

Capacitively coupled pickup in MCP-based photodetectors using a conductive metallic anode

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We have designed and tested a robust $20 \times 20 \text{ cm}^2$ thin metal film internal anode capacitively coupled to an external array of signal pads or micro-strips for use in fast microchannel plate photodetectors. The internal anode, in this case a 10nm-thick NiCr film deposited on a 96% pure Al_2O_3 3mm-thick ceramic plate and connected to HV ground, provides the return path for the electron cascade charge. The multi-channel pickup array consists of a printed-circuit card or glass plate with metal signal pickups on one side and the signal ground plane on the other. The pickup can be put in close proximity to the bottom outer surface of the sealed photodetector, with no electrical connections through the photodetector hermetic vacuum package other than a single ground connection to the internal anode. Two pickup patterns were tested using a small commercial MCP-PMT as the signal source: 1) parallel 50Ω 25-cm-long micro-strips with an analog bandwidth of 1.5 GHz, and 2) a $20 \times 20 \text{ cm}^2$ array of 2-dimensional square ‘pads’ with sides of 1.27 cm or 2.54 cm. The rise-time of the fast input pulse is maintained for both pickup patterns. For the pad pattern, we observe 80% of the directly coupled amplitude. For the strip pattern we measure 34% of the directly coupled amplitude on the central strip of a broadened signal.

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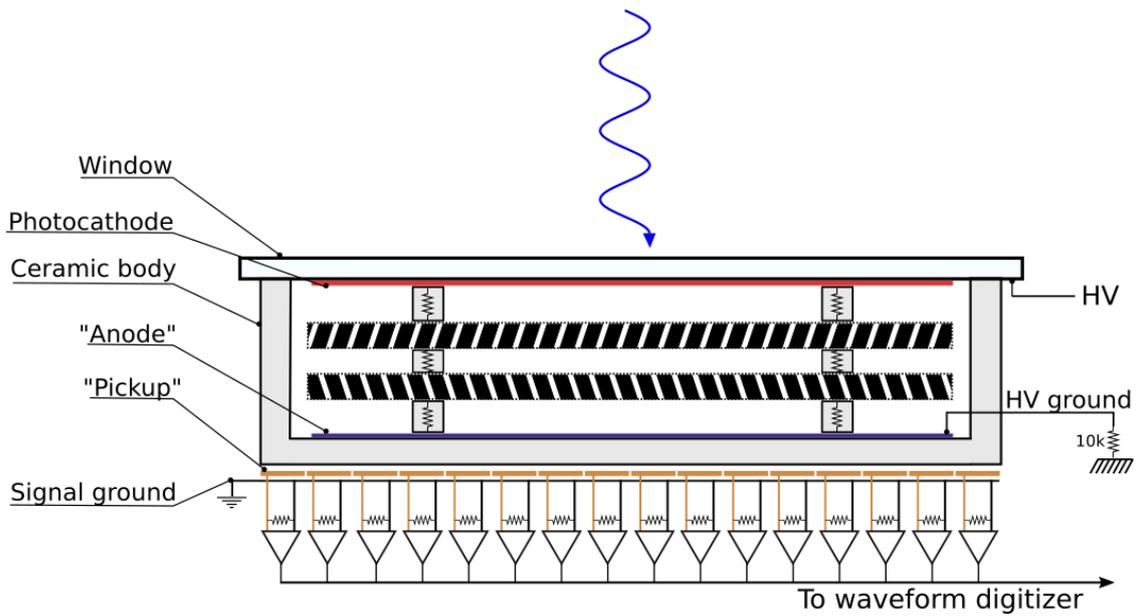


Figure 1: The structure of the MCP-PMT with the capacitive coupling readout. The internal anode is a 10-nm-thick NiCr film, grounded through 2-10 k Ω through a single connection from inside the vacuum package. The array of application-specific signal pickup electrodes outside of the vacuum package couples capacitively to the fast signal current in the thin metal anode film, and is measured across 50 Ω relative to the signal ground at the digitization readout .

1. Introduction

Microchannel-plate photomultipliers (MCP-PMT) are specialized vacuum photodetectors typically consisting of a photocathode, an amplification section consisting of several planes of glass micropores, and a segmented anode from which the amplified pulses are detected [1]. A hermetic package provides internal vacuum, mechanical support, and electrical connections. The photocathode is typically on the inside face of the top window; the anode electrodes are integrated into the bottom plate of the package.

In a capacitively coupled configuration, shown in Fig. 1, the charge shower from the MCP amplification section induces a current in a metallic anode deposited on the bottom plate of the detector package. The signal pickup consists of an array of conductors and a signal ground. The pickup electrodes capacitively couple to currents on the internal anode, producing a signal relative to the signal ground.

Traditionally, the anode readout pattern is sealed in the vacuum packaging of the photodetector, and cannot be modified after fabrication. In contrast, the capacitively coupled readout pattern is separate from the detector, mounted outside of the MCP-PMT vacuum packaging. The signal pickup can then be optimized for different applications with different requirements on time resolution, spatial resolution, and channel occupancy. The photodetector module and capacitive pickup board can be manufactured independently.

