Development of a 20-MeV Dielectric-Loaded Test Accelerator*

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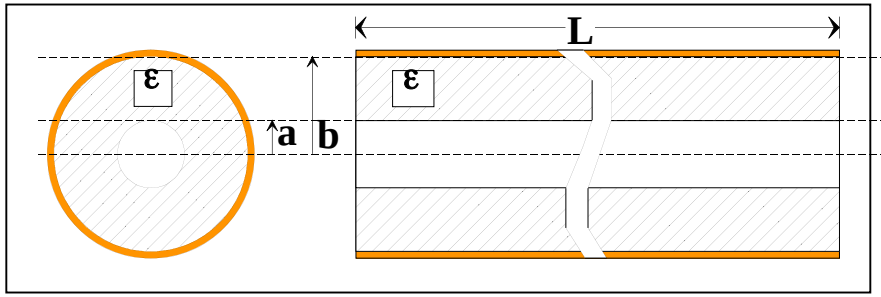
Introduction to Dielectric-Loaded Accelerators

DLA (Dielectric-Loaded Accelerator)

- Dielectric (instead of irises) is used to reduce v_{ph} to c.
- Ceramic is the material of choice
  - High ε, low $tan\ \delta$
  - High-vacuum compatible
  - Doesn't charge up

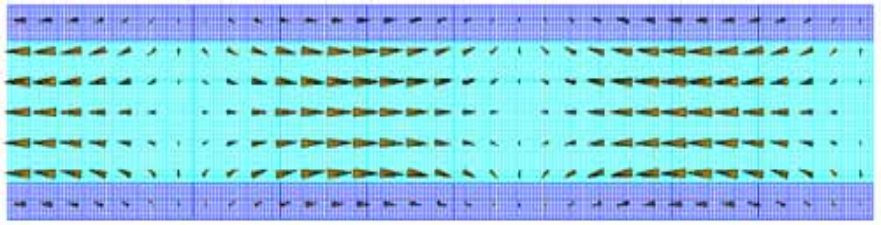
Geometry



Advantages of DLA

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

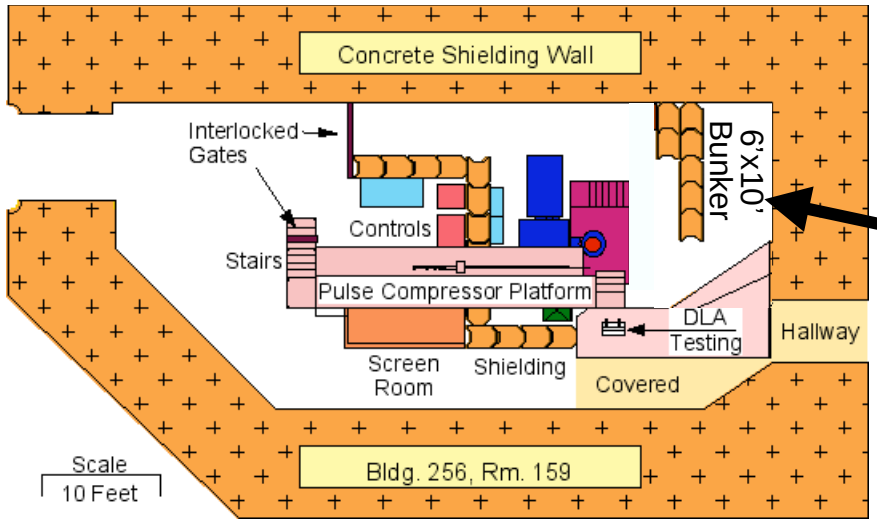
Electric Field Vectors



→ ***The goal is to build a compact dielectric-loaded test accelerator***

DLA Research Program
(NRL, ANL, SLAC)

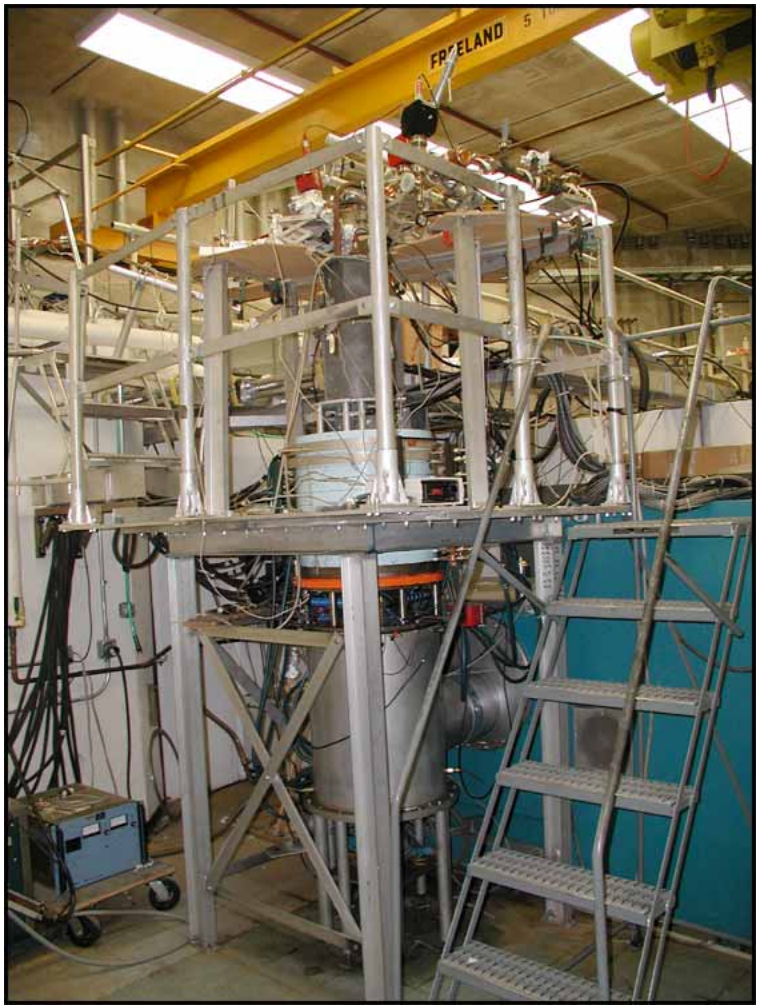
- NRL X-band Magnicon Facility (developed with Omega-P, Inc.)
- DLA Structure Development (ANL)
- High Power Testing (ANL + NRL)
- X-band Technology—rf power distribution (SLAC)
- 5-MeV Electron Beam Injector (Tsinghua University, Beijing)
- Ceramic Brazing Technology (RWBruce Associates + NRL)
- Goal: A compact 20-MeV Dielectric-Loaded Test Accelerator



