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Large CSC Chamber for the PHENIX Muon Detector with Ultra Thin Cathode Foils[1]

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Abstract

The muon tracking system for the PHENIX detector at RHIC uses cathode strip chambers(CSC) for the tracking detectors. These detectors must provide 100 μm resolution per measurement plane to give satisfactory mass resolution of the vector mesons. The intermediate station (station 2) must have a very small radiation length, and large acceptance. We have prototyped a full scale CSC chamber to test the use of 25 micron metalized mylar foils for the cathode strips at station 2. The full scale prototype detector is a trapezoid, 2.3 meters high and 2.3 meters wide. The foil and wire planes are mounted on thin 3.2 mm thick by 7.5 cm wide laminated frames and the tension of the planes is maintained by the two large 7.5cm wide x 3.0 cm thick aluminum support frames. The total radiation length of the active region is 8.5×10^{-4}.

I. INTRODUCTION

The primary physics goals of the PHENIX Muon Spectrometers are to contribute to both the Relativistic Heavy Ion Program and to the Spin Physics Program at RHIC. The physics requirements have led the muon subsystem to choose as the baseline detectors for the spectrometers, the cathode strip chamber (CSC) technology. The PHENIX muon spectrometers are radial field magnets with three detector stations along the axial length at approximate locations of 200cm, 350cm, and 600cm. One of the PHENIX muon spectrometers is shown in Figure 1.

The spectrometer magnets are eight sided polygons with a central piston that is the return yoke and holds the two magnet coils. The acceptance for the North Magnet starts at 10 degrees at the piston and extends to 37 degrees at the outer octogon surface. The physics acceptance is defined to be 10 deg to 35 deg. The magnet extends from 200 cm to 660 cm from the vertex . At 15 deg the field integral is 0.710 tesla-meters.
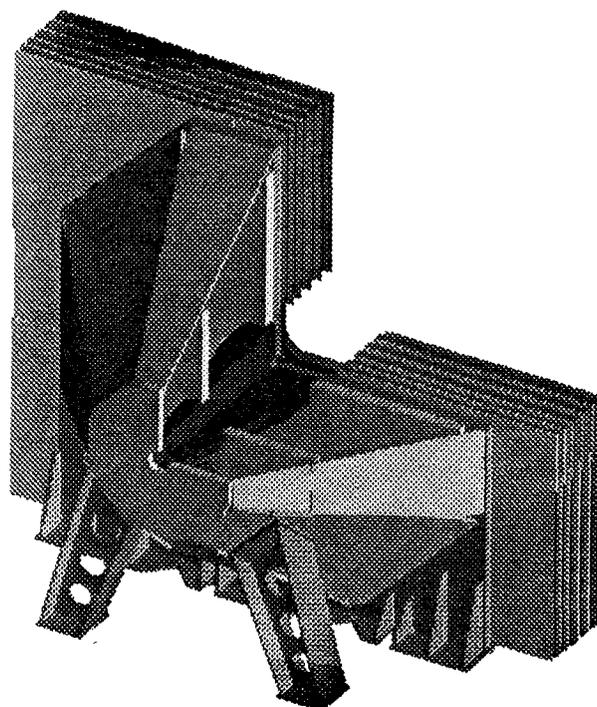

Figure 1. PHENIX North Muon Arm Spectrometer

Because of the need to maintain good momentum resolution down to 1.5 GeV, the second detector station has to have as small a radiation length as possible to minimize multiple scattering. To be able to separate the Y and the Y′ vector mesons, three CSC detectors with 100 μm resolution at each detector station were required to give a momentum resolution of 200 MeV. The requirements of good resolution and low radiation length led to the adoption of thin copper metalized mylar foils as the cathode strip structure for station 2 rather than the more conventional etched cathode printed circuit boards. The mylar foils are 25 μm thick with 600 angstroms of copper on one side. A large etching table was constructed to handle the large foils. The 100 μm detector resolution and 58 μm station resolution require

precisely constructed chambers, frames and support structures that are designed to be insensitive to environmental vibrational forces. The goals of the construction program are to maintain assembly tolerances and vibrational tolerances to less than 25 μm.

