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SBIR 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

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.

2007 – 8 SBIR granted, 5 people research staff (3 full time and 2 visiting), + AWA group support, + cooperation with ANL/FNAL/Yale University/other labs…

Dielectric Based Accelerator:

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High Gradient (>100 MV/m)

High Efficiency (high shunt impedance, low losses)

and

- Coupling (field enhancement) for externally powered (rf) structures
- High Transformer Ratio (energy transfer) for Wakefields
- Multipacting/Breakdown suppression
- Tuning

Current SBIR Funded Program, Phase II

Funded:

- Transformer Ratio Experiment – Phase II (2002-2006) - completed
- BST Ferroelectric Development – Phase II (2005-2007)
- Active Media Development – Phase II, (2006-2008)

Submitted:

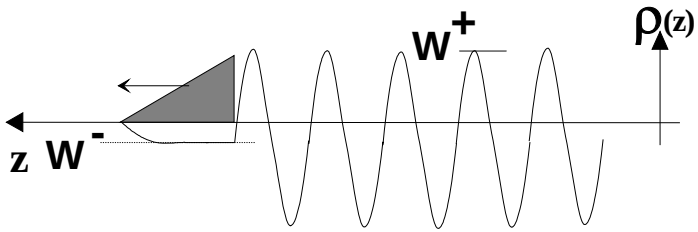
- SC Traveling Wave Accelerating Structure for ILC, Phase II, ?
- Diamond Based DLA Structure, Phase II, ?
- Coaxial Coupling Section for the DLA Structure, Phase II, ?

TRANSFORMER RATIO ENHANCEMENT EXPERIMENT FOR THE DIELECTRIC-BASED ACCELERATOR*

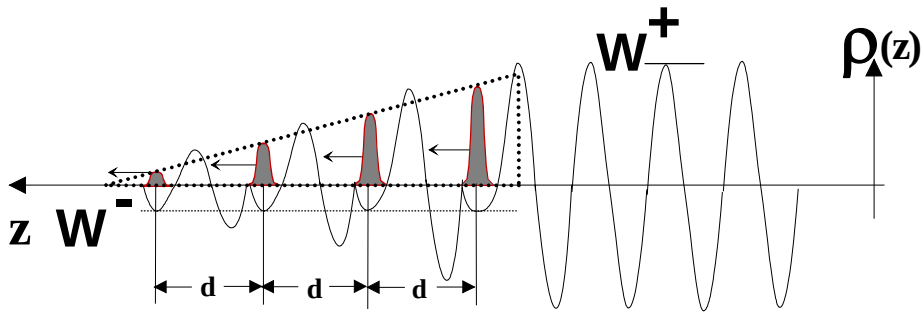
PROJECT IN COLLABORATION WITH ANL/AWA

* Talk by C. Jing

Transformer Ratio



Reference: Bane et. al., IEEE Trans. Nucl. Sci. NS-32, 3524 (1985)



Reference: Schutt et. al., Nor Ambred, Armenia, (1989)

Transformer Ratio

R = (Max. energy gain behind the bunch) / (Max. energy loss inside the bunch).

- From now on we consider 200 MeV drive beam, then we need R > 5
- For R=5, the wakefield amplitude is ~ 50 MV/m, down from 240MV/m.

Enhanced Transformer Ratio in Collinear Wakefield Experiment

PRL 98, 144801 (2007) PHYSICAL REVIEW LETTERS week ending 6 APRIL 2007

Observation of Enhanced Transformer Ratio in Collinear Wakefield Acceleration

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(Received 3 November 2006; published 2 April 2007)

One approach to future high energy particle accelerators is based on the wakefield principle: a leading high-charge *drive* bunch is used to excite fields in an accelerating structure or plasma that in turn accelerates a trailing low-charge *witness* bunch. The transformer ratio R is defined as the ratio of the maximum energy gain of the witness bunch to the maximum energy loss of the drive bunch. In general, $R < 2$ for this configuration. A number of techniques have been proposed to overcome the transformer ratio limitation. We report here the first experimental study of the ramped bunch train (RBT) technique in a dielectric based accelerating structure. A single drive bunch was replaced by two bunches with charge ratio of 1:2.5 and a separation of 10.5 wavelengths of the fundamental mode. An average measured transformer ratio enhancement by a factor of 1.31 over the single drive bunch case was obtained.