Magnicon Facility Summary

- Magnicon Facility offers a flexible venue for hands-on experiments requiring high power 11.4 GHz radiation, with reasonable work and safety rules and minimal red tape
- Magnicon properties: high power (10–25 MW), adjustable pulse length (150-ns FWHM – 1.1-µs flattop), moderate repetition rate (up to 10 Hz), stable gain, precise frequency control, a modest (~0.1%) tuning range, phase stability, and stable operation into resonant or mismatched loads; uses SLAC-compatible components
- Magnicon facility has been used for two series of collaborative experiments since 2001:
    - Nine high-power tests of DLA Structures
    - Seven high-power tests of Active Pulse Compressors

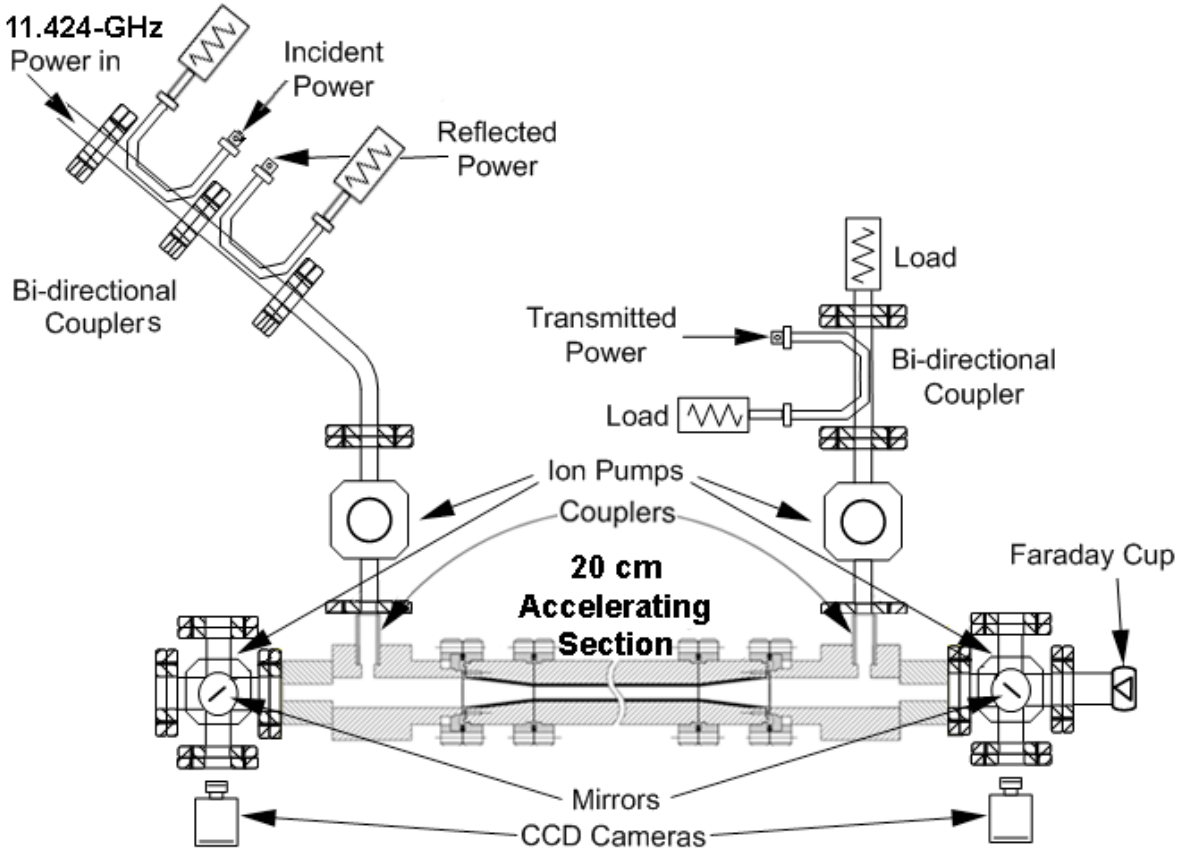
NRL 11.424-GHz Magnicon Facility

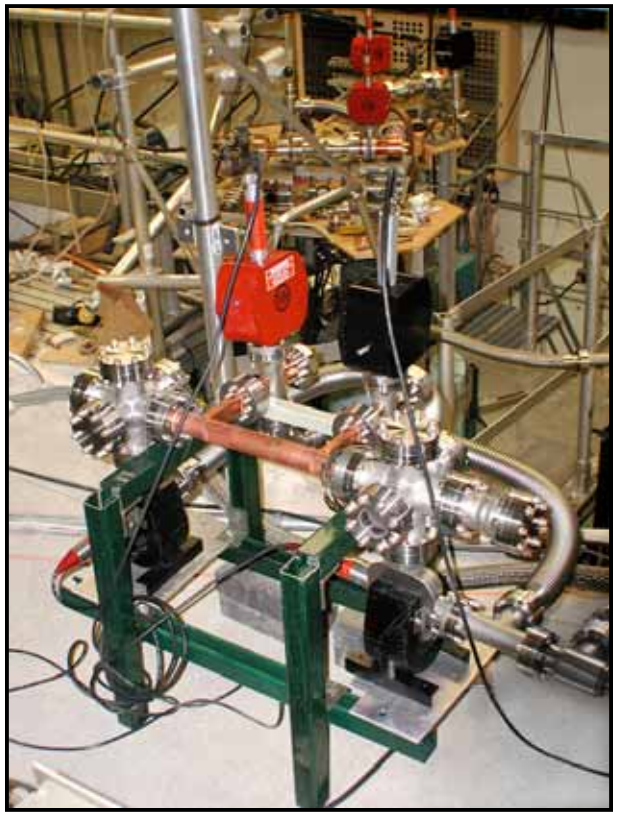


	Design	Operation*
Frequency	11.424 GHz	11.424 GHz
Power	61 MW	12 MW / 25 MW
Pulse width	~1 μs	1.2 μs / 200 ns
Repetition rate	10 Hz	2-4 Hz / 10 Hz
Efficiency	59 %	~16-28 %
Drive frequency	5.712 GHz	5.712 GHz
Gain	59 dB	~59 dB

