Presentation at EAAC, Elba, Italy
June 2-6 2013

Dielectric Based Accelerator: Subpicosecond Bunch Train Production and Tunable Energy Chirp Correction

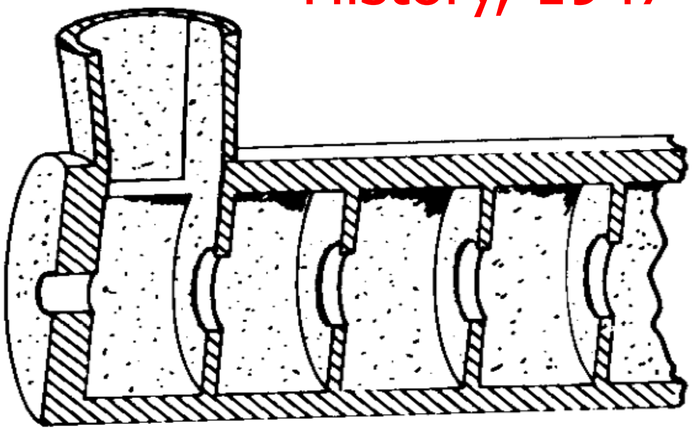
A.Kanareykin for

Euclid TechLabs LLC, Gaithersburg MD USA
in collaboration with ANL/AWA, BNL/ATF, UCLA and
Eltech Universtity "LETI" , St.Petersburg, Russia

Outline

- Dielectric accelerator: brief history
- Software development for the DLA
- Materials available for the DLA
- Key high gradient experiments
- Energy chirp compensation
- Subpicosecond bunch train production
- Beam based undulator
- Summary

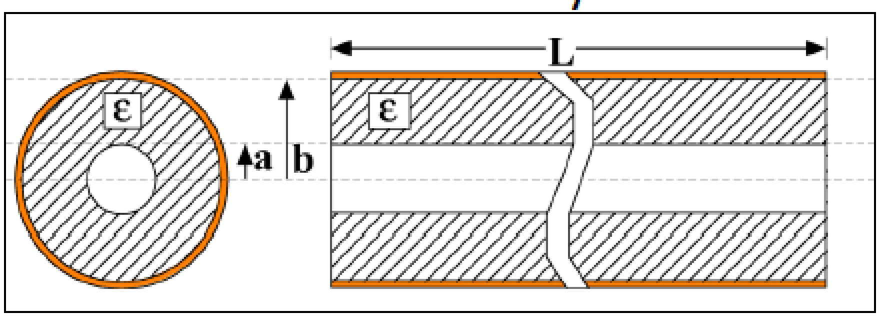
History, 1947 – first DLA linac paper



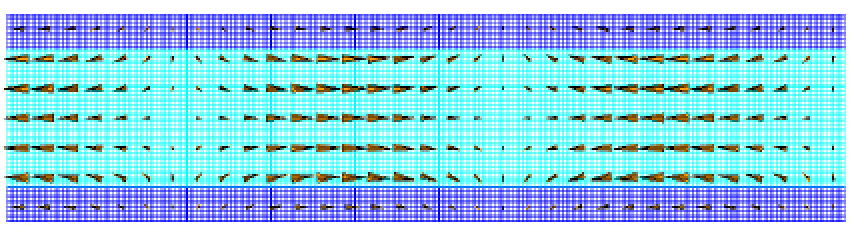
Frankel S. TM01 Mode in Cylindrical Waveguide with Two Dielectrics // J. App. Phys. 1947. V.18. P. 650.

First electron linac at Stanford (1947)

Geometry



Electric Field Vectors



Advantages

- Simple geometry
- No field enhancements on irises
- High gradient potential
- Comparable shunt impedance
- Easy to damp HOM

Major concerns

- Multipactor
- Breakdown

Mind the gaps, mind the steps !

Papers on Dielectric Accelerator published before 1960

- Frankel S. TM01 Mode in Cylindrical Waveguide with Two Dielectrics // J. App. Phys. 1947. V.18. P. 650-655.
- Bruck G.C., E.R.Wicher Slow Transverse Magnetic Modes in Cylindrical Waveguides // J. App. Phys. 1947. V. 18. P. 766-769.
- Shersby-Harvie R. B. R. A Proposed New Form of Dielectric-loaded Wave-Guide for Linear Electron Accelerators // Nature. 1948. V. 162. P. 890-890.
- Oliner A.A., Remarks of Slow Wave Cylindrical Waveguides // J. App. Phys. 1948. V. 19. P. 109-110.
- Flesher G., Cohn G. Dielectric Loading for Waveguide Linear Accelerator // AIEE Transactions. 1951. V.70. P. 887-893.
- Shersby-Harvie R. B. R. et al. Theoretical and Experimental Investigation of Anisotropic Dielectric Loaded Linear Electron Accelerator // Proceedings of the IEE - Part B: Radio and Electronic Engineering. 1957. V. 104. P. 273-290.
- Walker G. B. and West N.D. Mode Separation at the π-Mode in a Dielectric Waveguide Cavity // Proceedings of the IEE - Part C: Monographs. 1957. V. 104. P.381-387.
- Walker G. B., Lewis E. L. Vacuum Breakdown in Dielectric-loaded Wave-guides // Nature. 1958. V. 181. P. 38 – 39.

Again some history: now 1988

VOLUME 61, NUMBER 24 PHYSICAL REVIEW LETTERS 12 DECEMBER 1988

Experimental Demonstration of Wake-Field Effects in Dielectric Structures

W. Gai, P. Schoessow, B. Cole,[a] R. Konecny, J. Norem, J. Rosenzweig, and J. Simpson
High Energy Physics Division, Argonne National Laboratory, Argonne, Illinois 60439
(Received 10 August 1988)

We have measured the wake fields induced by short, intense relativistic electron bunches in a slow-wave structure consisting of a dielectric-lined tube, as a test of the dielectric wake-field acceleration mechanism. These fields were used to accelerate a second electron bunch which followed the driving bunch at a variable distance. Results are presented for different dielectrics and beam intensities, and are compared with theoretical predictions.

PACS numbers: 41.80.−

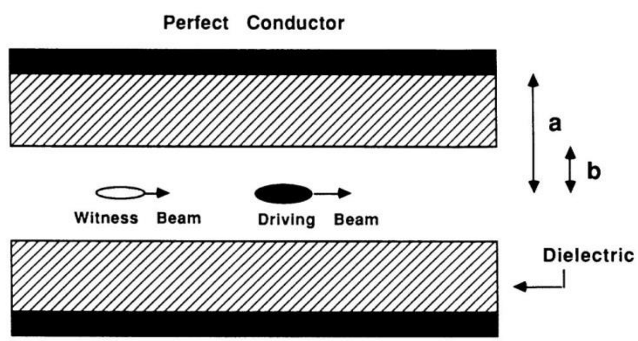


FIG. 1. Sketch of the dielectric cavity.

But before in Russia: theory of Cherenkov radiation in waveguide:

B. M. Bolotvskii, Usp. Fiz. Nauk., 75, 295 (1961) [Sov. Phys. Usp. 4, 781 (1962)]

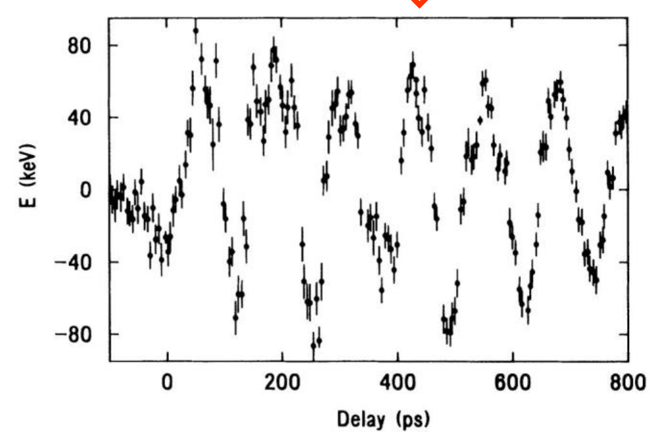


FIG. 4. Nylon scan: Wake potential measured as a function of witness-bunch delay.

Finally "Wakefields" !

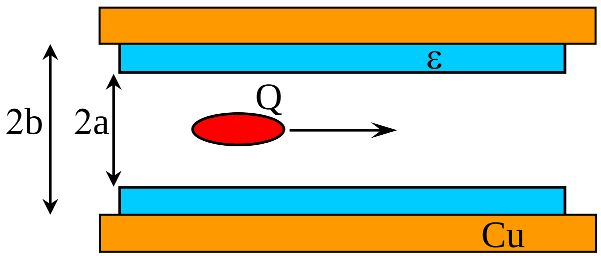
Finally it's today…Cherenkov Wakefields in Dielectric Structures

PHYSICAL REVIEW D VOLUME 42, NUMBER 5 1 SEPTEMBER 1990

Longitudinal- and transverse-wake-field effects in dielectric structures

M. Rosing and W. Gai
High Energy Physics Division, Argonne National Laboratory, Argonne, Illinois 60439
(Received 8 March 1990)

A dielectric-loaded circular waveguide structure is a potential high-gradient linear wake-field accelerator. A complete solution is given for the longitudinal electric and magnetic fields excited by a δ function and a Gaussian charge distribution moving parallel to the guide axis. The fields are then



$$W_Z(z) \approx \frac{Q}{a^2} \exp\left[-2\left(\frac{\pi \sigma_z}{\lambda_n}\right)^2\right] \cos(kz)$$

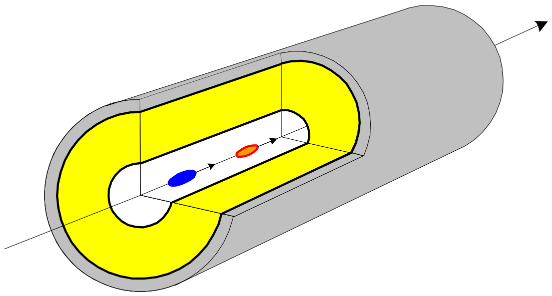
$$\sigma_r = \left(\frac{\varepsilon_N}{\gamma}\beta\right)^{1/2}$$

Direct Wakefield Acceleration:

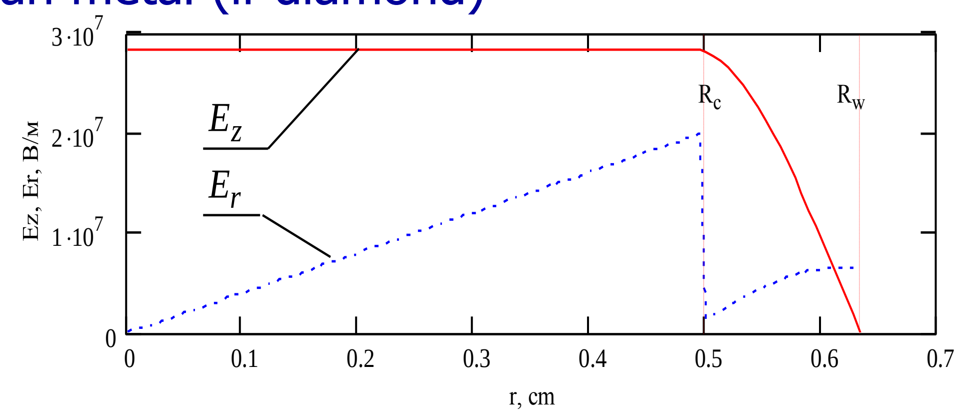
- Dielectrics: ε = 4.4 (cordierite-10 (alumina) – low-loss ceramic, ε = 5.7 – diamond, ε = 3.7 - quartz
- Electron beam for GHz (AWA): σ_z = 1-2 mm, Q = 10-100 nC, yielding ~ 200-300 MV/m at 20-30 GHz
- Electron beam for THz (FACET): σ_z = 20-30 um, Q = 1-3 nC, 0,5-1,0 THz frequency, 1-10 GV/m gradient

Why Dielectric Based Accelerator ?

