

Noiseless, kilohertz-frame-rate, imaging detector based on micro-channel plates readout with the Medipix2 CMOS pixel chip

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ABSTRACT

A new hybrid imaging detector is described that is being developed for the next generation adaptive optics (AO) wavefront sensors. The detector consists of proximity focused microchannel plates (MCPs) read out by pixelated CMOS application specific integrated circuit (ASIC) chips developed at CERN (“Medipix2”). Each Medipix2 pixel has an amplifier, lower and upper charge discriminators, and a 14-bit counter. The 256 x 256 array can be read out noiselessly (photon counting) in 286 μ s. The Medipix2 is buttable on 3 sides to produce 512 x ($n \times 256$) pixel devices. The readout can be electronically shuttered down to a temporal window of a few microseconds with an accuracy of 10 ns. Good quantum efficiencies can be achieved from the x-ray (open faced with opaque photocathodes) to the optical (sealed tube with multialkali or GaAs photocathode).

Keywords: Photon counting, noiseless, microchannel plate, Medipix, high frame rate, imaging, detector

1. INTRODUCTION

Advances in adaptive optic (AO) systems for ground based telescopes are placing ever more stringent requirements on the wavefront sensor (WFS) components of these systems. In particular, the push toward larger telescopes requires AO systems with many more actuators, each requiring a wavefront phase measurement. To accommodate the growing number of phase elements, WFS for the next generation of giant telescopes will have to grow accordingly. The ideal WFS¹ would have many image elements (512 x 512 pixels), very low read noise (≤ 3 electron), operate at kilohertz frame rates, and have high optical and near infrared (NIR) quantum efficiencies ($\geq 80\%$).

Typically WFS have employed charge coupled devices (CCDs) because of their excellent optical/NIR quantum efficiency (QE). However, as WFS get larger, with more pixels per phase element to accommodate larger telescopes, the “read noise” associated with the analog to digital conversion of the charge collected in each pixel of a CCD becomes a significant penalty. Newer advances in CCD technology (such as massively parallel readouts² or on-chip structures that amplify the collected charge before the analog to digital conversion³) mitigate this penalty, but cannot entirely eliminate it.

Unlike charge integrating arrays (e.g., CCDs) photon counting detectors register each photon as a single count and so have no “read noise”. Examples of such devices include avalanche photodiodes (APDs) and imaging microchannel plate (MCP) detectors. While silicon based APDs are fast and have high QE in the optical and near infrared (IR) they have not been incorporated into large arrays. Imaging MCP detectors⁴ can have large areas (100 x 100 mm), high spatial resolutions (25 μ m FWHM), low background rates, and event timing resolution less than 1 ns. Their QE is determined by the photocathode that absorbs the incident photon and releases the photoelectron. Recent advances in gallium arsenide (GaAs) and gallium arsenide phosphide (GaAsP) photocathodes for image intensifier devices have resulted in optical/NIR QEs exceeding 50%⁵. Bolstered by this advance in optical/NIR photocathode technology we are actively developing a MCP-based, photon counting WFS detector with a GaAs photocathode⁶.

Most photon counting, imaging MCP-based detectors use readout schemes that are inherently serial in nature. For instance, a delay line anode which uses the difference in arrival times of an event signal at each end of the anode to calcu-

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late the event position, can only have one signal on the anode at a time else there is a confusion of events. With typical delay times of 50 ns for larger detectors dead time associated with “pulse pileup” starts to become significant at global rates as low as 2 MHz. The obvious way to avoid this problem is to use a more parallel readout structure (a pixelated counting device) behind the MCPs. The AO WFS detector we are developing uses just such a device, allowing us to maintain the “noiseless” readout of photon counting, while operating at global counting rates approaching 5 GHz and frame rates of a kilohertz. For a detailed comparison of the performance characteristics as a WFS of the photon counting MCP/Medipix detector discussed here versus state-of-the-art CCDs see reference 7.

2. A NOVEL DETECTOR DESIGN

Our novel detector scheme employs a CMOS application specific integrated circuit (ASIC) pixelated counting device to readout the MCPs. Specifically, we are using the “Medipix2”⁸ device, an ASIC designed and constructed by the Microelectronics Group at CERN for the multi-national MEDIPIX collaboration (<http://www.cern.ch/medipix>), which we have joined. The members of the consortium have input into the features that will be present in future versions of the Medipix ASIC and share the large costs associated with developing and fabricating a new ASIC.

The detector (Figure 1) is a vacuum sealed MCP imaging tube with a semi-transparent GaAs photocathode on the entrance window and a Medipix2 readout chip. A photon interacting with the photocathode produces a photoelectron which is proximity focused onto the input surface of the MCP. The MCP amplifies this single photoelectron with a gain on the order of 10^4 . The resultant charge cloud exits the MCP and lands on an input pad of the Medipix2 pixel where it is counted as one event. The Medipix2 pixel counters integrate until they are readout in a digital, noiseless process. Also because the data is digital, it can be read out at a fast clocking speed, allowing the entire frame to be read out in 286 μ s. This detector should achieve optical/NIR QEs of approximately 35% (the photocathode QE mitigated by the open area ratio of the MCP).