*With old collector

Experimental Setup for High Power Tests of DLA Structures





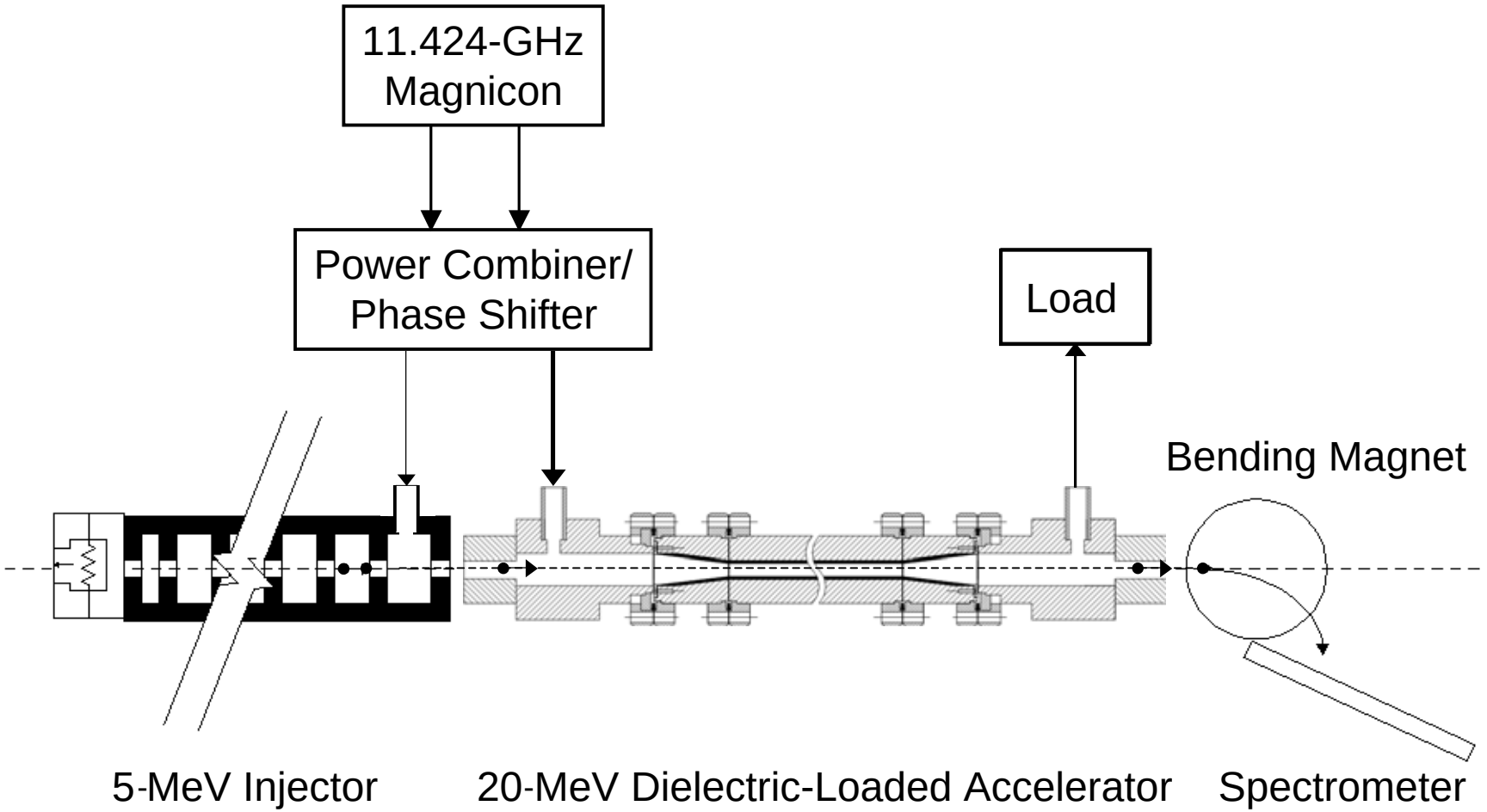
Summary of DLA Structures

Material	Al_2O_3 [±TiN]	$Mg_xCa_{1-x}TiO_3$	SiO_2
Dielectric constant	9.4	20	3.78
Loss tangent	$2x10^{-4}$	$3x10^{-4}$	$2x10^{-5}$
Inner radius	5 mm	3 mm	8.971 mm
Outer radius	7.185 mm	4.567 mm	12.079 mm
R/Q	6.9 kΩ/m	8.8 kΩ/m	3.6 kΩ/m
Group velocity	0.134 c	0.057 c	0.38 c
RF power for 1MV/m gradient	80 kW	27 kW	439 kW
Demonstrated Gradient	8 MV/m	6 MV/m	5 MV/m
Principal Problem	Multipactor	Multipactor/ Breakdown at joints	Multipactor

