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LATOF Prototype Lightguide Tests

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Several types of acrylic plastics light guides have been tested for the CLAS large angle time of flight (LATOF) scintillators. This is a follow-up of the Monte Carlo simulations on light guides done earlier[2].

In addition we investigated the differences between "UVT" and General Purpose plastic, the differences in reflection of polished and "diamond cut" surfaces, and the effects of heating and bending plastic. All tests were done with light, generated by cosmic rays interacting with a Bicron 408 type scintillator as a light source (figure 1).

1) Light collection tests

The following prototype light guides were tested:

Light guide	material	name	figure	output
A 4 part twisted/bent 45° (figure 1).	UVT	UNH1	2	1.2
A 4 part twisted/bent 30° (figure 2).	UVT	UNH2	3	1.2
A 2 part twist/bent 60° with prism/cyl. ends	UVT	W&M1	4	0.7
A bent only 60° with cylinder end.	UVT	W&M2	5	0.8
A set of straight fishtails (figure 3).	GP	FISH1, FISH2	6	1.2
A set of short cylindrical guides tilted 30°.	GP	CYL1, CYL2	7	1.0
No guides (PMT directly on scintillator).				1.6

The last column in table 1 gives the total light output (or light collection) of the guide relative to the short, cylindrical guides.

'Bent' refers to the angle between the scintillator and PMT axes. 'Twisted' refers to the bent section being split in two or more parts which are then twisted to form an approximately square output aperture.

'Prism'- and 'cylinder' ends refers to transition pieces that are inserted between the twisted guide and the scintillator / PMT [2]. The UNH1 and UNH2 guides were not equipped with these.

2) Timing resolution tests

With the test rig of figure 1 the timing resolution (σ, see reference 1) was measured for several combinations of two light guides. Table 1 shows the results.

UNH1 and UNH2	156 ps
UNH1 and W&M2	158 ps
CYL1 and CYL2	165 ps
FISH1 and UNH2	163 ps
FISH1 and W&M1	166 ps

Table1: Comparison of light guide timing performance (standard deviation in pico seconds, these numbers can be directly compared to those listed in ref. 4 for the FATOF scintillators).

The first two measurements were done to find the difference in performance between a twisted (UNH2) and a bent (W&M2) guide.

The last two measurements attempted to show a difference between two twisted guides (UNH2 and W&M1). UNH1 and UNH2 were designed from the simulation results of reference 2, using a 1.5" thick (actually two .75" plates) twisted section.

It follows from table 1 that the guides show little differences in timing response. Systematic errors are estimated to be around 5 ps, statistical errors are smaller. Simulations of these configurations show considerable differences in pulse shape[2)]. Also the light output differs considerably from one guide to another (section 1). It is interesting that no significant difference in resolution can be found between a UNH guide and either of the W&M guides. The UNH parts show 60% improved light collection. Section 5 addresses this discrepancy.

3) UVT versus GP acrylic and polishing versus diamond cutting

To test the difference in transmission of light guides finished with polished and diamond cut surfaces we ordered 3" x 24" x .5" acrylic UVT plates from Bicron Inc. The .5" sides were finished with a diamond fly cutter. We then also cut the same dimensions out of a .5" thick GP acrylic plate and finished the sides with #400, #600 sandpaper and then polishing rouge. The results are listed in table 2.

LIGHT GUIDE TYPE	OUTPUT
GP strip with polished sides	131
UVT strip with diamond cut sides	133

Table 2. Transmission of a 'diamond cut' UVT versus a polished GP acrylic strip (in arbitrary units)

No significant difference in transmission was found. Measurements at Bicron[3]) showed that internal reflection against a polished surface is 92-94% efficient, while a surface treated with a diamond fly-cutter shows 98-99%. In our 0.5" x 3" x 24" strips hooked up to the BC408 scintillator, typically six reflections against the 0.5" sides can be expected before a photon gets detected. With a 0.93 reflection coefficient, the sides would contribute a factor $0.93^6 \sim 0.65$ to the total transmission as compared to $0.985^6 \sim 0.92$ for the diamond cut case. We clearly could not verify this.

The test also suggests that GP acrylic does not affect the transmission of blue (420 nm) light, generated by the BC408 scintillator, any more than UVT acrylic does. Samples of the two materials were also tested with the spectrum analyzer from the Detector Meisters at CEBAF. Figures 8 and 9 show absorbtion curves.

