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A large open ratio, time and position sensitive detector for time of flight measurements in UHV.

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We report on the construction of a UHV compatible 40 mm active diameter detector based on micro channel plates and assembled directly on the feed-throughs of a DN63CF flange. It is based on the charge division technique and uses a standard two inch Si wafer as a collector. The front end electronic is placed directly on the air side of the flange allowing excellent immunity to noise and a very good timing signal with reduced ringing. The important aberrations are corrected empirically providing an absolute positioning accuracy of 500 μm while a 150 μm resolution is measured in the center.

I. INTRODUCTION

Micro channel plate (MCP) based position sensitive detectors are now widely used in atomic and molecular physics as well as in surface science. Such detectors can be placed in the focal plane of an electrostatic analyzer^{1,2} to allow ion energy measurements or in direct view of the interaction zone to record neutral and charged particles scattered^{3,4} or emitted from the surface^{3,5}. Depending on the respective geometry of the target and primary beam, such detectors are well suited for a variety of surface science techniques such as direct recoil spectroscopy (DRS), low energy ion scattering (LEIS)¹, grazing incidence ion scattering⁴ as well as grazing incidence atom diffraction⁶.

II. DETECTOR OVERVIEW

The detector displayed in figure 1 has been designed to be mounted on a DN63CF port in an molecular beam epitaxy chamber⁶ where space is limited and UHV compatibility stringent. When doing time of flight for DRS

prevent the broadening of the time of flight peaks due to the rapid variation of the binary collision kinematics with outgoing angle⁵. With a simple counting detector such as a channeltron the acceptance is usually below a degree opening angle and these aberrations are not considered as a problem^{7,8}. Four such detectors were needed justifying a little investment in design. We have used the well-established charge division technique which already showed to be rather compact. To meet the tight space budget, the collector is a silicon wafer having the same size as the MCP and the whole detector is supported by the electrical feed-troughs. The noise sensitive electronic is mounted directly on the air side of the flange taking advantage of modern printed circuit boards facilities which allow a smart combination of electronic and mechanical properties up to the signal and high voltage plugs (figure 2, 3). The distortions associated with this anode are measured and corrected by software with a polynomial equation (eq 1) allowing a 500 μm absolute position accuracy well enough for DRS and LEIS measurements but probably not for application such as diffraction where accurate line profiles are important.

III. THE RESISTIVE ANODE

Quite a number of position sensitive detectors have been developed with various aspect ratio and performance⁹. Delay line detectors^{10,11} have the highest count rates and lower dead time but tend to be large whereas charge division techniques have shown to be highly adaptable^{1,2,12} and robust limiting the need for maintenance. The distortion-free resistive anodes matching the Gear conditions¹² would have been a obvious choice but the 40 mm active diameter commercially available has a 72 mm overall diameter, too large to fit in a DN63CF flange. Since UHV compatibility is mandatory, we have decided to use high impedance 2 inch Si wafers (high purity single crystal un-doped float zone Si(111), 280 μm thick one side polished) available at almost no cost from the semi-conductor industry. The size perfectly matches the 40-44 mm active diameter of 50 mm MCP. A simple mask was designed to evaporate four sub micron thick copper collection stripes (fig. 1).

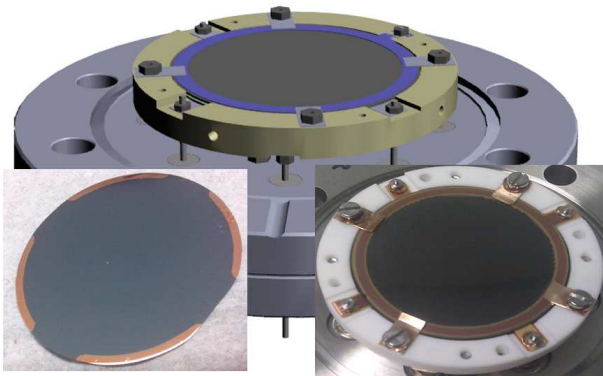


FIG. 1. designer view of the detector mounted on eight 5 kV UHV feed-throughs threaded on the vacuum side. The insets are photos of the resistive anode (lhs), a two inch silicon wafer with four collection anodes made of evaporated copper and of the assembled detector (rhs) the four large head screws press the assembly while contacts are made by the small nuts.