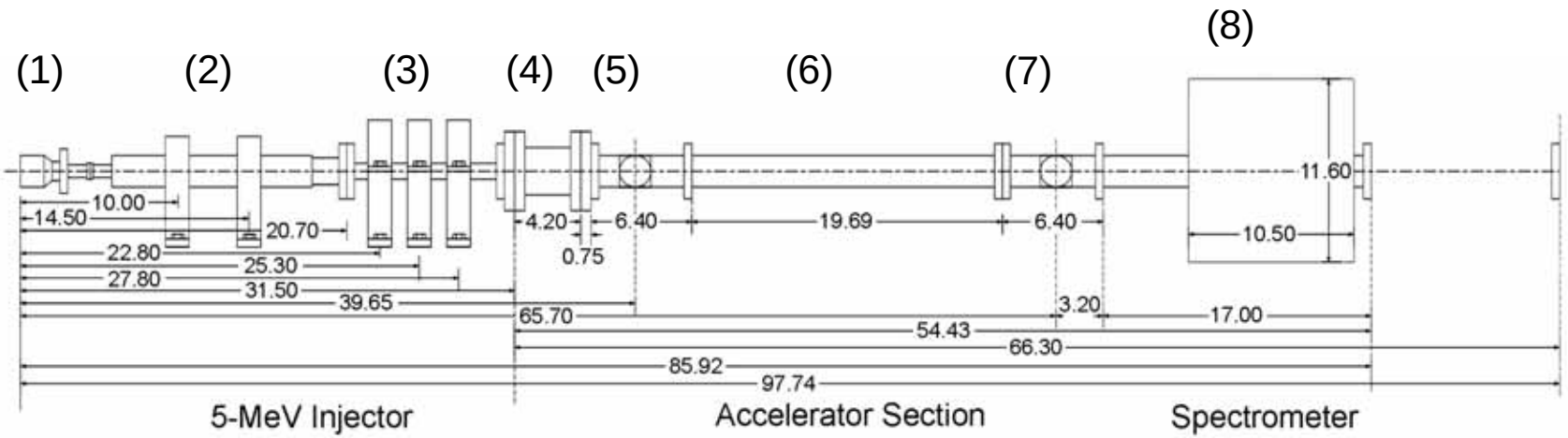
DLA Progress to Date

- → Four generations of couplers and structures designed and tested
- → Four different dielectric materials (Alumina, Fused Silica, MCT, TiN-coated Alumina) tested at gradients up to 8 MV/m
- → No breakdown of the bulk dielectric observed
- → Strong multipactor loading as well as joint breakdown problems discovered
- → Developed new theory of resonant single-surface multipactor and gained fundamental understanding of joint breakdown issues
- → Plans to test: jointless DLA structures (to avoid joint breakdown); smaller i.d. structures (to reduce multipactor loading); dual layer structures (to reduce rf attenuation); other structures to further explore multipactor issues

Dielectric-Loaded Test Accelerator



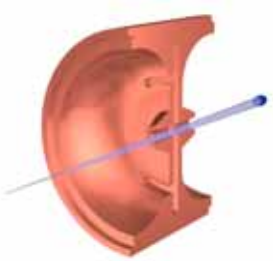
Planned Accelerator Layout



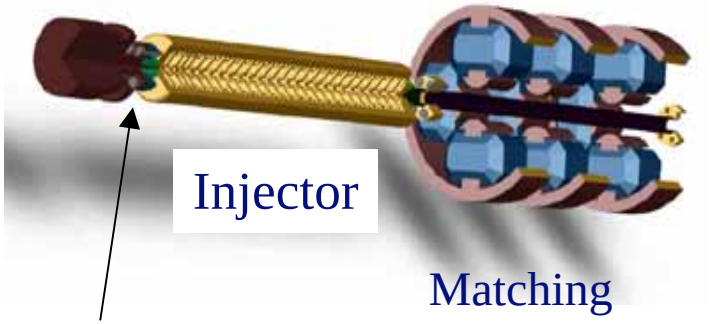
Left to right:
(1) Thermionic cathode assembly
(2) Injector accelerator section (on two supports)
(3) Three focusing quads
(4) Vacuum break to hold an ICT beam current measuring toroid
(5) 6-way cross to accommodate a YAG diagnostic, ion pump, view port
(6) Accelerator section (device under test)
(7) 6-way cross with a YAG diagnostic, ion pump, and view port
(8) Spectrometer with a Faraday cup, turbo/ion-pump port, possibly a YAG

清華大學 Tsinghua University

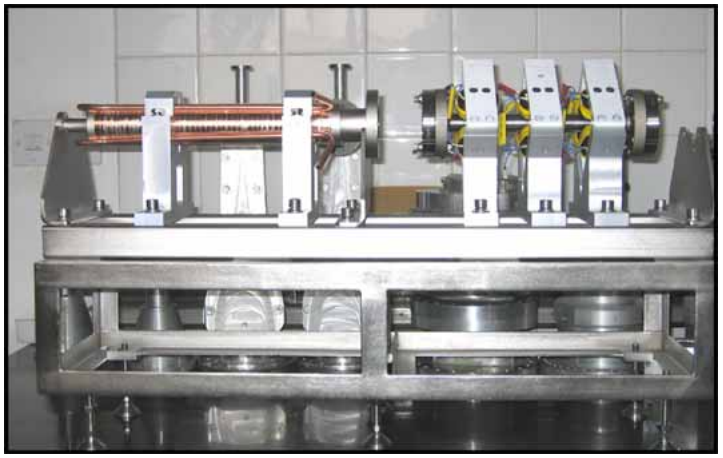
Accelerator Lab of Tsinghua University
胡源 (Y. Hu, Student), 杜晓福 (X. Du),
唐传祥 (Prof. C. Tang), and 林郁正 (Prof. Y. Lin)



