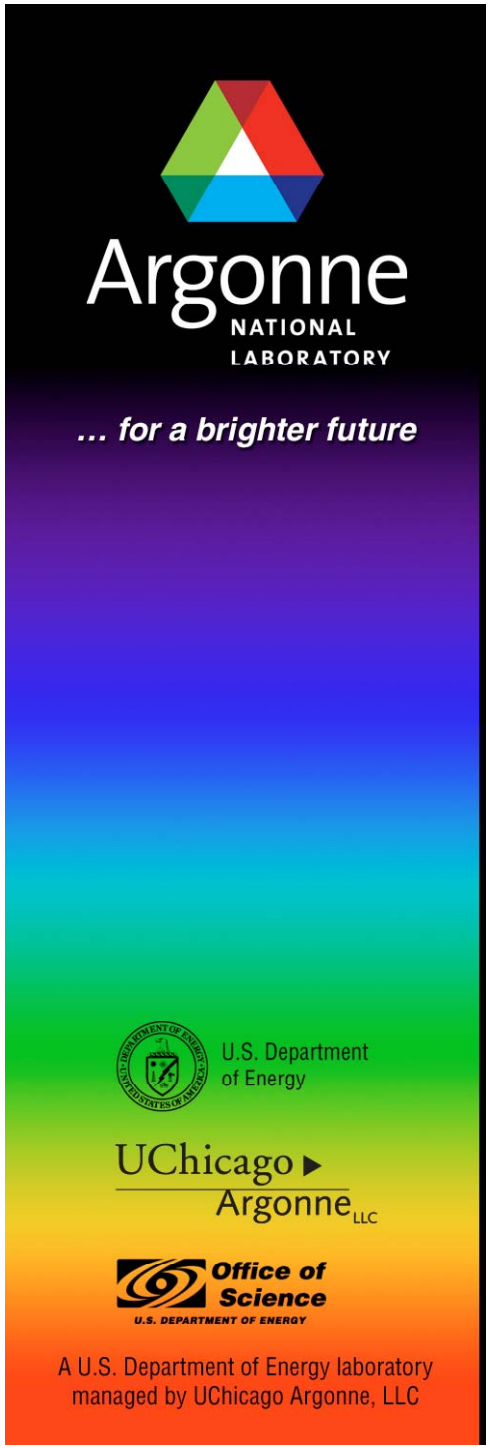

Recent ANL 7.8 GHz Power Extraction Experiment

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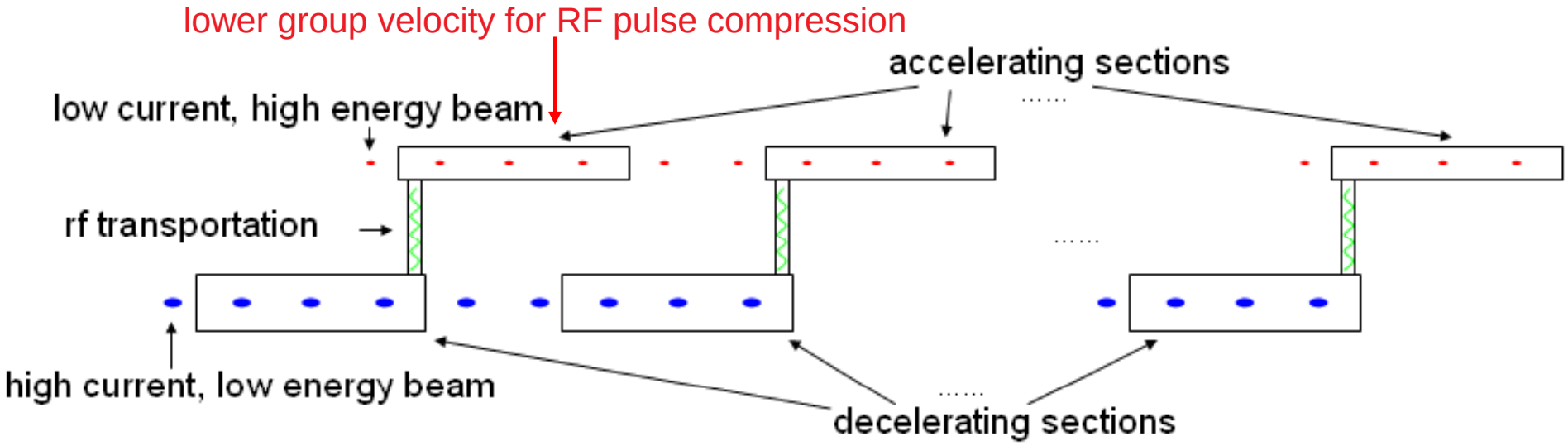
Outline

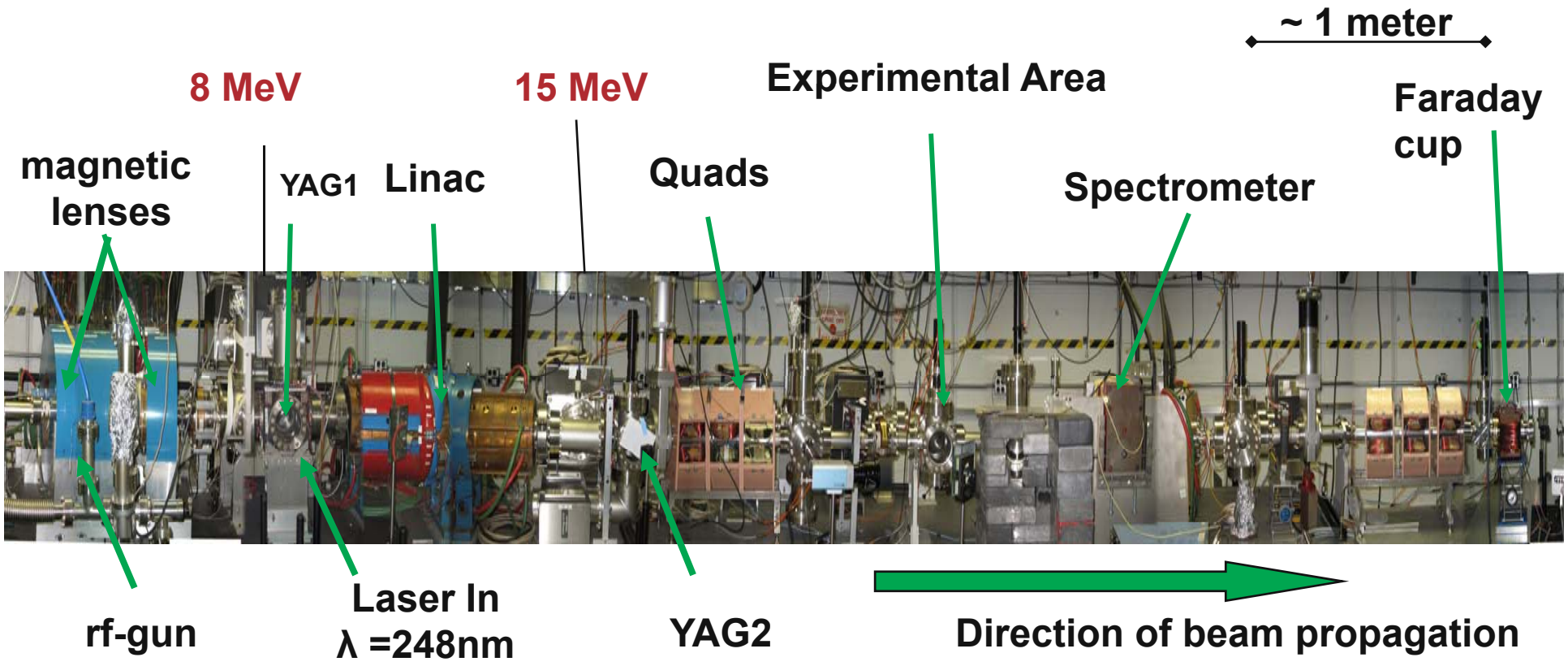
- Introduction
- Design of a 7.8GHz power extractor
- Beam tests of the 7.8GHz power extractor:
  i. Single bunch tests
  ii. Bunch train tests
- Design of a 26GHz power extractor
- Summary

Dielectric loaded scheme for two beam acceleration



- Power: >100MW
- Frequency: up to 30GHz
- RF pulse length: a few nanoseconds to a few tens of nanoseconds

The Argonne Wakefield Accelerator (AWA)



Single bunch operation

Q = 1-100 nC (reached 150 nC), 15 MeV, 2-2.5 mm bunch length (rms), emittance < 200 mm mrad (at 100 nC)

