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A THRUST VECTORING SYSTEM FOR AN ECR PLASMA THRUSTER

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Plasma thrusters are advantageous for both satellite maneuvering within orbit and for undertaking deep space expeditions because they can produce a moderate level of thrust (approximately between 1 to 1000 mN) alongside a high efficiency factor (specific impulse exceeding 5000 seconds). This performance characteristic distinguishes them from traditional chemical propulsion systems. Unlike conventional designs such as Hall effect or gridded ion thrusters, an electrode-less plasma thruster functions without the requirement of electrodes for ion acceleration or a neutralizer. This unique approach results in lower maintenance needs and lighter payloads. One such indigenously developed electrode-less thruster was studied at Plasma Lab, IIT Delhi, which employed a compact microwave (2.45 GHz) electron cyclotron resonance (ECR) source, namely CEPS for plasma generation [1].

Deep space thrusters encounter a significant challenge in utilizing conventional gimbal platforms for course corrections, as these systems are prone to mechanical failures due to their bulky size and mechanical movements. A potential alternative is to use a magnetically steered nozzle for thrust vectoring (MTV) [2, 3] that involves changing the trajectory of the ion stream in the plasma exhaust plume using a set of electromagnets to generate variable external magnetic field. It has been found that modern spacecraft propulsion systems require a change in direction of about 8-10 degrees to balance out shifts in the center of mass [4]. For ECR thruster the challenge lies in the simultaneous need to deflect the expanding magnetic streamlines of the nozzle but without disturbing the primary ECR region (875 G) through the external vectoring field.

A plausible design of an ECR-based plasma thruster with MTV system was optimized using COMSOL multi-physics simulation tools. Four solenoid coils were placed at the exit of the thruster plane (Fig. 1 a). The ECR thruster consisted of three permanent ring magnets (NdFeB) having their magnetization directed along its axis (z-axis). Any two opposite pair of MTV electromagnets were activated at a time to produce the deflecting field along x or y axis. Maximum deflection of magnetic streamlines of 20 degrees could be achieved at 8 cm away from the thruster exit when the coils were activated with an input current of 20 A each (Fig. 1 b). The ECR field contour (red line in fig 1 b) was found not to be disturbed by the coil field. The plasma simulation with this configuration showed to produce an asymmetric radial ion density profile at the centre of the coil plane inside the expansion chamber (Fig 1 c, d) indicating deflection of plasma plume by activating the vectoring coil. Plans are underway for experiments using the MTV coil assembly.

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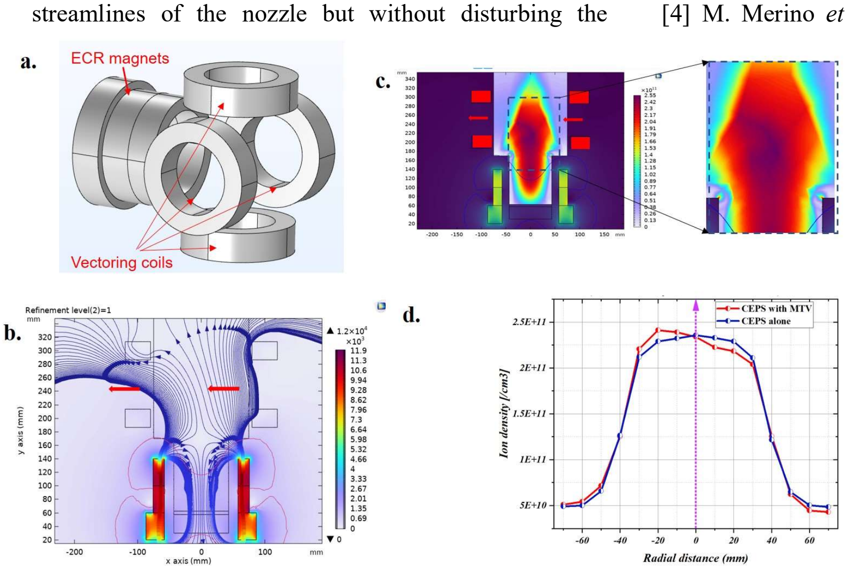

Figure 1 a. Isometric view of the System design. b. Deflection of magnetic streamline deflection (Red arrows represents the magnetisation direction of coil). c. Surface plot of Ion density. d. Comparison of radial plot of Ion density at the mid plane of MTV coils.