NRL X-Band Injector

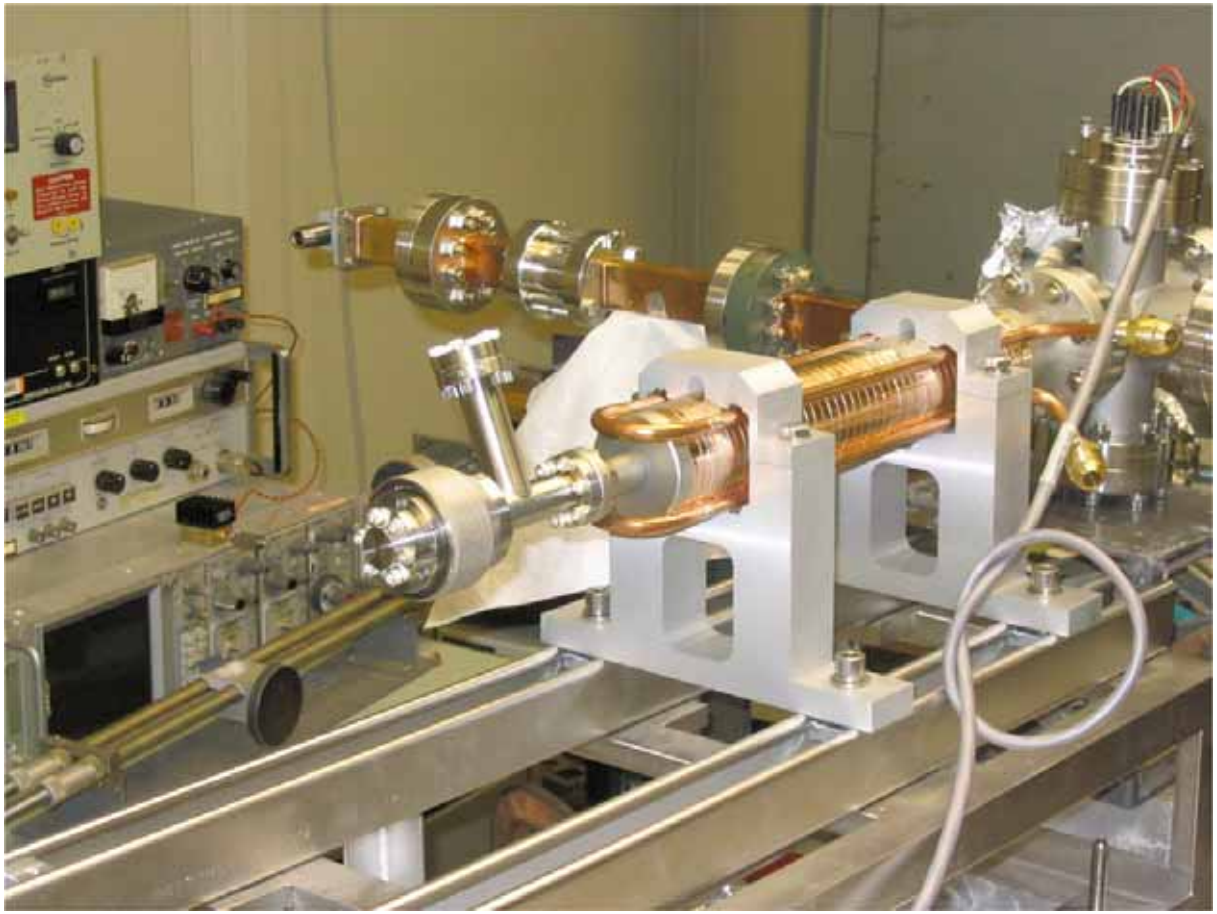


Parameters	
Energy	5.2 MeV
Charge/Bunch	>5 pC
RF Frequency	11.437 GHz
RF Power in	~2 MW
Norm.Emittance	3.1 π mm mrad
Energy Spread	~6%



Delivered to ANL in 2005

NRL X-Band Injector

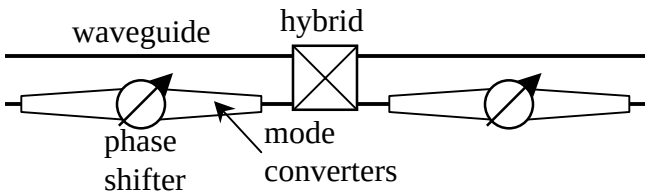


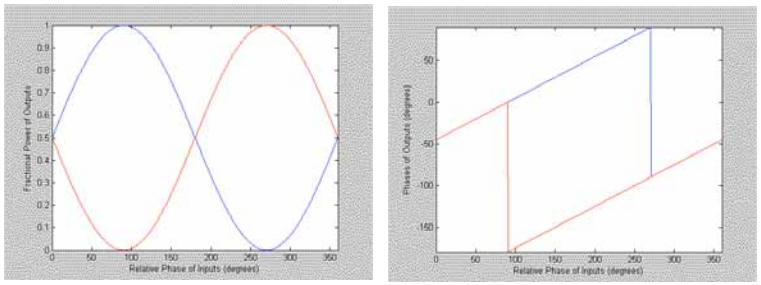
At ANL last month, in final preparation for shipping to NRL

Magnicon Power Combiner

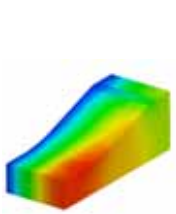
(To combine magnicon output arms, and resplit with continuous control of power ratio and relative phase)

Basic Circuit

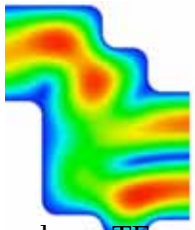




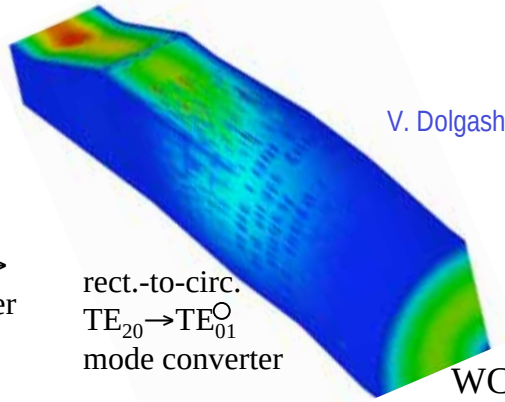
Mode Converter



height taper (.400”→.800”)



planar TE_{10}→ TE_{20} converter

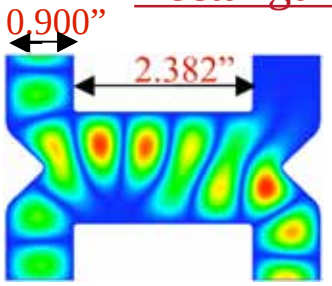


V. Dolgashev

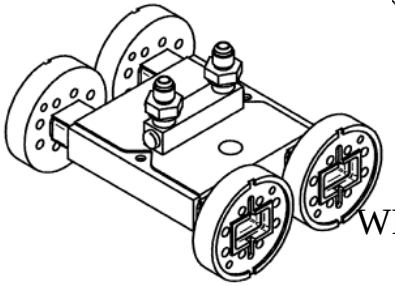
rect.-to-circ. TE_{20}→TE_{01}° mode converter

