Carbon Nanotube Vacuum Electron Radiation Sources

X. S. Yuan[1,2]*, Y. Yan[2], W. I. Milne[1], & M. T. Cole[1]*

Simulating nano-CNT Field Emitters

Based on large area carbon nanotube (CNT) field electron emission experimental results, we have simulated CNT field emission using a numerical fitting method and 3D PIC simulation software; critical techniques in developing pragmatic emission models for design-centric CNT-based field emission vacuum electron devices which can be parametrically optimised to maximise the emission current density.

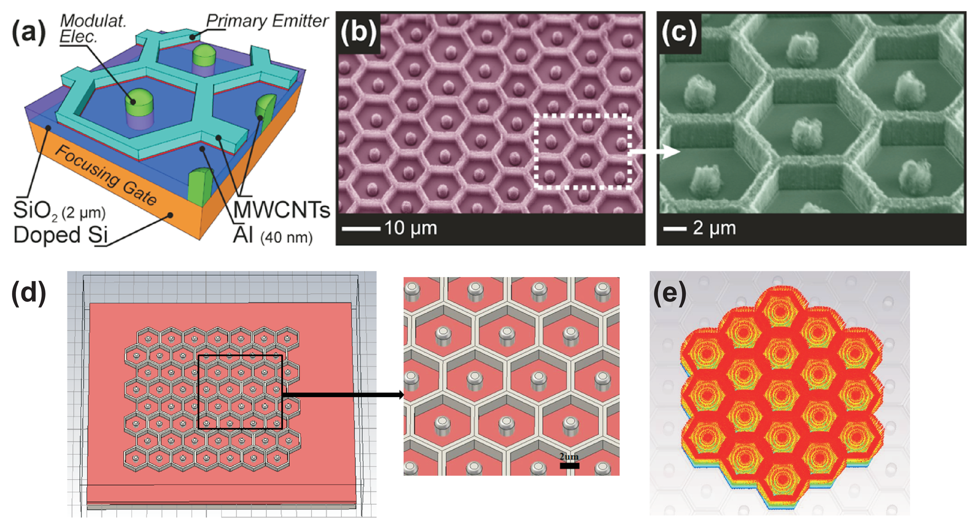


Figure 1. (a-c) A typical hexagonal CNT forest field emitter, corresponding (d) model and (e) beam trajectories