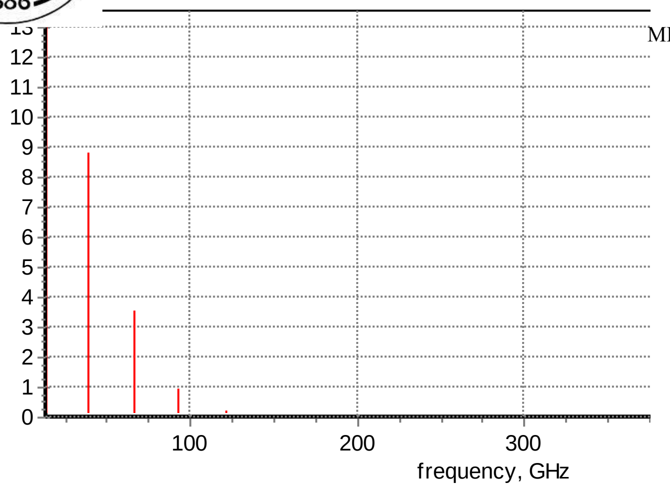
Dielectric based accelerator advantages:

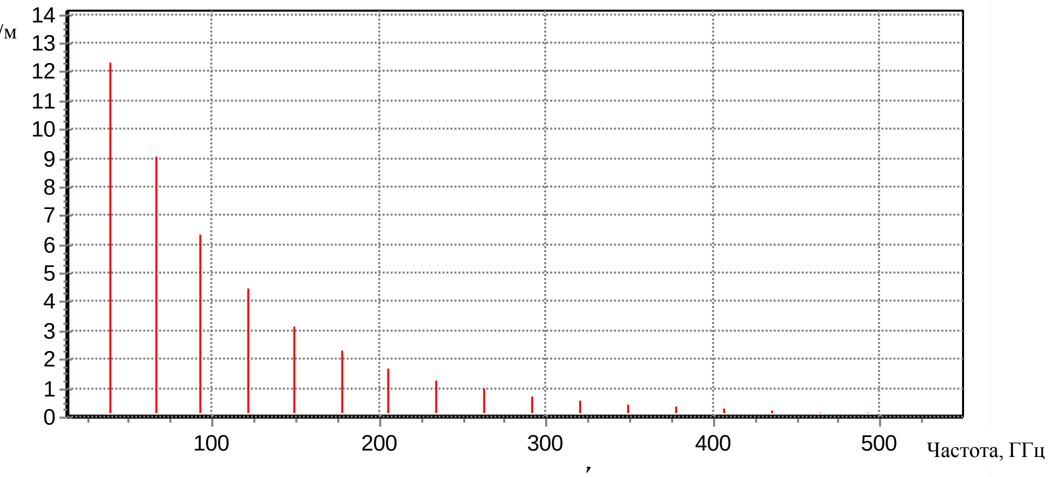


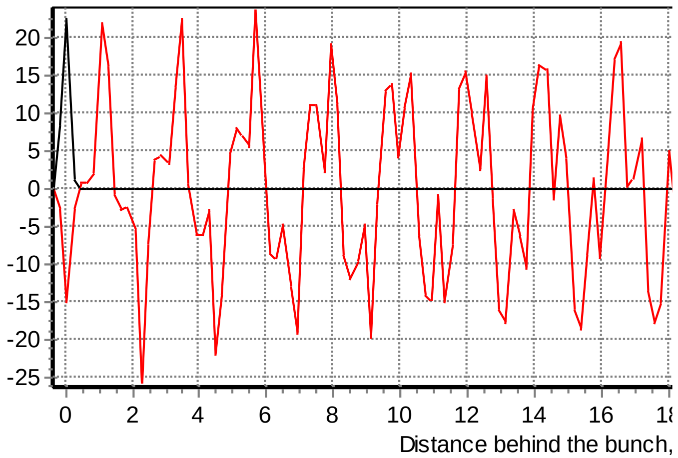
- ❑ design simplicity: no tight tolerances;
- ❑ maximal field magnitude at the structure center;
- ❑ GHz,THz structures at ~ 0.5-1.0 GV/m gradient
- ❑ enables tuning;
- ❑ reduced sensitivity to the beam break-up (BBU) instability;
- ❑ thermal conductivity better than metal (if diamond)
- ❑ .....

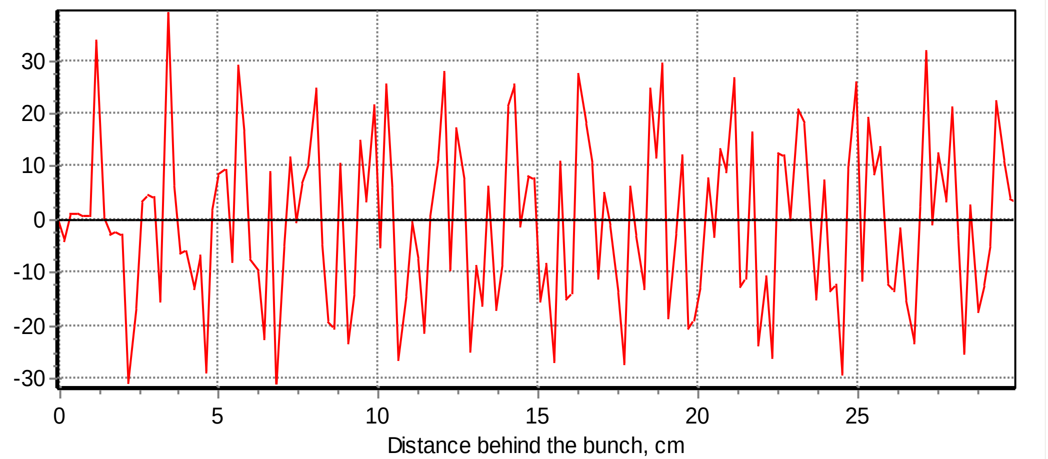


Spectra and Accelerating Fields, ε=16. TM_{01} f= 13.6 GHz





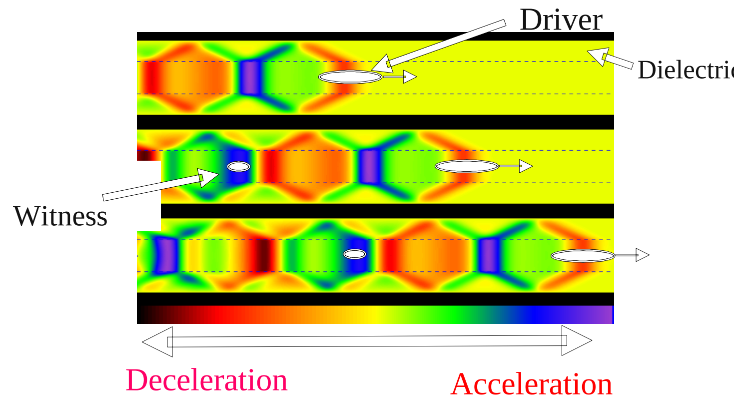




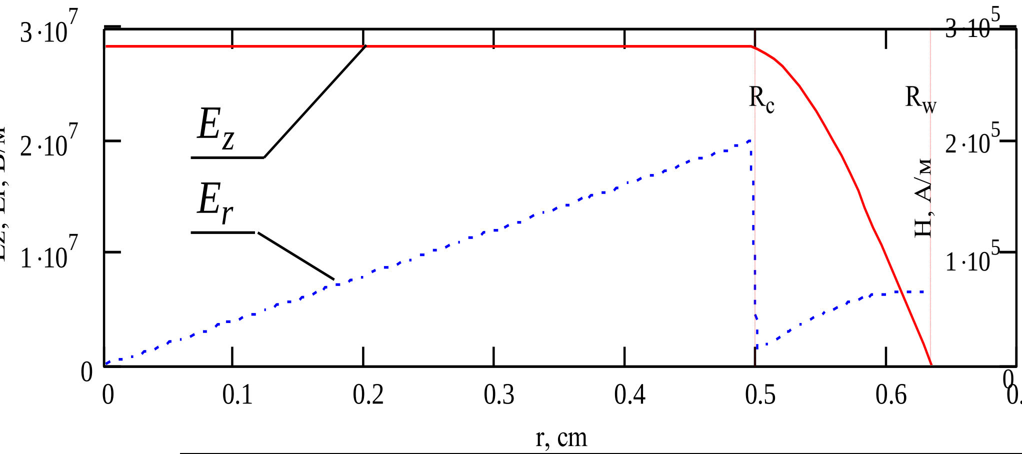
50 nC, σ_z=0.1cm

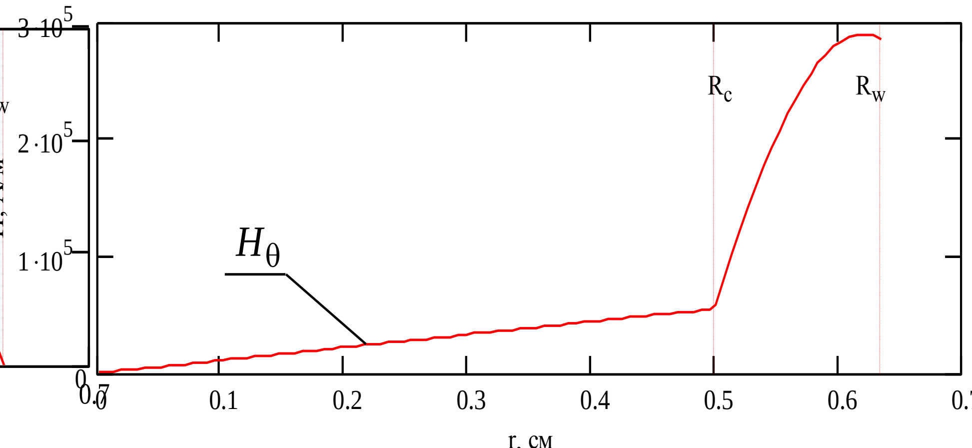
50 nC $\sigma_{z=}$ 0.01 cm

The longitudinal (accelerating) fields for the three positions of the driver and witness beams simulated with the ARRAKIS code (P.Schoessow).



Longitudinal and radial components of electric and magnetic fields in the cross-section

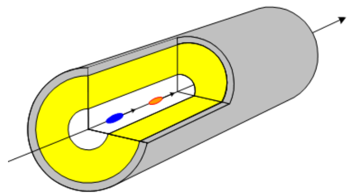
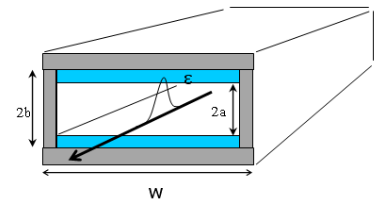
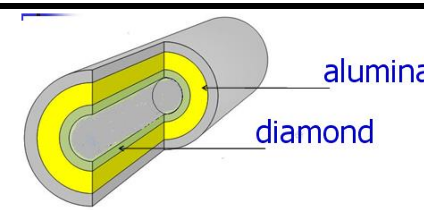
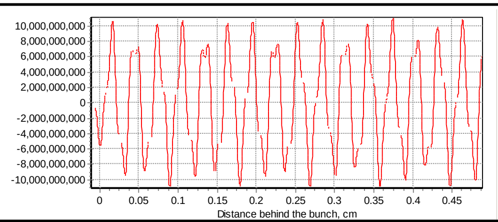
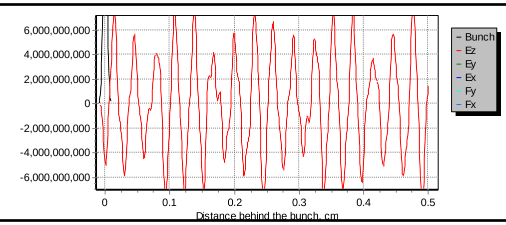
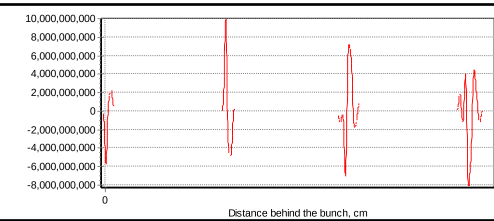
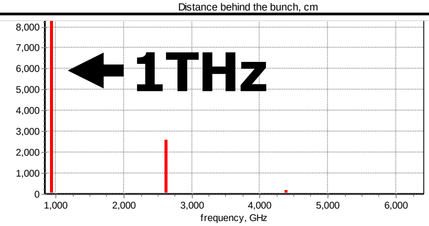
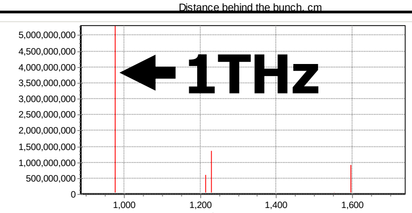
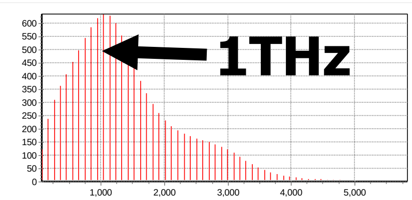




Мода	f, ГГц	v_g/c	$\frac{P_m}{P_d}$	α 1/м	Q_w	r_s, МОм/м	r_s/Q_w, Ом/м
TM_{01}	13.625	0.11	27.79	0.57	2366	16.6	5916.3
TM_{02}	39.252	0.30	16.90	0.31	4348	7.94	1413.4
TM_{03}	65.830	0.45	12.82	0.23	6480	4.40	493.0

Accelerating structure parameters

FACET structures

			
	ID=80 μm (a=40 μm) OD= 152 μm (b=76 μm) b - a= 30 μm (diamond thickness)	2a=80 μm, a= 40 μm, b= 70 μm; w= 300 μm b - a= 30 μm (diamond thickness)	ID=80 μm (a=40 μm) diamond thcknss= 30 μm alumina thcknss= 446 μm
	2 GV/m/nC	2 GV/m/nC	2 GV/m/nC
wake			
spectrum			

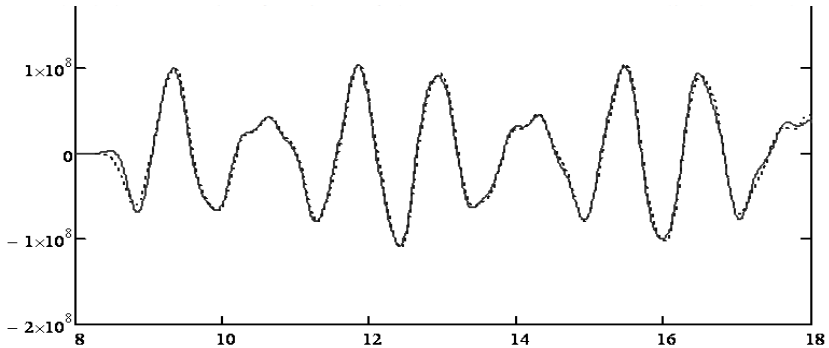
double-layer / thick layer

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **16**, 051302 (2013)