4) Transmission degradation due to heating and bending

To estimate the influence of heating and bending on the transmission of acrylic plastic, we made rough measurements on the transmission of strips of 3/4" UVT acrylic after different operations (table 3).

OPERATION	TRANSMISSION
unheated, unbent	1.0
heated to 300^{o} F for 1 hour, unbent	0.9
heated, bent 45^{o} and twisted 90^{o}	0.7

Table 3. Transmission reduction due to heating and bending.

5) Pulse shape measurements

In order to find an explanation for the insignificant differences in timing performance between the light guides (section 2), the pulse risetimes of the UNH2 and W&M1 guides were measured (figure 10), plotted on different voltage scales to compensate for the 60% difference in light collection). Even with the scintillator, PMT and oscilloscope risetimes folded in, W&M1 shows a consistently shorter rise time than UNH2. This is presumably caused by the reduced angular acceptance of this guide. The 30% improved resolution expected due to the 60% increased light output seems to disappear with the increase in risetime. This is consistent with the assumption that the timing resolution depends mostly on the number of photons generated in the first part (~nanosecond) of the signal.

References:

1) First tests of a CLAS TOF scintillator at UNH -93-020
2) CLAS Large Angle Time Of Flight Light Guides. Clasnote ~~#003 Sept. 1994~~
3) C. Hurlbut, Bicron Inc., private communication
4) Final results on the CLAS Forward Angle TOF scintillators.

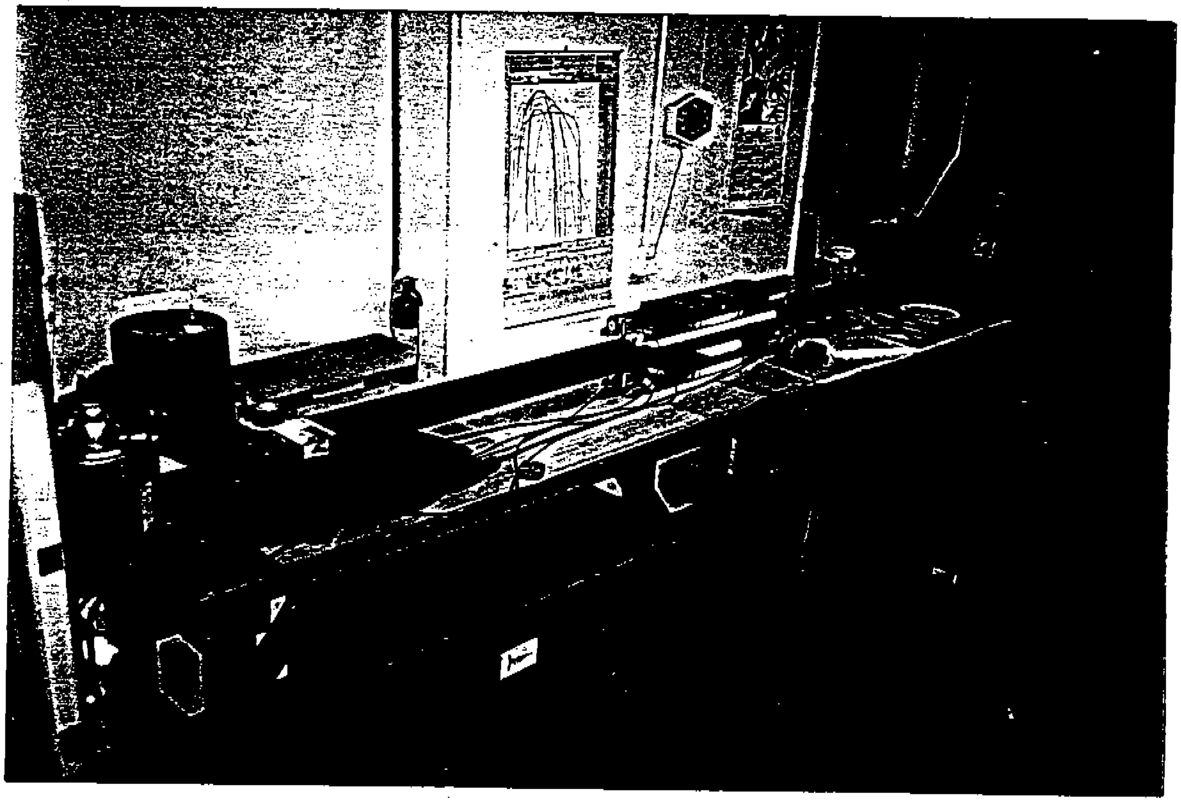

Figure 1. Test rig: A 4m long scintillator with installed light guides (UNH1 and UNH2) and 3" THORN-EMI PMT's, triggered by a small coincidence setup in the center.