WC150

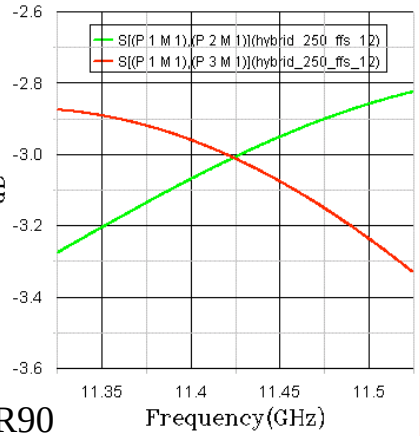
Rectangular TE_{10} Hybrid



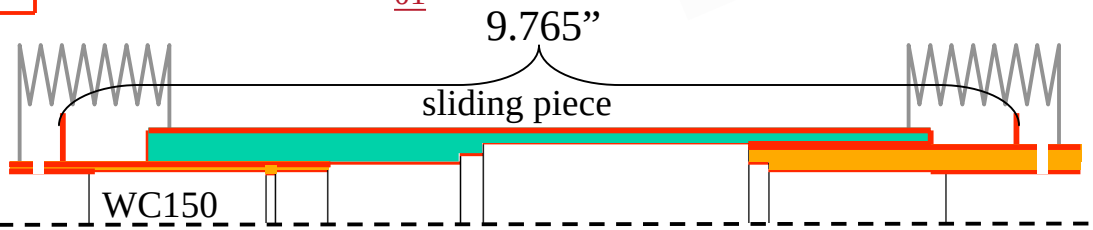
C. Nantista



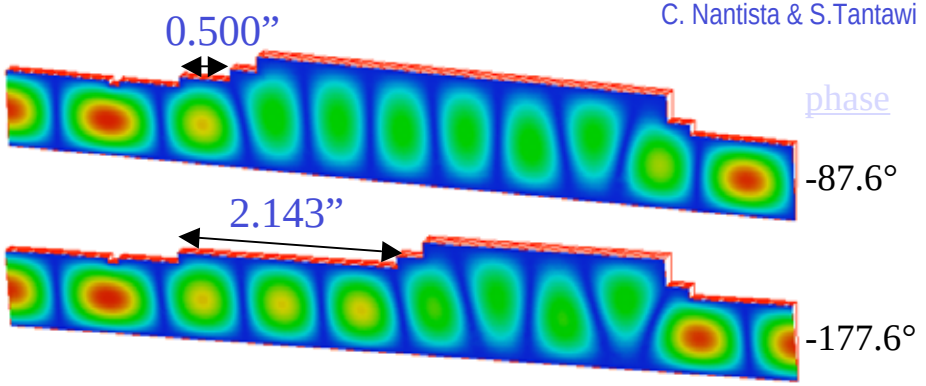
WR90



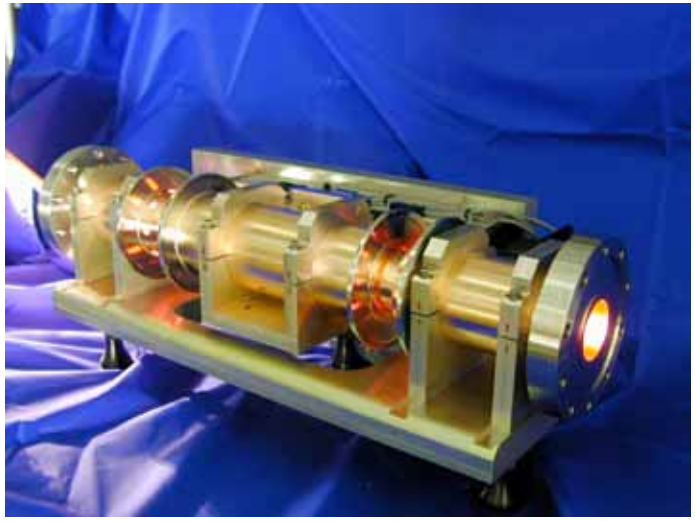
Circular TE_{01} In-Line Phase Shifter

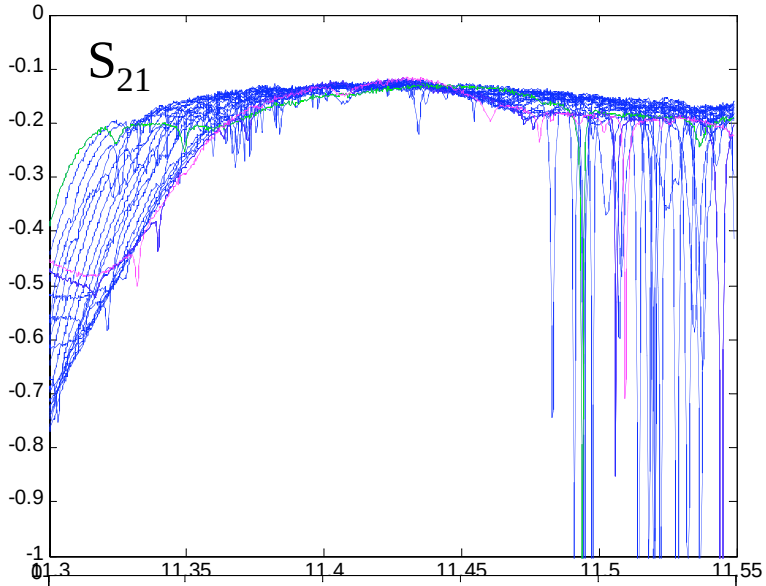


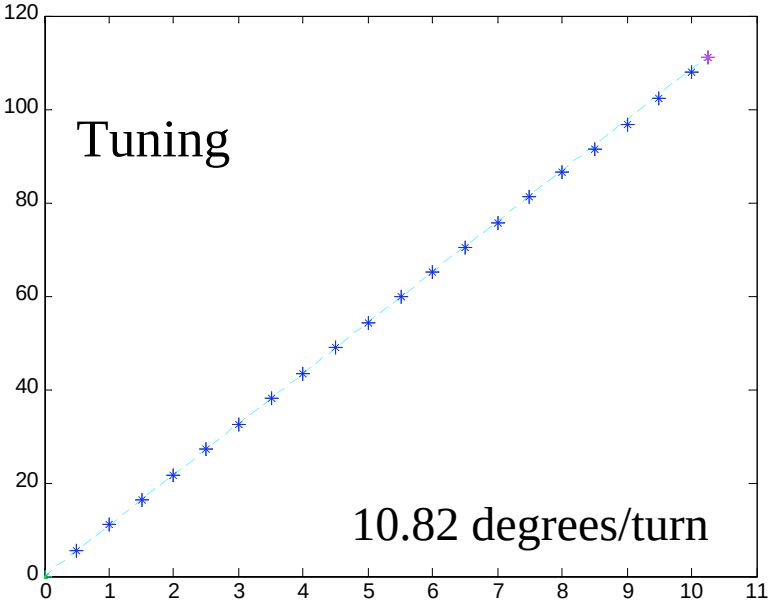
C. Nantista & S.Tantawi

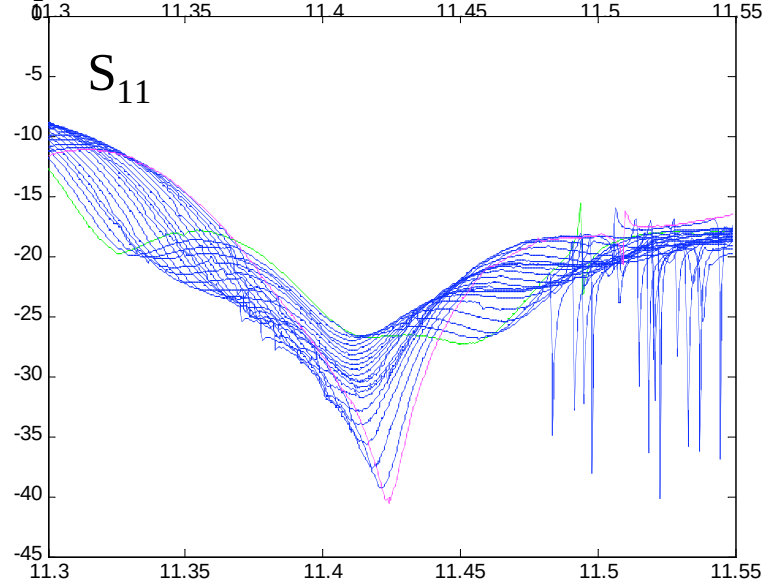


TE_{01} Phase Shifter Cold Test Results









At SLAC, in final preparation for shipping to NRL

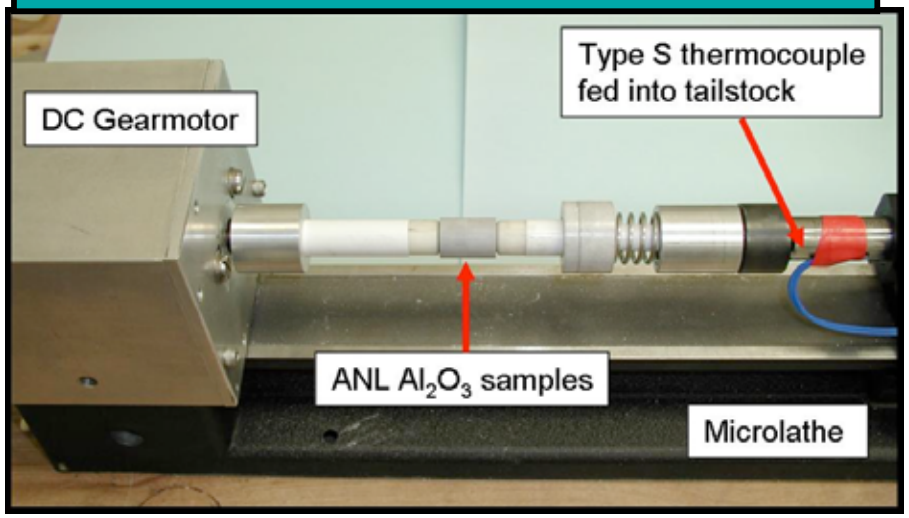
Problem of Joints in DLA Structures

- **Present DLA structures are made up of separate ceramic sections pressed into mechanical contact**
- **Axial electric field is uniform across accelerating tube, continuous at dielectric surface**
- **Small gaps (~100 μm) can occur during assembly or during bakeout. Electric field is ε larger in the gaps.**
- **Such gaps can cause substantial mismatches, as well as rf breakdown in high-power experiments**
- **A method to join the ceramic sections into a uniform, continuous structure is needed**

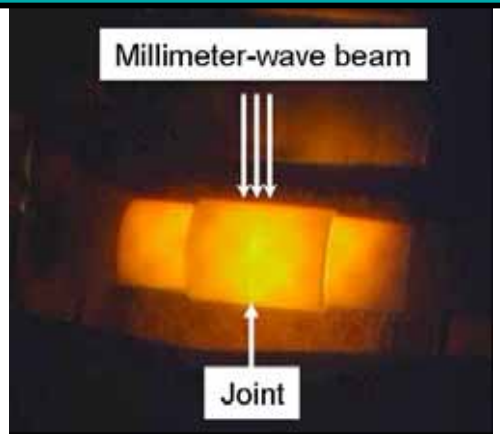
Millimeter-Wave Brazing of Ceramic Joints