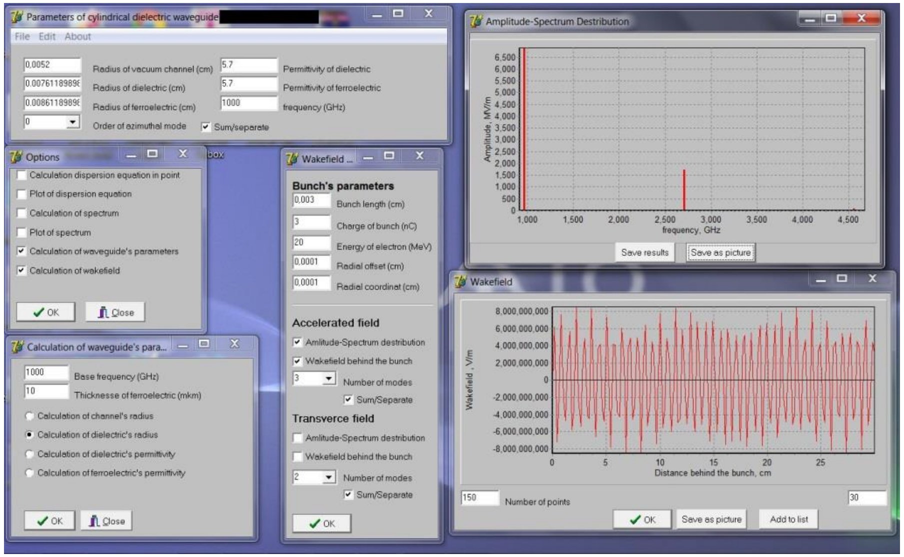
Transverse operator method for wakefields in a rectangular dielectric loaded accelerating structure

S. S. Baturin,[1,*] I. L. Sheinman,[1] A. M. Altmark,[1] and A. D. Kanareykin[1,2]
[1]*St. Petersburg State Electrotechnical University, St. Petersburg, Russia*
[2]*Euclid Techlabs, LLC, 5900 Harper Road, Solon, Ohio 44139, USA*
(Received 12 February 2013; published 16 May 2013)

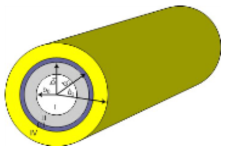
Cherenkov radiation generated by a relativistic electron bunch in a rectangular dielectric-loaded waveguide is analyzed under the assumption that the dielectric layers are inhomogeneous normal to the beam path. We



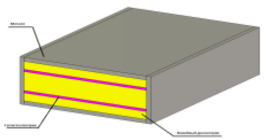
CST vs.”Waveguide”



Waveguide

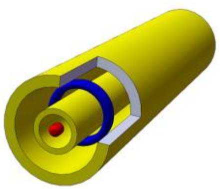


Rectangular

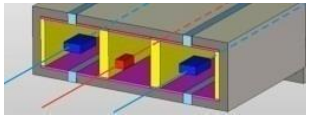


Multibunch

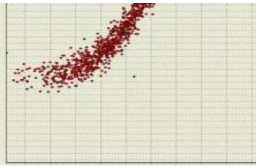
Annular



Multizone.



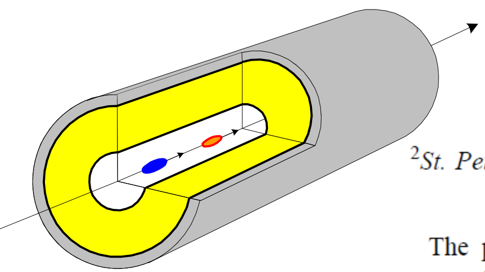
Beam Breakup (BBU)



Beam Breakup in the Planar and Cylindrical DLA

euclid TECHLABS

PHYSICAL REVIEW E VOLUME 55, NUMBER 3 MARCH 1997

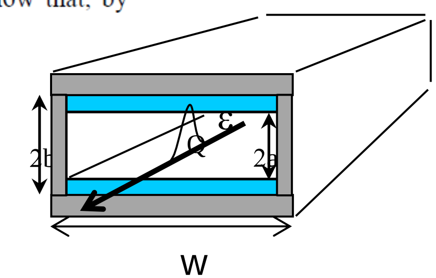


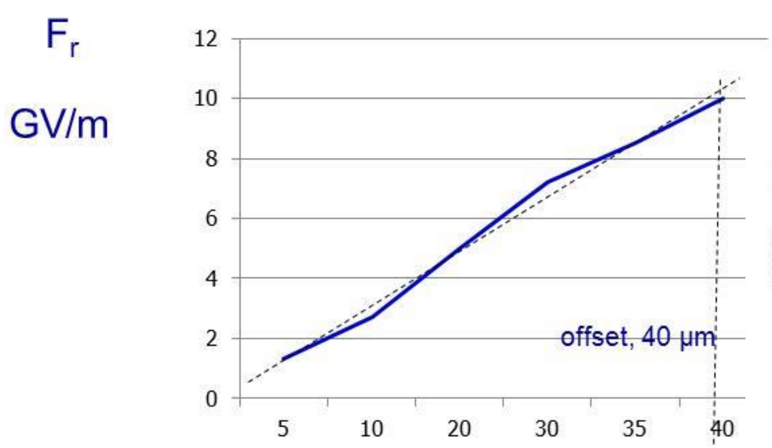
Numerical simulations of intense charged-particle beam propagation in a dielectric wake-field accelerator

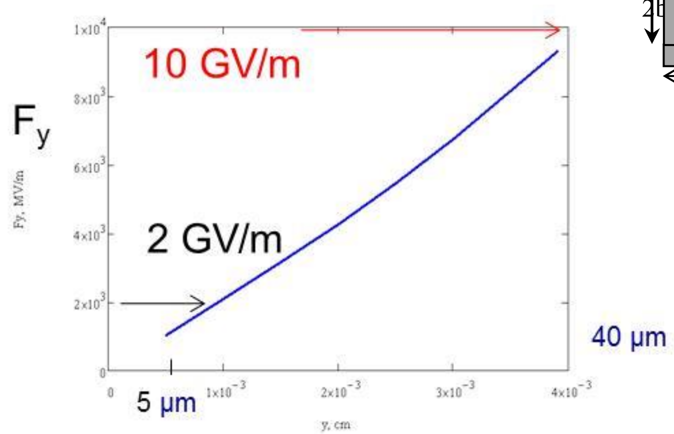
W. Gai,[1] A. D. Kanareykin,[2] A. L. Kustov,[2] and J. Simpson[1]
[1]*Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439*
[2]*St. Petersburg Electrical Engineering University, 5 Professor Popov Street, St. Petersburg 197376, Russia*

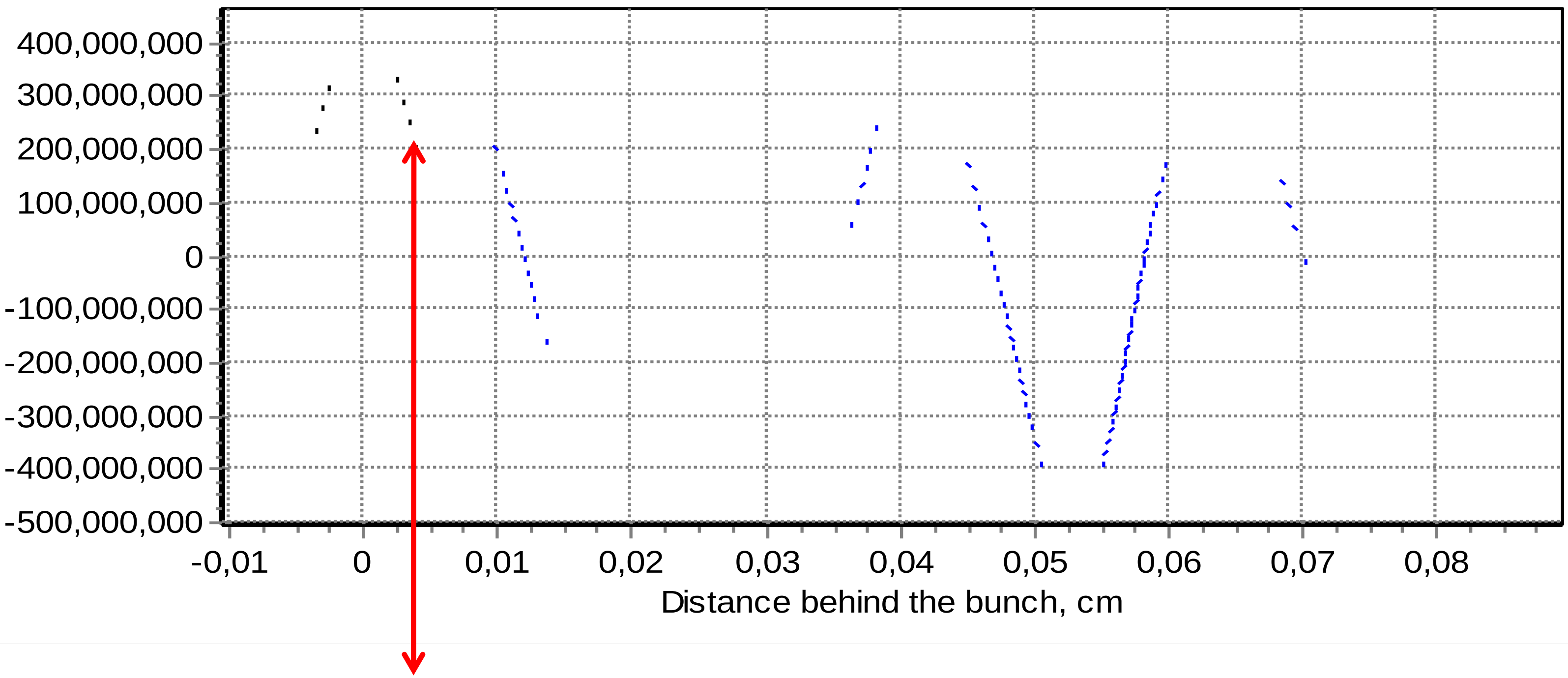
(Received 24 July 1995; revised manuscript received 5 August 1996)

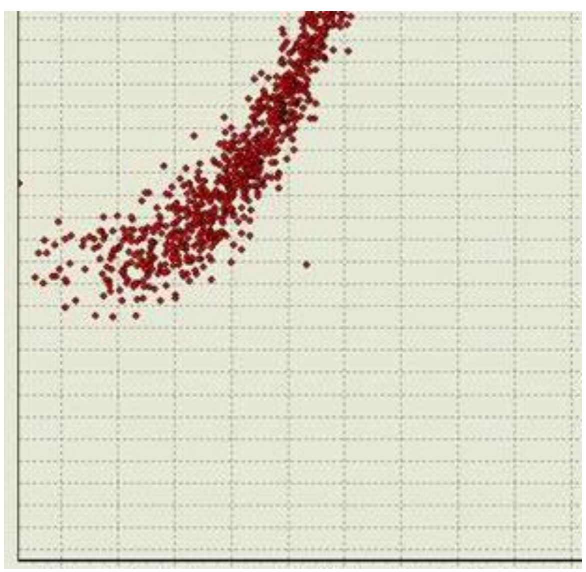
The propagation of an intense electron beam through a long dielectric tube is a critical issue for the successful demonstration of the dielectric wake-field acceleration scheme. Due to the head-tail beam breakup instability, a high-current beam cannot propagate long distances without external focusing. In this paper we examine the beam handling and control problem in the dielectric wake-field accelerator. We show that, by









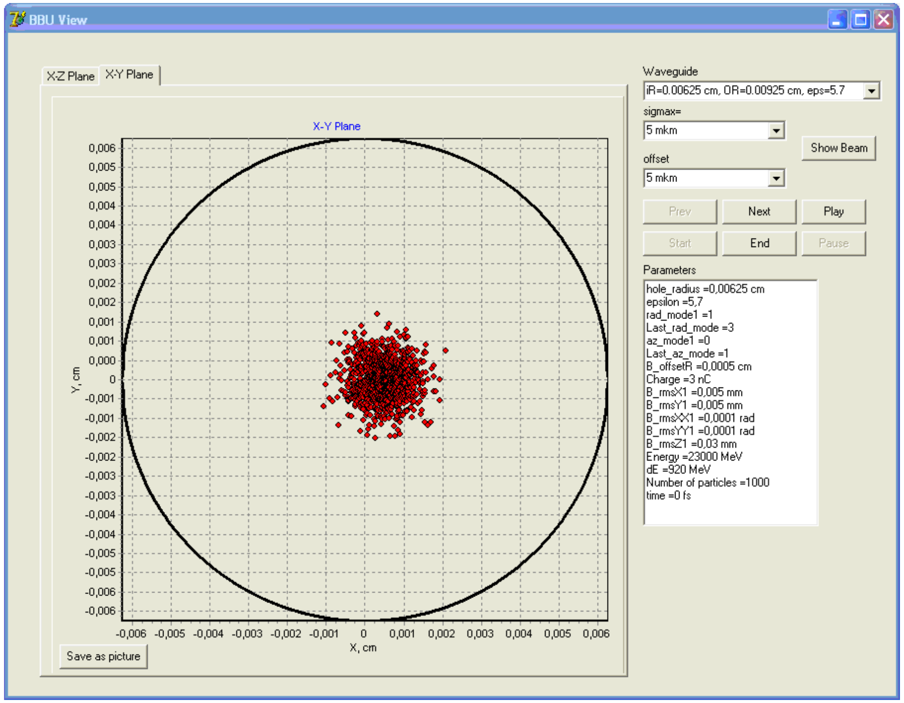


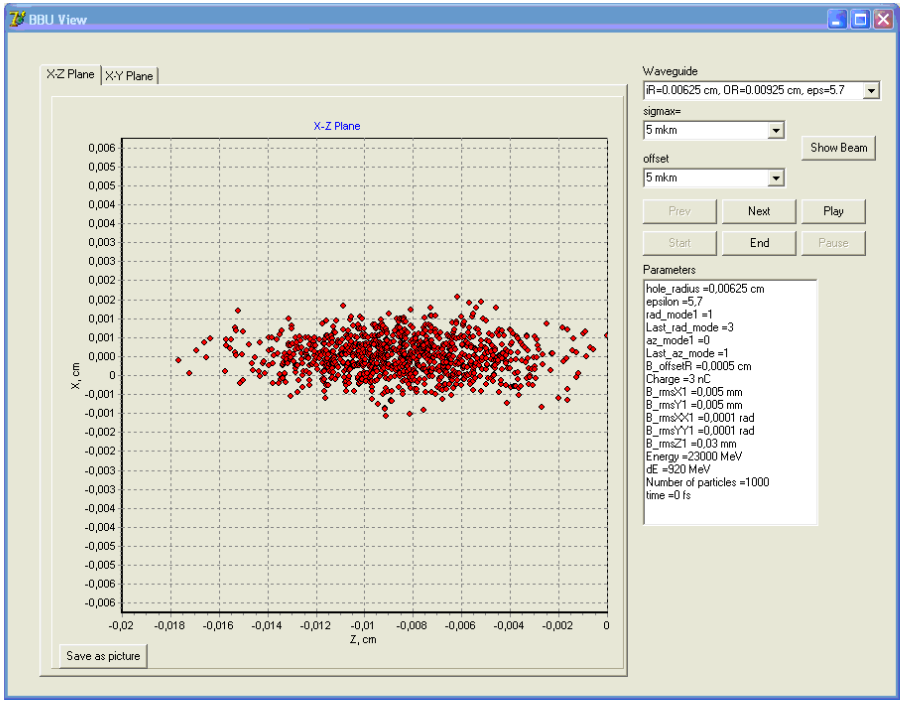
Euclid has developed in-house software for dielectric wakefield simulations