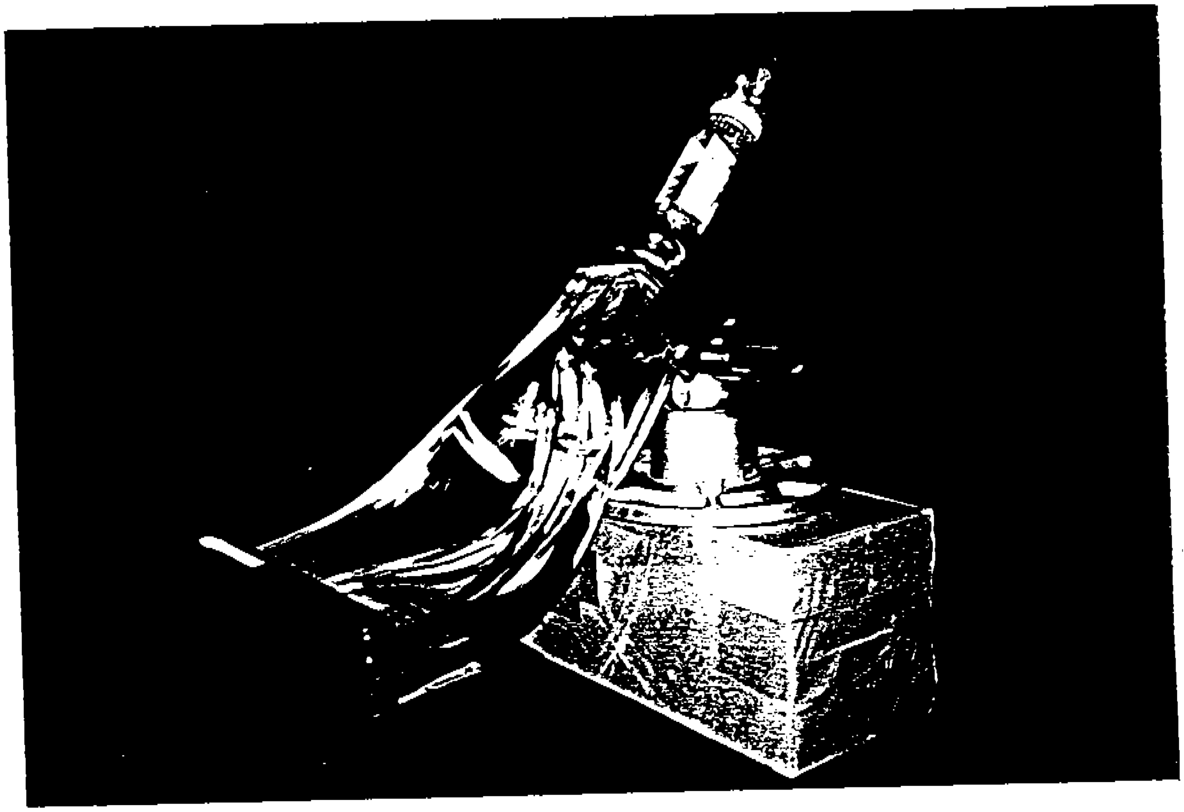

Figure 2. A twisted/bent guide made up of four 3/4" thick plates, bent and twisted according to ref.2 to produce an approximately square output aperture. No prism and cylinder ends. Light collection is expected to be optimal[2].

