A Modular Multi-Source X-ray Tube for Novel Computed Tomography Applications

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A modular implementation of a scanning multi-source x-ray tube is designed for the increasing number of multi-source imaging applications in computed tomography (CT). An electron beam array coupled with an oscillating magnetic deflector is proposed as a means for producing an x-ray focal spot at any position along a line. The preliminary multi-source model includes three thermionic electron guns that are deflected in tandem by a slowly varying magnetic field and pulsed according to a scanning sequence developed for a high-speed CT scanner. Particle tracking simulations with particle dynamics analysis software demonstrate that three 100 KeV electron beams are laterally swept a combined distance of 15 cm over a stationary target with an oscillating magnetic field of 102 G perpendicular to the beam axis. Beam modulation is accomplished using 25 μs pulse widths to a grid electrode with a reverse gate bias of -500 V and an extraction voltage of +1000 V. Projected focal spot diameters are approximately 1 mm for 138 mA electron beams and the stationary target stays within thermal limits for the 14 kW module. This concept could be used as the basis for increasing scan throughput for high-speed stationary CT scanners, for lowering dose with virtual fan beam formation, for reducing scatter radiation in cone-beam CT, or in other industrial applications.

A benchtop implementation of the multi-source x-ray tube model is subsequently developed to demonstrate proof of concept for the system. Particle tracking simulations for the benchtop system demonstrate that three 80 KeV electron beams are able to be focused and laterally swept a combined distance of 15 cm over a stationary target with an oscillating magnetic field of approximately 60 G. Beam spot diameters are approximately 1 mm for 27 mA beams and the stationary target stays well within thermal limits. The relevant hardware and control circuits were developed for incorporation into a physical prototype, including the development of a programmable high voltage bi-polar square wave pulser for electron beam gating. The particle tracking, electromagnetic, and thermal simulations inform the design of a 2.2 kW benchtop system that is currently under construction.