Prospects for Ultra-High Gradient Cerenkov Wakefield Accelerator Experiments at SABER

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GigaWake Dielectric Accelerator Experiment Collaboration at FFTB

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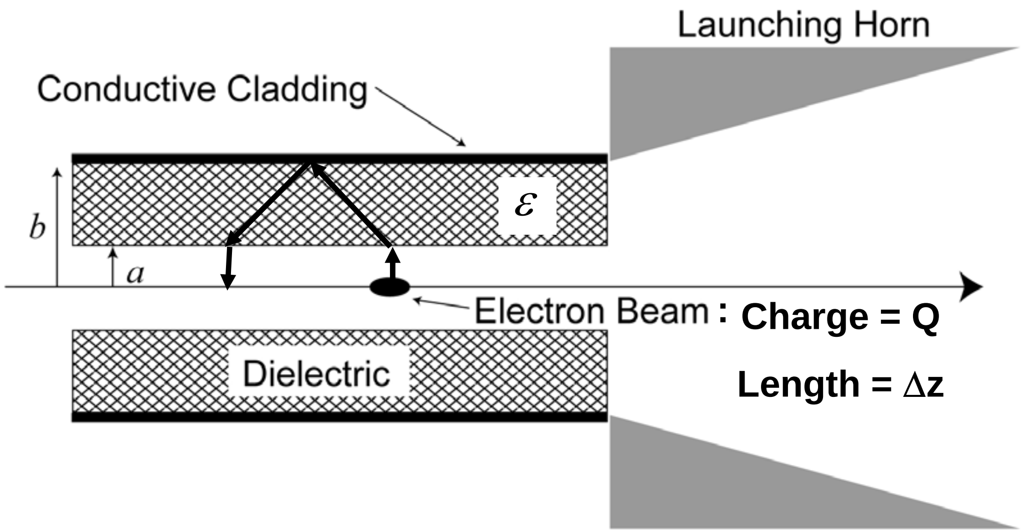
Dielectric Cerenkov Wake Accelerators

The addition of a conductive cladding to a dielectric tube creates a dielectric accelerator structure. When an intense electron beam passes through center of the tube its electric field bends at the Cerenkov angle within the dielectric, reflects off the outside conducting layer, and returns to the axis where it can be used to accelerate other particles.



Schematic of the dielectric wake experiment.

On Axis Accelerating Field:

$$E_{z,vac} = \frac{4Q}{a\left[2\frac{\varepsilon}{\sqrt{\varepsilon-1}}\Delta z + a\right]} \xrightarrow[\Delta z \ll a]{} E_{z,vac} = \frac{2Q}{a^2}$$

Wavelengths of Coherent Cerenkov Radiation Excited:

$$\lambda_n \cong \frac{4(b-a)}{n}\sqrt{\varepsilon-1}, \quad n = 1,2,3\ldots$$

Ultra-High Gradient Cerenkov Wakefields at FFTB

Our pioneering experiment is designed around the **SLAC FFTB** beam and short (~1 cm) dielectric structures made from commercial fused silica capillary tubing.

Goals:

✓ **Observe the threshold for breakdown in fused silica dielectric tubes.**

Measure THz range Coherent Cerenkov Radiation emitted from the fiber, which is directly related to surface and accelerating fields.

Table 1: Experiment Design Parameters

Bunch Population (N_b)	1.87 x 10^{10}
Bunch Energy	30 GeV
Beam Radius (σ_r)	10 μm
Beam Length (σ_z)	100 - 20 μm
Inner Dielectric Radius (a)	50 and 100 μm
Outer Dielectric Radius (b)	162 μm
Dielectric Relative Permittivity (ε)	$\sim$ 3
Peak Decelerating Field	8 GV/m
Peak Accelerating Field	12 GV/m ★
Peak Field at Dielectric	22 GV/m

Expected Fundamental Excitation Wavelengths:

350 µm for a = 100 µm (0.9 THz)

