DEVELOPMENT OF X-BAND PHOTONIC BAND GAP ACCELERATING STRUCTURE

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Abstract

We present the new experimental results for an X-band (11.42GHz) metallic PBG accelerating cavity. A coupler of a single cavity was fabricated and cold tested. An X-band traveling-wave PBG accelerator was designed based on CST MWS transient analysis. The X-band PBG accelerator is now under construction, future work will focus on the structure to be cold tested and tuned.

INTRODUCTION

Photonic band gap (PBG) structure [1, 2], or simply, photonic crystal, has been introduced to the field of new accelerating structure design since 1990s. The PBG accelerating structure can solve the HOM Suppression problem which is a very important issue in linear accelerators operating at high frequency. A 2-dimensional Metallic PBG structure (Fig. 1) received more attention because it is mechanically easy and has a higher sextuple symmetry which provides acceptable transverse uniformity in the accelerator. At MIT, this kind of a six-cell Ku-band traveling wave PBG structure was successfully designed, fabricated and tuned. The accelerating gradient of 35MV/m was acquired [3].

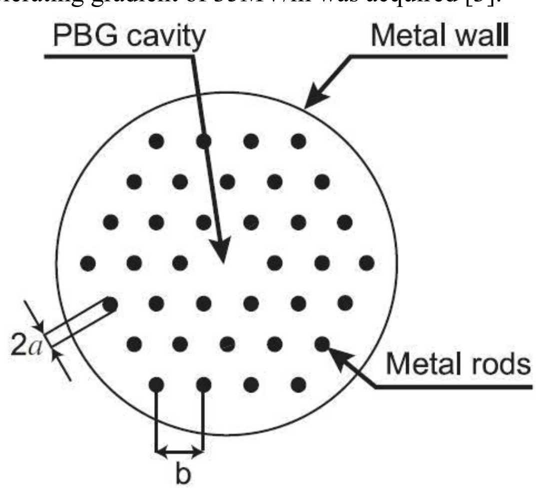

Figure 1: The geometry of a PBG resonator formed by removing a single rod in a triangular array.

By using the coordinate-space, finite-difference method, the global band gaps was calculated for general 2-dimensional PBG structure formed by triangular lattice of metal rods. The PBG cavity with the characteristics of single mode confinement was demonstrated by numerical simulations [3]. Since the fundamental mode is only confined in the center region while the HOMs exist in the whole cavity, we suggested to use SiC rods to replace some metal rods at the outer circle in the cavity. The outer circle of lossy rods can suppress the HOMs effectively while the influence on the cavity fundamental mode is quite little [4].

We've designed a PBG accelerating cavity working at the operating frequency of 11.42GHz. Fabrication with a better manufacturing technic was accomplished and cold test was performed The coupling of the PBG cavity was investigated. At last, the design of a 4-cell traveling wave PBG accelerating structure was finished and the accelerator is under construction.

STUDY OF 2-DIMENSIONAL PBG STRUCTURE

Design and Cold Test for PBG Cavity

It's noted from the conference [3] that for some values of rod's radii ($0.1<a/b<0.2$) only one single lowest order mode is confined by a PBG structure. The mode confined in the structure resembles the TM_{01} mode in a pillbox resonator, and it can be employed as the accelerating mode.

A PBG resonator was designed by keeping $a/b=0.15$ and changing the value of b to bring the frequency to 11.42GHz (without probes). Fig.2. Shows the fabricated cavity. The cavity was fabricated with much better manufacturing technic than the former one, the TM_{01}-mode Q-factor is greatly increased from 800 to nearly 3000 (Fig.3). However, we observed there's still a discrepancy between the measured Q-factor of the resonator's and the theoretically calculated Q-factor of 5100. The reason was the poor contact between the rods and the plates. So we put Brazing material in the gaps between the rods and the plates and heated them in a hydrogen furnace. After the resonator was brazed, the TM_{01}-mode Q-factor increased to be more than 4000.

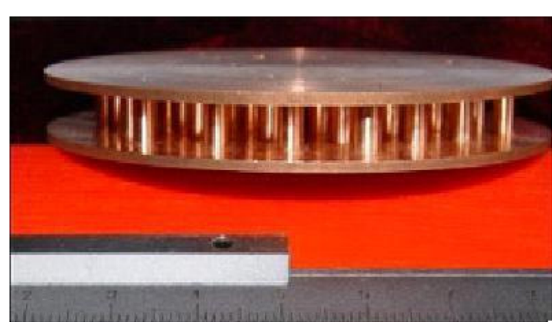

Figure 2: PBG cavity built for cold test.

