MODELING OF SUB-THZ DIELECTRIC-LINED WAVEGUIDE ACCELERATION

Argonne Wakefield Accelerator Facility

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INTRODUCTION AND MOTIVATION

Purpose: Wakefield accelerators have the potential to achieve accelerating gradients at the sub GV/m at a fraction of the current distance and cost, vital for the next generation of accelerators. Unlike other methods, structure-based wakefield accelerators do not consist of creating and maintaining a plasma, so it is the chosen accelerator for testing. It uses dielectric material and an electron bunch to create an electromagnetic wake that the drive beam loses energy to that is then used to accelerate a witness bunch.

The Argonne Wakefield Accelerator (AWA) facility has applied a single-shot longitudinal phase space (LPS) measurement system (Fig. 3) to a structure-based wakefield accelerator consisting of quadrupoles, a transverse deflecting cavity, and a spectrometer to measure the time to energy distribution of the beam projected onto orthogonal axes on the screen. This will be used as the experimental setup for these simulations and, thus, is essential to analyze in simulation.

Scope of Project: Test various structures with different cross-sections to determine structure with highest acceleration capability

Work Accomplished:

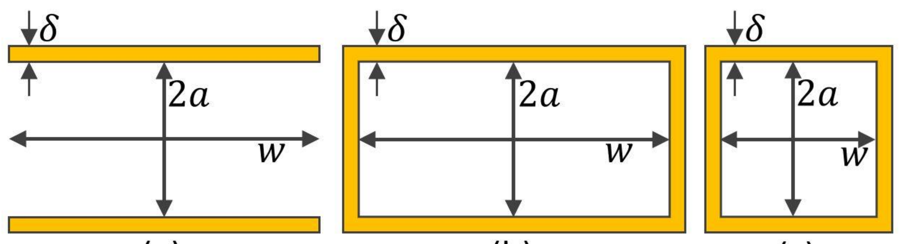
- Performed WarpX simulations of three different cross-sections
- Created python script to analyze WarpX simulations before and after LPS measurement system

STRUCTURES/AWA BEAMLINE

- Three cross-sections consisting of slab, rectangular, and square (Fig. 1) all of length 150 mm
- Beamline (Fig. 2) consists of structure ("THz"), YAG screen, three quadrupoles with variable strengths, a slit, the transverse deflecting cavity, a spectrometer, and a final YAG screen

Structure	2a (mm)	w (mm)	δ (mm)
Slab	2	4	0.4
Rectangle	2	4	0.4
Square	2	2	0.4

Table 1: Structure Dimensions



(a) (b) (c)

