UPDATE ON PHOTONIC BAND GAP ACCELERATING STRUCTURE EXPERIMENT

J. Upadhyay and Evgenya I. Simakov
Los Alamos National Laboratory, Los Alamos, NM 87545, USA

Abstract

Photonic band gap (PBG) structures have great potential for filtering higher order modes (HOMs) without perturbing the fundamental mode and for suppressing the wakefields. An efficient PBG structure would help to improve the beam quality for high beam current future particle accelerators. A new design of X-band normal conducting PBG accelerating structure with inner elliptical rods is presented. This new optimized PBG structure would be fabricated and tested for RF breakdown at SLAC. The wakefield suppression experiment at Argonne Wakefield Accelerator (AWA) test facility is planned. The status of the experiment is reported.

INTRODUCTION

The future more compact particle accelerator with higher intensity, higher power will require higher frequency structures. The problem associated with the high frequency structures are higher order modes (HOM), excited by high current electron beam. These higher order modes interact with high current beam and disrupt them. The beam disruption or beam break up (BBU) instability is one of the biggest obstacles on the path to high current accelerators. High beam current accelerators are needed for future light sources and higher luminosity colliders. The photonic band gap accelerating structure provides a possibility to absorb HOMs and suppress the wakefields.

PBG structures are periodic structure (metallic, dielectric or both) which allows to confine the drive mode and damp higher order modes. PBG structures must be tested for acceleration and wakefield suppression [1, 2].

WAKEFIELD EXPERIMENT

A room temperature traveling-wave PBG accelerating structure operating at 11.700 GHz was built and successfully tested for wakefield suppression at Argonne wakefield accelerator (AWA) facility at Argonne national lab. This is a 16 cell travelling wave 2π/3 mode PBG structure which has 9 times the operational frequency of the AWA facility. The PBG structure is electroformed and could not be brazed due to internal stresses, a vacuum compatible epoxy was used to attach the components. Due to the use epoxy the vacuum chamber containing the PBG structure could not reach ultra-high vacuum. To isolate and protect the cesium telluride photocathode used in the photo injector in AWA facility the vacuum chamber containing the PBG structure is separated from the beamline with a thin Beryllium (Be) window (178 micron). The experiment on the wakefield suppression experienced a strong noise due to the scattering of electron beams through this Be window. The iris diameter of the PBG structure is 6.3 mm and the transverse rms size of the electron beam could be up to a few millimetres.

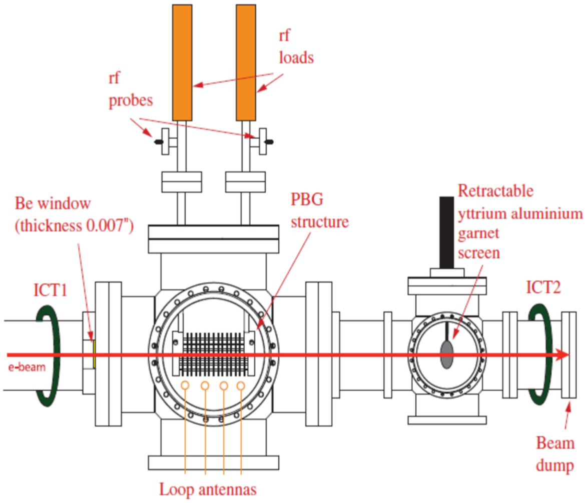

Figure 1: The experimental setup on the beam line at Argonne Wakefield Accelerator.

In the original wakefield experiment a good fraction of electron beam was hitting the front of the PBG structure and not entering the beam pipe of PBG structure. The experimental setup to do the wake field suppression experiment at AWA is shown in Figure 1. In order to understand how to send the beam through the PBG structure a series of experiment were done at AWA facility with three different thickness (30, 75, 127 micron) Be window. The beam size was measured before and after these window with different charges and different beam energies.

