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Frequency Selectivity of Hybrid Bragg Resonator for Free Electron Maser
大強度FEMに用いるハイブリッド・ブラッグ共鳴器の優位性について

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A normal Bragg resonator utilizing two traditional Bragg reflectors and a hybrid Bragg resonator with an advanced and a traditional Bragg reflector were designed to develop the frequency selectivity of the free electron maser with frequency of 40 GHz using a helical wiggler coil and an intense relativistic electron beam. In the cold test, the frequency resolution of the hybrid Bragg resonator was appeared to be 0.05 GHz, while that of the normal one was 0.5 GHz.

1. Introduction

There are still few light sources in the range of 0.1-10 THz. As candidates of the THz source, laser, solid state components, an electron tube, etc. are mentioned. THz sources using laser and solid state components have developed in advance with average output power of less than mW and have explored every new possibility of application. Electron tubes are expected to realize a steady state THz source with output power of > 1 W or an intense pulsed THz source with power of >1 MW. The intense THz source will apply for thermonuclear fusion, particle accelerators, radars, etc. Among electron tubes, gyrotrons[1] have realized for thermonuclear fusion with output power of 1 MW and frequency of ~170 GHz.

One of the other candidates of electron tubes for an intense THz source is a free electron maser (FEM) using an intense relativistic electron beam (REB). However, one of the problems for the FEM using REB is the wide frequency spectrum because of its strong self electric field. Usually, a normal Bragg resonator is utilized to develop the frequency selectivity. Traditional Bragg reflectors work as mirrors in the optical distributed feedback laser [2-3]. However, as the frequency increases, the traditional Bragg reflector loses the selective features over transverse indexes. An advanced Bragg reflector proposed by N. S. Ginzburg[4] utilizes the interaction between a propagating wave and a quasi-cutoff mode to provide a higher selectivity over the transverse index than a traditional Bragg reflector. Structural difference between the traditional and the advanced reflectors is mainly on the periodic length of the corrugation. The period of corrugation of an advanced Bragg reflector is longer nearly twice than that of a traditional Bragg reflector. In the hybrid Bragg resonator [5], an advanced Bragg reflector is used at the entrance side and at the exit side the traditional Bragg one is utilized. The hybrid Bragg resonator is expected to realize a selective frequency band narrower than the traditional Bragg resonator.

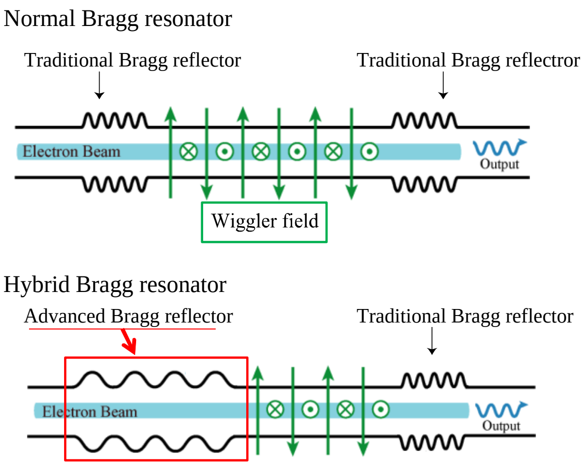

Fig. 1.　Schematics of the normal Bragg resonator (upper) and the hybrid Bragg resonator(lower). A REB is injected from left side.

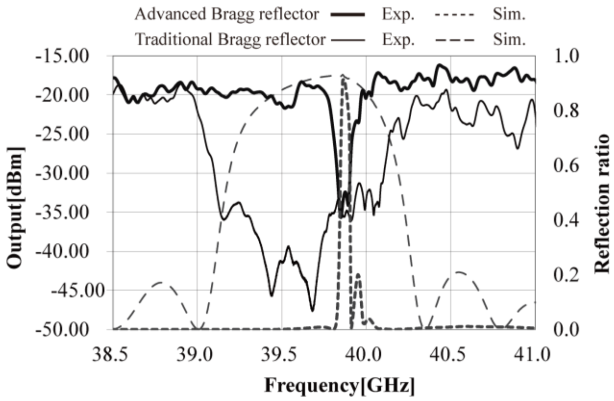

Fig. 2. Transparent characteristics of normal and advanced Bragg reflectors (cold test). And simulated reflective indexes of Bragg reflectors are also indicated.

Figure 1 shows the difference between the normal and the hybrid Bragg resonators.

2. Cold Tests of Bragg Reflectors

Cold tests of the Bragg reflectors were carried out using network analyzer E8354C (Agilent Technology). The microwave passed through the Bragg reflector was detected. The advanced Bragg reflector reflected the frequency of around 39.85 GHz. The width of the reflected frequency of the advanced Bragg reflector is about 10 times narrower than that of the traditional one as shown in Fig.2. The simulated reflective indexes of the Bragg reflectors are also shown in Fig.2 with dotted lines. The experimental results of the Bragg reflectors show good agreements with the simulated results.

3. Cold Tests of Bragg Resonators

Cold tests for normal and hybrid Bragg resonators were carried out with the same network analyzer used for Bragg reflectors. Microwave was radiated at the center of the Bragg resonator. And the microwave passed through the traditional Bragg reflector located at the downstream side of both resonators was detected. The distance between two reflectors was changed from 100 to 500 mm at interval of 100 mm.

The experimental result of the normal Bragg resonator is shown in Fig. 3. Several peaks were observed within the frequency range 39.8 $\pm$0.5 GHz in which the microwave was reflected by the traditional Bragg reflector. The frequencies of each peak are the function of the distance between two Bragg reflectors. As the distance increased, the frequency width of each peak decreased but the number of frequency peak increased.

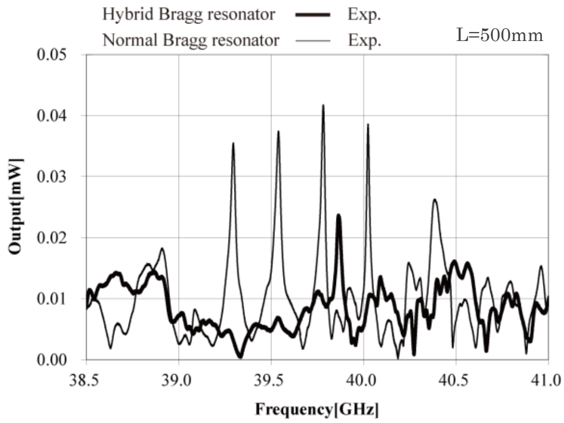

Fig. 3. Transmitted frequency spectra of the normal and the hybrid Bragg resonators.

The frequency spectrum passed through the hybrid Bragg resonator is also shown in Fig. 3. A single narrow peak is observed at the same frequency 39.85$\pm$0.05 GHz that was observed in the cold test of the advanced Bragg reflector. As the distance of the two reflectors increased, the frequency width of the peak decreased a little but the number of the peak kept one with the same frequency. The output power is a little lower than the normal one. It might indicate more careful adjustment of the distance of two reflectors.

An intense FEM using a REB radiates microwave with wide frequency spectrum. Though many peaks should be observed with the normal Bragg resonator, with the hybrid Bragg resonator a single peak should be detected. Therefore, we can expect the higher frequency selectivity of the hybrid Bragg resonator.

4. Conclusion

From the results of the cold test of both Bragg resonators, the frequency selectivity of the hybrid Bragg resonator is about 10 times narrower than the traditional Bragg resonator. The hybrid Bragg resonator can be used not only in the intense FEM using a REB but the other steady state THz source.

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