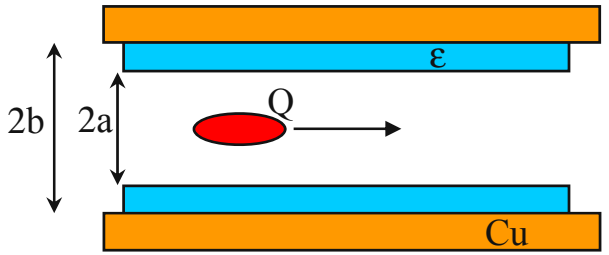
High Current: ~10 kA

Bunch train operation

4 - 16 bunches x 20 - 5 nC (current)

16 - 64 bunches x 50 - 100 nC → 10 - 50 ns long (future)

Example: Dielectric Loaded WF Accelerator



Looking at dielectric structure properties:

- **Comparable accelerating properties as metal structures;**
- **More material options; Possibly higher gradients;**
- **Simpler geometry, easy to construct and HOM damping.**

Applications

- ***Two-beam acceleration***
- ***Collinear wakefield acceleration***

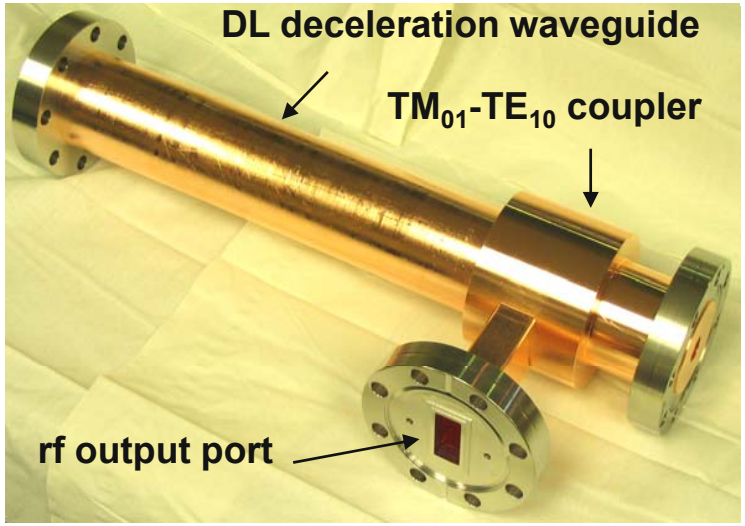
Keys to the success:

- **Drive beam, drive beam and drive beam!**

  ➔Energy ↑, Charge ↑ Bunch length ↓ Emittance ↓

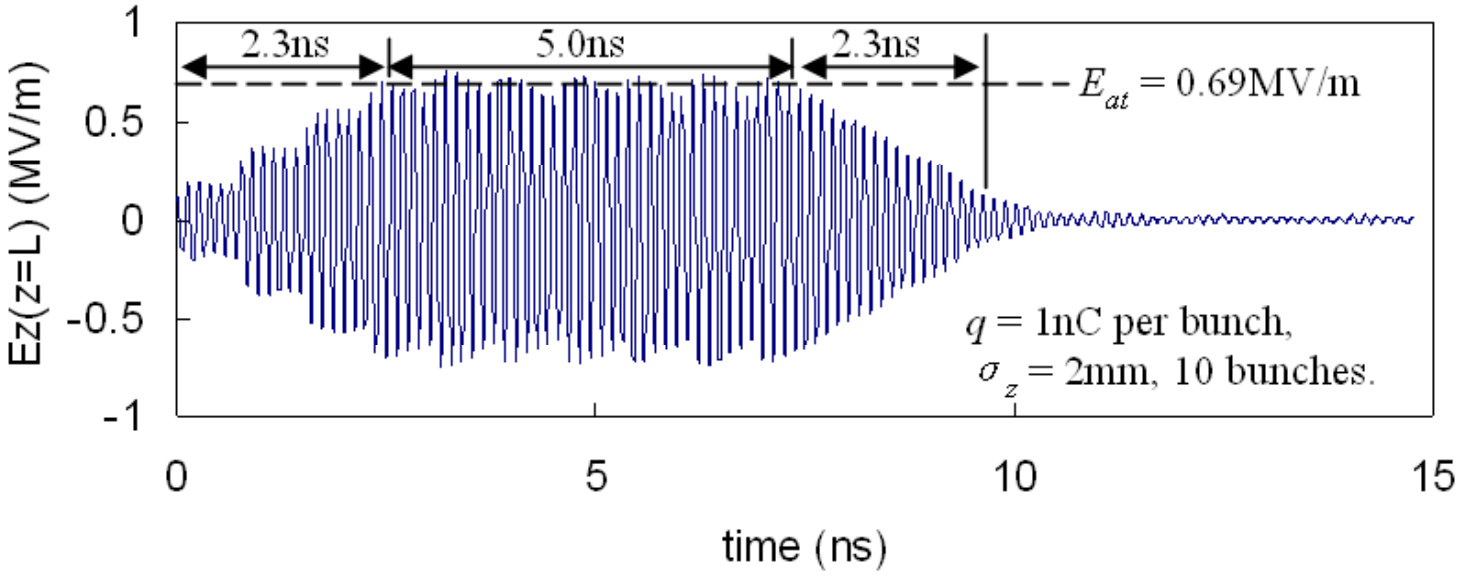
$$W_Z(z) \approx \frac{Q}{a^2} \exp\left[-2\left(\frac{\pi\sigma_z}{\lambda_n}\right)^2\right]\cos(kz)$$

Design of the 7.8GHz power extractor: the deceleration tube

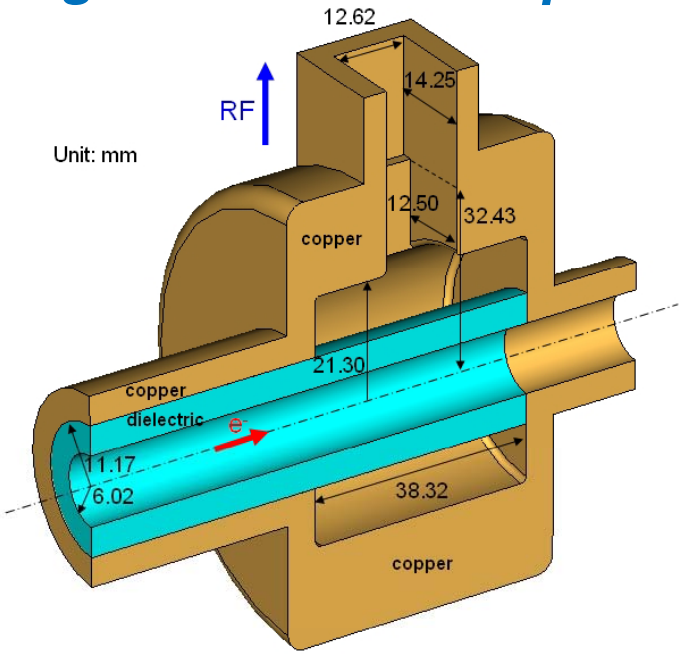


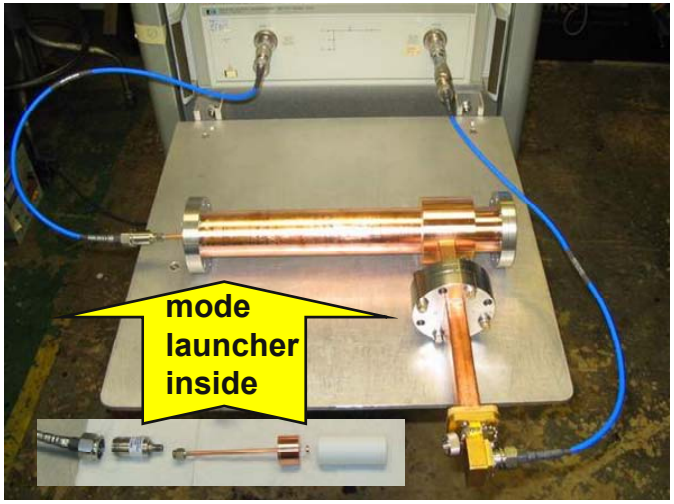
Frequency:	7.8GHz
Inner diameter:	12.04mm
Outer diameter:	22.34mm
Dielectric constant:	4.6
Deceleration section length:	266mm
Group velocity:	0.23c

Generated power (Gaussian bunch length = 2mm):
Single bunch: 79MW @100nC per bunch
Bunch train (T_b = 769ps): 100MW @30nC per bunch
280MW @ 50nC per bunch
1.1GW @ 100nC per bunch

