Dielectric Based Accelerator
Collaboration Program
Euclid Techlabs and Accelerator R&D, HEP, ANL

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This work is supported by
the DOE, High Energy Physics

Euclid Techlabs

www.beamphysics.com **www.hep.anl.gov/awa**

Euclid TechLabs LLC, founded in 1999 (as Euclid Concepts LLC) is a company specializing in the development of advanced dielectric materials for particle accelerator and other microwave applications. Additional areas of expertise include theoretical electromagnetics; dielectric structure based accelerator development; superconducting accelerating structure design; "smart" materials technology and applications; and reconfigurable computing.

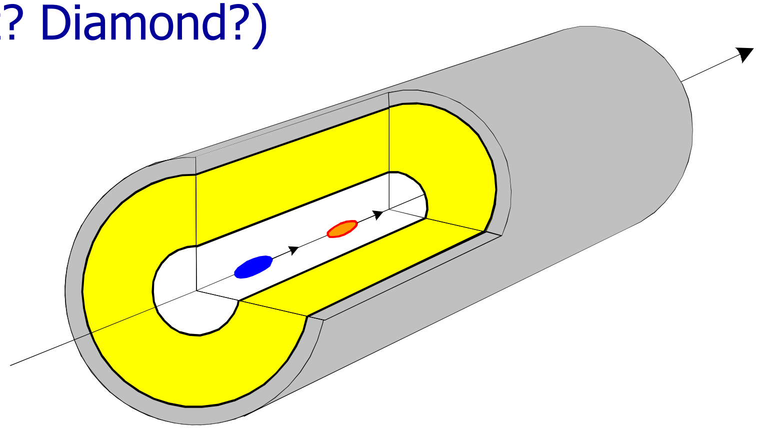
Euclid and the Argonne Wakefield Accelerator group at ANL have a long history of successful collaboration in engineering development and experimental demonstration of high gradient acceleration using a number of different dielectric structures and electron beam configurations.

2009 – 8 Phase II SBIR granted, 7 people research staff (5 full time and 2 visiting), + AWA group support, + cooperation with ANL/FNAL/Yale University/other labs…

Motivation/Outline

MW DLA issues: high gradient – drive beam, power extraction, tuning, efficiency, beam control (BBU).

- Drive Beam – Beam Train - High Gradient DLA
- Material Sustaining High Gradient (Quartz? Diamond?)
- Dielectric - Wakefield Power Extractor
- Tunable Dielectric Based Accelerator
- Energy Transfer: High Transformer Ratio
- Beam Handling, Beam Breakup (BBU)
- Multilayer structure – High r/Q.



Current SBIR Funded Program, Phase II

Funded previously:

- Transformer Ratio Experiment – Phase II (2002-2006)
- BST Ferroelectric Development – Phase II (2005-2007)
- SC Traveling Wave Accelerating Structure, Phase II (2007-2009)
- New Coupler Design for the DLA Structure, Phase II (2007-2009)
- Active Media Development – Phase II, (2006-2008

Funded, and in progress now:

- Diamond Based DLA Structure, Phase II (2009-2011) - new
- Tunable DLA Structure, Phase II (2008-2010)
- Beam Break-Up (BBU) of the DLA Structure (2008-2010
- 26 GHz DLA Based Power Extractor (2008-2010)

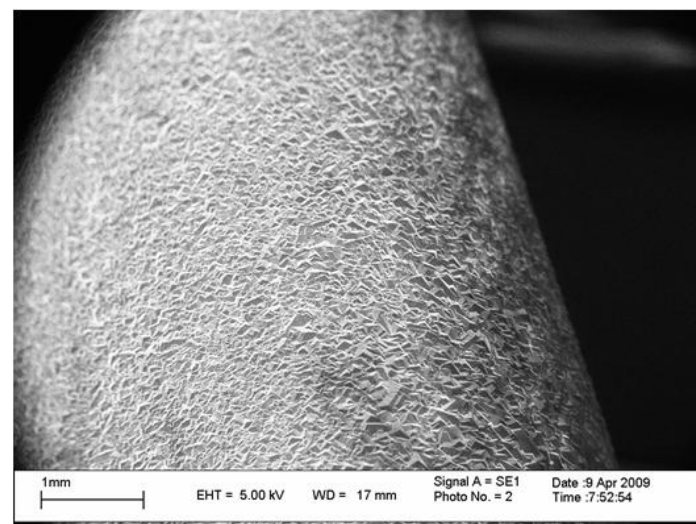
Motivation for CVD Diamond for DLA

CVD DIAMOND PROPERTIES:

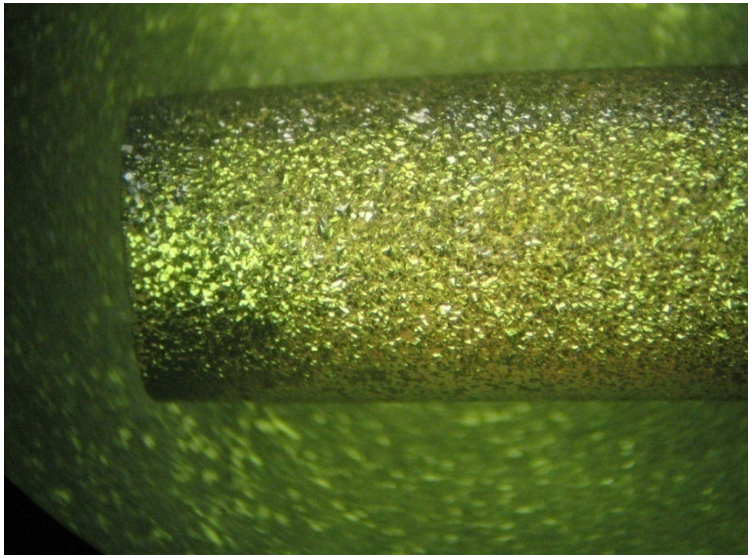
- RF BREAKDOWN THRESHOLD OF ~ 2 GV/m
- LOSS FACTOR DOWN TO $5x10^{-5}$ AT 30-140 GHz
- HIGHEST THERMAL CONDUCTIVITY
- MULTIPACTING CAN BE SUPPRESSED (NEW !)