- analytical/fast
- accelerating and dipole modes
- losses
- BBU

BBU Simulation

euclid TECHLABS





Beam:

- 23 GeV energy; 920 MeV spread
- 3 nC; σ_r = 5 μ; offset = 5 μ
- σ_z = 30 μ;

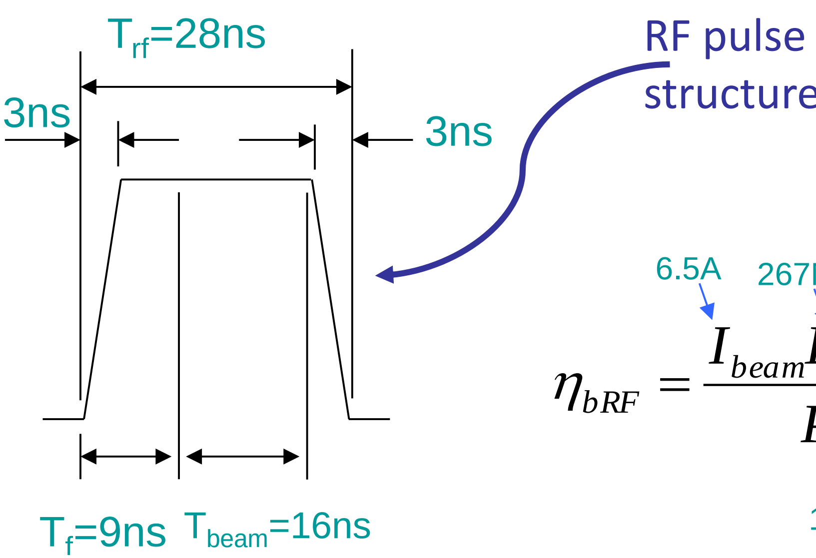
Structure:

- iR = 62.5 μ, ID=125 μ, f = 1 THz
- oR = 92.5 μ, ID=185 μ
- ε = 5.7 (diamond)

DLA Based Collider Concept

AWA/Euclid proposed a 26GHz short pulse collider concept*

- modular design with each module - 100 GeV.
- 26 GHz RF power extracted from the drive beam using a low impedance dielectric structure
- the main linac based on high impedance high gradient DLA.
- dielectric structures sustain *high fields for short RF pulse*



- fast rf rise time (<3ns) → Broadband (>150MHz)
- less filling time → Large (~10%c) Vg.

$$\eta_{bRF} = \frac{I_{beam} E_{load} L_s}{P_{rf}} \times \frac{T_{beam}}{T_{rf}} = 26\%$$

(I_{beam} = 6.5A, E_{load} = 267MV/m, L_s = 0.3m, P_{rf} = 1.264GW, T_{beam} = 16ns, T_{rf} = 25ns)

*W. Gai, M. Conde, J.G.Power and C.Jing. 2010, Proc.Int.Part. Accel.Conf. IPAC'10, Kyoto, p.3428.

DLA Based FEL*

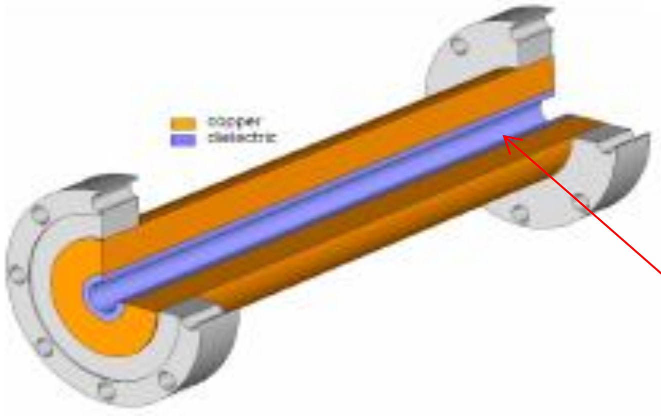
DLA is proposed to provide the electron beam to drive a CW x-ray FEL light source*

- 100 MV/m loaded gradient,
- 850 GHz dielectric DWA to generate the beam for the FEL
- 10 parallel beams operating at 10 kHz all driven by a single 100 kHz beam.
- A collinear DLA generates a beam of 8 GeV, 50 pC/bunch, ~1.2 kA of peak current, in less than 100 meters.

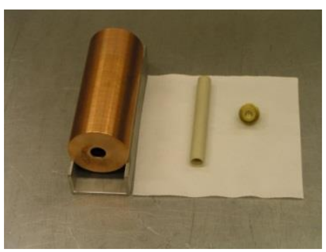
*C. Jing, J. Power, and A. Zholents. ANL/APS LS-326, http://www.aps.anl.gov/Science/Publications/lsnotes/

** C.Jing, A. Kanareykin, J.G. Power, A. Zholents. Proceedings IPAC'11, 1485, (2011).

MW/THz Materials for the Dielectric-Based Accelerator



Materials	ε (f = 9,4 GHz)	tan δ (f = 9.4 GHz)
Cordierite	4.5±0.2	$\leq 2\times10^{-4}$
Forsterite	6.3±0.3	$\leq 2\times10^{-4}$
Alumina	9.8±0.3	$\leq 1\times10^{-4}$
D-10	9.7±0.2	$\leq 1.5\times10^{-4}$
D-13	13.0±0.5	$\leq 2\times10^{-4}$
D-14	14.0±0.5	$\leq 0.6\times10^{-4}$
D-16	16.0±0.5	$\leq 2\times10^{-4}$
MCT-18	18.0±3%	$\leq 1\times10^{-4}$
MCT-20	20.0±5%	$\leq 1.5\times10^{-4}$
V-20	20.0±5%	$\leq 3\times10^{-4}$
V-37	37.0±5%	$\leq 3\times10^{-4}$



Diamond, ε~ 5.7, tanδ<10^{-4}

Quartz, ε~ 3.75, tanδ~10^{-4}

Linear MW/THz ceramic materials

Nonlinear MW/THz ceramic materials

BST+Mg based oxides, ε~ 50–100, tan[illegible]10^{-3}

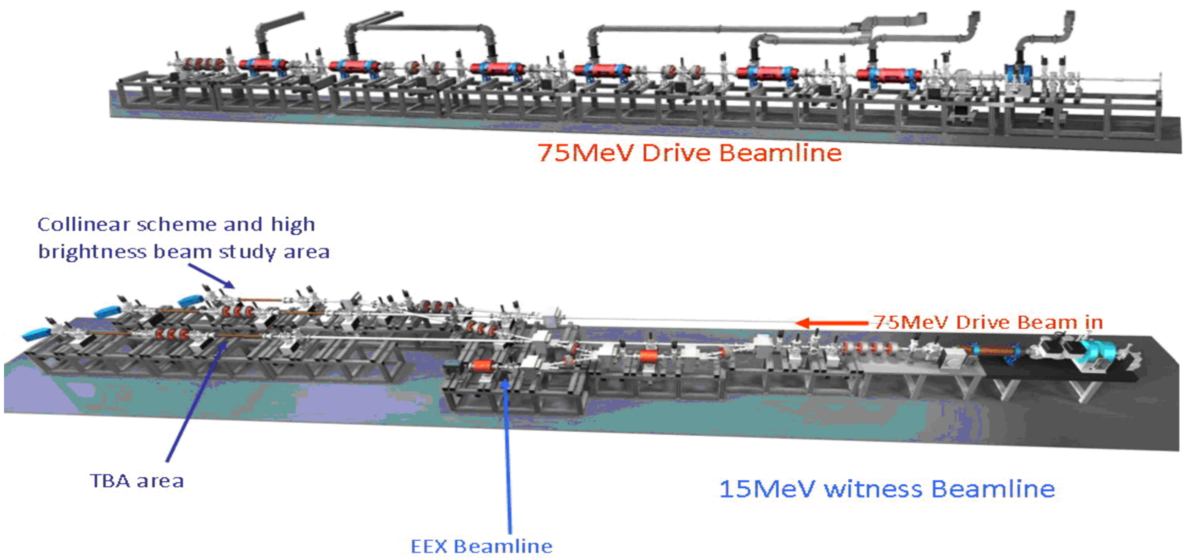
Dielectrics Tested as DWA Loading

THz experiments at FFTB and ATF

dielectric	ε	Tan δ (10 GHz)	Frequency (GHz)	Experiment, reference
Quartz	3.8	$<1\times10^{-4}$	11.4	High Gradient Standing Wave
Cordierite	4.7	$<1.5\times10^{-4}$	7.8 8.6 21 11.4/30	7.8 GHz TBA Power Extractor High Gradient Standing Wave 21 GHz DL Power Extractor Two Channel High Transformer Ratio
Diamond	5.7	$<1\times10^{-4}$	26-35	High Gradient Standing Wave
Forsterite	6.3	$<2\times10^{-4}$	11.4 26	Traveling Wave DLA 26 GHz DL Power Extractor
Alumina	9.8	$<1\times10^{-4}$	11.4	Dual Layer DLA (outer layer)
$MgTiO_3$ - Mg_2TiO_4	16	$<1.2\times10^{-4}$	13.6	Collinear High Transformer Ratio
MCT $(Mg,Ca)TiO_3$	20	$<2\times10^{-4}$	7.8	Two Beam DLA Accelerator
$BaTi_4O_9$	37	$<3\times10^{-4}$	11.4	Dual Layer DLA (inner layer)
$CaTiO_3$-$LaAlO_3$	38.1	$<5\times10^{-4}$	1-30 (multimode)	Multimode DLA bunch train generation

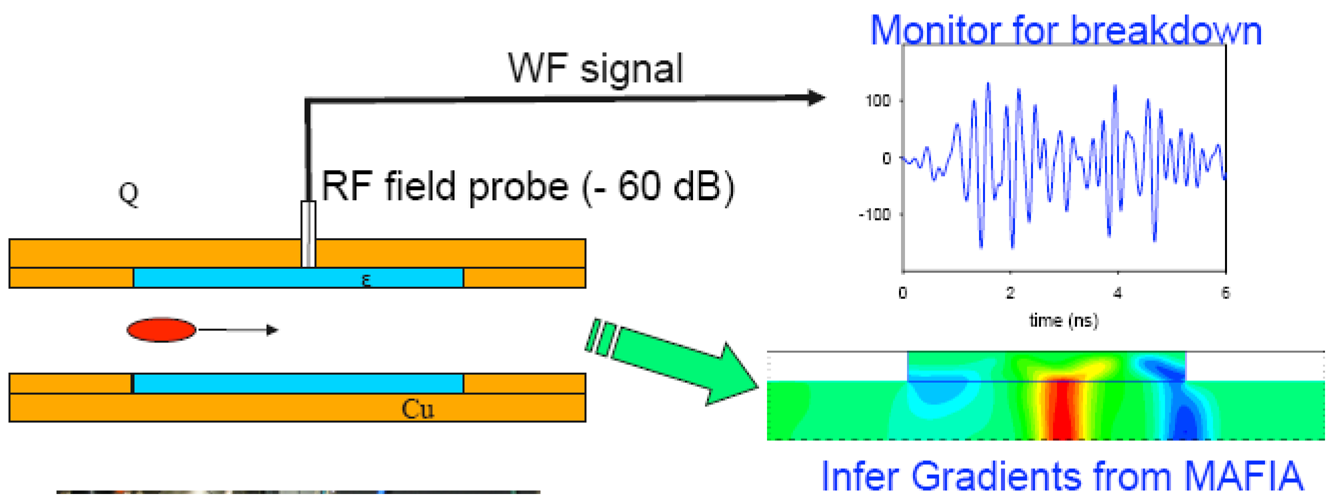
The Facility will be up to 75 MeV

- the facility to 75 MeV
  - Two additional Klystrons and associated RF components.
  - 6 Additional Linac Tanks
  - Reconfigured Tunnel and Beamlines



The AWA Upgrade Plan

AWA Wakefield Measurements



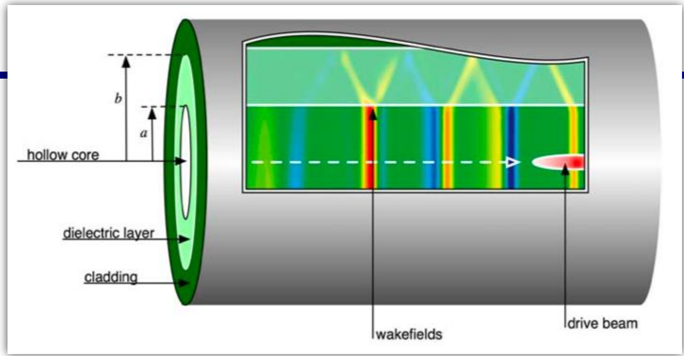
SW Structure	#1 C10-102	#2 C10-23	#3 C5.5-28	#4 Q3.8-25.4
Material	Cordierite	Cordierite	Cordierite	Quartz
Dielectric constant	4.76	4.76	4.76	3.75
Freq. of TM01n	14.1 GHz	14.1 GHz	9.4 GHz	8.6 GHz
Inner radius	5 mm	5 mm	2.75 mm	1.9 mm
Outer radius	7.49 mm	7.49 mm	7.49 mm	7.49 mm
Length	102 mm	23 mm	28 mm	25.4 mm
Wakefield Gradient	0.45 MV/m/nC	0.5 MV/m/nC	0.91 MV/m/nC	1.33 MV/m/nC

Goal:
Direct test breakdown thresholds of dielectric structures under short RF pulses.