or LEIS, the required spatial resolution is needed only to

IV. THE VACUUM-SIDE ASSEMBLY

The eight high voltage feed-troughs that support the detector are welded directly on the DN63CF flange. Four are used to bias a two MCP stack and four are used to connect the four copper, charge collection stripes of the anode. The stems of the feed-throughs on the vacuum side were threaded for 1.4 nuts before welding allowing tight and short UHV connections. As shown on the inset on fig. 1 the detector structure is a 7 mm thick ring made of Macor or PEEK with the MCP on top and the collector on the bottom side. The detector is sitting on the four anode connectors and compressed by the four other ones connecting the MCP's with copper coated kapton rings. The MCP stack as well as the collector are compressed independently by four flat pieces of CuBe acting as springs so that the detector can be assembled either separately or directly onto the flange acting as a holder.

V. FRONT END ELECTRONIC, ADC

The detector is designed to operate indifferently for neutrals, positive or negative ions (or electrons), provided that neither HV^+ nor HV^- exceed 5 kV while $HV^+ - HV^- \lesssim 2kV$. The decoupling and the readout electronic are placed close to the detector. This is easily achieved with modern printed circuit board (PCB) facilities offering custom machining of the PCB so these can be part of the mechanical structure. The assembly is made of three circular PCB. The first one (fig.2) holds the high voltage divider to bias the MCP's as well as the decoupling of the fast timing signal from the output of second MCP. This PCB is soldered to the flange by the four MCP feed-throughs.

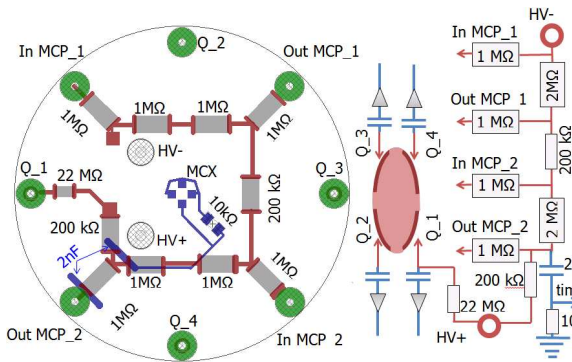


FIG. 2. Schematic view of the base PCB with the HV divider made of surface mount 1kV resistors on one side and the timing signal pickup (MCX connector) on the other side (blue). It includes MCP protection resistors, inter-plate acceleration and acceleration to the collector. The electrical connection is sketched on the right. The collector itself bias is biased only via one input with a 22 MΩ resistor.

The four other ones, connected to the anode, are

capped by the tip of a 1.55 mm ITT CANNON connector head and used as male connectors for the 2nd and 3rd PCB (see fig.3). The 2nd PCB imprisons the female connector in a plastic cylinder to allow flexibility. The PAC09 charge preamplifiers purchased at the Orsay institute of nuclear physics (IPNO) are connected to these pins via four 5 kV, 2 nF ceramic capacitor. These are soldered to 3rd PCB and compressed between the 2nd PCB and 3rd PCB. The third PCB holds all the connectors; two MHV high voltage connectors to bias MCP's, four SMA connectors for preamplifier outputs, a test input common to all preamplifiers and a SMA output for the fast timing signal. Grounding and shielding are achieved by a simple metal tubing fixed directly onto the flange. The contact with the top PCB turned out to be more tricky than expected and CuBe springs pressing the top PCB have been needed.

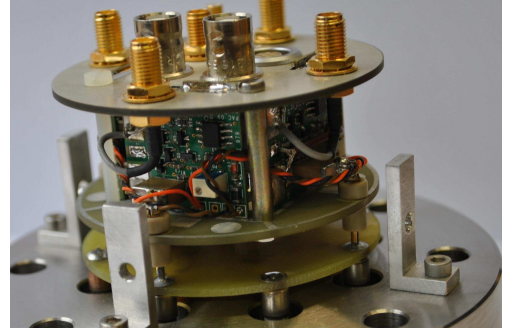


FIG. 3. Air side view of the front end electronic with the three PCBs holding the voltage divider, the charge preamplifier and all the connectors

The rest of the electronics is rather standard with four triangular shape linear amplifiers with a 2 μs shaping constant (also from IPNO). The analog to digital conversion is achieved with low cost NI6143, eight channels, 250 kHz simultaneous sampling ADC. The maximum count rate should therefore lie in the 100 kHz range. Higher count rate would require faster digitizer but would rapidly hit the pileup limit of the amplifiers. The cards offers an embedded 50 ns counter which could allow stand alone coincidence operation of two PSD. For better timing resolution, an additional electronics is needed but could be as simple as a time to amplitude converter fed in one of the four unused channels. The fast signal decoupled from second MCP is probably in the 1 ns range but could not be measured accurately on our test system.

