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BIDIRECTIONAL SLAPPER SYSTEM

by

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ABSTRACT

A unique bidirectional "slapper detonator" has been demonstrated. A single bridge foil propels two flyers in opposite directions, thereby initiating two explosive pellets. Its use in producing a nearly perfect spherically expanding detonation front is shown.

I. INTRODUCTION

Slapper detonators and their function have been described[1] in terms of their construction: substrate, foil bridge, flyer, barrel, and acceptor explosive pellet. The similarity of the substrate-bridge-flyer part to a propellant-fired gun is evident. In each, an action/reaction occurs between the velocity and mass of the bullet (or flyer) and the velocity and mass of the gun (or substrate). The energy going into the reaction mass is, in a sense, lost. In this work, we reasoned that the "lost" reaction energy might be used to propel a second flyer, a bidirectional slapper, initiating a second acceptor pellet in the opposite direction. This report describes the construction of this device, some of our observations of it, and how it is used to initiate the center of a spherical charge. A patent application is being reviewed in Washington, DC.

II. BIDIRECTIONAL SLAPPER CIRCUIT DESCRIPTION

Figure 1 shows a single-bridge bidirectional slapper circuit that is etched from approximately 4.6-μm Microclad copper on either 25.4-μm- or 50.8-μm-thick Kapton. The circuit etched on 50.8-μm Kapton is easier to handle during construction of the circuit because of the thicker Kapton.

III. BIDIRECTIONAL SLAPPER CIRCUIT CONSTRUCTION

Construction of the cable circuit is seen in Fig. 2. The circuit is folded on itself, around an insulating film. Without the indicated relief, the resulting laminate would become an ordinary unidirectional slapper. The relief hole permits the Kapton on the ground return side of the assembly to be laminated directly onto the bridge. Thus the bridge is covered on both sides with just 25.4 μm (or 50.8 μm) of Kapton (plus a thin layer of glue on one side), and slapper detonators can be built on both sides of it. Special care must be taken to make the layer of glue between the bridge and the flyer very thin so that the flyer with the glue is propelled with nearly the same velocity as that without glue. A 25.4-μm sheet of polyester cast adhesive glues the opposite side flyer onto the bridge. During the laminating process the adhesive thins to approximately half its original thickness. Thinner glue layers can be obtained with wet adhesives, but this technique does not lend itself to current production operations and has not been pursued.

IV. BIDIRECTIONAL DETONATOR SYSTEM

Figure 3 describes the components in a bidirectional detonation system. Sapphire barrels are placed on both sides of the slapper cable to help direct the Kapton flyer

