Design and performance of a direct charge-collecting pixel sensor for gaseous beam monitors

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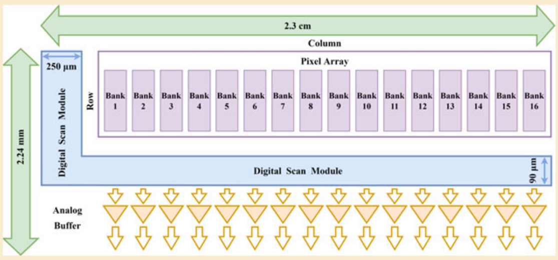
Introduction

The beam monitoring system, known as the eyes of the accelerators, plays a vital role in tuning and monitoring the beam in heavy-ion accelerators. Its function is to monitor the beam parameters to improve the beam quality. The gaseous detector with direct charge collecting pixel readout shows excellent potential for non-destructive beam monitoring since it can provide high spatial resolution and handle high flux beam rates. Hence, a novel silicon pixel sensor that can directly collect charge with avalanche amplification has been designed for future gaseous beam monitoring systems.

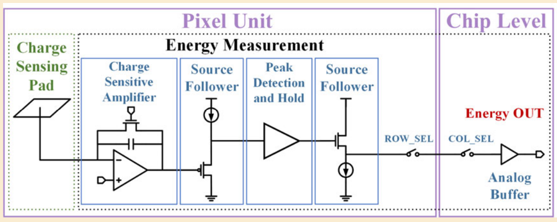
Design of the Silicon Pixel Sensor

This silicon pixel sensor ASIC uses 1P7M 130 nm CMOS technology. The main building blocks are the Pixel Array, the Digital scan Module and the Analog Buffer. The overall size is 2.24 mm x 2.3 cm. The Pixel Array comprises 28 rows x 768 columns of 29 um square pixels and it is divided into 16 regions, with each region consisting of 28 rows x 48 columns of square pixels. The Digital scan Module performs row and column scanning of the pixel array, which is L-shaped on the Pixel Array's lower and let sides. And it uses the Rolling shutter readout mode to scan the 16 regions simultaneously. Each region is equipped with an Analog Buffer, which transmits the energy information recorded by the pixels the outside of the ASIC.



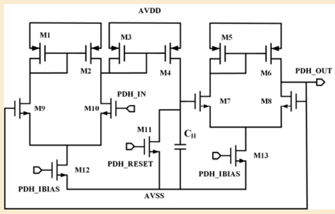
- Entire architecture

- Microscope photo



- The schematic block diagram of the pixel

The charge signal collected on the Charge Sensing Pad is directly DC-coupled into the Charge Sensitive Amplifier. Then, the Peak Detection and Hold circuit, located in between two source followers, captures the CSA's peak output.



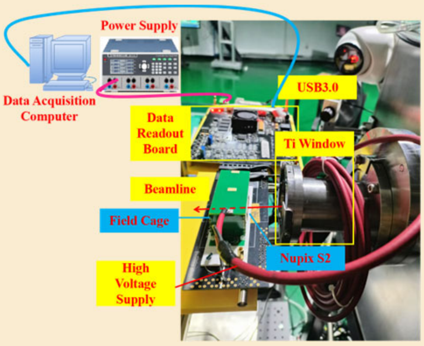
- Schematic of PDH

✓ an Operational Transconductance Amplifier
✓ a current mirror
✓ a charging capacitor
✓ a discharge switch
✓ a buffer

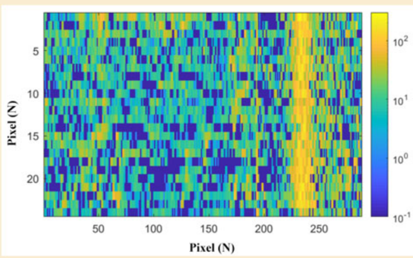
Heavy-ion Beam Measurement

The heavy-ion beam measurement platform of the ASIC was set up at Space Environment Ground Simulation Device in Ha erbin .

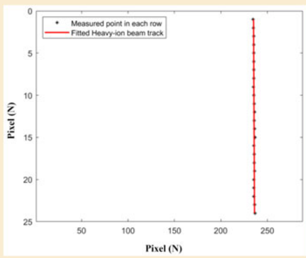
- ➢ The intensity of the beam is 2×10^3 ions /(cm^2·s).
- ➢ The heavy-ion is ^{181}Ta^{35+} .
- ➢ The energy is 10.3 MeV/u.
- ➢ LET is 82.1 MeV/(mg/cm^2).



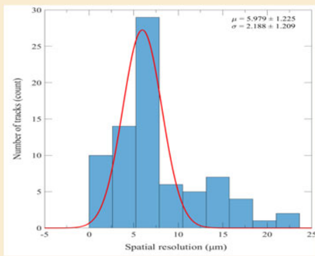
- The setup of test platform



- The reconstructed projection of a single ^{181}Ta^{35+} track



- Track fitting for a single ^{181}Ta^{35+} projection



- The resolution distribution histogram

We utilizes a 3×3 median filter to suppress noise in colourmap, which reconstructed routine of the heavy ion beam. Then, the values of all pixels are summed row by row to obtain a one-dimensional distribution of the collected charge. The center of mass position for each row of the track is obtained through this one-dimensional distribution. Subsequently, a fitted line is derived based on all the center of mass points, representing the true track. After obtaining the statistical histogram of track centroids, the position resolution (expressed as standard error) is calculated to be 5.98 μm.