To verify that the Medipix2 device was a viable readout device for an MCP detector we developed a photocathodeless, open-face, MCP detector with a Medipix2 readout. Stimulation was performed primarily with UV light from a Hg penray lamp. This detector works very well and has allowed us to experiment and optimize detector parameters such as the MCP to Medipix gap and the accelerating voltage across this gap, important parameters for the final sealed tube design. We were able to use this detector to perform rudimentary verification that the MCP/Medipix combination will work as a Shack-Hartmann type WFS. We have also used the detector to detect low energy beta particles. Results obtained from this developmental detector have been previously published^{6,9}. The knowledge acquired from this developmental detector has been used to determine the parameters of the optical tube design presented in Section 3.

2.1 The Medipix2 ASIC

The Medipix2 is a pixel detector readout chip consisting of 256×256 identical $55 \times 55 \mu\text{m}$ pixel elements, each working in single photon counting mode. Each pixel consists of a preamplifier, a discriminator, and a 14-bit pseudo-random counter (Figure 2). The counter logic, based on a shift register, also behaves as the input/output register for the pixel. Each cell has an 8 bit configuration register which allows masking, testing, and 3-bit individual threshold adjust for the discriminator. Figure 3 shows the electrical schematic of the Medipix2 layout and how the shift registers relate to the parallel readout. The total active area of the chip is 2.0 cm^2 and is 3-side buttable (supporting larger, $512 \times [n \times 256]$, arrays) with 127 wirebond output/input pads along the inactive edge. The application of the Medipix2 for this detector has been discussed in greater detail previously⁶. Here we concentrate on the implementation using the Medipix2 as a readout in an MCP imaging tube.

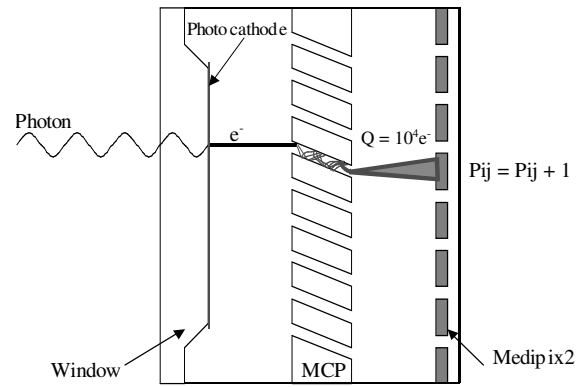


Figure 1: Schematic of a sealed tube MCP imager using a Medipix2 ASIC for readout. Each detected photon results in a single count increment in pixel P_{ij} .

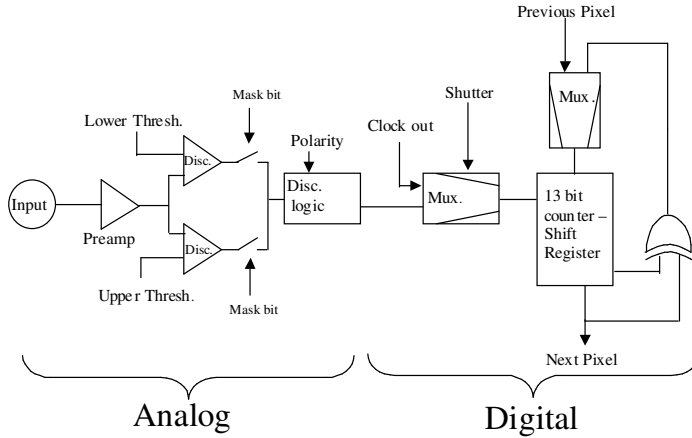


Figure 2: Schematic of the major functional blocks contained within a Medipix2 pixel. A fast charge event on the input is amplified and shaped by the preamp, discriminated, and counted at the shift register (if Shutter is disabled). The digital number count is clocked out at high rate through the shift registers of the pixel column when *Shutter* is enabled. Digital configuration bits are input through this same shift register to control thresholds, masking, and electrical testing.

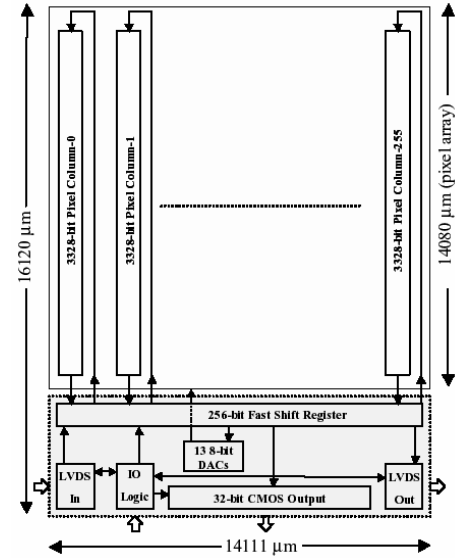


Figure 3: Schematic of the readout architecture of the Medipix2 chip organized into 3328 bit columns read out via a 256 bit fast shift register with a 32 bit parallel readout.

Readout of the Medipix2 chip can be performed via either a serial or a parallel interface. Upload to the chip is performed with a serial interface. Both serial and parallel interfaces are clocked by a fast external clock (up to 100 MHz). The serial input and output employ low voltage differential signal (LVDS) line pairs. The fast clock, for example, is brought into the chip via a LVDS line pair. In serial mode full 256 x 256 x 14-bit frame can be read in ~9.2 ms using a 100 MHz clock. The parallel readout is a 32-bit CMOS bus that outputs each 256 x 1-bit row of a frame in eight reads. A 100 MHz clock speed results in a parallel full frame read time of 286 μ s.