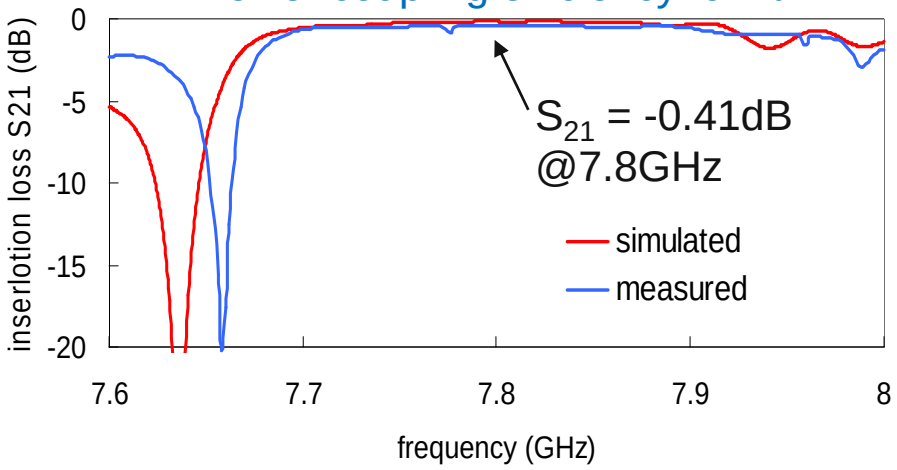


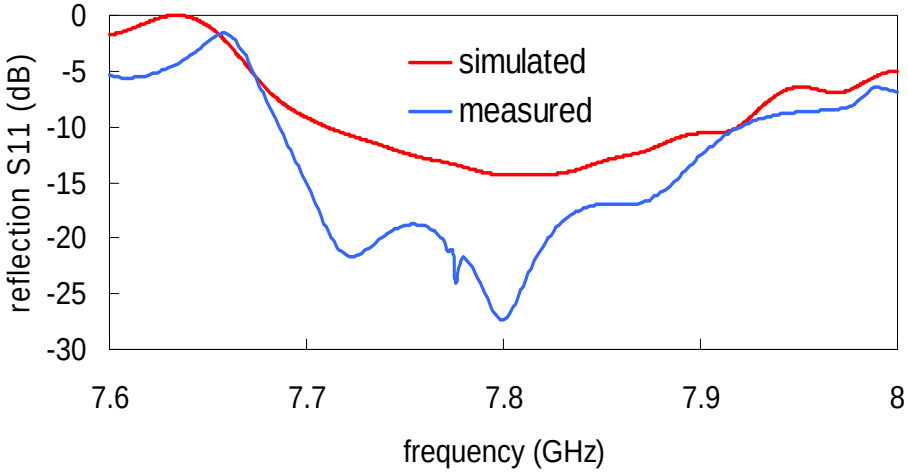
Design of the 7.8GHz power extractor: the RF output coupler





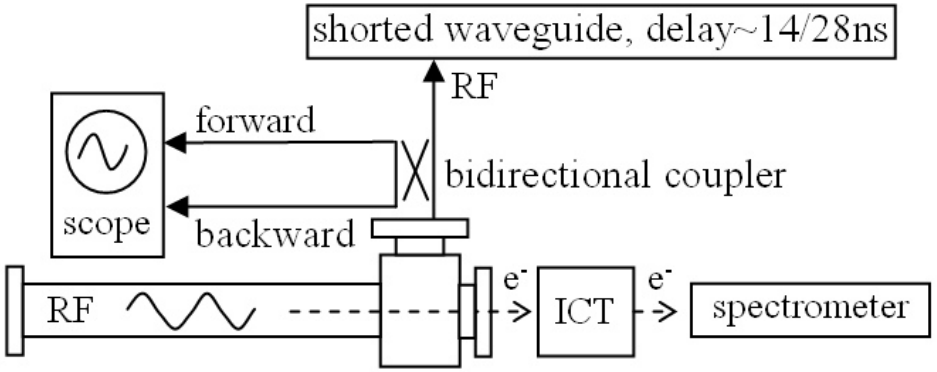
Power coupling efficiency: 91%.

