Beam Profile Monitor Incorporating Very Large Area Electron Generator Arrays

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Introduction:

The precise determination of transverse beam profiles in accelerator and collider systems is critical to proper operation. The high energy physics community has long sought a capability to determine location and focus of charged particle beams racing through accelerator tubes. Imaging a charged particle beam traveling at speeds approaching the speed of light without changing the velocity or focus has proven to be a challenging task.

One approach known as an Ionization Profile Monitor uses free electrons and ions produced as the bunches collide with light element residual gas molecules. The resultant ions and electrons can be laterally swept away and the resultant signals used to determine the beam profile.[1]

Whenever scientists have had difficulty measuring small or fast events, they often find the answers lie in observing the things around the event of interest which can be observed. This approach is used by astrophysists to determine the location of black holes by observing the gravitational effects on nearby stars.

A similar approach for imaging high velocity charged particle beams may also prove useful.

Microchannel Plates:

Microchannel plates (MCPs) are solid state detectors consisting of parallel arrays of tiny, single channel electron multipliers fused together in a parallel array. Channel densities are typically 1 – 10 million channels per cm^2 (Figure 1). These devices can be used to detect ions, electrons, UV photons, and soft and hard X-rays.

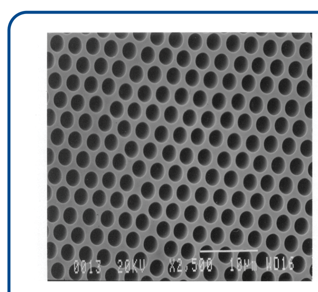

Figure 1: *Photomicrograph of 2 micron pore microchannels.*

Microchannel plates are extremely fast devices with rise times of less than 100 ps. In addition, they can be made with pore sizes as small as 2 microns producing high spatial and temporal resolution.

In operation, an input event (ion, electron, photon etc…) impinging on the focal plane will trigger an avalanche of electrons resulting in an amplification factor of up to 100,000. Cascading a second or third array can result in an amplification factor of up to 100,000,000 with less than 1 count/sec/cm^2 added noise. (Figure 2)

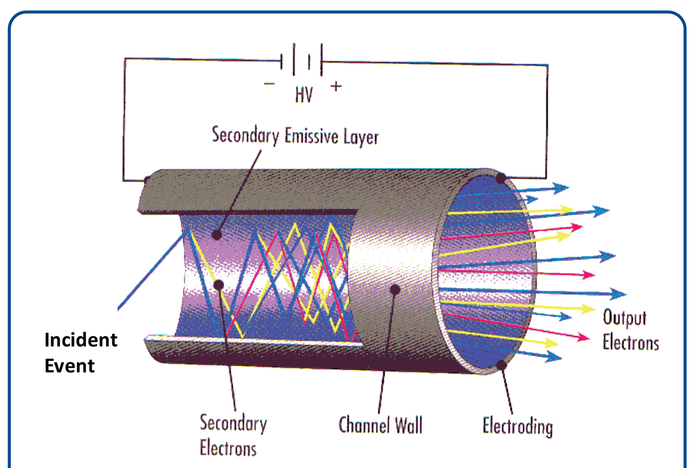

Figure 2: *Multiplication Process.*

Approach:

The PHOTONIS charged particle beam imager is a two part system:

The first part consists of a large area Electrogen™ Electron Generator Array (EGA). The emission array can be constructed from mosaic panels which are 80 X100 mm (each), typically 240 X 100 mm in the final configuration.

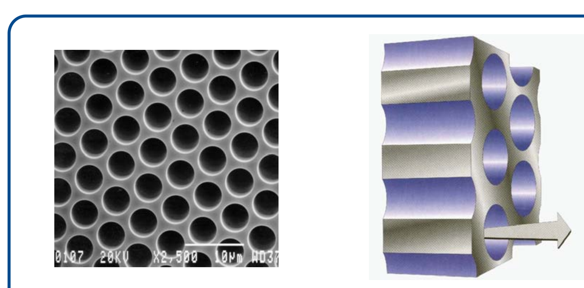

Figure 3: *Beam Emission.*

- An Electron Generator Array is a specially processed microchannel structure which emits an Electron Beam from each channel when a voltage is applied across the array. (Figure 3)
- The emission current can be modulated by simply changing the voltage across the array.
- Unlike filament-based devices, the EGA produces no heat.
- Electron Generator Arrays (EGAs) can be fabricated in various sizes and shapes with seamless active dimensions ranging from 3 to 150 mms.
- Very large arrays can be fabricated by tiling large rectangular arrays together. (Figure 4)

Figure 4: *Twin 100 X 240mm EGA Arrays used in Image Intensifier Scrub Station continuously operated for over 3 years.*