Based on these experiments (Table 1), a 30 micron Be window is chosen and another wakefield suppression experiment is planned. We will also demonstrate the beam acceleration/deceleration by powering the PBG structure and placing a spectrometer after the PBG structure.

Table 1: The table of beam size with 65 MeV beam energy and 1.5 nC charge for different Be window thicknesses.

	rmsx (mm)	rmsy (mm)	Mean Q (nC)
Initial	1.36	2.11	1.40
No foil	1.20	1.83	1.42
30 um	1.62	2.12	1.45
75 um	1.83	2.21	1.44
127 um	2.55	2.59	1.39

RF BREAKDOWN EXPERIMENT

A photonic band gap accelerating structure has been built by MIT group and tested for high power rf breakdown at SLAC [3, 4]. The tests suggest that the PBG structure with the inner row of rods with the elliptical shape compared to round shape shows a reduced breakdown rate.

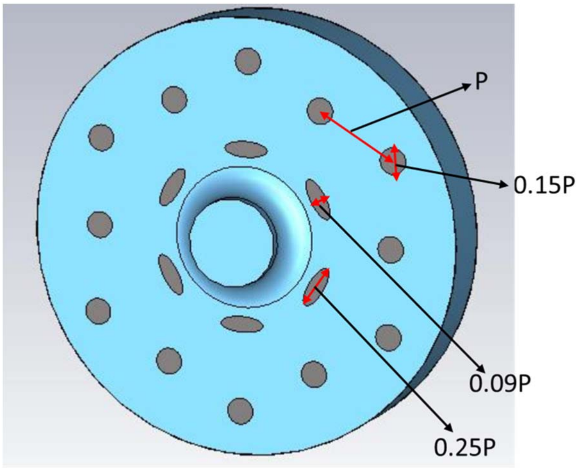

Figure 2: The improved design of PBG structure for rf breakdown experiment.

The probable cause for this phenomenon is the reduced magnetic field strength at the inner rod due to smaller curvature [5]. The reduced magnetic field leads to reduced pulse heating which helps in lowering the breakdown rate. To reduce the magnetic field on the rods of the PBG structure, we opted for the major radius of the inner rod to be 0.25p and then varied the minor radius for minimization of magnetic field. The minor radius value for minimizing the magnetic field came out to 0.09p and then p was varied to get the desired frequency. The outer rod radius is 0.15p to filter out higher order modes. The dimensions for the improved design of the PBG structure and different dimensions are shown in the Fig. 2 and summarized in Table 2.

In order to do the breakdown tests with SLAC's setup, we attached two coupling cells to the PBG cell. This two coupling cells which do not have the PBG structures are modeled similar to the structure earlier tested at SLAC [3]. This three cell structure is designed in such a way that the magnitude of the electric field in the PBG structure is twice more than the electric field in the coupling cell. The pictorial representation of the field in this structure and the magnitude variation of the electric field along the axis of this structure is shown in the Fig. 3.

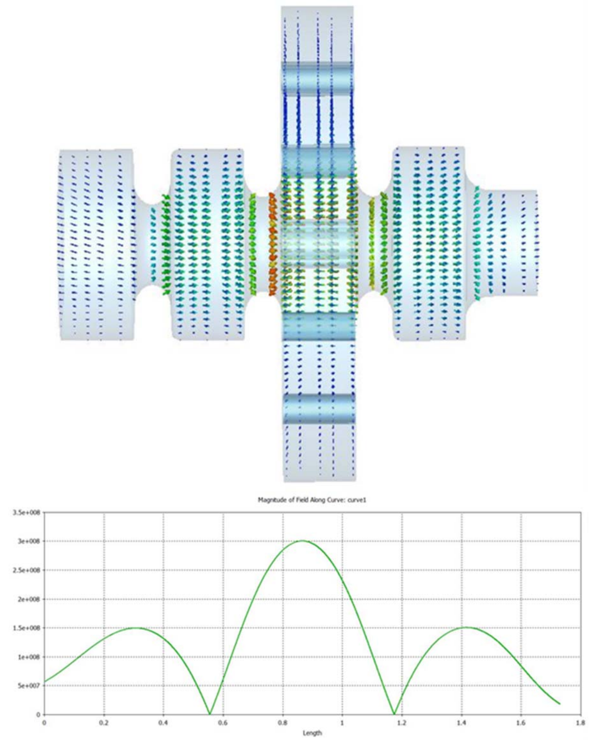

Figure 3: The pictorial representation of the EM field (Top) and the magnitude variation of the electric field on the axis of three cell structure (Bottom).