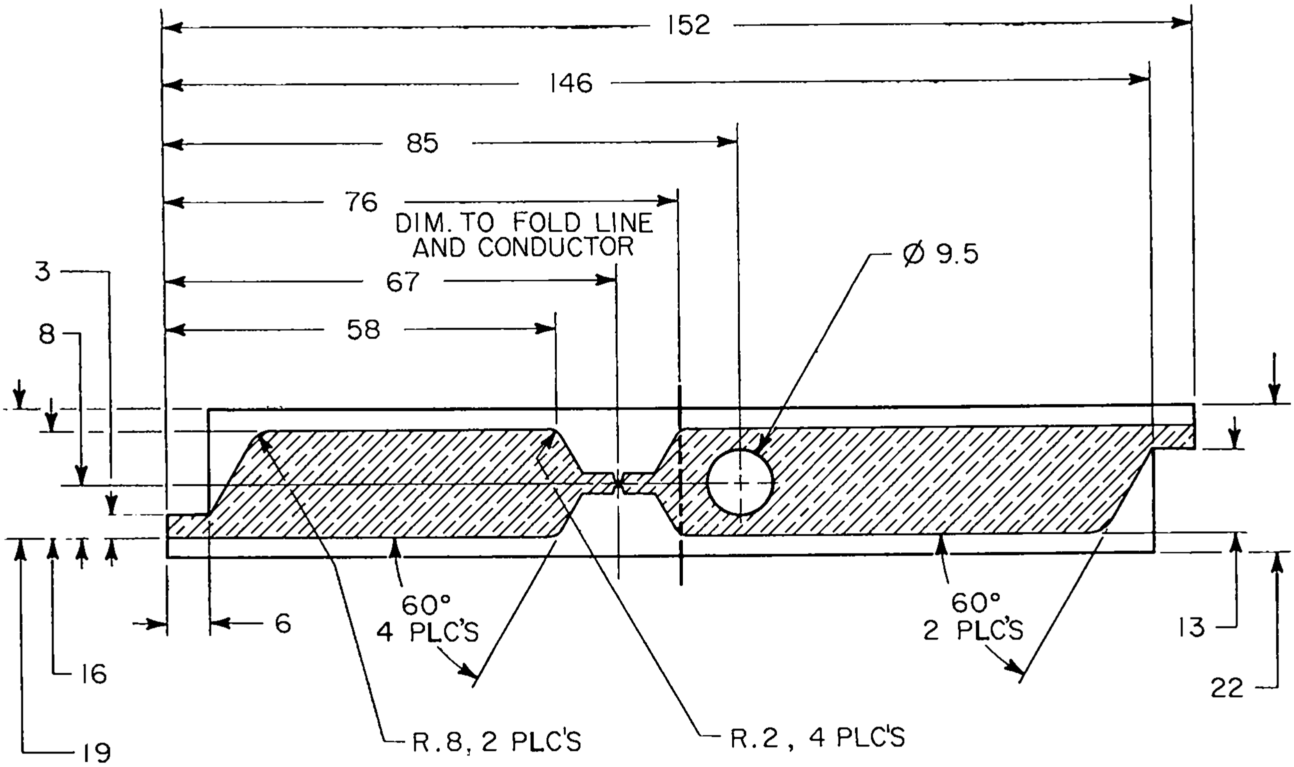

Fig. 1. Bidirectional slapper circuit (dimensions in millimeters).

to hit the explosive pellet. A barrel holder, made of Artus shimstock material, holds the small barrel in place. Advantages of this type of barrel are that it is small, perfectly round, and rather inexpensive. The explosive pellets are placed directly over the sapphire barrel, which is approximately 0.039 mm longer than the barrel holder to ensure that there is no gap between the barrel and the explosive pellet.

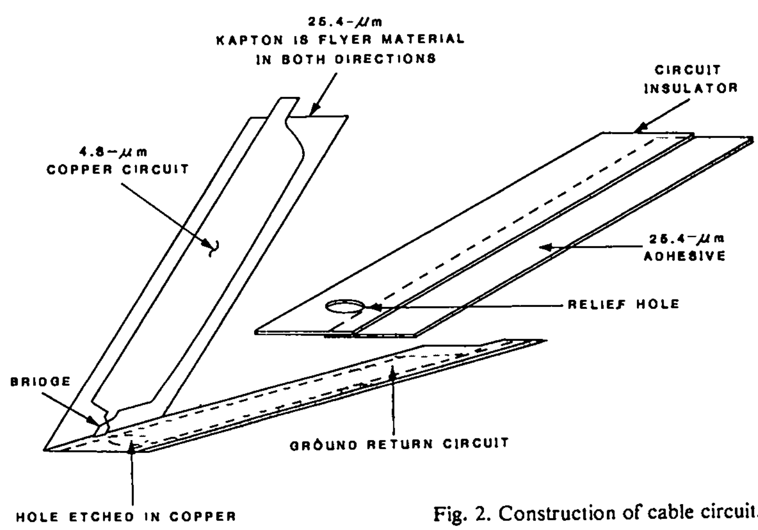

Fig. 2. Construction of cable circuit.

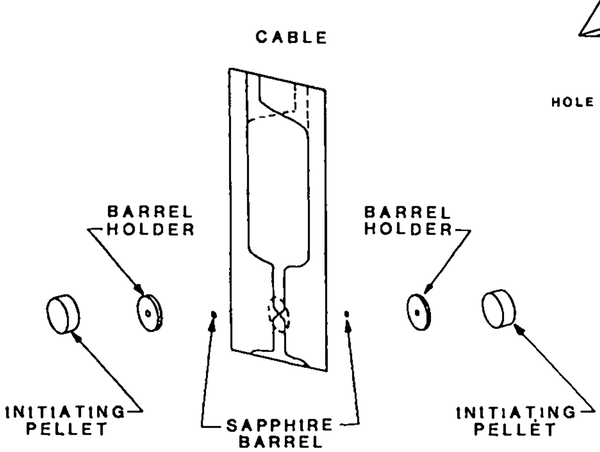

Fig. 3. Bidirectional slapper detonator system components.