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Capacitively coupled MCP-PMT anodes have been successfully demonstrated using resistive thick films or semi-conductors [2, 3, 4, 5, 6], and MCP-PMTs using them are commercially available [4, 7]. Here we demonstrate that a thin metal layer can also transmit the high-frequency components of the fast pulses from an MCP-PMT to an external array of electrodes.

The development and testing of the metal-film capacitively coupled anode has been done in the context of the commercial development of $20 \times 20 \text{ cm}^2$ MCP-PMTs [8] following the R&D of the LAPPD Collaboration [9]. Metal film deposition is widely available commercially, and making a uniform metal anode on the interior of an LAPPDTM module has proved to be much easier than silk-screening and firing a resistive film.

1.1 Ceramic/NiCr Anode Plane and Photodetector Package

The test anode was constructed by evaporating a 10-nm-Nichrome (NiCr) [10] film onto a 3-mm-thick alumina-ceramic substrate [11]. In an operational MCP-PMT the ceramic substrate acts as the bottom layer of the hermetic package, with the anode on the inner surface. The NiCr film of the anode has a sheet resistance of $\sim 100\Omega$ per square.

1.2 Source of MCP generated pulses

Previous tests of large-area microstrip performance have been performed using MCP-PMT pulses generated by a Ti-Saph laser in a pumped vacuum test facility [12, 13], or on a stand-alone anode in air with a fast pulse generator and a spectrum analyzer [14]. Here, for convenience and compatibility with the dark box, a commercial Planacon MCP-PMT [15] is used as the source of MCP pulses.

1.3 Signal Pickup Arrays

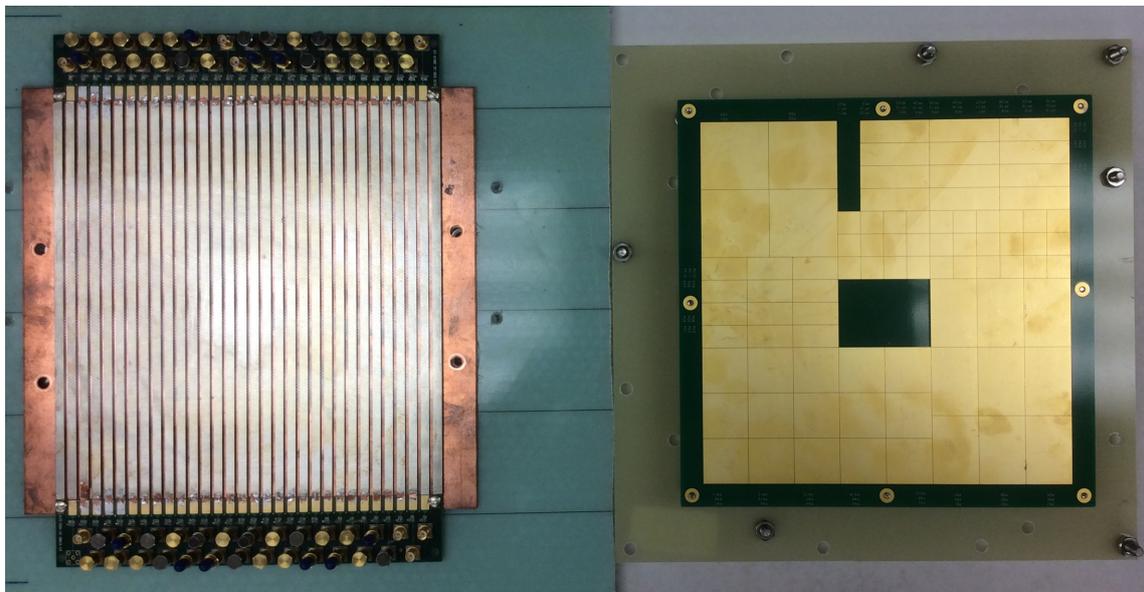


Figure 2: The signal pickup planes for the micro-strip lines (left-hand panel) and 2-dimensional pad array (right-hand panel).

