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Development of Dielectric-Based Wakefield Power Extractors

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U.S. Department of Energy

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** Now with National Light Source, BNL*

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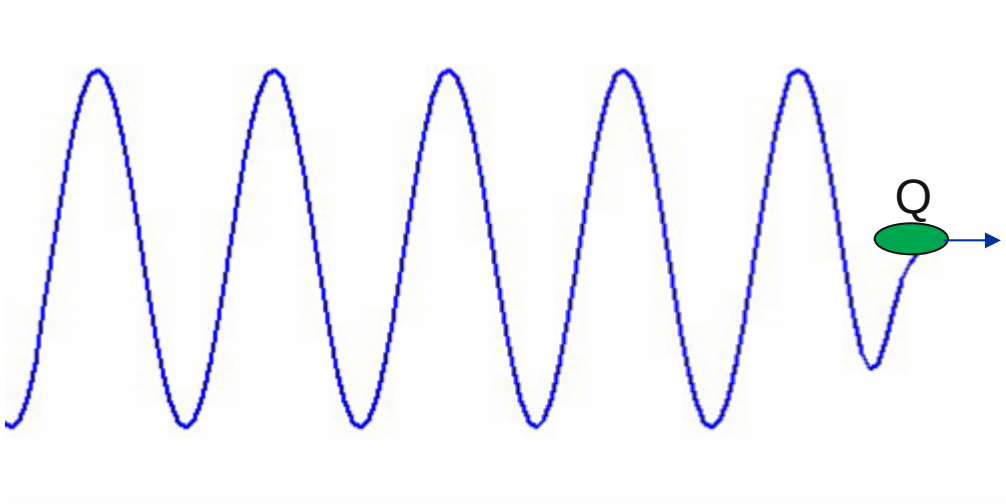
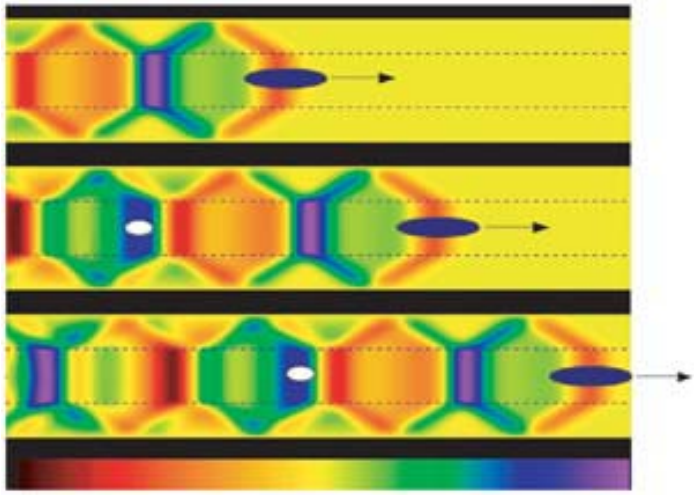
Wakefield Power Extraction

- A way to generate a stable high power RF is to extract energy from the Cherenkov radiation (wakefield) of a high current relativistic electron beam in a predetermined frequency slow wave structure. In the process, the beam kinetic energy is converted into electromagnetic energy at the mode frequency. The RF power produced is collected at the downstream end of the structure and coupled out for other applications.

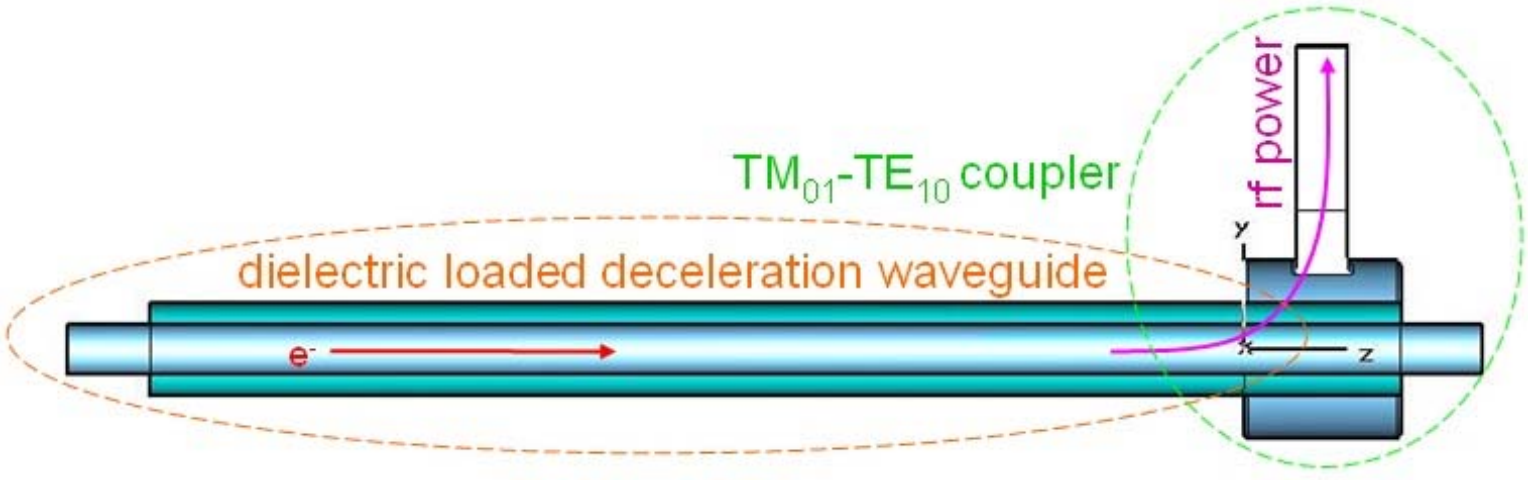




7.8GHz Dielectric-Based Wakefield Power Extractor

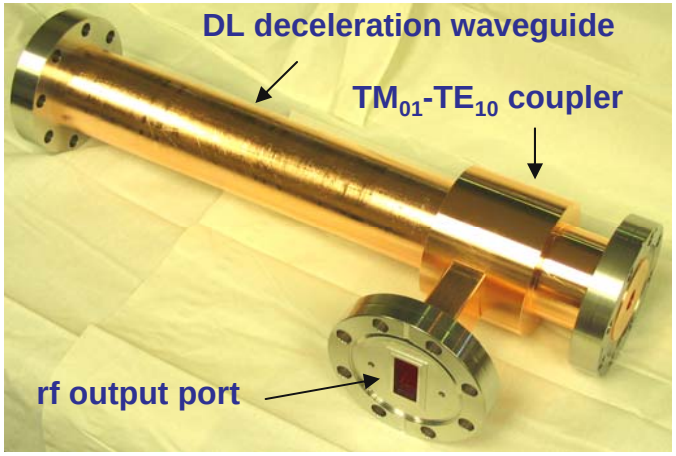
Two related journal publications: 1) F. Gao, *et al*, *PR ST-AB,* **11**, 041301 (2008); 2) F. Gao, *et al*. *IEEE Trans. NS*, **56**, 3, JUNE (2009) 1492-1497.