E_z > 100 MV/m !

THz DLA Structure FFTB/FACET Experiments

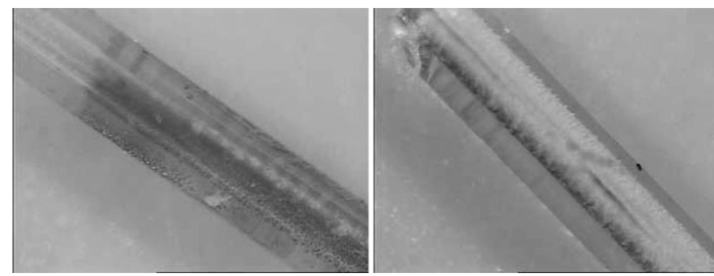
UCLA Group



30-330 fs, 28 GV bunch;
100 um ID Si structure
surface field of ~ 14 GV/m

High accelerating gradients: GV/m level

- Dielectric based, low loss, short pulse
- Higher gradient than optical? Different breakdown mechanism
- No charged particles in beam path…



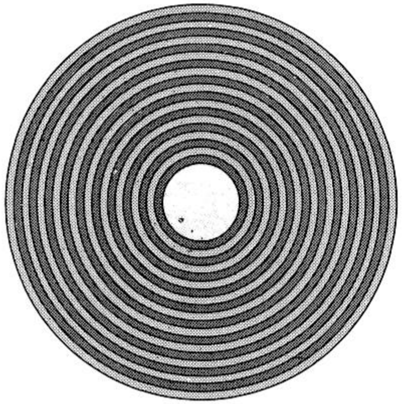
Parameter	Value
Dielectric inner diameter ($2a$)	100 μm
Dielectric outer diameter ($2b$)	324 μm
Dielectric relative permittivity (ε)	$\sim$3
Number of e^- per bunch (N_b)	1.4×10^{10}
RMS bunch length (σ_z)	$100 - 10$ μm
RMS bunch radius (σ_r)	10 μm
Beam energy	28.5 GeV
Maximum radial field at dielectric surface	27 GV/m
Maximum decelerating field (vacuum)	11 GV/m
Maximum accelerating field (vacuum)	16 GV/m

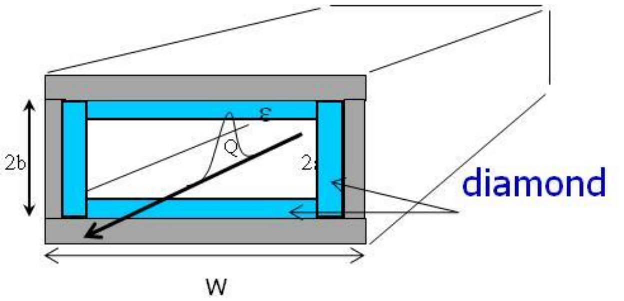
- **Determine field levels in experiment: breakdown**
- **Gives breakdown limit of > 5.5 GV/m deceleration field**

FACET: Ultra-Short Intense Beams

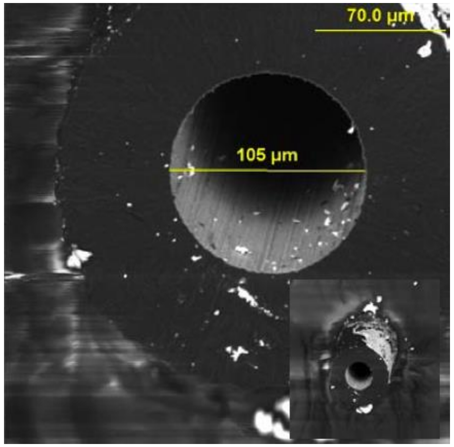
quartz, diamond

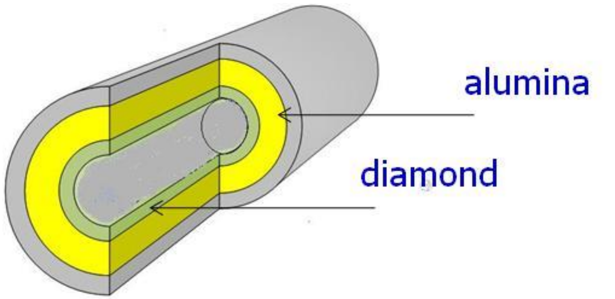
σ_z	≥ 20 μm
σ_r	< 10 μm
energy	25 GeV
charge	3 - 5 nC





- structure
- breakdown study
- observe acceleration
- accelerated beam

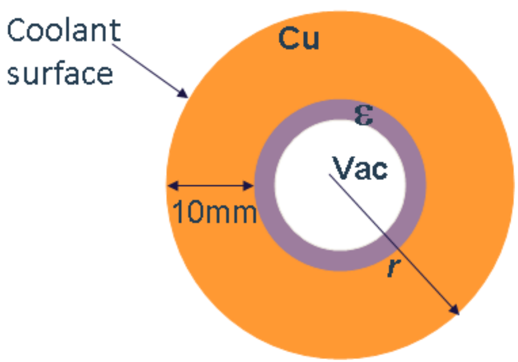


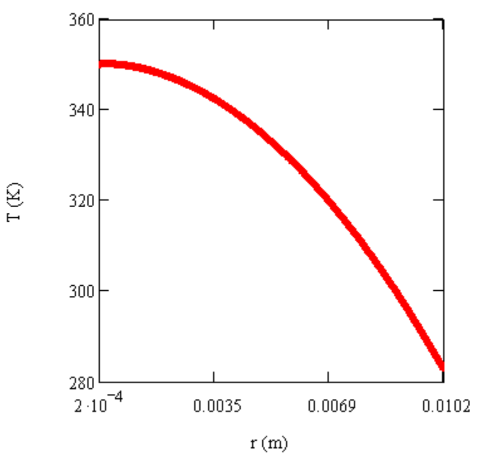


Material Properties for DLA

Quartz	1.3 W/(m·K)	charging ?
Cordierite	3 W/(m·K)	DC conductivity
Alumina	18-30 W/(m·K)	DC conductivity
Sapphire	23-25 W/(m·K)	charging ?
Copper	401 W/(m·K)	metal
Diamond	**2200 W/(m•K).**	**no charging**

*Monocrystalline synthetic diamond enriched in 12C isotope (99.9%) has the highest thermal conductivity of any known solid at room temperature: **3300.2 W/(m●K)**





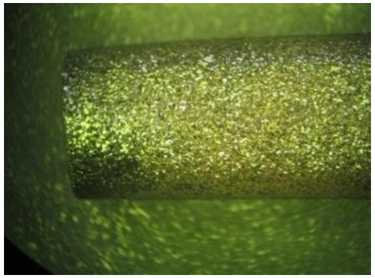
CVD DIAMOND PROPERTIES:

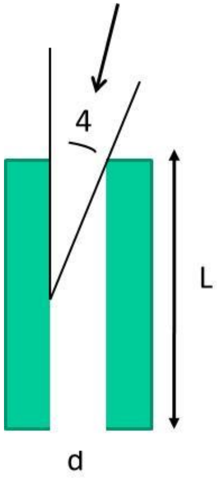
- DC BREAKDOWN THRESHOLD OF ~ 1 GV/m
- LOSS FACTOR 5-9 x10^{-5} AT 30-140 GHz
- HIGHEST THERMAL CONDUCTIVITY
- MULTIPACTING CAN BE SUPPRESSED

and

CVD DEPOSITION NOW CAN BE USED TO FORM CYLINDRICAL WAVEGUIDES

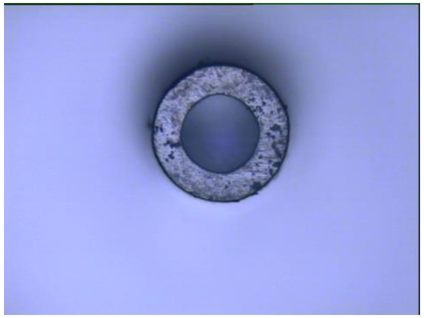
Diamond Based Structures for DLA

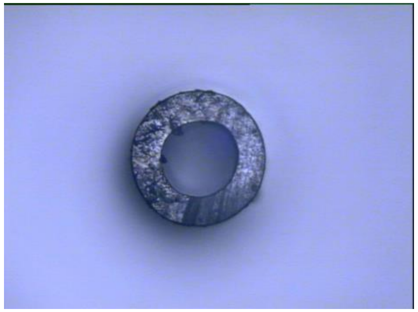


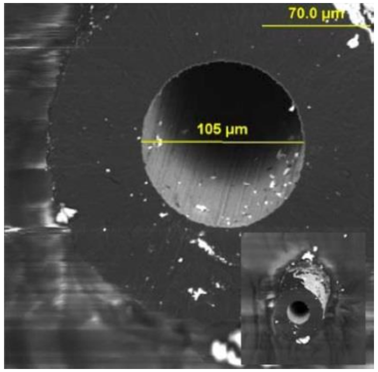


35 GHz polycrystalline structures

Diameter ~ 100 µm



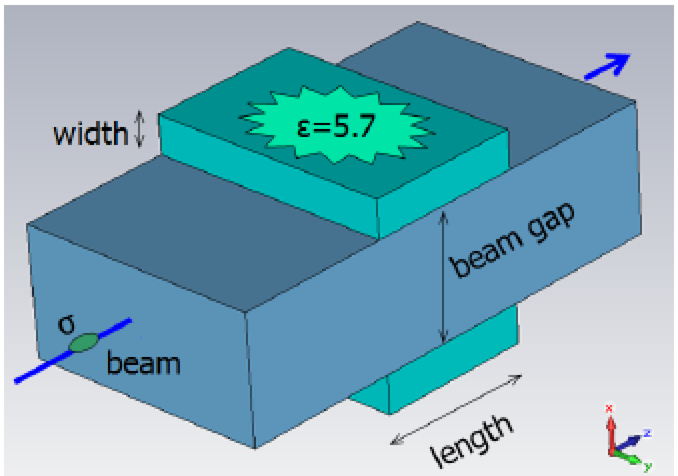




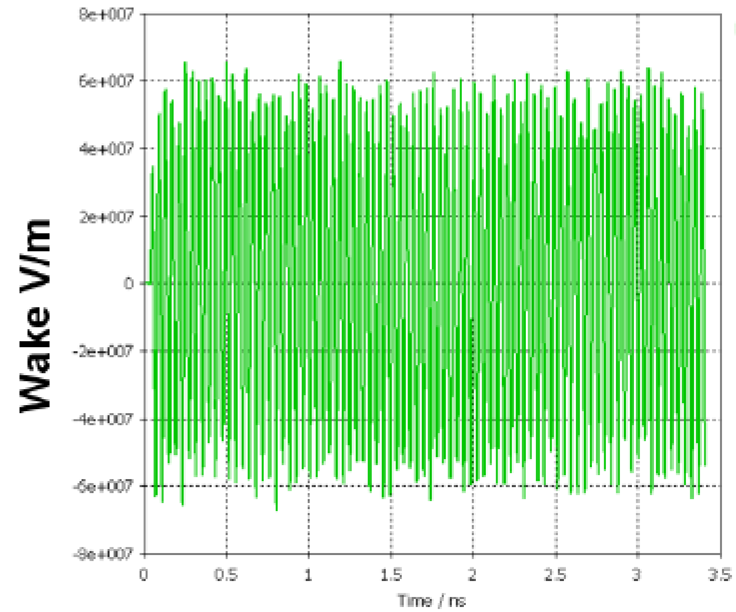
Diamond, single crystal, 427 µm ID, 755 µm , 3.99 mm;

High Gradient Breakdown Study of a Diamond Slab

Our goal is to perform first WF experiment with Diamond-based DLA, test for breakdown



50MV/m per 50 nC beam



Bunch length	**2~2.5 mm**
Beam gap	**4.0 mm**
D thickness	**1.2 mm**
width	**8 mm**
length	**5.0 mm**