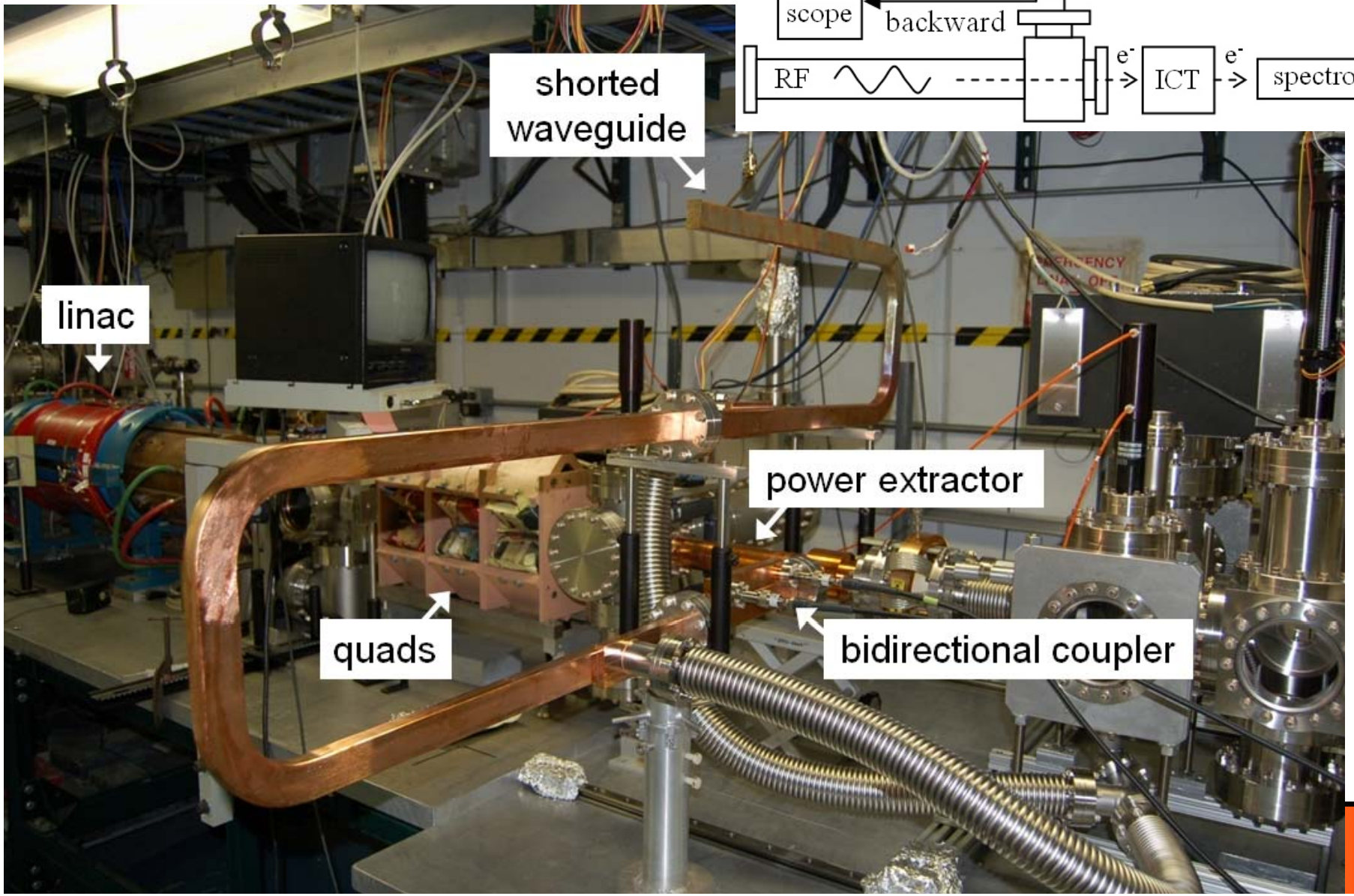




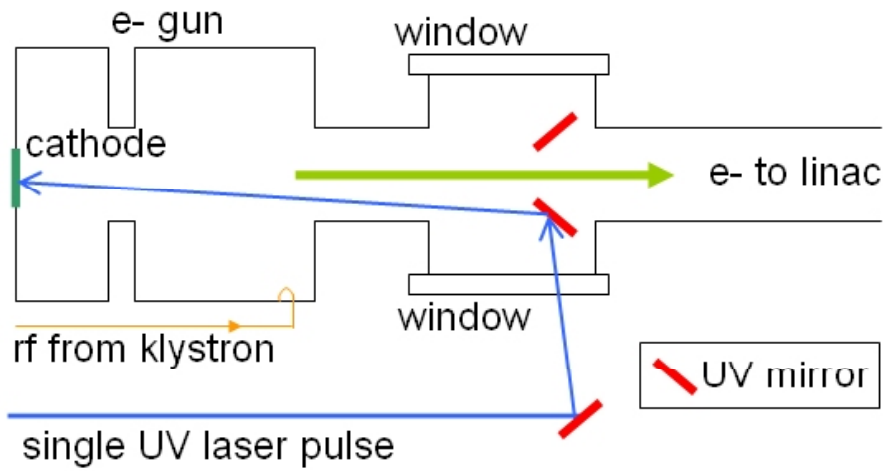
7.8GHz Experimental setup

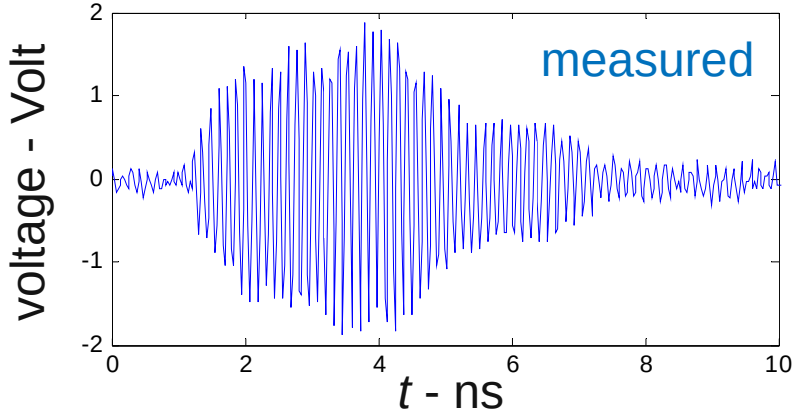
Beam energy: 15MeV

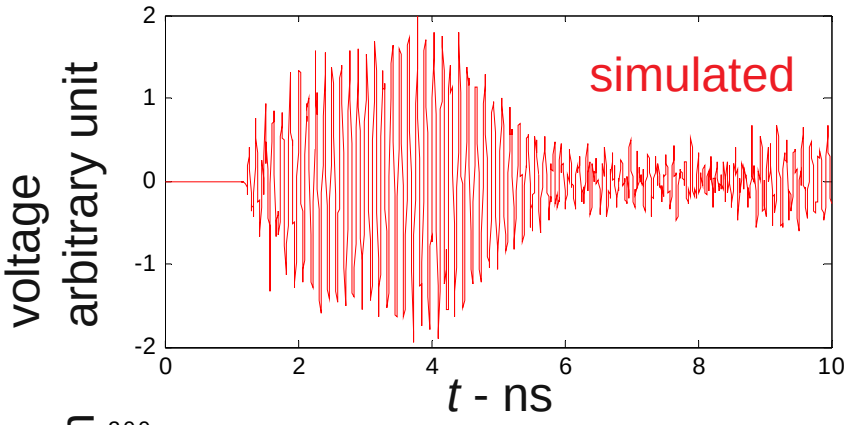


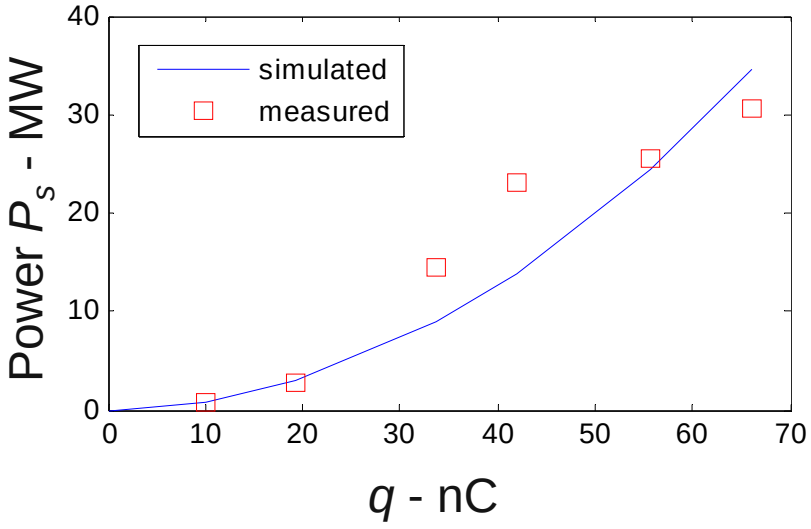