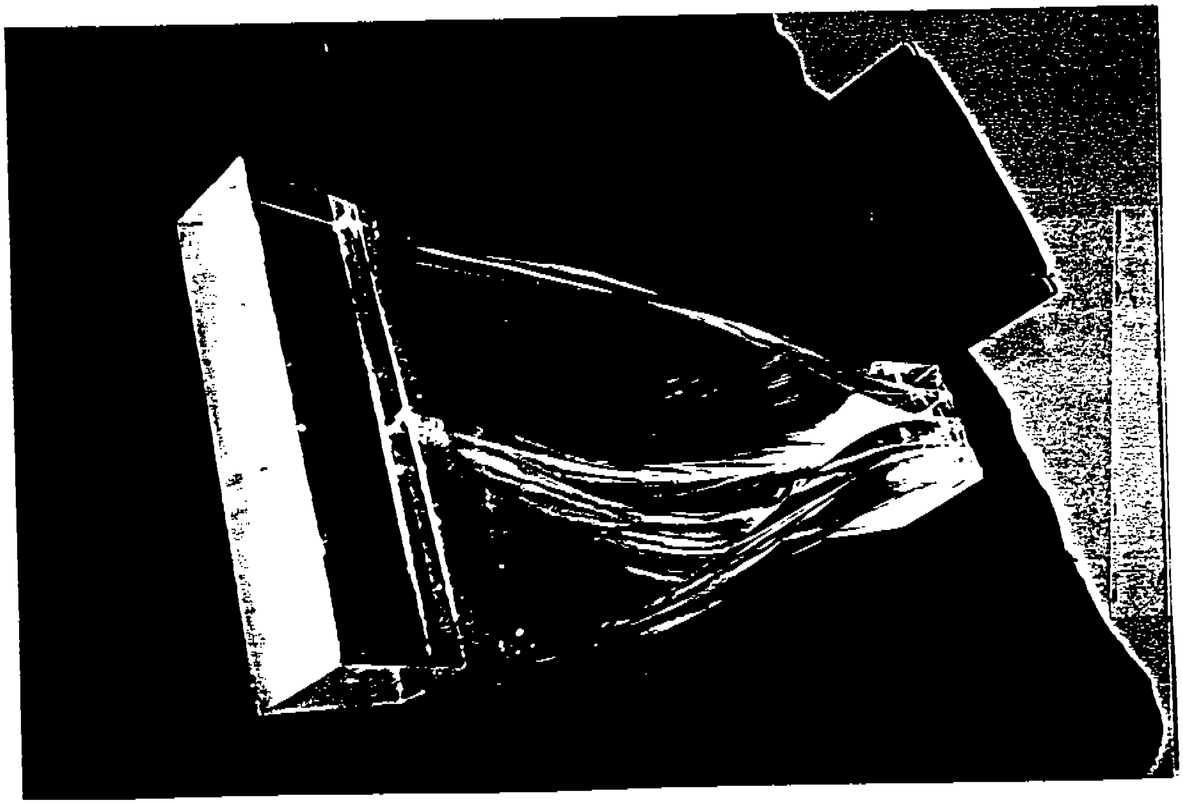

Figure 3. As in figure 1 with smaller bend angle.

