Multicell Dielectric Disk Accelerating Structure

DDA Multicell Design and High Power Results

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ABSTRACT

A Dielectric Disk Accelerator (DDA) is an accelerating structure designed to be loaded with dielectric disks to increase its shunt impedance. These structures use short RF pulses of ~9 ns to achieve accelerating gradients of more than 100 MV/m. A single cell and a multicell clamped structure have been designed and high power tested at the Argonne Wakefield Accelerator. During testing, the single cell clamped DDA structure achieved an accelerating gradient of 102 MV/m with no visible damage in the rf volume region. The minimal damage that was seen outside the RF volume was likely due to uneven clamping during assembly. After the success of that experiment, a clamped multicell DDA structure has been designed and tested at high power. Simulation results for this new structure show a 108 MV/m accelerating gradient with 400 MW of input power with high shunt impedance and group velocity. Engineering designs were improved from the single cell structure to ensure consistent clamping over the entire structure. Preliminary test results show a maximum input power of 222 MW and an accelerating gradient of > 70 MV/m.

MOTIVATION

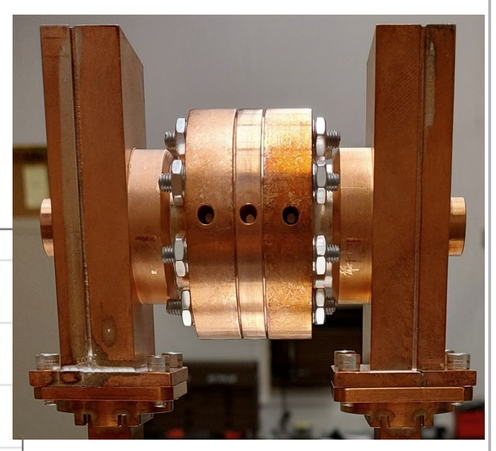
- Future of high energy, small footprint accelerators require high accelerating gradients.
  - 500 MeV Linear Accelerator Demonstrator
- Use of Short RF Power Pulses
  - Shorter pulse lengths = lower rate of breakdown.

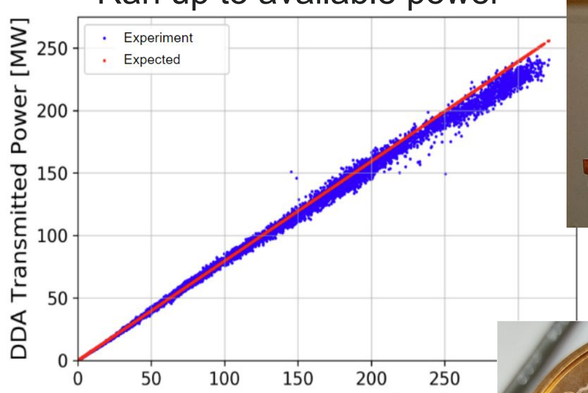
EXPERIMENT GOALS

- Test high power tolerance capabilities of materials in structure.
- Produce a large accelerating gradient using high power, short rf power pulse with an advance accelerator concept structure with minimal breakdown events.
- Scale up design for acceleration test.

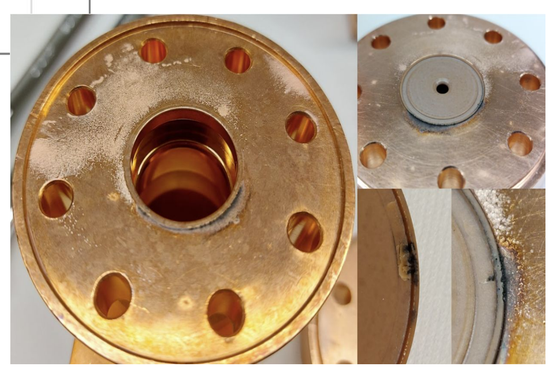
PREVIOUS DDA PROTOTYPES

- Previous DDA structures had issues with brazed assembly, newer prototypes were designed to be clamped
- High power tested
  - Withstood **321 MW** of input power
  - Accelerating gradient of **>102 MV/m**
  - Ran up to available power



