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Development of a Millimeter-Wave Beam Profile Monitor in Mega-Watt CW ECH Transmission Line
メガワット定常ミリ波伝送系におけるミリ波強度分布モニターの開発

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In an ECRH system for magnetic confinement devices, over 1 MW/ CW millimeter-wave is transmitted through an over-sized corrugated waveguide in vacuum. Precise alignment between a millimeter-wave beam and waveguide axis is required to improve transmission efficiency. For that purpose, the profile of the propagating millimeter-wave in the evacuated corrugated wave-guide should be measured even during an actual high power operation. We have been developing a millimeter-wave beam position and profile monitor (BPM) that consists of a Peltier-device array installed in atmospheric-side of a miter-bend reflector and a heat sink. A proto-type BPM was designed, assembled and high-power tested. The voltage profile of the devices well coincided with the temperature profile of the reflector measured by an infrared camera. A new BPM for higher spatial resolution was constructed and is under test.

1. Introduction

The Large Helical Device (LHD), which is the largest Heliotron-type plasma confinement device in the world (Major radius 3.9 m and average minor radius 0.6 m), confines high-temperature and high-density plasmas by the external magnetic field. Electron Cyclotron Resonance Heating (ECRH) using high power millimeter-waves (mmw) is one of the main plasma production and heating methods in LHD.

We have been developing and installing three high-power 77 GHz gyrotrons under collaboration with University of Tsukuba. The output power of each gyrotron has been improved from 1 MW to 1.5 MW step by step, and the gyrotrons also achieved 0.3MW CW operation [1].

It is important to precisely align a propagating mmw-beam to a transmission line to avoid mode conversion to the other modes. We have been developing a real-time beam-position and profile monitor (BPM) to measure the intensity profile of a high power (Megawatt level) mmw propagating even in the evacuated corrugated waveguide without any disturbances. It was improved to obtain higher spatial resolution and is under test.

2. Structure of a Millimeter-Wave Beam Position and Profile Monitor (BPM)

In the long-distance transmission lines, the reliable gyrotron operation can be much improved by the evacuation, sufficient cooling and precise alignment of the system. A real-time beam-position and -profile monitor is required to evaluate the position and profile of a high power (Megawatt level) mmw propagating even in the evacuated corrugated waveguide. Two-dimensional array of Peltier devices is installed and aligned on the atmospheric side of a thin miter-bend reflector, as schematically shown in Fig. 1. A mmw-beam propagating in the corrugated waveguide is reflected on the mirror surface of the miter-bend and partly absorbed in the reflector plate. The

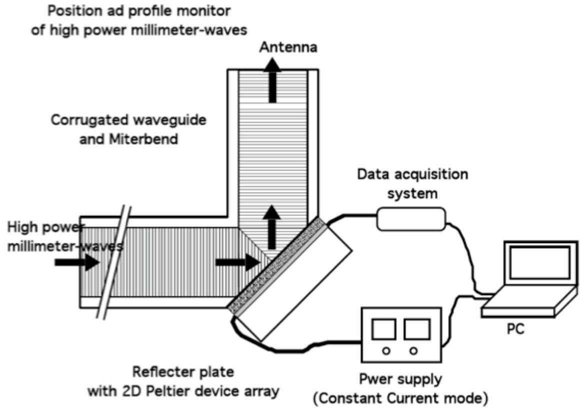

Fig. 1 Schematic diagram of a mmw beam position monitor.

generated heat by the Ohmic loss diffuses to the outside of the reflector and removed by the Peltier devices. A voltage of each Peltier device is approximately expressed as a following equation.

$$V = IR + S(T_H - T_c) \ , \qquad (1)$$

where I, R and S are a current, resistance and Seebeck coefficient, respectively. T_H and T_C represent hot- and cold-side temperature of the Peltier device. When these devices are connected serially and driven by the constant current control (I=constant), the voltage change of each device is almost linearly proportional to the temperature change of the cooled side of the device, if the temperature at the hot-side of the Peltier device is kept constant. The information of the two-dimensional temperature profile of the miterbend reflector can give the real-time information of the position and profile of the mmw beam.

3. High Power Test results of a Proto-Type BPM and Its Upgrade

A prototype beam profile monitor, which consisted of 20 Peltier devices with a heat sink, was assembled and tested [2]. The equipment was installed in one of the miter-bends in the LHD transmission line, which is connected to an 82.7 GHz gyrotron. Another side of the miter-bend was connected to a dummy load. High power test was performed using 82.7 GHz power with about 200 kW and 100 ms pulse every 30 s. The temperature increase of the reflector measured by an RTD was about 0.5 degree around the center. Figure 2 a) shows the voltage change normalized by the initial voltage of each Peltier device. Each quadrate in the figure corresponds to the device position. The ellipse indicated by a white dotted line shows the cross section of the corrugated waveguide at the miter-bend. In this case, the peak of the voltage change is slightly off-center. After the test, we tried to obtain a thermal image using an absorber-coated reflector and IR camera at the same position. Figure 2 b) shows the obtained thermal image. The peak temperature position and profile well coincide with the position with the highest voltage change shown in Fig.2 a).

For higher spatial resolution, 52 Peltier devices with 10 mm square are now aligned on a circuit board and the voltage of each Peltier device can be measured at the same moment (Fig. 3). A heat sink is cooled by water to remove the heat generated by mega-watt, CW millimeter-waves. This device will be installed in the high power transmission line of ECRH system and will be tested.

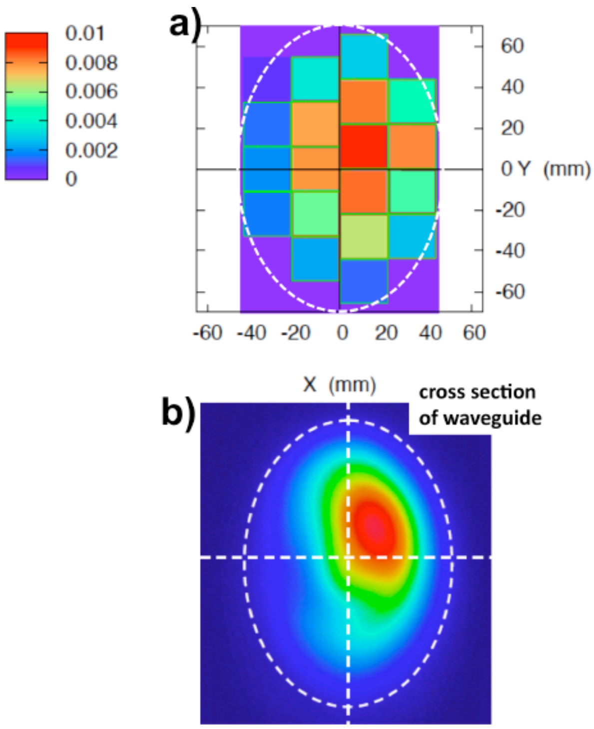

Fig. 2 Comparison between the output of the beam position monitor in a) and measured IR image of the reflector in b) .

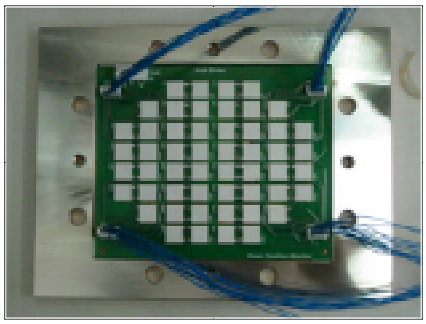

Fig. 3 Hot side of Peltier-device (52 devices) array on a backside of a reflector

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