Magnetic Surface Visualizations in the Columbia Non-Neutral Torus

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***Abstract*—Visualizations of magnetic surfaces are a valuable diagnostic in the Columbia Non-neutral Torus (CNT). The CNT is a compact stellarator, which is currently being used to study non-neutral plasmas confined on magnetic surfaces. The full 3-D shapes of magnetic surfaces created by CNT's simple four circular coil geometry are readily visualized by using an electron beam and neutral gas. These visualizations are useful for probe alignment and the confirmation of the magnetic surface topology, and they were necessary for the recent installation of a conducting boundary conforming to the last closed magnetic surface.**

***Index Terms*—Magnetic surfaces, non-neutral, stellarator, visualization.**

As a STELLARATOR, the Columbia Non-neutral Torus (CNT) offers unique benefits for the study of non-neutral plasmas [1]. Plasmas of various degrees of neutrality can be studied because no external electric field is required for confinement. Steady-state low-density plasmas can be confined without internal currents. Long confinement times are expected as a result of the large-space charge electric field [2].

Magnetic surfaces in CNT are created using a simple four circular coil design. Thus, design, optimization, construction, and installation were relatively fast and inexpensive [1]. Currently, the confinement [2], stability [3], and equilibrium [4] of pure electron plasmas are being studied in CNT.

Pure electron plasmas in CNT are usually studied with pressures in the 10^{-9} torr range to minimize the effect of electron-neutral collisions. However, by backfilling to a pressure above 10^{-5} torr and emitting a beam of electrons from an electron gun, it is possible to visualize the complete 3-D shape of the magnetic surfaces (Fig. 1). The electron gun is a heated-biased filament surrounded by a grounded metal cap with a hole in the end. The emitted electrons are accelerated out of the cap and travel along the magnetic surface with enough energy to excite the neutral background gas, which then emits visible light. Brightness increases with background pressure at the cost of reduced electron-beam-path length. Changing backfill gas results primarily in different color visualizations, although inert gases also allow for longer filament life.

Before magnetic surface topology was confirmed [1] by using the electron-beam fluorescent-rod technique [5], this visualization method demonstrated CNT's magnetic surfaces.

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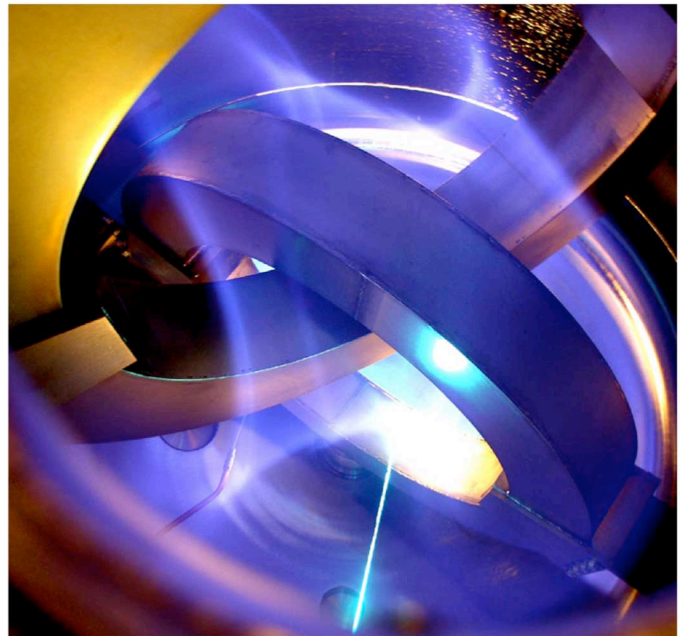

Fig. 1. Photograph of a surface visualization made by using an electron gun, which was taken with an Olympus C-8080 8 megapixel digital camera (15-s exposure). Used with permission from Thomas S. Pedersen.

An example of such a visualization at 5×10^{-5} torr with a 200-eV electron beam is shown in Fig. 1. These glowing magnetic surfaces are bright enough to be seen by the naked eye.

Recently, a conducting boundary conforming to the last closed flux surface (LCFS) was installed. The conducting boundary should improve confinement by setting the electrostatic potential at the LCFS, reducing the mismatch between equipotential and magnetic surfaces in the confining volume [6].

The conducting boundary has also improved visualizations. Previously, the e-gun's grounded metal cap collected the majority of emitted electrons. The cap is now no longer required because the grounded conducting boundary is sufficient to accelerate electrons off the bare filament. Therefore, more emitted electrons are free to travel along the surface. This results in significantly brighter visualizations that proved necessary for proper installation of the mesh.

