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Preliminary Experiments on Intense Free Electron Maser using Bragg Resonators
大強度FEMに用いるブラッグ共鳴器の効果

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An intense electron beam was injected into a cylindrical tube immersed in a double helical wiggler and an axial guide magnetic coils. Microwave with frequency around 45 GHz±1GHz was observed when the wiggler magnetic field was applied without a Bragg resonator. To develop the frequency selectivity, two Bragg resonators are planned to be used. One is a normal Bragg resonator using two traditional Bragg reflectors. Another is a hybrid Bragg resonator using an advanced and a traditional Bragg reflectors. Cold tests indicated that the advanced Bragg reflector could make the frequency spectrum narrower than the traditional one.

1. Introduction

Intense light sources with frequency range of 0.01~10 GHz will be applied to thermonuclear fusion, particle accelerators, radars, etc. One of the candidates of intense light sources is a free electron maser (FEM) using an intense relativistic electron beam (REB). However, the frequency selectivity of an intense FEM is one of problems to be solved. To develop the frequency selectivity, a Bragg resonator using two traditional Bragg reflectors located at the upstream and the downstream sides of a drift tube was utilized [1-3]. A Bragg reflector is composed of cylindrically periodic corrugations. It can provide a reflection of nearly unity through the principles of constructive interference. However, as the frequency increases, a traditional Bragg reflector loses the selective features. A hybrid Bragg resonator utilizes an advanced Bragg reflector at the upstream side instead of a traditional one could solve the problem at high frequency range. Here, we present the preliminary experimental results of FEM and an advanced Bragg reflector.

2. Advanced Bragg reflector

An advanced Bragg reflector proposed by Ginzburg [4] employs the coupling between the propagating and the cutoff modes to develop the frequency selectivity. The corrugation period of an advanced Bragg reflector is twice longer than that of a traditional one. Due to small variation of the mean radius of the advanced Bragg reflector at the boundaries, the quasi cutoff mode is trapped inside the advanced Bragg reflector. The advanced Bragg reflector works like a resonator. Cold tests of an advanced and traditional Bragg reflectors designed for 40 GHz were carried out with vector analyzer (AB millimeter MVNA 8-350) at Fukui University. Microwave with frequency from 35-45 GHz was radiated from a horn antenna located at one side of a reflector and the transmitted microwave was observed at the other side. The transmitted spectra of both reflectors are shown Fig. 1. Though the traditional Bragg reflector reflects the frequency range of 39-41 GHz, the advanced

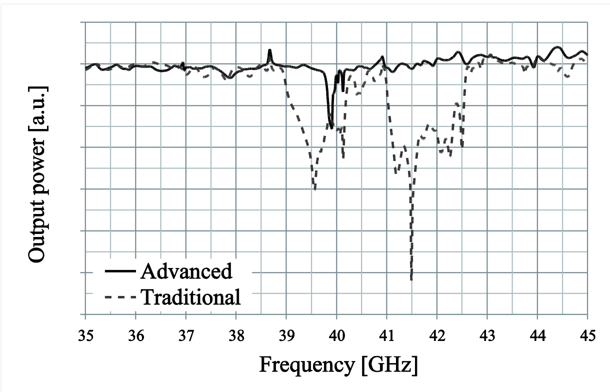

Fig.1 Waveforms of microwave transmit through the reflectors.

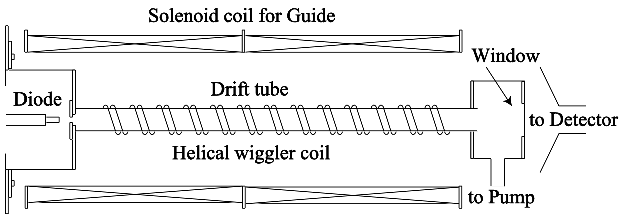

Fig.2 Experimental setup (not to scale).