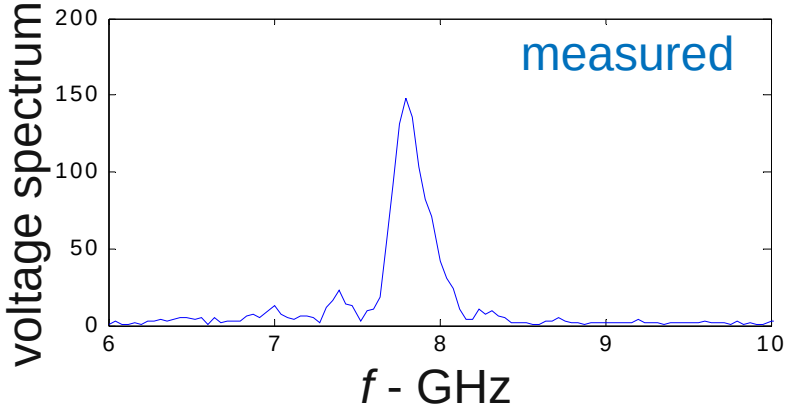
78GHz single bunch test



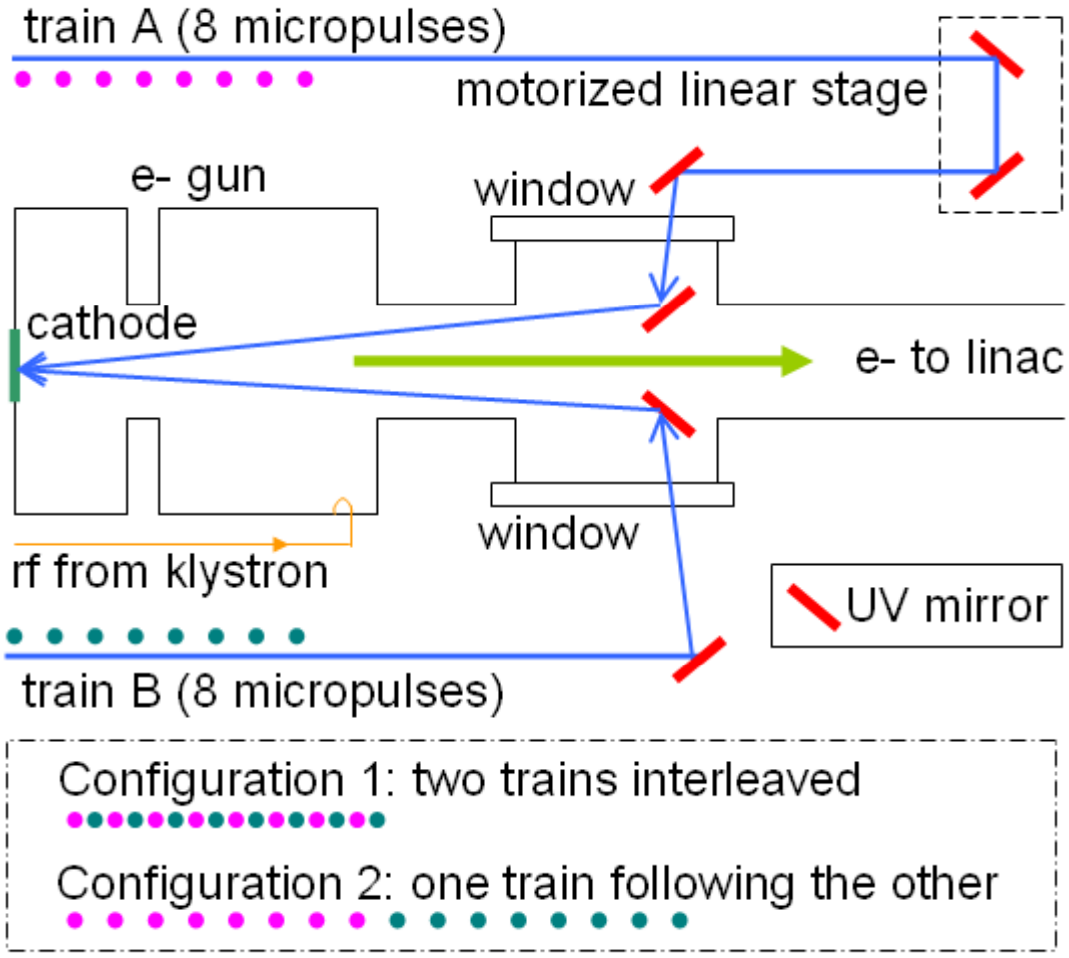


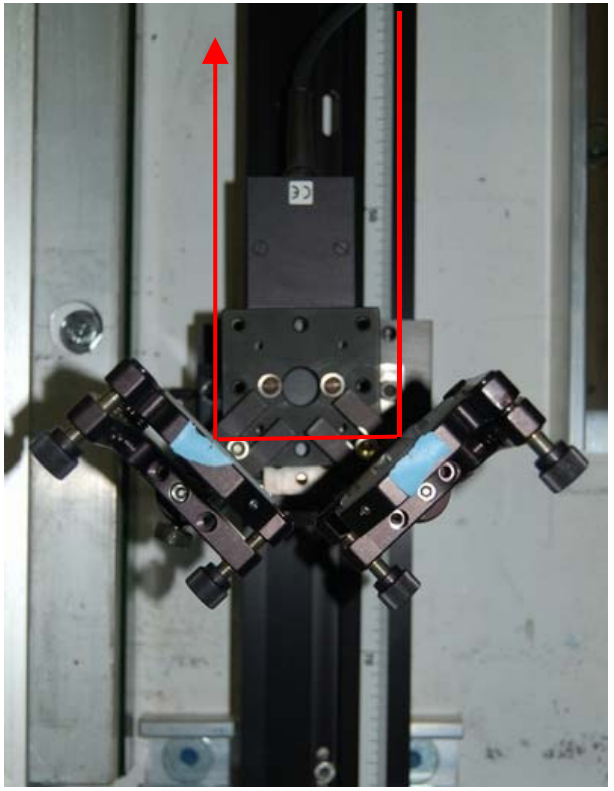






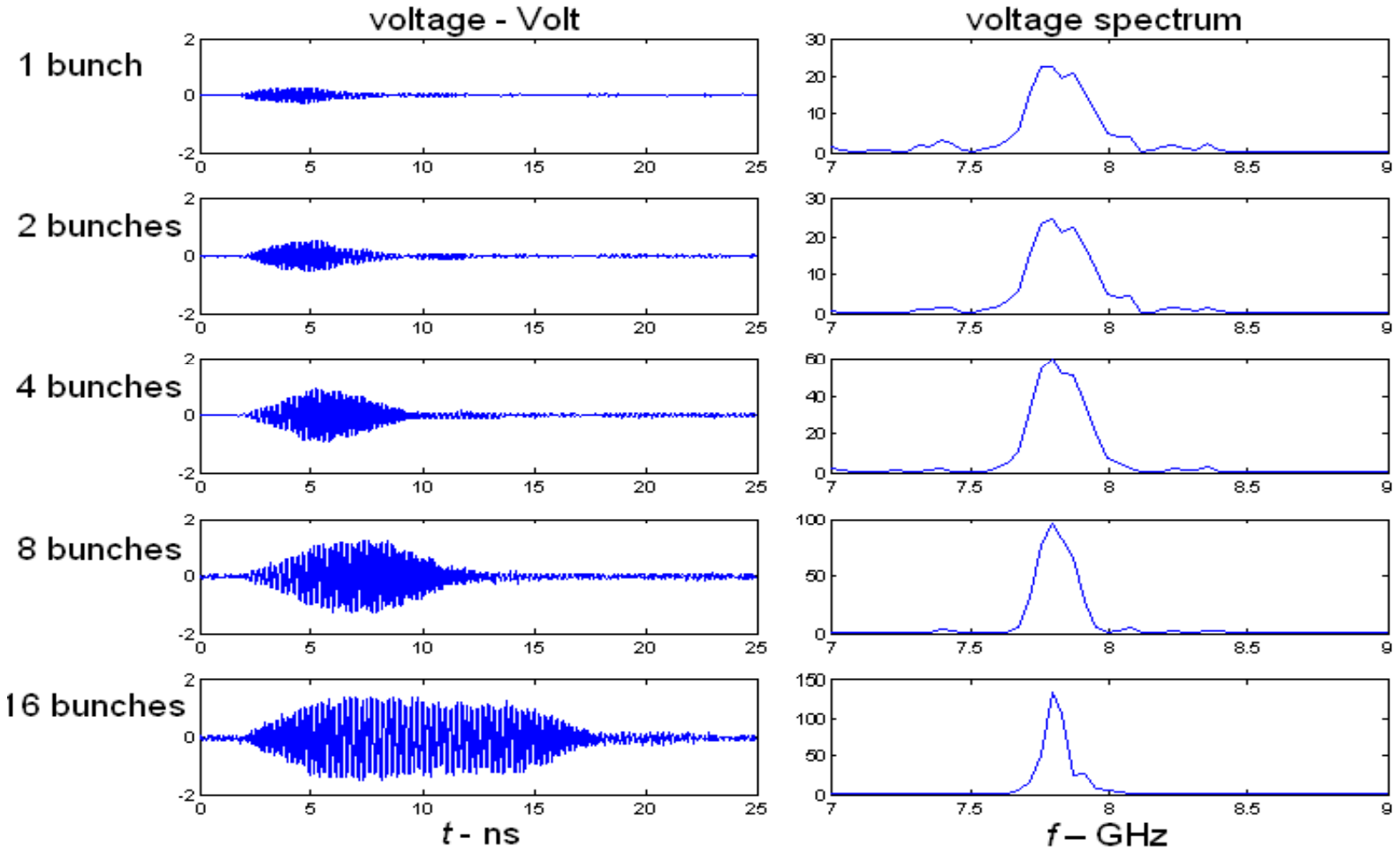
7.8GHz bunch train test – electron bunch train generation