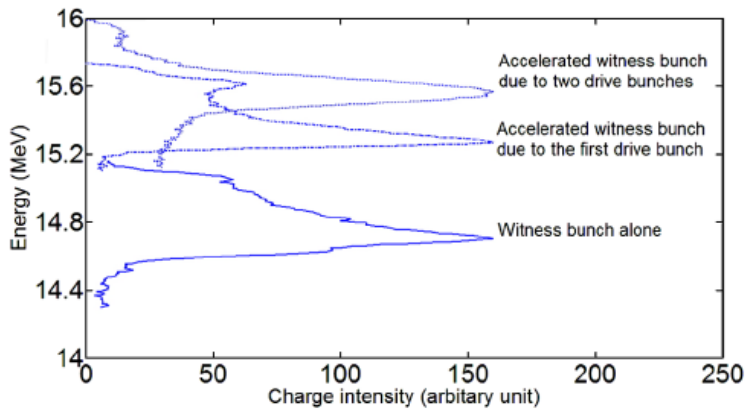
DOI: 10.1103/PhysRevLett.98.144801 PACS numbers: 29.17.+w, 41.60.−m, 41.85.Ct

In a wakefield accelerator, the fields generated by a leading, high-charge *drive* bunch (either a single drive bunch or a train of drive bunches) are used to accelerate a trailing, low-charge *witness* bunch. An important pa-

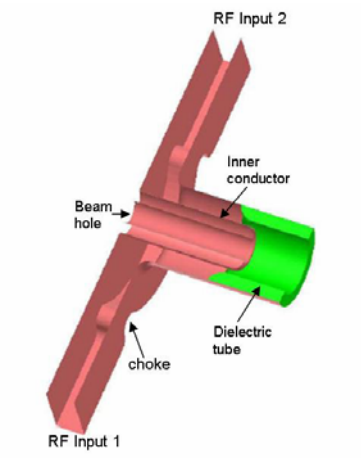
transformer ratio enhancement has been fully in Refs. [14,15], which emphasized that the t rameters necessary to adjust in order to effec former ratio enhancement are the optimized cl

