Thermo-Hydraulic Performance and High Power Transmission Characteristics of the RS Torus Window Prototype

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High power CVD-diamond torus windows being the 1st tritium barrier of the ECRH upper port launcher should be able to provide continues transmission of 2 MW power beam at 170 GHz. Power absorption of about 0.1% (which is a characteristic value for CVD-diamond disks) in the window induces thermal (secondary) stresses in it. Moreover the mm-wave optics of the remotely steering (RS) concept require off-centre propagation of the beam through the window (± 12° steering angle corresponds to about 27 mm off-centre shift of the beam spot), which in turn leads to the asymmetrical heating of the window disk and brazed cuffs. Finite element analysis of the different cooling concepts allowed choosing direct edge cooling of the diamond disk as the only one which fulfils cooling efficiency requirements.

For high power, short pulse tests the torus window prototype was manufactured at the FZK workshops based on a large area CVD diamond disk (106 mm dia. x 1.85 mm, 95 mm of free aperture) grown by Element Six (Ascot, UK) and on the brazing of copper cuffs to the disk which was realised by a Ag-Cu braze at Thales Electron Devices (Velizy,F). The experiments were performed with cooperation with FOM "Rijnhuizen" during the mock-up tests of the beam line. The window transmission characteristics were obtained by means of the analysis of the beam quality (Gaussian content). It was found that RS-window prototype 1) did not provoke arcing even at air conditions; 2) does not affect the mm-wave antenna pattern (which is confirmation of the earlier made low power high dynamic range experiments at FOM); 3) provided specified vacuum performance; 4) circulating cooling water did not bring any parasitic vibrations to the RS launcher.

For the thermo-hydraulic characterisation of the RS window prototype, a test facility was set up to provide the parameters of the component cooling water system at ITER (water pressure of 1.0 MPa and a water temperature of up to 40°C were made available). The maximal pressure could be extended to 3.5 MPa for the case of the stagnant water. During the tests temperature, flow rate, pressure of the cooling water as well as deformation of the copper cuffs of the window units were measured. This allowed verifying cooling efficiency, pressure drop and maximum allowed water pressure. An elastic behaviour of the copper cuffs (no residual deformations) was observed up to the pressure of 1.6 MPa which is twice higher then the water pressure specified for the cooling system of the RS window prototype. The pressure drop in the RS window prototype for the flow rate of 10 l /min and the water pressure of 1 MPa was 0.6% (6 kPa) which is much smaller than the pressure drop in supplying line. The flat dependence of the cooling efficiency on the water flow rate which was set during the previous design development to be given for 10 *l*/min and above could be therefore verified down to the flow rate 5 *l*/min.

References

[1] I. Danilov, R. Heidinger, A. Meier, P. Spaeh. Torus window development for the ITER ECRH Upper Launcher Third IAEA TM on ECRH Physics and Technology in ITER, Journal of Physics: Conf. Series 25 (2005), p. 173-180

[2] R. Heidinger, I. Danilov, A. Meier, P. Spaeh, B. Piosczyk, M. Thumm, W.A. Bongers, M. Graswinckel, B. Lamers, A.G.A Verhoeven. Design and performance tests of a high power torus window for a remotely steered EC launcher; Dig. Joint 30th International Conference on Infrared and Millimeter Waves and 13th International Conference on Terahertz Electronics, September 19-23, 2005, Williamsburg (USA) Proc.Vol.2, pp. 565-66, Piscataway, N.J. : IEEE, 2005 ISBN 0-7803-9348-1

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