Bridge:	0.381-mm-square bridge. 4.6-μm-thick copper
Pellet:	1.65-g/cm³ PETN. 3 mm long by 12.7 mm in diam
Barrel holder:	9.52 mm in diam by 0.318 mm long. 0.965-mm-diam hole
Barrel:	Sapphire. 0.965 mm in diam by 0.356 mm long. 0.406-mm-diam hole
Flyer:	25.4-μm Kapton on both sides of bridge

V. EXPLOSIVE INITIATION USING A BIDIRECTIONAL SLAPPER SYSTEM

Assemblies like that shown in Fig. 3 were tested to determine the difference in timing between the pellet fired with the glued flyer and that fired with the laminated flyer. Figure 4 shows how these assemblies were viewed by the streak camera.

The streak camera is focused on the mirror images so the sides of the pellets are seen as a blurred image in the photo and dynamic record. A set of recorded film traces is shown in Fig. 5.

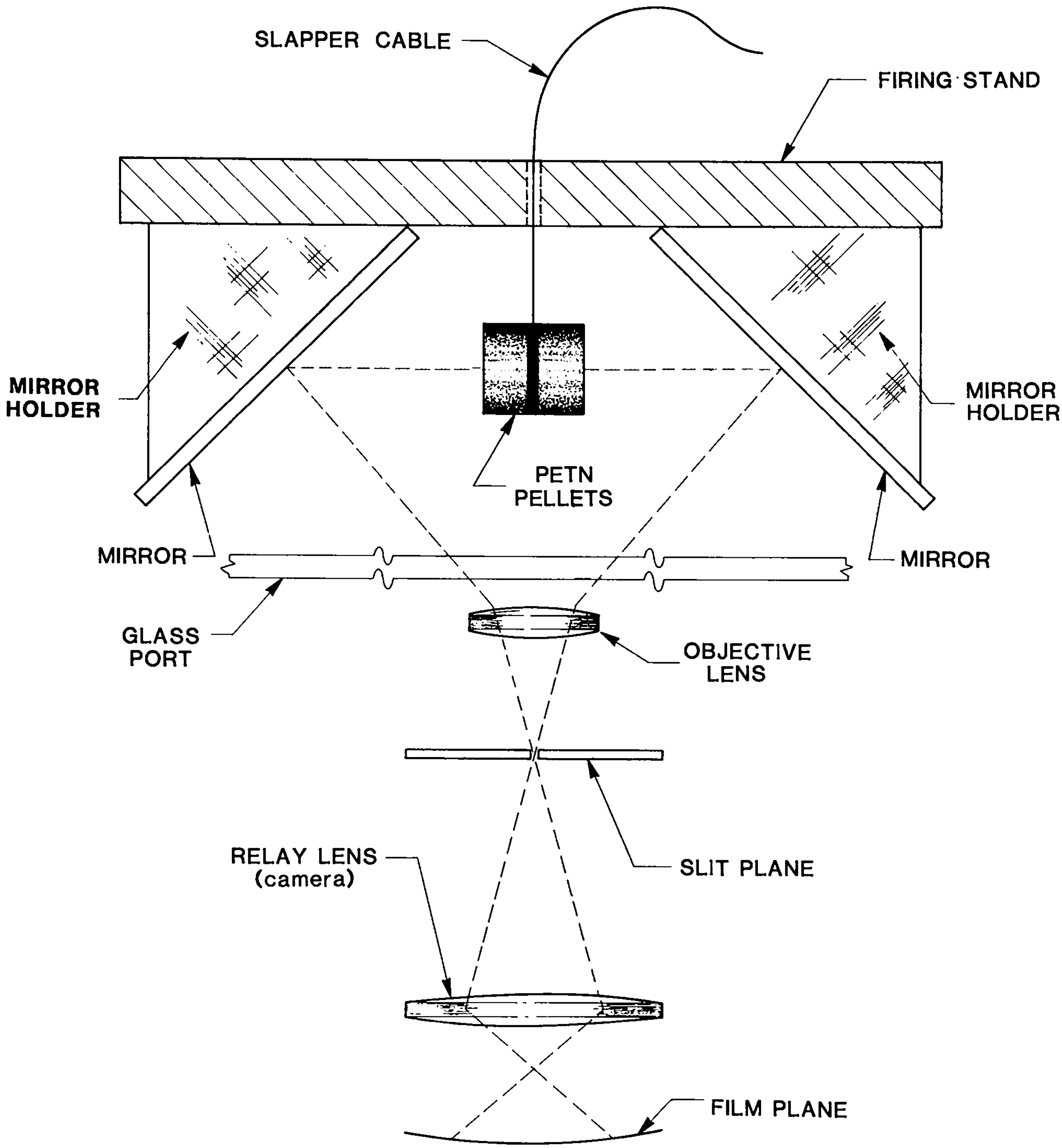

Fig. 4. Streak camera view of bidirectional assembly.

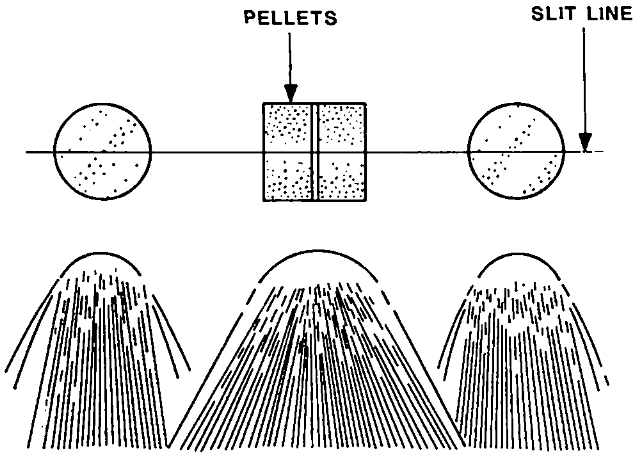

Fig. 5. Recorded film traces.

Bidirectional slapper assemblies were fired using two types of capacitor discharge units (CDUs), charged to different voltages, at both ambient temperature and at −54°C to test the system over a wide temperature range. Table I lists test results of a number of these experiments. Bias time is the time from breakout of the pellet being initiated with the unglued flyer to the breakout time of the pellet fired by the glued flyer. Table I shows that all assemblies fired well at ambient temperature, except those fired near the threshold voltage. Best results at −54°C were achieved with the larger firing unit.

