Long-lifetime, wide dynamic range detectors for ion trap and Quadrupole mass spectrometers

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Introduction

Ion trap and quadrupole-based tools constitute most mass spectrometers. Most common detectors are electron multipliers which have limited lifetime. Other configurations require applying high voltage to a conversion dynode. Here we present two concepts for optically based dual-polarity detectors that have high sensitivity, long lifetime and wide dynamic range. Both concepts, that can be adapted for both traps and quads were built and tested with electron beam and are currently being tested in mass spectrometer.

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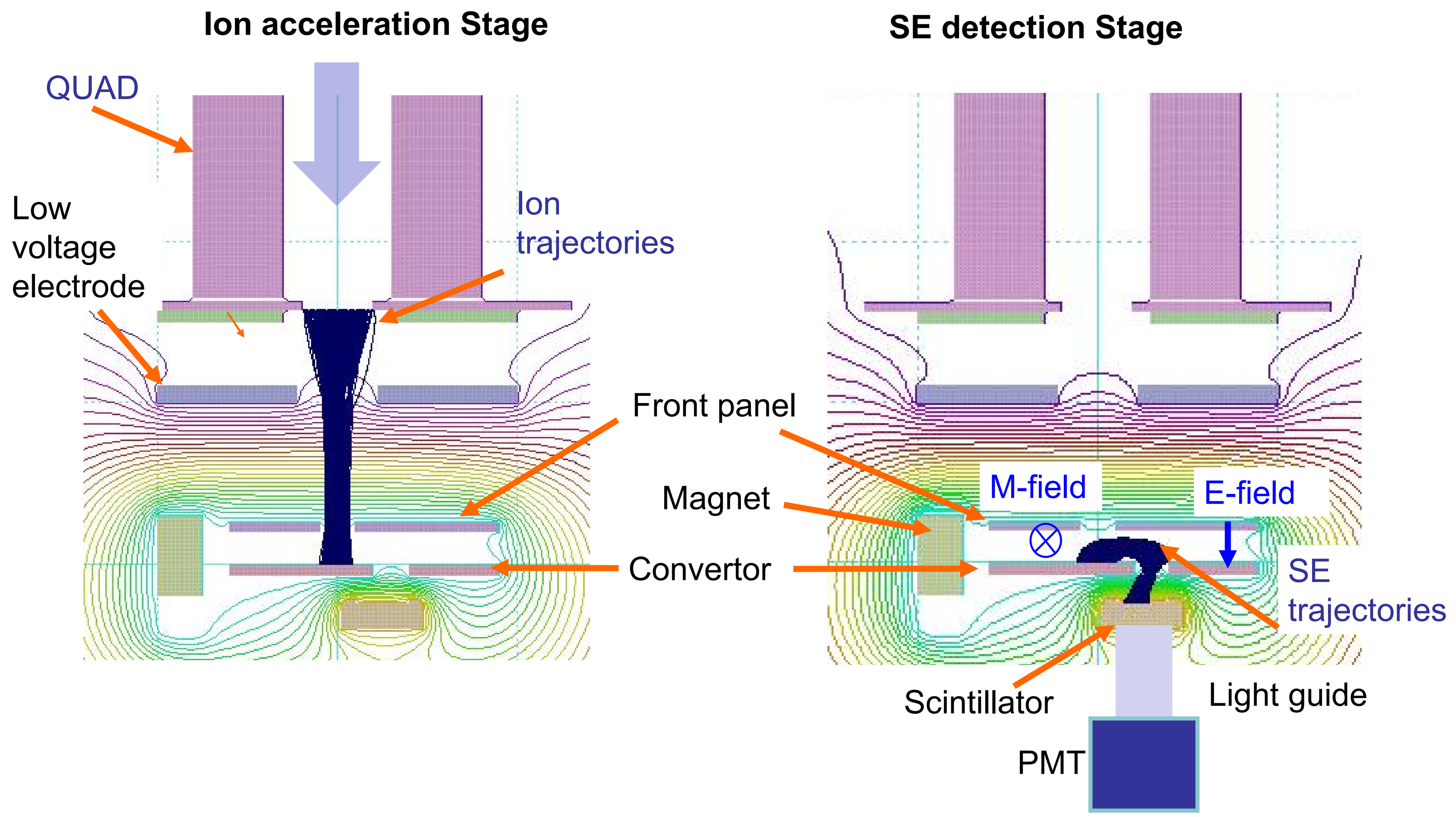
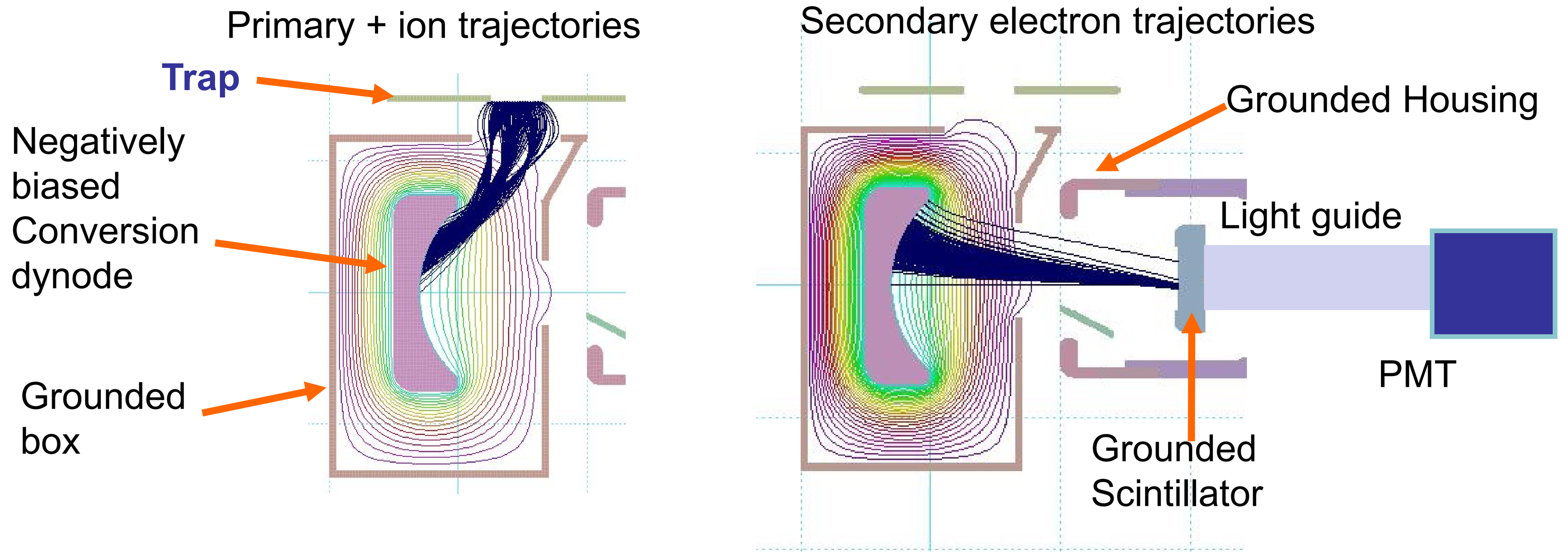
The Helitron™ concept