2.2 Microchannel plates

Microchannel plates consist of an array of holes in a specialized glass substrate whose surface has a high secondary electron coefficient. When biased with a high voltage across the plate, electron(s) entering a pore are accelerated and eventually impact the channel wall, releasing more electrons which continue the process resulting in an avalanche of electrons exiting the rear surface. Typical gains (electrons out/ electrons in) for a single MCP range up to 5×10^4 , depending on the voltage applied and the length to diameter (L/d) ratio. For the relatively low gain 10^4 we use for the MCP/Medipix detector either a single MCP with high L/d ratio or a “chevron” pair can be used (two MCPs stacked with their pore bias angles reversed at the interface). The advantage of the chevron is that any ions generated in the residual gas of the tube at the MCP output cannot be accelerated back to the photocathode, possibly damaging it. They would be absorbed in the first MCP because of the “bend” at the interface. We have chosen to use a chevron stack of 10 μ m pore diameter MCPs for the Medipix imaging tube.

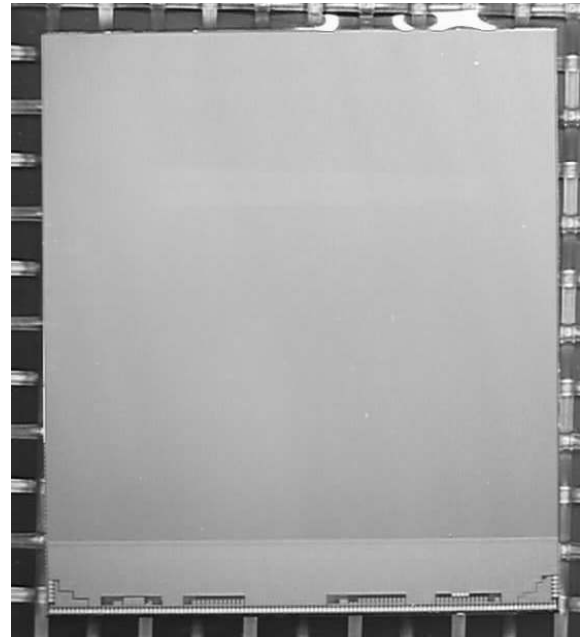


Figure 4: Image of the input face of a Medipix2 chip. The dimensions are 1.6 cm high and 1.4 cm wide. The active area has 256 x 256 pixels and is buttable on 3 sides. Inactive bottom edge has input/output wirebond pads.

2.3 High QE photocathodes in the optical

GaAs photocathodes have been used extensively for a number of years, mainly in night vision applications as the photocathode for Generation III image intensifiers. During that time many advances in performance have been achieved. As demonstrated in Figure 5, quantum efficiencies in excess of 50% can now be achieved from 550 nm to 850 nm making them very attractive for optical/NIR astronomical applications. However, these photocathodes are extremely environmentally sensitive and must be kept at ultrahigh vacuum to prevent QE degradation. They are deposited on windows and built into vacuum tubes constructed to seal and maintain vacuum levels of 10^{-9} Torr or better. Furthermore, production of reliable GaAs photocathodes is expensive to implement, so working with an established volume production facility is important.

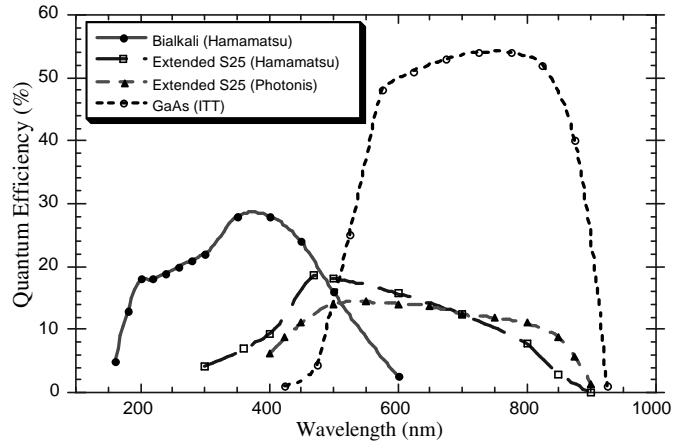


Figure 5: Quantum efficiencies for commonly used optical regime photocathodes (Sources: www.itnrv.com, www.hamamatsu.com), and the more recent GaAs advances⁵.

3. OPTICAL MCP/MEDIPIX IMAGING DETECTOR DESIGN

Although the approach of using a volume supplier of GaAs devices to process the photocathode greatly reduces the cost of achieving high QE imaging device it places significant constraints on the detector design. In particular our vacuum tube and entrance window must be compatible with the fixtures of the production facility, effectively dictating the use of a standard size tube and window. The interior of a standard night vision type vacuum tube is only marginally larger than the Medipix2 device, making space constraints inside the vacuum tube very restrictive. Also the sensitivity of the photocathode to contamination means that everything that goes into the tube must be extremely low outgassing.

The Medipix2 device also places significant constraints on the design. The input/output contact pads of the Medipix are primarily along one edge and are spaced on a 120 μm pitch. About half of the 127 contacts on the Medipix need to be brought out of the vacuum, requiring a relatively fine spacing of contacts and dense population of hermetic vias on the header to which the Medipix is bonded. Also the readout rates we wish to achieve require attention be given to impedance matching and power and ground filtering on the Medipix header. Add to all this the requirement that the header and die bond material must be able to withstand the temperatures ($\sim 300^\circ\text{C}$) reached during the vacuum tube processing while still being extremely low outgassing to avoid photocathode degradation.