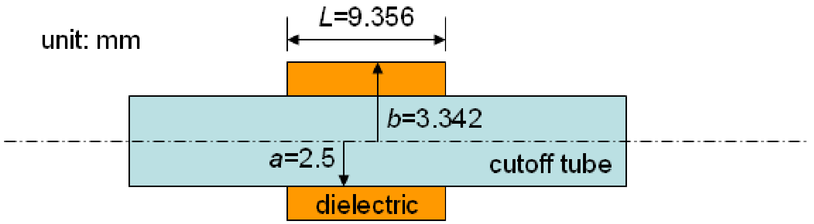
and

CVD DEPOSITION NOW CAN BE USED TO FORM CYLINDRICAL WAVEGUIDES

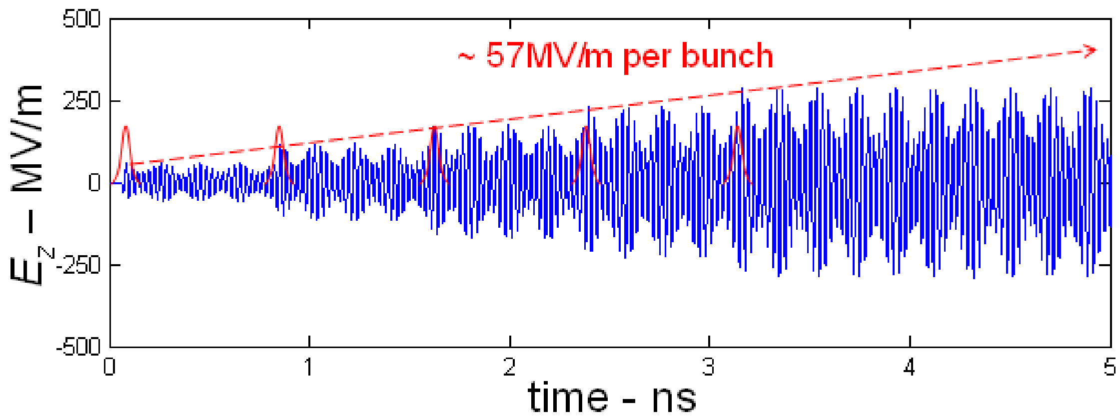


35 GHz Diamond Based DLA Structure



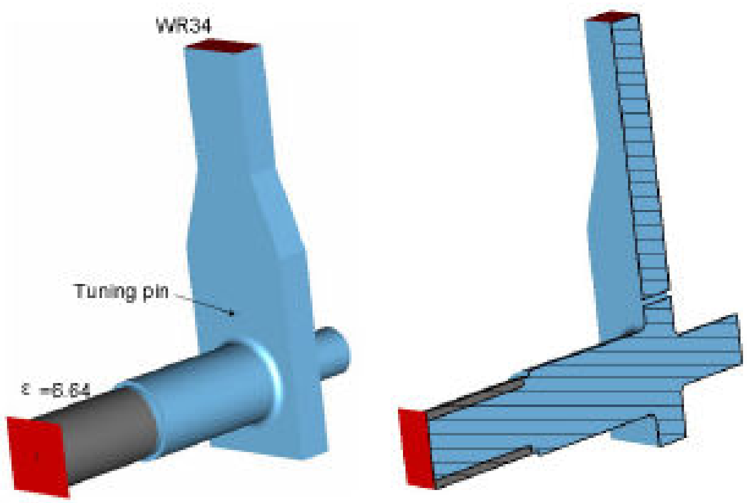


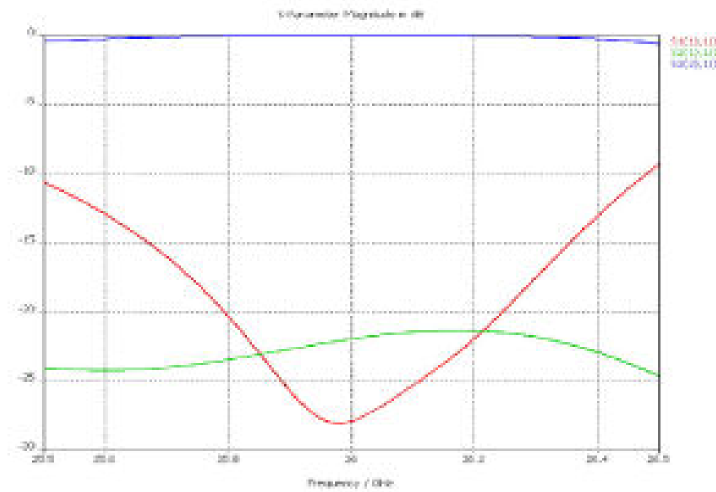
CVD diamond tube fabrication



A. Kanareykin, Euclid Techlabs LLC, CLIC'09

26GHz Dielectric-Based Wakefield Power Extractor----design





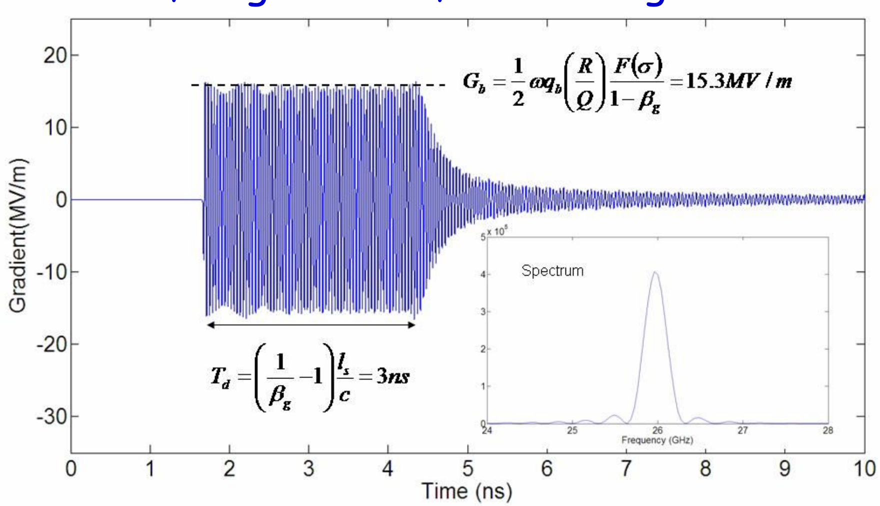
Geometric and accelerating parameters	value
ID / OD of dielectric tube	7 mm /9.068 mm
Dielectric constant	6.64
Length of dielectric tubes	300 mm
Synchronous frequency of TM_{01} mode	26 GHz
Group velocity	0.25c/0.42c
R/Q of TM_{01} mode	9788(Ω/m)
Q of TM_{01}mode	2950
Generated rf power (bunch train)	**37MW/10nC per bunch**

Update on 26GHz Dielectric-Based Power Extractor

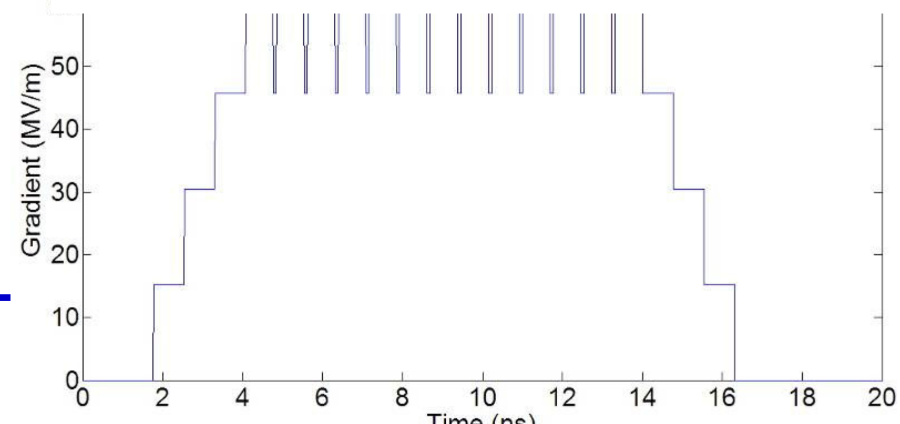
Parameters of 26GHz Dielectric Based RF Power Extractor

Geometric and accelerating parameters	**value**
ID / OD of dielectric tube	7 mm /9.068 mm
Dielectric constant	6.64
Length of dielectric tubes	300 mm
R/Q	9788 Ω/m
Drain time Td	3 ns
Steady power from AWA bunch train (20nC/bunch)	148 MW

