Low Temperature Plasma
Technology Laboratory

# Permanent-magnet helicon discharge array

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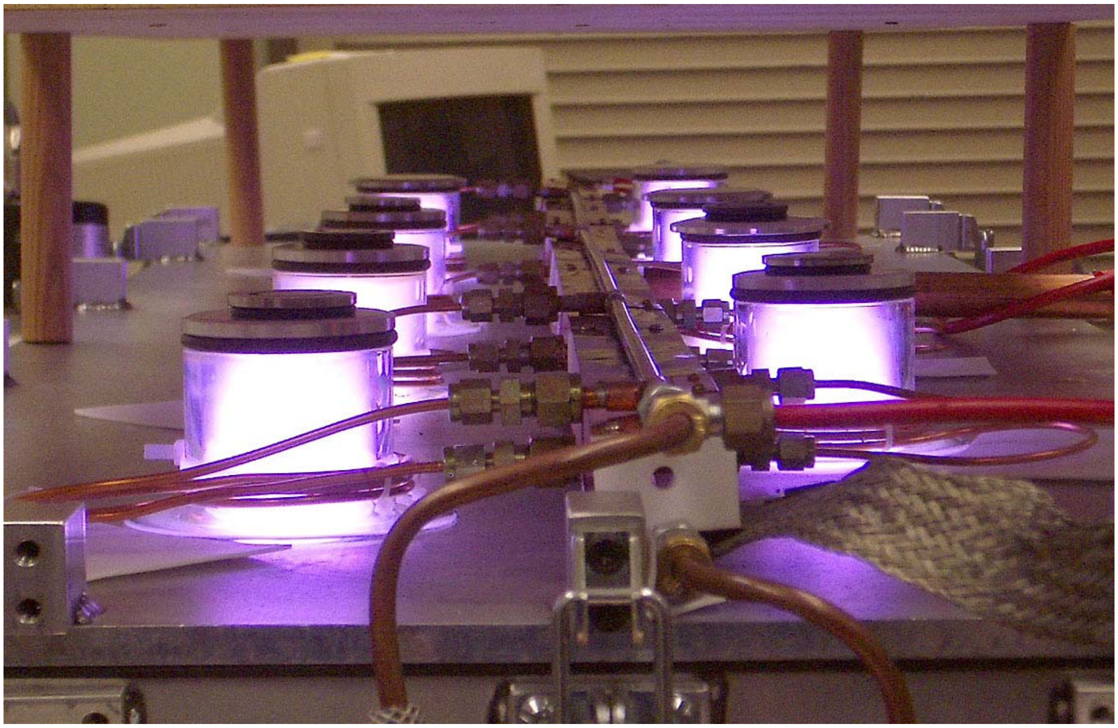

For processing large substrates with high-density, low-pressure plasmas, an array of small sources can produce uniform coverage within a few percent. Helicon sources are known for their high ionization efficiency, but they require a dc magnetic field, which normally would be an electromagnet large enough to cover the entire area. Here the B-field is produced by small annular permanent magnets, one for each tube, lying in a tray above the discharges. Shown in the photograph is the Medusa 2 machine, which consists of an array of eight tubes driven in parallel by a 3.2 kW rf supply at 13.56 MHz. Between the two staggered rows of tubes is a 50-Ω rectangular transmission line in which the center conductor is a ¼-inch (6.4 mm) diam copper pipe which carries both the rf current and the cooling water. The 3-turn $m$ = 0 antennas are of 1/8-inch (3.2 mm) diam copper tubing and are cooled in pairs, so that the water enters and leaves at ground potential. The quartz discharge tubes are 2 inches (5 cm) in diam and 2 inches high, and the system operates in steady state.

Use of the reverse, external field of the ring magnets allows the plasma to follow the slowly diverging field lines downwards to the substrate. The behavior of the B-field can be seen from plasma shape. Since the field at the antenna is less than 100G, the tube height is set by the condition that the helicon wave reflected from the aluminum to plate interferes constructively with the downward wave, enhancing the density at low fields. In this configuration, a plasma density of order $2 \times 10^{11}$ $cm^{-3}$, uniform to about ±3%, can be obtained on a plane 7 inches (18 cm) below the source. The array of tubes and magnets occupies only about 6 inches (16 cm) of vertical space. Details on this device can be found in previous publications[1,2,3].

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[1] H. Torreblanca, *Multitube helicon source with permanent magnets*, Thesis, UCLA (2008).

[2] F.F. Chen and H. Torreblanca, *Large-area helicon plasma source with permanent magnets*, Plasma Phys. Control. Fusion **49**, A81-A93 (2007).

[3] F.F. Chen and H. Torreblanca, *Permanent magnet helicon sources and arrays: a new type of rf plasma*, Phys. Plasmas **16**, 057102-1 to -8 (2009).