Ultrafast High-brightness Electron Source

Jangho Park

Advanced Energy Systems Inc.
P.O. Box 7455, Princeton, NJ 08543-7455
Phone: (609) 514-0319
Fax: (609) 514-0318
E-mail: park@aesprin.com

Putting Accelerator Technology to Work

Introduction

- Generation and preservation of ultrafast high-brightness electron beams is one of the major challenges in accelerator R&D.
- In order to generate and preserve the ultrafast high-brightness electron beam, transverse and longitudinal space charge effects have to be considered.
- Several approaches to achieving ultra-short bunches have been explored such as velocity bunching and magnetic compression.
- However, each option suffers drawbacks (extra RF and bulky) in achieving a compact ultrafast high-brightness source.
- **A tabletop ultrafast high-brightness electron source** is demanded for Ultrafast/Femtosecond Electron Diffraction (UED/FED) and advanced accelerator experiment.

Bunch Lengthening

- For a high-aspect-ratio (short bunch length) electron bunch, the asymptotic bunch length due to the space charge forces of a uniformly accelerated bunch, ignoring the drive laser duration and assuming prompt response from a copper cathode where the laser spot radius is kept constant, is expressed by:

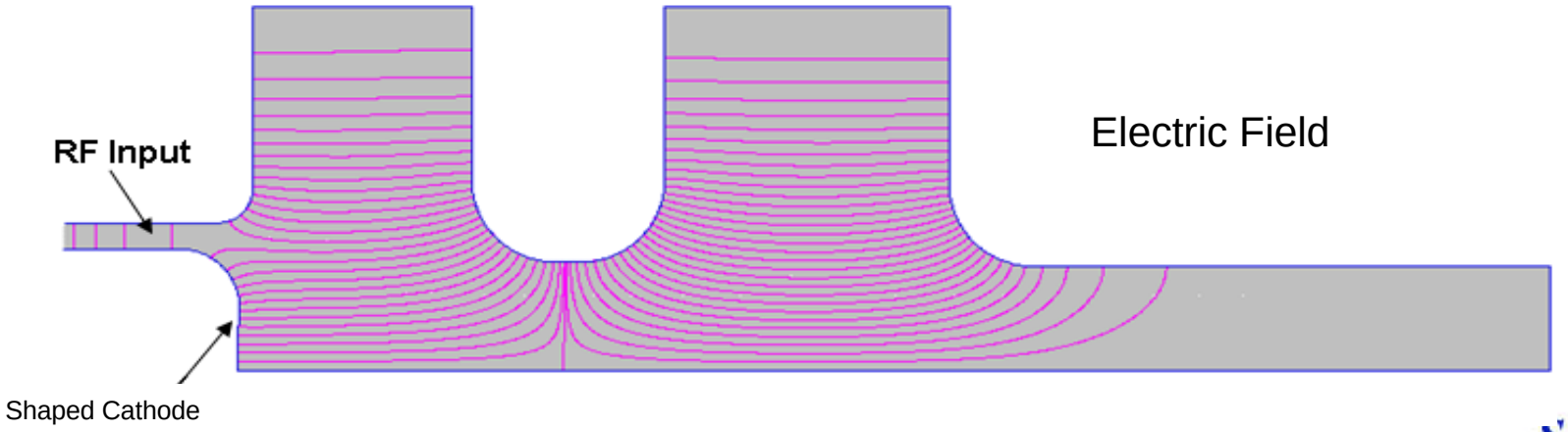
$$\Delta t_{sc}(\infty) = \frac{mc^2}{e}\frac{Q}{\pi R^2 \varepsilon_0 c E^2}.$$

- Bunch lengthening due to the space charge is inversely proportion to the square of the bunch radius and the square of the accelerating field.