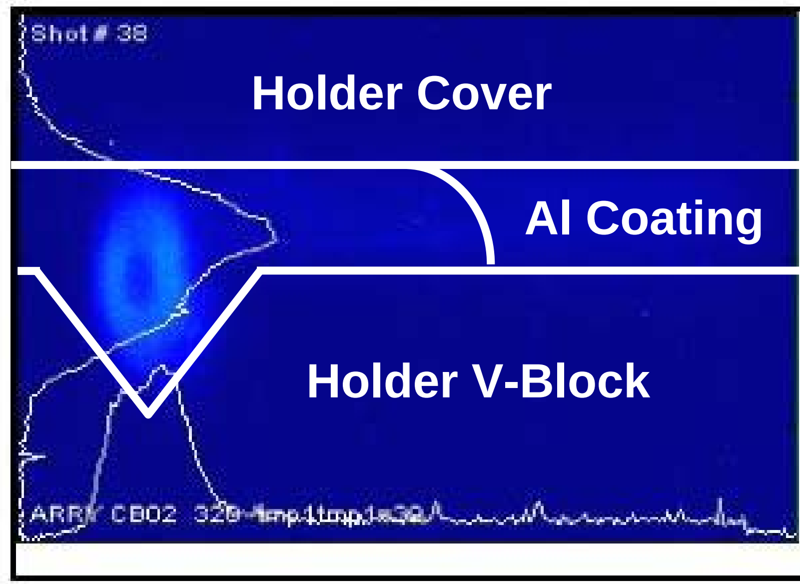
633 µm for a = 50 µm (0.5 THz)

Phase One of the Experiment

The first run of the experiment occurred in Aug 2005. The objective of the run was to examine breakdown thresholds. Direct Measurements of CCR will be attempted in the next run in ~~April 2006~~?

Major Observations:

- A sharp increase in visible emission from the capillaries near the mid-range of beam current, probably indicating breakdown.
- Principle form of damage to the dielectric wake structures appear to be vaporization of the aluminum cladding. The fused silica appeared substantially intact.



- Frames sorted by increasing peak current.
- Bad (missing) shots removed.
- Visible CCD camera with telescope lens.

Breakdown Observations

Most of the observations were of 200 µm ID fibers and the general impression is that the visible light output of the fibers jumped up sharply in the middle of the beam pulse length range. We believe that the initiation of breakdown discharges are responsible for the increase.

Visible Light Sources Below Threshold:

- **Incoherent Cerenkov Radiation, Incoherent Transition Radiation, Scintillation**

Visible Light Sources Above Threshold:

- **All of the above plus emissions from Plasma formed during breakdown events.**

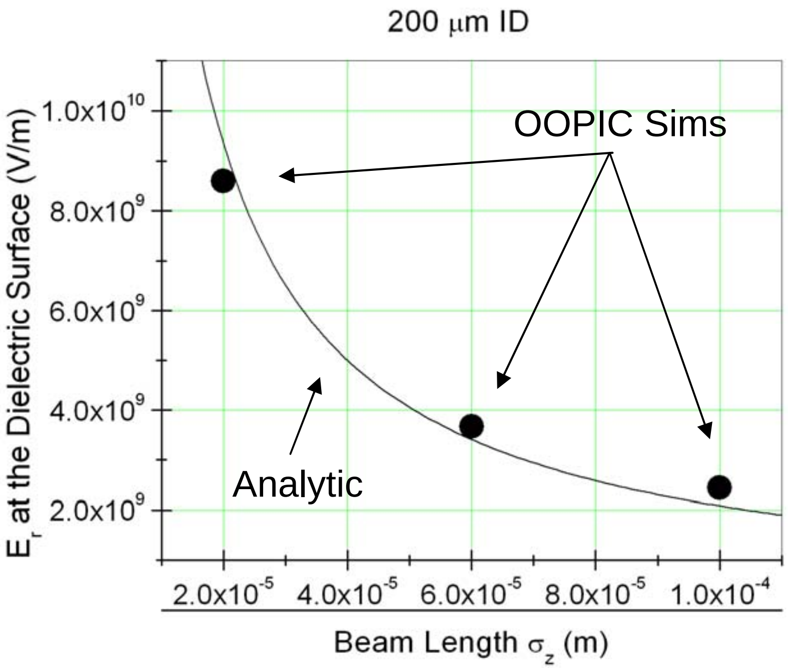
Breakdown fields implied by these preliminary observations :

~ 4 GV/m at the dielectric surface

~ 2 GV/m on axis accelerating field

Analysis of the data is ongoing.

We are pursuing the possibility of conducting further experiments at the BNL ATF.