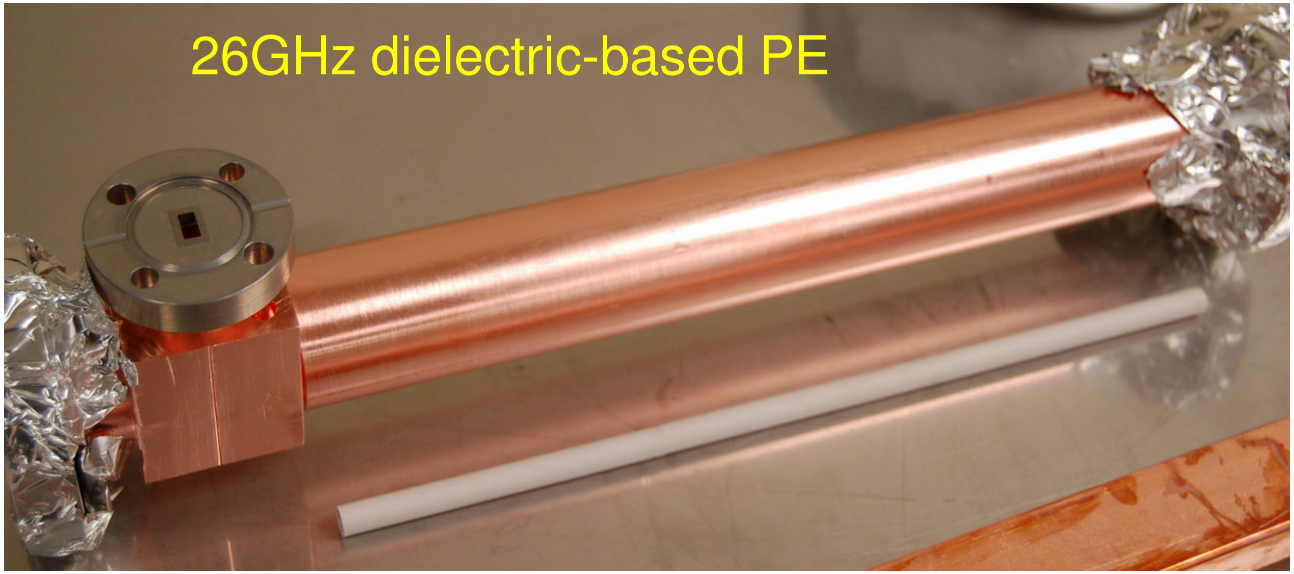
*20nC, single bunch, bunch length 1.5mm.

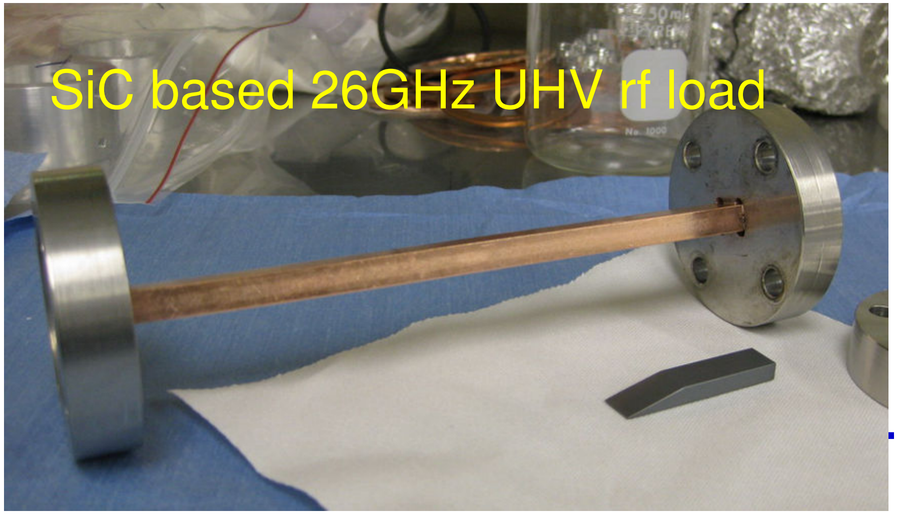


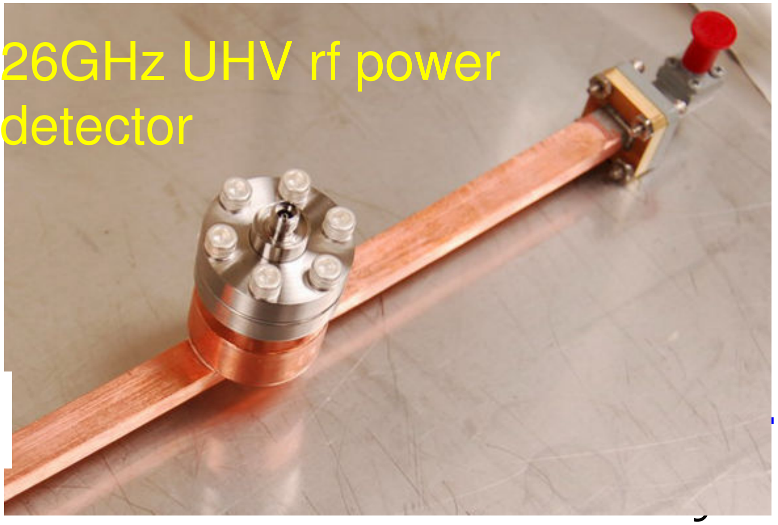
*16, 20nC bunch train, steady output power of 148 MW and 56 MV/m peak gradient. The energy loss is 5.7 MeV for the last bunch in the bunch train .