CNT-based Magnetic Injection E-Gun

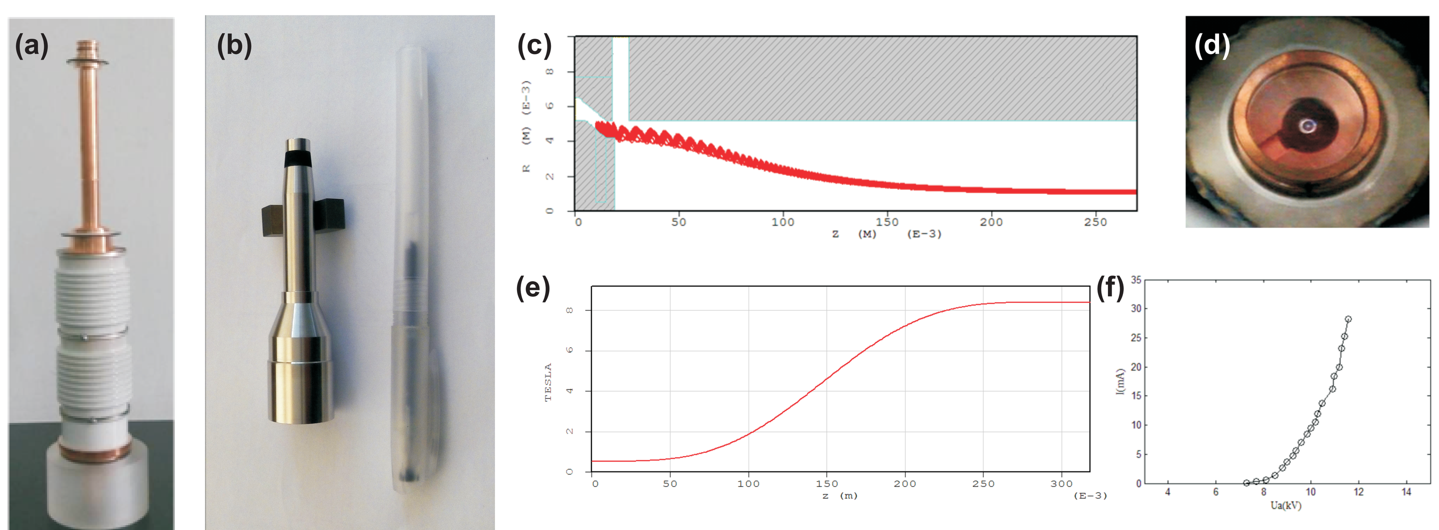
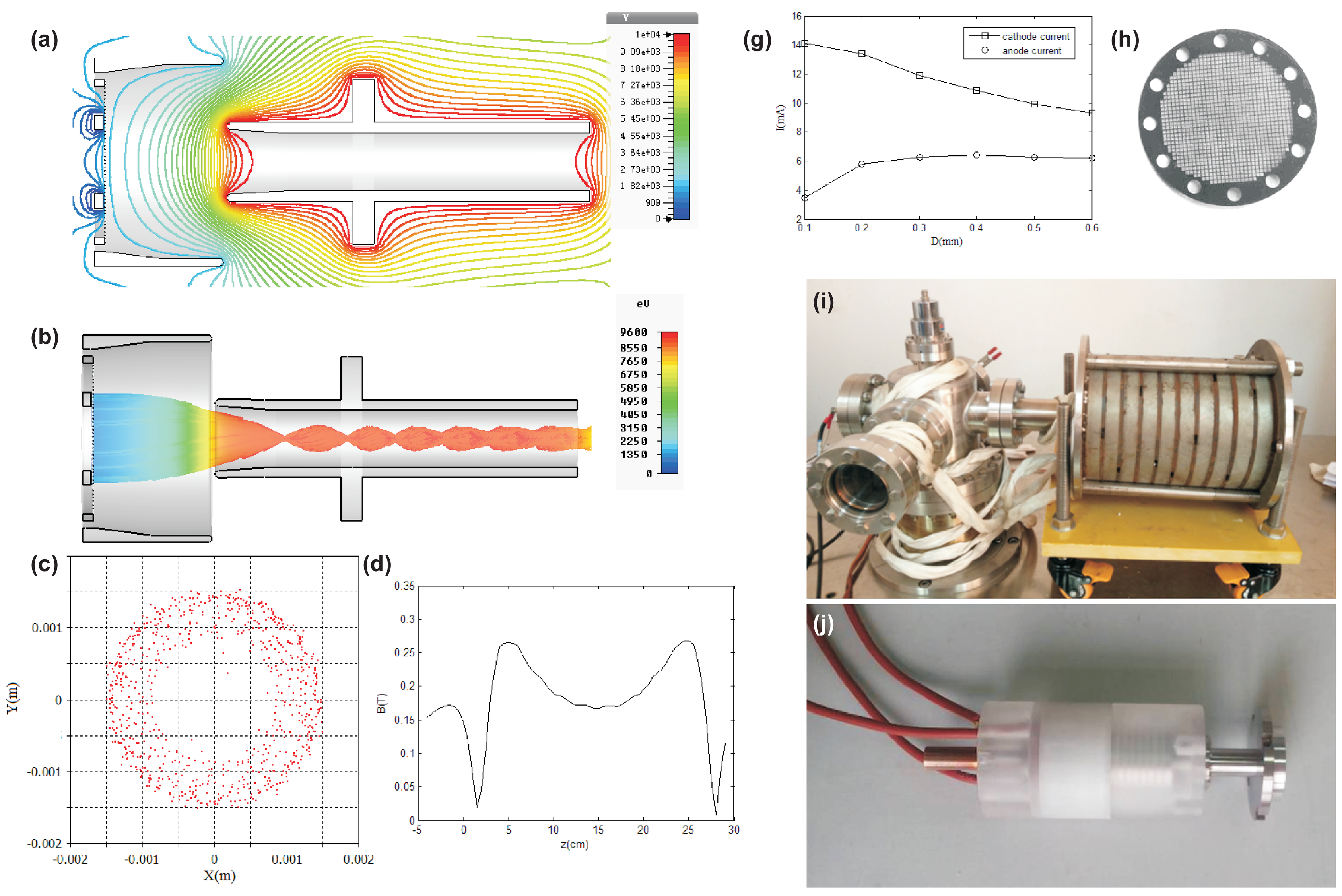


Figure 2. (a) The developed double-anode magnetic injection CNT-based electron gun, (b) the cold cathode, (c) beam trajectories, (d) beam spot, (e) the simulated on-axis magnetic field, and (f) the field emission current vs. control anode voltage.