Proper alignment of the conducting boundary is necessary to ensure that the segments are not limiting the plasma. Without visualizations, alignment would be a complicated process. However, visualizations make misalignments quite obvious [Fig. 2(a)]. Since installation, adjustments have been made with this alignment method so that the conducting boundary encloses a large confining volume [Fig. 2(b) and (c)].

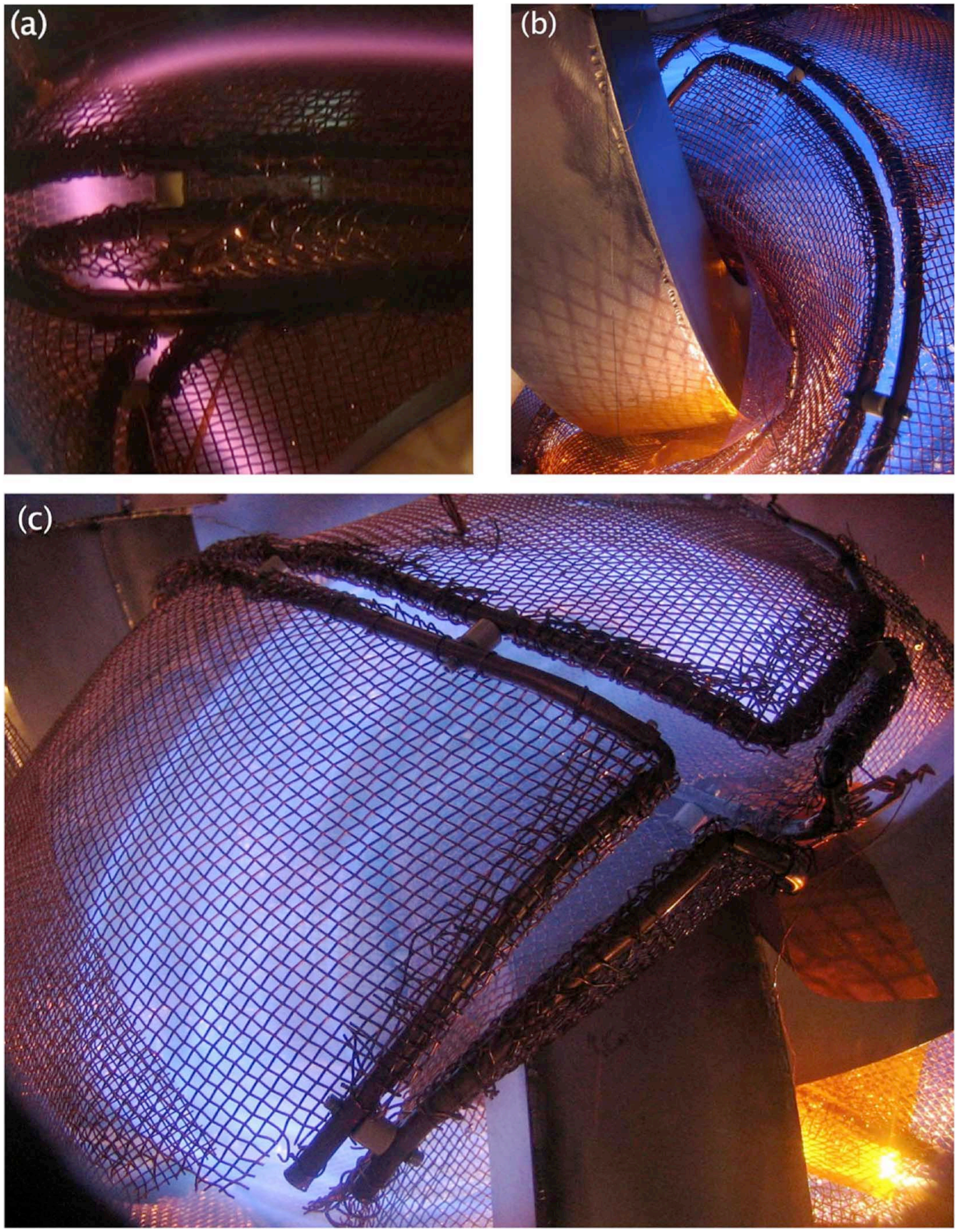

Fig. 2. Visualization photographs taken with a Canon SD200 3.2 megapixel digital camera. (a) A glowing field line intersecting the conducting boundary prior to alignment (1-s exposure). (b)–(c) Large outer surfaces glowing inside the conducting boundary without intersecting it (1/8-s exposure).

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