Achieving good spatial resolution requires a relatively small gap between the photocathode surface of the window and the input face of the MCPs. To keep the MCP output charge cloud spread to a minimum the gap between the MCPs and the Medipix must also be minimized. Both of these affect the allowable stack up tolerance of the piece parts of the tube body as well as the tolerance on the braze line thicknesses between parts. The MCP to Medipix gap also constrains the maximum permissible wirebond loop height. Externally controlled high voltage potentials need to be applied across the photocathode to MCP gap (improves spatial resolution), the MCP input to output surfaces (controls MCP gain), and the MCP to Medipix gap (minimizes charge cloud spreading). All these requirements lead to a fairly standard metal ceramic brazed body tube assembly with tight stack up tolerances, employing a drop faced entrance window and having a rather complex ceramic thick-film hybrid header for mounting the Medipix readout device (Figure 6 and Figure 7).

3.1 Medipix header

At the heart of the MCP/Medipix imaging tube is the mounting header for the Medipix2 chip. Internally this header provides the mounting surface and electrical interface for the Medipix2 chip and externally functions as the signal interface to the readout electronics. It must provide a hermetic seal on the vacuum tube while getting approximately 60 individual signals from the Medipix to the outside of the tube. It must be very low outgassing and compatible with not just tube processing temperatures, but also active vacuum brazing temperatures ($\sim 850^\circ\text{C}$). The interior contact pads need to be compatible with Al wedge wirebonding with spacing close to that of the Medipix 120 μm pad pitch. For

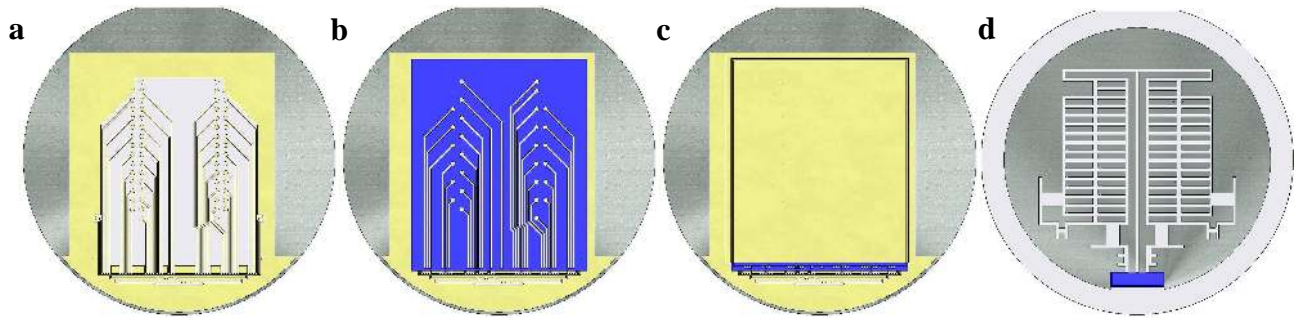


Figure 6: Ceramic hybrid thick film header design. Header diameter is 27.5 mm. **(a)** Interior view of the first trace layer and the hermetic vias connecting the interior traces to the exterior connector land pads, note approximately every other via is consumed in this layer. This layer is applied directly to the bare alumina. **(b)** The second layer of fingers are screened on after the application of an insulating layer of glass and make contact to the unused ceramic vias through holes in the glass. **(c)** The header is completed by application of another layer of insulating glass and finally a ground plane layer is screened over this glass. The Medipix2 chip is die bonded to this “upper” ground plane and the signal pads are Al wedge wirebonded to the exposed tips of the header traces (cf., Figure 11). **(d)** Exterior view, showing the land pads for two 34 contact 0.8 mm pitch connectors and decoupling capacitors.

these reasons we chose to have a hybrid header made using thick-film screening technology on a ceramic substrate. We have used this technology with great success in many of our UV photon counting detector devices¹⁰. The thick-film technology provides an extremely robust final product that is compatible with active brazing. It is not, however, compatible with hydrogen furnace brazing as the hydrogen reduces the thick-film materials.

There are many screening/firing steps in the creation of a multilayer thick-film header such as this one. The process begins with a bare alumina blank with laser drilled via holes. The holes are filled with a conductive material providing an electrical path through the ceramic and a hermetic seal of the vias. After the vias are filled each subsequent material or layer needs to be screened on and fired separately. Thick-film screening technology can provide approximately 125 μm features with 125 μm spacing ($\sim 250 \mu\text{m}$ pitch) and each metallic layer is 10-15 μm thick after firing. To more closely match the 120 μm Medipix output pad pitch, two layers of signal traces separated by an insulating glass were used on the inside of the header (Figure 6). Each layer of traces has 125 μm on 125 μm featuring, and the second layer is registered with its traces over the gaps of the lower layer to provide an effective trace pitch of 125 μm . A second layer of insulating glass is screened over the upper traces to isolate them from the final ground plane (screened beyond the edges of the glass to make contact to the base ground plane) to which the Medipix is bonded. Each “layer” of glass is 60 μm thick and is formed by screening and firing four separate 15 μm patterns. The insulating glass further ensures the hermeticity of the header and all vias are covered by at least one layer of glass. Note that only the very tips of the traces on each layer are left exposed by the glass layer above those traces. The second, upper set of traces does not reach the edge of the lower glass, producing a stair-like cross-sectional vertical profile for the two sets of traces and glass.