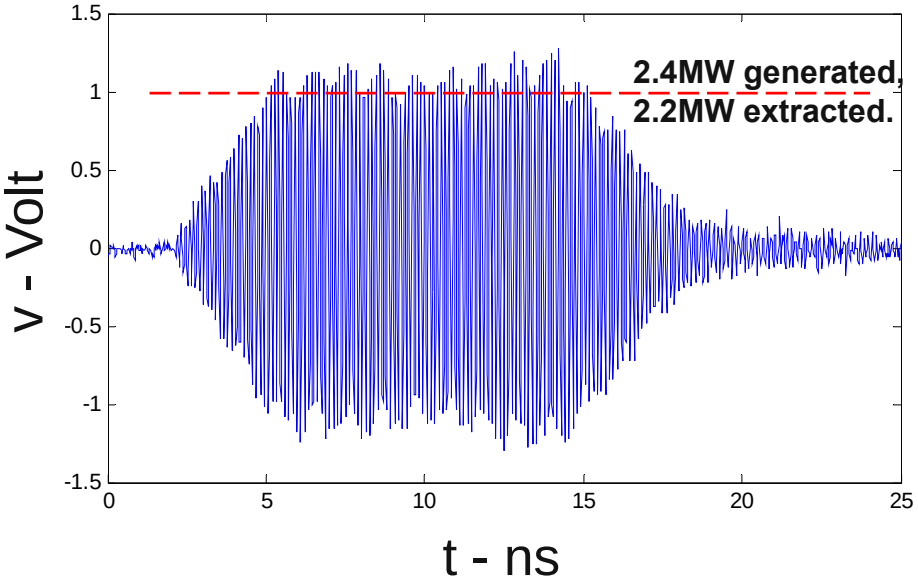


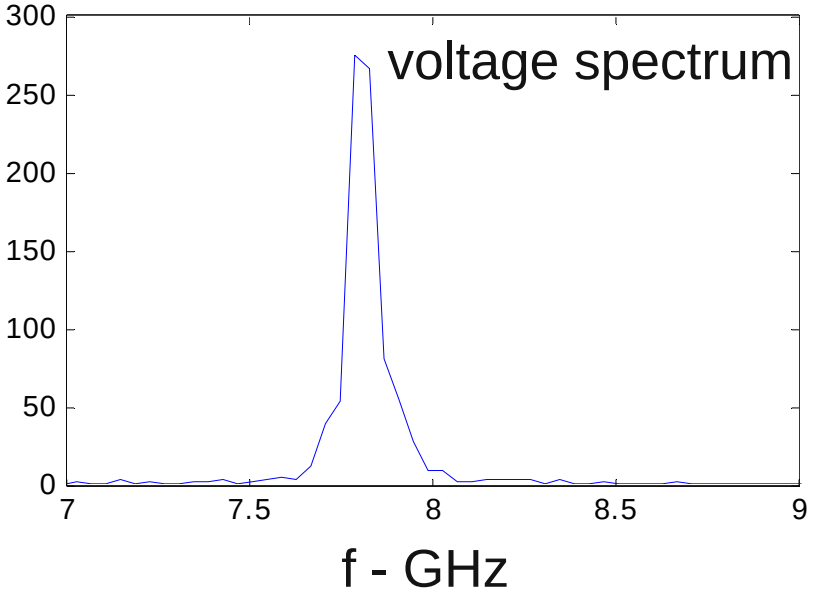
7.8GHz 10ns pulse generation

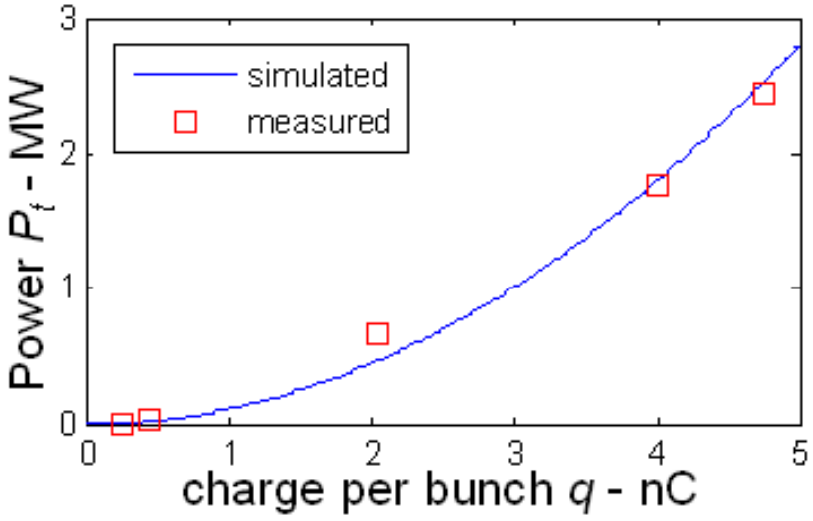
- Beam for ~10ns RF pulse generation



7.8GHz, 2.4MW, 10ns RF pulse generation

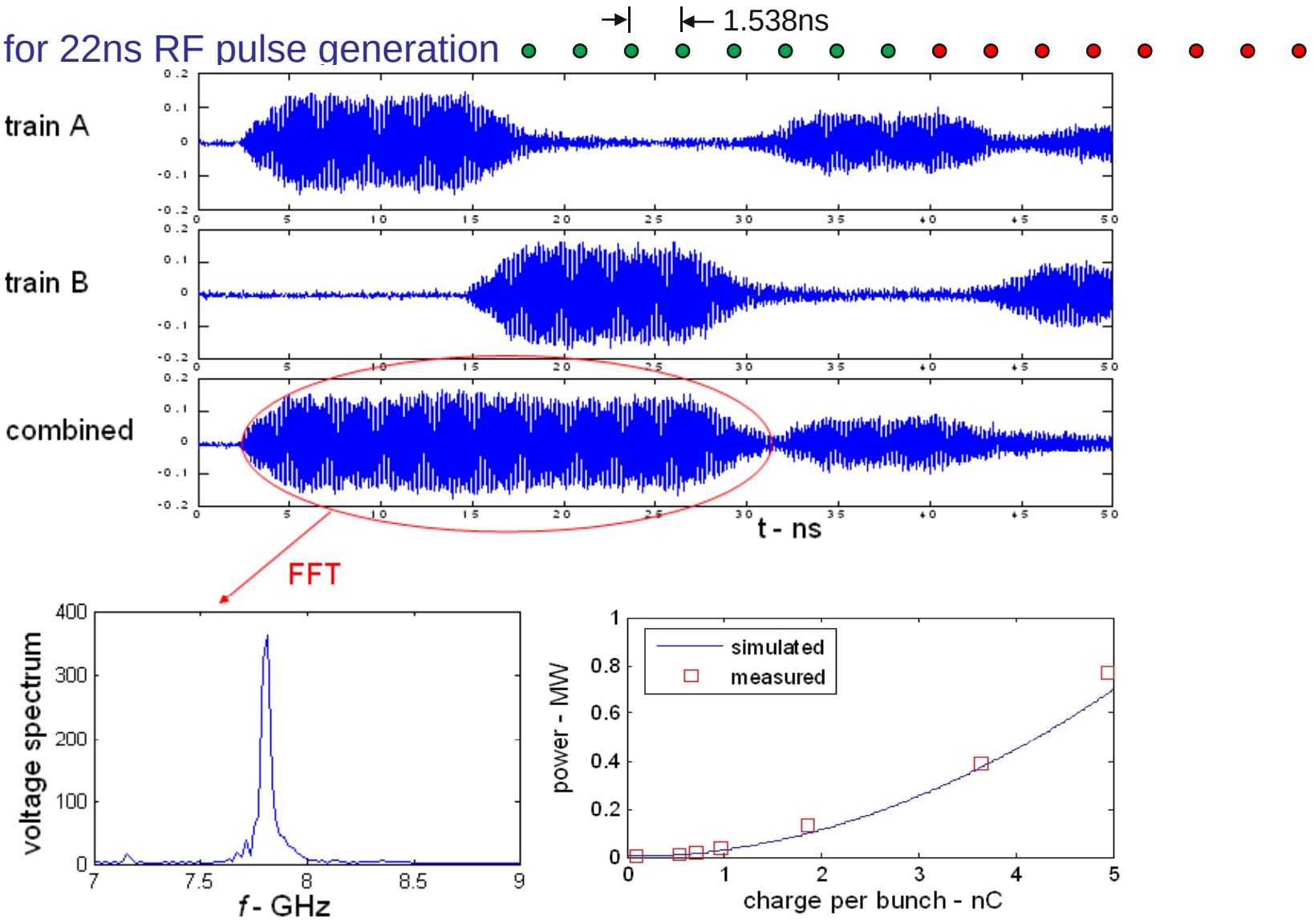




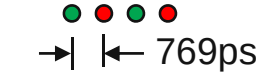


7.8GHz, 0.77MW 22ns RF pulse generation

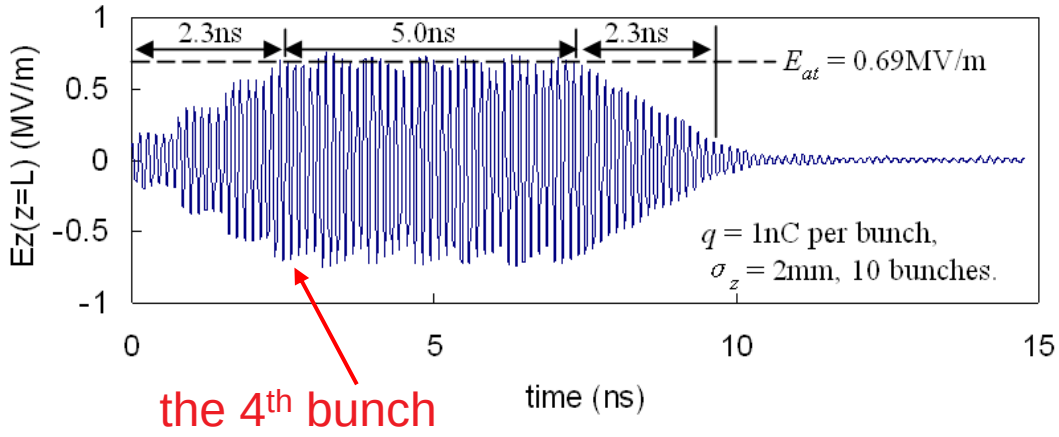
- Beam for 22ns RF pulse generation

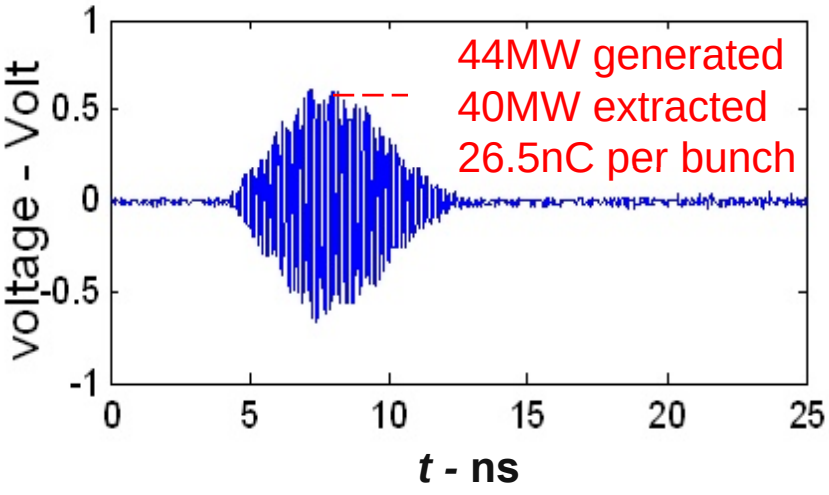


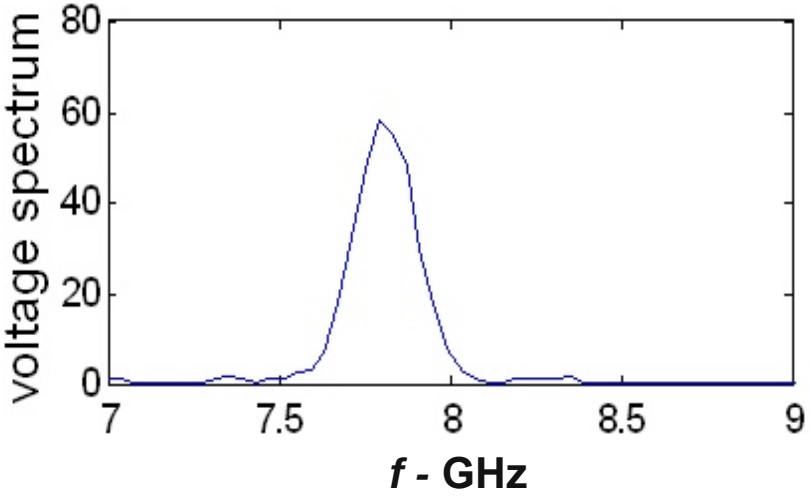
7.8GHz 4-bunch test for high power generation



- Simulation shows the power reach “flat-top” saturation level when the drive bunch contains 4 or more consecutive bunches spaced by 769ps.
- To maximize this power level the UV laser bunch was only split into 4 bunches.