(RWBruce Associates, Inc. + NRL)

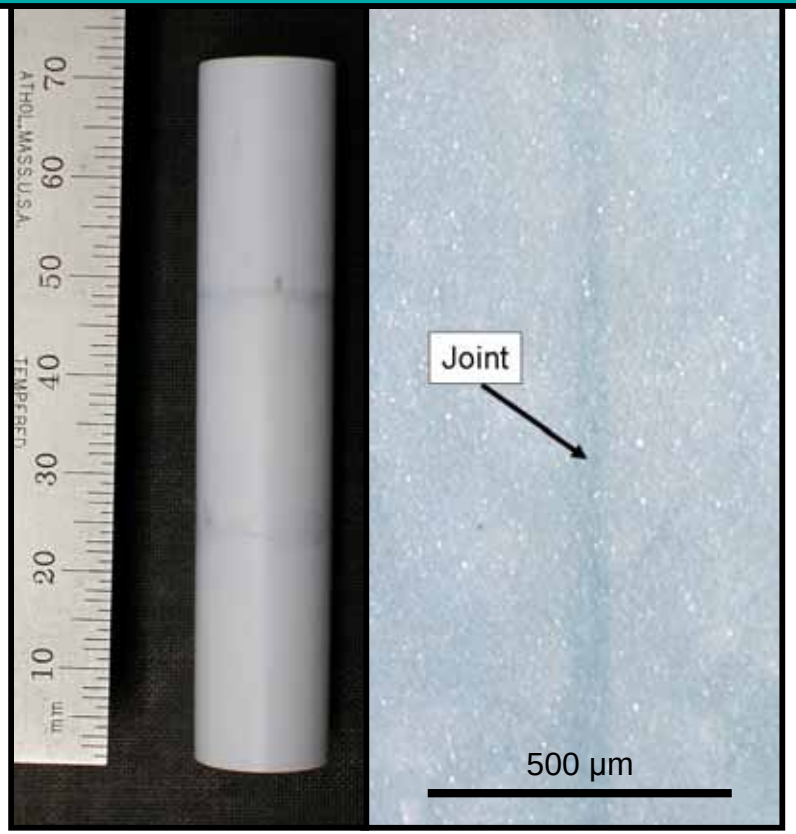
Rotating fixture system for heating tube assemblies with mm-wave beam



In situ video monitoring system

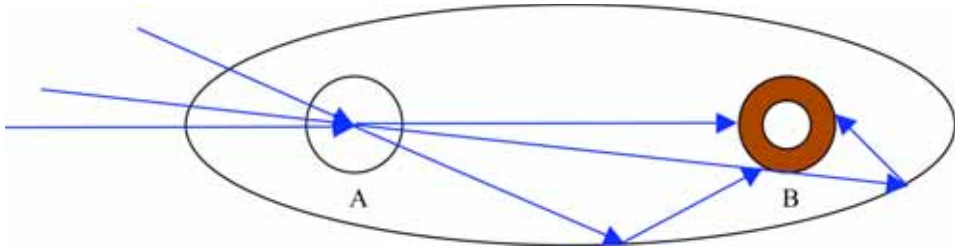


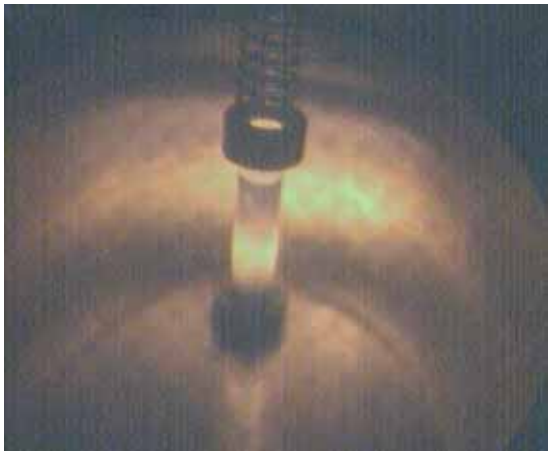
Long tube assemblies fabricated with multiple highly diffused joints, using special reactive oxide glass brazes

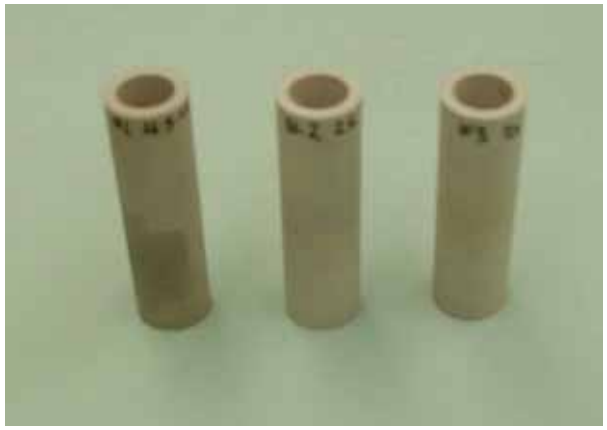


Millimeter-Wave Brazing of Ceramic Joints

(RWBruce Associates, Inc. + NRL)







Summary

- Magnicon facility fully operational (but power lower than desired)
  - New magnicon collector resulted in decreased power; experiments under way to solve the problem
  - Accelerator bunker and table installed
- High-power series of tests on DLA structures continuing, and understanding of key scientific issues improving
- 5-MeV injector expected at NRL in next month
- Power combiner expected at NRL in next few weeks
- Proof-of-principle technologies for ceramic brazing of long DLA structures demonstrated
- First test of DLA accelerator (injector, DLA structure, spectrometer)—perhaps in one year

Accompanying Papers

- Summary of results from DLA structures
- Development of a theoretical multipactor model

} **J. Power**

- Recent test results for quartz DLA structure
- Design of improved DLA structures with lower rf fields, decreased loss

} **C. Jing**