Cerenkov Wakefield Experiments at SABER

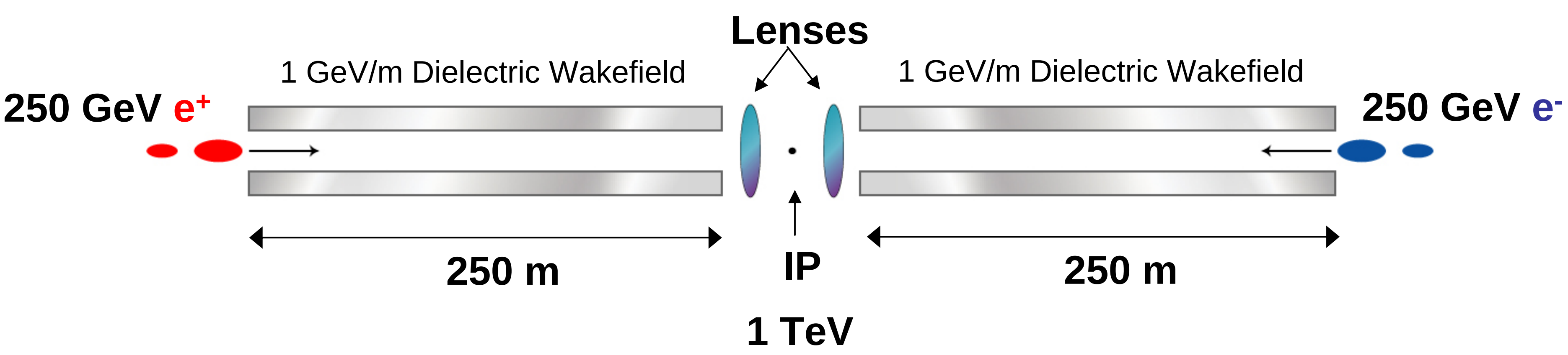
The e$^-$ and e$^+$ capabilities of SABER will provide unique opportunities for new dielectric wakefield experiments.

Chief Goals of a Dielectric Wakefield Experiment at SABER:

Demonstrate particle energy gain at GV/m fields.

Demonstrate charge reversal symmetry.

Establish dielectric wakefield accelerators as a serious option for a **Linear Collider Afterburner** scenario immune to **ion collapse** and **electron/positron asymmetry** problems.



A Proposal for SABER

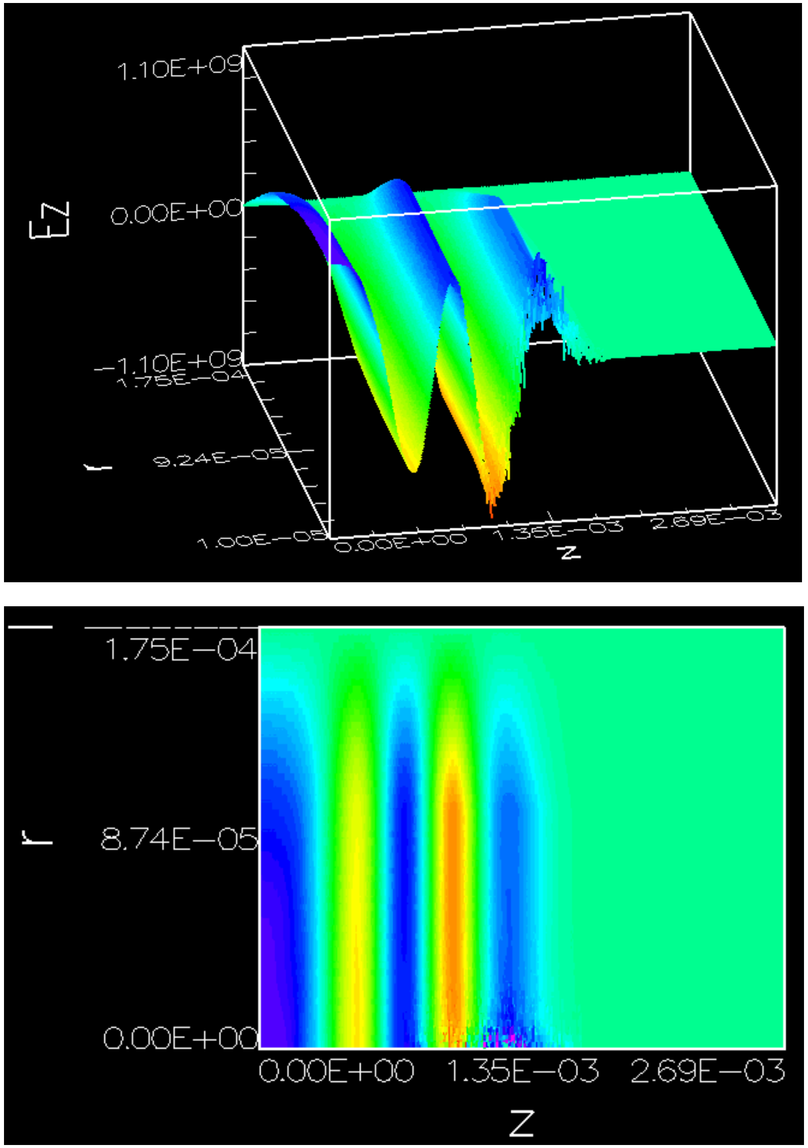
- **We suggest an experiment to look at energy modulation of the drive beam as it passes through a 10 cm dielectric tube.**
- **This experiment can be done at SABER with electron and positron beam with identical parameters.**
- **The result should provide a clear measurement of the wakefields within the beam.**
- **This flexible set of experimental parameters can easily be optimized for a true drive / witness beam scenario or other situations.**