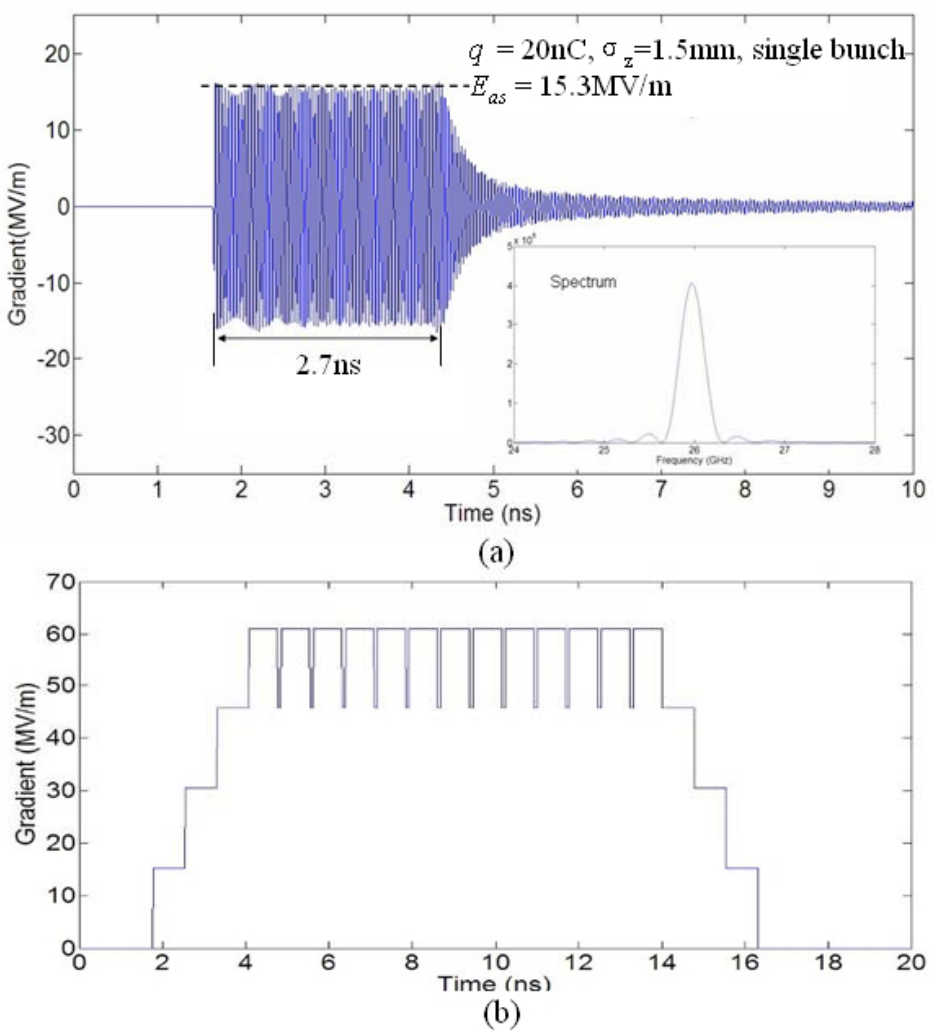




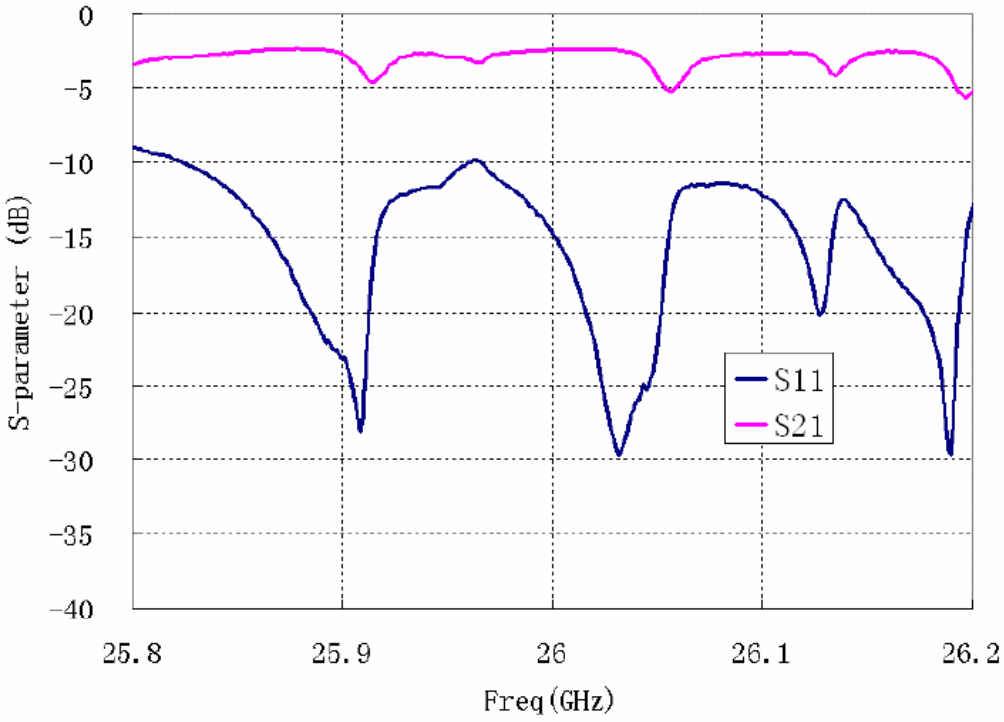
26GHz power extractor design: deceleration tube

Frequency:	26GHz = 1.3GHz*20
Inner radius:	7mm
Outer radius:	9.068mm
Interaction length:	300mm
Dielectric constant:	6.64
Group velocity:	0.25c
Q:	2950
r/Q:	9.8KΩ/m

Generated power
(Gaussian bunch length = 1.5mm):
Single bunch: 8.2MW @20nC per bunch
Bunch train (*Tb* = 769ps):
148MW @20nC per bunch