Figure 1: Structure Cross-Sections for (a) Slab, (b) Rectangle, and (c) Square

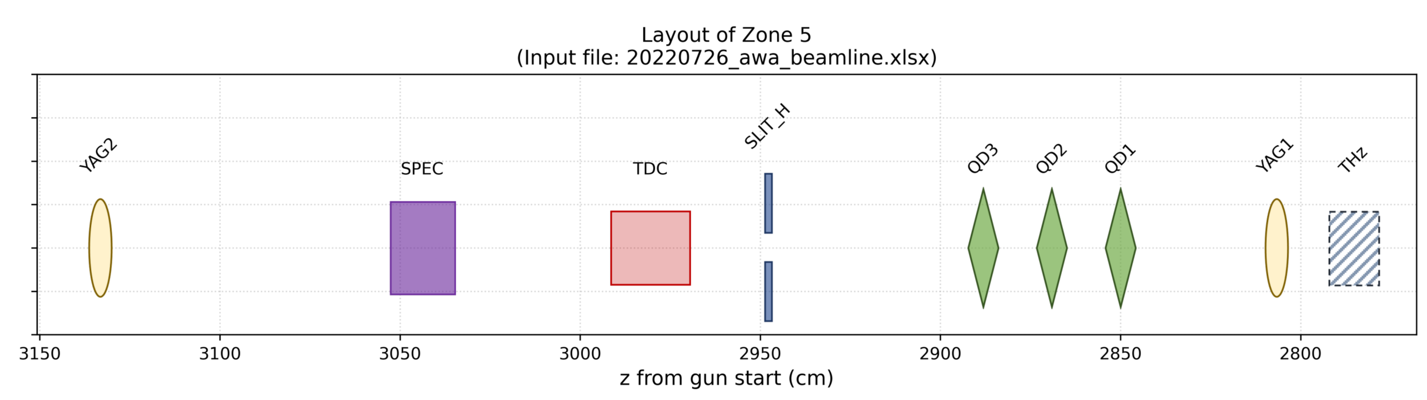


Figure 2: AWA Beamline right to left for distance from the gun

WARPX

WARPX is an open-source finite-difference time-domain (FDTD) particle-in-cell (PIC) framework. WARPX's macroscopic solver was used to simulate the propagation of a 3D gaussian beam through three different dielectric structures: a slab, a rectangular, and a square cross-sectional structures.

Structure	λ (mm)	Fundamental-mode Frequency (GHz)
Slab	4.78	62.75
Rectangle	5.98	50.20
Square	2.99	100.4