II. Station 2 Mechanical Design

A. Station 2 Octant Assembly

The station 2 octant detector assembly is shown in Figure 2. A cross section of the CSC octant assembly is shown in Figure 3. The station 2 design is a laminated structure of thin frames for the wire and foil planes and two thick aluminum support frames. Each assembly contains three CSC detectors. The total cathode to cathode gap is 6.35 mm for each CSC detector. The anode plane is an alternating structure of 20 μm gold plated tungsten sense wires and 75 μm CuBe field wires with the sense wire spacing of 10 mm. The anode wires follow the chord in each 22.5 degree segment.
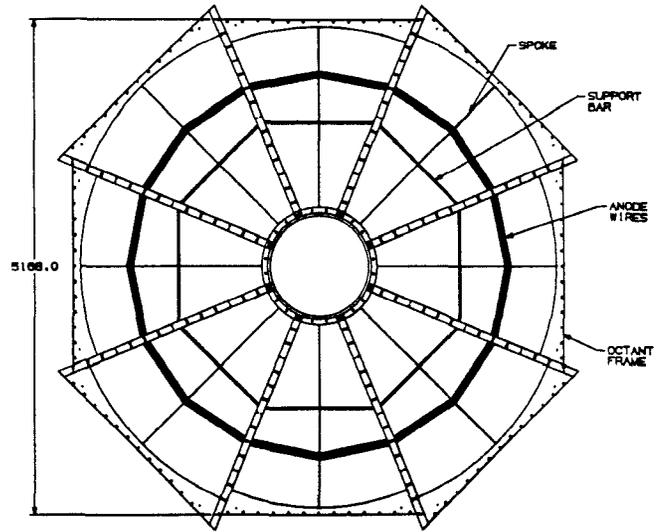

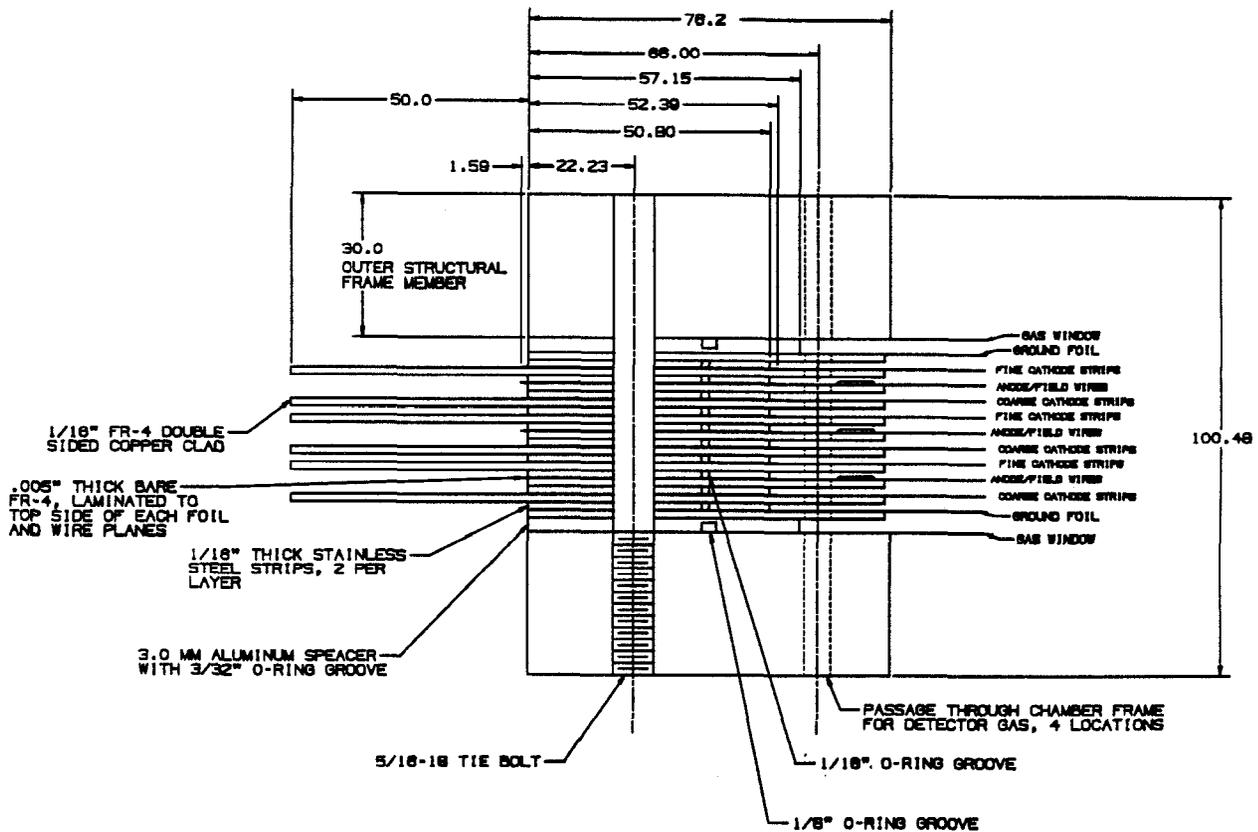Figure 2. Station 2 octant detector assembly