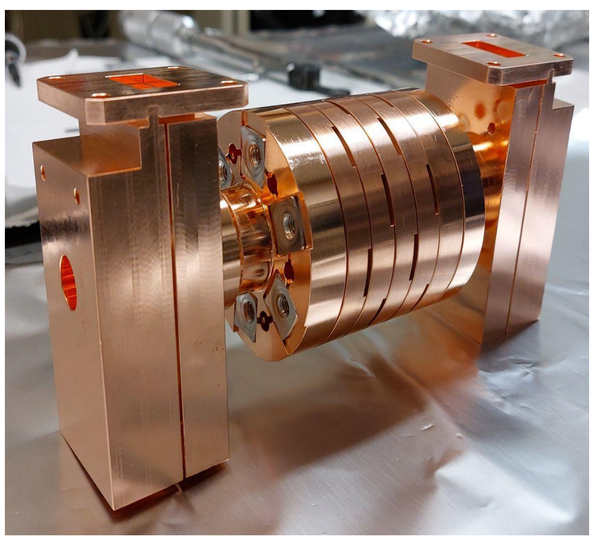


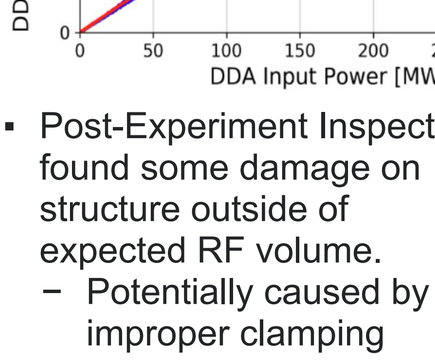
- Post-Experiment Inspection found some damage on structure outside of expected RF volume.
  - Potentially caused by improper clamping



MULTICELL ENGINEERING DESIGN AND ASSEMBLY

- To improve clamping, a more sophisticated assembly was designed, using torque wrench for each cell.
- Assembly occurred March 2023.

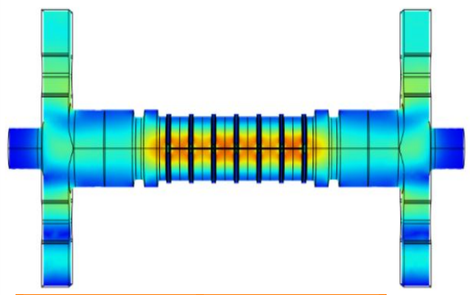




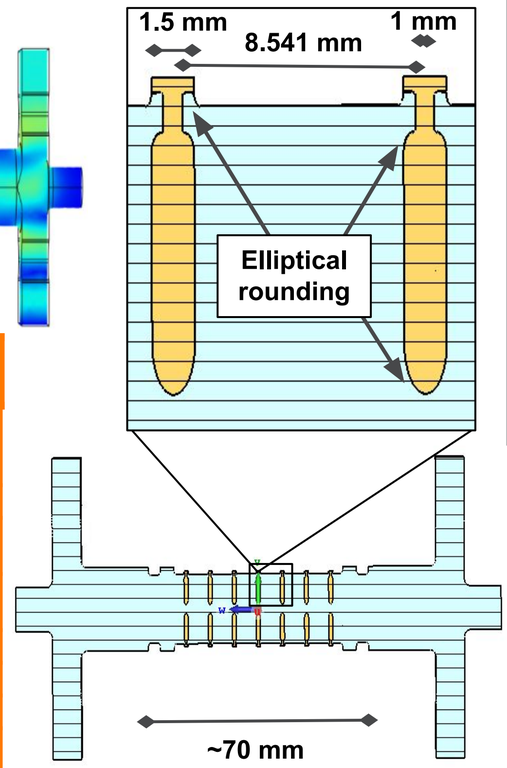
- Issues with Fabrication
  - Due to the small details required for the ceramics, only 6 of could be produced correctly.
  - Five cell DDA had to be simulated.
  - Coupler brazing done on an angle.

MULTICELL DDA SIMULATION

- With the success of the clamped single cell DDA structure, a clamped six cell structure was designed and tested.
- Original design had 7 ceramics making 6 dielectric cells.



Parameter	Simulated Value
Accelerating Gradient at 400 MW	108 MV/m
Group Velocity	0.24 c
Working Frequency	11.7 GHz
Cell Phase Advance	120°
Quality Factor	9,612
r	184 MΩ/ m
r/Q	19.2 kΩ/ m
S11 10 dB Bandwidth	> 600 MHz
S21 3 dB Bandwidth	> 700 MHz

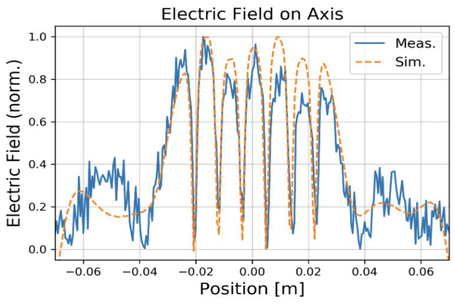


MULTICELL DDA COLD TEST

- After assembly of the revised multicell DDA structure, a cold test was conducted to measure S parameters and do a beadpull.

