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SIMULATIONS AND MEASUREMENTS OF THE WAKEFIELD LOADING EFFECT IN ARGONNE WAKEFIELD ACCELERATOR BEAMLINE

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Abstract

A collinear beam driven acceleration experiment in a photonic band gap (PBG) structure is underway at Argonne wakefied accelerator (AWA) test facility at Argonne National Laboratory. We plan to pass a high charge (drive) beam through a travelling wave 11.7 GHz PBG structure and generate a wakefield. This wakefield will be probed by a low charge (witness) beam to demonstrate wakefield acceleration and deceleration. The drive and witness bunches will be accelerated to above 60 MeV in the main accelerator at AWA which has a frequency of 1.3 GHz. The charges used in this experiment could be as high as 20 nC. To measure the direct effect of PBG structure on acceleration and deceleration of the witness bunch we have to exclude the effect of beam loading of the main AWA accelerator structure. To understand the wakefield effect in AWA, we conducted an experiment where we passed the high charge (10 nC) beam through the accelerator structure which was followed by a 2 nC witness beam separated by 4 wavelength. The energy of the witness beam was measured in the presence and absence of the drive beam. The beam loading was observed and quantified. The results of these works are presented in the conference and reported here.

INTRODUCTION

Future high beam current compact accelerators will need high frequency rf structures. High frequency rf structures have problems associated with higher order modes, which leads to beam breakup instability in high current accelerators. To supress higher order modes and to avoid beam breakup instability, PBG structures are used. PBG structures are good in retaining fundamental mode and not supporting higher order modes. PBG structures must be tested for suppression of higher order modes [1] and for their accelerating properties.

A high frequency (11.7 GHz) normal conducting travelling wave PBG structure is installed in AWA beam line to test for the acceleration and wakefield suppression experiment. This is a 16-cell travelling wave structure, which has 9 times the operational frequency of the AWA accelerator frequency. The beam tube diameter of this structure is 6.31 mm. The structure is fabricated by attaching the electroformed copper components with the help of vacuum compatible epoxy.

The AWA facility can produce high charges (up to 100 nC) and energy up to 65 MeV. It can also produce a bunch train of charges of up to 8 bunches. Due to the use of Cesium telluride as a photo cathode, the AWA beam line has stringent vacuum requirements. This makes the testing of complex rf structures that cannot fulfil these vacuum requirements very hard. To enable the test of these structures, there is a thin beryllium window separating the test chamber and main linac. Three Be windows of 30, 75 and 127 micron thicknesses were tested and based on their transmission characteristics, a 30 micron thick Be window is chosen [2]. The thickness of the Be window is 30 micron and diameter is 9.00 mm. The window can withstand the atmospheric pressure. In the experiment, this Be window separates the ultrahigh vacuum side to high vacuum side. Though the transmission characteristics of the Be windows are pretty good, the small diameter of the window makes passing of the higher charge beam difficult.

The higher order mode suppression in PBG structures was demonstrated in AWA beam line and reported in [3]. To show the acceleration in this structure a two beam experiment is underway. In this experiment a 10-20 nC first bunch (drive beam) will be sent through the structure creating a wakefield. While a second bunch with lower charge up to 1-2 nC (witness beam) will probe this wakefield. The phase of the witness beam with respect to the drive beam will be varied and the effect of this phase variation on the wakefield will be measured. The change in the energy with varying phase will show the acceleration characteristics of the wakefield created by the PBG structure.

To accurately measure the two beam acceleration in the PBg structure on the AWA beam line we have to first measure the effect of the wakefield of AWA linac structure on the beam energy of the witness bunch due to the drive bunch charges. Though the frequency of the AWA accelerator structures (1.3 GHz) is 9 times smaller than the PBG structure (11.7 GHz), due to bigger length of the AWA linac, the wakefield effect can be of the same order. Also due to Be window and the smaller beam tube diameter of the PBG structure the transmission of charge is roughly 50% through the PBG structure. So the AWA beamline see more charges going through it than the PBG structure. Which makes the charge that excites the wakefield in AWA linac higher than the charge exciting the wakefield in the PBG structure.

To see the wakefiled effect of the AWA linac, an experiment was planned where the drive beam of 10 nC was sent through the AWA lianc and the wakefield was probed with the witness beam of 1-2 nC, aprox 4 wavelength apart. The energy of the witness beam with and without the drive beam was measured on a spectrometer placed before the PBG structure.

MEASUREMENT OF THE WAKEFIELD EFFECT IN AWA ACCELERATOR

Figure 1 shows the experimental setup at AWA facility. There are two spectrometer placed in the beam line one is before the PBG structure and the other is placed after the PBG structure. The Be window is placed before the PBG structure.