TABLE I. Results of Experiments Using Two Types of CDUs

CDU (Type) (μF)	Temperature	Firing Voltage (V)	Bias Time (μs)
0.2	Ambient	6000	0.017
0.2	Ambient	6000	0.015
0.2	Ambient	6000	0.011
0.2	Ambient	5000	0.033
0.2	Ambient	4000	0.258
0.2	−54°C	6000	0.086
2.0	Ambient	6000	0.014
2.0	Ambient	6000	0.025
2.0	−54°C	6000	0.040
2.0	−54°C	5000	0.297

VI. IHE INITIATION WITH THE BIDIRECTIONAL SLAPPER SYSTEM

We have demonstrated that the bidirectional slapper system is capable of good performance when initiating an IHE (insensitive high explosive) acceptor charge at cold temperature. Figure 6 shows a bidirectional slapper system using 1.8-g/cm^3 TATB hemispherical booster pellets. The hemispherical pellets are machined to accommodate the sapphire barrels and initiating pellets and allow them to be embedded in the IHE.

Figure 7 shows that the assembled components create an almost perfect spherical assembly, except for the thickness (0.127 mm) of the slapper cable.

In this type of assembly, each detonation wave must spread in a hemispherical fashion. To best achieve this goal, the size of the acceptor pellet is adjusted experimentally.

Several experiments were conducted using 12.7-mm-diam initiating pellets of different lengths. Figure 8 shows such an experiment as viewed by the streak camera.