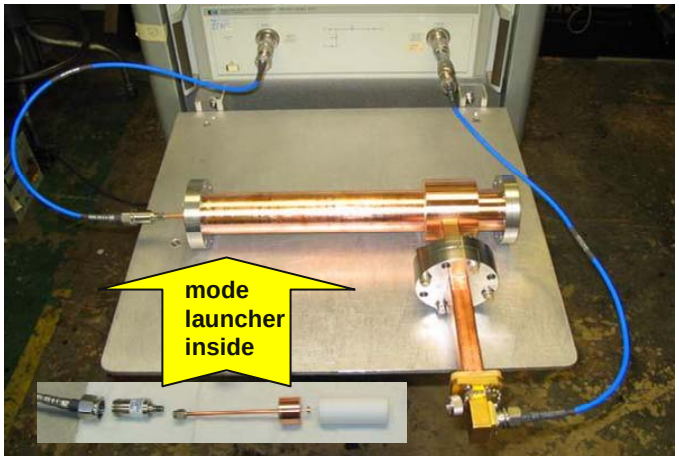
7.8GHz Dielectric-Based Wakefield Power Extractor----design

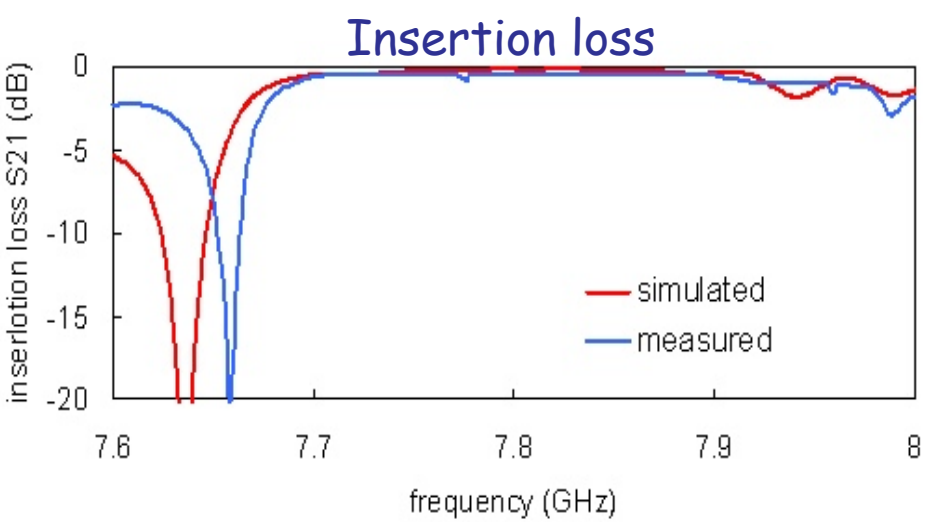


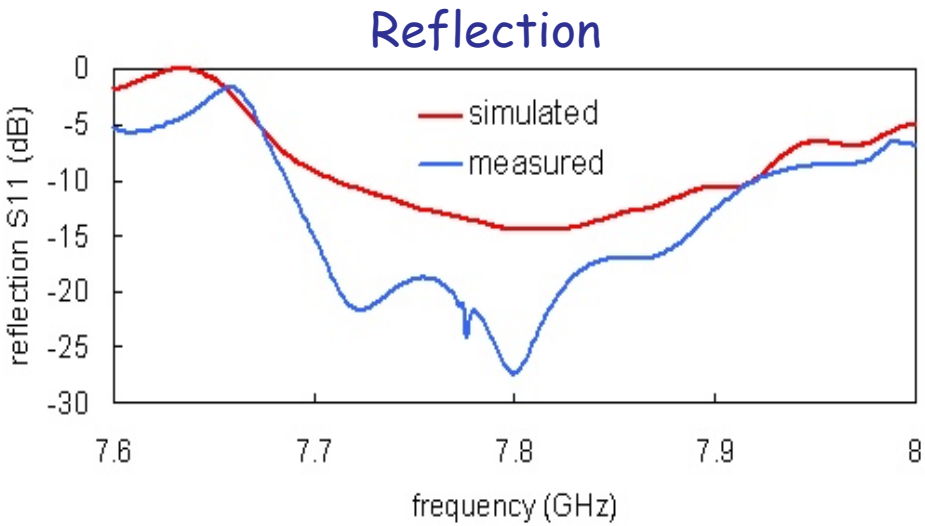
Geometric and accelerating parameters	**value**
ID / OD of dielectric tube	12.04mm /22.34 mm
Dielectric constant	4.6
Length of dielectric tubes	266 mm
Synchronous frequency of TM_{01} mode	7.8 GHz
Group velocity	0.23c
R/Q of TM_{01}mode	6090(Ω/m)
Q of TM_{01}mode	2745
Generated rf power (bunch train)	**11MW/10nC per bunch**