A double-anode magnetic injection CNT electron gun has been investigated to develop various field emission vacuum electron radiation sources, including gyrotrons and gyro-TWTs. A truncated cone CNT cold cathode and a crossed E-B device is central to the operation of the gun. Such devices have no extraction grid, reducing manufacturing complexity and cost, whilst also allowing for field emission currents in excess of 100 mA in a coaxial diode setup.

A Gated CNT Electron Gun



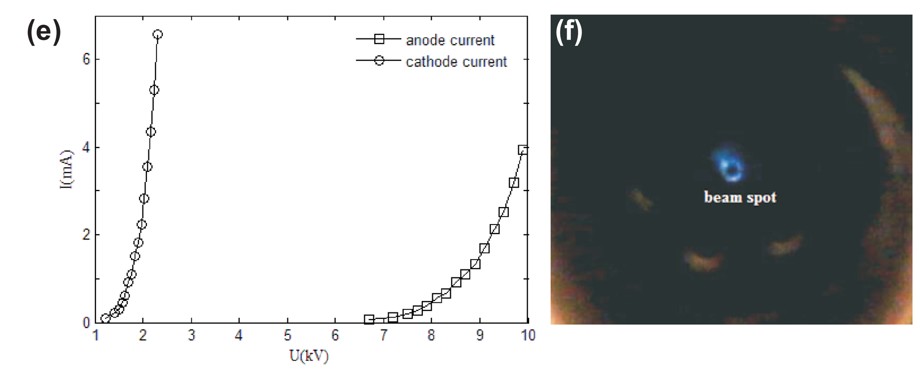
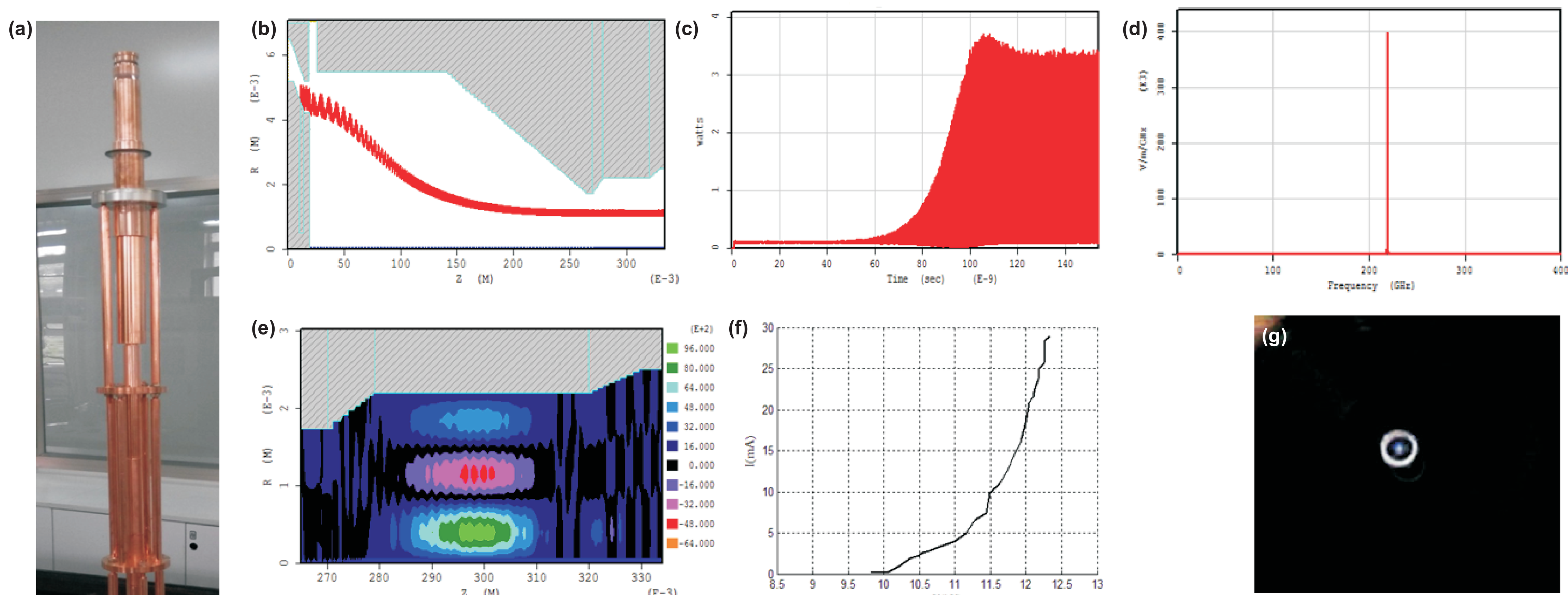


Figure 3. (a) Electrostatic potential distribution and (b) beam trajectories, (c) beam phase space at output port plane, (d) on-axis permanent magnetic field, (e) emission current and anode current. (f) measured beam spot size. (g) Variation in beam current with gate aperture size. (h) Photo of the stainless-steel gate grid. Photo of the (i) system, and (j) the gated CNT electron gun.