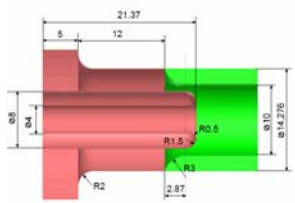
enhancement factor of 1.31

R~2.23



NEW COAXIAL-TYPE COUPLER FOR THE DIELECTRIC-BASED ACCELERATOR*

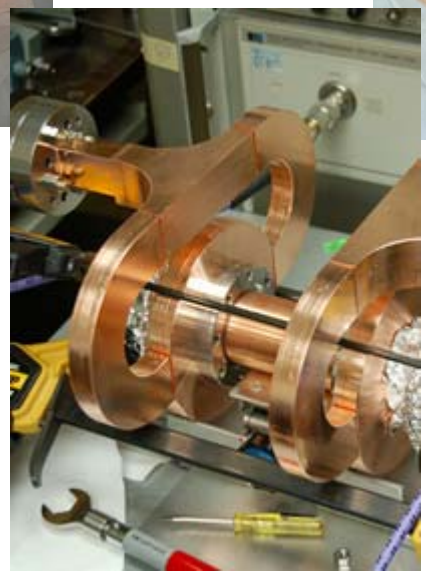


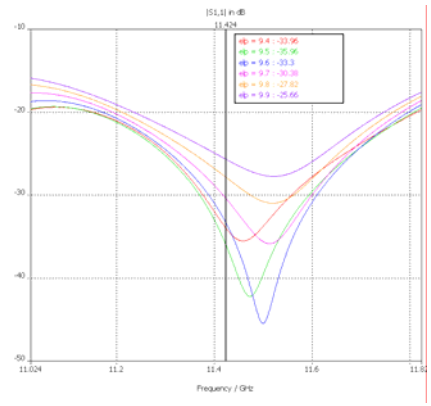


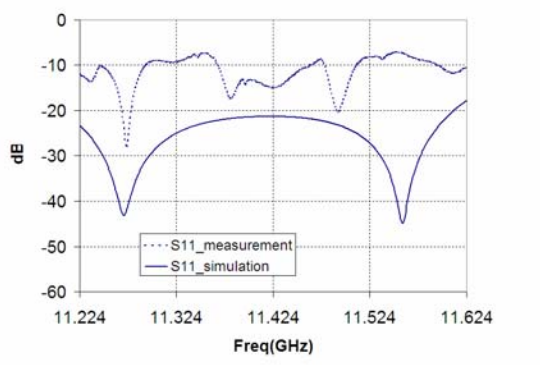
PROJECT IN COLLABORATION WITH ANL/AWA

* Talk by C. Jing

New Coupler Design for DLA Structures







Euclid Techlabs LLC

DoE Review
2007

CVD DIAMOND-BASED ACCELERATOR

*

PROJECT IN COLLABORATION

WITH ANL/AWA

* Rough Octohedral Diamond Crystal USGS, http://chemistry.about.com/cs/geochemistry/a/aa071601a.htm

DIAMOND CHEMICAL VAPOR DEPOSITION (CVD)

CVD DIAMOND PROPERTIES:

- RF BREAKDOWN THRESHOLD OF ~ 2 GV/m

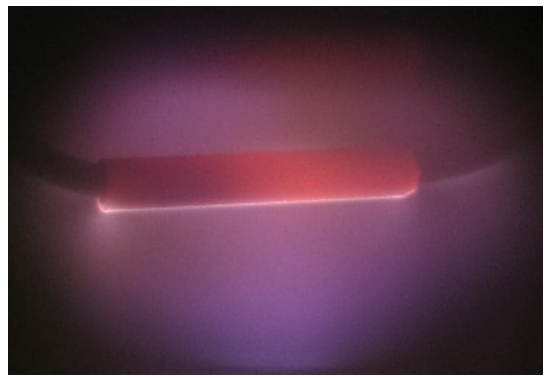
- HIGHEST THERMAL CONDUCTIVITY (2×103 W m−1 K−1)

- MULTIPACTING CAN BE SUPPRESSED

- We measured the loss tangent and permittivity of the sample at 19.25 GHz. The dielectric constant 5.69±0.02 (5.7 nominal for diamond) and LOSS TANGENT is of $(22\pm4)*10^{-5}$ at 19.25 GHz.

...and CVD DEPOSITION NOW CAN BE USED TO FORM CYLINDRICAL WAVEGUIDES

PLASMA SUPPORTED CVD-DIAMOND CYLINDRICAL WAVEGUIDE FABRICATION

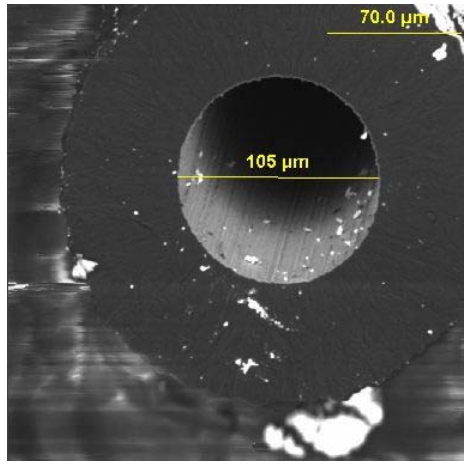


Photographs of the 5 mm ID alumina substrate in the PECVD reactor *.

*Developed for Euclid Techlabs by Coating Technology Solutions, Inc. Somerville, MA

CVD – DIAMOND 34 GHz and - THz Range Structures

CVD-diamond Ka-band 5 mm ID cylindrical waveguide*



Scanning electron microscope images of a THz diamond microstructure produced using the hot wire deposition technique.