Figures 9a-c show film traces of experiments using different lengths of PETN pellets to light spherical assemblies of 1.8-g/cm^3 Micronized TATB. An ideal spherically expanding detonation wave produces

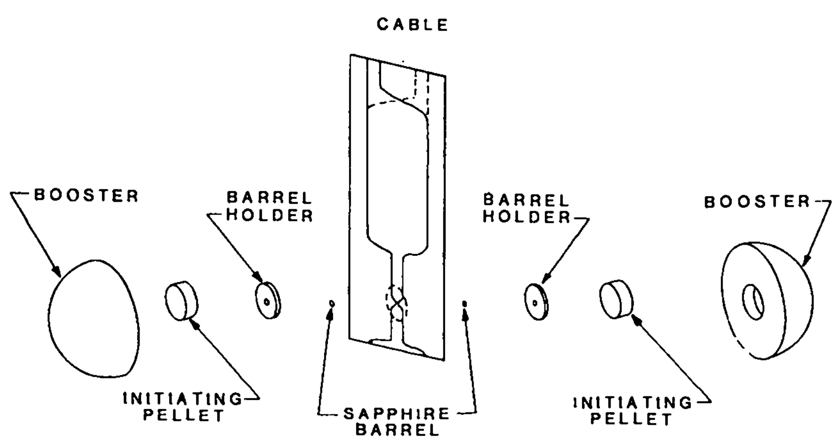

Fig. 6. Bidirectional slapper system using 1.8-g/cm^3 TATB hemispherical booster pellets.

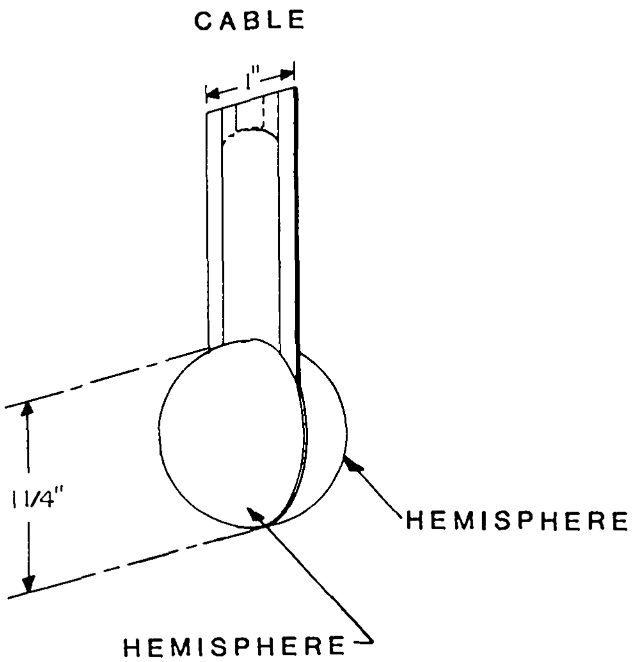

Fig. 7. Spherical assembly bidirectional slapper detonating system.

perfectly flat traces. Figure 9a shows traces of an experiment using 3-mm-long pellets. Tests have shown that the smallest 1.65-g/cm^3 PETN pellets that promptly initiate 1.8-g/cm^3 Micronized TATB at −54°C are 3 mm long by 12.7 mm in diameter. Both traces are relatively flat; except the side initiated with the glued flyer initiated approximately 0.060 μs later than the side with the unglued flyer. Figure 9b shows film traces of an experiment using 4-mm-long initiating pellets. The results are very similar to those from the experiment using 3-mm-long pellets. The side with the glued flyer is approximately 0.050 μs later than the other.

Figure 9c shows film traces of an experiment using 5.689-mm-long PETN pellets. The hemispherical pellets were machined to a depth of 6 mm, then the PETN pellets were pressed to a length that enabled both the sapphire barrels and initiating pellets to be embedded in the acceptor material to form an almost perfect spherical assembly. We obtained the best results from this experiment. The traces are very flat, with both sides firing at approximately the same time. Experiments show that initiating pellets longer than 6 mm produce very uneven waveforms in the IHE.

