18PB-016

High Power Test of a Real-Time High-Resolution Millimeter-Wave Beam Profile Monitor in a Mega-Watt CW ECH Transmission Line

メガワット定常ECH伝送系における実時間、高分解能ミリ波ビーム分布モニタの高パワーテスト

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In a high power Electron Cyclotron resonance Heating (ECH) system, a long-distance and low-loss transmission system is required to realize effective heating of nuclear fusion-relevant plasmas. A millimeter-wave beam position and profile monitor, which can be used in a high-power (Mega-Watt level), evacuated, and sufficiently cooled transmission line, is proposed, designed, manufactured, and high power tested. The beam position and profile monitor consists of a reflector, Peltier-device array and a heat-sink. It was tested using Mega-Watt gyrotron output power. The data obtained by the monitor were agreed well with the burn pattern measurement results obtained in a short pulse test.

1. Introduction

In a high power Electron Cyclotron resonance Heating (ECH) system with long-distance transmission lines, the reliable millimeter-wave (mmw) transmission can be much improved by evacuation, sufficient cooling, and precise alignment of the whole transmission system. For example, in the Large Helical Device (LHD) of National Institute for Fusion Science (NIFS), the length of the ECH transmission line, which consists of corrugated waveguides, miterbends, and some mmw components, extends longer than 100 meters from gyrotrons to antennas [1].

In order to maintain high transmission efficiency, the method of precise mmw beam alignment is required. A real-time mmw beam-position and profile monitor (BPM) is required to evaluate the position and profile of a high power (Megawatt level) mmw even in the evacuated corrugated waveguide. We proposed a new type of BPM, which can be used in the evacuated corrugated waveguide in real-time.

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

The idea of the BPM is shown in reference [3]. A two-dimensional array of Peltier devices is aligned and installed on the atmospheric side of a thin miterbend reflector with a heat-sink, as shown in Fig. 1 a). An mmw beam propagating in the corrugated waveguide is reflected on the mirror surface of the miterbend and partly absorbed in the reflector plate. The generated heat by Ohmic loss of the electromagnetic wave diffuses to the outside of the reflector and is removed by the Peltier devices. When these Peltier devices are connected serially and driven by the constant current control, the voltage change of each device is almost linearly proportional to the temperature change of the cooled (reflector) side of the device, if the temperature at the hot-side of the Peltier device is kept constant by a heat-sink. The actual structure of the BPM without a heat-sink is shown in Fig. 1 b).

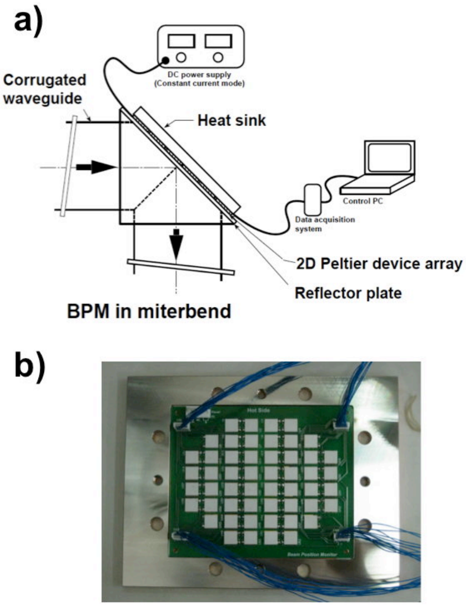

Fig. 1. a) Structure of a BPM system. b) Photograph of the BPM consisted of the Peltier–device array and reflector.

3. High Power Test of a BPM Using Gyrotron Output

A high space-resolution BPM, which consisted of 52 Peltier devices with a heat-sink was installed in one of the miterbends in the LHD transmission line, which was connected to a 154GHz/ 1MW gyrotron. The mmw with 0.8 MW power and 0.5 sec pulse was transmitted in the corrugated waveguide and reflected on the miterbend reflector. The voltage time variation of a Peltier device placed near the center of the miterbend mirror, is plotted in Fig. 2 a) with the mmw pulse. The Peltier voltage gradually decreased after the on-timing of the mmw pulse.