The Helitron™ concept is made of two steps: first step (left image) is to attract the low-energy ions from the source, focus and accelerate them to a metallic uncoated convertor. The convertor is biased negatively for positive ions and positively for negative ions. Low voltage electrode(s) placed between the ion source and convertor is screening the ion source from the convertor potential. The ions impinging the convertor generate secondary electrons (SE). The high impact energy ensures almost 100% detection efficiency.
In the second step (right image), the secondary electrons are attracted to an inorganic scintillator (ScintiFast™) using cross electric and magnetic fields. The electric field is determined by the voltage difference between the front panel and convertor. The fields are designed so only the low energy secondary electrons pass through an opening in the convertor and reach the scintillator. This ensures that ions do not reach the scintillator and degrade it. Light from the scintillator is coupled to PMT with specially designed active voltage divider.

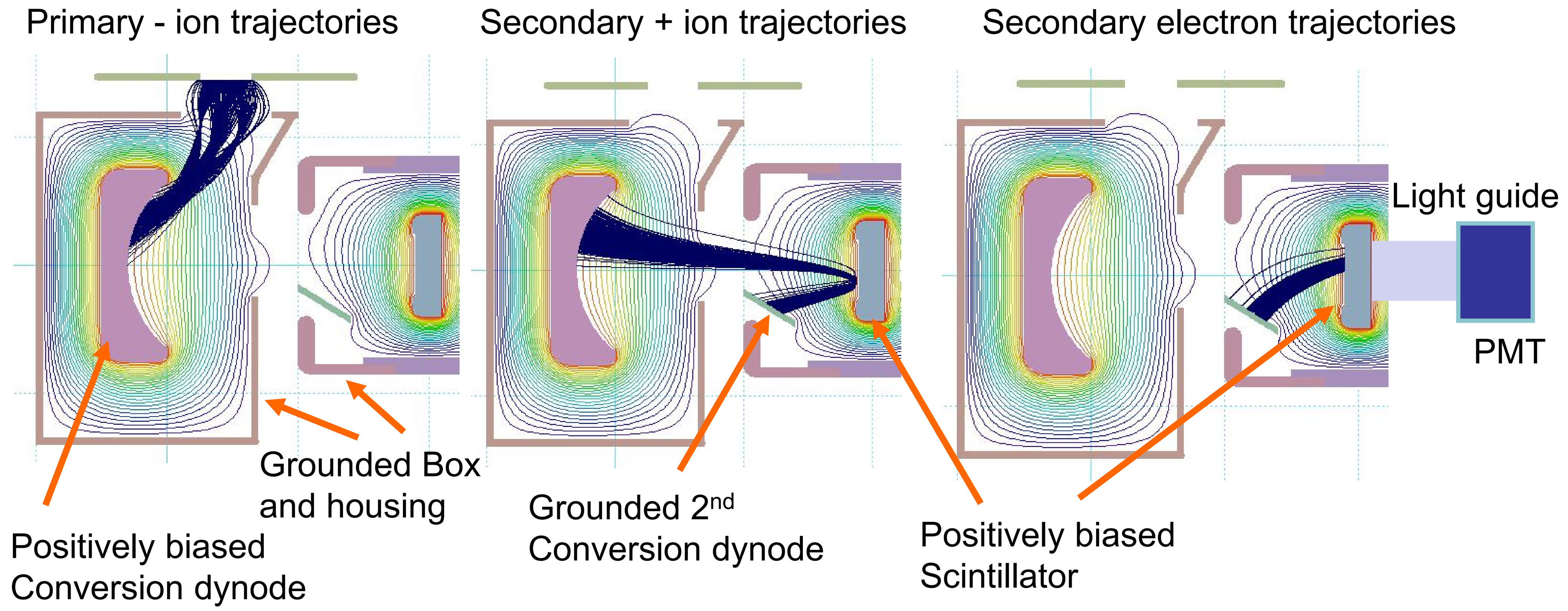


The Scintitron™ concept

The Scintitronn™ concept works differently for positive and negative ions. Positive ions are converted to SE on a negatively biased high voltage electrode. The SE are then focused to a scintillator at ground potential. The ground box design ensures 100% collection efficiency of the SE, and consequently almost 100% ion collection efficiency.



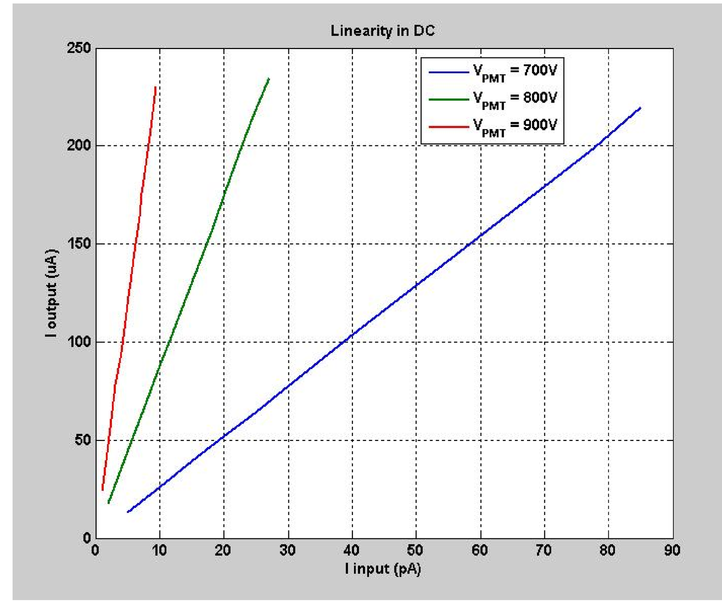
For Negative ions, double conversion takes place as shown in the figure below: the negative ions attracted to the positively biased electrode emits both secondary electrons and secondary ions (SI). Attracting the SE directly to the scintillator (as in positive ion polarity) requires scintillator biasing to very high positive voltage that may also affect the primary ions. The Scintitron™ solution is to attract the positive secondary ions towards the scintillator but since the scintillator does not emit light with ion impact, the SI are pushed by the scintillator positive voltage (slightly higher than the conversion dynode) to a 2nd conversion dynode and converted back to electrons. The final SE are attracted to the scintillator coupled to a PMT.