VII. BIDIRECTIONAL SLAPPER ASSEMBLIES WITHOUT BARRELS

Hemsing[2] has shown that the high-tolerance barrel assemblies described earlier can be replaced by a spacer, which results in fewer critical dimensions and no critical positioning. The spacers have a hole much larger than the bridge, which relieves the need for critical positioning and for high-quality barrel edges.

The spacers are also short enough that the slapper never shears from the Kapton sheet but contacts the explosive while still in the form of a bubble on the Kapton surface. The larger area apparently compensates for the slower slapper velocity caused by the shorter acceleration. In the future we plan to use this type of design in slapper type detonator assemblies.

VIII. CONCLUSIONS

We have demonstrated that a bidirectional slapper system can be built that will initiate pellets in both directions with or without barrels, and do so with small energy requirements. This kind of system will initiate IHE in both directions, at cold temperatures, and achieve good spreading when initiating Micronized TATB hemispherical pellets.

ACKNOWLEDGMENTS

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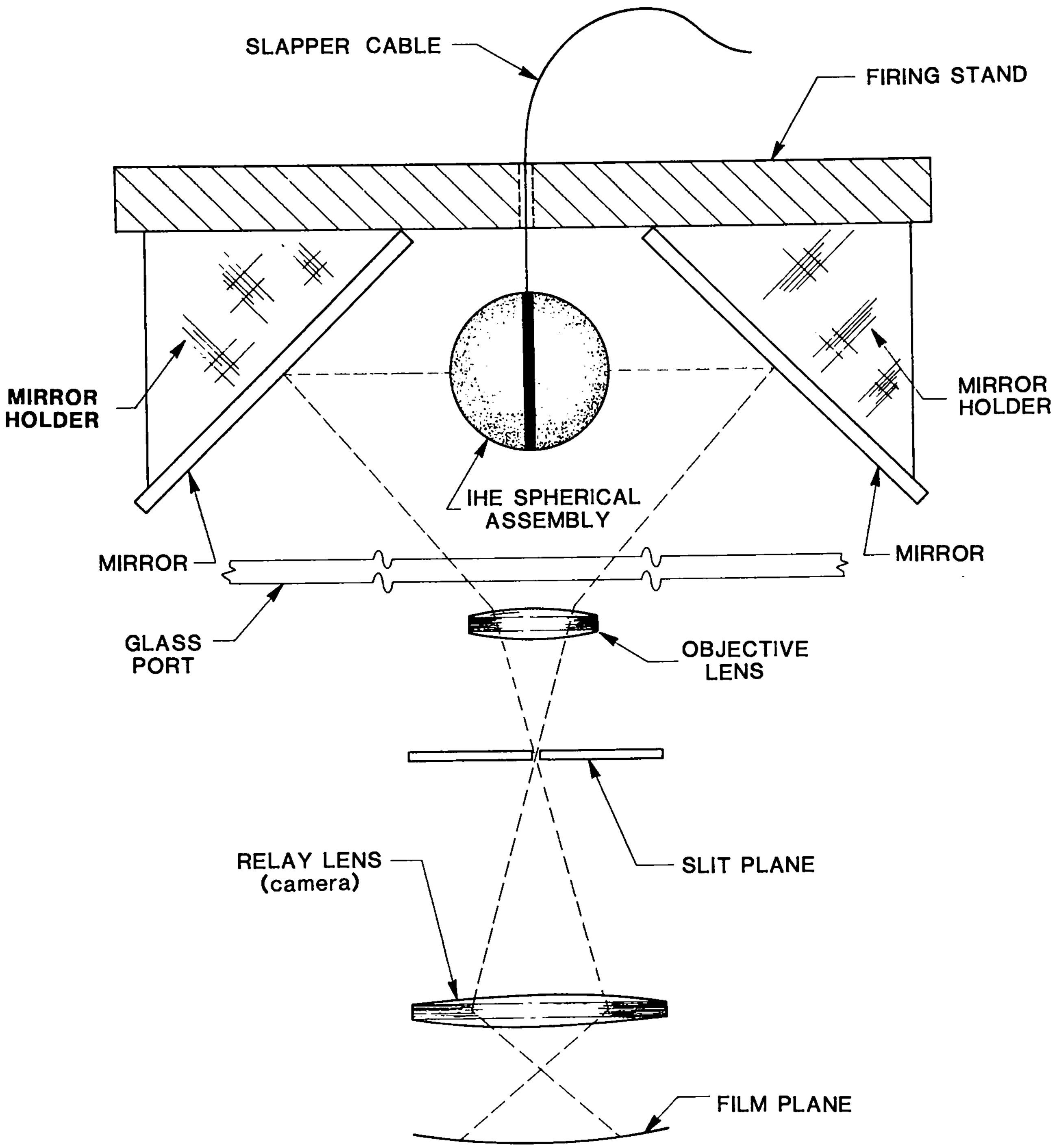