Figure 3. Cross section of the station 2 octant assembly

A support spoke at 22.5 degrees is used to support the wire plane and to limit the resolution degredation due to nonnormal incidence. The support spoke is attached to the top of the octant and is free to slide at the bottom of the octant and maintains the anode-to-cathode spacing to 50

μm. The 5mm wide spoke is constructed to form a laminate with one piece grooved to define the the anode-to-field wire spacing and the cathode-to-anode spacing. A top cap is glued to the grooved piece to define the cathode-to-cathode spacing and to aid in making the spoke a more rigid structure. During the wiring process the anode spoke

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is held fixed in an aluminum channel. The CSC chamber frames are held rigid and in proper shape and tension by 2 aluminum support frames which are 3 cm thick and 7.5 cm wide. Nine alignment pins, 3 on each long edge properly locate the thin frames during the assembly process. A single support frame is used during the etching and wiring process to pin the thin chamber planes to insure proper tension. A number of detailed finite element calulations were performed to verify this design.

B. Station 2 Mounting Structure

The mounting structure for the station 2 octants in the magnet must hold the octants rigidly to 25 μm over the short period of time (< 15 min) when vibrational and environmental forces could move the chambers. The mounting structure is shown in Figure 4.
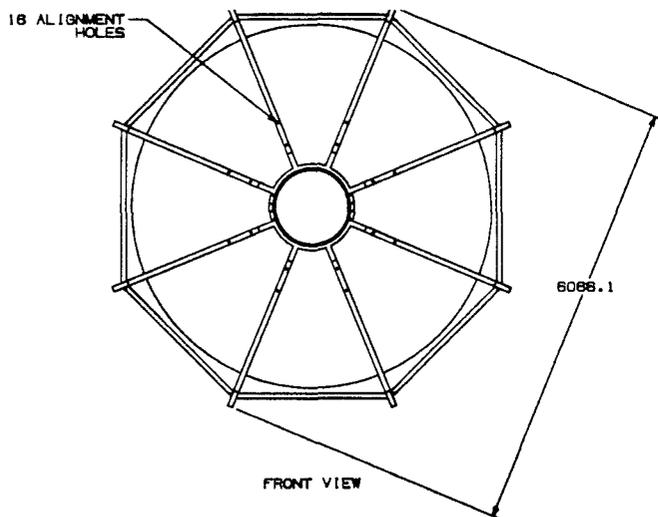

Figure 4. Station 2 Mounting structure, front view.

It consists of stainless steel tubing, rectangular in shape, on the front and back of the octants with a truss structure at the top and mounting ring at the inner radius. The mounting ring does not come in contact with magnet piston. The mounting structure is mounted to the magnet at four points at the bottom of the magnet and at four points at the top. The mounting structure and therefore the chamber octants are electrically isolated from the magnet. The mounting structure design criteria was to have vibrations from natural frequencies less than 25 μm. Static distortions due to gravity, thermal, and magnetic effects were minimized but allowed. The active alignment system is designed to account for static distortions. An analytic calculation of the weight and maximum distortions of the space frame were carried out for a variety of tubing sizes and for stainless steel and aluminum. The results pointed to stainless steel with a cross section of 7.5 cm x 5.0 cm x 0.3175 cm wall as an acceptable material. The maximum displacement under gravity load is 0.399 mm. A finite element analysis of the mounting structure with the octants in place was carried out with the program COSMOS/M to

define the natural frequencies of vibration and the static distortions due to gravity. The maximum static distortions due to gravity is 0.362 mm, less than the frame alone indicating that the chamber frames provide structural rigidity. The alignment system will be used to correct for distortions due to gravity and temperature.