7.8GHz Dielectric-Based Wakefield Power Extractor---- fabrication & bench test

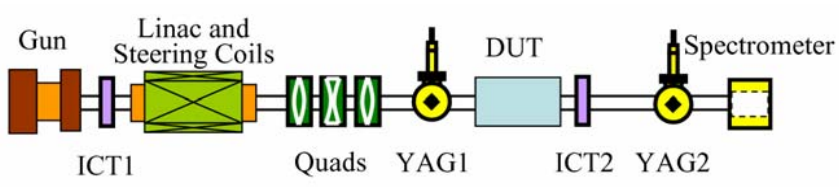


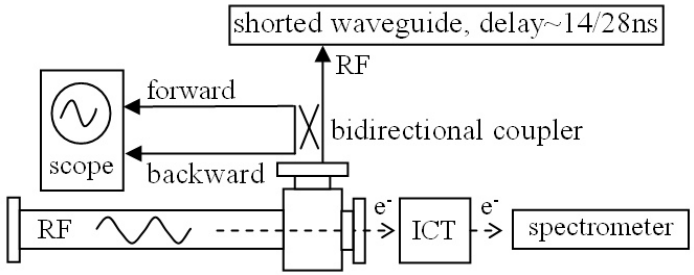


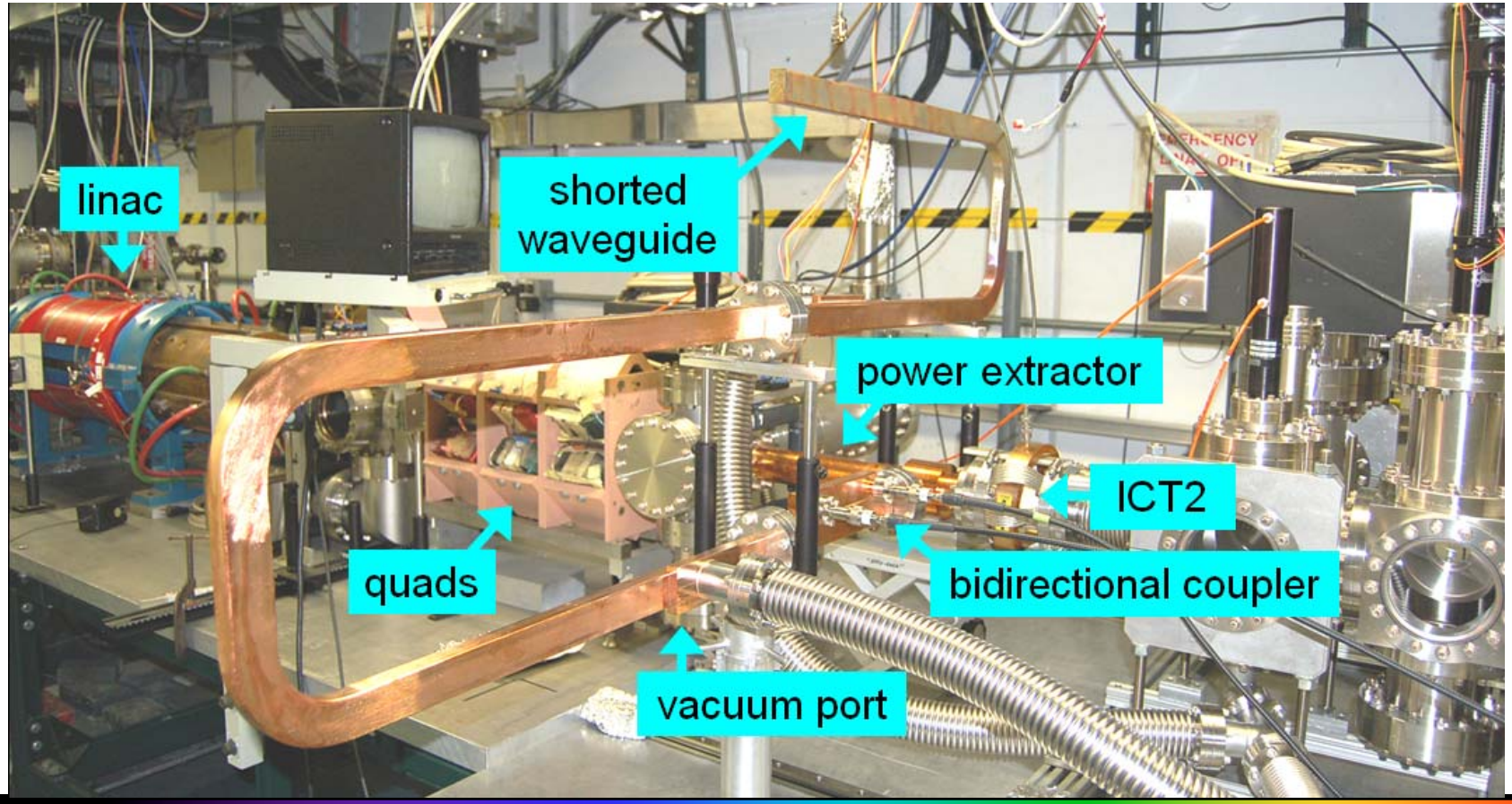




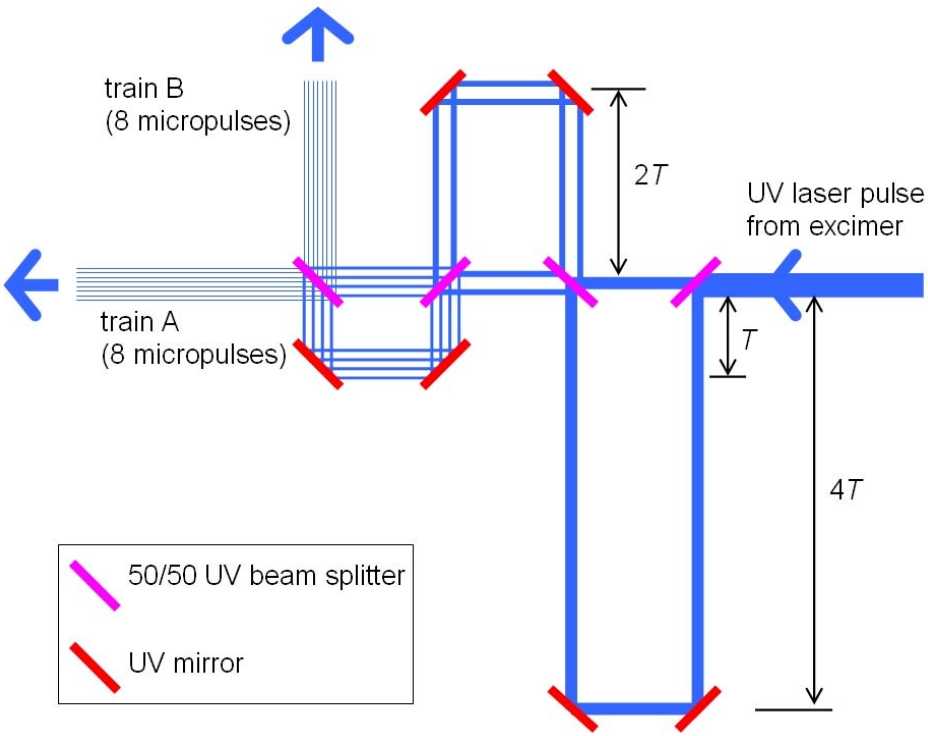
7.8GHz Dielectric-Based Wakefield Power Extractor---- beam test (I): setup

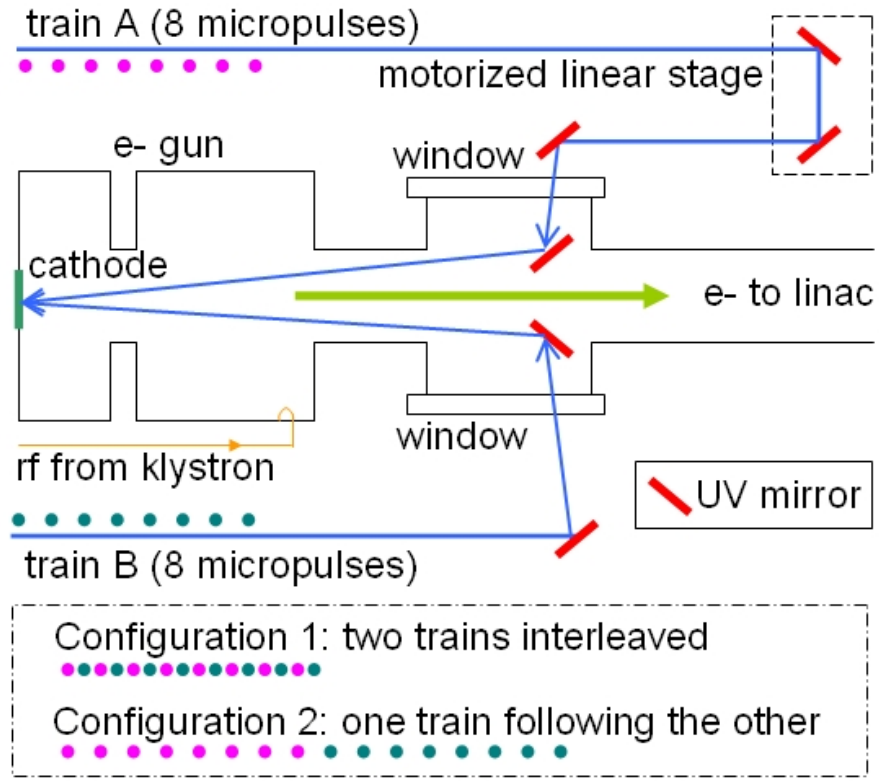






7.8GHz Dielectric-Based Wakefield Power Extractor---- beam test (II): e-bunch train generation





A UV laser pulse is split into two trains, each consisting eight micropulses spaced by $2T$.

e^- bunch train generated:

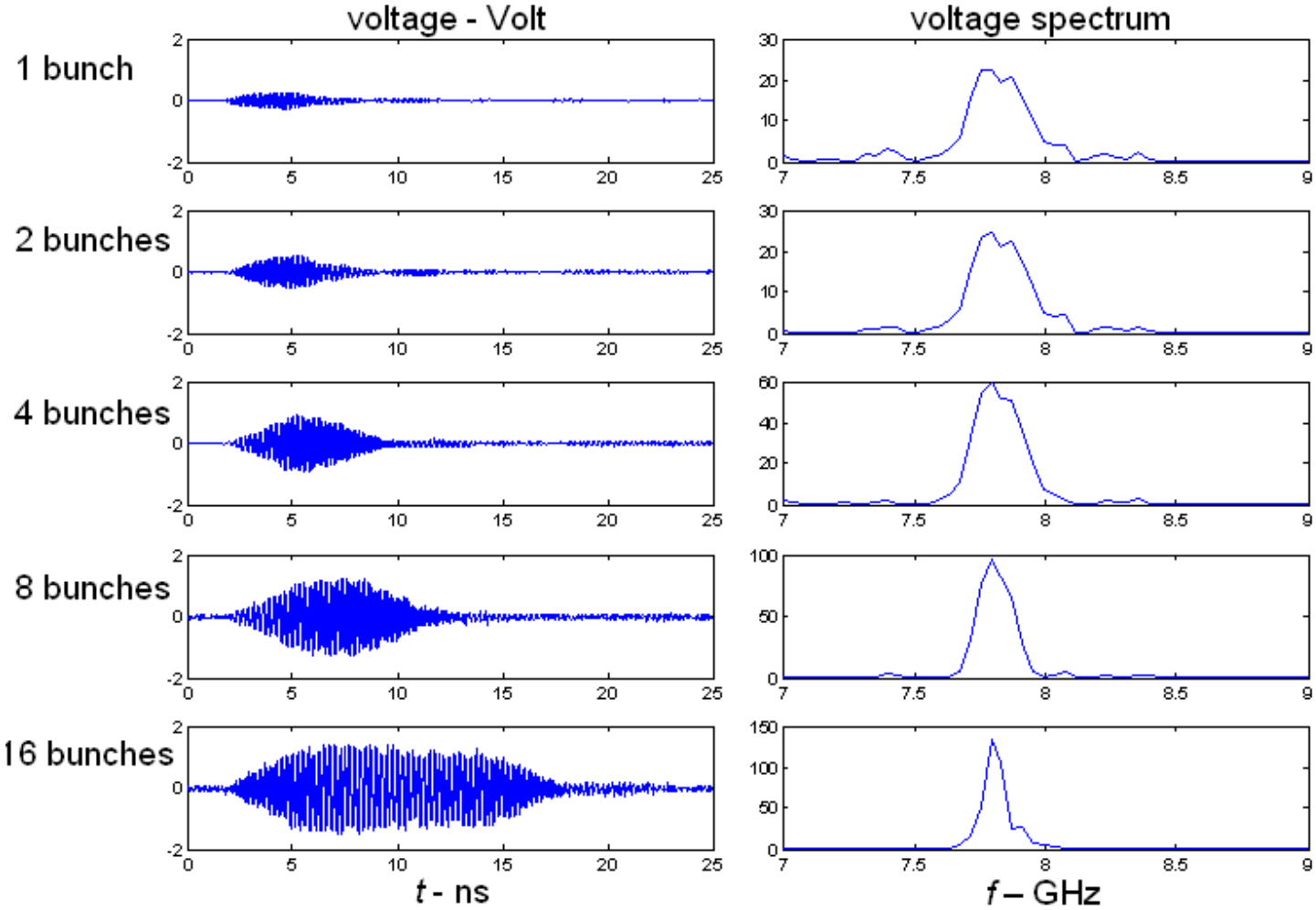
i). 16 bunches, T_b = 769ps, q_{max} = 4.8nC