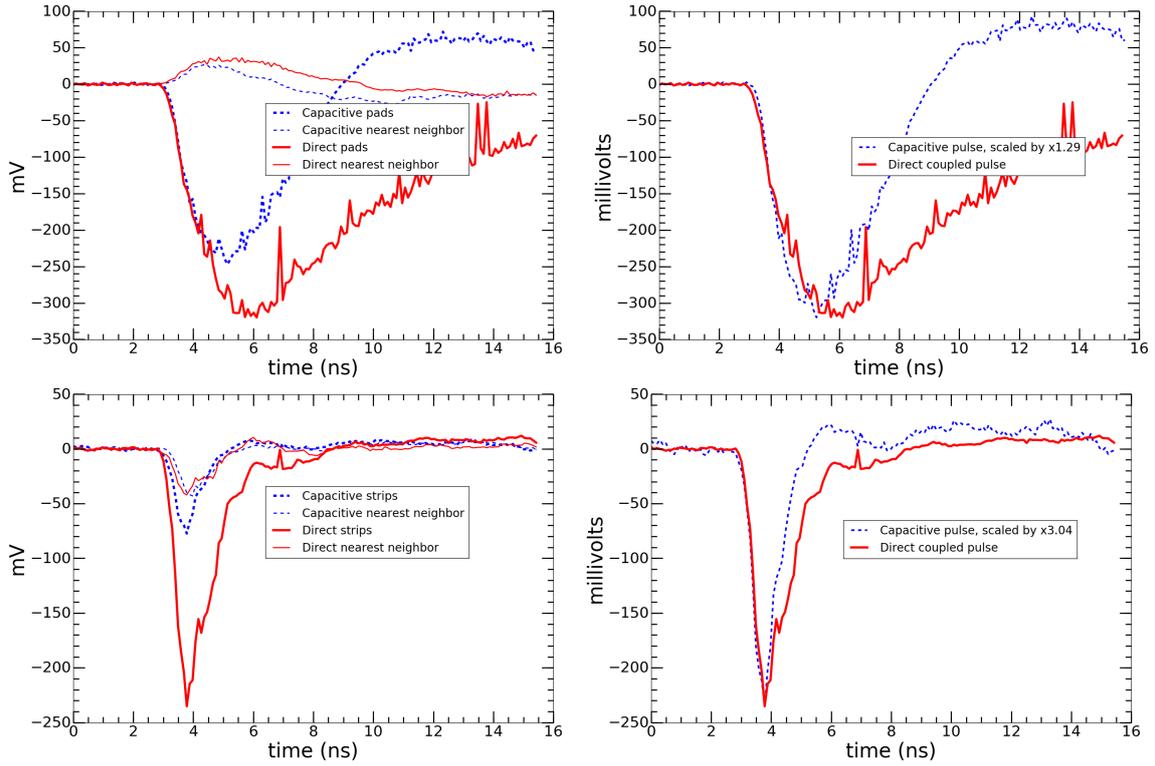


Figure 3: Left: A typical pulse trace on the (red) direct coupling and (blue) capacitive coupling configurations for $2.54\text{ cm} \times 2.54\text{ cm}$ pads (upper panels) and 0.44 cm -wide micro-strips on a 0.69 cm pitch (lower panels). Two traces are shown for each configuration: the pad or strip directly beneath the laser head and a neighboring pad or strip. Right: The pulse traces normalized to the same amplitude, showing that the high-frequency response is unchanged by the capacitive coupling through the metal film.

The geometric layout of readout conductors determines the temporal and spatial resolutions of the photodetector. Typical anode patterns include transmission-line micro-strips [14], two-layer crossed delay lines [2, 16], and pad arrays [15].

Tests were performed using two separate signal pickups, one consisting of 50Ω micro-strips, and the other an array of 2-dimensional pads. The strip pickup, shown in the left-hand panel of Figure 2, consists of silver strips fired onto a glass substrate [14]. This pickup has an analog bandwidth of 1.5 GHz and good signal characteristics up to a length of 90-cm [12, 14].

The right-hand panel of Figure 2, consists of a custom printed circuit board with three sizes of square copper pads: $1.27\text{ cm} \times 1.27\text{ cm}$, $2.54\text{ cm} \times 2.54\text{ cm}$, and $3.81\text{ cm} \times 3.81\text{ cm}$. The back side of the board supplies signal ground through which each pad connects to an SMA connector.

2. Results

Figure 3 shows typical individual pulses recorded by the test system. The panels in the upper row show a direct pulse (red solid line) and a capacitively coupled pulse (blue, dashed line) for the $2.54\text{ cm} \times 2.54\text{ cm}$ pad configuration. Approximately 80% of the direct amplitude is picked up by one pad in the capacitive geometry, with no degradation in risetime.

The two panels in the lower row show the same comparison for the micro-strip pickup configuration. In the capacitive case, shown in the left-hand panel, 34% of the direct amplitude is measured on the strip directly under the laser, and substantial portions of the amplitude are recorded on neighboring strips. The rise times and pulse widths are essentially identical in both configurations. The comparison between the top and bottom rows shows the inherently higher bandwidth of the RF micro-strips versus the two-dimensional geometry of the pads.

3. Conclusions

The results were compared with those obtained with the Planacon directly coupled to the signal pickup planes. The capacitive coupling has no effect on the measured rise-time of the pulse for both the pad and micro-strip pickup geometries, preserving the analog bandwidth for timing resolution. For capacitively coupled pads of $2.54\text{ cm} \times 2.54\text{ cm}$, we observe 80% of the directly coupled amplitude. For the micro-strip pattern, we measure 34% of the directly coupled signal on the strip with the largest signal, still large enough for precision spatial measurements. We attribute the loss on the excited strip to a lower impedance to signal ground due to crosstalk with multiple micro-strips, each terminated at both ends in 50Ω .

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