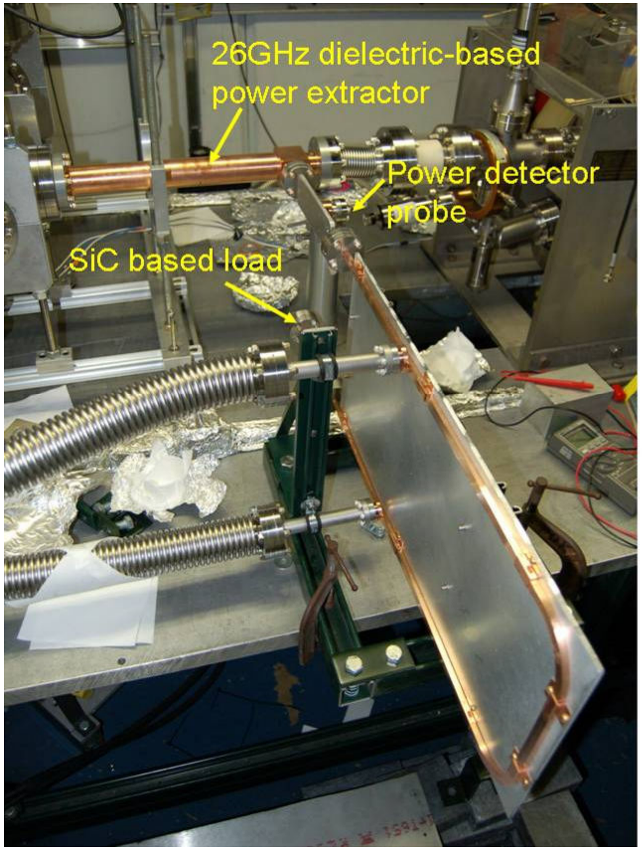
Fabrication

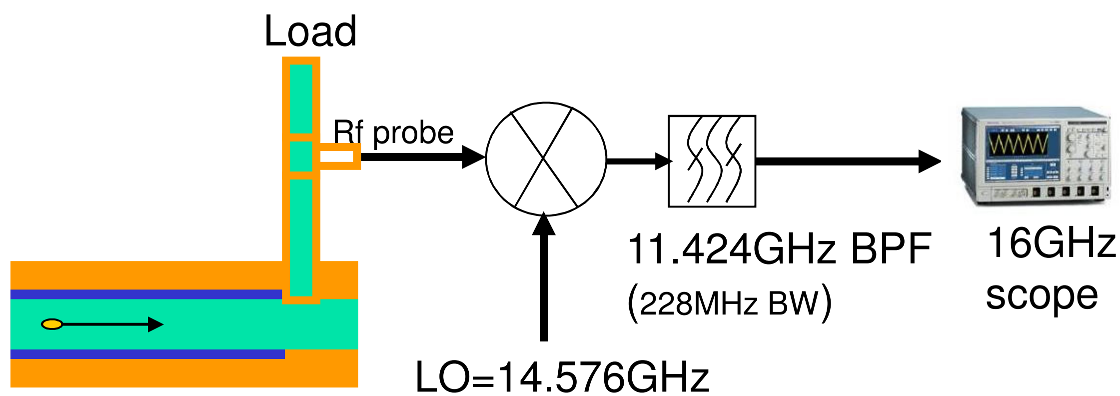




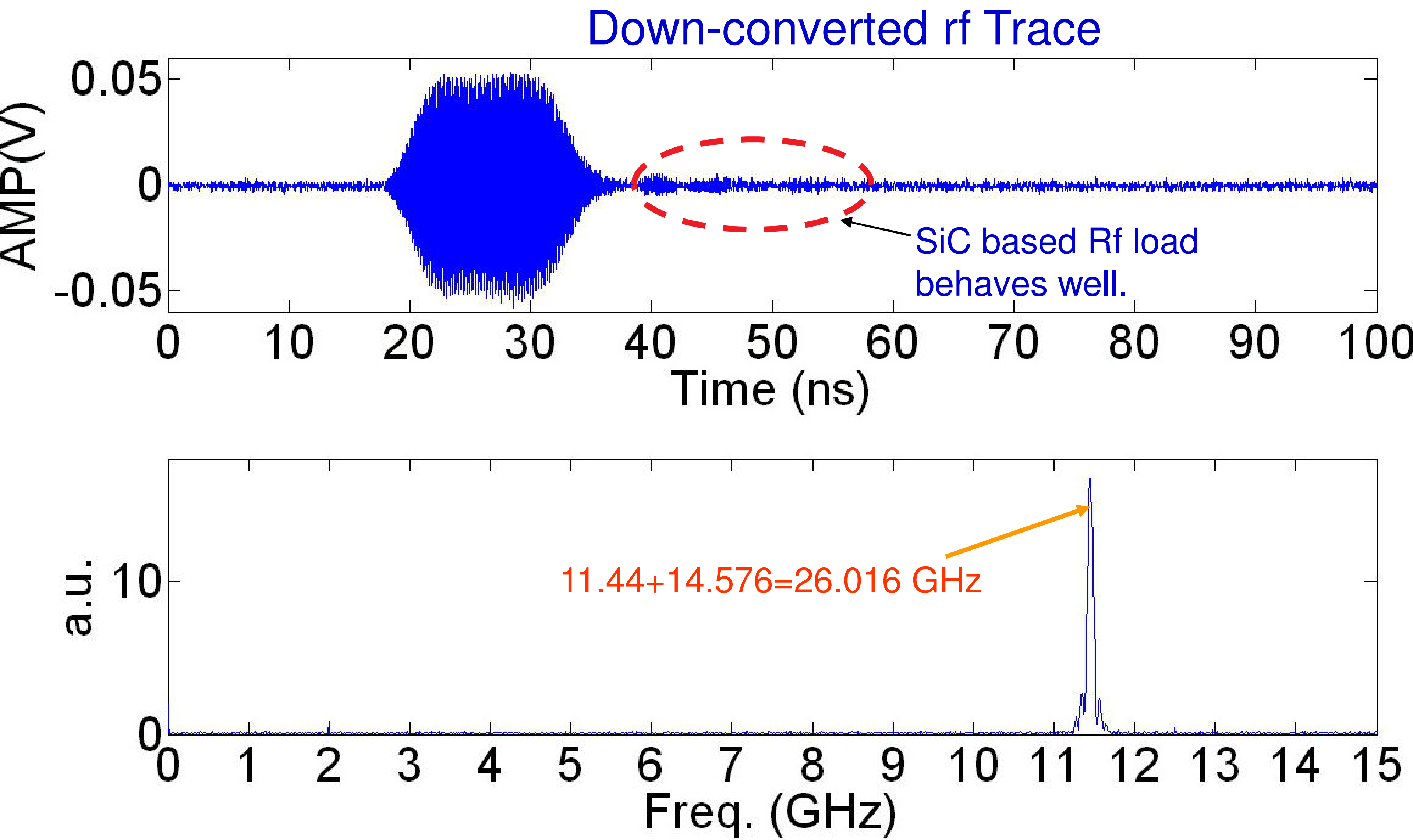


Beam Test Setup

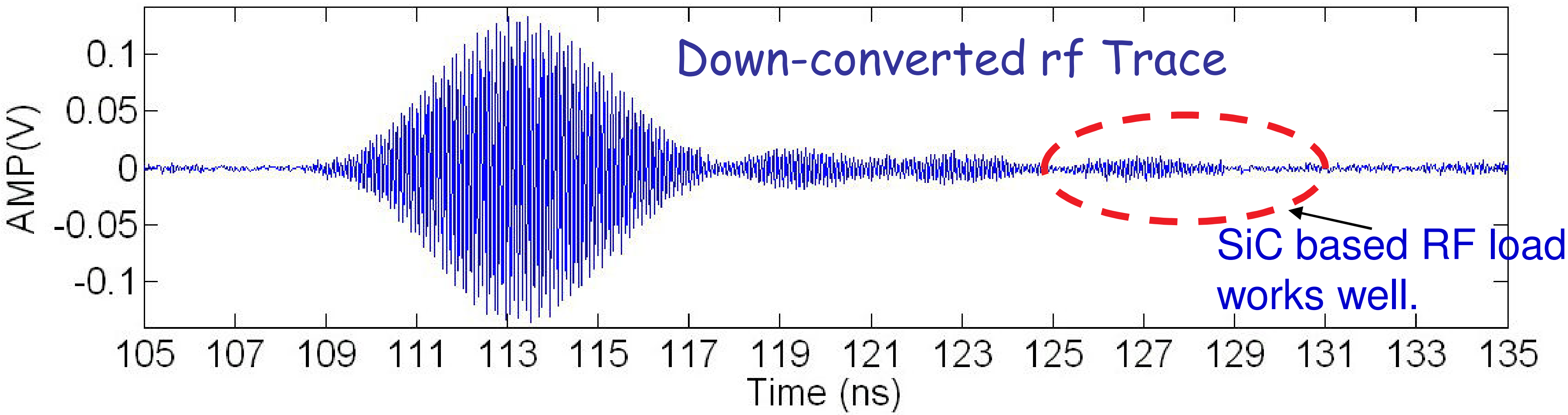


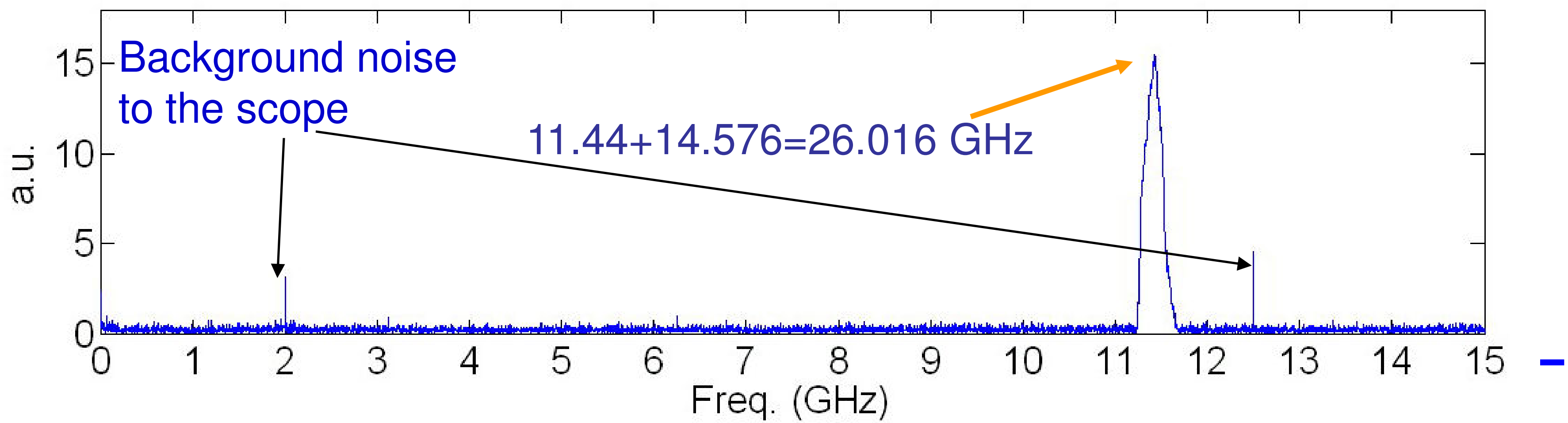


Result (I): 16 bunches, Tb=769ps



Result (II): 4 bunches, Tb=769ps