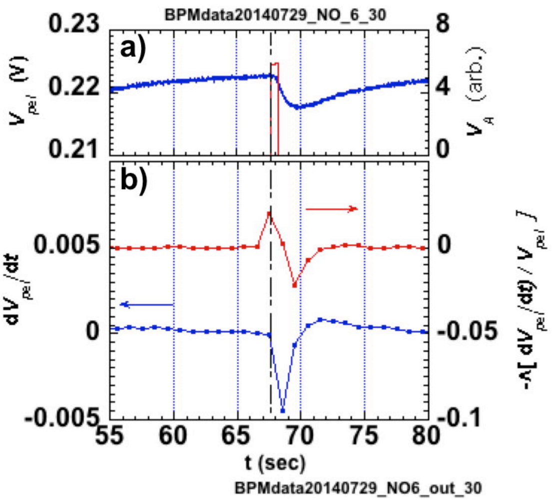

Fig. 2. a) Temporal variation of the voltage of Peltier device, V_{pel} (blue), together with gyrotron pulse (red). b) Time derivative of V_{pel}, dV_{pel}/dt (blue) and its difference, defined by $S = -\Delta\{(dV_{pel}/dt)/V_{pel}\}$ (red).

A transient analysis of the voltage variation of the Peltier device was performed. In order to find the start timing of the voltage decrease, the voltage signals are partly linear-fitted. Then the time derivative, dV_{pel}/dt, and its difference normalized by V_{pel}, defined by $S = -\Delta\{(dV_{pel}/dt)/V_{pel}\}$, are calculated and plotted respectively as blue and red curves in Fig. 2 b). At the earliest timing when the values S becomes maximum among all Peltier devices after the on-timing of the mmw pulse, the values S of all Peltier devices were calculated and mapped on the actual position of the Peltier devices, as shown in Fig. 3 a).

A burn pattern was obtained using a heat -sensitive paper at the short pulse operation with the same oscillation condition. The burn pattern is shown in Fig.3 b). The position and shape of high S value well coincide with those obtained by the BPM, as shown in Fig. 3 a). This result shows that the BPM has a possibility of a real-time high-power mmw beam profile and position monitor. The method of the analysis, however, should be improved considering the heat conduction in the copper reflector plate.

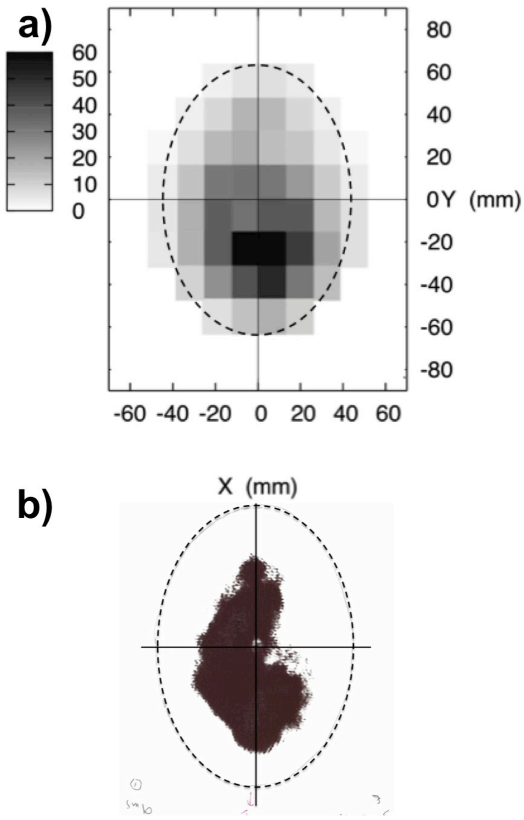

Fig. 3. A comparison of a) the analyzed signal of the BPM and b) the burn pattern measurement result using heat-sensitive paper under the same oscillation condition except the power level and pulse width.

Acknowledgments

This work is supported by National Institute for Fusion Science under grants ULRR701, 801, 804 and is also supported by a grant for scientific research from the Ministry of Education, Science and Culture of Japan (24560066, 25630423).

References

[1] H. Takahashi, S. Shimozuma, S. Kubo, et al., Phys. of Plasmas, **21** (2014) 061506.
[2] T. Shimozuma, S. Kobayashi, S. Ito, et al., Proc. in Plasma Conference 2011, Nov. 22-25, Kanazawa, Japan, 22P146-P.
[3] T. Shimozuma, S. Kobayashi, S. Ito, et al., 18th Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating, 22-25 April, 2014, Nara.