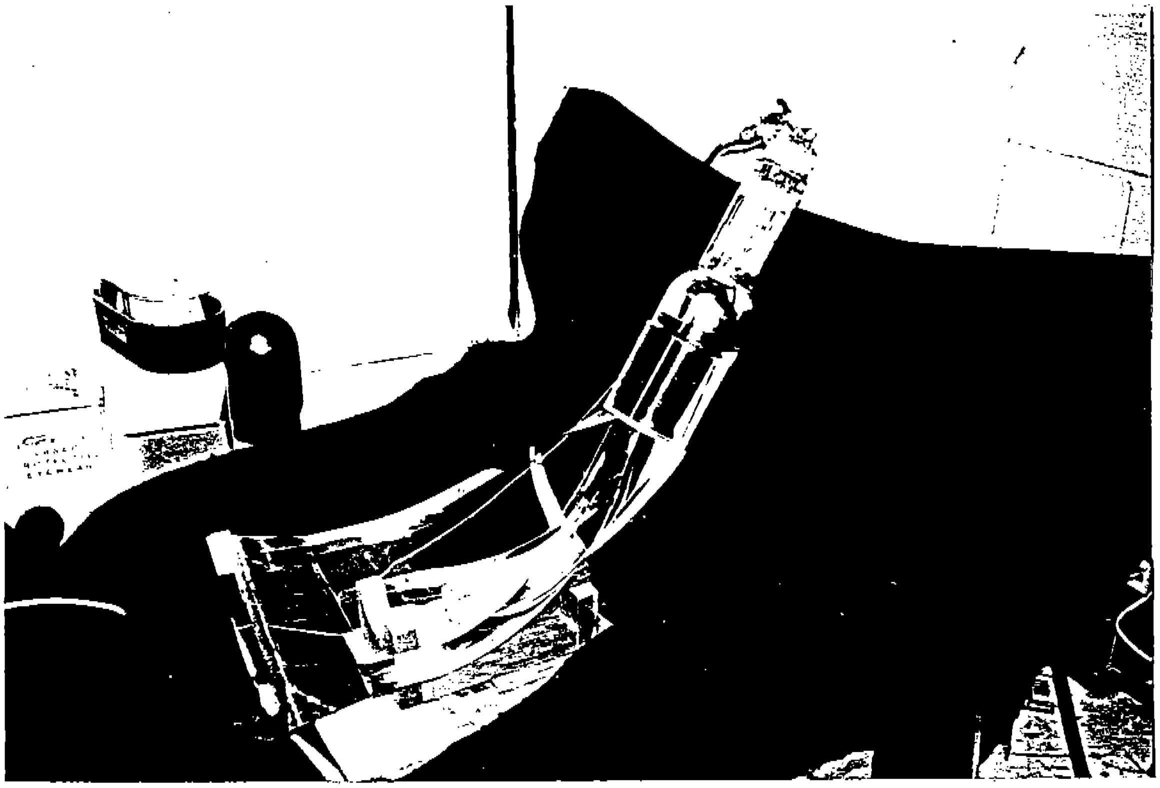

Figure 4. A twisted/bent guide made up of two 1" thick plates. With prism and cylinder ends. Light collection is reduced due to the smaller total thickness (UNH1, UNH2: 1.5").

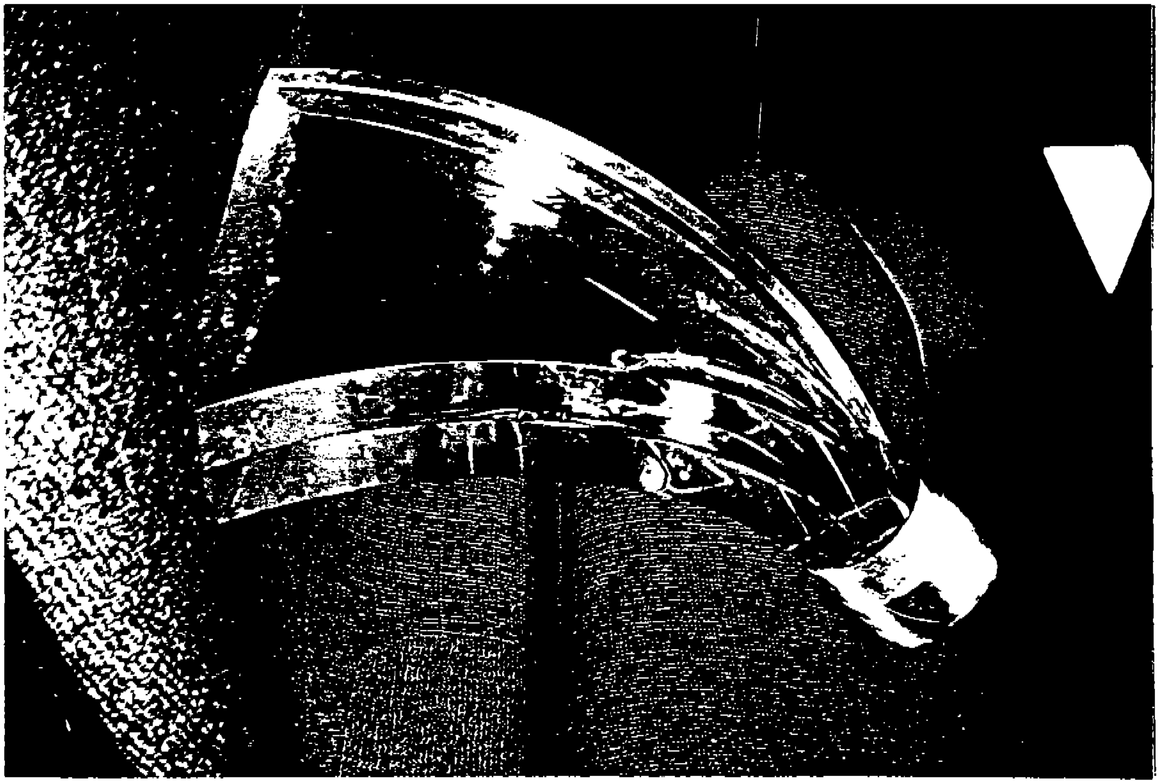

Figure 5. A bent only guide made up of two 1" plates. With cylinder end. Reduced light collection due to the tapering of the guide in only one dimension ('fishtail' type, see ref. 2).

