Development of medium power sub-THz CW gyrotrons for high power THz spectroscopy

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***Abstract*—Two sealed-off gyrotron tubes for high power THz spectroscopy are designed and constructed. One of them will be used for ESR echo experiment in sub-THz region, and another for 600 MHz DNP-NMR experiment etc. Both gyrotrons are named Gyrotron FU CW IIA and Gyrotron FU CW VIIA, because their cavities have same shapes as Gyrotrons FU CW II and FU CW VII. Both tubes are installed in 8T superconducting magnets. The operation mode is CW or long pulse.**

I. Introduction and Background

In FIR FU, we are developing THz CW gyrotrons named Gyrotron FU CW Series for application to high power THz technologies and for development of THz frequency region. Up to the present, we have developed Gyrotron FU CW I for material processing using high power submillimeter wave, Gyrotrons FU CW II [1],[2] and FU CW VII for 600 MHz DNP-NMR experiment as a radiation source for analysis of complicated protein molecules, Gyroitron FU CW III for application to many kinds of high power THz technologies, Gyrotron FU CW IV for 200 MHz DNP-NMR experiment as a radiation source for analysis of polymer surface, Gyrotron FU CW V for measurement of hyperfine structure of positronium. Almost all of these gyrotrons [3] consist of demountable gyrotron tube, except Gyrotron FU CW I.

Sometimes, demountable tubes are not convenient, because the treatment is a little bit complicated and stability of the operation is worse. Now, we have decided to develop sealed-off gyrotron tubes. At the first step, we have constructed two sealed-of gyrotron tubes, Gyrotrons FU CW IIA and FU CW VIIA.

Photo 1 The side view of Gyrotron FU CW IIA

These tubes were designed on the basis of successful development of Gyrotron FU CW II and FU CW VII. Same shapes of cavities as both gyrotrons are installed in Gyrotrons FU CW IIA and FU CW VIIA.

II. Gyrotron FU CW Series

We have already developed seven gyrotrons FU CW I to VII. Table 1 shows the list of these gyrotrons and additional two gyrotrons FU CW VIII and IX, which we are intending to develop in near future. In the table, frequency range, output power, maximum field intensity and application items are shown for each gyrotron included in Gyrotron FU CW Series.

Table 1 The list of Gyrotron FU CW Series

Gyrotron	Freq. range	Output power	Max. B	Applications
FU CW I	300 GHz	2.3kW, CW	12 T	Material processing, New medical technology
FU CW II	110–440 GHz	20–200 W, CW	8 T	DNP-NMR at 600 MHz for protein research (Osaka University)
FU CW III	130–1,080 GHz	10–220 W, CW	20 T	High power THz Technologies
FU CW IV	134–139 GHz	5–60 W, CW	10 T	DNP-NMR at 200 MHz for material science
FU CW V	203.4 GHz	100–200 W, CW	8 T	Accurate measurement on fine structure of positronium (Univ. Tokyo), new medical technology
FU CW VI	393–396 GHz	50–100 W, CW	15 T	Frequency tunable gyrotron for DNP-NMR at 600 MHz for protein research (Osaka University)
FU CW VII	203.7, 395.3 GHz	200W, 50 W, CW	9.2 T	DNP-NMR at 300 MHz and 600 MHz at Warwick University
FU CW VIII	131.5GHz	200 W, CW	8 T	ESR echo experiment in sub-THz region
FU CW IX	100 -350 GHz	100 W, CW	8T	XDMR experiment with high power THz radiation at ESRF

III. Construction of New Gyrotron FU CW IIA and VIIA

Both gyrotron tubes have already constructed and been un der operation test. Photo 1 shows the side-view of a completed Gyrotron FU CW IIA. Gyrotron FU CW VIIA has just the same view as Gyrotron FU CW IIA. The FU CW IIA tube is installed in the center axis of an 8 T superconducting magnet as shown in Fig. 2. Gyrotron FU CW IIA will be used for DNP-NMR experiments and Gyrotron FU CW VIIA for study on ESR echo experiment in sub-THz region.

Fig. 2 Gyrotron FU CW IIA with 8 T SC magnet

IV. Operation Test of Gyrotron FU CW IIA

The operation test of Gyrotron FU CW IIA has already carried out successfully in long pulse mode. Fig. 3 shows the first measurement of radiation power as functions of magnetic field intensity B. In the trace, the radiation power was measured by a pyro-electric detector after the radiation was transmitted by a circular waveguide system. Therefore, the upper includes both fundamental and the second harmonic operations. As seen in the trace, many fundamental and second harmonic modes are excited.

Designed cavity modes are TE23 mode at the fundamental and TE26 mode at the second harmonic. In the design, the diameter and the length of the cavity are 4.72mm and 15mm, respectively. The estimated frequencies are 201.75GHz for the designed mode TE23 and 394.61GHz for TH26. We have measured by a heterodyne detection system the frequency of the radiation coming from the excitation of TE23 mode. It was 201.50GHz, which is a little bit lower frequency than the estimated. The difference may results from the fabrication error of the cavity diameter. From the simple estimation, the error is only + 5.7 μ m. Considering this result, we can estimate the frequency of TH26 cavity mode. It will be 394.13 GHz.

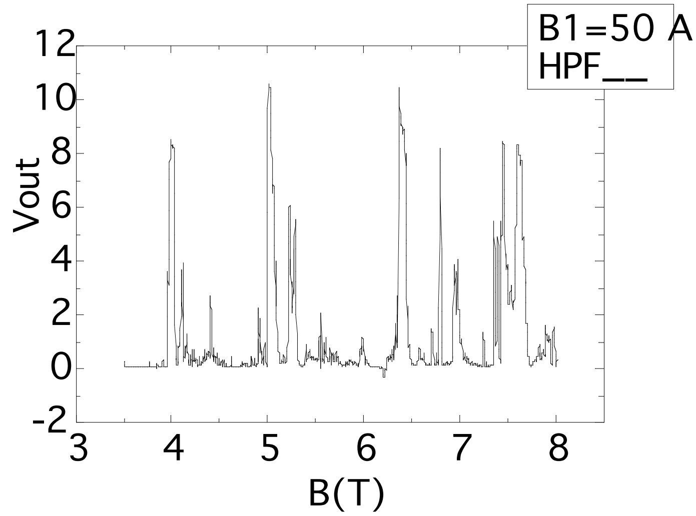

Fig.3 Radiation power as a function of magnetic field B

V. Summary

The compact gyrotron tubes for CW or long pulse operation were fabricated. These gyrotron tubes are named Gyrotron FU CW IIA and VIIA, because installed cavities are same shapes as Gyrotron FU CW II and VII, respectively. The gyrotron FU CW IIA tube was installed on the center axis of an 8 T superconducting magnet and the operation test was carried out successfully. Many fundamental and second harmonic operations were observed. Measured frequency of designed cavity mode TE23 suggests that the fabrication error of the cavity diameter is + 5.7 μ m. On the basis of this result, we can estimate the frequency of another designed cavity mode TE26. It will be 394.13 GHz. The frequency of ESR corresponding to the 600 MHz proton NMR is around 394.6 GHz. Therefore, we hope the output power from the Gyrotron FU CW IIA at the cavity mode of TE26 can be used for 600 MHz proton DNP-NMR experiment.

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References

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