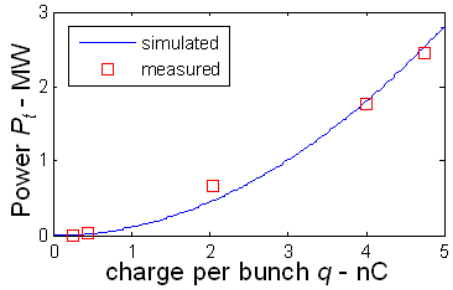
ii). 16 bunches, T_b = 1.54ns, q_{max} = 4.9nC

iii). 4 bunches, T_b = 769ps, q_{max} = 26.5nC

7.8GHz Dielectric-Based Wakefield Power Extractor---- beam test (III): 1-16 bunches, Tb=769ps

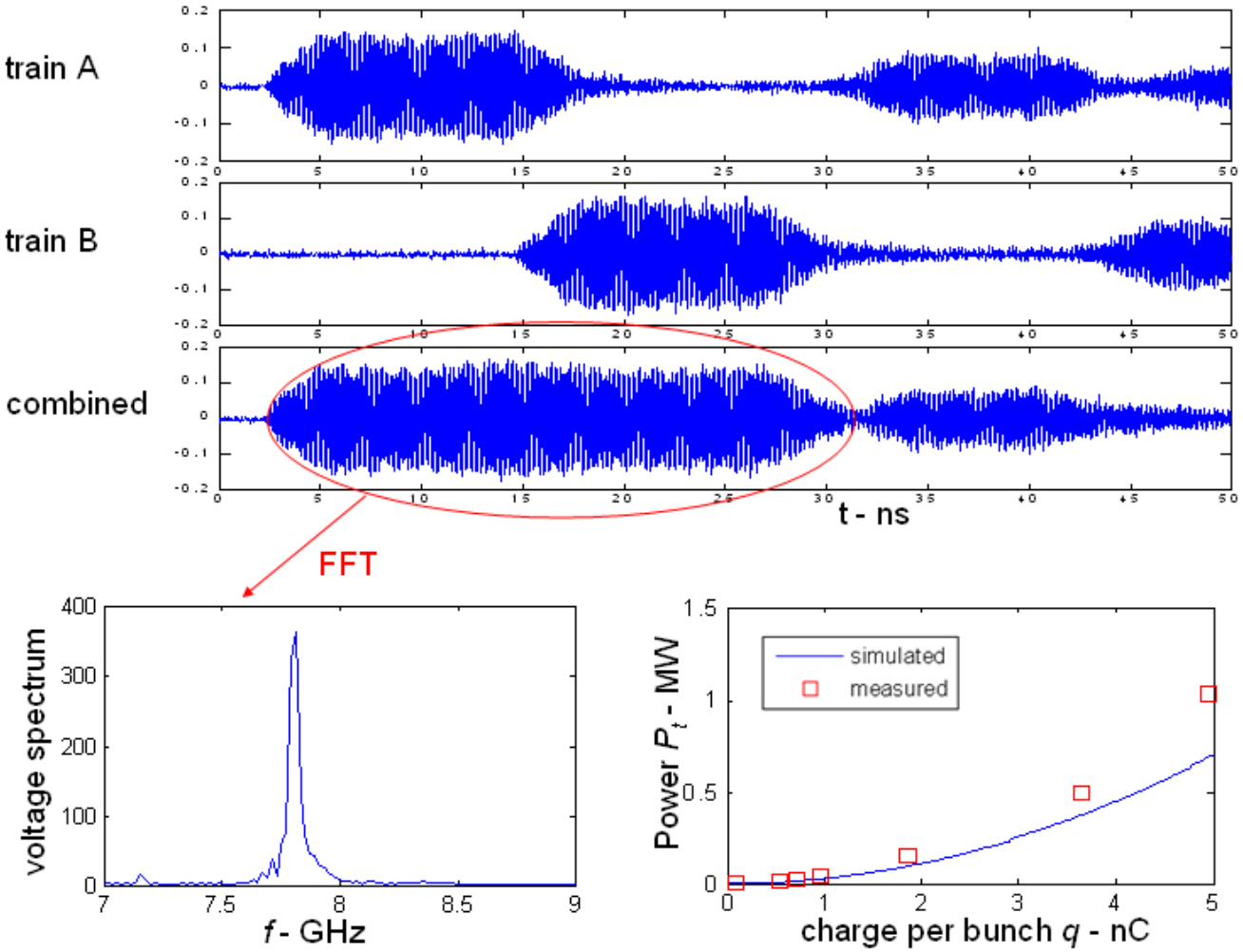
15ns rf pulse generated, P_{max} = 2.4MW @ q_{max} = 4.8nC.





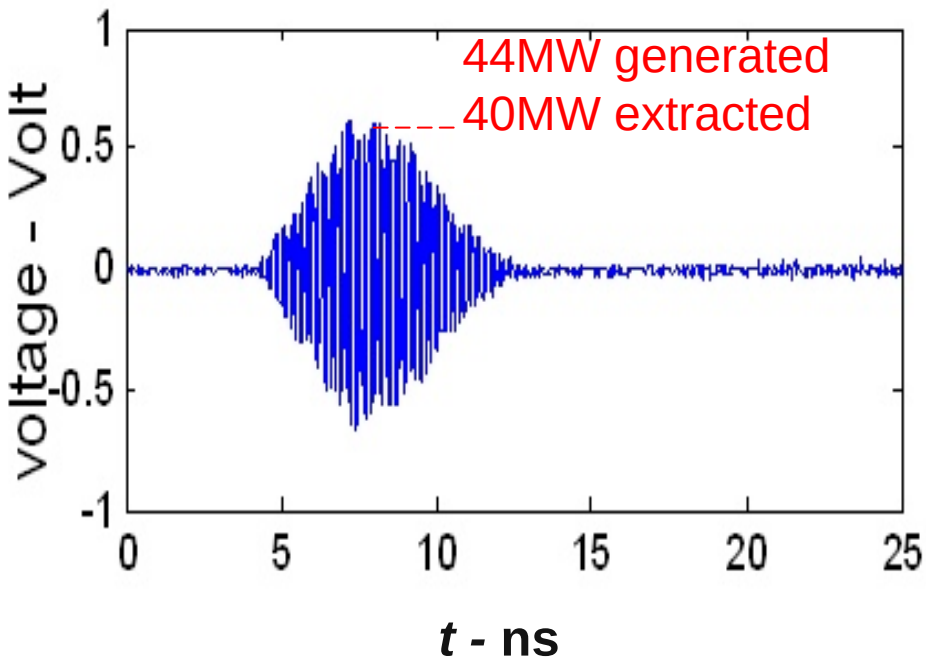
7.8GHz Dielectric-Based Wakefield Power Extractor---- beam test (IV): 16 bunches, Tb=1.54ns