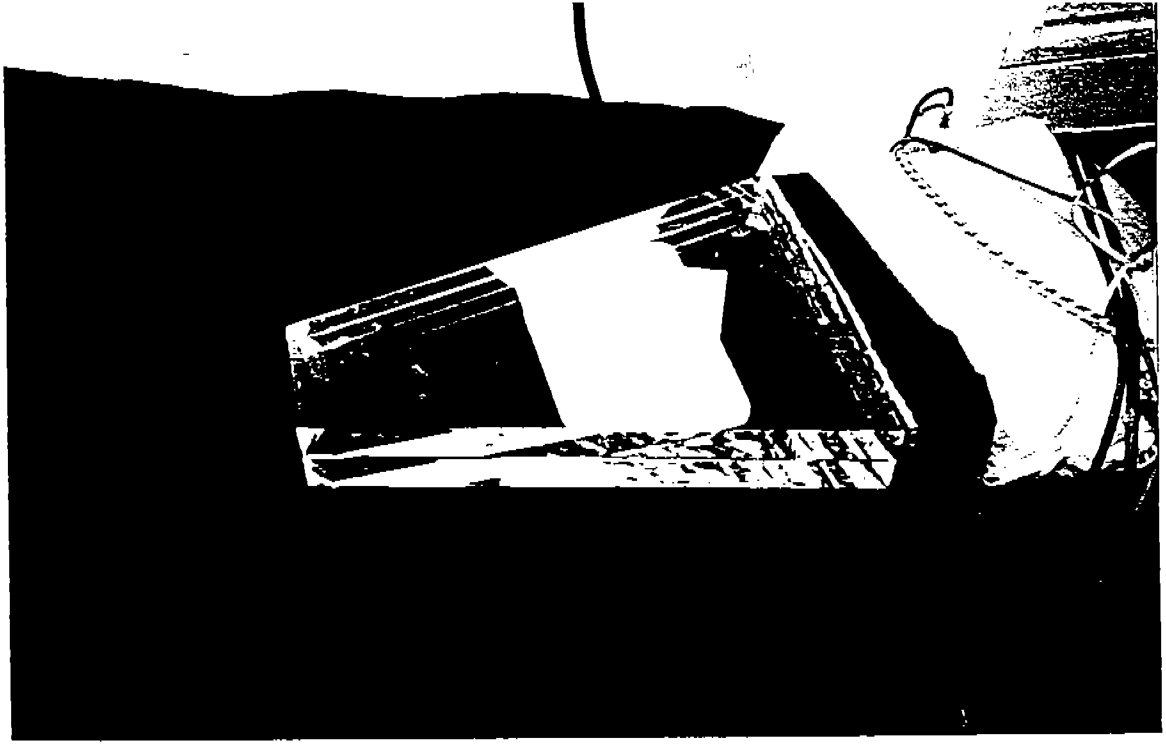

Figure 6. Straight fishtail, the most simple, widely used guide. Expected reduced light collection due to tapering in only one dimension does not show because sample was not heated or bent (see section 4).

Figure 7. Short, cylindrical guides with 30° angles. These were at one time seen as the most simple solution for the LATOF scintillators. Light losses due to mismatch between scintillator (5 x 20 cm) and cylinder (3" diameter) cross sections.