Vibrations due to ground motion coupling into the station 2 assembly require a knowledge of the natural frequencies of the structure. The natural frequency modes are shown in Table 1.

Table 1
Station 2 natural frequencies

Mode #	1	2	3	4	5
Freq(Hz)	7.9	12.4	16.6	25.5	27.9

The first three modes correspond to displacements in the z direction. The fourth and fifth modes are displacements in the phi and r direction and therefore are of greatest concern. To determine the maximum displacements expected from these and all frequency modes, a dynamic analysis was done using the finite element analysis program ABAQUS. The excitation to the station 2 structure was based on measurements made at four laboratory facilities [2]. It was considered roughly typical of what one would expect at the PHENIX facility. No site specific ground motion measurements have been made and the excitation function does not represent vibrational forces that could be generated by equipment (e.g. vacuum pumps,etc.) attached directly to the magnet. In the calculation, the sagitta error was determined under the assumption that stations 1 and 3 are fixed. The frequency analysis for the magnet suggests that motion in the x and y coordinates of stations 1 and 3 is negligable owing to the large massive back plate and tea cup to which they are attached. The response power spectral density for x and y components of the sagitta at the node at the top of the frame is shown in Figure 5.

This node corresponds to the vertical frame of the octant at the top of the magnet at the 12:00 o'clock location. The peaks in the spectrum correspond to the frequencies where the coupling is the largest. The z component is added for reference but does not effect the sagitta. The largest x component of the sagitta rms response is 0.17 μm. The largest Y component of the rms response is 0.11 μm and occurs at the horizontal frame of the octant on the side of the magnet at the 3:00 o'clock location. The largest Z component of the rms motion relative to the base is 1.1 μm at the horizontal member on the top of the octant at the top of the magnet. The results show that the largest sagitta error introduced because of ground motion is approximately 0.2 μm. We expect to measure the ground motion at the PHENIX site and redo this calculation but the results indicate that we have two orders of magnitude margin before ground motion becomes a problem.
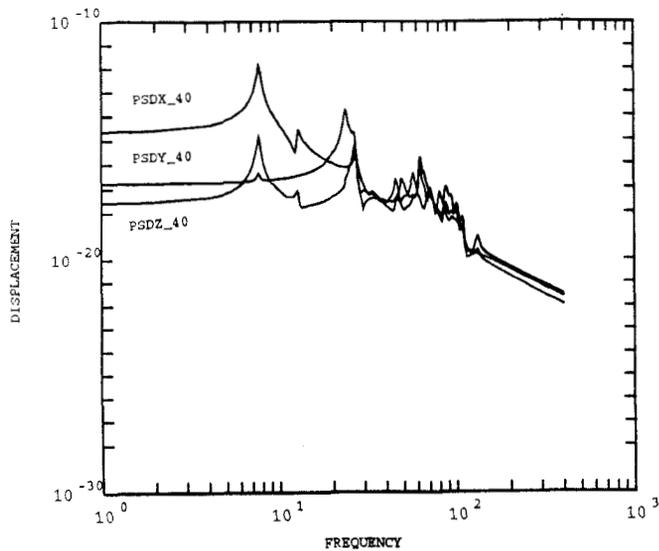
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Figure 5. Power Spectral Density sagitta response for x and y directions at the top of the frame

C. Foil Etcher

A technique to etch the thin mylar foil has been developed that allows the etching process to be done on the foil after the foil has been stretched on the support frame. This process involves electroetching the copper coated
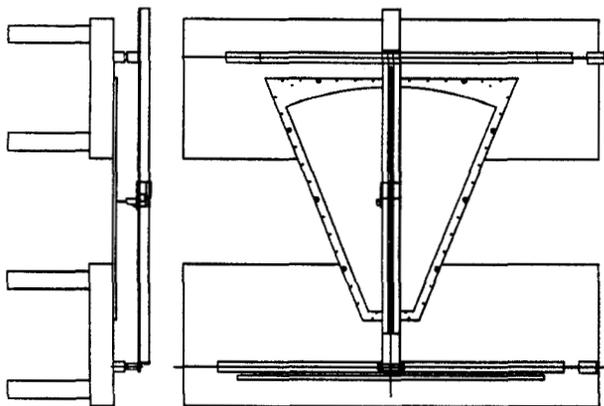

Figure 6. Etching setup for etching stretched cathode

mylar foils in the presence of an insulating gas with a probe tip attached to a low voltage source. The tip is mounted on a computer controlled x-y table and positioned with an accuracy of 10 µm by a linear slide. A drawing of this setup is shown in Figure 6.