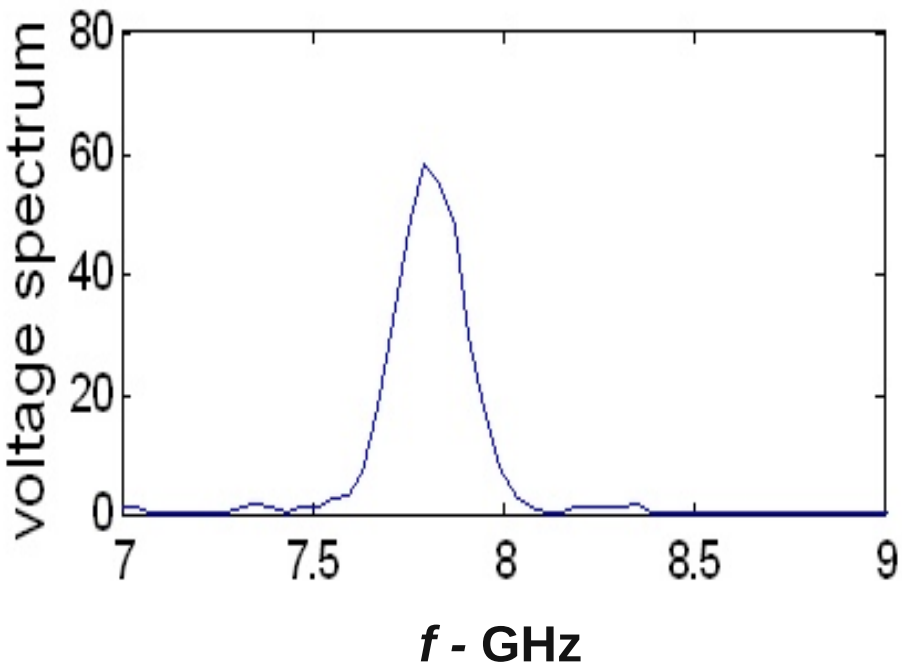
30ns rf pulse generated, P_{max} = 1MW @ q_{max} = 4.9nC.



7.8GHz Dielectric-Based Wakefield Power Extractor---- beam test (V): 4 bunches, Tb=769ps

7.5ns rf pulse generated, P_{max} = 44MW @ q_{max} = 26.5nC.

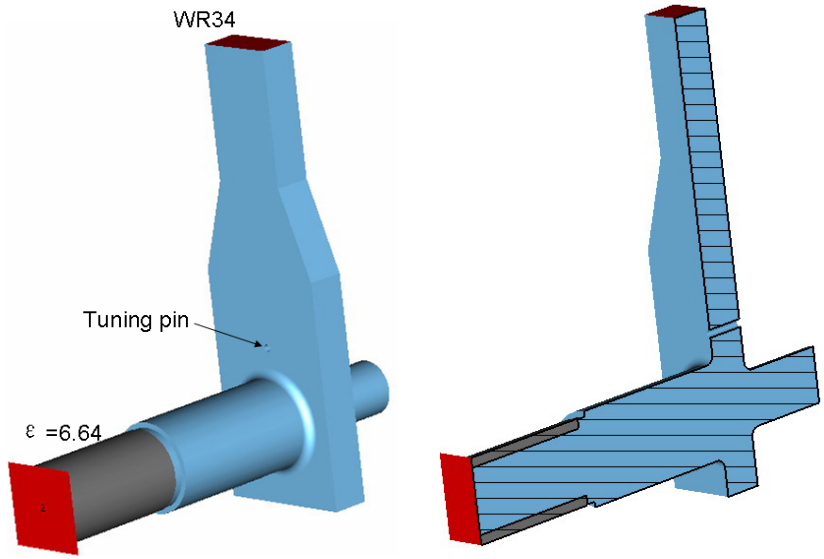


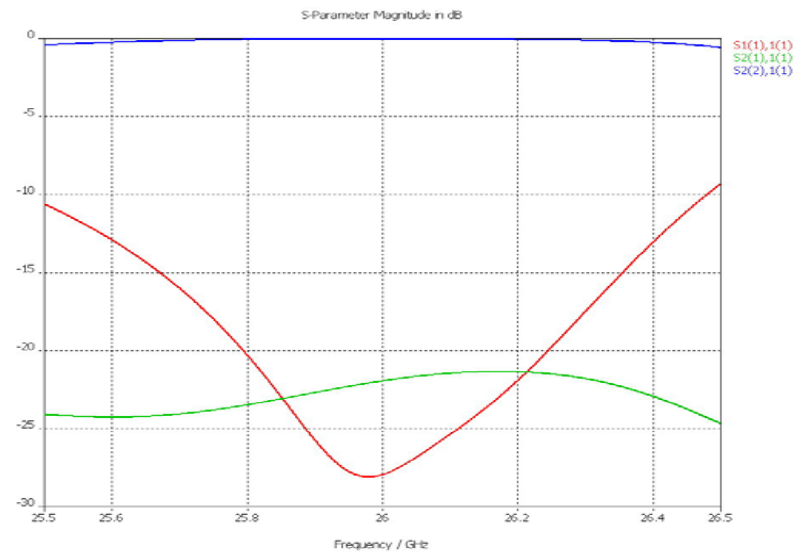


26GHz Dielectric-Based Wakefield Power Extractor

----by Euclid Techlabs, supported by DoE SBIR program

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

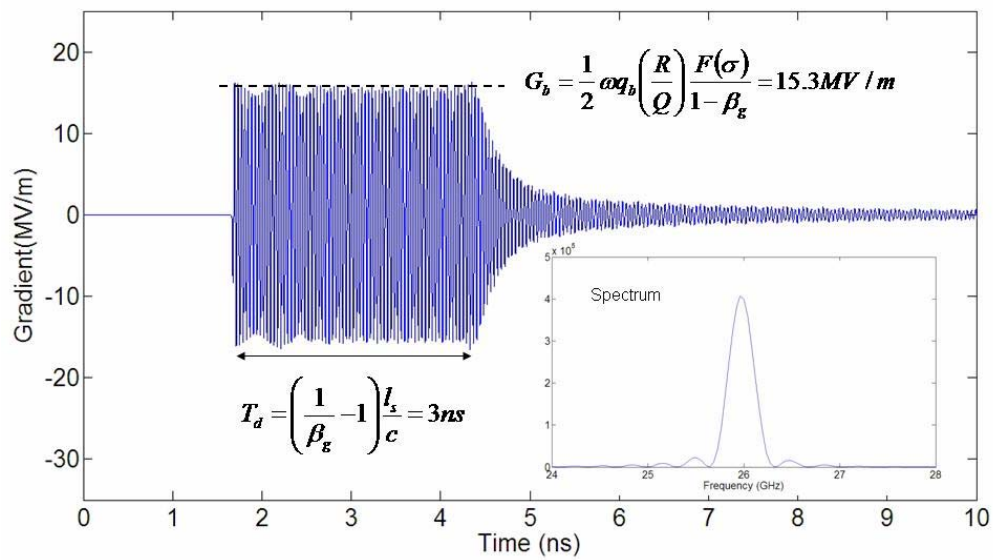




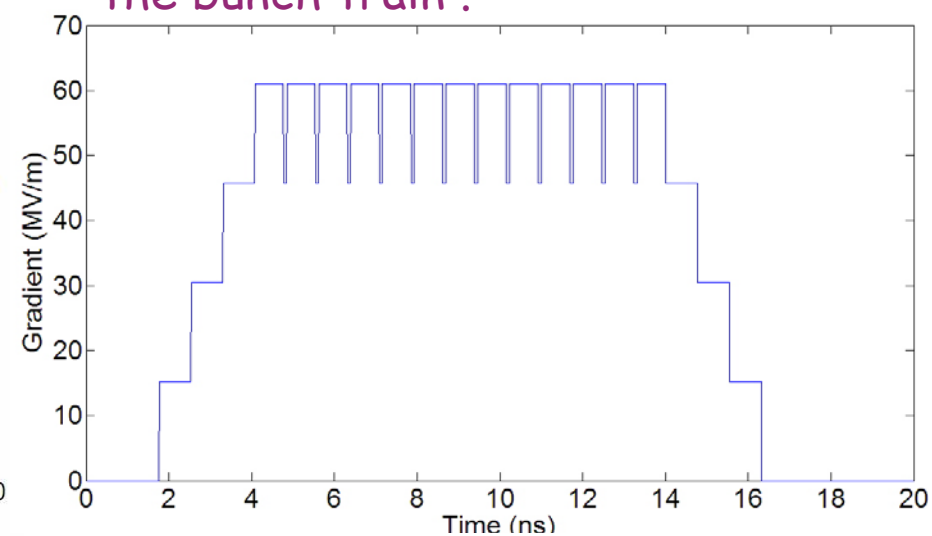
Geometric and accelerating parameters	value
ID / OD of dielectric tube	7 mm /9.068 mm
Dielectric constant	6.64
Length of dielectric tubes	300 mm
Synchronous frequency of TM_{01} mode	26 GHz
Group velocity	0.25c/0.42c
R/Q of TM_{01} mode	9788(Ω/m)
Q of TM_{01}mode	2950
Generated rf power (bunch train)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