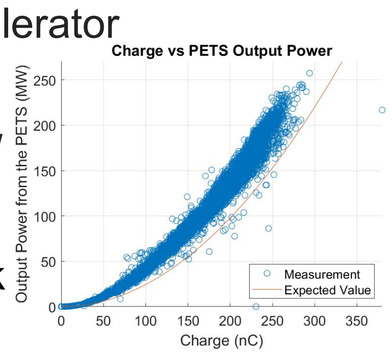
Parameter	Simulated Value (5 cell)	Measured Value
S11 at 11.7 GHz	-22.25 dB	-21.52 dB
S21 at 11.7 GHz	-0.090 dB (97.9%)	-1.18 dB (76.2%)
S11 10 dB Bandwidth	> 600 MHz	~ 600 MHz
S21 3 dB Bandwidth	> 700 MHz	> 650 MHz

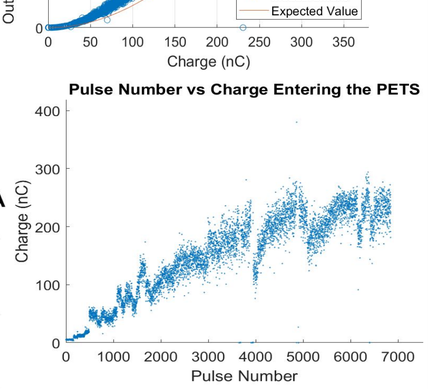
- Low power tests were completed to compare to simulation and to determine best input port.
- Noise seen in electric field measurement may be due to improper clamping.

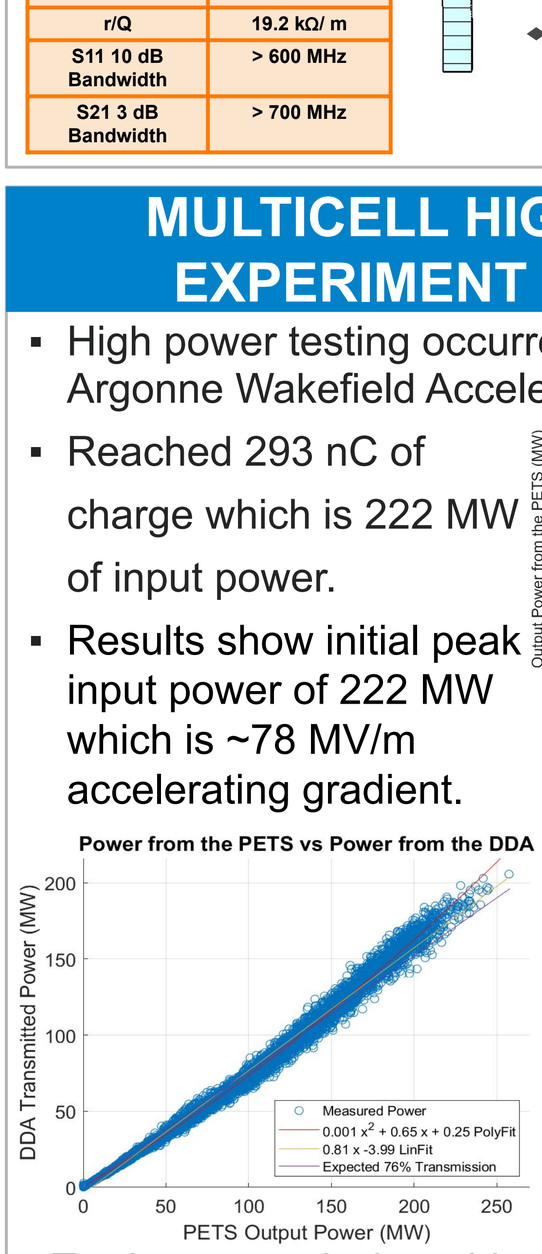


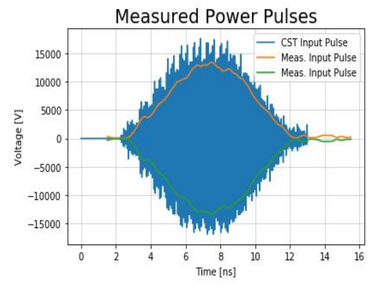
MULTICELL HIGH POWER EXPERIMENT RESULTS

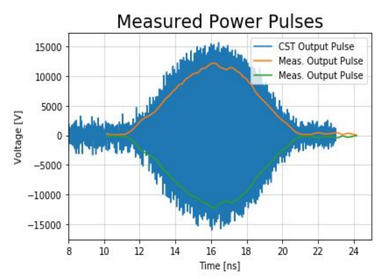
- High power testing occurred Summer 2023 at Argonne Wakefield Accelerator
- Reached 293 nC of charge which is 222 MW of input power.
- Results show initial peak input power of 222 MW which is ~78 MV/m accelerating gradient.











- Testing paused when drive beam had a large charge jitter and arcing in gun limited charge levels.
- Improvements of gun and laser are in progress at AWA.

CONCLUSIONS & NEXT STEPS

- Multicell Clamped DDA structure's high power experiment is successful and will continue in the fall.
- Staged DDA demonstration of Two Beam Acceleration to follow.
- This is an attractive candidate to be used in short, high energy linear accelerator.

REFERENCES

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