The high resolution cathode foil is prestressed on the support frame during the etching process so that when the

frame distortion occurs when all of the foils and wires are in place the cathode strips will be positioned correctly.

Creep of mylar foils occurs in the first few days after stretching. Experience with full size stretched mylar foils have shown no unacceptable loss in foil tension due to creep over 6 months. Previously stretched 1 meter foils have shown no loss in tension over 4 years. Our experience has shown relaxation appears not to be a problem.

The alignment of the etcher lead screws to the structural frame via the 9 alignment pins is first determined [1] and a file is produced that includes the alignment information and lists the location of all the strips. For each strip the pen is moved in the up position to the beginning of the strip to be etched, lowered to the foil, moved to the end of the strip,and then raised to the up position, ready to be moved to the next strip. This process is repeated for each strip to be etched. The pen is moved at the rate of ~100cm/min. At each move the computer incorporates a search procedure to locate the lead screws and remove any backlash. We rely on the linear optical encoders rather than the stepping motors to locate the actuators. The quality of the etch depends on the pen voltage and the speed of pen motion as well as the presence of an insulating gas. The quality of the etched line was investigated by varying the voltage between 12 and 30 volts DC and the speed of the pen. The optimum was achieved for 16 volts and a pen speed of 100 cm/min. We have used nitrogen as the insulating gas. The etcher head is shown in Figure 7. The etcher head holds the pen which is controlled by a solenoid, the nitrogen gas nozzle, and the alignment telescope. An example of the etched line is shown in Figure 8. The width of the etched line is approximately 250 microns. The line width increases with the applied voltage and the edge definition worsens with increased voltage.
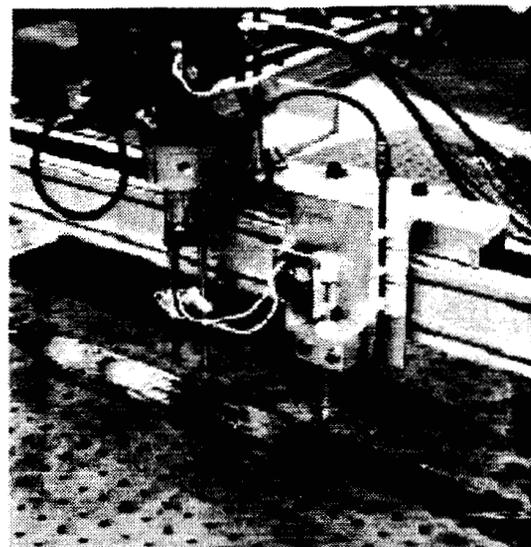

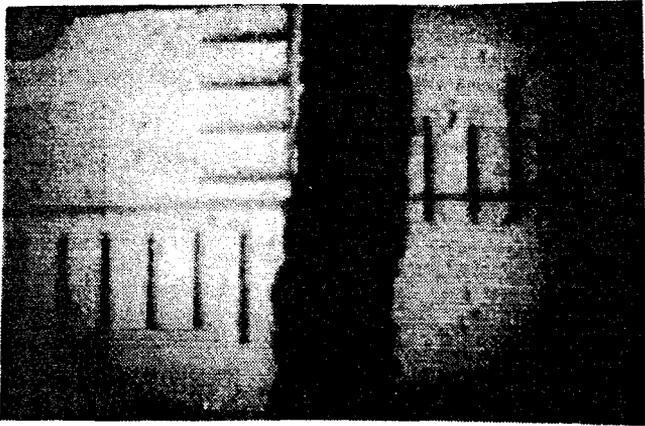Figure 7. The etcher head with the etcher pen on the right and the alignment telescope on the left.

Figure 8. TV image of etched line.