26GHz Dielectric-Based Wakefield Power Extractor---- power estimation

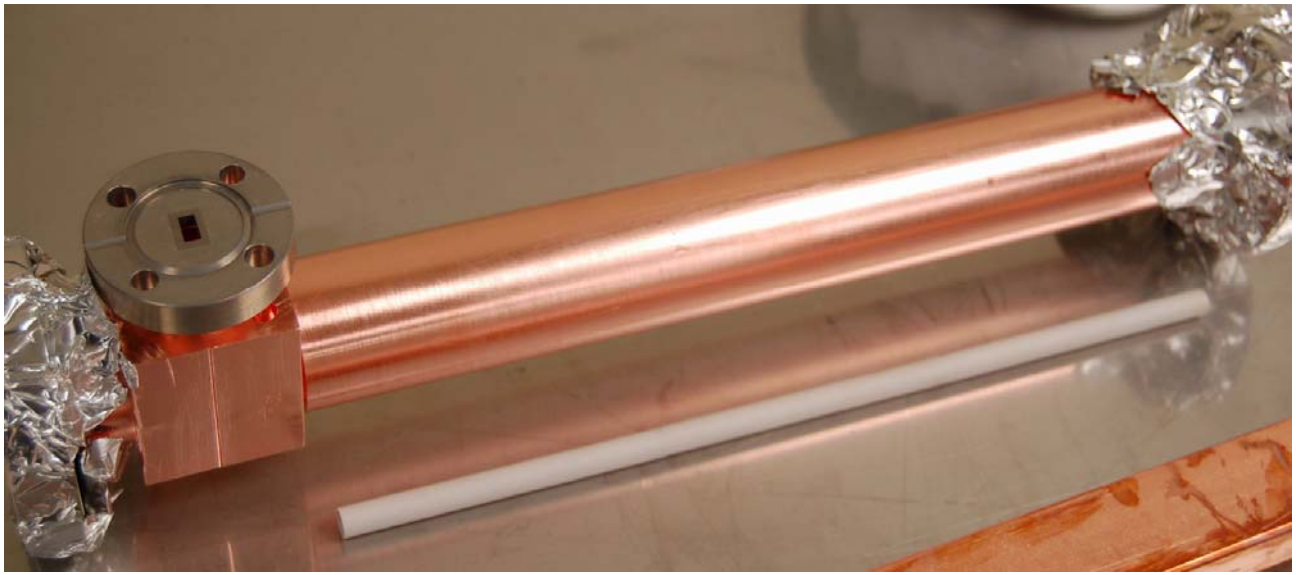
*20nC, single bunch, bunch length 1.5mm.

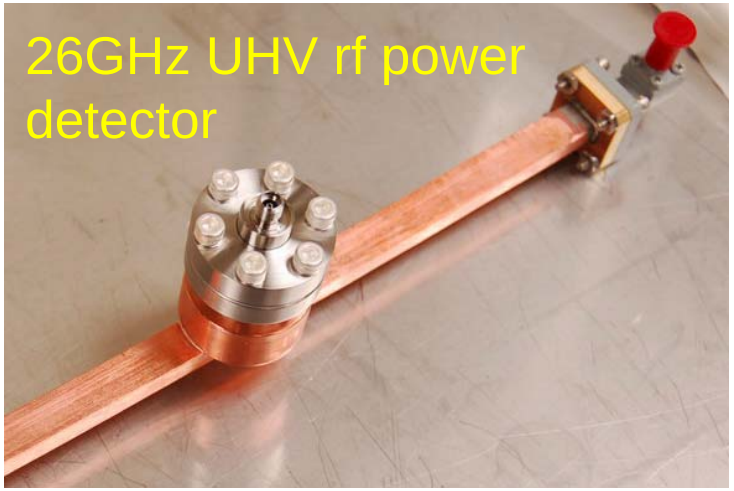


*16, 20nC bunch train, steady output power of 148 MW and 56 MV/m peak gradient. The energy loss is 5.7 MeV for the last bunch in the bunch train .

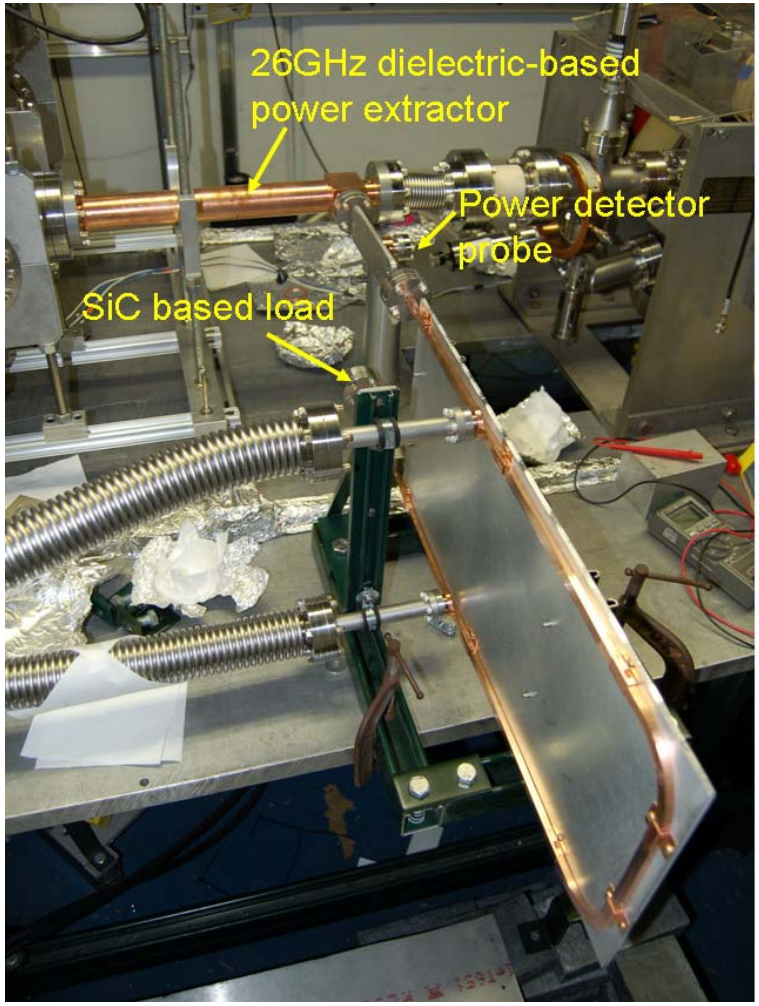


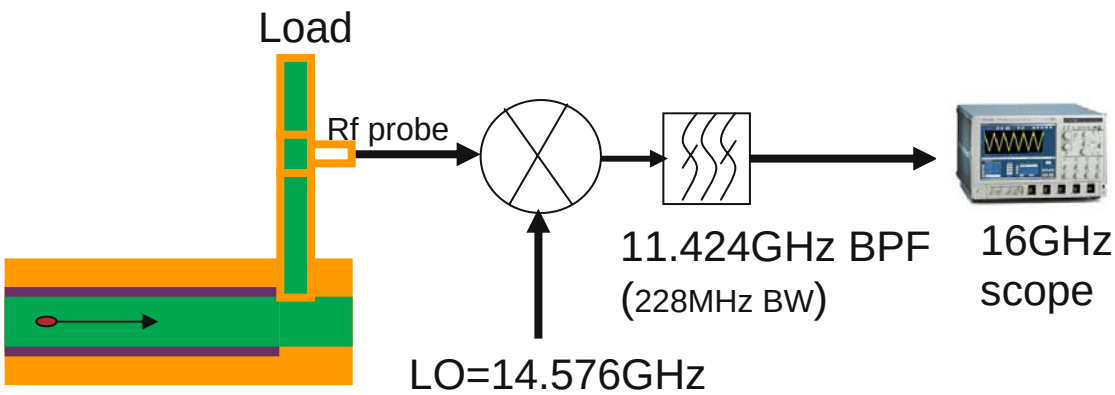
26GHz Dielectric-Based Wakefield Power Extractor----fabrication



