A STEERABLE ECRF LAUNCHER FOR ITER*

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Electron Cyclotron Heating (ECH) and Electron Cyclotron Current Drive (ECCD) can meet the heating and current drive requirements for ITER. In order to accommodate central heating and central or off-axis current drive over a range of toroidal field of 4.0 to 5.7 T using a fixed frequency power source at 170 GHz, it is necessary to steer the ECH power in the toroidal direction, thereby using the Doppler shift to change the location of the wave-particle interaction. It has been shown that steering over the range 15 degrees to 45 degrees from radial can meet the ITER physics requirements. In this work, a design is proposed that uses rotatable mirrors to steer the ECH power in the toroidal direction, hydraulic actuators to provide the steering force, and waveguide bellows to accommodate the changes in length of the waveguide when the temperatures of the vacuum vessel and the cryostat change. Analyses show that the design meets the engineering requirements for ITER ECRF port components. Also described is an alternative concept that requires no moving parts within the ITER cryostat and that utilizes wave reconstruction within the waveguide to effect the steering.

The goal of this work was to conceive a mirror steering system that is as small, light, and low in friction as possible, and that is consistent with the design requirements of ITER and the ASME Code. The design features water-cooled mirrors mounted on frictionless flexural pivots that are steered by low pressure hydraulic actuators. Water coolant flows to and from the rotatable mirrors through spirals of thin-walled stainless steel tubing. These spirals allow rotation of the mirrors without large forces or metal fatigue in the tubing. A thermal-hydraulic analysis shows that eight coolant passages through the mirror body are sufficient for cooling the mirror. A structural analysis of the flexural pivot shows that a stable, frictionless, rotatable platform for the mirror is possible without imposing too great a load on the steering actuators. The proposed actuator utilizes low pressure, hydraulic power to expand and contract bellows on opposing sides of a moving actuator plate. A radiation-resistant, high temperature, low vapor pressure silicone fluid serves as the hydraulic medium, and a linear position sensor in a closed feedback control circuit controls displacement of the actuator. Motion is transferred from the actuator to the mirrors by a steering linkage. Heat from nuclear irradiation is transferred out of the linkages through braided copper cooling straps. To accommodate the change in length of the waveguides necessitated by differential thermal displacement between the cryostat and the vacuum vessel, a sliding waveguide bellows is described which accomplishes this with a minimum of mode conversion. Finally, the alternative mirror system, which has no moving parts inside the ITER cryostat and uses wave reconstruction to effect the steering, is assessed for compatibility with the ECRF port geometry.

Analyses of the preliminary design of the rotatable steering system have determined that the requirements for the ITER steerable ECRF launcher can be met. The proposed design and key analytical results that support this conclusion are described. The alternative concept using wave reconstruction inside the waveguide continues to show promise.

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