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

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***Abstract*—In experiments of Gyrotron FU CW GIA, improvement of the energy conversion efficiency was investigated by two approaches; one is reducing 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 a result, increases in the efficiency were obtained by both the reduction of the misalignment and the modification of MIG.**

I. 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]. It is equipped with an internal mode converter. It was designed aiming at a net energy conversion efficiency η more than 15 percent taking account of the transmission loss inside the gyrotron. However, results of the initial experiment showed a considerably lower value of $\eta < 5$ % [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. A photograph of the Gyrotron FU CW GIA is shown in Fig. 1. It has the same structure as Gyrotron FU CW GI except a mirror-moving mechanism.

As possible causes of the low efficiency observed on Gyrotron FU CW GI, the poor quality of the electron beam was considered. The misalignment in setting of gyrotron tube on the magnet leads the poor quality. 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 a high enough position accuracy.

As another cause of the low efficiency, the magnetron injection gun (MIG) was not optimized for the gyrotron. The pitch factor spread of the electron beam at the cavity was more than 30% with the MIG installed on the Gyrotron FU CW GI. Therefore, a new MIG was designed to reduce for the spread.

Fig.1 A photograph of Gyrotron FU CW GIA

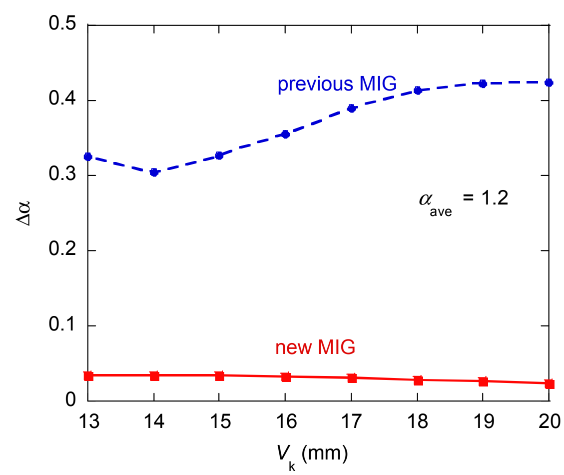

Fig.2 Comparison of pitch factor spread between the previous and new MIG's.

The pitch factor spread Δα calculated with the EGUN code for the two MIG's are plotted in Fig. 2. Here, Δα is defined as the difference of the maximum and minimum pitch factor divided by the averaged pitch factor α_{ave} and the results with α_{ave} =1.2 are plotted. The spread $\Delta\alpha$ is suppressed to be less than 5 % for the wide range of the cathode voltage V_k with the new MIG.

In this paper the improvement of η is investigated by improving the electron beam quality, that is, by reducing the misalignment of gyrotron in its setting and by modifying the MIG itself. The two effects were separately examined.

II. Results

A position-tuning device was manufactured to reduce the misalignment and to improve η. It can move the gyrotron position on the magnet surface with an accuracy of 0.1 mm. While tuning the position of the gyrotron equipped with the previous MIG, signal intensity of the electromagnetic wave radiated from the gyrotron window was measured with a pyro-electric detector. The result is shown in Fig. 3. The distance d = 0 mm indicates the gyrotron position when the measurement started. The optimal position to give maximum output was obtained at d = 0.8 mm. With this position, the power measurement was carried out with a water load for various values of the cathode voltage V_k. The results are shown as the blue squares in Fig. 4. In result, maximum η of ~13 % was obtained for various V_k by reducing the misalignment between the gyrotron and coil axes.

Next, MIG was replaced with the new one which was specifically designed for this gyrotron. The spread of pitch factor has been reduced to be less than 5 %. The optimal condition to achieve highest η was searched for. Figure 5 indicates the measured signal intensity with changing the voltage between the cathode and anode, $V_{K\text{-}A}$. It was obtained with the collector current I_c fixed. The signal intensity increased with $V_{K\text{-}A}$, and had a maximum at certain $V_{K\text{-}A}$. It means that there are optimal values of $V_{K\text{-}A}$ for each I_c. These optimal values of $V_{K\text{-}A}$ 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 maximum η is plotted as indicated with red filled circles in Fig. 4. The efficiency η obtained with the new MIG reaches 15 % and it is successfully increased compared to that with the previous MIG.

III. Summary

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

References

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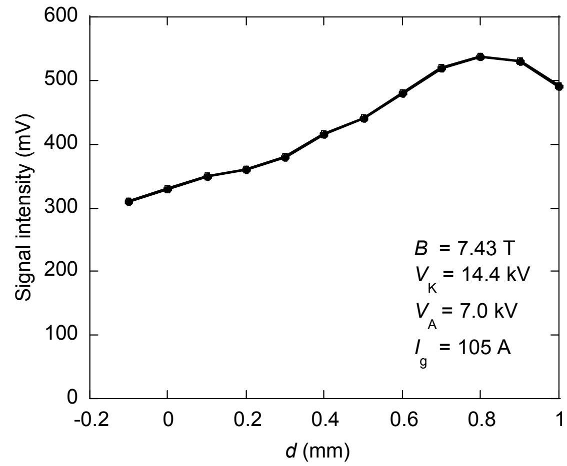

Fig 3. Observed signal intensity when the gyrotron position was moved horizontally

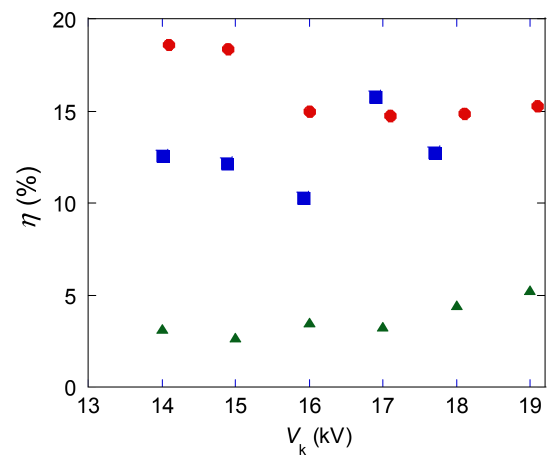

Fig.4 Estimated efficiency η from power measurements (red circles) with a new MIG and with the axes in alignment, (blue squares) with an old MIG and the axes in alignment, and (green triangles) with an old MIG and the axes in non-alignment.

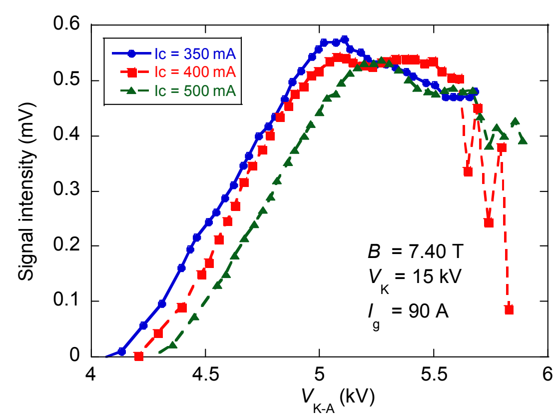

Fig 5. Observed signal intensity as functions $V_{K\text{-}A}$ for three values of I_c