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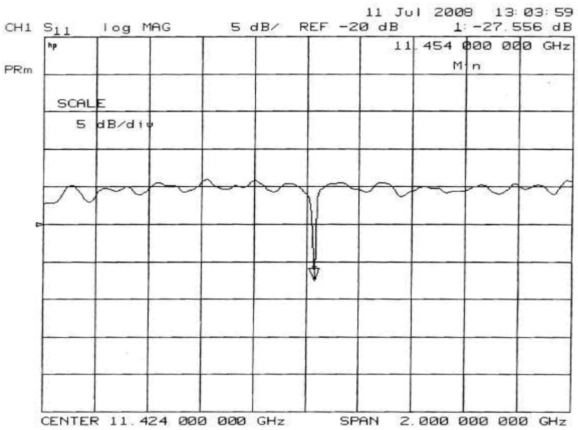

Figure 3: Cold test measurement of the PBG cavity.

Coupling Method Study

To couple the microwave power into the PBG resonator, we have studied the method of coupling between a waveguide and a PBG cavity. Some rods in front of the waveguide aperture have to be removed [3]. The coupling scheme finally chosen is shown in Fig.4.

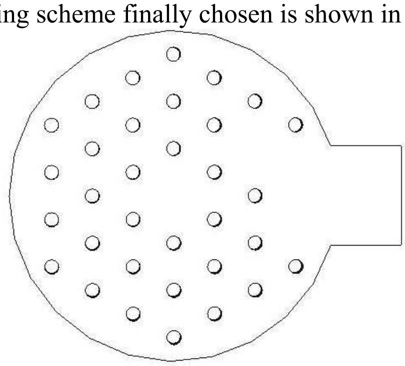

Figure 4: Coupling scheme for the PBG resonator in Fig. 5.

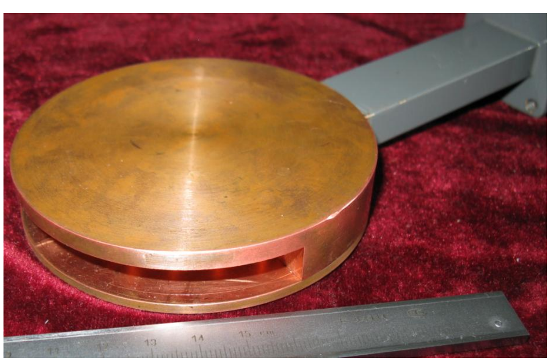

Figure 5: PBG resonator with a WR90 waveguide fabricated.

We built a cavity which is shown in Fig.5 and a WR90 waveguide was employed to feed rf power into the resonator. The rods and the plates were made of oxygen-free copper. Half of the wall was removed to obtain the HOM damping and the other half remained to acquire good input coupling [5] The simulation result and cold test result are shown in Fig.6. The experimental result is consistent with the theoretical one.

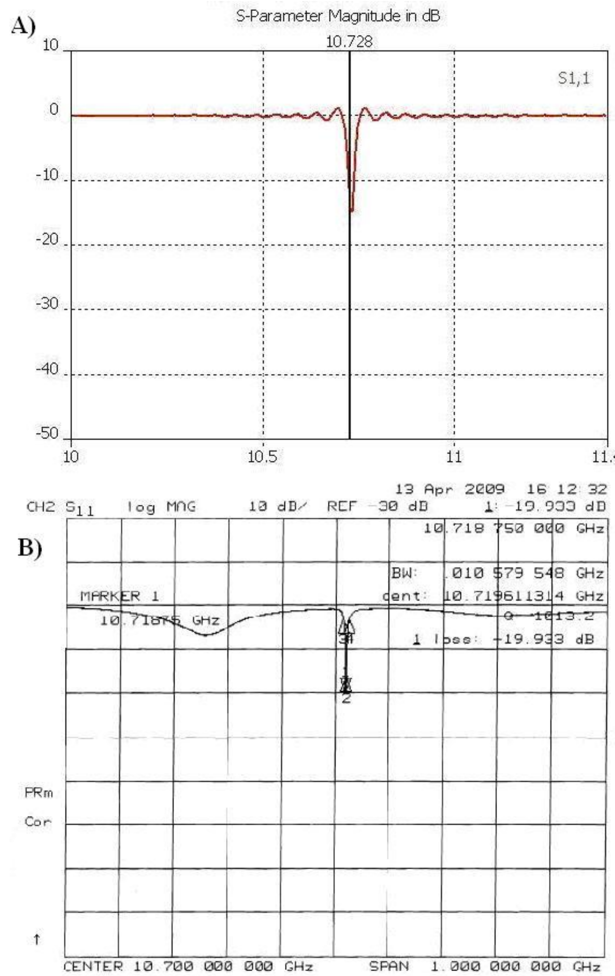

Figure 6: A) Numerical simulation result of the PBG resonator in Fig.5), B)Cold test measurement of the resonator.

PBG ACCELERATOR DESIGN

Based on our previous work, a PBG structure which consists of two couplers and two accelerating cavities was designed. The operating mode chosen is $2\pi/3$ and the operating frequency is 11.42GHz. The group velocity was tuned to 0.04C, which is higher than those of common electron linear accelerators to obtain effective acceleration in long cavities.

