressure containers (glass spheres) arises whenever one considers PMT's too large for the 16" I.D. spheres, the largest currently available. A conversation between JGL and Ken Irving of Benthos has given the following information:

1. They strongly favor staying with the existing 16" sphere. A large amount of effort has been invested in learning how to produce this size, and they can now be sold for $272 each in quantity. By contrast, Benthos has found no one willing to produce larger spheres. At one time a few 24" spheres were made, and Irving will call around to see whether some of these can be located, and perhaps borrowed. Prospects for a 26" sphere, large enough to contain the present Hamamatsu 20" PMT, look dim. The development cost would be very high, and the quantity production cost would probably exceed $1000.

2. Benthos is engaged in a low-priority investigation of making a cylinder with 17" hemispherical endcaps. JGL encouraged them to continue this. He also encouraged a meeting between Hiruma and Sam Raymond, chairman of the Board at Benthos, concerning putting PMT's directly into pressure envelopes.

As a consequence of this information, we discussed with Hamamatsu the following subjects.

ITEM	STATUS OR RESPONSIBILITY
1. Tests on 20" tube.	Being done at Irvine. (now complete)
2. Search for large housing to deploy existing 20" PMT.	Hamamatsu and JGL Started; not hopeful.
3. Make modified 20" PMT's (i.e. shorter) to fit in 20" housing, if available.	No 20" housings now known.
4. Further explore larger sphere sizes.	JGL-U.S.; Hamamatsu - Japan.
5. Make and test segmented-anode tubes. Try 4, 9, 16 segments.	Hamamatsu
6. Design a new PMT to be largest that can fit into a 16" sphere.	Hamamatsu
7. Hiruma suggests a PMT with both high-gain first dynode and segmented anode.	Hamamatsu

SUMMARY

Following these discussions, several points emerge that ought to be kept firmly in mind.

1. The difficulty and cost of using spheres larger than 16" I.D. has been underestimated. If at all possible, we ought to try to stick to that standard size.

2. The Monte Carlo calculations on muon neutrino detection (and also preliminary indications on cascade detection) indicate that the rate of performance gain with increasing PMT sensitivity is not remarkably high. Going from the 13" PMT to Sea Urchin, with four times the sensitivity, did not produce a corresponding improvement in performance, and would not even save money.

3. If it turns out to be possible to
a) make a 16" PMT to fit in a 16" housing, or
b) make a spherical 16" tube with the PMT built into a sphere,
then that size and sensitivity will be entirely adequate. The 13" PMT that EMI is working on would also be adequate.

4. The alternatives for reducing K^{40} background are

a). High-gain first dynode, conventional multiplier.

b). Segmented anode;

c). Both a) and b).

d). Channel-plate PMT or equivalent, with segmented anode.

e). Ordinary PMT's, multiple sensors, and coincidence rejection of background. Least desirable because of very high cost.

REFERENCES.

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2. "Estimation of 1st High-Gain Dynode Utility," T. Hayakawa and T. Hayashi, ibid. 1, p. 83.

3. "Calculation of Accidental Coincidence Rates in a DUMAND Array," T. Bowen, ibid, 1, p. 88.

4. E.J.Sternglass, Paper no. XVIII, Proc. DUMAND 1975 Summer Study, P. Kotzer, ed., Western Washington Univ., Bellingham, WA., 1976.