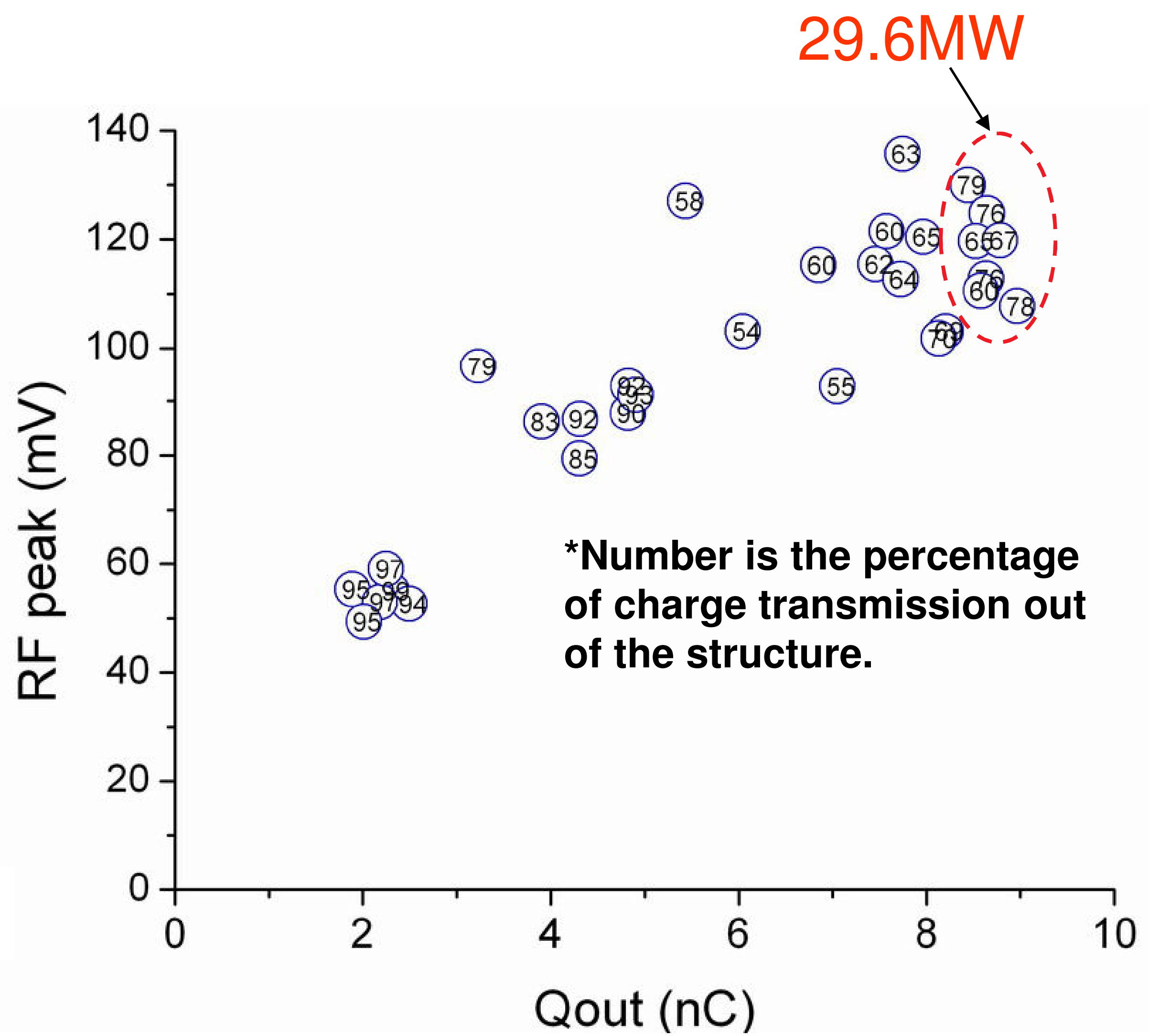


Result (III): Charge sweeping, 4 bunches, Tb=769ps

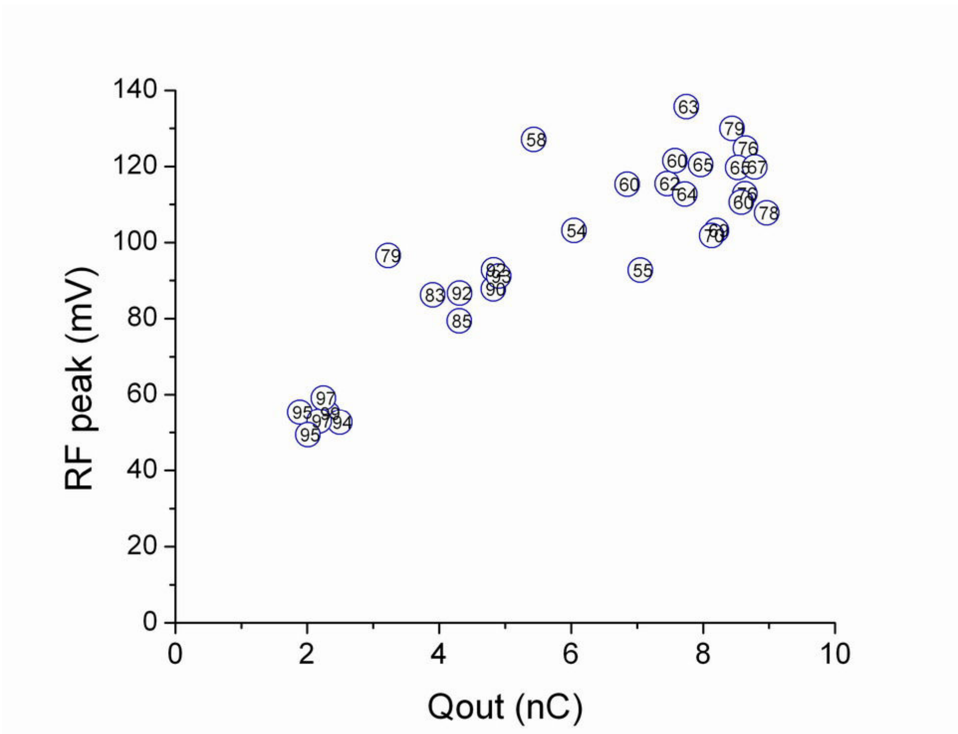
BBU observed when beam current is high.

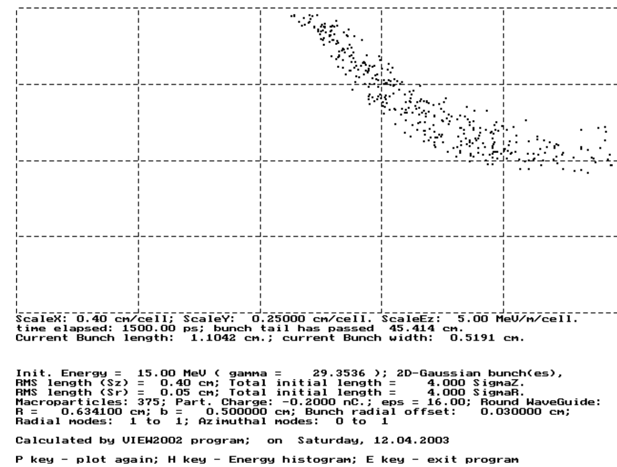
Designing the beam control magnet (quartz channel) to push the high current transportation.