Fig. 8. Streak camera view of hemispherical assembly.

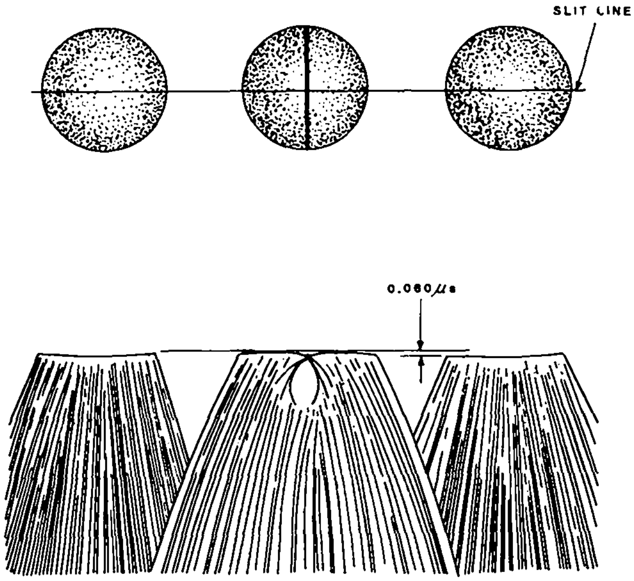

Fig. 9a. Initiating pellets 3 mm long.

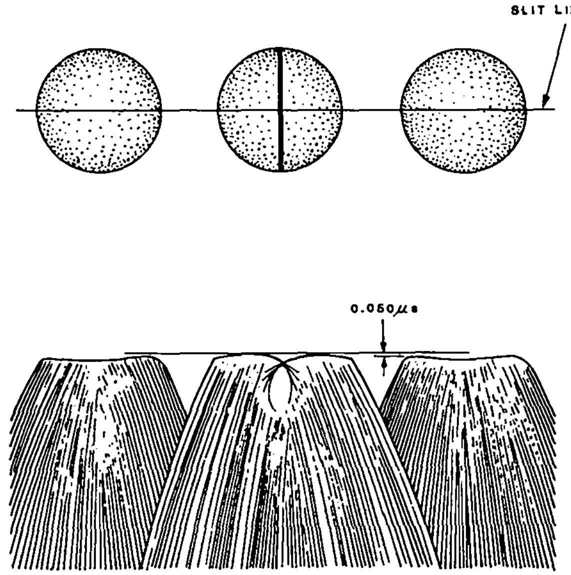

Fig. 9b. Initiating pellets 4 mm long.

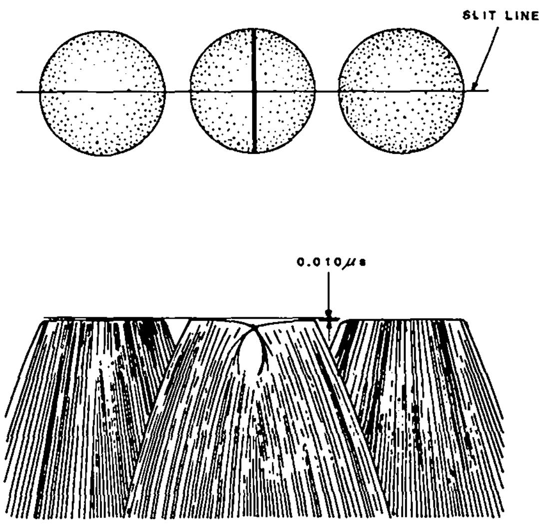

Fig. 9c. Initiating pellets 5.689 mm long.

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