Table 2: Wavelengths created by Structures

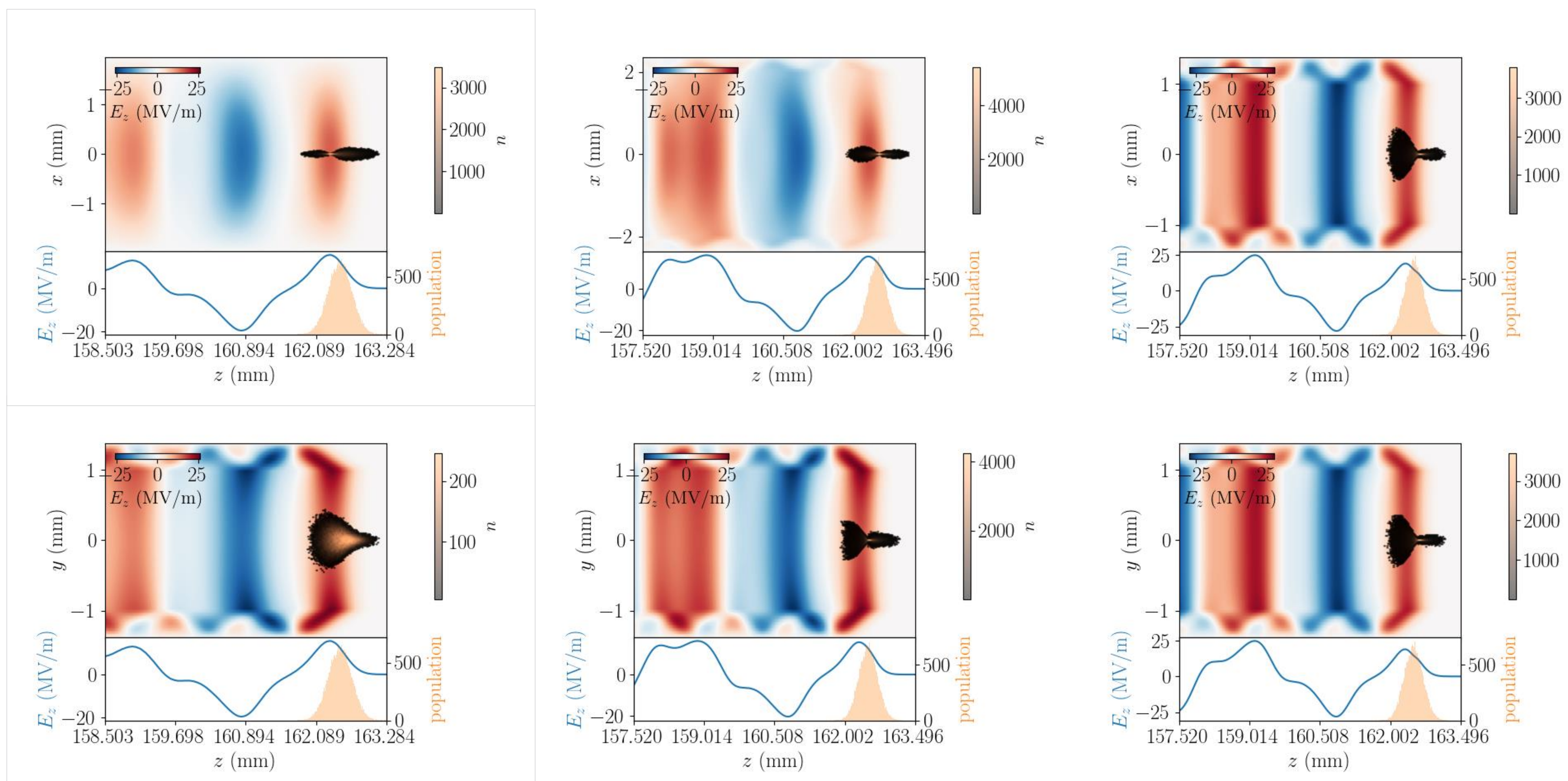

(a) (b) (c)

Figure 3: E_z Plots for (a) Slab, (b) Rectangular, and (c) Square Cross-Sections

LPS MEASUREMENT SYSTEM

Through analysis of the LPS measurement system, the necessary strengths of the quadrupoles (Table 3) were found such that the beam reaches a waist at YAG2 when the TDC and spectrometer are off.

Structure	k_q of QD1 (m^{-1})	k_q of QD2 (m^{-1})	k_q of QD3 (m^{-1})
Slab	0.945	-1.658	0.962
Rectangle	0.780	-1.578	0.946
Square	0.917	-1.609	0.904