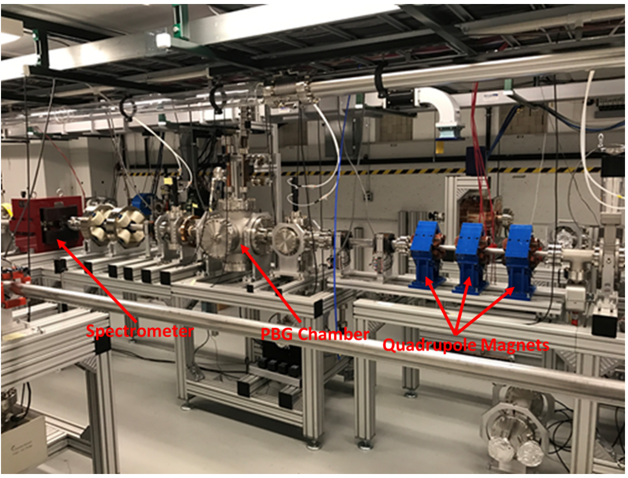

Figure 1: The experimental set up for the PBG experiment.

There are three quadrupole magnets placed before the PBG chamber to focus the beam through the PBG structure. There are also a couple of quadrupoles placed after the PBG chamber to focus the beam. There are two magnet kickers placed in the beam line before the PBG structure to steer the beam through the structure. There are two inductive current transformers (ICTs) to measure the charges before and after the Be window to measure the losses due to the window and the structure.

There is an optical setup for the AWA photo injector, which produces a bunch train of charges. An 8-bunch train can be created with each bunch one wavelength apart. The charge of different bunches of the train can be varied by reducing the laser intensity for that particular bunch. Only certain combination of these bunches can be produced. In our experiment for the PBG structure, the first bunch was chosen as a drive bunch and the fifth bunch as a witness bunch. The first bunch was of approximately 20 nC and the 5th bunch was 2-3 nC. Due to the Be window and smaller beam tube diameter of the PBG structure the charges passed through the PBG structure are 10-11 nC and 1-2 nC respectively. So to test the wakefield effect of the AWA beamline the chosen charge of the drive beam was 10 nC and the witness beam was 1-2 nC.

Before sending it to the spectrometer we focussed both beam on the YAG screen. This was to check that there is no axial position variation in both of the beams. Multiple shots of the drive beam, the witness beam and drive and witness beam combined were taken and the average positions were calculated. There is no significant variation in the position of these beams as shown in Fig. 2. The x and y axis are showing the coordinates on YAG screen in each case of Figure 2 and Figure 4.

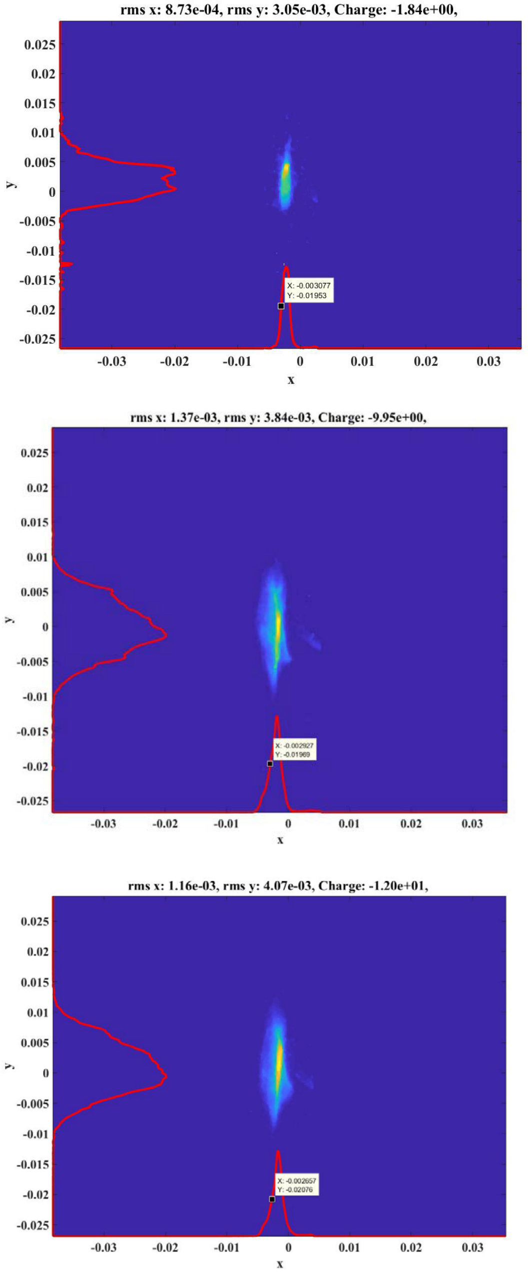

Figure 2: Beam positions of the witness beam (top), the drive beam (middle), and drive and witness combined (bottom) on the YAG screen before the spectrometer to measure the axial position difference.

