High Power THz Radiation from a Cylindrical Grating Structure Using a High Current Relativistic Electron Beam

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***Abstract*—A Smith-Purcell radiation source using a grating structure modified in a cylindrical manner was considered to utilize a high power relativistic annular electron beam. The output characteristics were confirmed by numerical simulations assuming a 500 keV-5 kA electron beam. The experiment is being prepared.**

I. Introduction And Background

Since its first discovery, Smith-Purcell radiation (SPR) [1] has been attractive as a tunable light source that covers a wide range of electromagnetic spectrum. However, to increase its inherently low output power, researches has been focused on the way of increasing output power using such methods as resonator structure [2], bunched electron beam [3].

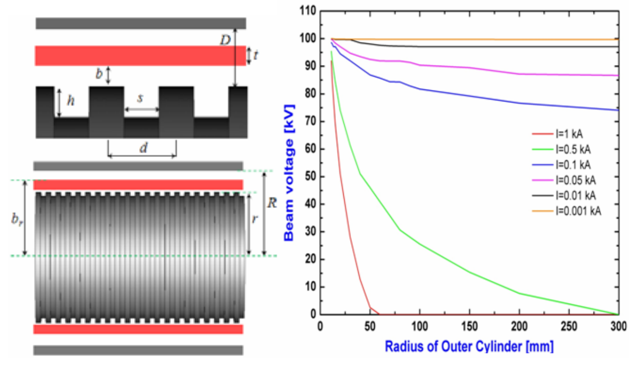
In this study, we utilize a high power relativistic electron beam from a pulsed power machine and transform its huge power into SPR radiation. The pulsed power machine produces a pulsed electron beam of 500 keV, 5kA with 100 ns pulse duration. The cross section of the electron beam is annular with inner radius = 10 mm and outer radius = 11 mm. Instead of using the usually adopted planar structures for SPR such as gratings and photonic crystals, a cylindrically symmetric grating structure is used. The high power THz radiation will interest the areas of nonlinear interactions with various objects.

II. Results

As a first stage, a grating structure with cylindrical symmetry was designed to be optimized to the 100 keV annular electron beam in the THz range at frequencies of 50 and 200 GHz. To optimize the output energy at this electron beam energy, a certain set of grating parameters such as grating period, impact parameter, etc. was chosen according to the perfectly conducting strip grating model [4, 5] and space-charge limited (SCL) current [6].

It has been known for nearly a century that there is an upper limit on the amount of current that can pass between two electrodes. This limiting current is known as the SCL current and is one of the most important phenomena related to charged particle beams. For beam currents below this limit, the beam flow is laminar through the drift space and the problem is time-independent. However, if the beam current exceeds the SCL current a virtual cathode is formed and the transmitted current decreases. Fig. 1(a) shows the geometry and parameters of simulation and (b) shows that with increasing the beam current beam voltage decreases, while beam passing over grating. To avoid this phenomenon, we can put an outer cylinder close to the grating. In this case the cavity mode between the grating and the outer cylinder has to be considered, like as an orotron [2].

The following set of grating parameters are obtained as a result of the optimization: grating period *d*=1.97 mm, grating slot width *s*=0.983 mm, grating to beam distance *b*=0.313 mm, radiation angle = 72.6° (Fig. 4). Fig. 6 shows the 2D PIC (particle-in-cell) simulation result showing the bunching of electron beam as a result of its interaction with the optimized grating structure.



(a) *(b)*

Fig.1 (*a*) The parameters of geometry, (*b*) Effect of the radius of outer cylinder to beam voltage.

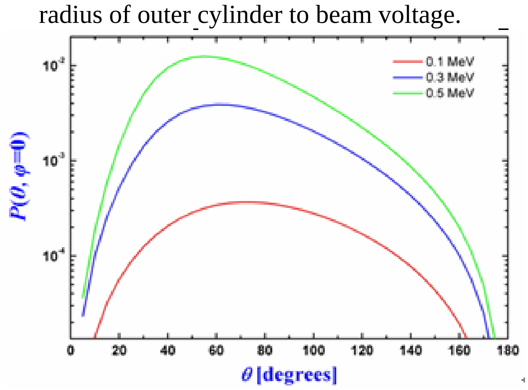


Fig. 2 Angular distribution of radiation power (theoretical calculation)