A gated CNT cold cathode electron gun has been investigated in order to develop vacuum power electronics devices, such as Travelling Wave Tubes, Backward Wave Oscillators, and Xray sources. A planar grid gate annular CNT cold cathode was used and optimised for maximal compression ratios using PIC simulations. A 4 mA / 10 kV annular electron beam with an average radius of 1.75 mm has been demonstrated based on a permanent magnet design. The area compression ratio of the electron beam was approximately 10.

A 220 Ghz CNT Cold Cathode Radiation Source



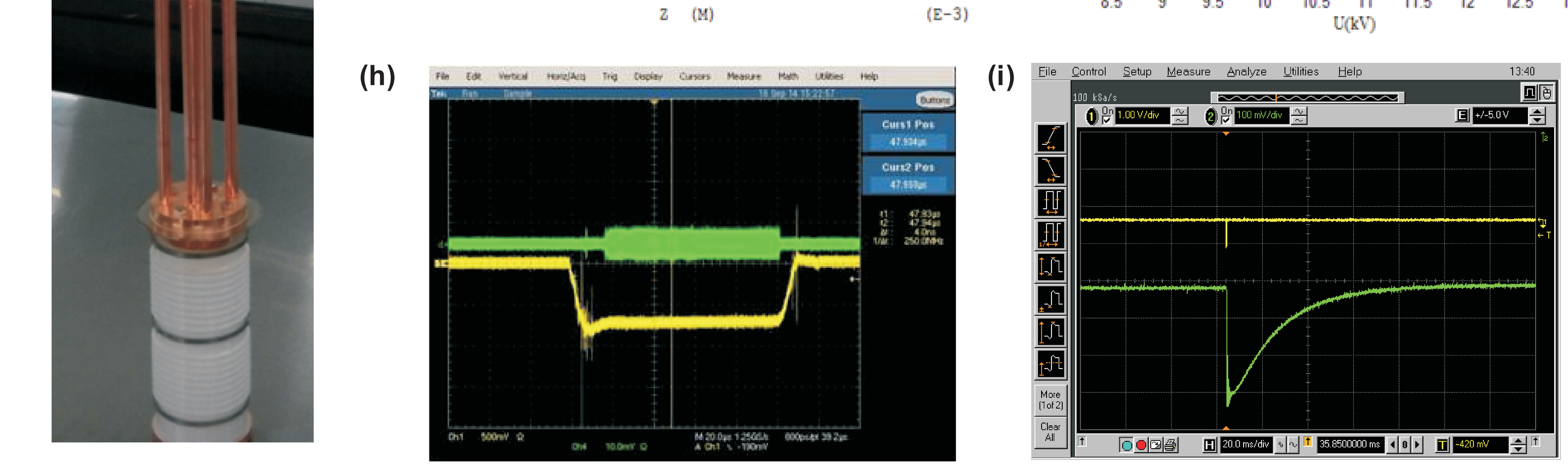


Figure 4. (a) Photo of the 220GHz CNT cold cathode radiation source, (b) beam trajectories, (c) output power, (d) operation frequency, (e) TE03 operation mode, (f) emission current vs. control anode, (g) beam spot, (h) frequency mixer test, (i) output power signal and pulse high voltage signal.

A 220 GHz CNT cold cathode radiation source has been developed that makes use of magnetic injection CNT-based electron guns. Electrons are emitted from the CNT cold cathode in the crossed electric and magnetic fields, forming a cyclotron motion and a resulting electron beam. By magnetic compression, a field emission electron beam generates cyclotron resonance in the electron beam in a MASER process within the cylindrical waveguide resonator. The device operates at a TE03 cavity mode with experimental results demonstrating that the operation frequency is 219.86 GHz with an output power of around 500 mW.

References

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Acknowledgements

This work was supported by the National Basic Research Program of China (No. 2013CB933603).

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[1]Electrical Engineering, Department of Engineering, University of Cambridge, 9 JJ Thomson Avenue, Cambridge, CB3 0FA, United Kingdom
[2]School of Physical Electronics, University of Electronic Science and Technology of China, North Jianshe Road, Chengdu, 610054, China
*yuanxs@uestc.edu.cn / mtc35@cam.ac.uk