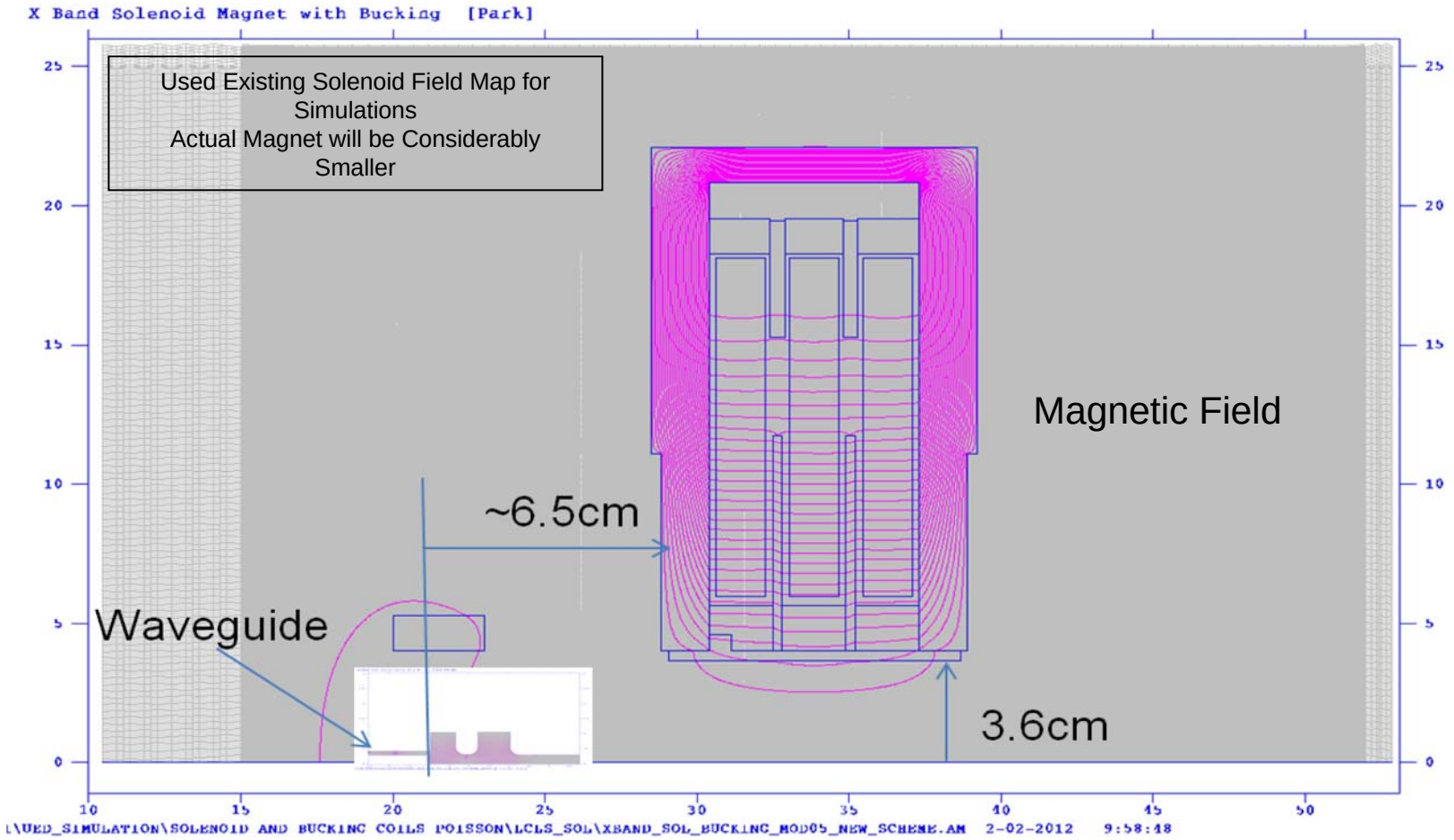
- Bunch length stretches due to the longer path lengths of the outer particles compared with electrons closer to the axis.
- Bunch lengthening due to the geometrical effects is proportional to the square of the beam radius.

New Gun Cavity Design Aspects

- High acceleration field with X-band RF gun
- Curved copper cathode
- Axisymmetry coupling
- Backward RF Feeding