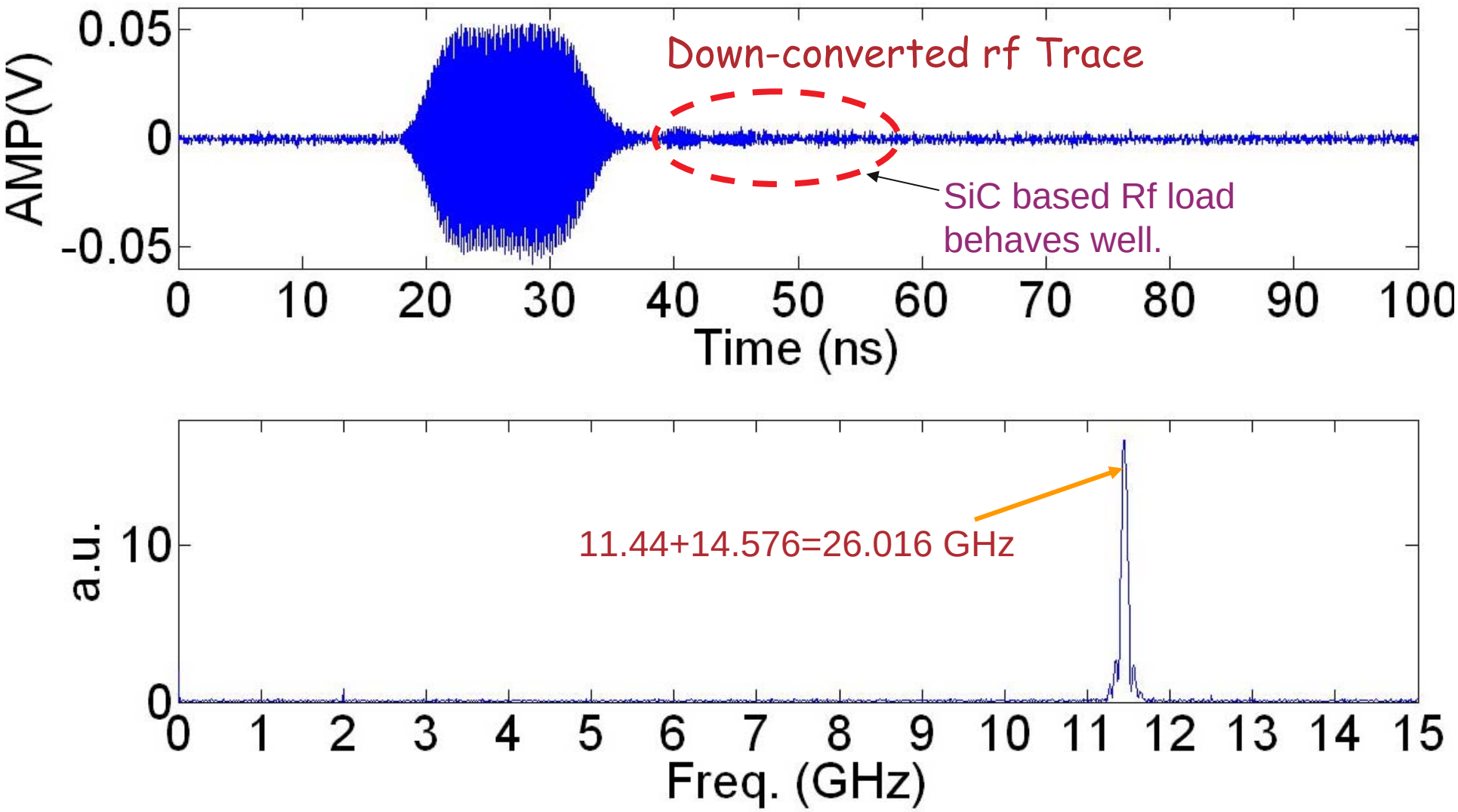


26GHz Dielectric-Based Wakefield Power Extractor---- beam test (I): setup

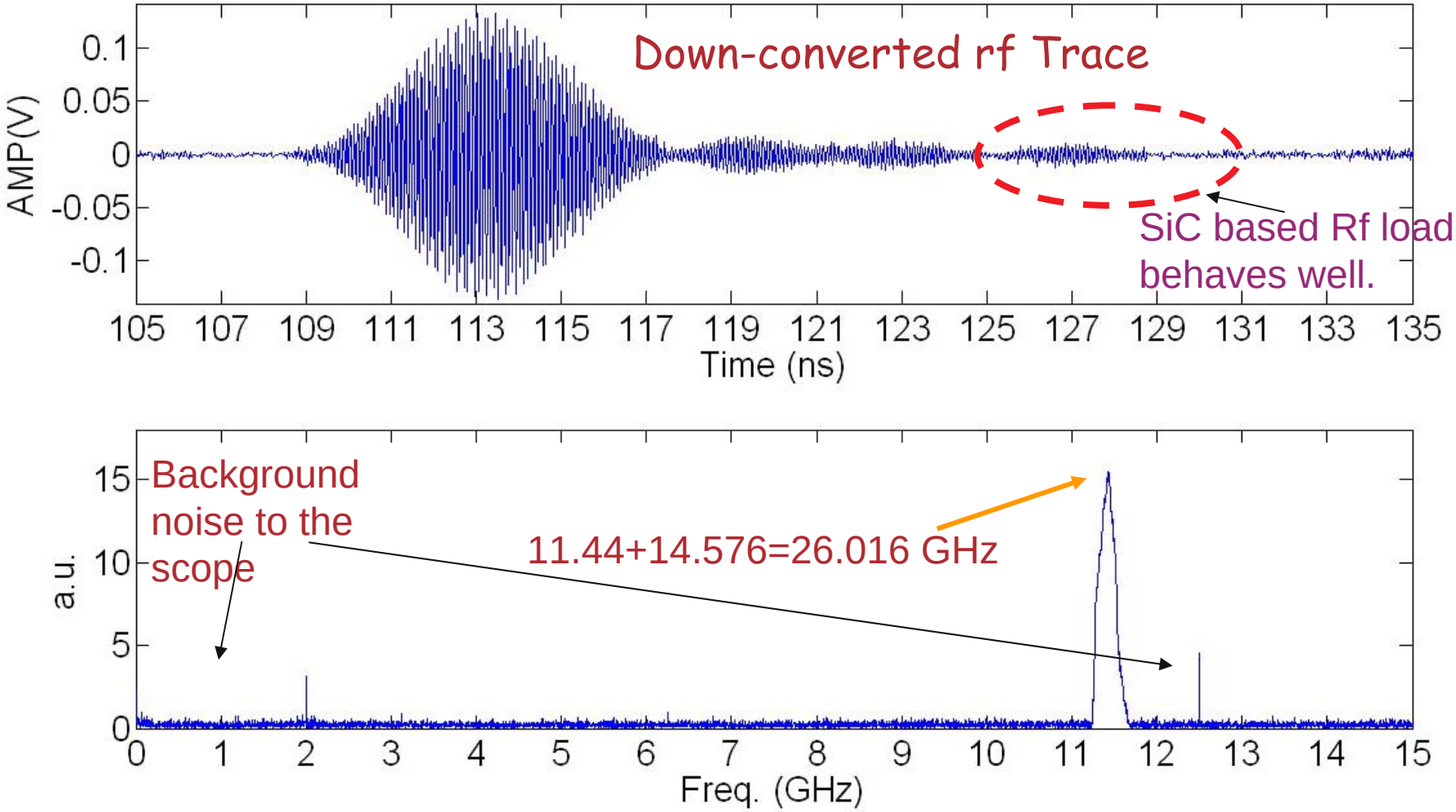




26GHz Dielectric-Based Wakefield Power Extractor---- beam test (II): 16 bunches, Tb=769ps

