Microchannel Plate Cross-Strip Detectors with High Spatial and Temporal Resolution

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Microchannel Plate Sensor

- Photocathode converts photon to electron
- MCP(s) amplify electron by $10^4$ to $10^7$
- Rear field accelerates electrons to anode
- Patterned anode measures charge centroid - Or pixel type device
**Microchannel Plate Detectors**

There are many MCP detector schemes each with specific advantages /limitations. General scheme is photon conversion (photocathode) or direct detection (ions/e⁻), 2 or 3 MCPs to provide gain, and then some type of readout.

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**Photocathodes**
- Alkali halides
- Multialkali
- GaAs, GaN

**Microchannel plates**
- Glass
- Ceramic - lithographic

**Readouts**
- Delay line
- Cross strip
- ASIC/APS

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22mm Cross Strip sealed tube detector design concept
Microchannel Plate Sensor Applications

Biological lifetime fluorescence imaging

Neutron imaging
Cd mask image, NIST NCNR

UV Astronomy (GALEX)

High time resolution Astronomy - Crab pulsar

33ms period, 250µs resolution
1m Lick observatory telescope

Fluorescent dye decay time

6.5mm wide star, 6Å neutrons

530 DF 30

M101)
Cross strip is a multi-layer cross finger layout. Fingers have ~0.5mm period on ceramic. Charge spread over 3-5 strips per axis. Event position is derived from charge centroid. Can encode multiple simultaneous non overlapping events. Fast event propagation (few ns).

Anodes up to 45 x 45mm have been made. Signals go to backside by hermetic vias. Electronic packaging can be compact. Processing speed supports >> MHz rates. Compact and robust (700°C).
Cross Strip Anode Designs

45mm square Cross Strip Anode with 0.6mm finger period.

22mm round cross strip showing vias and connector
Prior system event rate limited by serial output ASICs and serial ADC conversion.
Now using fast (40ns) parallel RD20 ASICs & ADCs. Timing produced by MCP output, remains <100ps.
FPGA does charge measurement, corrections and position centroids, event rates of \( \geq \)MHz expected.
Non overlapping events could also be processed nearly simultaneously to push up rates by >3x.
Time tagging of events to \(~1\)ns is achieved with signal digitization and FIR filter techniques.
Cross Strip Electronics, RD20 Amplifier Board

RD20 64 channel ASIC boards plugged into 45 x 45mm Cross strip anode X and Y on 40mm MCP detector
64 Channel 60MHz ADC module coupled to the Xilinx Virtex 5 FPGA board for amplifier signal digitization and subsequent signal conditioning and centroid calculation.
The shape of the RD20 pre-amplified signal digitized. Various different levels of input charge shown.

Measured charge (empty markers) and noise (filled markers) as a function of signal amplitude.

ADC sampling of the RD20 pulse is processed with an FIR filter to give total charge value on each strip and the time of arrival of the pulse.
Image tests with 32mm XS lab detector

Shows charge on each strip

Shows Amplified Signal shape

Image display
Charge Cloud Size, RD20 Gain Calibration

Stimulation of RD20 amplifier channels to correct for gain variations.

Single MCP event charge spread, MCP pair, 6µm pore, 200v bias over 2.5mm.

Single MCP event charge spread, MCP pair, 6µm pore, 800v bias over 2.5mm.
Stimulation Tests of Electronics

Linearity of the RD20 amplified signal measured v.s. input levels.

Position error of final centroid for discrete charge input values. FWHM improves from <20μm at 7 x 10^4 to <5μm at 3 x 10^5.

Pulser stimulation of the anode allows gain non-linearities, offset pedestal and channel variations to be corrected in software / firmware. Electronics resolution is good (5μm at 3 x 10^5).
32mm XS MCP Detector Test Data
Histogram images of 10μm pinhole using 10μm pore MCP

Pinhole separation 2mm  Resolution as a function of gain
2D tests with 32mm XS lab detector

Spatial resolution as a function of MCP gain for the 32 mm XS detector with 10 μm MCP pores measured using 10 μm pinhole images.

Each pinhole image depends on the position of the pinhole over the pore pattern, so some (below) straddle several pores giving double images.

Spatial resolution as a function of MCP gain for the 32 mm XS detector with 10 μm MCP pores measured using 10 μm pinhole images.
Cross Strip MCP Detector Imaging

Air force mask on 6µm pore MCP pair with cross strip readout

Image of 7µm pore MCP pair at 10⁶ gain

Spatial resolution <5µm for gain 5x10⁵ for ~500e⁻ noise, 10 bit charge/strip digitization

Previous slow amp system
**Event timing resolution**

The time of each event can be registered several ways:
- Time to digital interval times from the back of the MCP
- Digitization and digital filtering of the RD20 signals directly

- Signal e⁻

Pulse generator pulses amplified by the RD20 board, digitized and peak times determined with FIR filter algorithm.

Time jitter measurement for a 25mm MCP detector using a fast amp and TDC on the MCP output, 80ps laser input.
**Cross Strip MCP Sensor Prospects**

- Various sealed tube cross strip detectors for time stamped imaging for biology (eg. FLIM), ground based astronomy (imaging photometry, polarimetry), LIDAR, future space borne imaging and spectroscopy (SFO, USO).
- Open face detectors for UV imaging/spectroscopy, ion/electron imaging (time of flight imaging spectroscopy) & neutron imaging.
- Cross strip anodes with 22mm to >100mm formats of any shape
- Single event processing electronics with >1 MHz rates and <10mm resolution at low gains (<5 x 10^5) providing high local rates and longer overall lifetimes.
- Multiple closely spaced event handing with digital pileup processing to achieve >5 MHz rates.

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