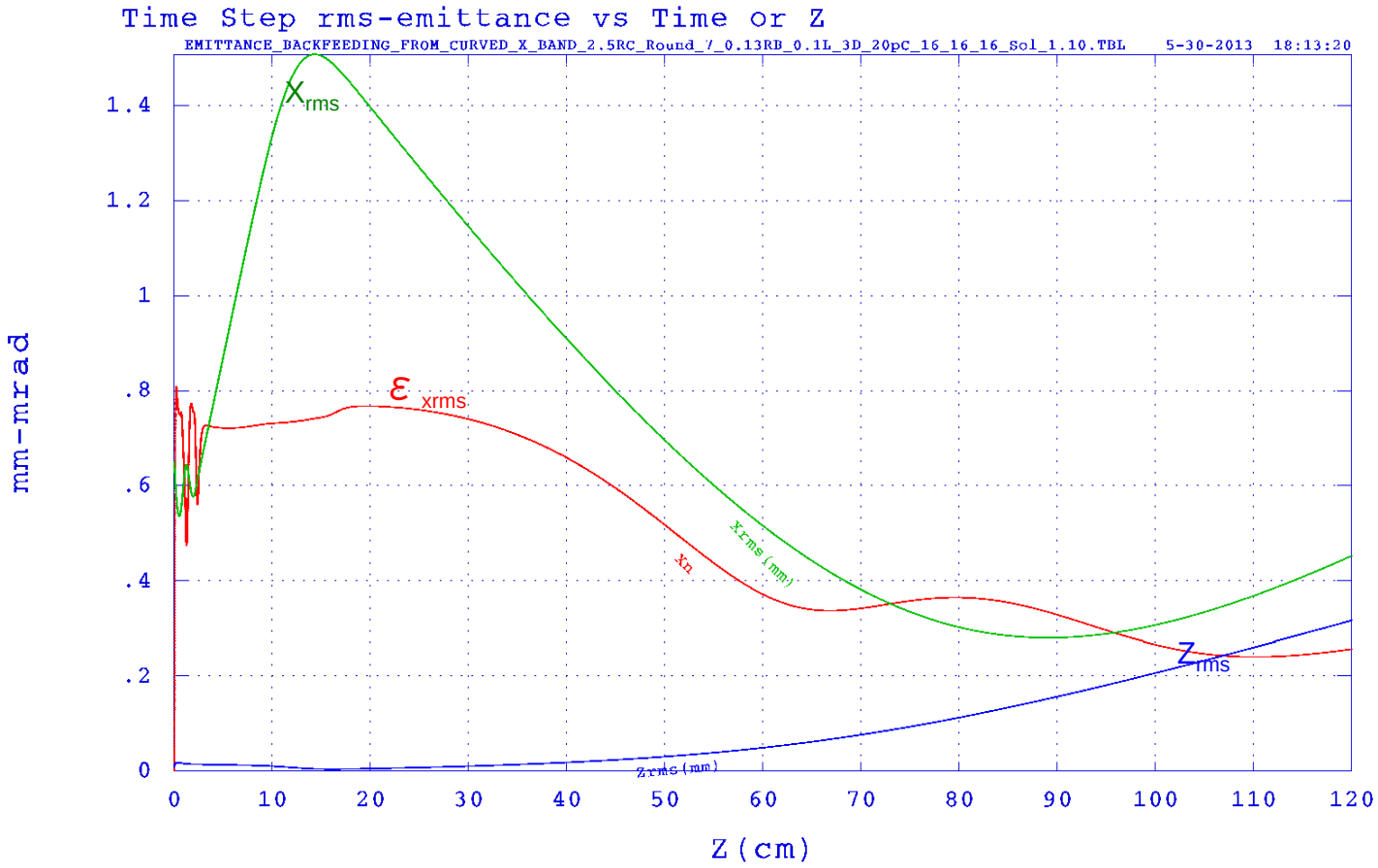


UED Gun Simulation

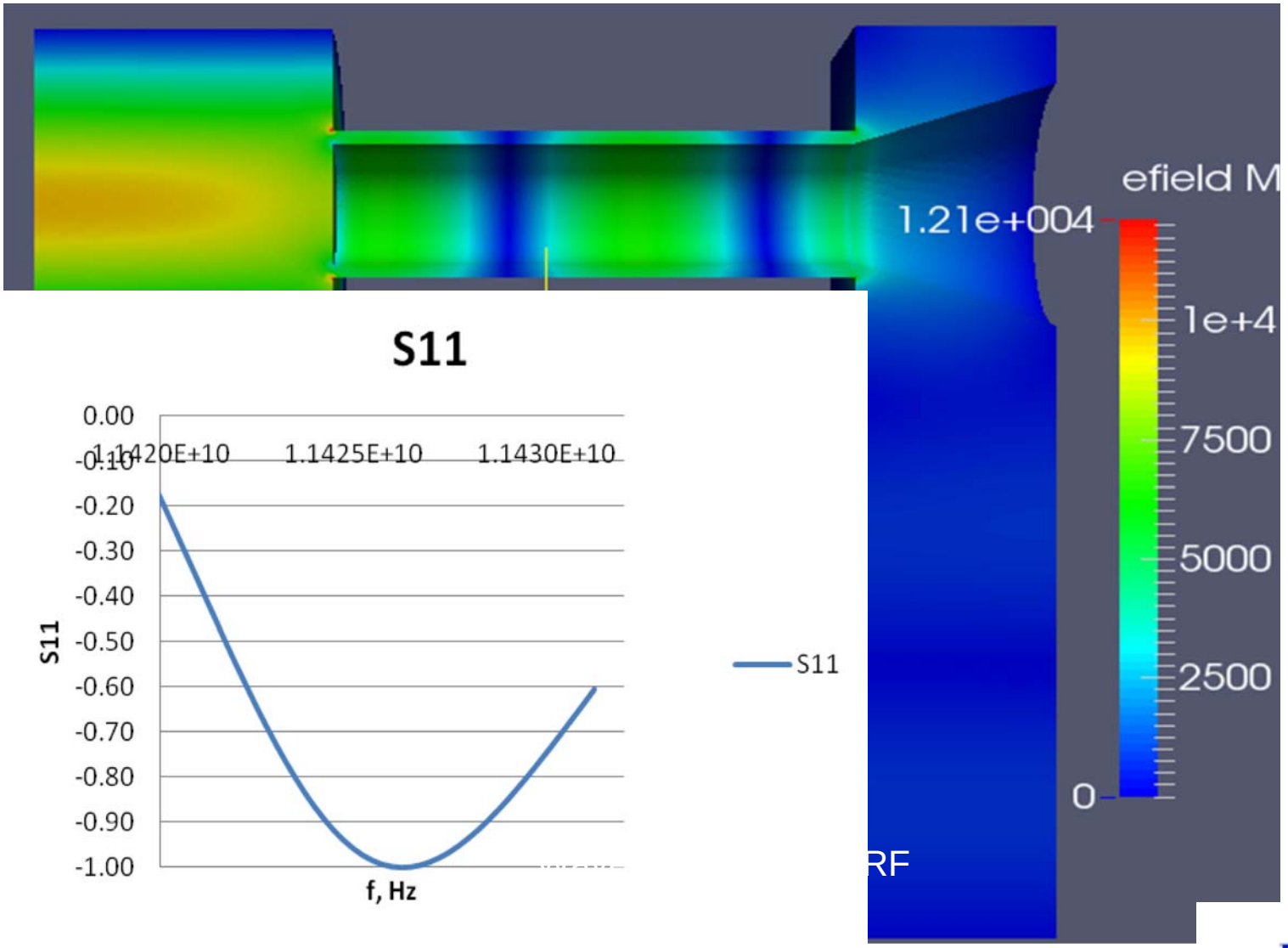


