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Advancement of Oscillation Efficiency by Electron Beam Quality Improvement in Gyrotron FU CW GIA

Gyrotron FU CW GIAにおける
電子ビームクオリティ改善による発振効率の向上

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Gyrotron FU CW GIA has been developed as a successor of Gyrotron FU CW GI. By using Gyrotron FU CW GIA, improvement of the energy conversion efficiency by improving the electron beam quality was investigated with two approaches; one is to reduce the misalignment between the cavity and magnetic coil axes. The other is the design modification of the magnetron injection gun (MIG) to suppress the electron velocity spread at the cavity. The two effects were separately examined. As the result an increase in the efficiency by several percent was obtained through reduction of the misalignment and a further increase by a few percent was obtained with modification of MIG.

1. Introduction

At the Research Center for Development of Far-Infrared Region, University of Fukui, advanced research of gyrotron is in progress. In this research, several issues, such as increase of energy conversion efficiency and output power, the stabilization of the oscillation, and direct output of Gaussian beam, are included. As the start of such gyrotron development, Gyrotron FU CW GI was developed [1]. Gyrotron FU CW GI is equipped with an internal mode converter. It was designed aiming at a net energy conversion efficiency η more than 10 percent taking account of the transmission loss due to the mode converter. However, results of the initial experiment showed a considerably lower value of $\eta \sim 5\%$ [1].

After the initial experiment, Gyrotron FU CW GI was provided as a power source for direct measurement of hyperfine splitting of the positronium by the University of Tokyo [2,3]. Then, in order to continue the issue of improving η, a new gyrotron, Gyrotron FU CW GIA, was manufactured. It has the same structure as Gyrotron FU CW GI and it is demountable type. Among possible causes of the low efficiency observed on Gyrotron FU CW GI, the poor quality of the electron beam was considered. The magnetron injection gun (MIG) was not optimized for this gyrotron. The pitch factor spread of the electron beam at the cavity was more than 20% by using this MIG. Therefore, a new MIG was designed for the spread less than 5 %. As other cause of the low efficiency, misalignment in setting of gyrotron tube on the magnet was considered. After the initial experiment of Gyrotron FU CW GI, power calculation including a transverse shift of the electron beam to the cavity was carried out. As the result, a 0.5 mm shift brings a significant power-drop. So it must be set on the magnet with an accuracy less than 0.5 mm. However, in the experiment of Gyrotron FU CW GI, there was no position-tuning device which could move it with high enough a position accuracy. In this paper the improvement of η is investigated by improving the electron beam quality by reducing the misalignment of gyrotron in its setting and modifying the MIG itself.

2. Experimental result

A position-tuning device was manufactured to reduce the position shift and placed on the top surface of an 8-T magnet, on which Gyrotron FU CW GIA was set. The tuning device can move the gyrotron position on the magnet surface with an accuracy of 0.1 mm. At first, the gyrotron tube was moved in one direction. Signal intensity of the electromagnetic wave radiated from the gyrotron window was measured with a pyro-electric detector. The result was shown in Fig. 1. The position d = 0 indicates the initial gyrotron position just after the installation onto the magnet. When it was moved by 0.8 mm from the initial position, the signal intensity became maximum. After that, the gyrotron position was moved to the perpendicular direction and the optimal tube position giving the maximum signal intensity was found. With this position, the power measurement was carried out with a water load. In result, η of 10-12 % was obtained. Thus, electron beam quality improvement due to gyrotron position-tuning made η increase.

Next, MIG was replaced with the new one which was specifically designed for this gyrotron. To examine the effect of the characteristics of the electron beam emitted from the MIG, the optimal condition to achieve highest η was searched for. Figure 2 indicates the measured signal intensity with changing $V_{\mathrm{K\text{-}A}}$. It was obtained with the cathode current I_{C} fixed. The signal intensity increased with $V_{\mathrm{K\text{-}A}}$, and had a maximum at certain $V_{\mathrm{K\text{-}A}}$. It means that there are optimal values of $V_{\mathrm{K\text{-}A}}$ for each cathode current. These optimal values of $V_{\mathrm{K\text{-}A}}$ generate optimal values of the electron pitch factor α. The same result was obtained for another gyrotron [4].

After searching for the optimal operation conditions for the different cathode voltage V_{K}, the power measurement was carried out. The obtained η is plotted as indicated with red filled circles in Fig. 3. In Fig. 3, η measured with the previous MIG is also plotted with black open triangles. The efficiency η obtained with the new MIG reaches 13-14 % as the average and it is successfully increased compared to that with the previous one.

3. Summary

In the experiment of the Gyrotron FU CW GIA, improvement of the energy conversion efficiency η was intended with improvement of the electron beam quality. Reducing the misalignment between gyrotron and magnetic coil axes makes η improved. Moreover, use of the new MIG further leads to increase in η.

References

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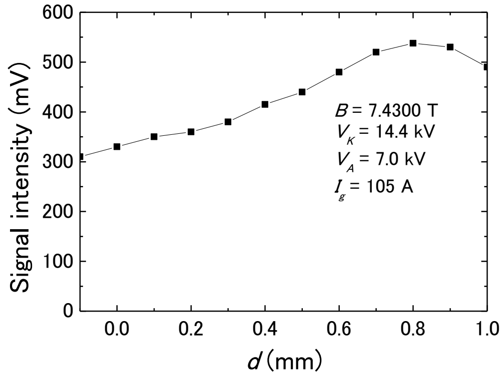

Fig 1. Measured signal intensity with changing the gyrotron tube position

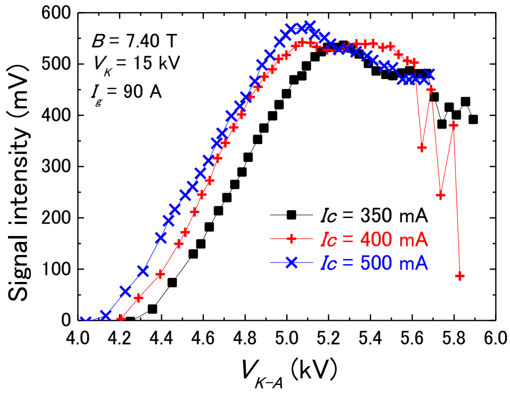

Fig 2. Measured signal intensity with changing $V_{\mathrm{K\text{-}A}}$

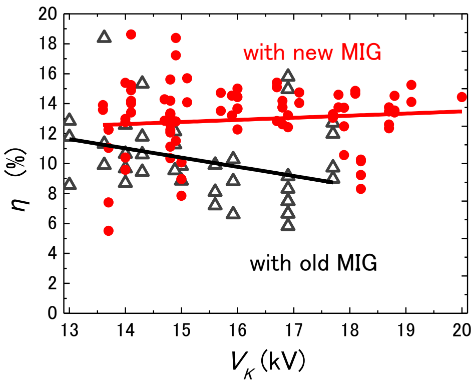

Fig 3. The efficiency η obtained by the power measurement with the new MIG (red circles) and with the old one (black triangles)