The exterior pattern provides land pads for two 34 contact, 0.8 mm pitch connectors and decoupling capacitors that will be installed after the tube is sealed (see Section 3.2). The Medipix needs to be mounted and wirebonded to the header before the tube can be sealed. As the Medipix will certainly not survive the $\sim 850^\circ\text{C}$ active braze process a lower temperature method is needed to seal the header and Medipix into the tube body. The header is brazed to a kovar adapter flange before the Medipix is installed. Later the flange/header/Medipix assembly will be laser welded into the tube backend. The bare ceramic outer annulus on the exterior of the header provides a surface for the active brazing of the header to the adapter flange. The edge of the header is also screened with metal. During the brazing process the braze material will slightly overflow (“run-out”) this region, providing a continuous, low impedance ground plane from inside to outside. The small glass patch on the exterior protects the power lines under it from being shorted by braze run-out (as well as ensuring the seal of the vias below it). Special care was given to the 2 x 6 LVDS traces at either end. These traces were designed (trace width, spacing, distance to ground plane, and dielectric of insulating glass) to provide as close to 100 Ω differential impedance for each LVDS pair as possible given the space and materials constraints. Finally, the use of a conductive epoxy to bond the Medipix to the uppermost ground plane provides a low inductance path for the chip backside ground plane.

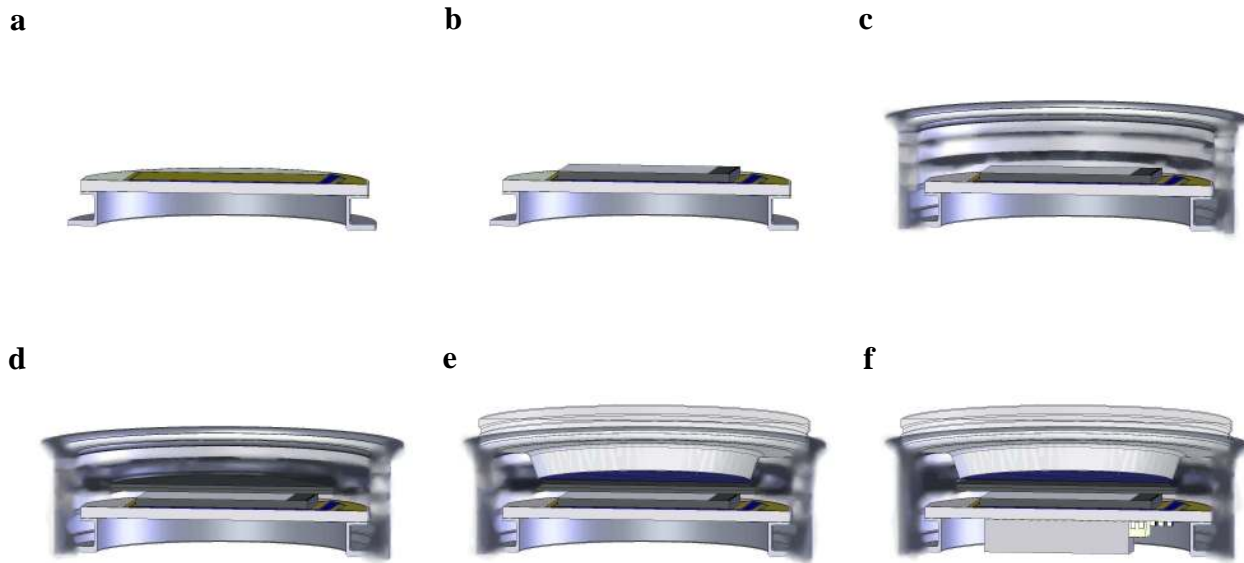


Figure 7: Cross-sectional views of the optical image tube fabrication process. **(a)** The ceramic header is active brazed to a kovar adapter flange. **(b)** A Medipix2 chip is die bonded and wirebonded to the header assembly. Electrical testing of the Medipix2 is performed via a serial interface board. **(c)** This assembly is laser welded to the back flange of the vacuum tube brazed body. **(d)** The MCPs are installed in the tube, the tube is placed in an ultrahigh vacuum processing chamber and prepared for sealing. **(e)** The photocathode is activated and the tube is sealed and can be removed from the vacuum processing chamber. **(f)** Finally the passive components (connectors and capacitors) are bonded to the exterior surface of the ceramic header.

3.2 Vacuum tube design and assembly

To facilitate the production and processing of the GaAs photocathode our tube design needed to comply with the standard sizing of the image intensifier industry. We are using a tube designed around 25 mm diameter MCPs with approximately 18 mm diameter active area. We have selected to use a fairly standard combination of drop face window and upper tube stack height that will yield a nominal 300 μm photocathode to MCP gap. The smaller this gap and the higher the voltage applied across the gap the smaller the spatial blur will be incurred from the initial lateral velocity of the photoelectron. This gap is smaller than we need for the resolution requirements of the Medipix tube, but allows us to use the tube for more demanding projects (and operate at a lower gap voltage for the Medipix project). The back flange of the tube and the adapter flange of the brazed header assembly are designed to provide a nominal 500 μm gap between the MCPs and the Medipix. This gap can be adjusted by post braze machining of the tube body rear flange. Making this gap smaller (or increasing the voltage across the gap) reduces the footprint at the Medipix of the charge cloud exiting the MCPs. A more compact charge footprint means more charge falling in each activated pixel, so increasing the likelihood of exceeding the Medipix threshold. Alternately, the MCPs could be operated at lower gain without a loss of counting efficiency (relative to a larger gap and higher gain).

