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ABSTRACT

We describe the construction, operation, and characteristics of a spark chamber with a digital readout of coordinates that is unaffected by magnetic fields.

With the use of magnetostrictive readout spark chambers[1] becoming widespread, the usefulness of such devices in or near magnetic fields has become evident.

It has been shown[2] that magnetostrictive signals can be generated in high magnetic fields. We have constructed and operated a magnetostrictive chamber in a 20-kG field, in which the readout wire was inclined at ≈1 deg to the field, and the pickup was outside the magnet. The disadvantage of this approach is that it produces signals of varying size and polarity in regions of strongly varying fields, such as the fringe area of a magnet.

It is possible to construct the chamber in such a way that its wires are carried to the outside of the magnetic field and then read magnetostrictively, but this is quite cumbersome even for dealing with just one plane. Furthermore, the large inductances produced by the long wire planes tend to distort voltage and current pulses considerably.

We describe now a spark chamber in which the acoustic pulses in the transducer are generated by sparks (sparkostriction) and the readout is piezoelectric. Its characteristics are similar to the magnetostrictive ones but with the added advantage of being completely insensitive to magnetic fields.

1. Sparkostrictive Signal Generation

We have known for some time now that the shock wave of a spark on a wire will produce an acoustic pulse on it (sparkostriction)[2]. Once detected, this pulse can be processed in the same way as magnetostrictive ones[3].

2. The Transducer

The wire used is chosen for good acoustical transmission properties and low resistivity, and preferably is nonmagnetic. Although a coil together with a magnetostrictive coating (i. e., nickel) at the end of such a wire could be used to detect the acoustic pulse, such an arrangement would have to be shielded adequately from the external magnetic field, and we have decided to avoid this. For this purpose different transducers[4] have been built and have proven satisfactory.

Figure 1 shows the transducer assembly used in the chamber. We use a chip of PZT-5 crystal[5] to detect the acoustic pulse. Its dimensions are approximately 0.030×0.030 in., 0.025 in. thick, and it is glued with Eastman 910 to the aluminized plane of a 3/8-in.-diameter disc of 0.010-in. Mylar on which a 0.001-in. aluminum coat has been previously deposited. The pickup wire has a small ball formed at its end, and then is cemented to the Mylar, opposite the crystal, with epoxy. This wire is 0.007-in.-diameter Be-Cu alloy, chosen for its conductivity, elasticity, and good transmission qualities. A second Mylar washer helps to keep the ball in place. The small ball is useful both for mechanical reasons, and for avoiding high electric field gradients on the Mylar, which is necessary to isolate the piezoelectric pickup from the sensor wire. This arrangement allows for good frequency response, low ringing in the crystal, and sound mechanical properties. The aluminum is kept grounded, thus effectively shielding the pickup from potentials developed on the wire. We obtain acoustic pulses which yield an amplitude of 10 mV, as seen at the output of the transducer, a width of 0.5 μsec for sparks with peak input current of 10 A, and a total charge of 3 microcoulombs. Such a pulse, after amplification, is represented in fig. 2. We are using one of our standard magnetostrictive amplifiers with the addition of a high-impedance input stage.

3. The Chamber

We have built and operated a 6×12-in. one-gap sparkostrictive chamber with piezoelectric readout. Since we have been using aluminum planes to give the chamber transmission-line-like characteristics[6)], we find that the obvious development in this case is to use these aluminum plates to bring the wires up to potential through capacitative coupling. The gap consists of two 0.005-in. Mylar planes with 0.001-in. aluminum deposited on them, separated by 0.520-in. These planes are connected by a 50-Ω resistor, thus terminating the chamber properly. Between them, and 0.010 in. from each, there are two layers of 0.006-in. aluminum wires, 24 to the inch. These wires are insulated from the planes by the Mylar, which faces into the gap (fig. 3).

The wire planes extend away from the aluminum planes to outside the chamber's gap. The pickup wire lies on top of the wire plane, separated by a thin layer of fiberglass cloth. This cloth has a high density of holes, so that the signal spark between the chamber and pickup wire is unimpeded.

