Hi'Beam-SEE: a real-time high-resolution Single Event Effects locating device for heavy ion facilities

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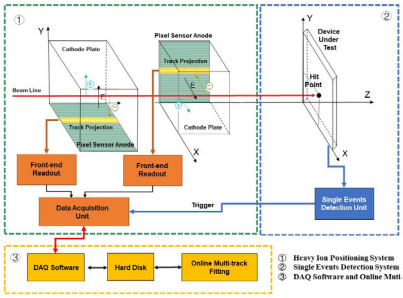
Introduction

Integrated Circuits(ICs) are widely used in satellites and aircraft. High energetic particles such as protons, electrons, and heavy ions will hit these devices, causing the Single Event Effect(SEE). The TR5 terminal on the Heavy Ion Research Facility at Lanzhou (HIRFL) is the largest SEE research facility in China, with the most variety of ions and the highest energy. The experimental terminals primarily serve the purpose of acquiring key parameters associated with SEE through the irradiation of integrated circuits via beam spot and beam flux. To meet the acquirement of SEE-sensitive areas location, an efficient micrometer-scale locating device for testing SEE in integrated circuits, named Hi'Beam-SEE, has been developed. The device can precisely locate the hitting position of each heavy ion generating SEE on the integrated circuit and obtain the SEE-sensitive area distribution of the integrated circuit.

Detection Principle

A beam traverses through the heavy ion positioning system, and the negative ions generated by the heavy ions ionized air are collected by the anode of the track detector under the electric field. The single events detection system can detect single event efforts occurring in the device under test and provides a trigger signal to the heavy ion positioning system.

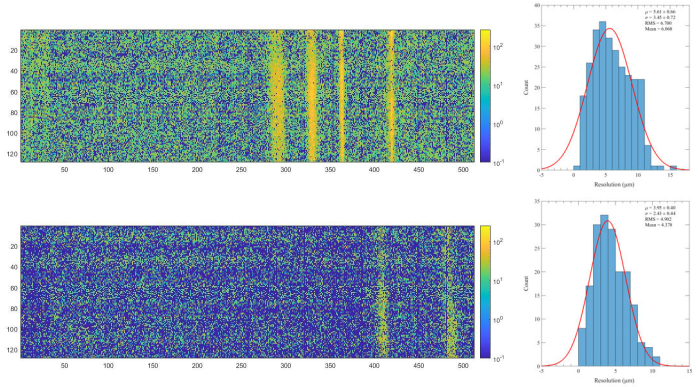


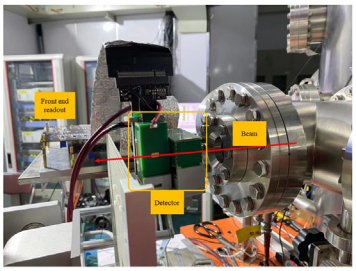
DAQ software read the data and store it, and the online muti-track algorithm processes the data to locate the track. The sensitive area of DUT can be given accurately by calculate the hit position.

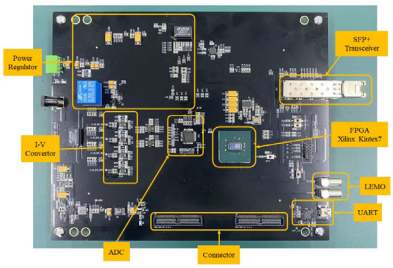
Test Setup and Performance

■ Heavy ion positioning system

The beam test has been carried out with $^{181}Ta^{35+}$ with energy of 16 MeV/u. The spatial resolution of measured single track are 5.61 ± 0.66 μm in XOZ planer and 3.95 ± 0.40 μm in YOZ planer.





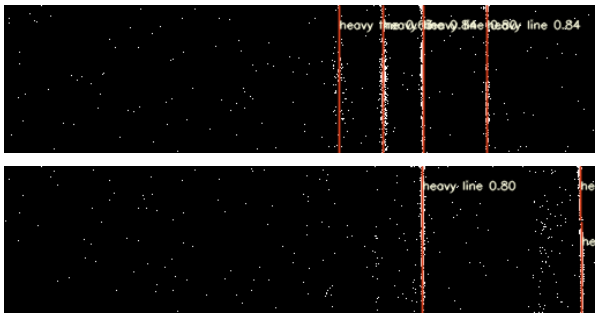


■ Single event detection system

The hardware design is implemented using a main control board and a daughter board. A set of LDO chips power the DUT through a sampling resister, and the voltage on resistor is amplified and sampled by the ADC to monitor the current of the DUT in real time. At the same time, the connector also reserves enough differential and single-ended interfaces to control DUT. The DAQ software is connected to the control main board via Ethernet or serial ports.

■ DAQ software and multi-track locating algorithm

DAQ software reads the data through PCIe from data acquisition unit, and transfer to hard disk. The data processing method first converts raw data into visual images . Then, the images are fed into the neural network. The network calculates the features of the image and gives the approximate location of the track. Then the center of gravity is calculated within the localization area using the track-fitting method to obtain an accurate track localization.



Conclusion

To meet the requirements on micrometer-level, high-efficiency localization of single event effects in integrated circuits, we have designed Hi'Beam-SEE for the single event effects experimental terminal at HIRFL. The pixel sensor based heavy ion positioning system tests with $^{181}Ta^{35+}$ ions achieve spatial resolution of better ~ 6 μm. A general-purpose single events detection board has been designed for SEU and SEL test. The algorithm demonstrates exceptional real-time processing capabilities, achieving a spatial resolution of ~ 4.54 μm in handling data and framework operates at an impressive 110+ fps on a single GPU.