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OpenStar: Developing the levitated dipole as a magnetic fusion device

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The dipole is nature's way to magnetically confine a plasma. Planetary magnetospheres confine high beta plasmas with centrally-peaked density and pressure profiles that form in the aftermath of turbulent solar storms.

These properties prompted Akira Hasegawa, while observing Voyager 2's encounter with Uranus, to propose the levitated dipole as a fusion confinement concept [1]. Predicted favorable properties of dipole-confined plasmas such as high betas and good energy confinement combined with engineering advantages such as a relatively cheap, replaceable, and singular plasma-confining magnet merit their investigation as fusion power plants. In the laboratory, RT-1, at the University of Tokyo showed plasma $\beta \sim 1$ [2]. The Levitated Dipole eXperiment (LDX), a joint Columbia/MIT project, demonstrated peaked "stationary" profiles driven by a turbulent pinch [3].

Now, OpenStar Technologies is reviving the concept. OpenStar has manufactured and is commissioning a new generation of levitated dipole devices leveraging the advances made in high-temperature superconducting (HTS) magnet technologies since the last experiments of LDX. OpenStar's first experiment called "Junior", shown below in Fig. 1, aims to replicate the results of LDX in a 5.2 m vacuum chamber with a modest ECRF power < 50 kW. Importantly, this experiment integrates novel HTS power supply technology on board the dipole magnet, paving the way toward larger, commercial, fusion scale magnets.

On the path to net energy-production, OpenStar plans to build multiple devices to validate both the physics basis for dipole-confined fusion plasmas and the engineering technology required for future dipole reactors. To this end, a next-generation machine "Tahi" is being designed to be the first example of a levitated dipole reactor that produces a fusion 'relevant' plasma, helping to validate predictions of their performance made by physics models. Importantly, this device aims to be the first experiment designed to confine and measure warm ions (> 1 keV) confined by a levitated dipole field.

A major consideration for future levitated dipole reactors (LDRs) is the thickness of the neutron and gamma shielding on the dipole magnet which sets the location of the inner plasma limiter, defining a 'first closed flux surface', and thereby reducing the effective magnetic flux on the plasma. Reducing shielding allows for smaller magnets but makes it difficult to achieve a balance of plant with net energy gain due to an increased cryogenic load on the superconducting coils. Thus, there is an inherent trade-off between heat shielding and fusion performance which any plant design that optimizes the engineering fusion gain, Q_{eng}, must take into consideration.

References

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Figure 1: OpenStar team with the "Junior" device vacuum vessel.