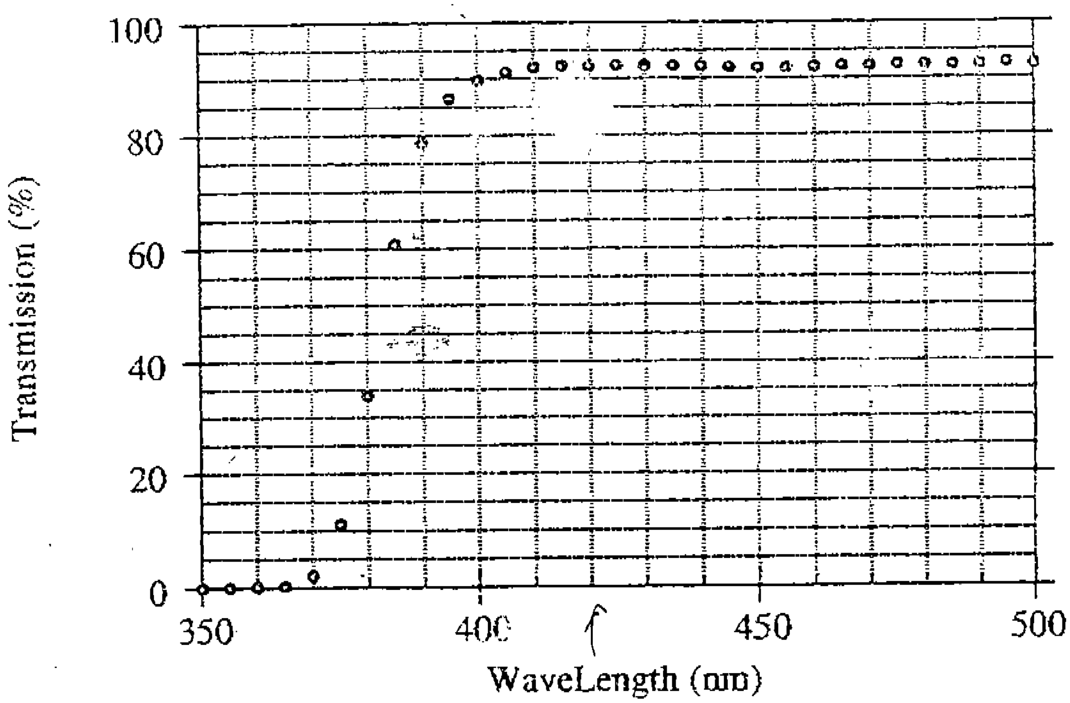

Figure 8. Transmission of GP Polycast acrylic.

