Performance of a spiralled continuous electron multiplier in a magnetic field

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The gain and detection efficiency of a spiralled electron multiplier (Spiraltron) have been measured in a magnetic field. Results are presented as a function of field strength and angle between the field and detector. The multiplier is useful in fields as high as 900 G, considerably higher than the limit that has been obtained on a Channeltron curved electron multiplier.

The channel electron multiplier, a compact and rugged particle detector usable with positrons, electrons, ions, energetic neutrals, and high-energy photons, is limited in its ability to work in magnetic fields above 300 G.[1,2] Work by Hashimoto and Hayashi,[3] however, showed that a field parallel to the channel allowed operation in higher fields, and thus it appeared that the straight-line geometry of the spiralled continuous electron multiplier (SEM) might allow operation in magnetic fields into the kilogauss range. The SEM used, Galileo Electro-Optics model 4219,[4] consists of a collection cone 10 mm in diameter, a single channel preamplifier section about 2 cm long, followed by a spiralled amplifier, also 2 cm long, consisting of six capillary channels twisted together. The SEM was rigidly mounted in a brass can evacuated to 5×10^{-6} Torr. Positioned on the outside of the chamber was a 1.4-mCi ^{58}Co source which supplied γ-rays to be counted by the detector. By counting the neutral γ-rays the flux incident on the cone was unaffected by the applied magnetic field. The assembly could be rotated between the 15-cm-diam poles of an electromagnet without changing the relative position of source and detector. The 2-terminal mode of operation was used with the maximum operating voltage of 5.5 kV.

The signal pulses were amplified by an Ortec 113 preamplifier and 485 amplifier, then accumulated in a Nuclear Data 2400 multichannel pulse height analyzer.

A continuous channel electron multiplier consists of a thin glass capillary tube with resistive secondary electron emitting walls. An energetic particle striking the cone will cause the emission of several secondary electrons which will be accelerated into and down the tube by the axial electric field set up by the 5.5-kV potential difference across the SEM. These electrons will strike the wall farther down the tube because of their initial velocity component perpendicular to the walls. Further secondaries will be emitted, eventually resulting in a cascade which is terminated either by the end of the tube or by gain saturation.

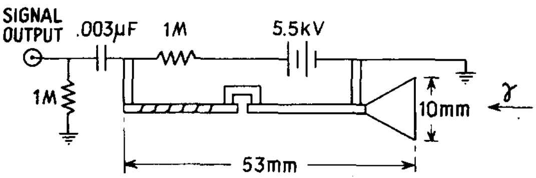

FIG. 1. Electrical connections to SEM.

The distribution of pulse amplitudes from an SEM depends on the applied potential difference, the primary particle, and the age of the device (presumably due to changes in the secondary emitting surface). We set the threshold for particle counting at approximately 1 mV as measured at the output of the circuit of Fig. 1. As the magnetic field was increased the number of pulses above threshold dropped and the pulse amplitude distribution changed. Figure 2 shows the normalized number of pulses above threshold (relative detection efficiency) as a function of magnetic field, while Fig. 3 shows the pulse amplitude distribution at various magnetic field strengths.

The reduction in detection efficiency and overall drop in mean pulse amplitude may be explained by noting that a magnetic field applied along the axis of the capillary tube will cause the secondary electrons to execute helical motion down the tube. When the cyclotron radius is comparable to the tube radius a secondary electron will be deflected back to the tube wall before it has been accelerated to a sufficient

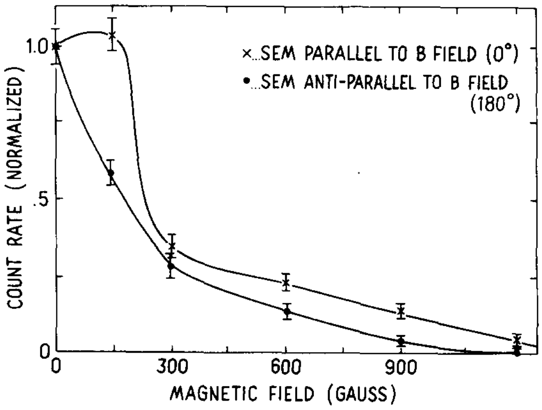

FIG. 2. Count rate as a function of field strength for the SEM at 0° (parallel) and 180° (antiparallel) to the field.

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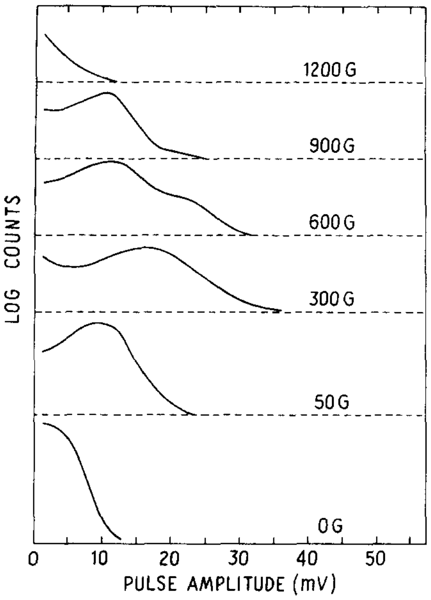


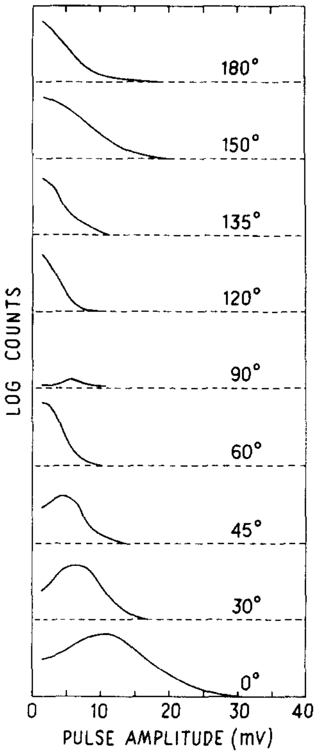
FIG. 3. Differential pulse amplitude distributions for various magnetic fields. The SEM is parallel to the field.

energy to be an efficient producer of additional secondaries. As the SEM consists of both the relatively large diameter preamplifier section and the smaller, twisted, amplifier tubes, the changes in the pulse amplitude distributions are complex.

The SEM was rotated to several angles with respect to the applied field. The spectra shown in Fig. 4 were taken at 800 G. Both mean pulse amplitude and detection efficiency dropped steadily as the angle increased to 90°, then increased again as the angle approached 180°. However, they peaked near 150°, rather than 180°. For lower fields the mean pulse amplitude and detection efficiency also were larger at 150° than at 180°.

It is clear that the SEM retains both pulse amplitude and detection efficiency in magnetic fields significantly stronger than those in which the original C and helically shaped channel electron multipliers are useful. If 10% detection efficiency is considered the minimum acceptable level, then the SEM is useable in parallel fields (0°) up to 900 G and in antiparallel fields (180°) to 700 G. These results illustrate the definite advantage the SEM has over other continuous channel electron multipliers in counting individual particles in a magnetic field.

FIG. 4. Differential pulse amplitude distributions as a function of angle at 800 G.



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