*Developed for Euclid Techlabs by Coating Technology Solutions, Inc. Somerville, MA

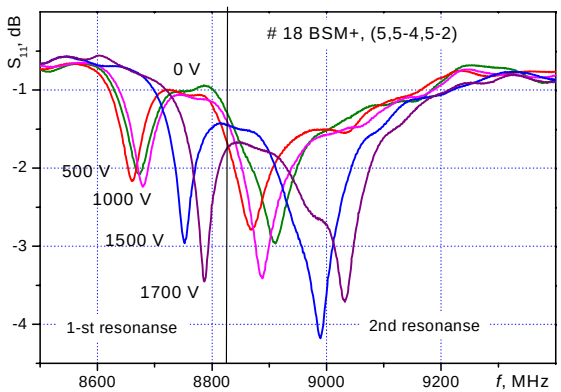
FERROELECTRICS

FERROELECTRIC MATERIALS FOR:

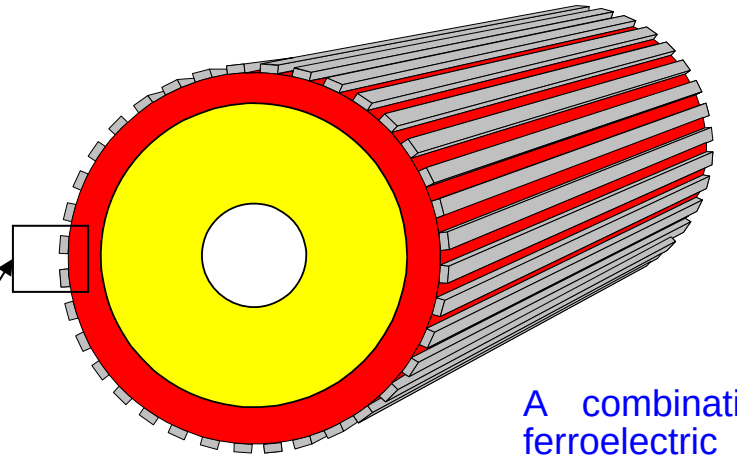
- PULSE COMPRESSION AND POWER DISTRIBUTION FOR LINEAR COLLIDER
- SC CAVITY COUPLING ADJUSTMENTS FOR ILC
- FREQUENCY TUNING FOR DIELECTRIC BASED ACCELERATORS

PROJECT IN COLLABORATION WITH YALE/OMEGA-P, INC AND ANL/AWA

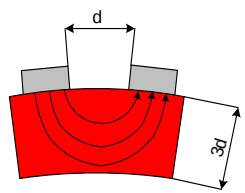
Tunable Dielectric Loaded Accelerator



permittivity of the ceramic and ferroelectric of 20 and 481 respectively, frequency shift of 162 MHz (second resonance) at 1.7 V/ μm bias field.



Microstrip electrodes

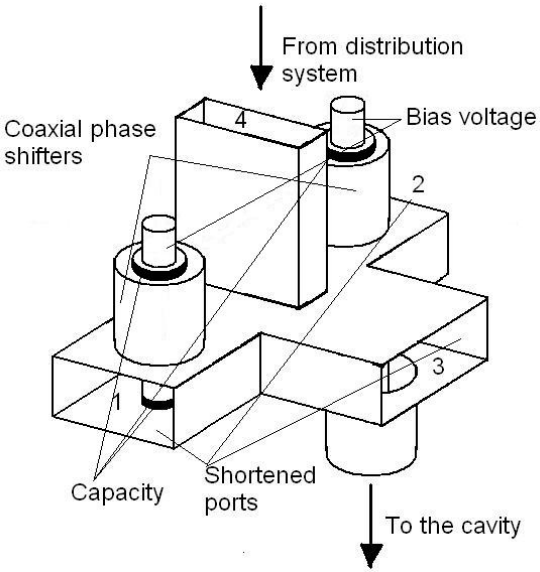


$d = 60\mu m$

A combination of ferroelectric and ceramic layers have been used to implement tuning of a composite waveguide.

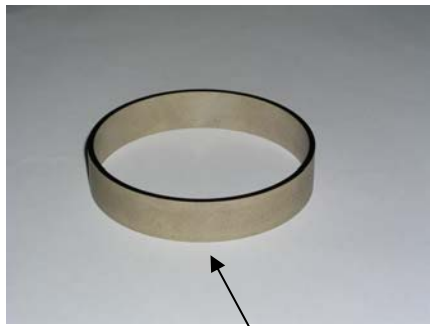
Dielectric constant variation with DC electric field allows control of the matching between the longitudinal wakefield phase and the witness beam position for acceleration efficiency.