The structure is designed in such a way that the highest electric and magnetic field remain in PBG structure and not in the adjacent coupling cells. This ensures that the rf breakdown occurs in the PBG structure. A normal conducting copper cavity will be fabricated based on these simulations. The fabrication has to be done carefully as rf breakdown is also a surface related phenomenon and any minor surface damage might make structure to show lower breakdown threshold than estimated.

Table 2: The dimensions of the final design of the PBG structure for breakdown tests.

Spacing between the rods, p	0.44474 inches
Diameter of the outer rods, r	0.1342 inches
Minor radii of the inner elliptical rods, α	0.0402 inches
Major radii of the inner elliptical rods, β	0.1118 inches
Outside diameter of the cell, R0	1.1186 inches
Length of the cells. L	0.3354 inches

The value of p is optimized for 11.424 GHz and the reflection coefficient for the π mode is around -30 dB. The structure will have four tuning rods in each cells adjacent to PBG structure to tune the overall structure. The structure will be brazed and it will perturb the frequency, these tuning rods will be used to bring back the frequency to 11.42 GHz and field profile to 1:2:1. This structure will then be tested according to methodology and test procedure developed during the earlier high power breakdown test of similar structures.

CONCLUSION AND PLANS

We are planning to do the wakefield suppression experiment with the reduced thickness of Beryllium window at AWA. We will use 30 micron thickness window which would reduce the beam scattering and allow more charge to pass through the PBG structure. We are planning to use a spectrometer post PBG structure which will be used to measure the acceleration/deceleration in the PBG structure. We are also building a normal conducting PBG structure with reduced magnetic field by improving the design parameters of rod inside the PBG structure. We will test this PBG structure for rf breakdown at SLAC.

ACKNOWLEDGMENT

This work is supported by the Office of High Energy Physics, Office of Science, U.S. Department of Energy.

REFERENCES

[1] E. I. Smirnova. A. S. Kesar, I. Mastovsky, M. A. Shapiro, and R. J. Temkin, *Phys. Rev. Lett.* Vol. 95(7), p. 074801, 2005.

[2] Evgenya I. Simakov, Sergey A. Arsenyev, Cynthia E. Buechler, Randall L. Edwards, William P. Romero, Manoel Conde, Gwanghui Ha, John G Power, Eric E. Wisniewski and Chunguang Jing, *Phys. Rev. Lett.* vol. 116, p. 064801, 2016.

[3] Brian J. Munroe, Alan M. Cook, Michael A. Shapiro, Richard J. Temkin, Valery A. Dolgashev, Lisa L. Laurent, James R. Lewandowski, A. Dian Yeremian , Sami G. Tantawi and Roark A. Marsh, *Phys. Rev. ST Accel. Beams*, vol. 16, p. 012005, 2013.

[4] Roark A. Marsh, Michael A. Shapiro, Richard J. Temkin, Valery A. Dolgashev, Lisa L. Laurent, James R. Lewandowski, A. Dian Yeremian, and Sami G. Tantawi, *Phys. Rev. ST Accel. Beams*, vol. 14, p. 021301, 2011.

[5] Evgenya I. Simakov, Sergey S. Kurennoy, James F. O. Hara, Eric R. Olivas, and Dmitry Yu Shchegolkov, *Phys. Rev. ST Accel. Beams*, vol. 17, p. 022001, 2014.