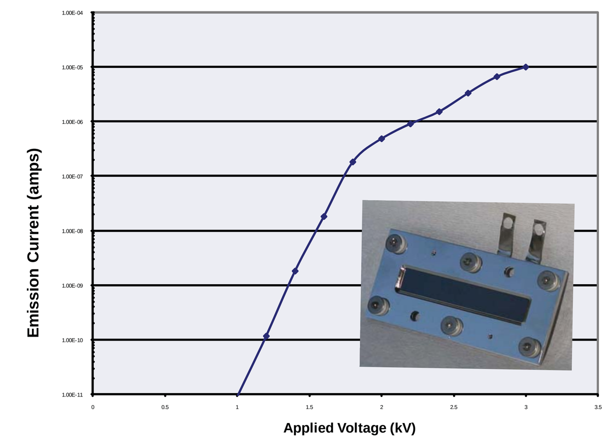

Figure 5: *The emission current of the EGA can be modulated by adjusting the array voltage. Data shown is for a 50 X 8 mm array (inset).*

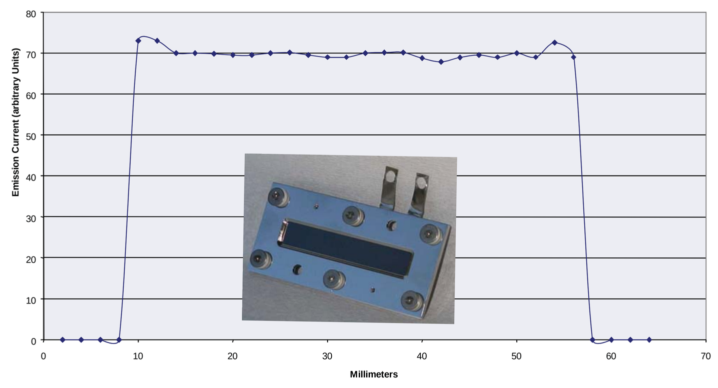

Figure 6: Uniformity of Emission Current. *Emission current uniformity from an EGA is typically better than 10% (without edge effects). Data is taken from a 50 X 8 mm Array (shown, inset).*

Approach, continued:

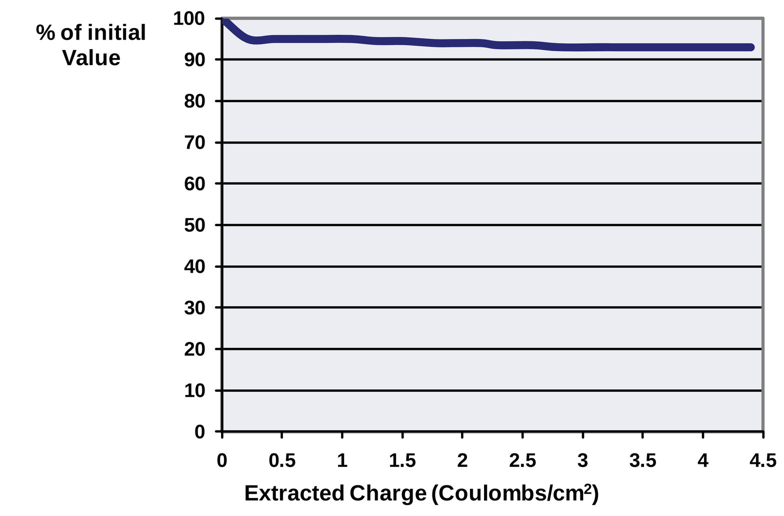

Figure 7: Electrogen™ EGA Stability. *Following proper degassing, EGA emission current is stable over prolonged periods of time with large amounts of extracted charge.*

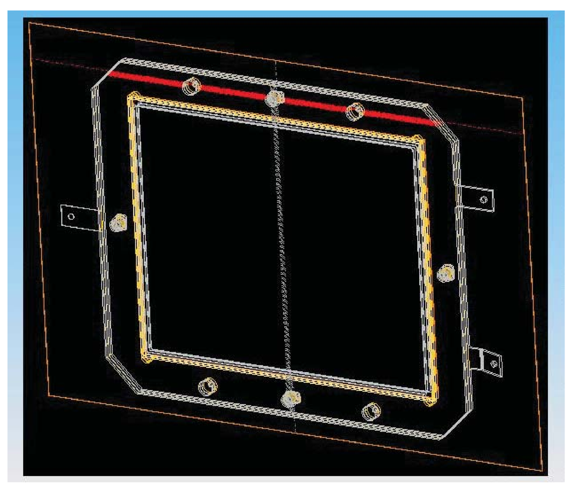

Figure 8: *Twin EGA array 160 X 100 mm.*

Electrogen™ Electron Generator Array Advantages Over Filament Based Sources:

- Uniform, high density electron flux
- "Cold" electron source
- Large emission area (150 mm dia.) Tiling extends area (Figure 4)
- Millions of parallel electron beams
- Not sensitive to field strength changes
- Fine emission level control
- Won't burn out, durable
- Excellent stability
- No photon noise
- Maximum bake temperature 300 °C
- Maximum operating temperature 200 ºC

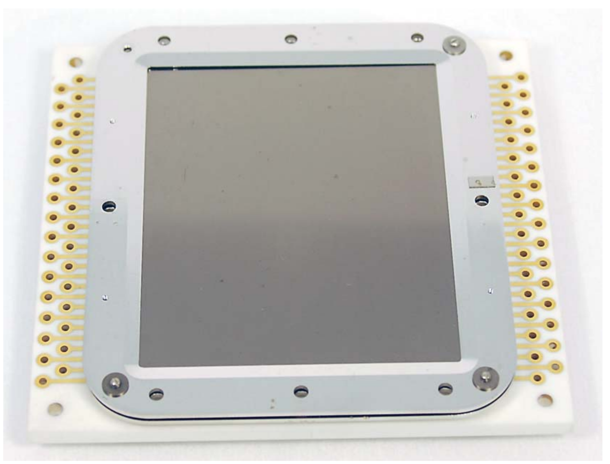

Figure 9: *Micochannel plate with anode array.*

The second part of the imager consists of a large area matching microchannel plate assembly which can be run in the analog or pulse counting mode, producing an amplification factor of 10^7 with readout.

The readout can be a fast phosphor screen with CCD/frame grabber, or a segmented anode array, or two dimensional readouts such as the cross wire or wedge and strip anode array. (Figures 10 and 11.)

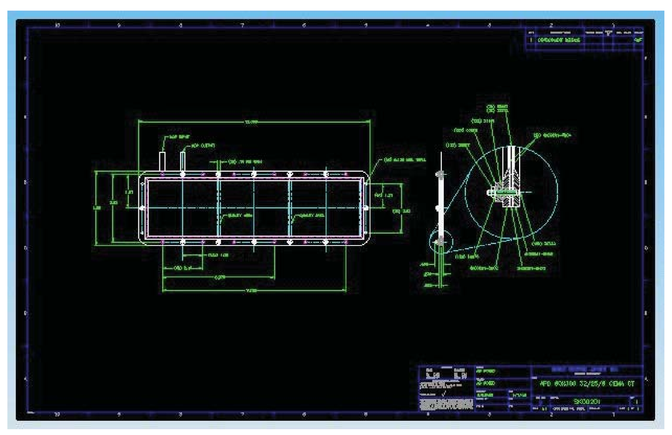

Figure 10: *240 X 100 mm microchannel plate Imaging Array.*

Figure 11: Microchannel plate detector. *Positively biased MCP panels detect beam arrival and departure; capture beam position and profile. 160 X 100 mm EGA Array shown.*

In operation (Figure 12), voltage is applied to the EGA (Figures 8 and 9) creating a high density shower of relatively low energy electrons. The flux rate is modulated by increasing the voltage across the array. The resultant electrons are accelerated to and amplified by the matching microchannel plate assembly and readout.

As the charged particle beam travels through the electron shower, it will cast an electron shadow on the microchannel plate. The width of the shadow and the timing information at arrival and departure provide critical information about the positioning and speed of the beam.

Electron generator arrays and microchannel plates are UHV compatible and can be custom designed for each beam line application.

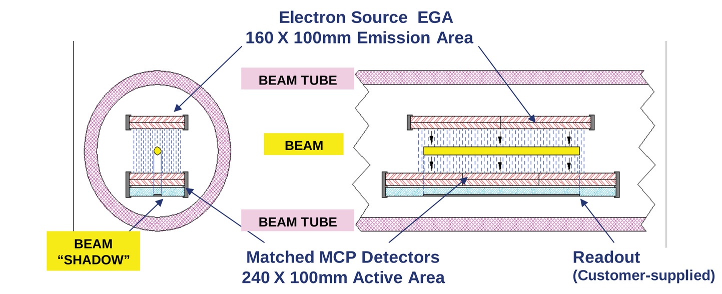

Figure 12: Contact of Beam with Electron Shower Causes "Shadow" Detected by MCP Plates. *No Effect on Beam Speed or Energy.*

Summary:

- A very large area beam profiler tool has been designed which combines a novel cold electron source and microchannel plate imager.
- Shadows cast during beam passing through the electron shower produce information about beam focus and timing.
- The profiler can be made in very large arrays by tiling rectangular devices together.
- All materials used in the profiler are UHV compatible.

Reference:

1 R. Connolly, et al, *Beam Profile Measurements on RHIC*, 2000 Beam Instrumentation Workshop.