The pickup wire is backed by a 1/2-in.-wide copper sheet, but insulated from it by a 1/32-in. Lucite strip (fig. 4).

The wire is connected to the copper backing at two points: at one end (the closest to the pickup) by pressing lightly on it with a thin aluminum foil; at the far end by direct contact at the wire's anchor point. The effect of low-inductance backing and two-point contact is that it helps to keep the wire at a uniform potential.

Two fiducial wires are provided on each wire plane, before the first and after the last chamber wires. Each hv fiducial is connected to the respective ground fiducial through an RL circuit consisting of a 12-Ω resistor in series with a 20-μH inductor. The purpose of the inductor is to prevent the fiducials from drawing a large amount of current before the spark has formed. Figure 5 shows the electrical connections.

4. Mode of Operation

Referring to fig. 5, let us assume that a particle's track has intersected wires a and b. Then, upon applying a hv pulse to the aluminum planes, we produce a spark across the wire planes, which are capacitatively coupled to the aluminum planes. Wire a, originally at high voltage, is now being shunted to ground. Its potential drops and we obtain a spark from the pickup wire to it at point x_1.

Similarly, wire b is raised in potential and sparks to the ground pickup, producing a spark at x_2.

These signals, together with the fiducials, are picked up by the transducers T, amplified, and timed by the usual 20-MHz scalers.

To limit spark current, it is convenient to use a square pulse, so that the voltage on the chamber can be cut off shortly after spark formation. We have decided to pulse the chamber by discharging a 40-ft 50-Ω cable, which matches the characteristic impedance of this chamber. The pulse is represented in fig. 6.

5. Characteristics of the Chamber

a. Position Accuracy

This was measured by placing the sparkostrictive chamber between two magnetostrictive ones. Cosmic rays were used as a source of tracks. The distribution of the differences between the coordinate measured by a sparkostrictive readout plane and the intersection of the track as determined by the other chambers with that plane is given in fig. 7. The HWHM is 0.63 mm. The HWHM in the sparkostrictive readout is ±0.42 mm, after subtraction of the contribution from the magnetostrictive chambers.

b. Efficiency

For the hv pulse shape given in fig. 6, the efficiency as a function of voltage is given in fig. 8. Notice that, since each chamber wire is decoupled from the rest, and the presence of a spark does not appreciably change the potential of the aluminum planes, we expect the multispark efficiency to be higher than in conventional wire chambers.

c. Reliability

At the points where we have sparks between the chamber and pickup wires, we observe a wearing out of the wires caused by spark erosion. Although the sensor wires are easy to replace, the chamber wires are not. The fiducials get the most wear, of course, but they can easily be made replaceable.

One can increase the chamber's lifetime by displacing the pick-up wire slightly along the chamber wires to change the sparking points; but the main consideration is to minimize the spark current, thus keeping the damage to a minimum.

For a 7-kV pulse of the shape described before, we discharge a total of 3 μC into each spark.

We have measured the effect of this amount of charge on the wires, and we find that 10^5 pulses produce an average dent of about 20% of the diameter of a 0.007-in. Be-Cu wire and slightly less on the corresponding Al wire of the chamber. This, together with an increase in lifetime of a factor of 2 or 3 produced by moving the pick-up wire along the chamber wires, should give us a lifetime of 10^6 pulses for each chamber wire. For a 1-m chamber we can expect a lifetime of 10^9 pulses for a uniform spark distribution.

6. Conclusion

The sparkostrictive chamber described in this article is a powerful tool to complement magnetostrictive chambers when it becomes convenient or necessary to use these devices in magnetic fields.

ACKNOWLEDGMENTS

We express our thanks to Mr. Tom Droege and Mr. Jerry Stoker for their work in the development and testing of the sparkostrictive pickups. We are very grateful also to Mr. Budd Thompson for his work on the construction of the chamber.

FOOTNOTE AND REFERENCES

*Work done under auspices of the U. S. Atomic Energy Commission.