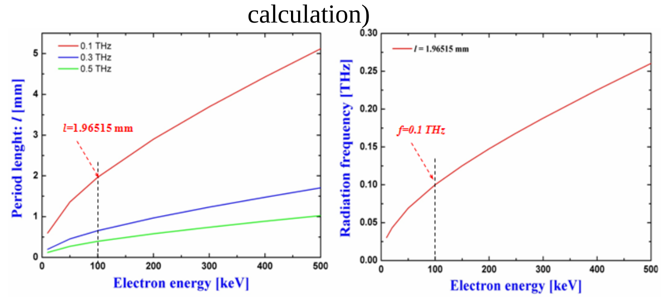


Fig. 3 Optimization of grating period and radiation frequency

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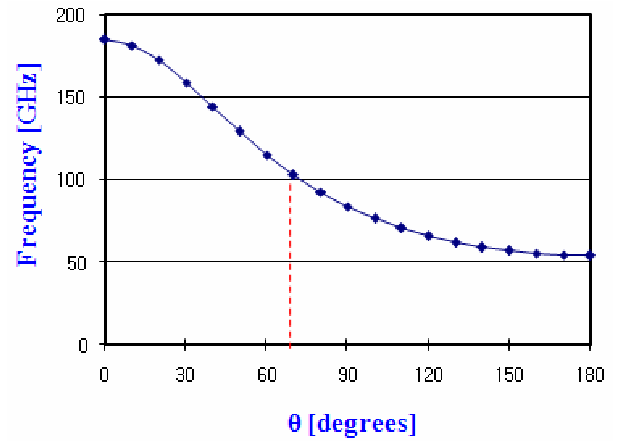

Fig. 4 Radiation frequency dependence of observation angle

The cylindrical grating structure will be placed inside the electron beam generator shown in Fig. 6. Further optimization process is continuing, and results will be present later.

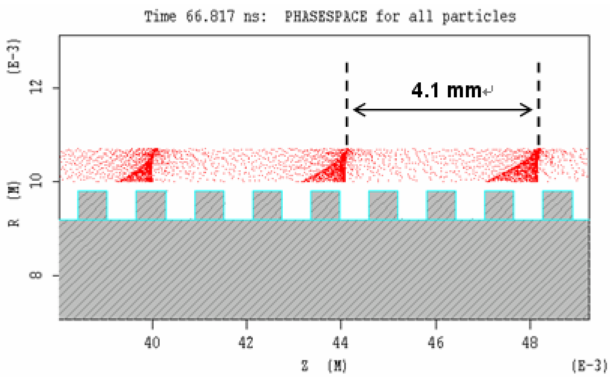

Fig. 5 Bunching of Electron Beam

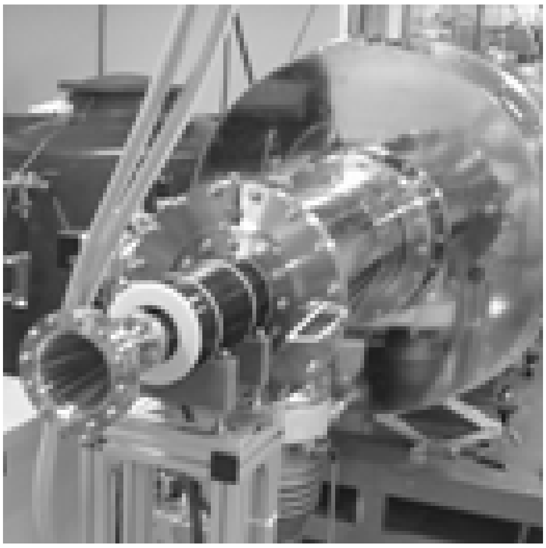

Fig. 6 Electron Beam Generator and Magnetic Confinement System

References

[1] S. J. Smith and E. M. Purcell, "Visible Light from Localized Surface Charges Moving Across a Grating", Phys. Rev. **92**, 1953, p. 1069.

[2] D. M. Vavriv and K. Schünemann, "Amplification regimes of the orotron: A single-resonator amplifier", Phys. Rev. E **57**, 1998, pp. 5993-6007.

[3] S. E. Korbly, A. S. Kesar, J.R. Sirigiri, and R. J. Temkin, "Observation of Frequency-Locked Coherent Terahertz Smith-Purcell Radiation", Phys. Rev. Lett. **94**, 2005, p. 054803.

[4] Seth R. Trotz, J. H. Brownell, and John E. Walsh, "Optimization of Smith-Purcell radiation at very high energies", Phys. Rev. E **61**, 2000, pp. 7057-7064.

[5] J. T. Donohue and J. Gardelle, "Simulation of Smith-Purcell radiation using a particle-in-cell code", Phys. Rev. Special Topics - Accel. Beams, **8**, 2005, p. 060702.

[6] Kenneth Frank Stephens II, "Space-charge saturation and current limits in cylindrical drift tubes and planar sheaths", Dissertation prepared for the degree of "Doctor of Philosophy", University of North Texas, August, 2000, 146 pp.

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