D. Anode Wire Stringing and Tensioning

All of the anode wires were stretched and attached by hand. A support frame held the wire frame in position and prevented distortion of the frame due the wire load. The central support spoke was held fixed by a metal groove. The wires were located by precision combs and tensioned by hanging weights. Before soldering, the tension of each wire was measured by a simple tension measuring device to insure any friction in the spoke or frame did not alter the tension of the wire. The tension measuring procedure consisted of inducing a standing wave in the wire by passing an alternating current through the wire in the presence of a magnetic field. A capacitive pickup sensed the oscillation. The correct frequency was observed by looking at Lissigous figures on an xy oscilloscope.
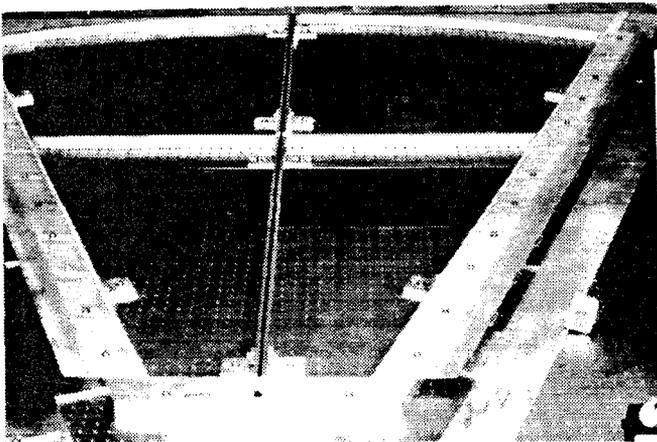

Figure 9. A completed wire plane with spoke attached to the support frame.

A rate of 200 wires per day were soldered and measured. A more automated procedure for stringing the wires is being studied. Removing the completed anode plane from the wiring table required a transfer support frame to keep the wires under modest tension so that during transfer the wires did not wrap around adjacent wires. No problem was encountered because of the support spoke.

III. ASSEMBLY AND TESTING

The anode and cathode planes were assembled with the sutructural frames to complete one CSC detector. No problems were encountered in the assembly process. The completed assembly is shown in Figure 10. Clearly visible are the 9 alignment pins that hold the thin foil and wire planes. The gas window visible is single sided 25 μm aluminized mylar. Also visible is the support tie bar that aids in maintaining the shape of the side members. The maximum deflection of the side bars is 30 μm.
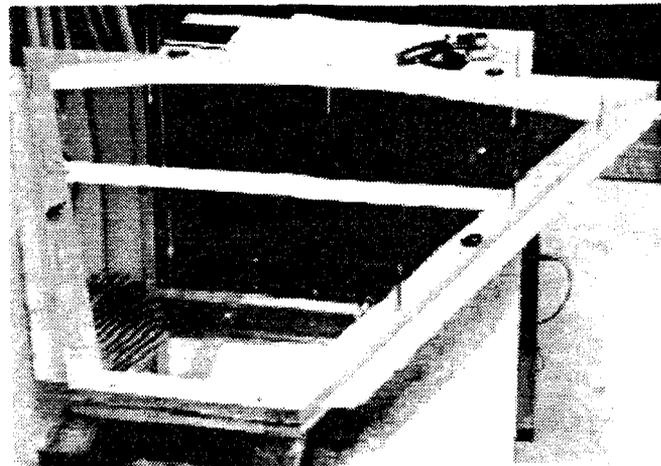

Figure 10. Complete CSC chamber assembly.

A. Preliminary Testing

The detector assembly was connected to an argon-isobutane (70:30) gas system and brought up to 1900 volts. Leakage currents were less than 30 nanoamps for the entire chamber. We connected a 16 channel section of the cathode strips to a transimpedence amplifier with a transfer gain of 0.3 volts/μAmp and observed signals reaching 500 mVolts with noise levels < 2 mVolts. These are fast amplifiers and are not optimized for the CSC chamber. Tests are now underway to measure the the efficiency plateau and resolutions and uniformity across the chamber. When better electronics become available the final resolution measurements will begin. Preliminary results indicate that the resolution without adequate calibration and amplifiers is < 130 μm. We find this very encouraging and expect these chambers to reach the design goal of 100 μm.

IV. REFERENCES

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