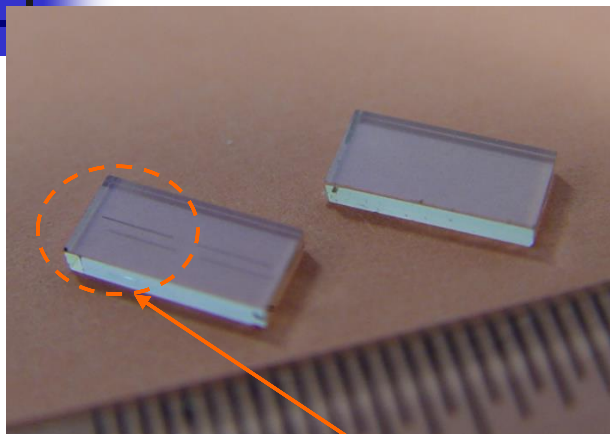
***AWA facility can generate up to 100nC beam with σ_z = 2.5 mm (14 MeV)**

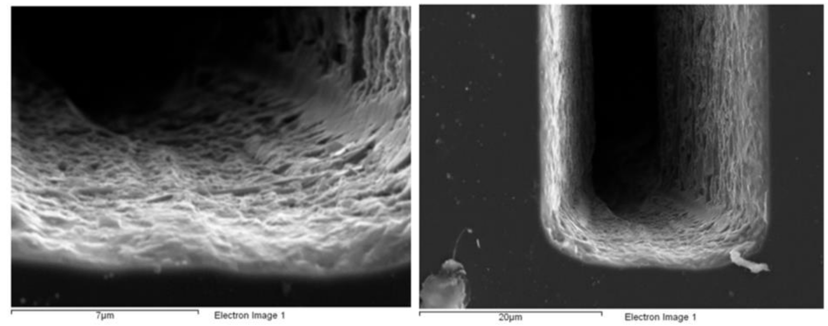
Structure is short, TM_{110} – based

Wake is a single mode at ~ 26 GHz

Q = 2800 (→decay time τ~35ns)

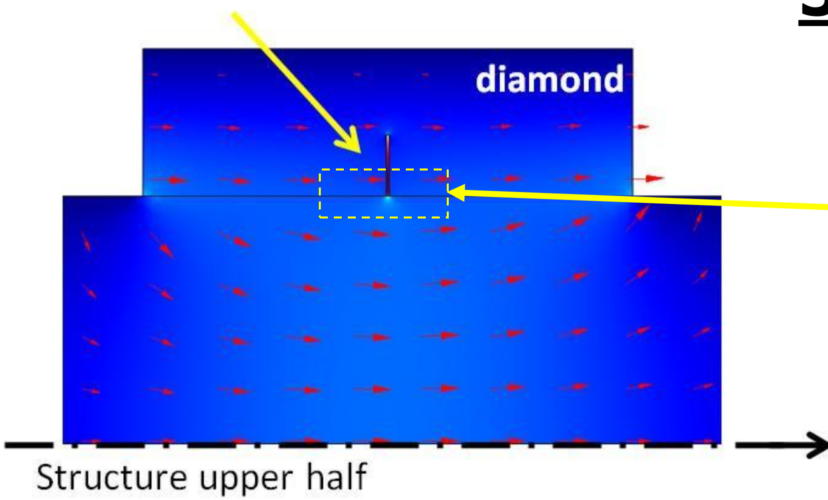
Field Enhancement in the Scratch

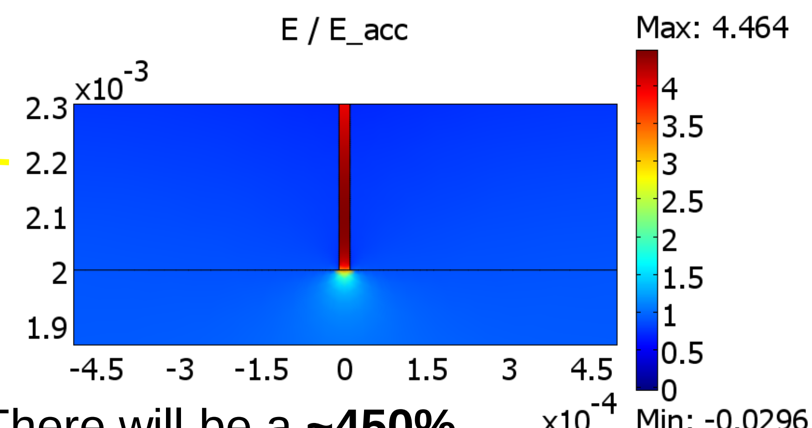




Diamonds (E6) ...**scratched**

50nC → 250 MV/m

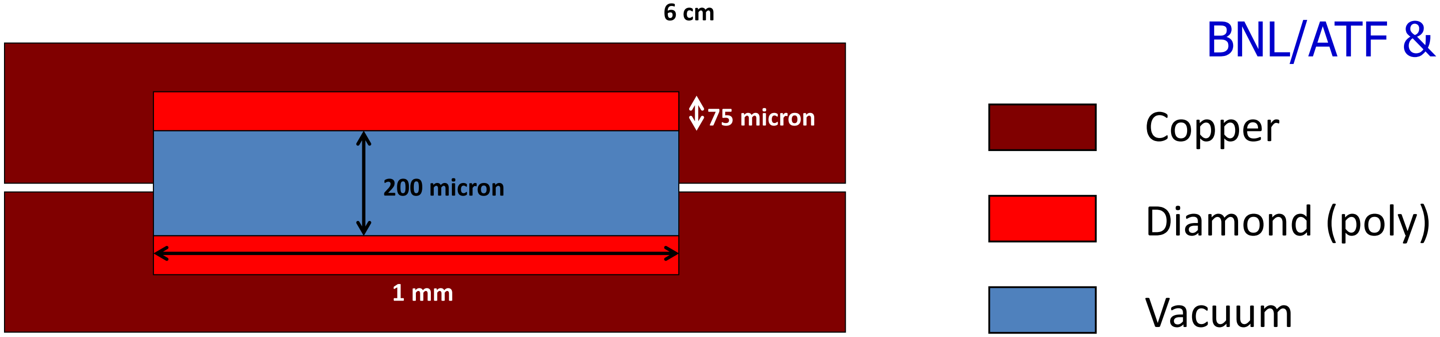


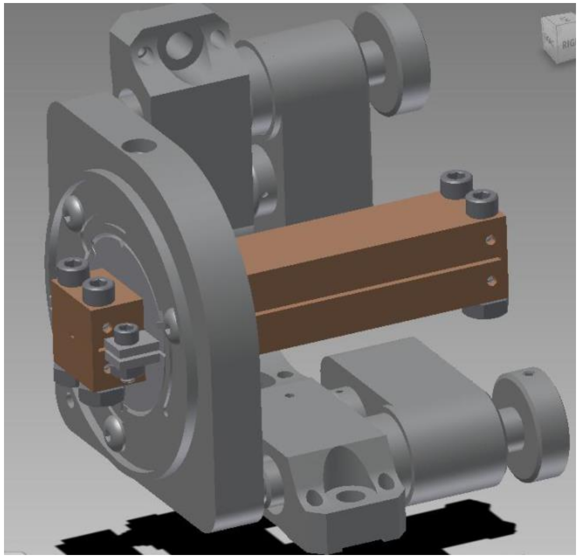


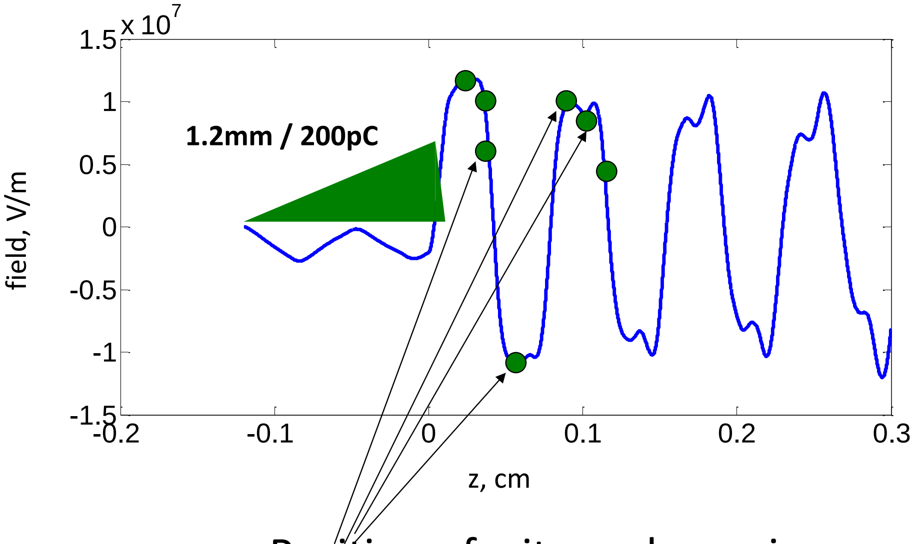
There will be a **~450% field enhancement** in the scratch

First Beam Test of the Diamond Accelerating Structure

BNL/ATF & S.Antipov







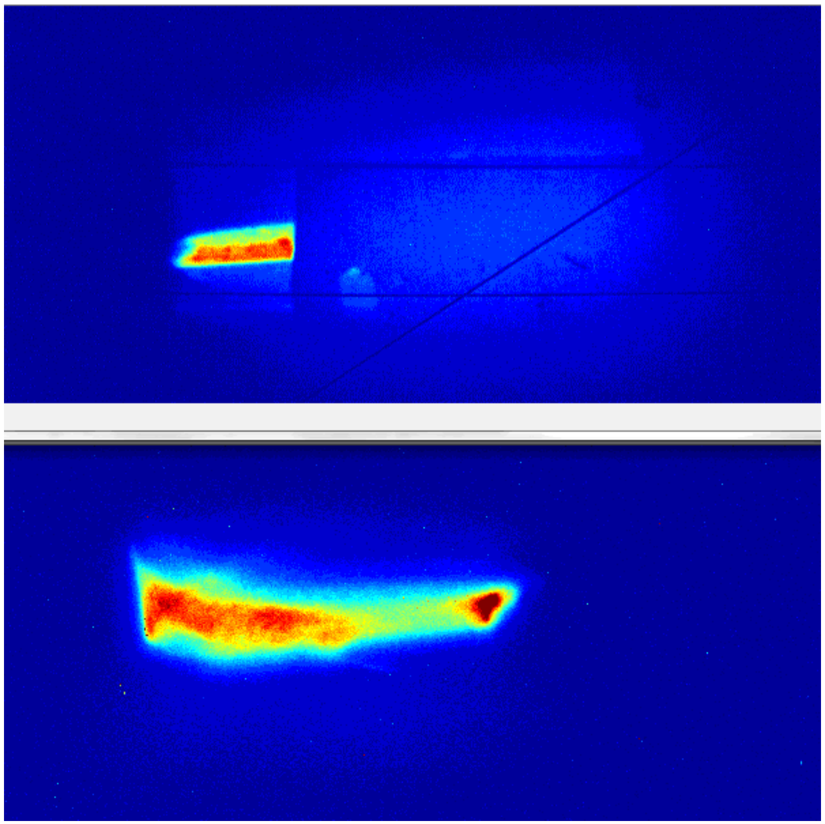
Position of witness beam is adjusted to map wakefield

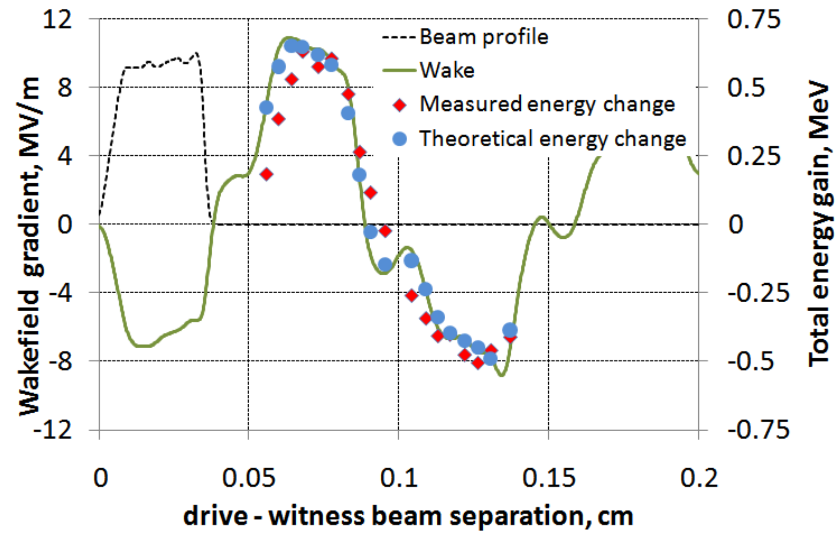
APPLIED PHYSICS LETTERS 100, 132910 (2012)

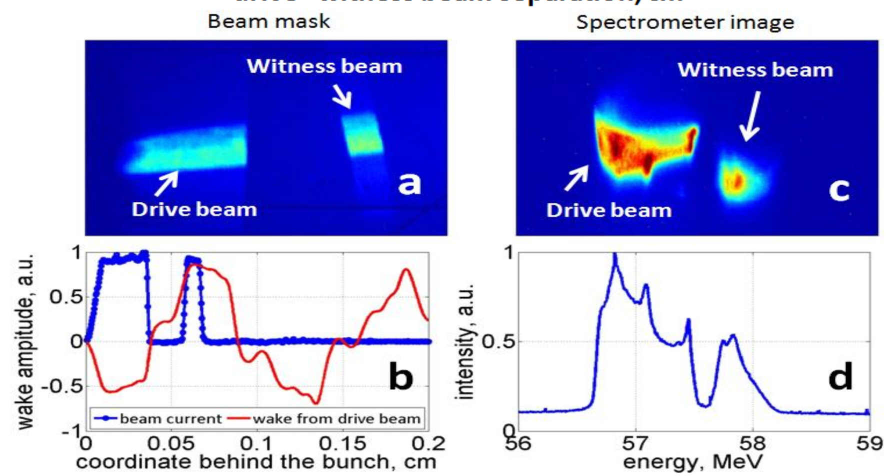
euclid TECHLABS

Experimental demonstration of wakefield effects in a THz planar diamor accelerating structure