Due to its complicated geometry structure, the coupler design is rather difficult. Xu Peng, etc. in Tsinghua Universiy found a simple and effective method for the coupler design of this kind of PBG accelerating structure[6]. Fig.7 shows the coupling scheme of the couplers. The three rods between the waveguide and the beam hole are removed. The locations of another four rods around the beam hole are ajusted. The four rods' positons are changed for the tuning and matching of the input and output couplers.

The S parameters and the phase shift of the eletric field along the axis in the cavity are acquired by CST MWS transient analysis. The frequency of the third dip which represents the operating $2\pi/3$ mode was tuned to 11.42

GHz (Fig 8 A). The phase shift per cell is finally tuned to approximately 120°while the that of the coupler is about 62° (Fig 8 B).

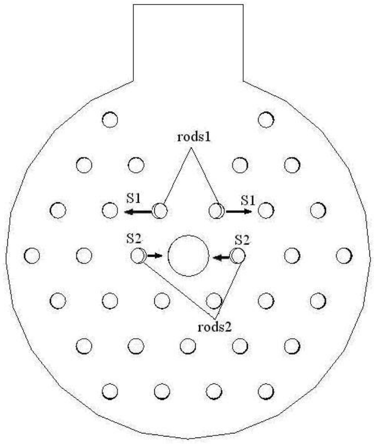

Figure 7: The coupling scheme of the Traveling wave stucture proposed by Tsinghua University.

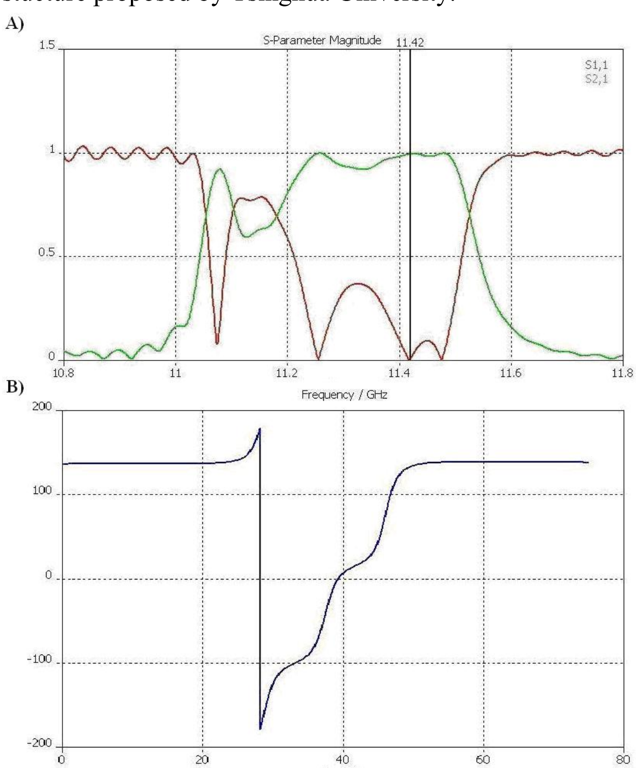

Figure 8: Simulation results of the 4-cell PBG accelerator: A) S parameters; B) Phase shift of electric field along axis

After the tuning and matching of the couplers were done, the design of a 4-cell PBG accelerating structure was finished and the main parameters of the structure is listed in Table 1. The accelerator is now being fabricated, Fig.9 shows the 3D model of the 4-cell PBG accelerator under construction.

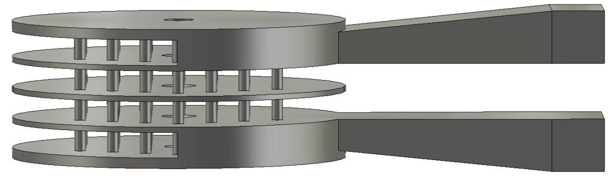

Figure 9: 3D model of the 4-cell PBG accelerator.

Table 1: Parameters of PBG accelerating structure

Operating frequency f	11.42 GHz
Operating mode	$2\pi/3$
Length of one period L	8.7535 mm
Rods radii a	1.62 mm
Rods spacing b	10.85 mm
Iris diameter d	8.4 mm
Iris thickness t	1.52 mm
S1/S2	0.54/0.56 mm
Group velocity v_g	0.040 C

SUMMARY

New experimental results for two X-band metallic PBG cavities are presented. The results show that our manufacturing technic is promising for the fabrication of the complex PBG accelerating structure. Design of a 11.42GHz PBG accelerator was accomplished and the accelerator is now under construction . The cold test and tuning will be the focus of our next work. The investigations of wakefield measurement and damping are in progress.

Thanks to Shuxin Zheng in Tsinghua University for his instructions of the coupler design.

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