Table 3: Quadrupole Strengths to Achieve Beam Waist

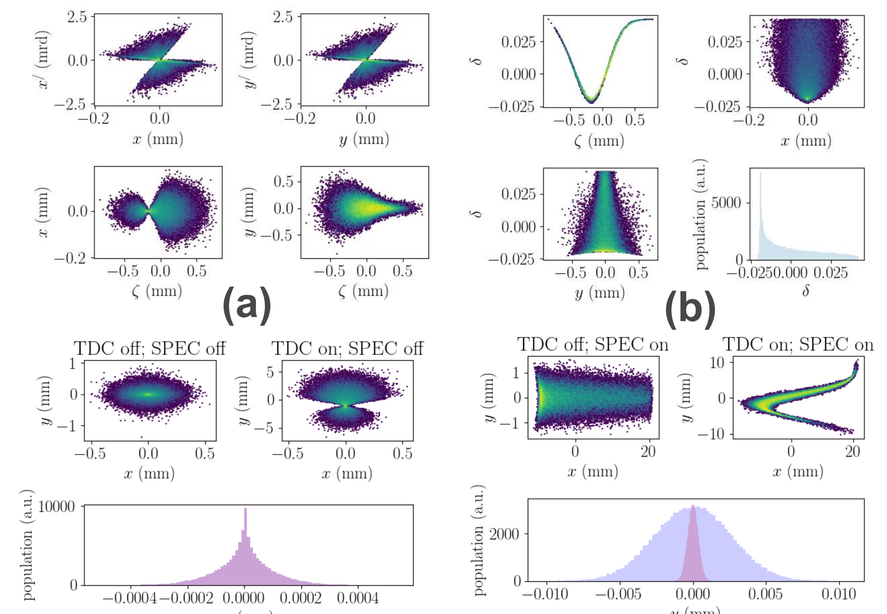


Figure 4: Slab Structure Analysis at (a) YAG1 and (b) YAG2

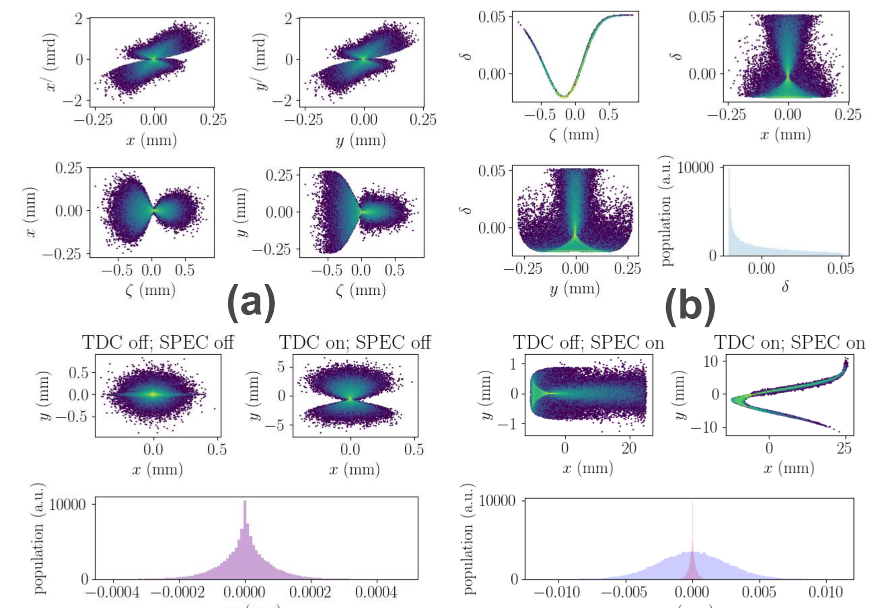


Figure 5: Rectangular Structure Analysis at (a) YAG1 and (b) YAG2

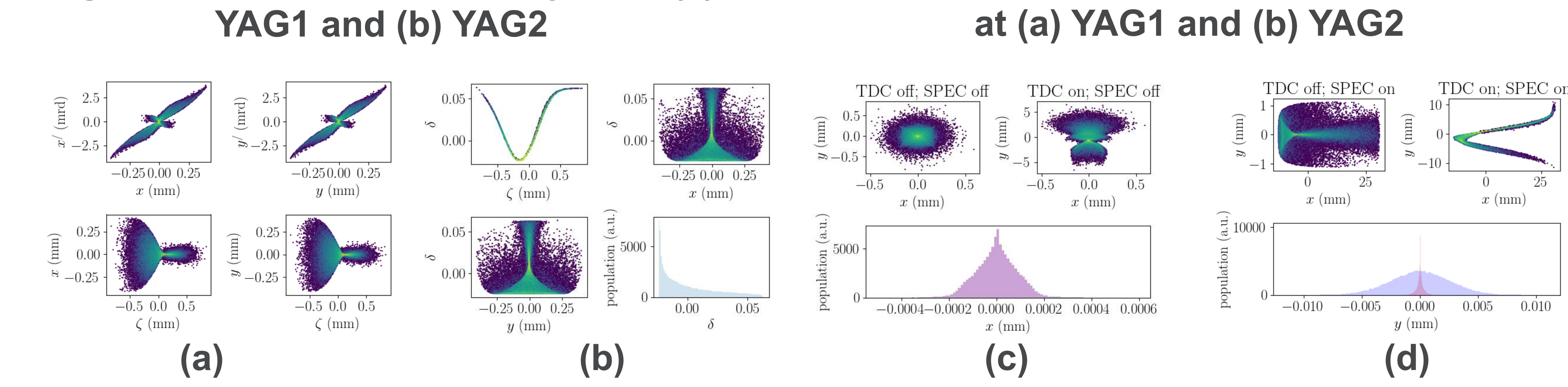

(a) (b) (c) (d)

Figure 6: Square Structure Analysis at YAG1 (a and b) and YAG2 (c and d)

CONCLUSION

- Successfully ran WarpX code for three dielectric structures with different cross-sections
- Created a python script to analyze results from WarpX simulations
- Determines ideal quadrupole strengths to create beam waist in both x and y at YAG2
- The analysis shows drive beam energy loss of about 500keV, which is more than enough experimentally to be able to observe results

FUTURE

- Cross-checking the python script with other beamline code OCELOT is needed to ensure its usability
- For experiment, a realistic input beam input is necessary to simulate and analyze
- Experimental preparation must be completed, such as buying and preparing structures
- Finally, running experimental setup with these structures and analyzing and comparing them to simulation will finish out this project

ACKNOWLEDGEMENTS

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