S. Antipov,[1,2] C. Jing,[1,2] A. Kanareykin,[1] J. E. Butler,[1] V. Yakimenko,[3] M. Fedurin,[3] K. Kusche,[3] and W. Gai[2]
[1]*Euclid Techlabs LLC, Solon, Ohio 44139, USA*
[2]*Argonne Wakefield Accelerator Facility, Argonne National Laboratory, Argonne, Illinois 60439, USA*
[3]*Accelerator Test Facility, Brookhaven National Laboratory, Upton, New York 11973, USA*





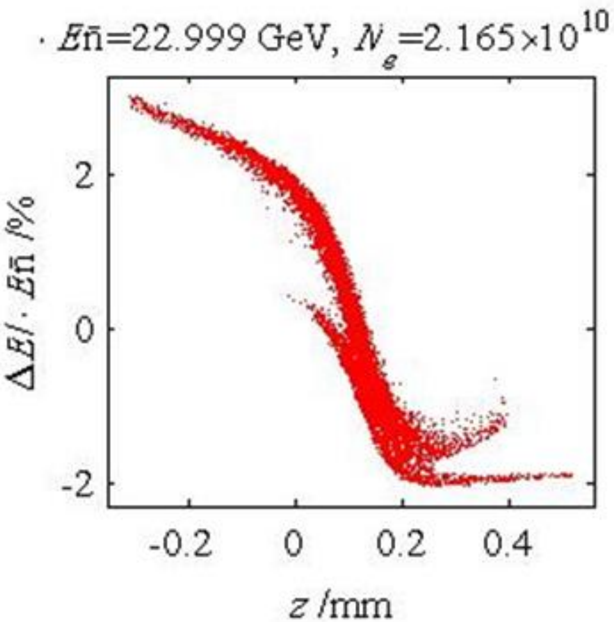


First Beam Test of the Diamond Accelerating Structure

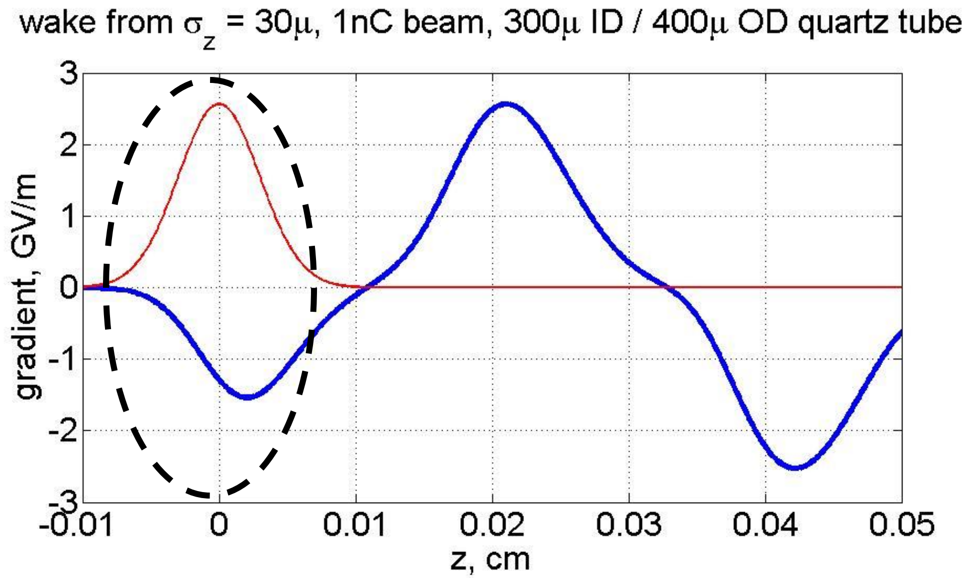
Energy chirp correction example

euclid TECHLABS

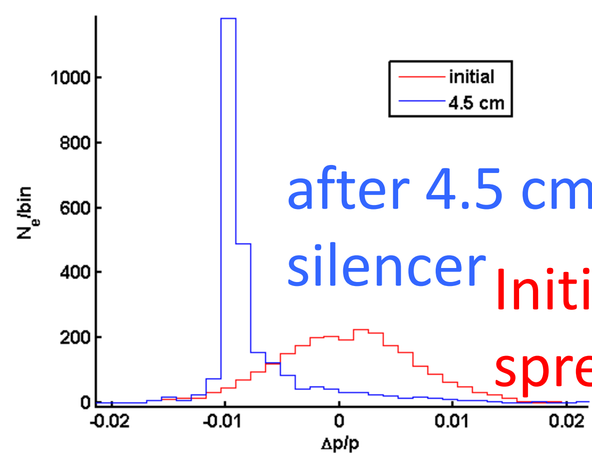
FACET beam



From M. Hogan, J. England (SLAC)



- Passive device (beam self-action)
- Can be tunable
- Ex. FACET 5% spread → 0.75% using a 5cm device

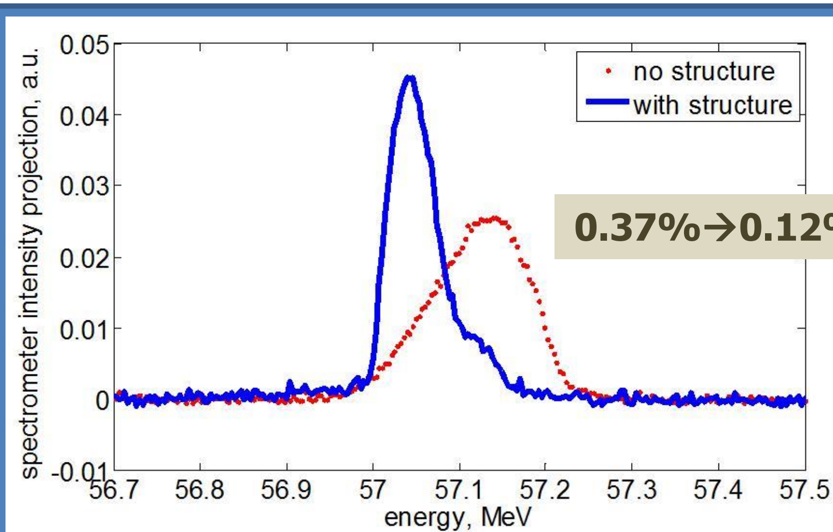


after 4.5 cm in silencer

Initial energy spread

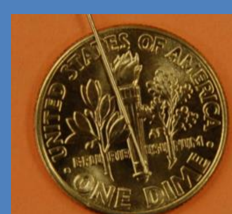
Energy chirp correction demonstrated ATF

measurement

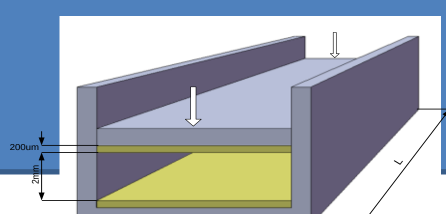


0.37%→0.12%

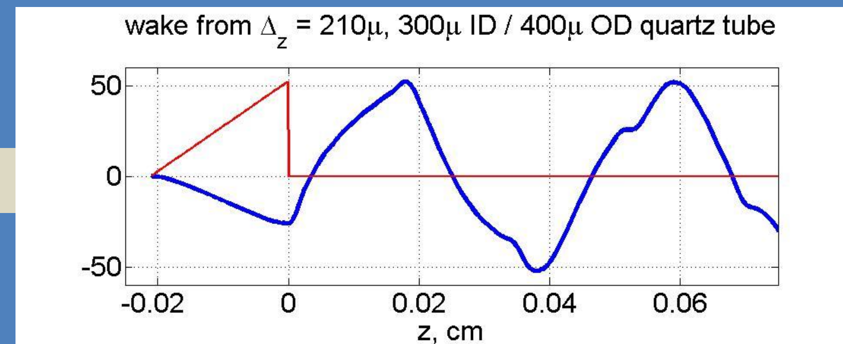
Limited by spectrometer resolution
Beam transmission

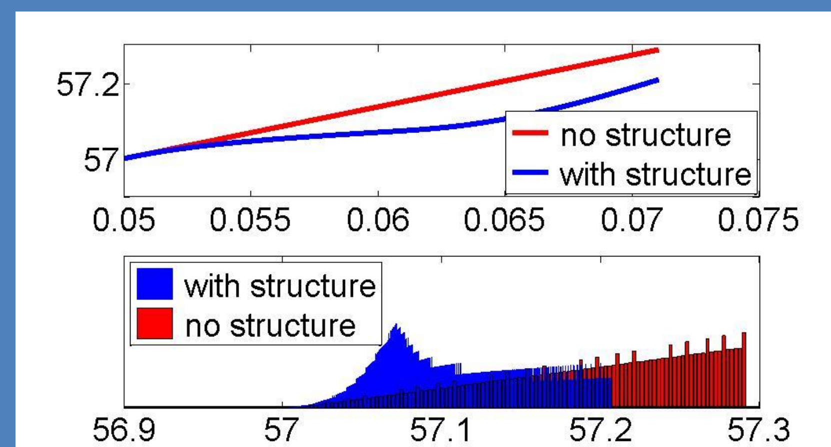


SS housing tubes
Quartz tubes (ε = 3.8)
(Gold sputtered)
Sizes (ID / OD):
1”, 200 x 330 μ
1”, 300 x 400 μ
2”, 400 x 550 μ



simulation

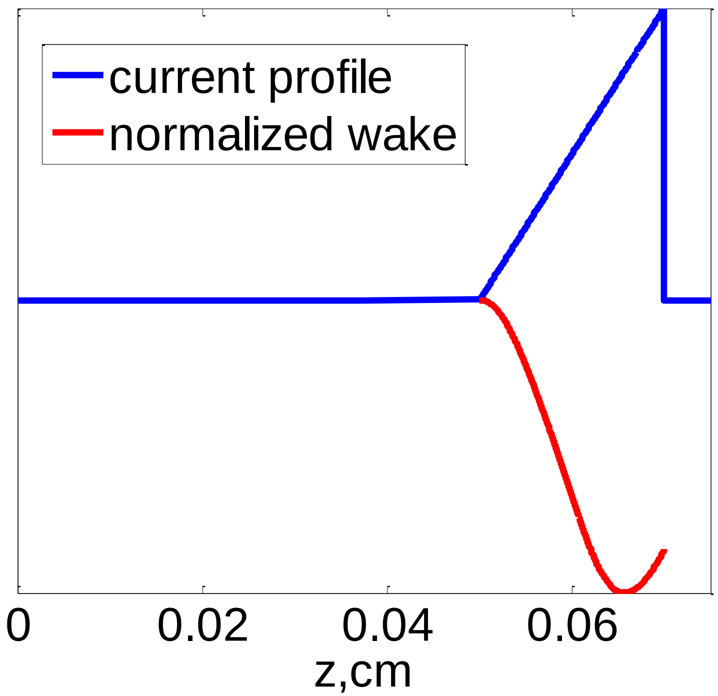


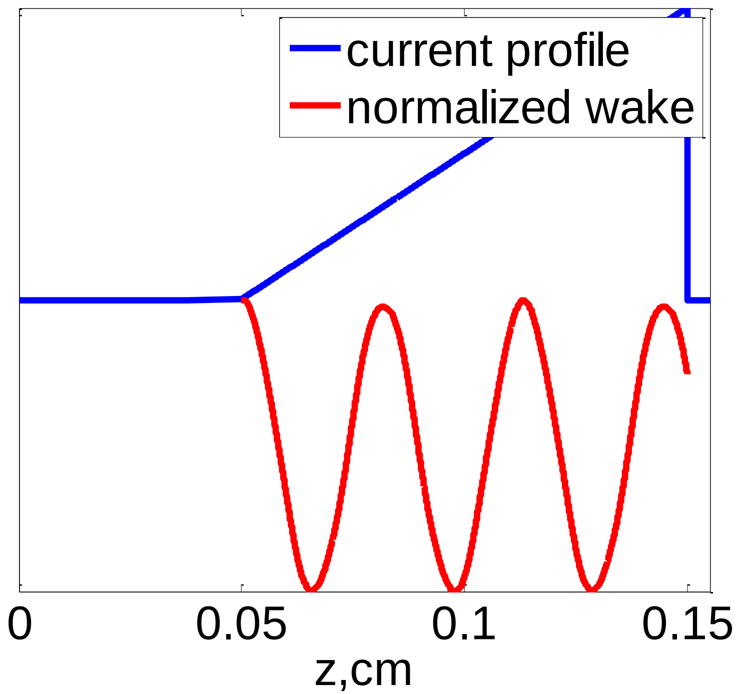


Linear chirp correction / energy

S. Antipov et al. Phys. Rev. Lett. 108, 144801 (2012)

Self-wake energy modulation





Chirp correction modulation

Energy

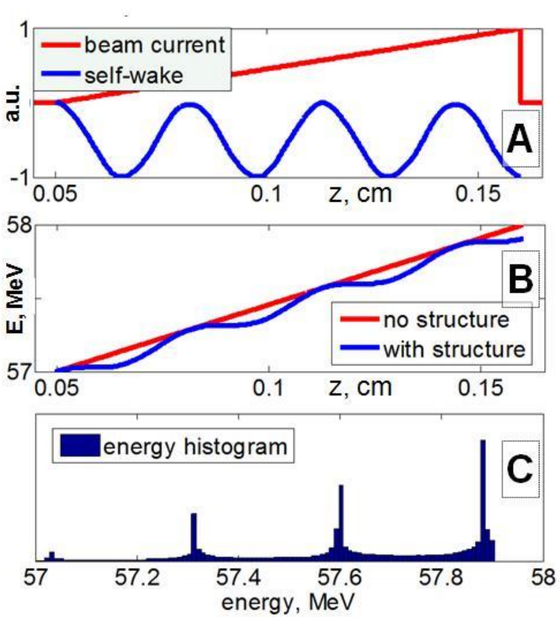
Antipov et al. Phys. Rev. Lett. (2012)