The stages of fabrication of a Medipix vacuum tube are shown in Figure 7. First, a ceramic header hybrid is brazed to a kovar adapter flange. A Medipix is die bonded and wirebonded to this brazed assembly. At this stage the Medipix can be tested by mechanically contacting a pair of connectors in a jig on a serial test board (Figure 8 and Figure 12) to the connector land pads on the back of the Medipix header. It is desirable to not bond or solder the connectors on the header at this stage as they and any bonding material will need to be removed before the tube can be placed in the vacuum processing and photocathode activation chamber. If the Medipix meets operational requirements then this assembly is laser welded onto the back flange of a tube brazed body and the MCPs are installed. At this stage the serial test board and jig can be used to verify imaging performance of the MCP/Medipix combination.

The device (as seen in Figure 7d) is then ready to be sealed with a window with a GaAs photocathode. This process involves a high temperature ($\sim 300^\circ\text{C}$) vacuum bake of the tube to ensure the tube will remain at ultrahigh vacuum

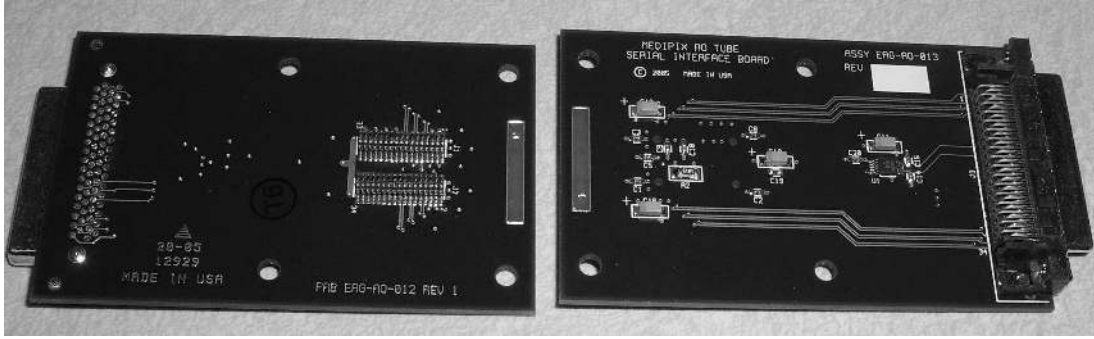


Figure 8: Serial readout boards that will be used for performance verification of bonded Medipix2/header assemblies prior to integration into a tube body. The two small 34-pin connectors visible on the bottom side of the board (at left) mate to the connectors on the back of the header. The larger 68-pin connector on the end of the board mates to an acquisition computer via a MUROS2 interface box (**ref**). Each board is approximately 2 in by 3 in. The long traces visible on the board on the right are the 100 Ω differential impedance LVDS lines.

(<10⁻⁹ Torr) after it is sealed. Also the MCPs will be taken through a pre-conditioning “scrub” to make sure that all the gas adsorbed on the MCP surfaces is removed prior to sealing. This also stabilizes the gain of the MCPs as a function of detector runtime. When the sealed tube with activated photocathode is complete we will bond the connectors and decoupling capacitors on the back of the header. At this point we will have an optical, photon counting, sealed tube imaging device ready for use as the detector head of an adaptive optics wave front sensor (or for other uses).

3.3 Readout electronics and software

We have benefited particularly on readout hardware and software from the developments of the MEDIPIX collaboration. For our lab test detector we have been using a well-proven serial readout system. This system consists of the Medipix2 mounted on a serial test board (designed at CERN) that connects to a “MUROS2”¹¹ communications box developed by the NIKHEF group. The MUROS2 box interfaces with an acquisition PC via a National Instruments DIO-32HS card. The data acquisition control and image display are through the Medisoft¹² graphical user interface software developed by the Univ. of Naples Federico II. The presence of these interface tools made it possible for us to start acquiring image data from MCPs with the Medipix2 chip very rapidly.

For testing of the Medipix2 chips once they are mounted on headers we have developed a serial interface board (Figure 8) based largely on the above mentioned serial test board. We have replaced the Medipix2 bonding pad on the old serial board with a pair of connectors that mate to the connectors on our ceramic header. This board also interfaces to the MUROS2 communications box and will allow image acquisition via the existing software. As with the ceramic header, particular care was taken to make the LVDS line pairs have 100 Ω differential impedance (long traces on board on the right of Figure 8).

A high speed parallel interface is under development by members of the MEDIPIX collaboration at the European Synchrotron Radiation Facility (ESRF) to facilitate their high speed x-ray scattering and x-ray diffraction experiments¹³. The interface is designed to have five Medipix chips (bonded to a common ceramic header board) readout simultane-

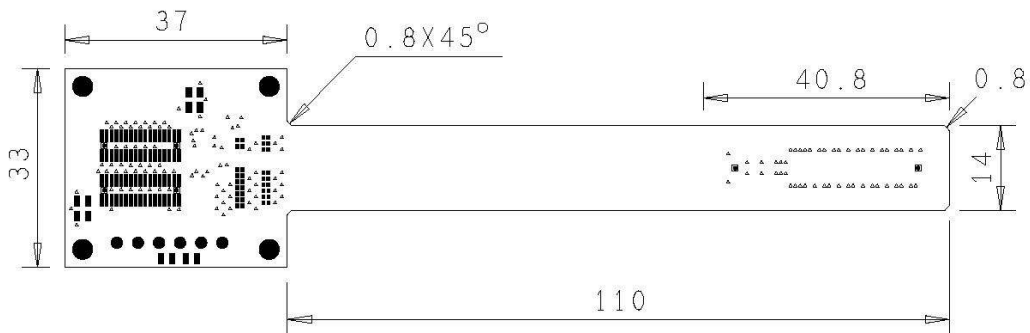


Figure 9: Preliminary design of the flexible interface cable design for parallel readout of the Medipix2 header. This flex cable adapts our tube output connections to one of the inputs of the ESRF parallel readout FPGA board.