Designing transverse mode damped power extractor.



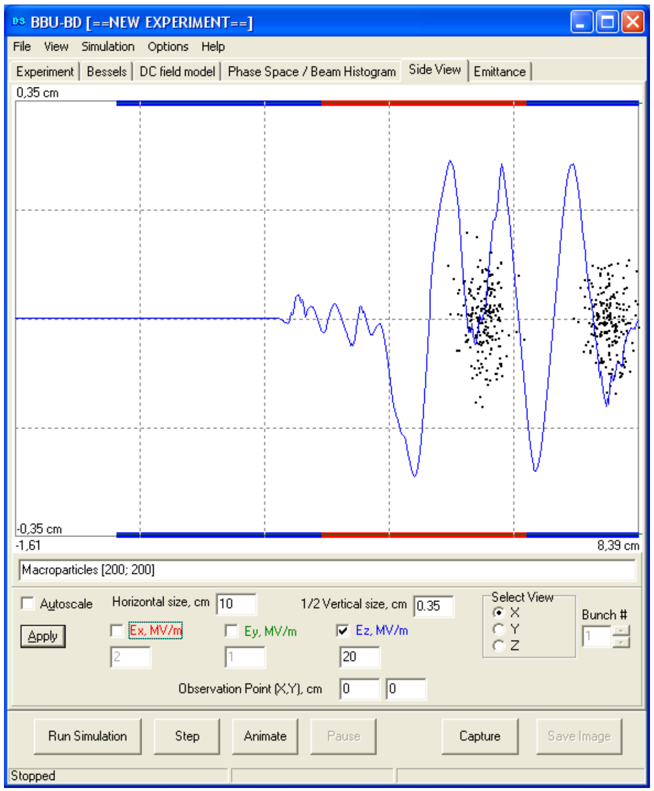
BBU and High Order Mode Damping

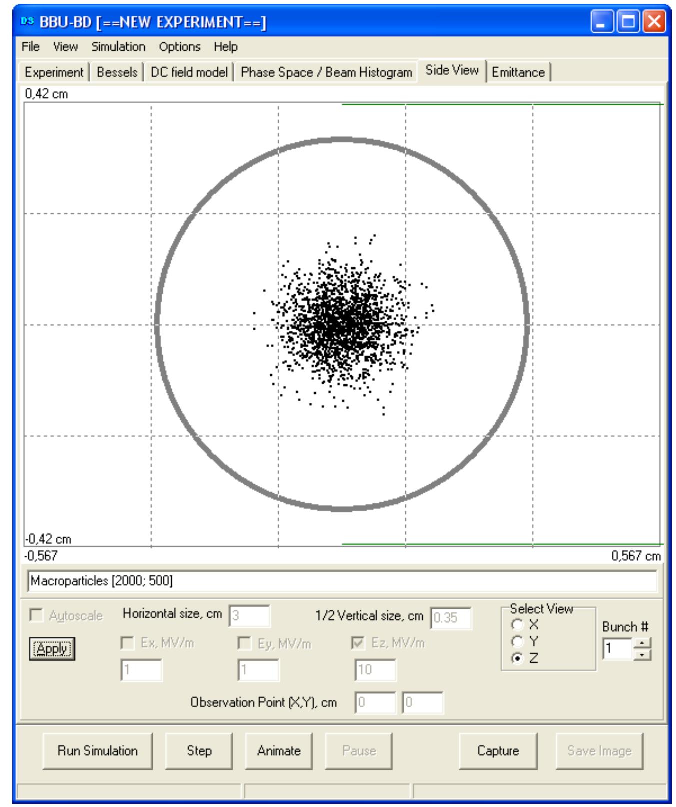




- Deflection of bunch tail by transverse wakefields from head
- Amplification of injection errors as beam propagates
- Especially significant for the high charge bunches used for wakefield acceleration
- Not controlled using Chojnacki mode suppressor

BBU Code Development

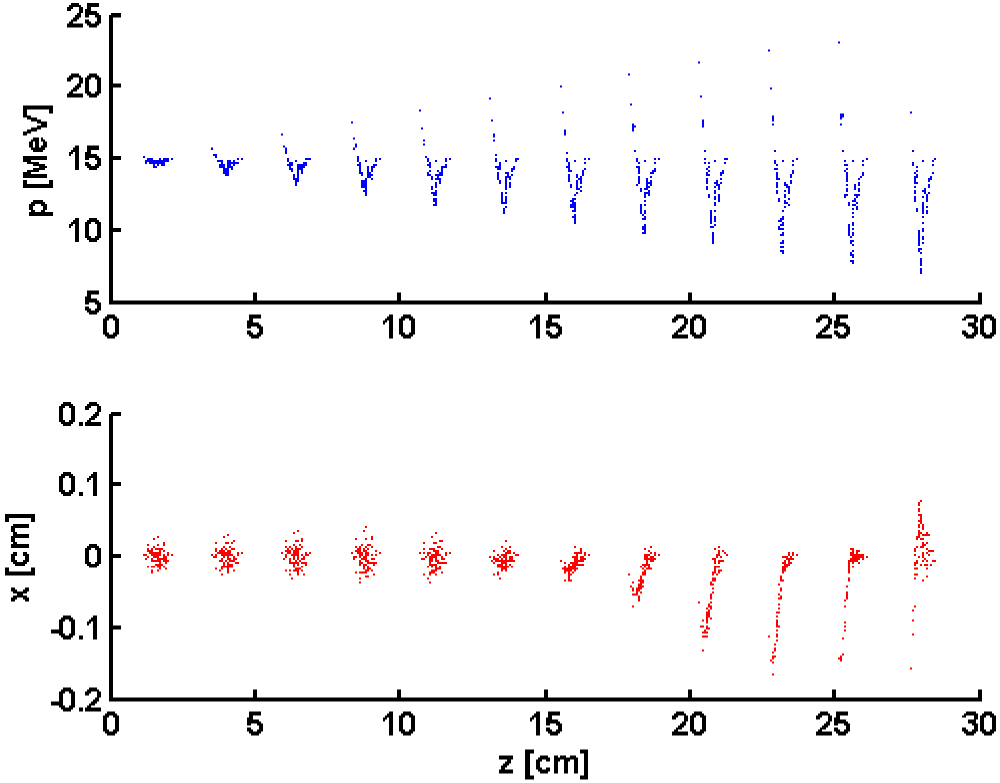




Focusing quads (in this case in the *x-x'* plane) are plotted with a solid blue line. Defocusing quadrupoles are shown with a solid red line. –

