Developments on the Toroid Ion Trap Analyzer

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A toroid ion trap analyzer has been constructed and preliminary results with the device have been presented previously (1). The advantages of this design are that for a given device radius (r_0), significantly higher ion storage capacity may be possible when this cross sectional trapping field is translated around a torus instead of a cylindrical rotation of the field as in the case of a traditional 3D quadrupole ion trap. An additional advantage may be that for significantly smaller radius devices, ion storage capacity may be comparable to that in a standard commercial 3D ion trap while allowing the operating rf voltage to be reduced dramatically. Finally, a new degree of freedom for the ion motion (around the toroid) may offer advantages in ion injection and ion activation,

While the toroid ion trap does function as a mass analyzer, resolution is not unit and under most operating conditions, the mass peaks exhibit notable splitting. Because of the curvature, additional non-linear tields complicate the trapping field. These non-linear fields may be the 'primary cause of the observed reduced performance. Other factors affecting the mass analysis performance may be machining imperfections on either the electrodes or spacers, a non-symmetrical trapping potential well (i.e. the potential well minimum is not in the physical center of the trap), and multiple, discrete trapping regions arising from the exit slit spacers in each endcap electrode. In addition, the multi-channel plate detector used for ion detection is expensive and also complicates the operation of the device. These and other limitations are currently being addressed in our research.

Investigations into several areas of research have been undertaken to address the performance limitations of the toroid analyzer. The Simion 3D6 (2) ion optics simulation program was used to determine whether the potential well minimum of the toroid trapping field is in the physical center of the trap electrode structure. The results (Figures 1) indicate that the minimum of the potential well is shifted towards the inner ring electrode by an amount approximately equal to 10% of the r_0 dimension. A simulation of the standard 3D ion trap under similar conditions was performed as a control. In this case, the ions settle to the minimum of the potential well at a point that is coincident with the physical center (both radial and axial) of the trapping electrodes. It is proposed that by using simulation programs, a set of new analyzer electrodes can be fashioned that will correct for the non-linear fields introduced by curving the substantially quadrupolar field about the toroid axis in order to provide a trapping field similar to the 3D ion trap cross-section. A new toroid electrode geometry has been devised to allow the use of channel-tron style detectors in place of the more expensive multichannel plate detector. Two different versions have been designed and constructed - one using the current ion trap cross-section (Figure 2) and another using the linear quedrupole cross-section design first reported by Bier and Syka (3).

References

(1) S.A. Lammert, M.B. Wise, C.V. Thompson, Presented at the 46ASMS Conference on Mass Spectrometry end Allied Topics. Orlando, FL 31 May – 4 June 1996

(2)David Dahl, Idaho National Engineering Laboratory

(3)Mark Bier and John Syka; U.S. Patent No.5,420,425 (30 May 1995)

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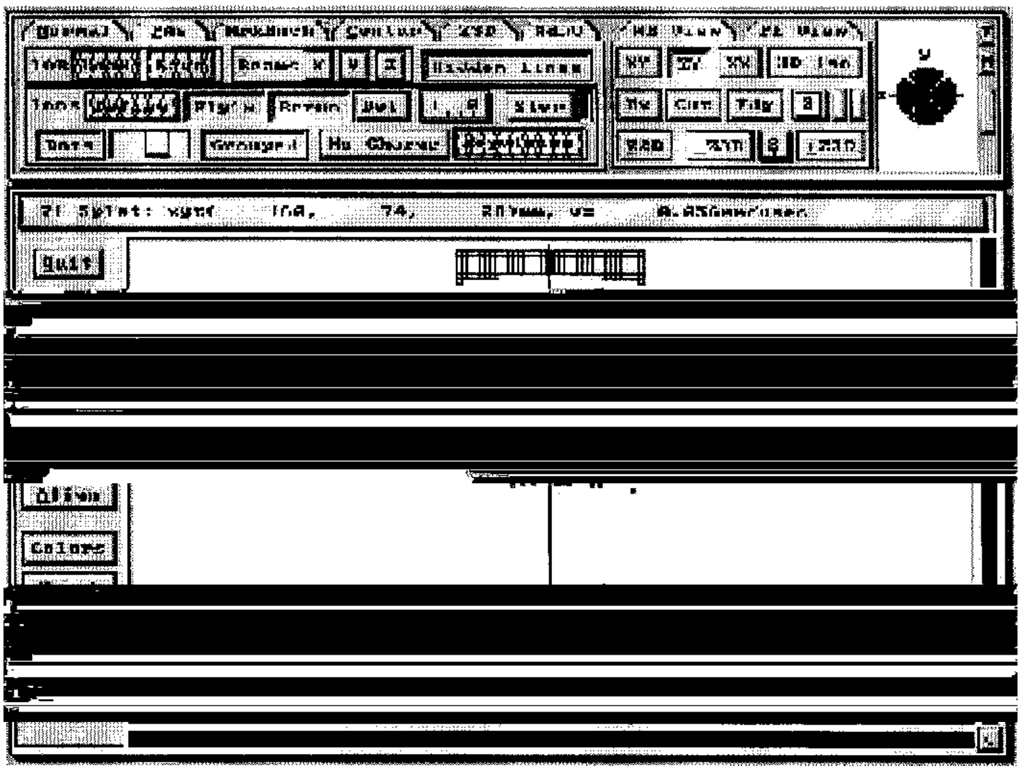

FIGURE 1: Toroid ion trap simulation showing final ion position at a point away (towards inner ring electrode) from the physical center of the toroid electrode structure (crosshair position)

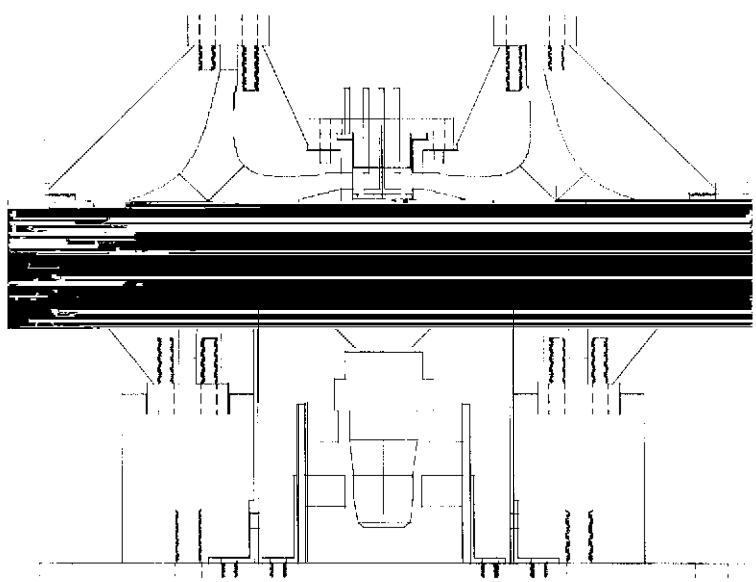

FIGURE 2: Schematic of new toroid analyzer geometry that allows use of standard electron multiplier in place of multichannel plate detector