ously by a single field programmable gate array (FPGA) via the parallel interfaces of the Medipix chips. The data from each Medipix flows through a pre-FPGA FIFO to prevent the data readout speed being limited by the FPGA processing speed. Implementing the FIFOs allows the FPGA to process the images during the integration of the next image frames. The parallel readout is designed to accommodate ~ 1 ms frames, $286 \mu\text{s}$ to transfer the Medipix' frames to the FIFOs, the remaining time for integration of the next frame. Once the Medipix frame transfer to the FIFO has *begun* the FPGA starts processing the data stream (manipulating data from all five chips simultaneously). Manipulation steps include reordering of the data bits (as they get shuffled due to the nature of the 8×32 -bit read of each 256-bit row); conversion of the pseudo-random counter output into real binary counts (this step can include a dead time correction for extremely high local counting rates); a flat field correction; and finally an optional AO spot by spot centroid calculation (including X and Y centroids and variances, and total counts for each spot based on 7×7 pixel regions). Alternatively, full image arrays can be passed to the output.

Preliminary calculations predict all data manipulation (including spot centroiding) can be completed by $\sim 800 \mu\text{s}$ from the beginning of the Medipix frame transfer. We plan to use the ESRF parallel readout board to read our MCP/Medipix2 imaging tube. Initially we will require only one of the five available channels of the board. We can envision using four of the channels with four of 256×256 tubes (and accompanying beam splitting optics) to accomplish an effective 512×512 WFS. Our collaborators at CERN are currently developing a flex-cable that will interface one MCP/Medipix2 tube to the ESRF parallel readout board (Figure 9). Until the parallel interface is fully developed we will use our serial test boards to readout the MCP/Medipix2 imaging tubes.

3.3 Current status and future work

Mechanical design of the sub-components of the vacuum tube and header assemblies is complete. The piece parts for the tube bodies are being fabricated. Brazing of tube bodies will occur after all parts are fabricated and inspected. Fabrication of the ceramic thick film hybrid headers has been completed and these items look very good (Figure 10). The braze adapter flanges for the header assemblies have been fabricated and are ready to be brazed to the headers. As the individual headers are complex and expensive pieces we are having brazing verification testing performed (to ensure proper hermeticity and appropriate braze run-out) prior to brazing the headers to the adapter flanges. When we are satisfied with the performance of the test brazing for the headers we will have the headers brazed to the adapter flanges.

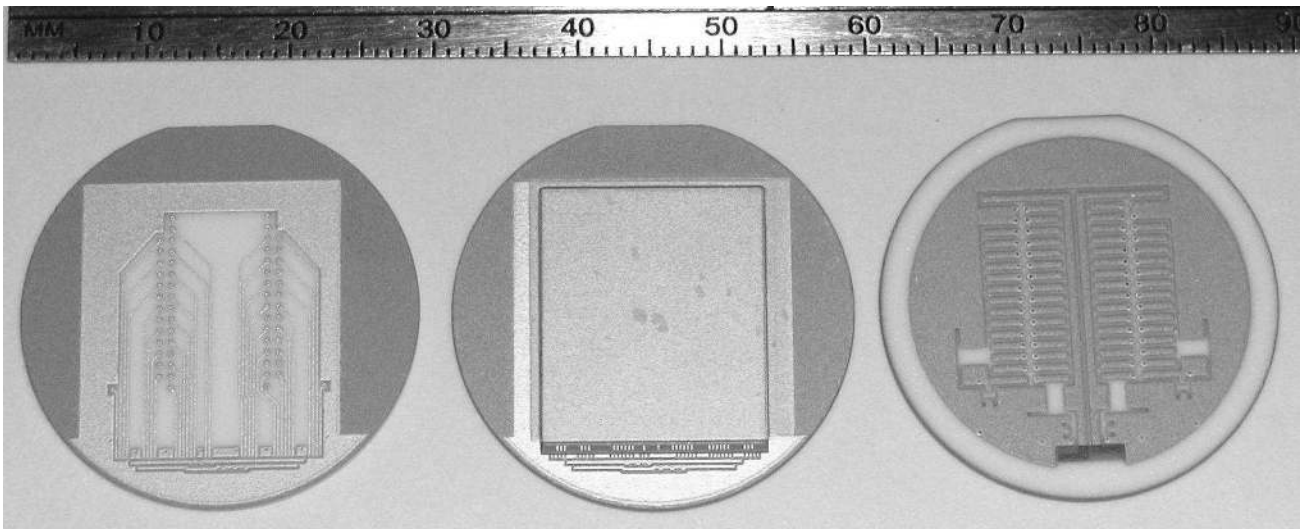


Figure 10: Image of as fabricated ceramic headers. The article on the left is at an intermediate stage of fabrication (equivalent to Figure 6a). The center and right items are final products, showing the interior (cf., Figure 6c) and exterior (cf., Figure 6d), respectively.

