§7. Collaboration with ITER in Testing RF Power Source for ICRF Heating and Current-Drive

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The planning of ICRF heating (H) and current-drive (CD) in ITER was summarized as follows,

1) frequency range: f=45~55MHz
2) injected RF power: 20MW
3) injection time: 3,600sec
4) two horizontal port: #13 and #15
   4 units at one port: The RF power of 2.5MW is delivered to each unit and is split into two at the 3 dB hybrid-coupler. The split RF power is supplied to three antennas arrayed in the poloidal direction: There are 24 antennas in one port.

There are three candidates as the tetrode tube for the RF power source: One is 4CM2,500KG (CPI, USA), and the others are TH525A and TH628 (THALES, EU). The ITER ICRF H & CD group asked the NIFS ICRF heating group to test the tetrode tube of 4CM2,500KG, because the high RF power up to 1.6MW at f=50MHz with a long pulse, i.e., 5,000 sec. was successfully achieved using this tube in 1995[1]. In general the RF output power decreases with the higher frequency due to the increase in Ohmic loss on the anode. So it was determined after several discussions that the RF test would be carried out at 65MHz. In addition, it was also added that the reduction in the RF net power with the increase in the reflected RF power fraction would be examined.

The achieved data are plotted in the plane of the RF output power and the duration time as seen in Fig.1. Three interlocks, i.e., over-current at control and screen grids, and the ion pump current monitoring the pressure in the tetrode tube are employed to protect it from serious damages. The interlock levels are 5A of the both grid currents and 40μA of the ion pump current, respectively. In the beginning of the test the ion pump current had indicated a large value, i.e., more than 40μA at the relatively low RF power. Therefore the RF output power had been limited to 0.5MW. But it was found that the largely measured ion pump current was caused with the RF noise. The correct measured one was obtained after reducing the RF noise with an electro-magnetic shielding. Operations of 0.5MW/1,000sec, 1MW/100sec., 1.3MW/10sec and 1.4MW/3sec were achieved as seen in Fig.1.

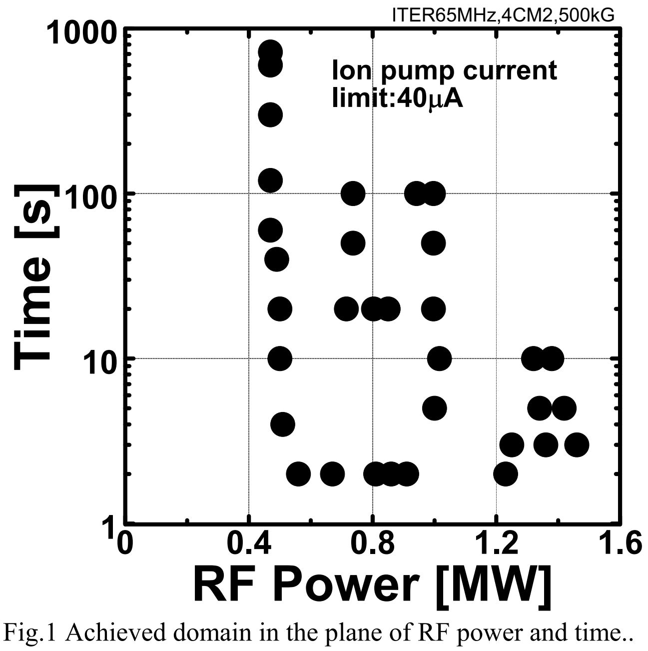

Fig.1 Achieved domain in the plane of RF power and time..

A reduction in the RF output power with the increase in the reflected RF power was examined. A double stub tuner was inserted between the RF generator and the dummy load. The reflected RF power fraction could be changed with detuning the double stub tuner. The maximum RF output power was measured in various reflected RF power fraction P_{ref}/P_{fw}, i.e., 1.5% (VSWR=1.2) to 14.7% (VSWR =2.5) as seen in Fig.2. The RF power was limited with the over-currents of the screen grid current or the control grid, i.e., 5A. The net RF power ($P_{net}=P_{fw}-P_{ref}$) is reduced with the increase in the reflected RF power fraction as predicted: $P_{net}@I_{SG,CG=5A}$ means the maximum RF power limited with the over-current of the screen or the control grids. P_{net} at P_{ref}/P_{fw}=1.5% and at =14.7% are 1.7 and 0.7MW, respectively as seen in Fig.2. Actually the RF output power was achieved at 1.4MW as the maximum, but the screen grid current is lower than the interlock level of 5A; then P_{net}=1.7MW is the extrapolated value at 5A. In addition these all data were obtained in the operation of the anode applied voltage of 24kV. When the higher anode applied voltage such as 28kV is employed, the higher RF power will be expected. The RF power limit has been analyzed by THALES engineer in the view point of the anode RF dissipation. This calculation shows that the RF output power reduces with the increase in the reflected RF power fraction; that is 1.25MW at P_{ref}/P_{fw}=1.0% and 0.8MW at P_{ref}/P_{fw}=11% as also seen in Fig.2.

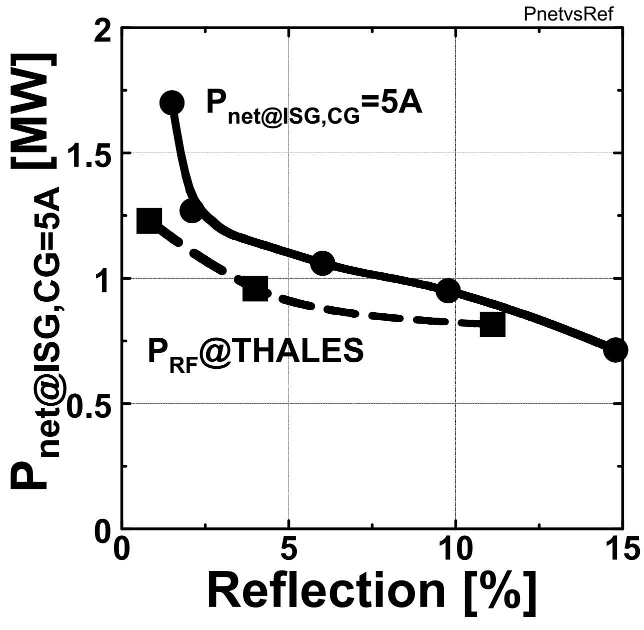

Fig.2 Dependence of net RF power on VSWR: experimental data and calculated data analyzed by THALES. Net RF power is limited with the over-current in screen grid or control grid.

[1] T.Seki et al., Fusion Technology, Vol.40, No.3(2001), pp.253-264