FAST ACTIVE L-BAND HIGH POWER TUNER FOR ILC



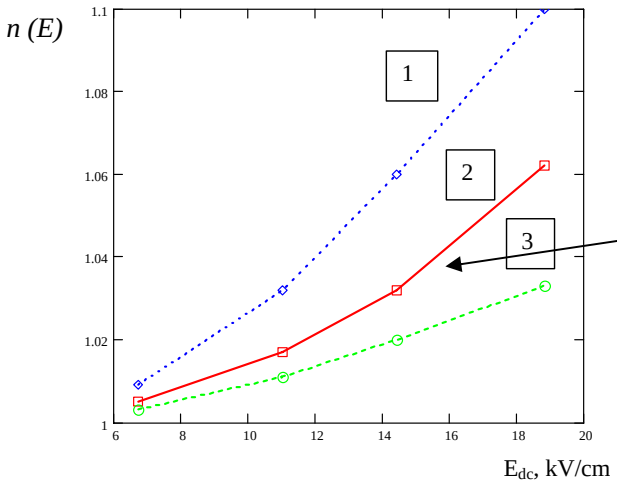
Schematic of the L-band tuner to produce fast ILC cavity coupling changes based on a magic-T and two phase shifters containing ferroelectric elements*.

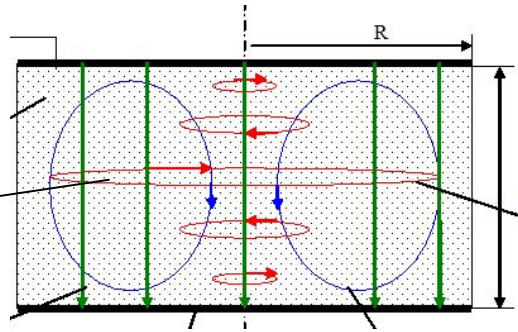
* Developed by Omega-P, Inc., New Haven, CT



Ferroelectric ring elements for the X-band high power phase shifter. The same technology will be used for the L-band tuner fabrication.

Transverse Bias Field





The BST(M)-3 dielectric-ferroelectric composite has been studied experimentally with respect to the dielectric response on the applied transverse and parallel bias fields. The absolute tunability vs. transverse and parallel biasing voltages has been measured. The theoretical analysis of the transverse bias applied to ferroelectric materials has been carried out. Finally, feasibility of the use of transverse bias configurations for ferroelectric based accelerator component tuning has been demonstrated

ACTIVE MEDIA

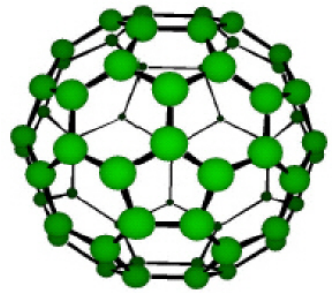
MASER CONCEPTS FOR ADVANCED ACCELERATOR:

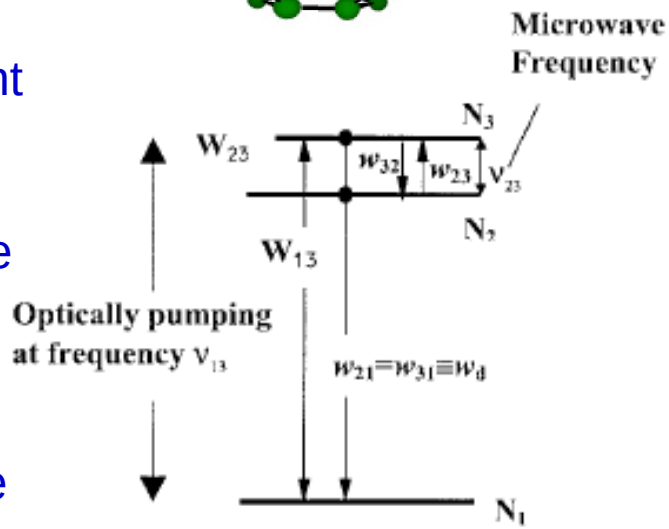
- BASED ON FULLERENE C_{60} IN LC SOLUTION
- OPTICAL PUMPING
- ALL BENEFITS OF CONVENTIONAL ACCELERATOR