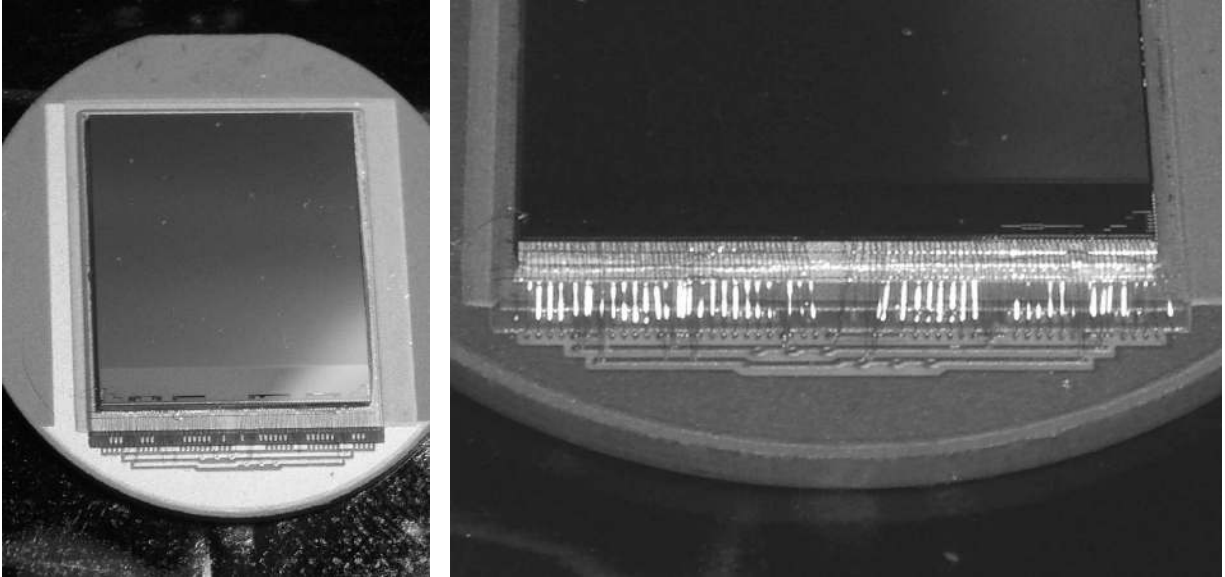


Figure 11: Images of a Medipix2 ASIC die bonded and wirebonded to a ceramic header. This device will be used for thermal prototype testing to verify compatibility of the Medipix2 device and bonding material with the temperatures necessary for vacuum tube processing. During final assembly the ceramic header will be brazed to the adapter ring before the Medipix2 is attached.

While the fabrication and brazing is ongoing we have had one Medipix2 die bonded and wirebonded to a ceramic header (without the adapter flange brazed on). The Medipix2 bonded very nicely to the header and the wirebonds are robust (Figure 11). We will be using this “thermal prototype” to verify that the Medipix2 and the die bonding material selected are compatible with the temperatures (~300 °C) needed for GaAs vacuum tube processing. CMOS devices of similar design have survived such processing¹⁴ so we are confident the Medipix will as well. This prototype device also allows for the first full electrical testing of the headers using the serial interface boards. We have developed a jig for this testing (Figure 12) that allows electrical contact to be made between the serial test board and the connector land pads on the header exterior without bonding/soldering connectors to the header. The connectors that would normally be bonded to the header are located mechanically by the jig and the header is pressed onto the connector tabs. This allows testing of the header/Medipix prior to tube processing tests, without contaminating the header with an epoxy or solder.

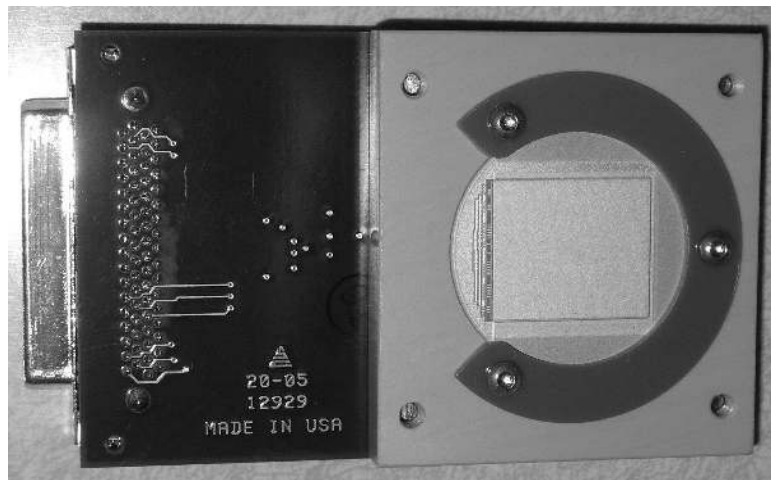


Figure 12: Serial test board with a ceramic header in a jig. The jig aligns the header mechanically to provide electrical contact between the connector land pads on the back of the header and a pair of connectors recessed in the jig. Those connectors are mated to the connectors on the serial board (left board in Figure 8). This setup will be used to test the thermal prototype header assembly before and after thermal testing.

A similar jig will be used to test the brazed header assemblies during the tube fabrication flow. This work is ongoing and results will be forthcoming.

Once the header assemblies and tube bodies are brazed we can begin buildup of MCP/Medipix2 imaging tubes as described above and have them sealed with an activated GaAs photocathode window. We may decide to seal a tube in our tube processing facility at the University of California, Berkeley. This device would employ a multialkali photocathode (Figure 5), as we do not have the capacity to process GaAs, but could be fabricated quickly after the parts are in hand and would provide valuable feedback for the final GaAs tubes. Furthermore, having a working MCP/Medipix2 imaging tube in hand will allow us to investigate other applications for this device.

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