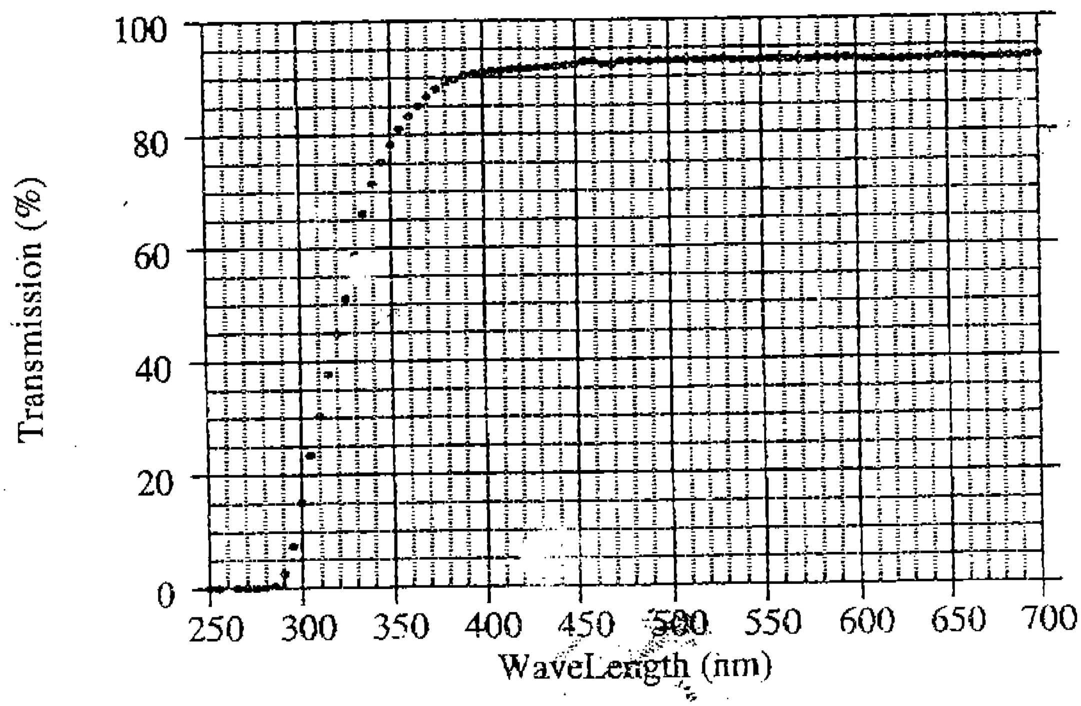

Figure 9. Transmission of UVT Polycast acrylic

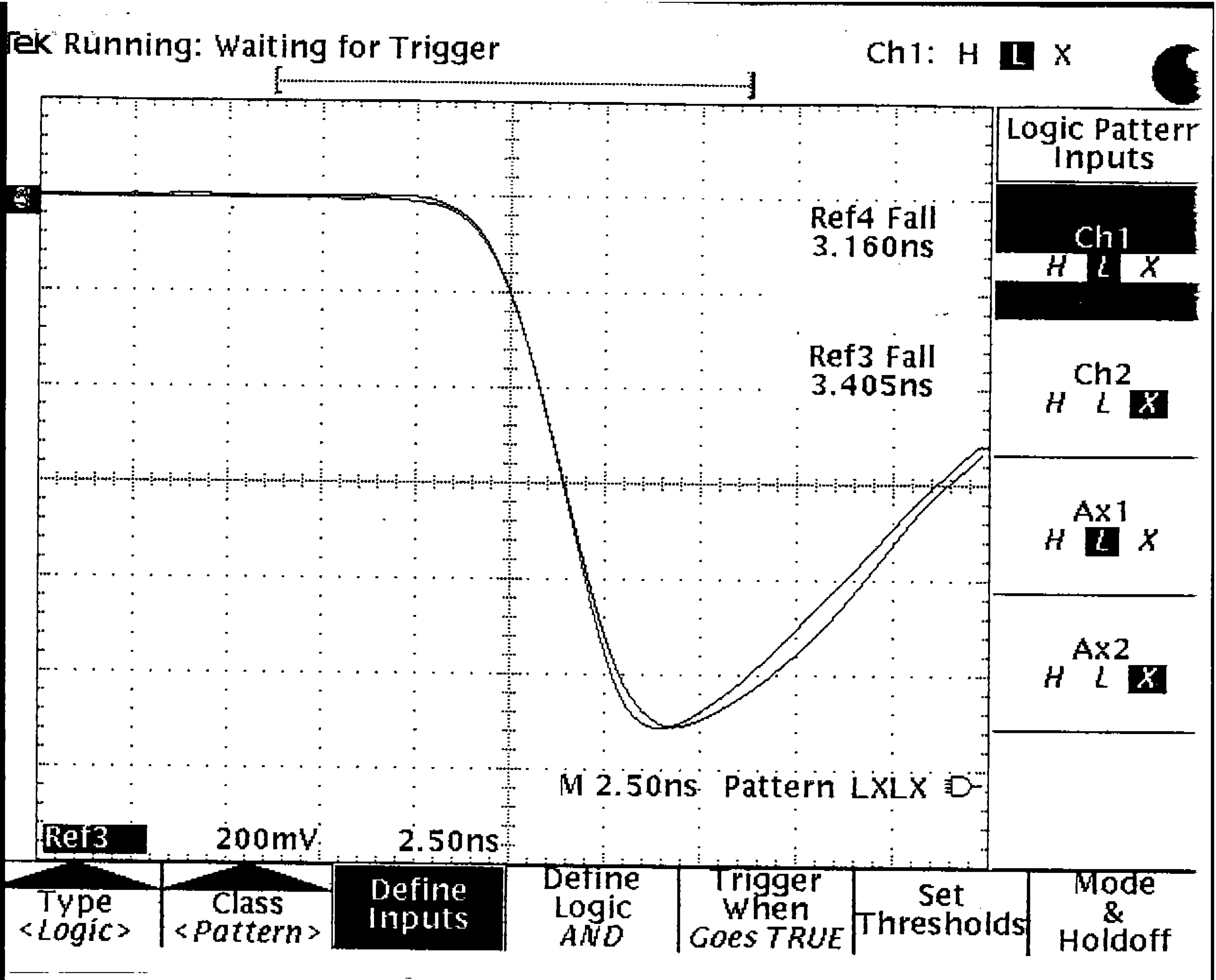

Figure 10 Rise times of UNH2 and W&M1 plotted on different scales (200 mV/cm and 125 mV/cm respectively)