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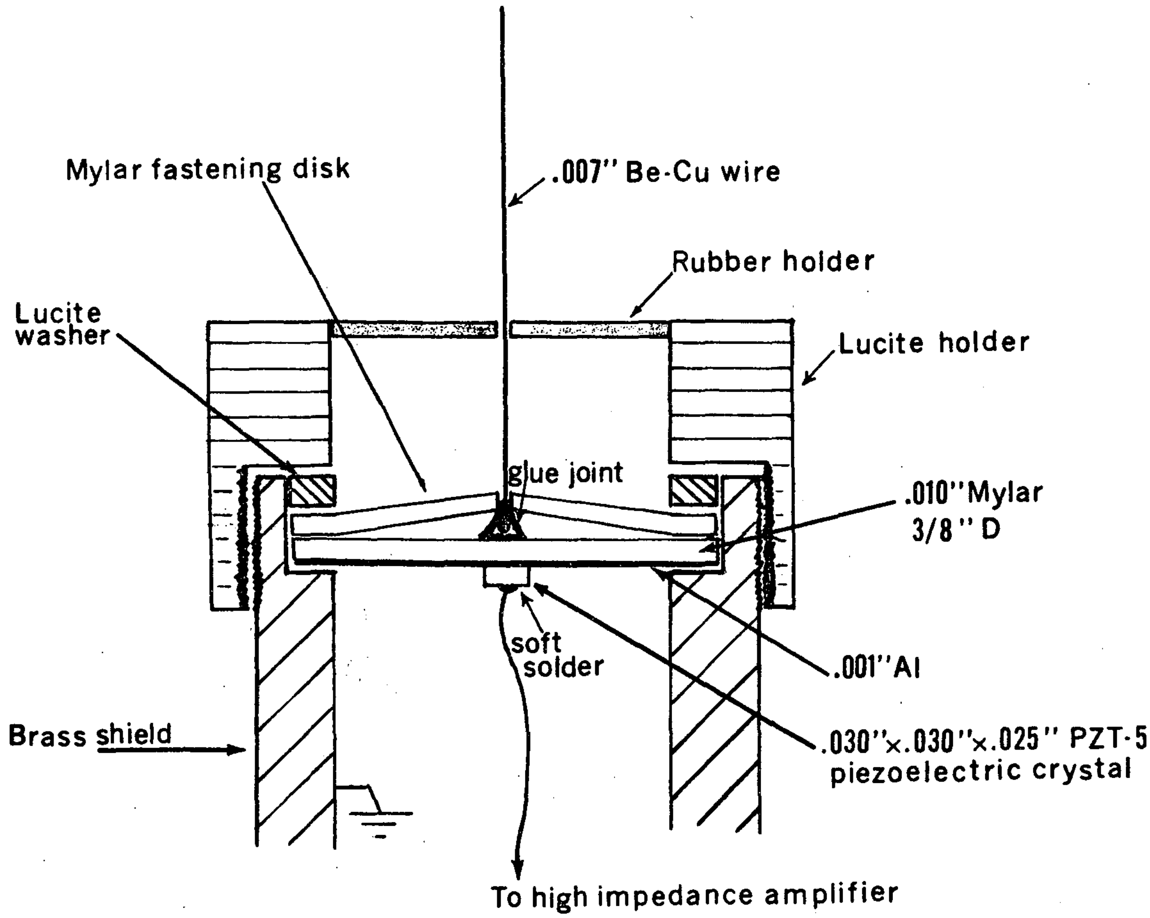

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Fig. 1. Piezoelectric pickup assembly.

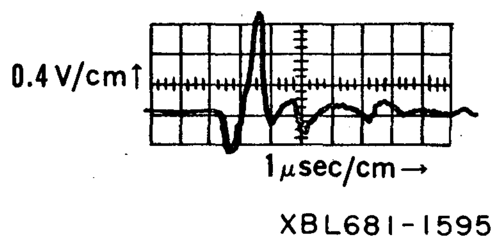

Fig. 2. Sparkostrictive Signal.