PROJECT IN COLLABORATION WITH ANL/AWA

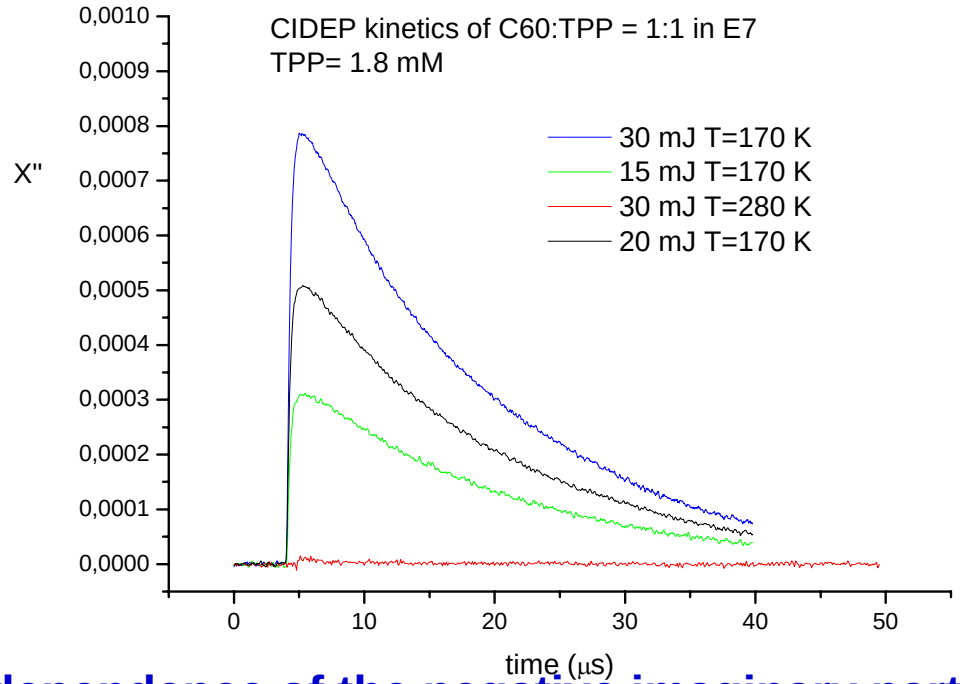
Activity in Fullerenes

- Active medium: TPhP-C_{60}-LC solution
- Photoexcitation of triplet states of C_{60} by optical pump
- Effect of the nematic liquid crystal component (rodlike molecules aligned to exhibit long range 1D order) is to introduce a symmetry breaking and allow the spin energy levels of the fullerene to become selectively populated.
- Operating temperature ~ 150 K
- Frequency of microwave transition is tunable by adjusting the applied magnetic field.





ESR Measurements of New Active Materials

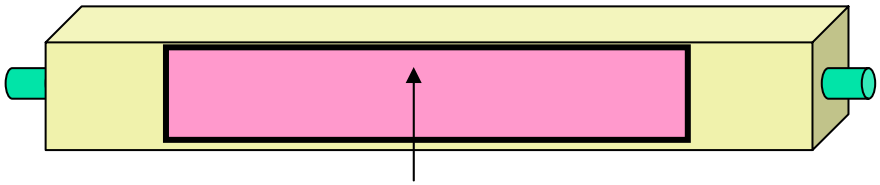


Time dependence of the negative imaginary part of the magnetic susceptibility for different pump energies. X''=10^{-4} corresponds to ~10^{17} spins/cc.