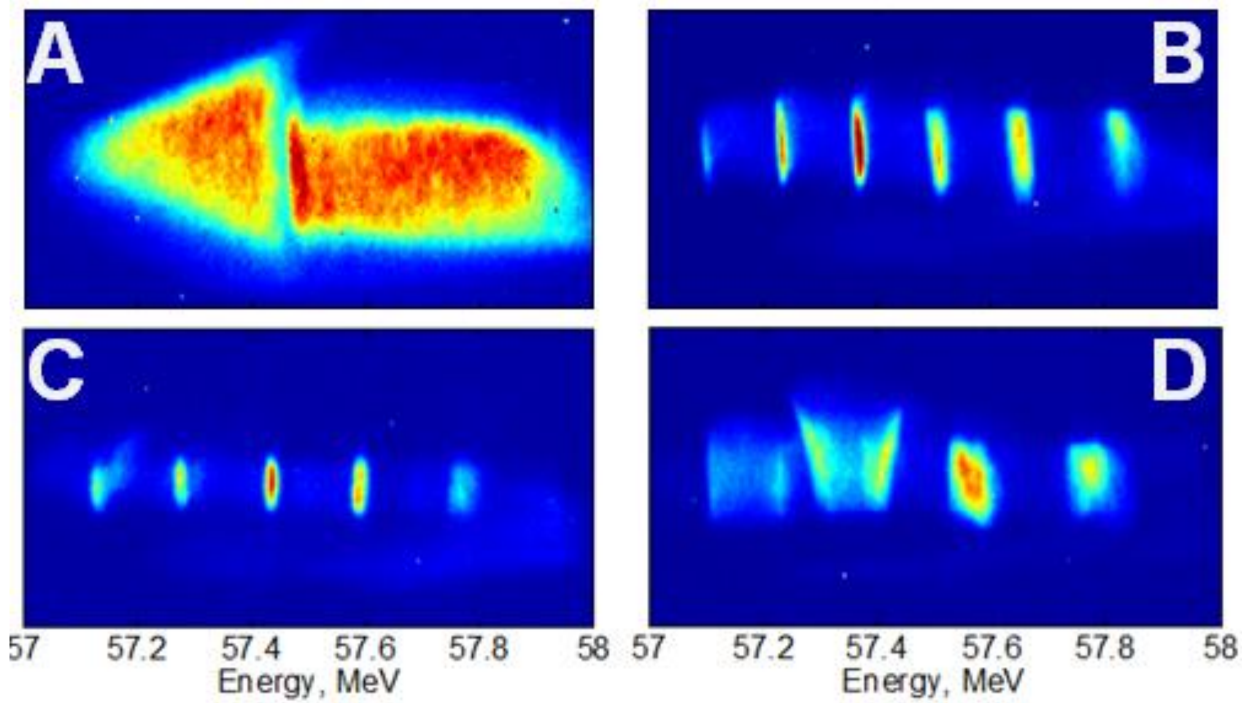
Energy Modulation Experiment

PRL 108, 144801 (2012) PHYSICAL REVIEW LETTERS week ending 6 APRIL 2012

Experimental Observation of Energy Modulation in Electron Beams Passing through Terahertz Dielectric Wakefield Structures

S. Antipov,[1,3] C. Jing,[1,3] M. Fedurin,[2] W. Gai,[3] A. Kanareykin,[1] K. Kusche,[2] P. Schoessow,[1]
V. Yakimenko,[2] and A. Zholents[4]
[1]*Euclid Techlabs LLC, Solon, Ohio 44139, USA*
[2]*Accelerator Test Facility, Brookhaven National Laboratory, Upton, New York 11973, USA*
[3]*High Energy Physics Division, Argonne National Laboratory, Lemont, Illinois 60439, USA*
[4]*Advanced Photon Source, Argonne National Laboratory, Lemont, Illinois 60439, USA*





High power beam-based THz source

Stage I

S. Antipov, C. Jing et. al. Phys. Rev. Lett. 108, 144801 (2012)

Energy modulation via self-wakefield

Stage II

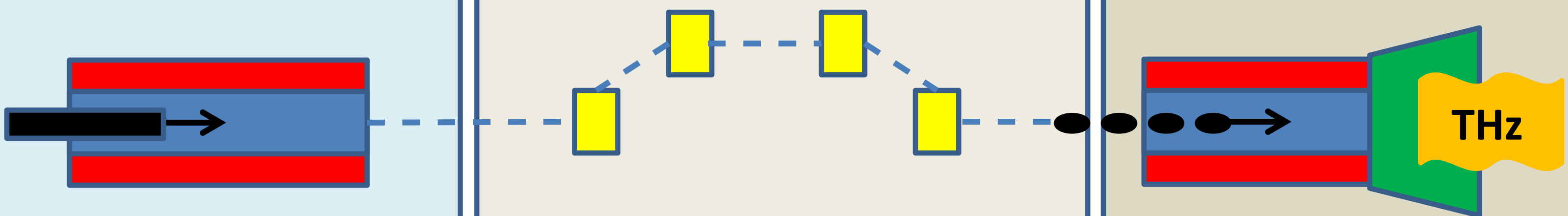
D. Xiang et. al. Phys. Rev. Lett. 108, 024802 (2012)
S. Antipov, et al. to be published

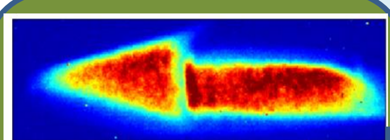
Chicane energy modulation conversion to bunch train

Stage III

G. Andonian et. al. Appl. Phys. Lett. 98, 202901 (2011)

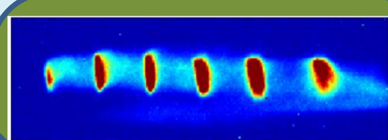
THz radiation wakefield structure





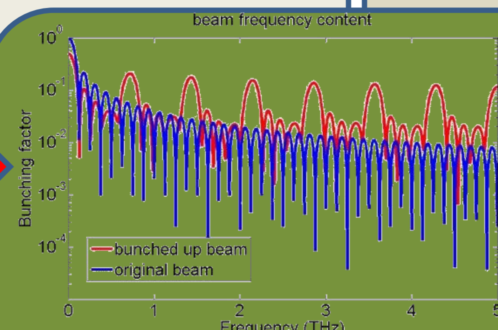
Measured beam spectrum

Energy chirped rectangular beam



Measured beam spectrum

Energy modulated rectangular beam



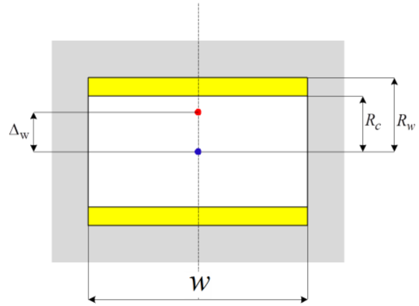
Bunch train frequency content

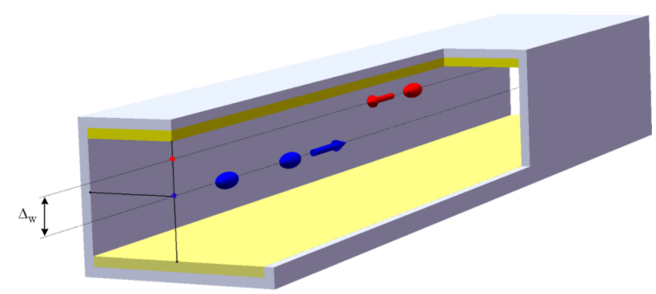
Tunable 100% source: Range: 0.3-1.5 THz
Pulse bandwidth: 1%
Energy in pulse: ~ mJ

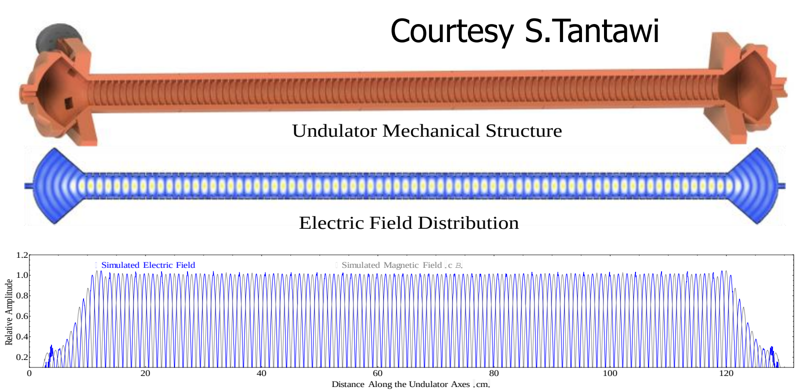
Flexible: each step has a tuning range

S.Antipov et al. Phys. Rev. Lett.

A Beam Based Undulator

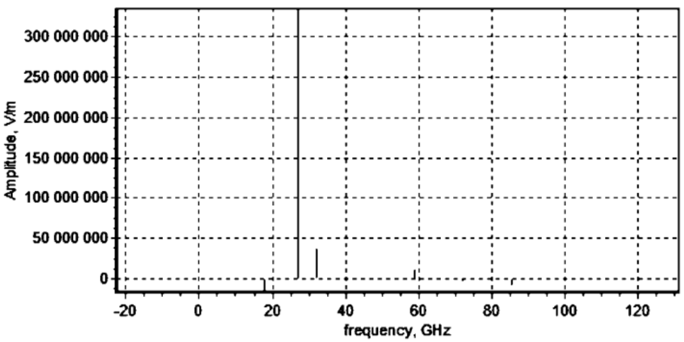






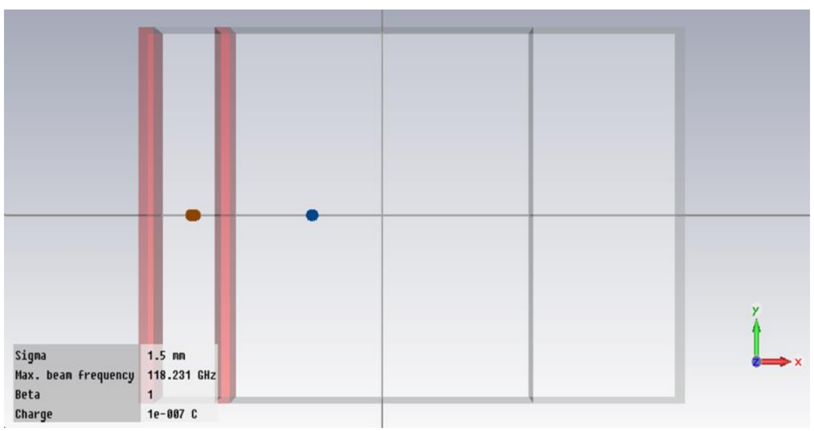
- Undulator is based on an electron bunch train powering a microwave or mm-wave waveguide.
- the **drive bunch train propagates towards the undulating beam** inside a dielectric loaded structure or corrugated waveguide generating high power RF.
- The beam driven undulator provides **strong phasing** between the undulating beam and the RF wave
- The “smart” waveguide design and a proper bunch spacing of the drive beam train provide **single mode generation**.
- for cylindrical and rectangular beam driven undulator waveguides, a parameter optimization in the range of **K~1 for an undulator period of 2-4 mm**

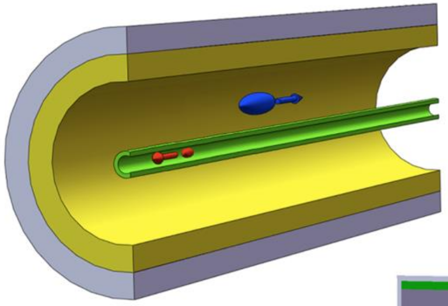
Undulator Parameters

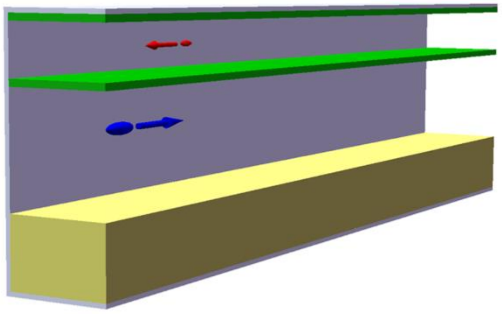


a train of 4×75 MeV bunches of 25 nC each. Structure parameters are: **a=375 um, c= 2.1 mm, d=2.85 mm** ; dielectric permittivity of the inner tube **ε=35.7** and of the outer layer **ε= 5.7**.

λ_u=2.9 mm, B_u=24kG K=1.1







SUMMARY

- We have studied various DLA structure configurations and tested the structures with the diamond, microwave ceramic and quartz loadings.
- Software have been developed for the comprehensive DLA analysis
- BBUs effects have been studied numerically and experimentally.
- Diamond structure is a promising solution because of the highest breakdown threshold and highest thermoconductivity.
- We have demonstrated energy chirp correction and subpicosecond bunch train production using dielectric based accelerator
- The dielectric beam based undulator has been proposed.