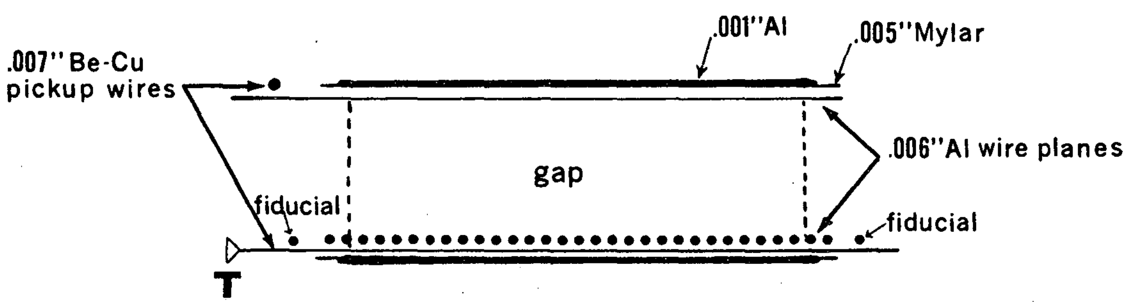

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Fig. 3. Schematic diagram of the sparkostrictive chamber.

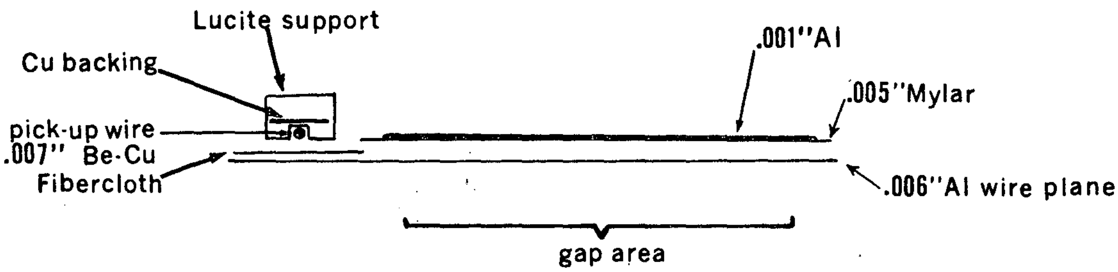

Fig.4. Sparkostrictive plane assembly.

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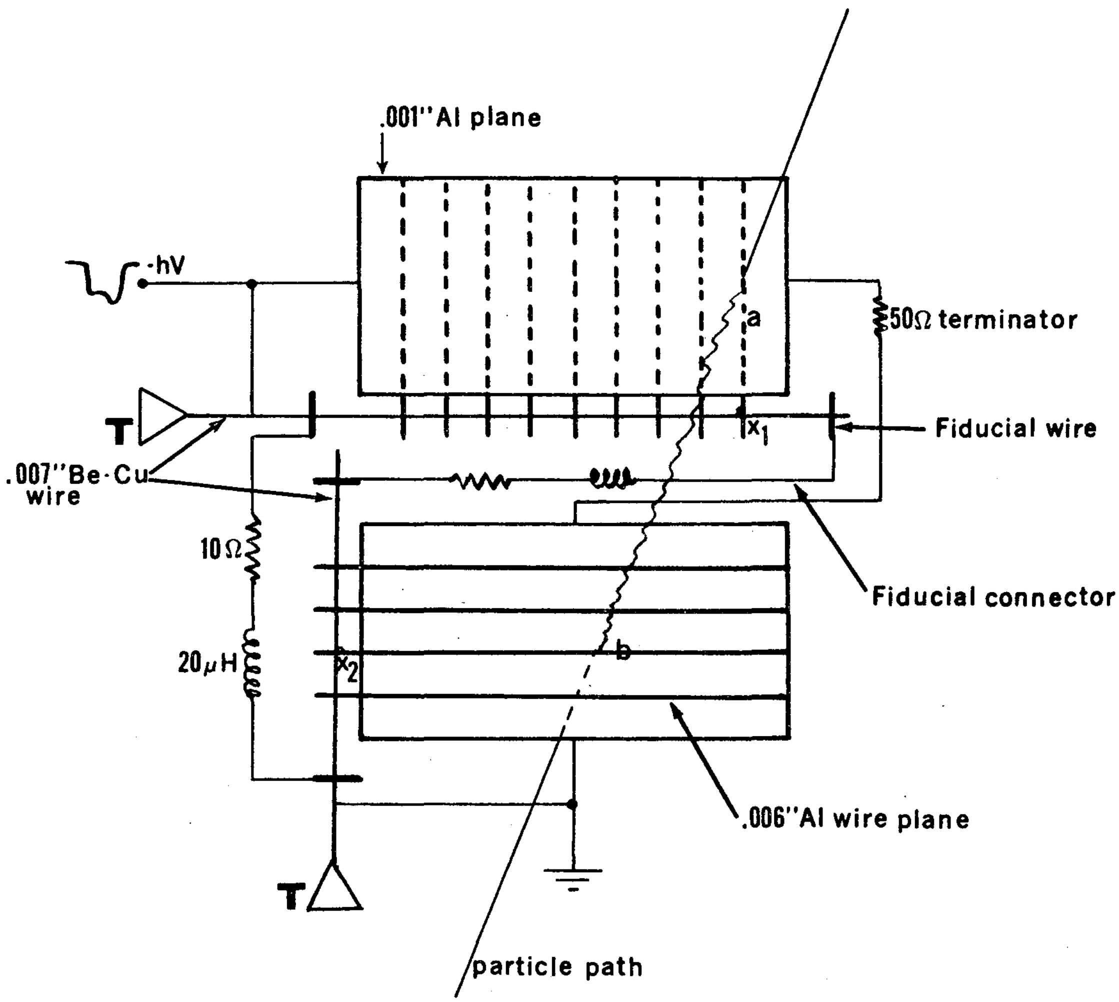

