CLAIMS

What is claimed is:

1. A plasma source comprising:

at least three hollow cathodes, including a first hollow cathode, a second hollow cathode, and a third hollow cathode, each hollow cathode having a plasma exit region; and

a source of power capable of producing multiple output waves, including a first output wave, a second output wave, and a third output wave, wherein the first output wave and the second output wave are out of phase, the second output wave and the third output wave are out of phase, and the first output wave and the third output wave are out of phase;

wherein each hollow cathode is electrically connected to the source of power such that the first hollow cathode is electrically connected to the first output wave, the second hollow cathode is electrically connected to the second output wave, and the third hollow cathode is electrically connected to the third output wave;

wherein electrical current flows between the at least three hollow cathodes that are out of electrical phase;

wherein each hollow cathode alternately serves as anode and cathode when powered by the multiple output waves, and

wherein the plasma source is capable of generating a plasma between the hollow cathodes.

2. The plasma source of claim 1,

wherein the plasma generated by the plasma source includes active electron emission for at least 80% of a period of the multiple output waves.

3. The plasma source of claim 1,

wherein the plasma generated by the plasma source includes active electron emission for at least 90% of a period of the multiple output waves.

4. The plasma source of claim 1,

wherein the plasma generated by the plasma source includes active electron emission for 100% of a period of the multiple output waves.

5. The plasma source of claim 1, wherein the at least three hollow cathodes are out of electrical phase by a phase angle different from 180°.

6. The plasma source of claim 1, wherein the at least three hollow cathodes are out of electrical phase by a phase angle of 120°.

7. The plasma source of claim 1, wherein each adjacent pair of the at least three hollow cathodes is out of electrical phase by the same phase angle as each other adjacent pair of the at least three hollow cathodes.

8. The plasma source of claim 1, wherein the at least three hollow cathodes are linear hollow cathodes.

9. The plasma source of claim 1, wherein the at least three hollow cathodes each include elongated cavities.

10. The plasma source of claim 1, wherein the plasma exit region for each of the at least three hollow cathodes includes a plurality of plasma exit orifices.

11. The plasma source of claim 1, wherein the plasma exit region for each of the at least three hollow cathodes includes a plasma exit slot.

12. The plasma source of claim 1, wherein the at least three hollow cathodes are each electrically insulated such that only interior surfaces of the hollow cathode and the plasma exit region are electron-emitting and -accepting.

13. The plasma source of claim 1, wherein virtually all the generated plasma flows through the plasma exit region of each of the at least three hollow cathodes

14. The plasma source of claim 1, wherein current flow is comprised of electrons derived from secondary electron emission.

15. The plasma source of claim 1, wherein the current flow is comprised of electrons derived from thermionic-emitted electrons.

16. The plasma source of claim 1, wherein the at least three hollow cathodes are linearly arranged.

17. The plasma source of claim 1, wherein the at least three hollow cathodes are configured to direct each of the plasma exit regions to a common line.

18. The plasma source of claim 1, wherein a distance between each pair of the at least three hollow cathodes is the same distance.

19. The plasma source of claim 1, wherein the electrical current flowing between the at least three hollow cathodes that are out of electrical phase is a result of an electric potential difference between the at least three hollow cathodes.

20. The plasma source of claim 19, wherein the electric potential difference is at least 50V between any two of the at least three hollow cathodes.

21. The plasma source of claim 19, wherein the electric potential difference is at least 200V between any two of the at least three hollow cathodes.

22. The plasma source of claim 1, wherein the multiple output waves comprise square waves whereby the electric potential difference is reduced relative to sinusoidal waves for the same overall power input.

23. The plasma source of claim 1, wherein the source of power is in the form of AC electrical energy.

24. The plasma source of claim 1, wherein the source of power is in the form of pulsed electrical energy.

25. The plasma source of claim 1, wherein the generated plasma is uniform over its length in the substantial absence of magnetic-field driven closed circuit electron drift.

26. The plasma source of claim 1, wherein the plasma is made uniform over its length from about 0.1 m to about 1 m.

27. The plasma source of claim 1, wherein the plasma is made uniform over its length from about 1 m to about 4 m.

28. The plasma source of claim 1, wherein the frequencies of each of the multiple output waves are equal and are in the range from about 1kHz to about 500MHz.

29. The plasma source of claim 1, wherein the frequencies of each of the multiple output waves are equal and are in the range from about 1kHz to about 1MHz.

30. The plasma source of claim 1, wherein the frequencies of each of the multiple output waves are equal and are in the range from about 10kHz to about 200kHz.

31. The plasma source of claim 1, wherein the frequencies of each of the multiple output waves are equal and are in the range from about 20kHz to about 100kHz.

32. The plasma source of claim 1, wherein the electrons from an emitting surface are confined by the hollow cathode effect.

33. The plasma source of claim 1, wherein the electrons from an emitting surface of each of the at least three hollow cathodes are not confined by magnetic fields.

34. The plasma source of claim 1, wherein at least one of the multiple output waves produced by the source of power is configured to power a plurality of the at least three hollow cathodes.