Table.1. Parameters for FEM

REB	Beam energy	830 keV
	Beam current	220 A
	Pulse duration	160 ns
	Beam radius	4.0 mm
Solenoid coil	Magnetic field	0.9~1.3 T
Wiggler coil	Magnetic field	0.0~0.18 T
	Period	54.4 mm
Drift tube	Radius	8.5 mm

one showed that the frequency range of 39.9±0.1 GHz was reflected. The frequency selectivity could be developed by the hybrid Bragg resonator with an advanced Bragg reflector.

3. Experimental Setup of FEM

A REB with energy of 830 keV, current of 220 A and pulse duration of about 160 ns was injected into a cylindrical drift tube (waveguide) with the length of 1.5m immersed in an axial guide and a double helical wiggler coils as shown Fig. 2. No Bragg resonator was used in this experiment. Parameters of the experiments are listed in the Table 1. The radiated microwave through a plastic window located at the end of the drift tube was observed by a 100 m dispersive line, a 3 band filter bank and a diffraction grating.

4. Experimental Results and Discussion of FEM

Waveforms of microwave observed by the diffraction grating are shown in Fig. 3. Microwaves with frequency of 44.5-46 GHz were observed when the helical periodic magnetic field was applied. Without the helical wiggler field, microwaves with frequency of 45-45.5 GHz were observed with lower intensity. The microwave was observed at nearly 100 ns after the beam injection. At the time when the microwave was radiated, the beam energy was considered to be nearly constant from the waveform of the diode voltage shown in Fig. 3.

The dispersion relation with the experimental parameters is shown in Fig. 4. Depicted beam modes are the space charge mode in the helical magnetic field and the cyclotron mode. The

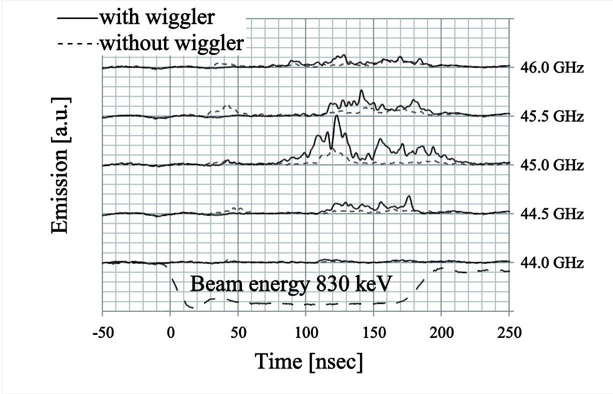

Fig.3. Waveforms of the microwave detected by a diffraction grating.

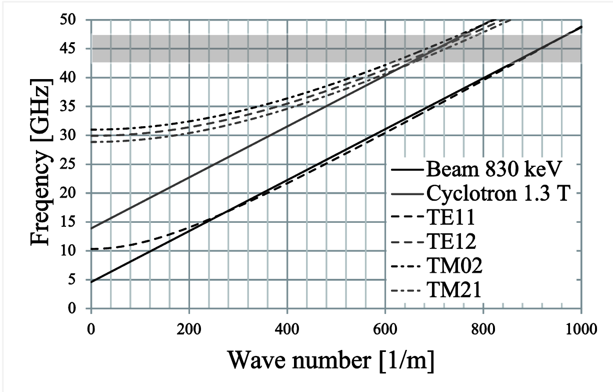

Fig.4. Dispersion relations of the experiment

radiation with the helical magnetic field is expected to be an interaction between the space charge mode and the TE_{11} waveguide mode. On the other hand, the radiation without the helical magnetic field is suspected to be the coupling between the cyclotron mode and the waveguide mode.

5. Conclusion

An advanced Bragg reflector showed an advantage of frequency selectivity to a traditional one. In preliminary experiments of FEM using REB, the radiation with the helical periodic magnetic field was observed and it was nearly identified. As the designed frequency of the Bragg reflectors is 40 GHz, we are now trying to decrease the radiated frequency.

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