VI. CALIBRATION AND ABERRATION CORRECTION

To calibrate the detector, a copper mask with an array of 0.5 mm holes every 3 mm is mounted 5 mm above the 1st MCP which was then grounded. The large size of the holes is to allow efficient illumination by a 2 keV Ar^+ beam. At variance, the central hole is only 0.1 mm in diameter allowing resolution information. The image in fig-

ure 4 is obtained with the standard formula (eq. 1) where Q_i are the four charges. The image displays all ion impact illuminating 145 holes. It shows a good occupancy of the electrical space together with very important distortions. The measured size of the central spot imaging the $100\ \mu\text{m}$ hole is $200\ \mu\text{m}$ fwhm suggesting an intrinsic resolution of $150\ \mu\text{m}$ fwhm which compares with that of aberration free anode operated with two MCP ref.¹².

$$X = \frac{Q_{left} - Q_{right}}{2 \sum_i Q_i}, Y = \frac{Q_{bottom} - Q_{top}}{2 \sum_i Q_i} \quad (1)$$

To recover a correct image, we have used brut force; each observed spot is fitted by a 2D gaussian and is associated to integer indexes i, j , then a 4th order polynomial (eq. 2) is optimized to adjust X, Y observed values to X', Y' values sitting on the mask position (fig.4).

$$X' = \sum_i \sum_j a_{mn} X^m Y^n, Y' = \sum_i \sum_j b_{mn} X^m Y^n \quad (2)$$

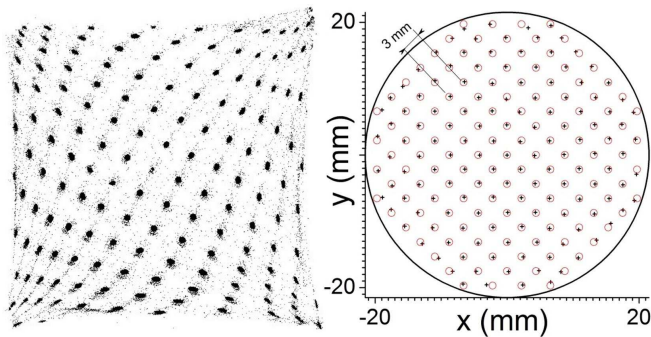


FIG. 4. Left is a raw image of all impact through the mask. After correction by formula 2, the image on the right shows that most of the spots centers are within $500\ \mu\text{m}$ of their ideal position as illustrated by the 1 mm circles sitting at mask locations. The 43 mm circle is only to guide the eyes.

VII. CRITICAL ANALYSIS

The outstanding quality of the mono-cristalline Si Wafer did not turn out to make a perfect collector. The measured level of distortions is larger than the one obtained in preliminary electrical tests using evaporated Ge or even painted carbon film suggesting that amorphous materials could give better results. Since kapton printed circuit are now easy to purchase from PCB industry, simple layers evaporated carbon or Ge could be a better choice and will be tested. The threaded feed-throughs are excellent to compress the detector but those connecting the anode and used in compression would probably

be easier to adjust with, for instance, male twist pins crimped on the stems and inserted into perforated screw. When additional space is available, a fourth PCB layer hosting linear amplifiers could suppress the need of bulky NIM crate. Surface mount high voltage resistor was a success but the use high voltage multilayer ceramic capacitors (visible on fig. 3) should be avoided, indeed, the insulating resistance in the 10-100 M Ω range is too low so that, when operated at high voltage, the collector injects charges directly into the preamplifier which then display a significant noise. In the present form the first PCB holding the voltage divider is soldered on the flange. Applying the trick of capping the stem with a connector tip would allow easy removal of all PCB making air side final impedance check as well as bake-out more simple. The present design is rather conservative, the outer diameter is 64 mm which fits easily in the 70 mm of so called large bore 63CF flanges.

VIII. ACKNOWLEDMENT

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