The computational simulation performed for the AWA linac is shown in the Fig. 3. The wake potential for the fifth bunch is 4.17 V/pC.

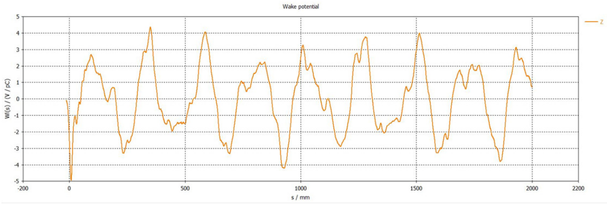

Figure 3: Computational simulation of the wakefield in the AWA accelerator structure.

There is a ten degree phase difference between the drive and the witness beam so the energy can be explicitly measured on the spectrometer for both beams. The spectrometer readings for drive, witness and drive and witness beams combined were taken. 100 shots of each measurement were taken and averaged out. The images of these measurements are shown in Fig. 4. It shows the loss of the energy for the witness beam in presence of the drive beam. For 10-degree phase difference and 10 nC drive beam charge the energy loss of the witness beam in the AWA linac was approximately 0.12 MeV.

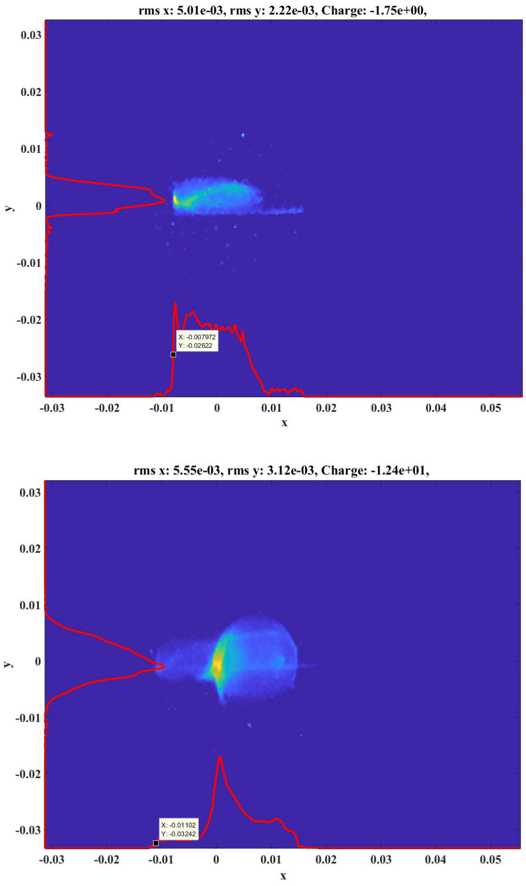

Figure 4: Witness beams energy measurement without the drive beam (top) and with the drive beam (bottom).

The measurements show that the witness beam loses the energy due to the wakefield created by the drive beam in the AWA linac structure. This shows that to do a two beam collinear experiment in a PBG structure, the beams energy should be measured before and after the PBG structure for all the phases and for all the conditions. This energy difference will reveal the exclusive wakefield characteristics of the PBG structure.

CONCLUSION

The experiment to measure the wakefield effect of the AWA linac structure is completed. Although the drive and the witness beams are accelerated under similar conditions, there is a significant change in the energy of the witness beams due to the wakefield of the drive beam. For a collinear two-beam accelerator experiment of rf structure in AWA beam line, this effect should be taken in to account. This would provide a more accurate measurement of the wakefield created in the rf structure under test.

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REFERENCES

[1] E.I. Simakov *et al.*, *Phys. Rev. Lett.* Vol. 116, p. 064801, 2016.

[2] E. E. Wisniewski *et al.*, in *Proc. NAPAC'16*, Chicago, IL, USA, p. 937.

[3] M. E. Conde, D. S. Doran, W. Gai, W. Liu, J. G. Power, C. Whiteford, E. Wisniewski, S. Antipov, C. Jing, J. Qiu, J. Shao, D. Wang and G. Ha, in *Proc. IPAC'15*, Richmond, VA, USA, p. 4272.