UED Gun Simulation Results

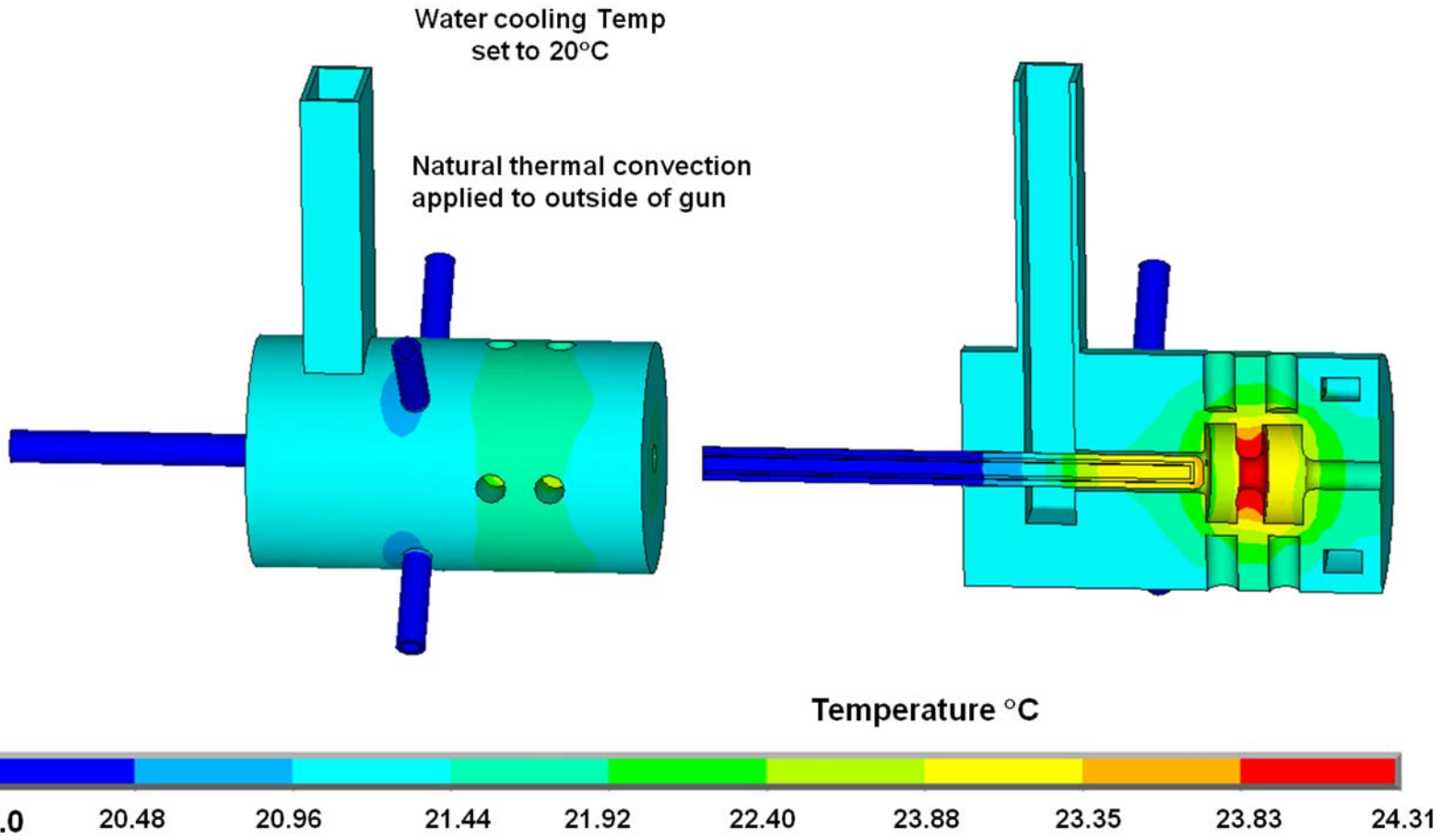
Ultrafast High-Brightness Electron Source