Experimental Parameters

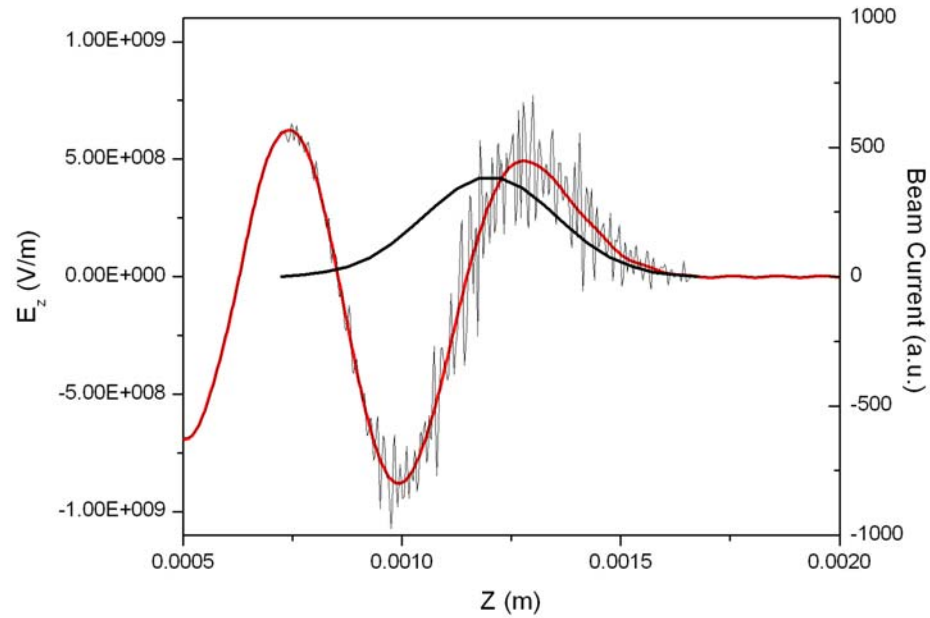
Beam Energy	30 GeV
Beam Energy Spread (FWHM)	< 0.25% (.075 GeV)
Beam Charge (**e^-** or **e^+**)	3 x 10^{10} (5 nC)
Beam Radius (σ_r)	10 μm
Beam Length (σ_z)	150 μm
Inner Dielectric Radius	100 μm
Outer Dielectric Radius	175 μm
Dielectric Permittivity	~ 3
Dielectric Length	10 cm
Peak Accelerating E_z	1.1 GV/m
Peak Surface Field	2.2 GV/m
Maximum Energy Gain	0.11 GeV

(Analytic Theory)

OOPIC Simulations for a SABER Dielectric Experiment



Contour plots showing E_z for a = 100 μm



Line out of E_z at
r = 10 μm with a = 100 μm
(Low pass filtered E_z in red.)

Necessary SABER Capabilities and Features

From our previous experience as FFTB users, and our discussion of the possibilities at SABER, we developed the following suggestions:

Key FFTB Features Worth Preserving:

Highly skilled and cooperative technical support

Experiment A out; experiment B installed, running and removed in < 72 hrs!

Physicists' playground

- **Windowed off vacuum area**
- **Highly evolved beamline controls**
- **Highly flexible experimental controls**

Minimal bureaucratic hassles

Key SABER Features Worth Emphasizing / Adding:

Ample and dedicated experimental beamline space.

Highly flexible focusing lattice to provide both short and long beta functions

Flexible e^- and e^+ bunch production:

Variable bunch length

Split bunches

Lots of built in diagnostics & controls

Real witness beams generated by an external injector.