Purpose: To evaluate the effectiveness of electrostatic mechanisms for controlling the focal spot position in X-ray tubes operating in the fringe field of an MR bore, and to determine a cathode design to implement the correction mechanism while not compromising normal X-ray tube operation.

Methods: Using a combination of theoretical calculations and high voltage vacuum standoff constraints, a cathode design was derived that is practical for standard X-ray tube geometry. The crucial part of the design consists of two voltage-biased deflection electrodes placed adjacent to the cathode. Space charge beam simulations were performed for the design to determine current density changes and beam deflection in the presence of a magnetic field. Phase space information from the beam simulation was input into a Monte Carlo engine to determine the effect of the cathode design on the X-ray photon energy spectrum.

Results: For a 0.07T magnetic field, a 120 kV cathode-anode potential, a 14.4 mm cathode-anode separation distance, and a 35 kV electrode potential, the deflection of the X-ray tube focal spot is within 2 mm of the original position with slight distortions to focal spot shape. However, the curvature of the electron trajectories is altered resulting in a significant velocity component tangential to the anode that is on average 10 times larger than in the control case. The electron velocity changes coupled with slightly lower current density on the anode reduces the total number of photons generated by 7.5% without significantly altering the energy spectrum of the X-ray photons.

Conclusions: The beam simulations demonstrate that focal spot deflection can be controlled to within reasonable values. The generated spectrum is not significantly different from that of a standard X-ray tube, with only a moderate decrease in overall photon fluence. Work is underway to evaluate the cathode design in an experimental setting.

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