

## Multibeam x-ray source array based on carbon nanotube field emission

Otto Zhou, Jianping Lu, Xiomara Calderon-Colon, Xian Qian, Guang Yang, Guohua Cao, Emily Gidcumb, Andrew Tucker, Jing Shan, Derrik Spronk, Frank Sprenger

Department of Physics and Astronomy, Curriculum in Applied Sciences and Engineering, Department of Biomedical Engineering, Lineberger Comprehensive Cancer Center, and Carolina Center for Cancer Nanotechnology Excellence, University of North Carolina, Chapel Hill, NC 27599, USA.

**Purpose:** We recently demonstrated the feasibility of generating high current and high energy x-ray radiation using field emitted electrons from the carbon nanotubes (CNTs). The purpose of the present work is to develop a spatially distributed multiple beam x-ray array technology for stationary tomography imaging, including digital breast tomosynthesis, with the goal of increasing the spatial resolution and scanning speed.

**Method and Materials:** CNT cathodes fabricated by patterned electrophoretic deposition were used as the field emission electron source for x-ray generation. Computer simulations and experimental measurements were carried out to design the electrostatic lens to focus the field emitted electrons to the predetermined area on the metal anode. Finite element analysis was performed to determine the anode heat load under the desired operation conditions. Spatially distributed x-ray source arrays with one- and two- dimensionally distributed focal spots were constructed using matrix addressable multi-pixel CNT cathode, and corresponding focusing and anode structures. By varying the extraction electrical field, x-ray radiation with programmable waveform was readily generated which can be gated with external triggers such as physiological signals with sub-microsecond response time. Dedicated control electronics were designed and manufactured to switch, scan, and regulate the x-ray beams.

**Results:** Several spatially distributed field emission x-ray source arrays with different configurations and performance parameters have been fabricated and characterized for different imaging systems. Stable operation at anode voltage up to 160kVp has been achieved. Through improvement of the CNT cathode and electronic regulation beam-to-beam consistency in intensity and focal spot size has been demonstrated. A dedicated x-ray source array has been designed and fabricated for stationary digital breast tomosynthesis. The source comprises 31 individually controllable x-ray beams covering 30 degrees viewing angle, allowing collection of the all the projection images from different angles without any mechanical motion blur. It is operated up to 50KVp anode voltage at an effective focal size comparable to that of the traditional mammography tube. Tomosynthesis images of a breast phantom were obtained using the new source array and a flat-panel x-ray detector.

**Conclusion:** The distributed field emission x-ray source array technology offers unique capabilities that are attractive for tomography imaging and potentially for radiotherapy. The flexibility in source configuration opens up new possibilities in system design.

**Conflict of Interest (only if applicable):**

Zhou is a board director of XinRay Systems which develops and commercializes the CNT X-Ray source technology.