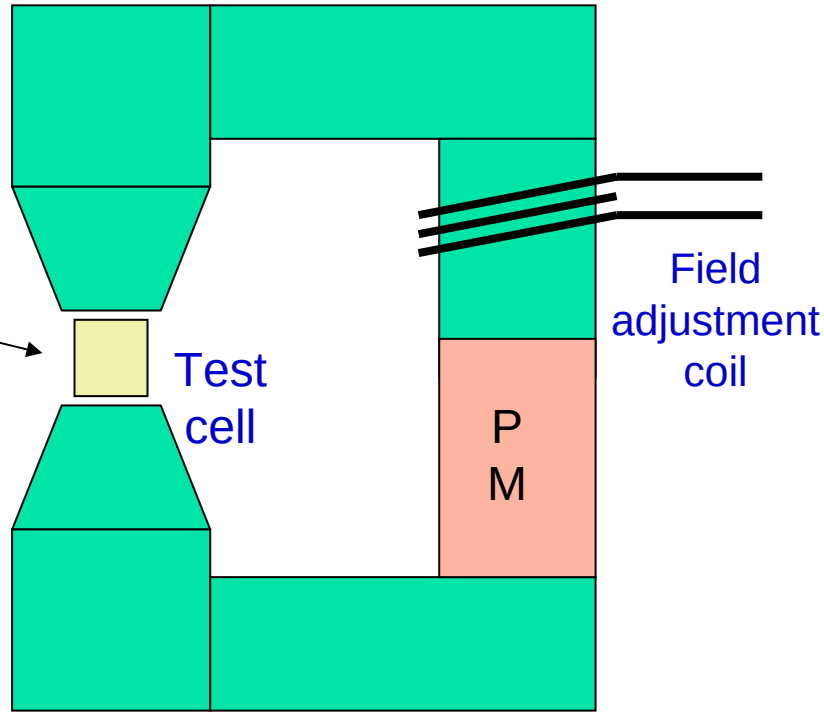
Activity in Fullerenes

- The achievable spin density impacts the total volume of active media required for these measurements.
- We use as a reference the maximum estimated number of 10^{17} spins/cm^3 for the E7-C_{60} -TPhP solution.
- This implies a stored energy in the medium of 6.6 erg/cm^3 excited by an optical pulse energy of 37 mJ/cm^3. (G=660 keV/cm for 1 pC bunch)
- Measurements have been made at lower temperatures than originally planned. (150 K)

Bench Test System



90% transmission mesh window for pump input



- Rectangular cell
- PM dipole
  - Physically smaller than solenoid
  - Cool in LN_2 bath
  - Adaptable to beam experiment

Bench Test/Acceleration Experiment

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- Redesign of bench test system from the original proposal to accommodate the beam acceleration experiment with minor modifications.
- Use PM dipole to produce uniform 3 kG field across 1 cm X 5 cm test cell. (Under design using Poisson/Pandira)
- Tuning coil to provide required ~400 G field swing
- Pump signal from flashlamp input via fiber optics or lucite light guide
- 3D FDTD simulation code being developed using active medium model, auxiliary differential equation technique.

Future SBIR Projects (?)

- Diamond-Based DLA Structure (collaboration ANL/NRL/UCLA)
- New Coupler Design for the DLA Structures (ANL)
- Superconducting TWA Structure (ILC, collaboration with FNAL)

- Ferroelectric Shifter and Switches – subcontracting, Phase II of Yale/Omega-P, Inc., 2004-20

- Tunable Ferroelectric-Based DLA
- Multilayer DLA

SUMMARY

NEW MATERIALS and technologies FOR ADVANCED CONCEPTS:

- TRANSFORMER RATIO GREATER THAN 2 HAS BEEN DEMONSTRATED. THE FOUR-BUNCH EXPERIMENT IS PLANNED FOR 2007-2008.
- CVD DIAMOND DEPOSITION HAS BEEN USED FOR THE 34 GHZ DLA STRUCTURE DEVELOPMENT. THE DIAMOND WAVEGUIDE HAS BEEN FABRICATED AND THE MATERIAL HAS BEEN RF TESTED.
- TUNABLE LOW LOSS FERROELECTRIC FOR PULSE COMPRESSION AND POWER DISTRIBUTION FOR LINEAR COLLIDERS HAS BEEN DEVELOPED. ILC COUPLING TUNER IS UNDER DEVELOPMENT.
- FULLERENE BASED ACTIVE MEDIA FOR SOLID STATE MASER POWER SOURCE FOR ADVANCED ACCELERATOR HAS BEEN STUDIED. EXPERIMENTAL SETUP IS UNDER DEVELOPMENT.
- RF COUPLING SECTION FOR THE CERAMIC-BASED AND DIAMOND-BASED DLA HAS BEEN DESIGNED. ALUMINA BASED DLA HAS BEEN FABRICATED AND BENCH TESTED. HIGH POWER TEST IS UNDER WAY.