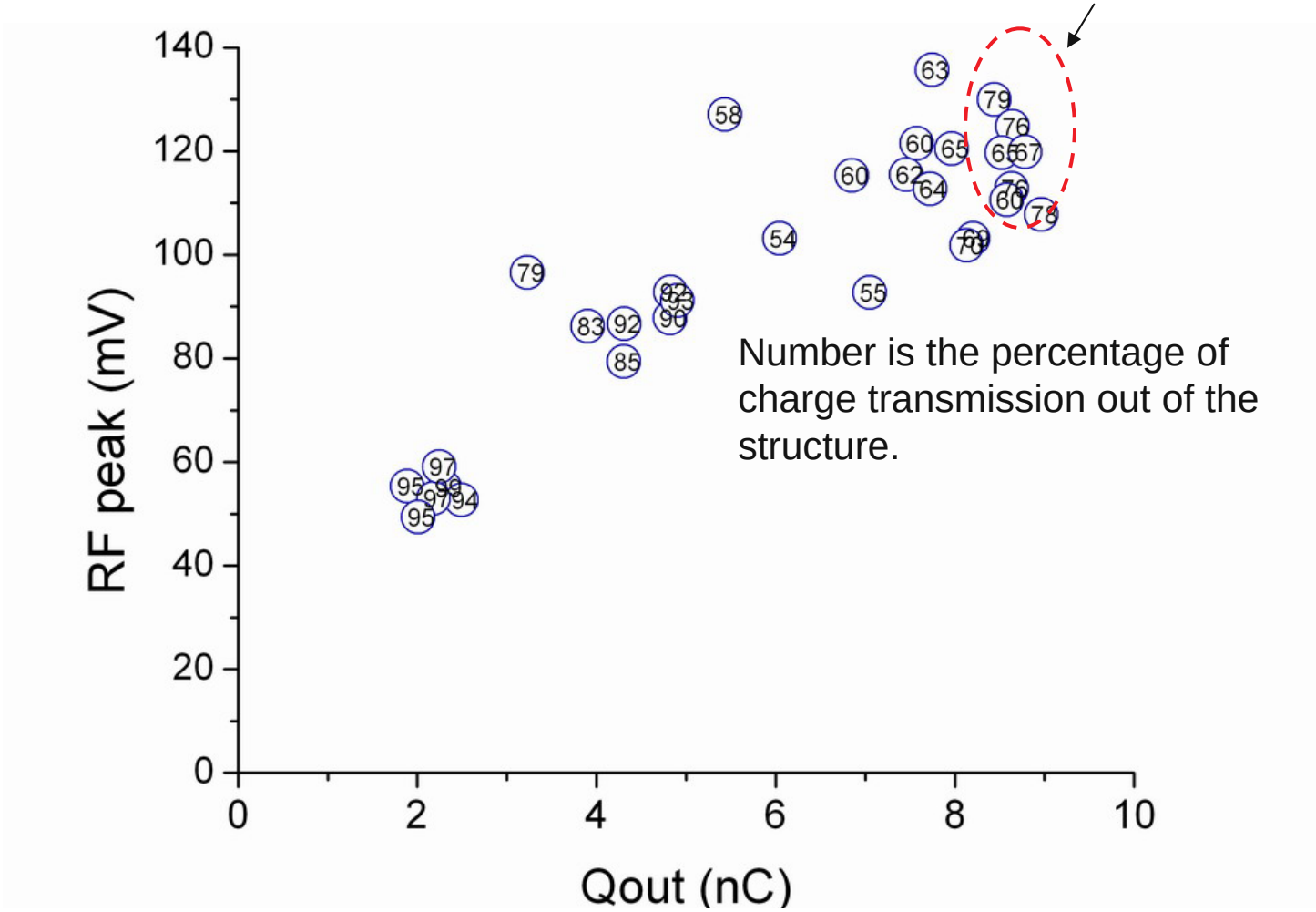


26GHz Dielectric-Based Wakefield Power Extractor---- beam test (III): 4 bunches, Tb=769ps



26GHz Dielectric-Based Wakefield Power Extractor---- beam test (IV): charge sweeping, 4 bunches, Tb=769ps

Theoretically, 9nC→29.6MW, 24.8MV/m



Power for future

Upgraded facility

75MeV beam

16 bunches

100nC/per bunch

σ z=2mm

Current Structures

7.8GHz power extractor

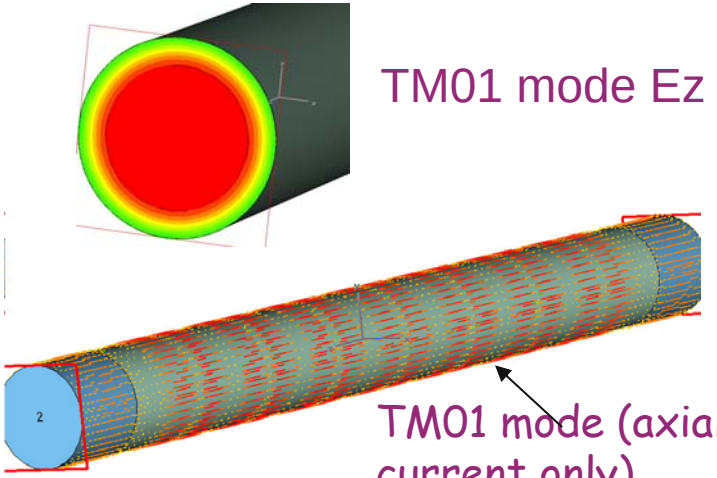
26GHz power extractor

Estimated Power

1.12GW,15ns, 7.8GHz rf (8.6MeV loss)

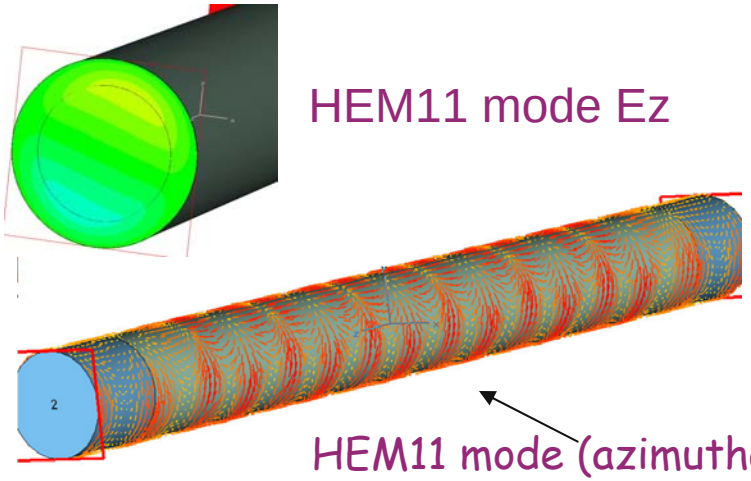
2.17GW , 15ns, 26GHz rf (16.7MeV loss)

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



TM01 mode Ez

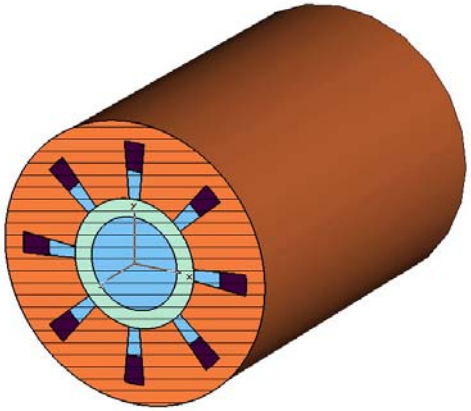
TM01 mode (axial current only)



HEM11 mode Ez

HEM11 mode (azimuthal current included)

SiC
Copper
Dielectrics
Vacuum



by Euclid Techlabs, supported by DoE SBIR program

SUMMARY

- Dielectric-based wakefield power extractors have been successfully demonstrated.
- Two structures, 7.8GHz and 26GHz, were fabricated and tested. 44MW for 7.8GHz and 30MW for 26GHz were achieved.
- Waiting for the high energy, high current beam.