Fig. 5
Schematic diagram of the sparkostrictive chamber with electrical connections.

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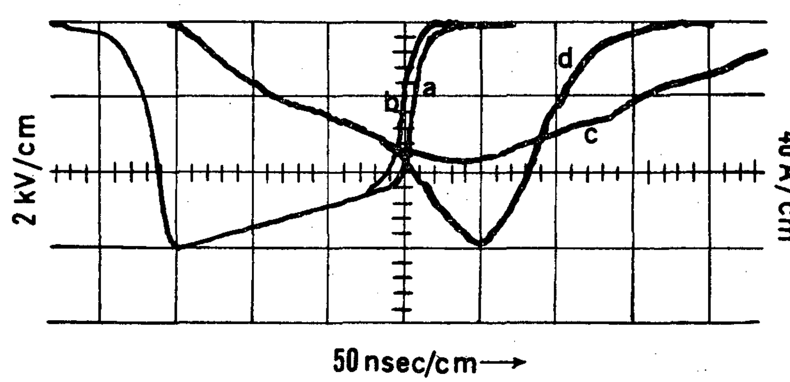

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Fig. 6. Voltage and current at sensor wire.
a: Voltage, fiducials only.
b: " , " and one spark.
c: Current, " only.
d: " , " and one spark.

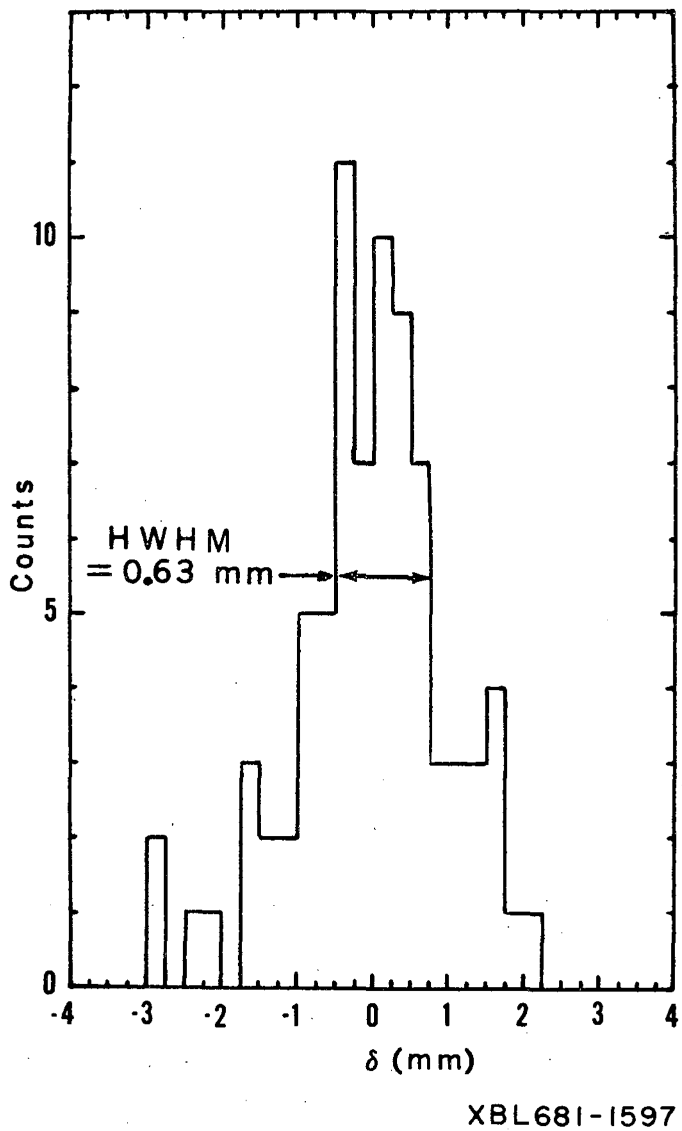

Fig. 7. Track deviation δ at the sparkostrictive chamber. The two magnetostrictive spark chambers contribute to this deviation, so that $\delta(\text{spark}) = (\delta^2 - 2\delta^2_{\text{mag}})^{1/2} = (0.63^2 - 2 \times 0.33^2)^{1/2}\text{mm}$

$= 0.42$ mm.

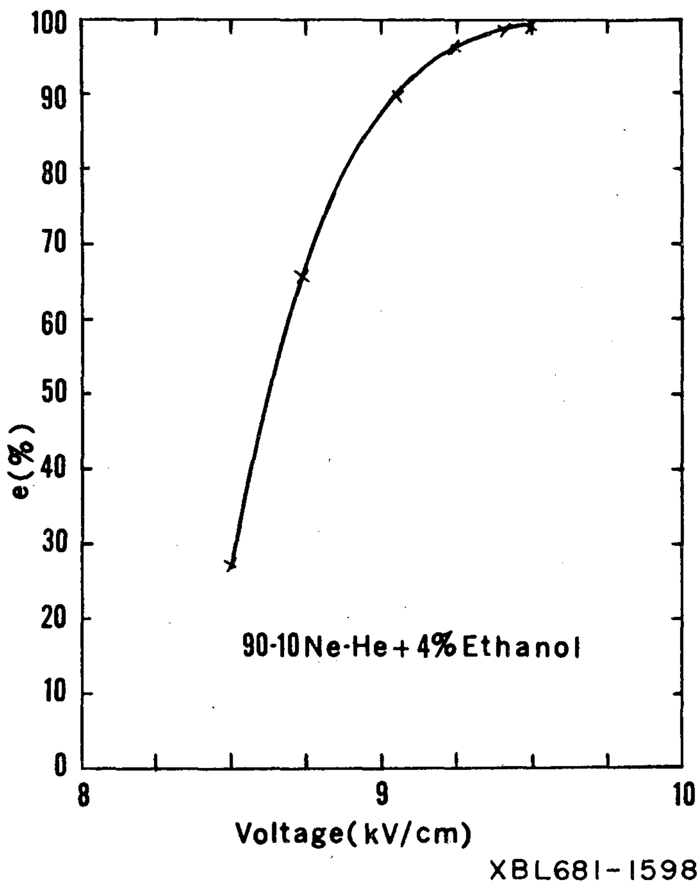

Fig. 8. Efficiency vs. applied voltage.