# Design of ring-cathode focused electron beam columns

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In the search for a focused electron beam column that is capable of providing both high spatial resolution (< 20 nm) and high probe current (> 1 μA), source cathode emission area is an important parameter. At present, conventional electron beam focused columns are not designed to make use of large area field emitter techniques, such as those that fabricate patterned Carbon Nanotube (CNT) arrays[1]. This paper presents focused electron beam columns designed to make use of ring-cathode emission, where the radius of the ring ranges up to several hundred microns and its edge diameter is typically less than 100 nm. The cathode area of emission is approximately four orders of magnitude greater than that of conventional field emitter cathodes, and therefore should be capable of generating micro-ampere total probe currents. In order to achieve spatial resolution in the tens of nanometer range, simple techniques of off-axis aberration correction are required.

Figure 1a shows a schematic diagram of the cathode-ring layout. Since the cathode-ring is rotationally symmetric, the current along the ring circumference will be suppressed and electrons are expected to travel primarily in radial directions in the r-z plane. The ring-cathode radius is set to 200 μm. Figure 1b depicts the ring-cathode biased to -10,000 V in a simple electric Einzel objective lens column. The ring-cathode is surrounded by a suppressor electrode at -10,620 V. In the exit bore of the Einzel lens, there is a geometrical aberration corrector unit that consists of an on-axis 0 V electrode surrounded by a positive voltage electrode (168 V). An annular aperture at the exit of the corrector unit controls the angular spread/energy spread that reaches the specimen. Figure 1c shows direct ray tracing of electrons leaving a 50 μm high cathode-ring with initial angles ranging from -50 to +50 mrad for an emission energy of 0.2 eV. The voltages on the suppressor, focusing and corrector electrodes have been carefully adjusted in order to minimize first-order and second-order geometrical aberrations. Correction of these aberrations is made possible by the divergence action of the anode aperture lens and corrector unit. Figure 1d shows the simulated probe radius as a function of angular spread at the specimen, indicating that residual third-order variations are obtained. If a normal emission energy distribution with a FWHM of 0.2 eV is assumed, a simulated probe diameter of 16.5 nm is obtained for an energy range of 0.05 to 0.4 eV and annular aperture radii of 101 to 113 μm. The paper will present simulation details, different types of ring-cathode layouts and other feasible column designs.

## References

[1]Lacobucci *et al*, *Applied Physics Letters* **100**, 053116 (2012)

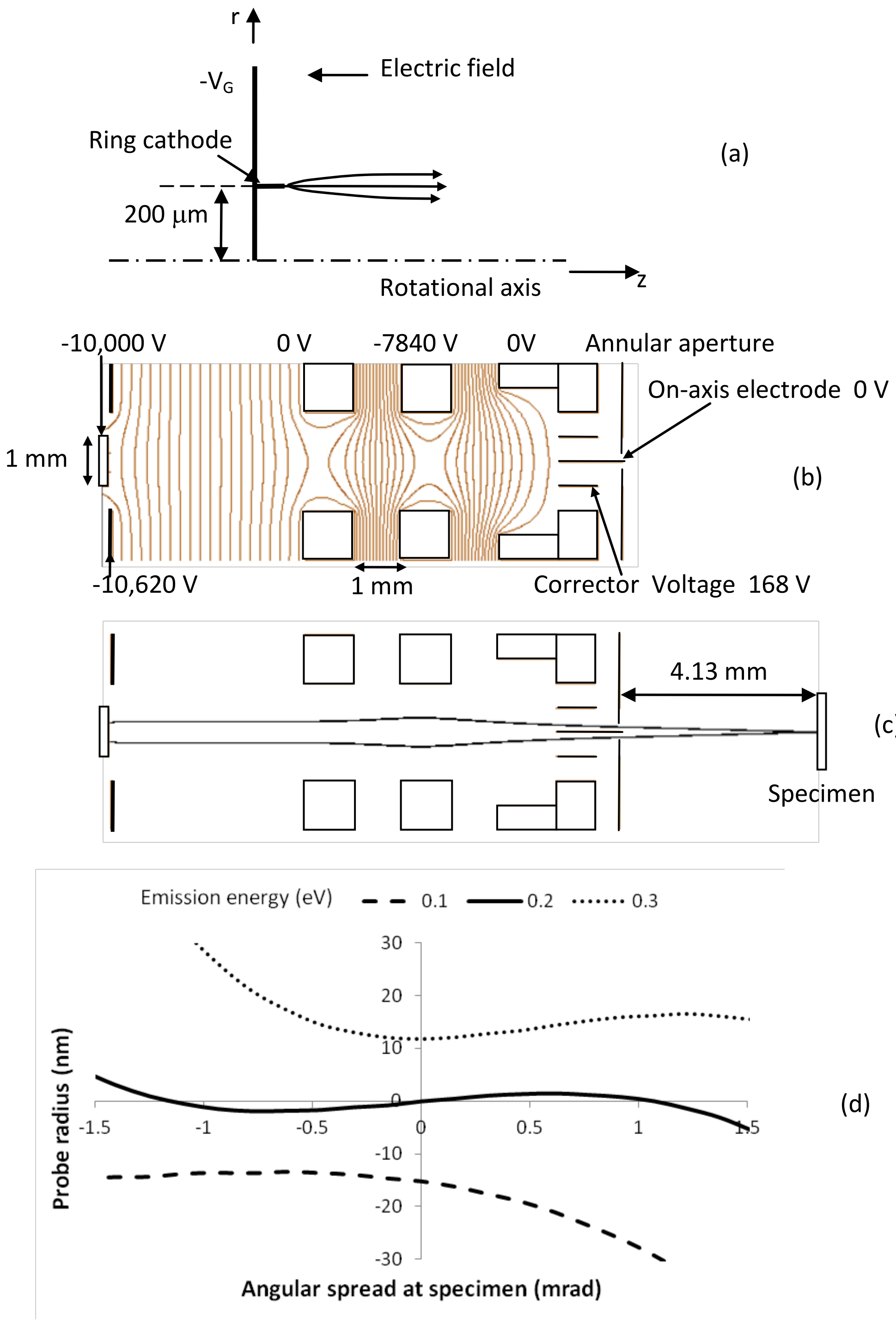


*Figure 1: Simulation of a ring-cathode focused electron beam column*

(a) Schematic of the emission plane (b) Equi-potential-lines (c) Direct ray tracing of electrons with an initial angular spread between -50 to 50 mrad and emission energies of 0.1, 0.2 and 0.3 eV (d) Probe radius as a function of angular spread at the specimen.