Cross-section view (*x-y* plane), Gaussian distribution

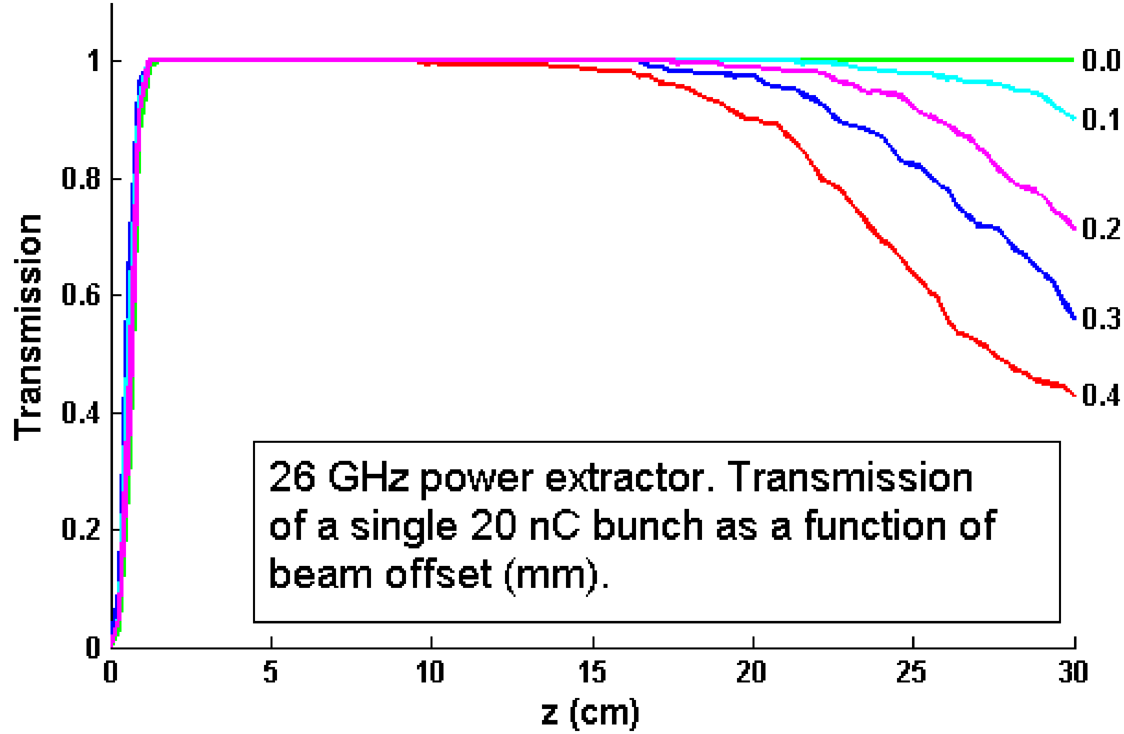
Example of BBU-3000 calculation of time evolution of BBU in a 26 GHz dielectric waveguide



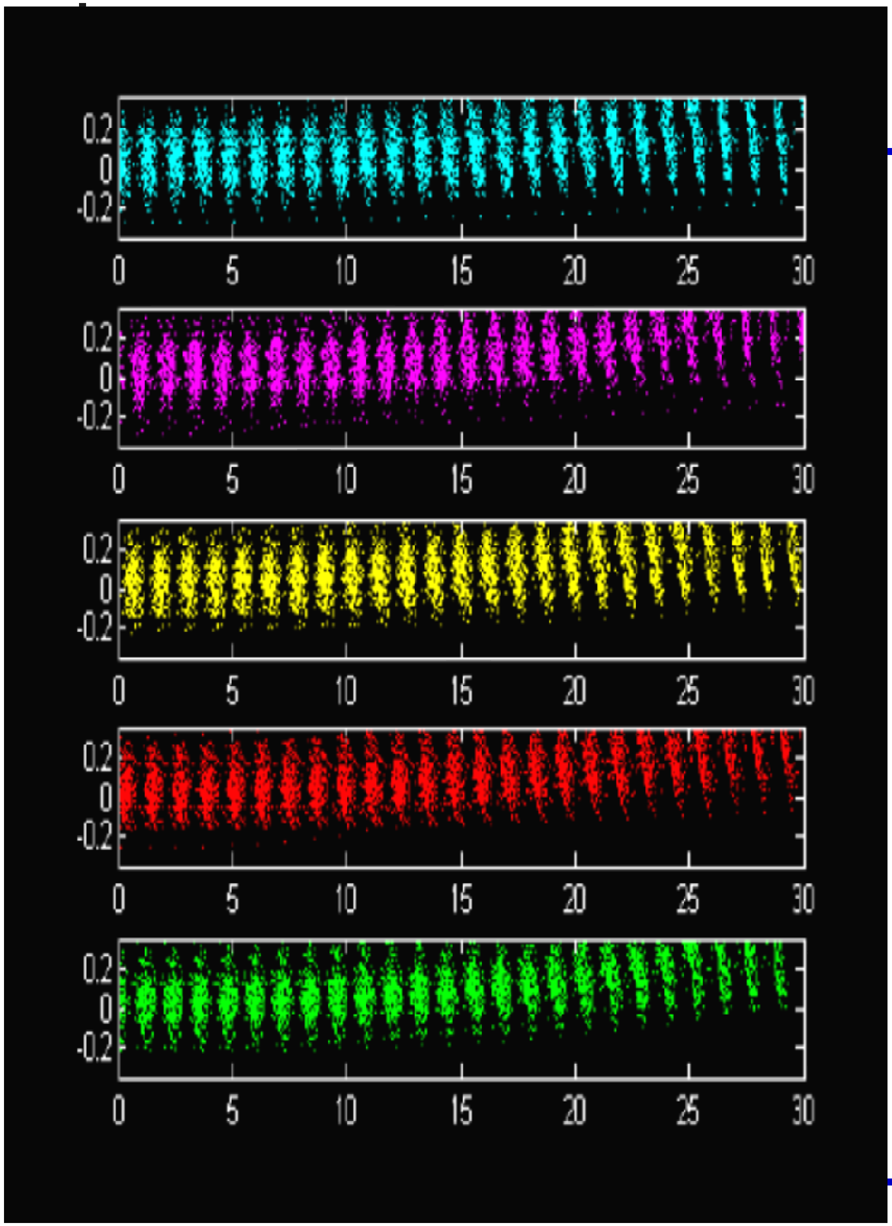
Phase space

X distribution

Power Extractor and Bunch Train Beam Dynamics Simulations



Relative intensity loss of a single bunch propagating through the 26 GHz power extractor.

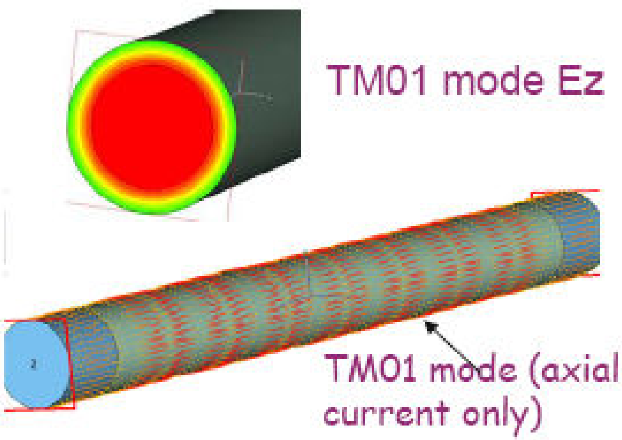


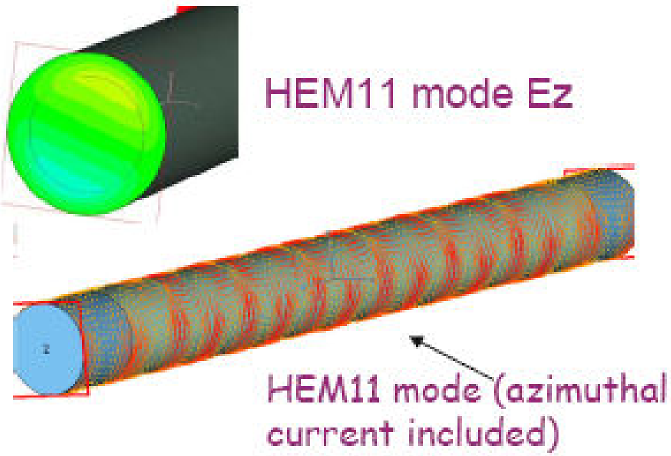
26GHz decelerator, five bunch train computed using BBU-3000.

