**Principles of Operation**

An **electron multiplier** is a vacuum-tube structure with a window that multiplies incident charges. In a process called secondary electron emission phenomenon, a single electron passing through the window, when bombarded on the secondary emissive material on the wall of the vacuum tube, induces emission of roughly 1 to 3 electrons. If an electric potential is applied between this metal plate and yet another, the emitted electrons will accelerate to the next metal plate and induce secondary emission of still more electrons. This can be repeated a number of times, resulting in a large shower of electrons all collected by a metal anode, all having been triggered by just one electron.

The avalanche can be triggered by any charged particle hitting the starting electrode with sufficient energy to cause secondary emission. It could also be triggered by a photon causing vacuum photoemission of at least one electron. In a photomultiplier tube, a photo-emissive surface is followed by an electron multiplier with several sequential multiplying electrodes called dynodes. Because these electrodes are separate from each other, this might be called a "discrete-dynode" multiplier. A voltage divider chain of resistors is used to place each dynode at a potential 100-200V more positive than the previous one.

A "continuous-dynode" structure is feasible if the material of the electrodes has a high resistance so that the functions of secondary-emission and voltage-division are merged. This is often built as a funnel of glass coated inside with a thin film of semi-conducting material, with negative high voltage applied at the wider input end, and positive voltage near ground applied at the narrower output end. Electrons emitted at any point are accelerated a modest distance down the funnel before impacting the surface, perhaps on the opposite side of the funnel. At the destination end a separate electrode (anode) remains necessary to collect the multiplied electrons. This structure is also known as a continuous electron multiplier.

Channel electron multipliers (CEMs or Channeltrons) are continuous windowless electron multipliers, i.e., not enclosed in vacuum tube, which respond to the charged particles, hard and soft X-rays, and ultraviolet radiation. It has a high surface resistance which forms a continuous dynode when potential is applied between the input and output end. The dynode emits secondary electrons and through this process makes CEM capable of detecting a particle or photon. The primary particles, entered in its funnel-shaped input aperture, generate secondary electrons that are accelerated down the channel by a positive bias. Upon striking the interior surface of the channel walls, these electrons keep generating secondary electrons. The resulting avalanche process produces an output pulse of charge containing up to $10^8$ electrons with duration (FWHM) of about 8 nanoseconds.

This enables the detection of over 5 million particles per second with the standard type CEMs and over 15 million particles per second with the extended dynamic range types. Due to the very low dark count rate of $< 0.02$ cps, which is caused by cosmic rays, the dynamic range for measurements is greater than 8 orders of magnitude.

The output pulses can be detected easily by using a preamplifier and a constant fraction discriminator to generate a NIM standard timing pulse. The standard CEMs are capable of detecting over 5 million particles per second.

The adjacent figure shows a cut view of a CEM (KBL210). The ceramic forms the structure and the black lead glass a continuous dynode with a secondary electron emitting surface. The electron avalanche that is generated by a primary particle follows the channel to the positively charged end and is collected by an anode. The curvature of the channel is necessary to prevent ion feedback caused by the high electron density at the end of the channel. In a straight channel, ions pick up too much kinetic energy and generate additional secondary electrons causing unstable operation of the CEM.

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The CEMs consist of three components:
A supporting body of ceramic material.
A specially formulated lead silicate glass inside the supporting body.
A metalization of gold or silver deposited onto both ends of the CEM.

The special ceramic material is chosen for its ability to maintain the lead glass under a compressive force thus preventing the appearance of fine cracks that may result from sudden fluctuations in temperature. The ceramic material is first processed and then sintered. Both halves and the funnel of the circular models are fused together without the use of adhesives. The procedure is followed by the final processing of the ceramic body. The colored glaze is necessary as a base for the gold layer, that is used for the electrical contacts.

The lead glass is hydrogen-reduced thereby producing the active surface of the CEM and the secondary emissive characteristics critical to CEM performance. The lead glass is coated on the entire surface of the inner wall so that a continuous dynode is formed.

In addition, the electrical contacts are applied on both sides of the CEM bodies.

**Characteristics of Standard CEM ----- KBL25RS (25mm)**

Typical gain at 2.3 kV applied voltage = $1 \times 10^8$

Typical wall resistance = 200 mho

Pulse height distribution at 2.6 kV and 3,000 cps = < 50%

Dark count rate above a threshold of - 5 mV = < 0.02 cps

(The dark count rates depend on the CEM opening and are minimum for smaller openings.)

Maximum Count Rate = 5 Mio cps

Typical Pulse Width (FWHM) at 2.3 kV = 8 nsec

Operating Voltage = 3.5 kV (max)

Temperature (operating & storage) = 70 °C (max)

Bake temperature in vacuum = 250 °C (max)

Fig. 1 – 6 show typical data plots of the CEM measured in our lab.