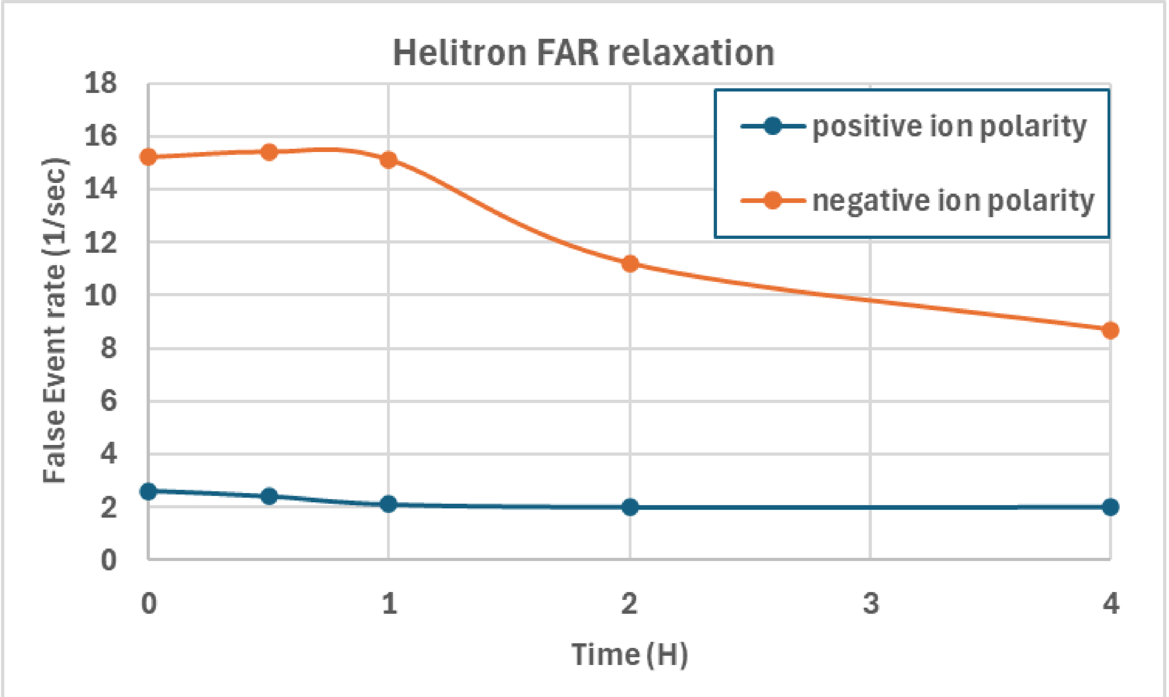
Results

These detectors are based on ScintiFast™ inorganic scintillator which is used for almost 10 years in detectors for Semiconductor SEM tools exposed to much higher currents than in traps and quads showing no signs of degradation.

Output linearity is achieved by using specially designed active PMT voltage divider. The figure below shows excellent linearity up to >200uA and was measured in DC mode on a sub-mount (scintillator – PMT) using electron-beam illumination.



False event rate (FAR) is a critical parameter for trap and quad detectors. In negative ion polarity, voltage differences are higher so false event rate is higher. The figure below, taken from a Helitron™ detector, shows that the FAR relaxes over a few hours from ramping up the detector voltages. These low FAR values further improve along time and remain low when the detector is ramped down and up again.



Conclusions

Two novel concepts for dual polarity detectors for ion trap and Quad systems were presented. Prototypes were built and tested, showing wide linear dynamic range, low noise, and long lifetime. Both concepts offer close to 100% ion detection efficiency.