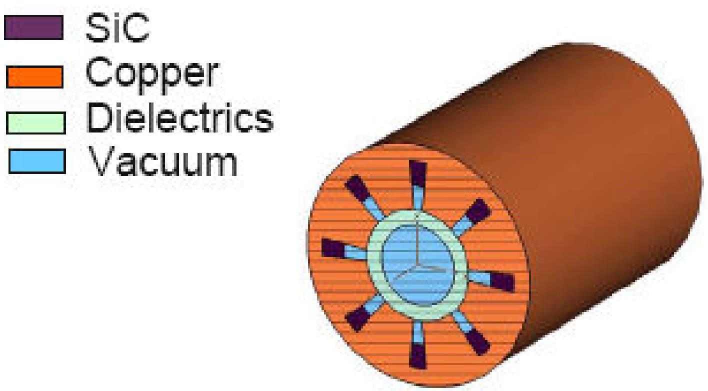
Top to bottom, bunches 1-5 at 40ps intervals. Initial offset of 0.4mm in the positive x direction.

Distances in cm; vertical extent of each plot corresponds to the width of the vacuum channel (±0.35 cm).

Transverse Damping---- to improve the high current beam transportation







7.8GHz Transverse Mode Damped DLA Structure

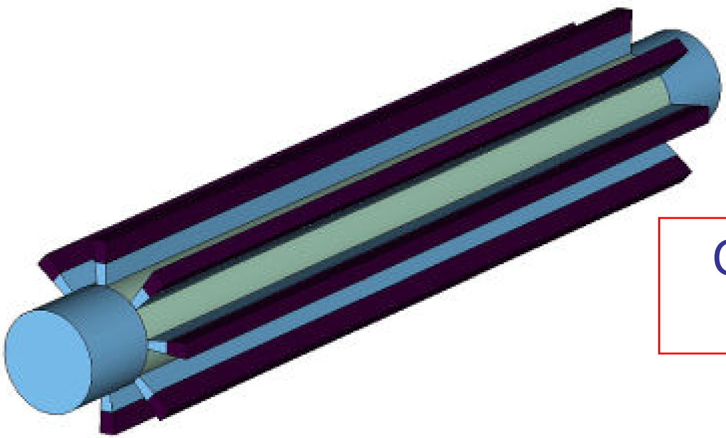
A new transverse mode damped DLA structure has been proposed.

A 7.8 GHz prototype has been built and bench tested.

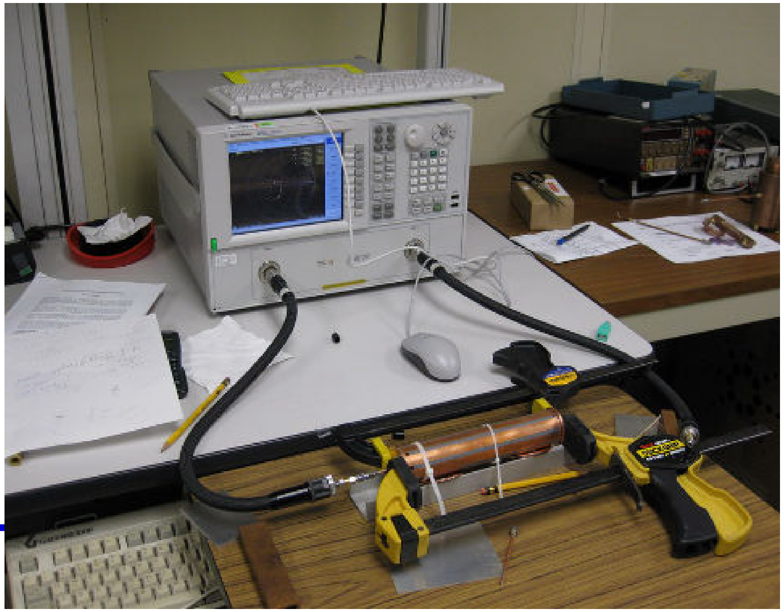
Beam test will be performed at AWA facility.

Comparison of the 7.8GHz Conventional and the Transverse mode Damped DLA structure.

	Freq.	Q in conventional DLA structure	Q in transverse modes damped DLA structure
Accelerating mode (TM_{01})	7.8GHz	6964*	6738*
Transverse modes (HEM_{11})	6.34GHz	6866*	23*



Collaboration with ANL



12GHz Dielectric Based Power Extractor Using CLIC Parameters: σ_z=2mm, Q=8.4nC, Tb=83ps

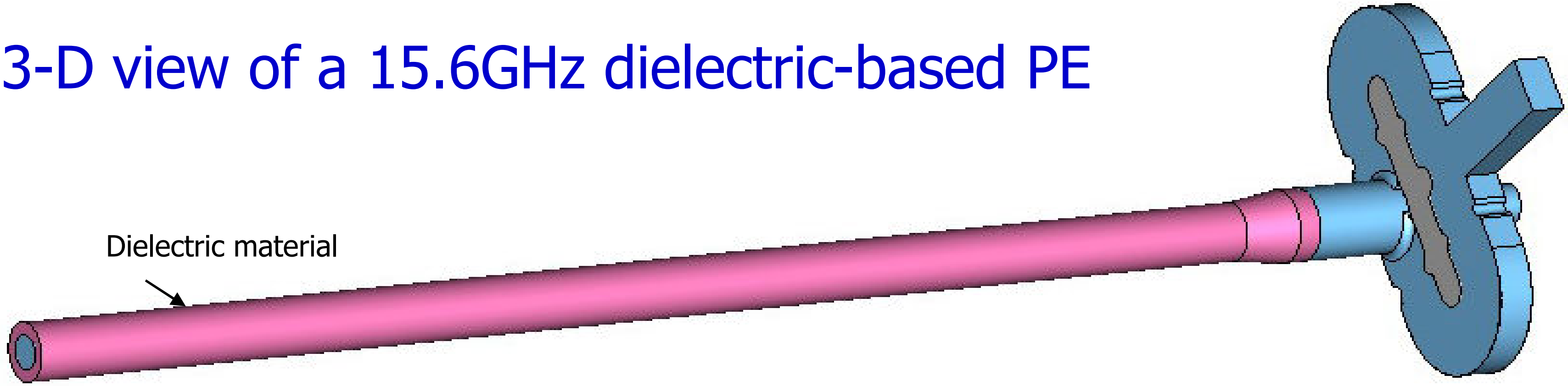
	DBPE1	DBPE2
Frequency	12GHz	12GHz
Effective Length	21cm	21cm
Beam channel	23mm	23mm
Dielectric constant	3.75(Quartz)	6.64 (Forsterite)
Q	6330	5623
R/Q	2.171kΩ/m	2.197kΩ/m
Vg	0.4846c	0.4021c
Peak Surface Gradient	10.5MV/m	12.8MV/m
Steady Power	98MW	119MW

Loss tangent is 1*10^-4 in both calculations.

12GHz Quartz-Based Power Extractor Using CLIC Parameters: σ_z=1mm, Q=8.4nC, Tb=83ps

Frequency	12GHz
Effective Length	23cm
Beam channel	23mm
Thickness of the dielectric tube	2.58mm
Dielectric constant	3.75(Quartz)
Loss tangent (@10GHz)	6*10^-5 (refer to the literature from Agilent)
Q	7318
R/Q	2.171kΩ/m
Vg	0.4846c
Peak Surface Gradient	12.65MV/m
Steady Power	142MW

3-D view of a 15.6GHz dielectric-based PE



- A 26GHz dielectric-based power extractor has been developed and beam tested.
- We have already completed the EM design for a 15.6GHz dielectric-based power extractor (this is part of the short rf pulse TBA prototype).
- The transverse mode damping scheme for the dielectric-based structures has been demonstrated, and this will be added in for the future power extractor design.

SUMMARY

- Diamond Based DLA has been developed to be used with the DLA structure intended for >200 MV/m gradient ranges.
- Successfully demonstrated the 26GHz, high power rf source using dielectric-based scheme. 30 MW power has been generated.
- Beam Breakup effects have been studied, focusing systems based on BBU is being developed. Quad channel currently under design.
- Power extractor will be the initial experiment on BBU control. New transverse stage for precise control of the beam is under development.
- 12GHz Quartz-Based Power Extractor using CLIC parameters has been proposed.