§ 5. Transmission Efficiency of RF for LHD Injection

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It is very important for the plasma heating such as ECH how effectively the generated microwave in a gyrotron can be transmitted to LHD. The efficiency is about 60% on average in our system. There are two reasons why the efficiency is low. One is loss in a Matching Optics Unit (MOU), and another is that in the long transmission line. The cause is originated in the insufficient optimization of mirror alignment in MOU. The mirrors are modified the microwave profile with phase correction. The setting of mirrors should be adjusted very precisely because of very short wave length. The scattered microwave by the misalignment of mirrors would be the cause of arcings in the MOU. Another cause is the abnormal attenuation in transmission lines, which does not depend on the length of transmission lines. It could be due to the higher mode excitation in waveguides and miterbends. This can be suppressed partly by adjusting the axis of waveguide using a laser. Thus, the number of miterbends should be minimized in the transmission line.

After the 5th experimental campaign, we improved the transmission lines. To increase power of injection we installed an evacuated transmission line with a diameter of 1.25 inch for the 84GHz gyrotron. One more 168GHz gyrotron was newly installed. The mirrors in the MOU were readjusted for 82.7 and 84GHz lines. For some miterbends in the transmission lines the back plates were replaced. Those can adjust easily the reflection angle when we can realign the beam axis by using a He-Ne laser beam. All the 3.5 inch waveguides on atmosphere pressure were adjusted the beam axis by the laser, but the 1.25 inch of waveguides could not be aligned by this method because the miterbend could not reflect the He-Ne laser beam.

We should measure the transmitted the power to assess the effect of the adjustment. Every year using the portable water dummy load, which is set near the injection port of LHD, we measure the transmitted power. The new development of the load is that the additional port was equipped to flow the dry air and to purge the gas when the arcing happens in it.

The result on the transmission efficiency is shown in Table.1. Compared with previous experiment, the efficiency in two lines, L1 L2 decreased. Especially the insufficient alignment of the waveguide axis in line L1 was considered to be one of the causes for low efficiency. The lines of L4 and L5 have much loss in the transmission line behind the MOU. We must proceed to find the new way of alignment for the 1.25 inch waveguide. In high power, the line is heated with the increasing loss of microwave. The lines in L11 and L12 have a high efficiency due to persistent effort the alignment in both MOU and waveguide. By the next experimental campaign a new CW gyrotron will be installed in the line with 1.25 inch evacuated waveguide. On the CW operation a little loss of microwave in the transmission line leads to the much heat generation. More precious adjustment is required before the start of the next experiment.

Transmission line(gyrotron frequency)	Coupling efficiency at MOU (%)	Transmission efficiency after MOU (%)	Total efficiency (%)
L1(168GHz)	77(0)	69(-10)	53.2(-7.3)
L2(168GHz)	76(0)	86(-3)	65.2(-2.1)
L3(168GHz)	86(0)	85(+10)	72.9(+8.2)
L4(84GHz-evacuated)	90(+22)	67(-10)	60(+7.6)
L5(84GHz-evacuated)	90	67	60
L7(168GHz)	67.2	80	53.7
L11(82.7GHz)	91.5(-0.5)	87(+10)	85.6(+14.8)
L12(82.7GHz)	93.5(-1.1)	93(+14)	83.5(+9)

Table1. Transmission efficiency at MOU, behind MOU, and total efficiency. Numbers in parentheses show increase or decrease compared with previous measurement. The L5 and L7 line are newly installed system.