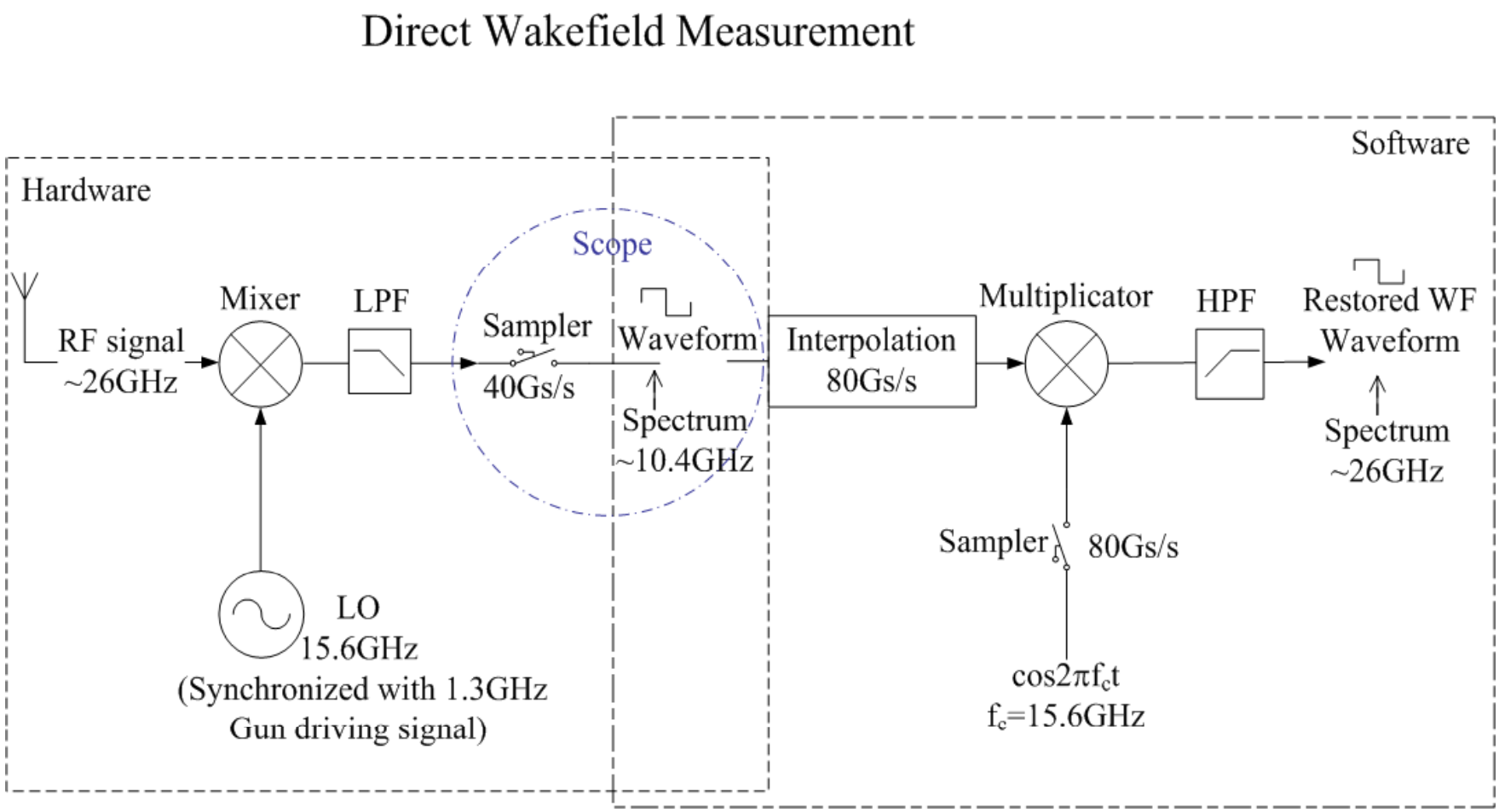
26GHz power extractor design: output coupler



S_{21}=-1.8dB after substracting the loss from the adapters.

power coupling efficiency is 66%.

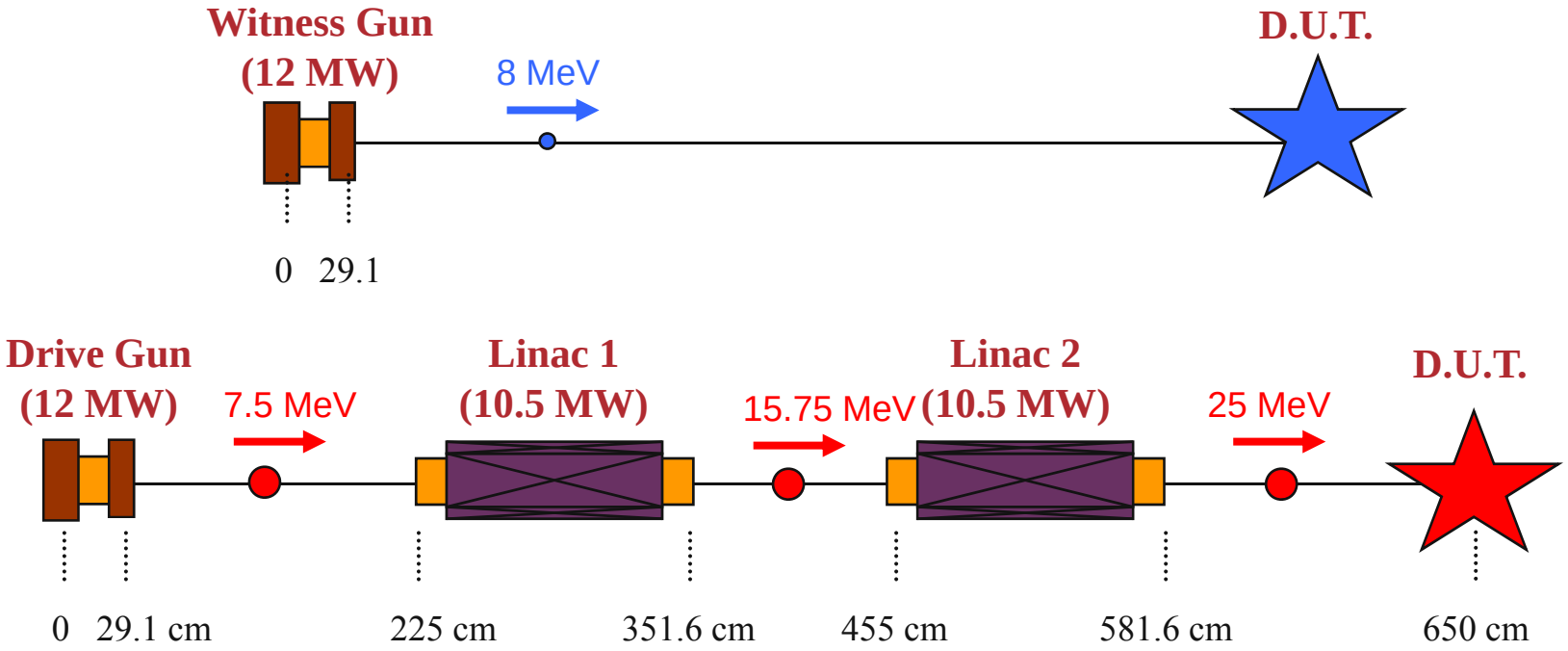
26GHz power extraction measurement scheme:



Next Steps at AWA:

- Test more structures;
- Upgrade the cathode from Mg to Cesium telluride (long, high charge bunch trains);
- Increase the beam energy to 25 MeV by using an additional Klystron.
- More power extraction experiments.

Future AWA Facility – (25 MW + 25 MW = 50 MW)



Single Bunch: 50 - 100 nC

Bunch Train: 16 – 50, total charge 1 – 2.5 μC

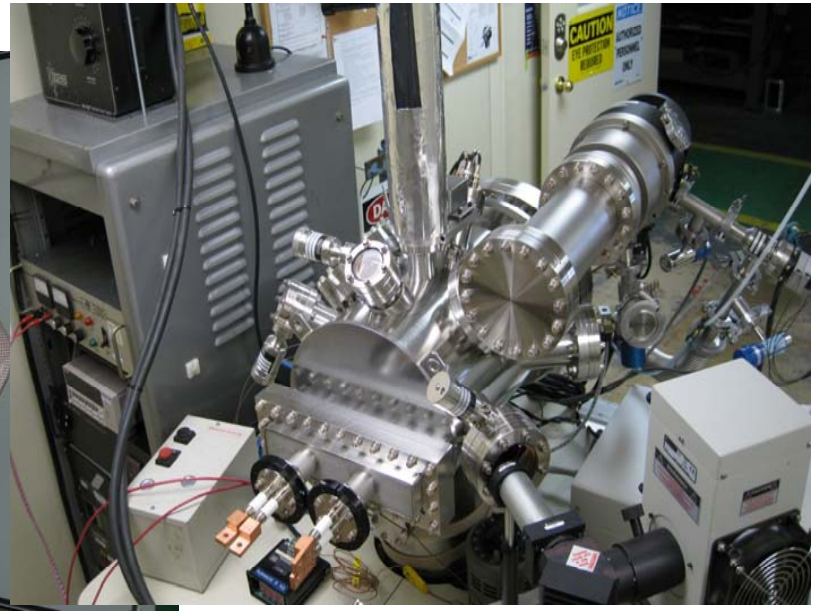
Goal for WF Acceleration: ~ 200 - 500 MV/m

Power Generation: ~ 500 MW

New 30 MW RF Station (1.3 GHz) and Cathode Fab Lab at the AWA

Klystron and solenoid
and HV Transformer

HV cabinet, Thyratron
Capacitors



CsTe Cathode
Preparation Chamber

Summary

- 7.8GHz dielectric-loaded power extraction has been demonstrated. 30MW of power has been generated in single bunch tests and 44MW in bunch train tests. 10ns and 22ns RF pulses have been detected.
- Currently the limitation for higher power generation is limited by the QE of the magnesium photocathode (~10^{-4}). A new cesium telluride photocathode with much higher QE (~10^{-2}) has been developed, yet to be installed and tested in a new gun (AWA G3). 280MW of output power is expected to be generated by electron charge of 50nC per bunch.
- A 26GHz dielectric-loaded power extractor has been designed and ready to be test.