UED Gun Simulation Results

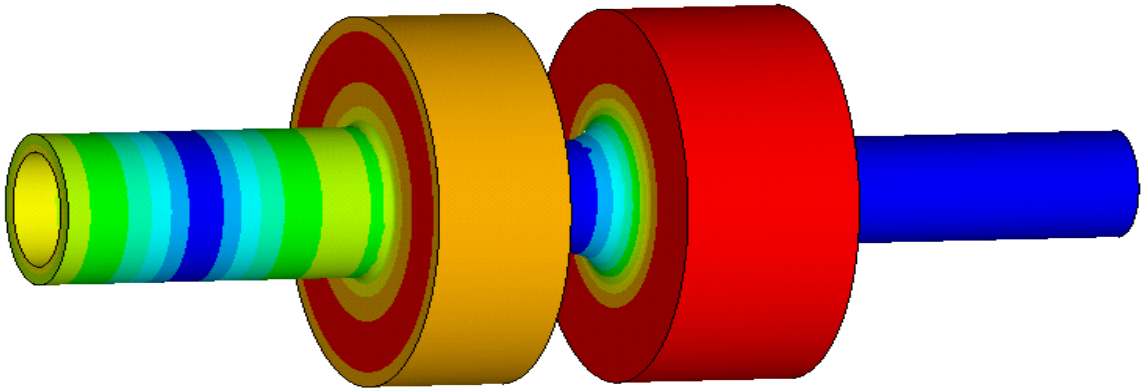


Thermo-Structural Analysis



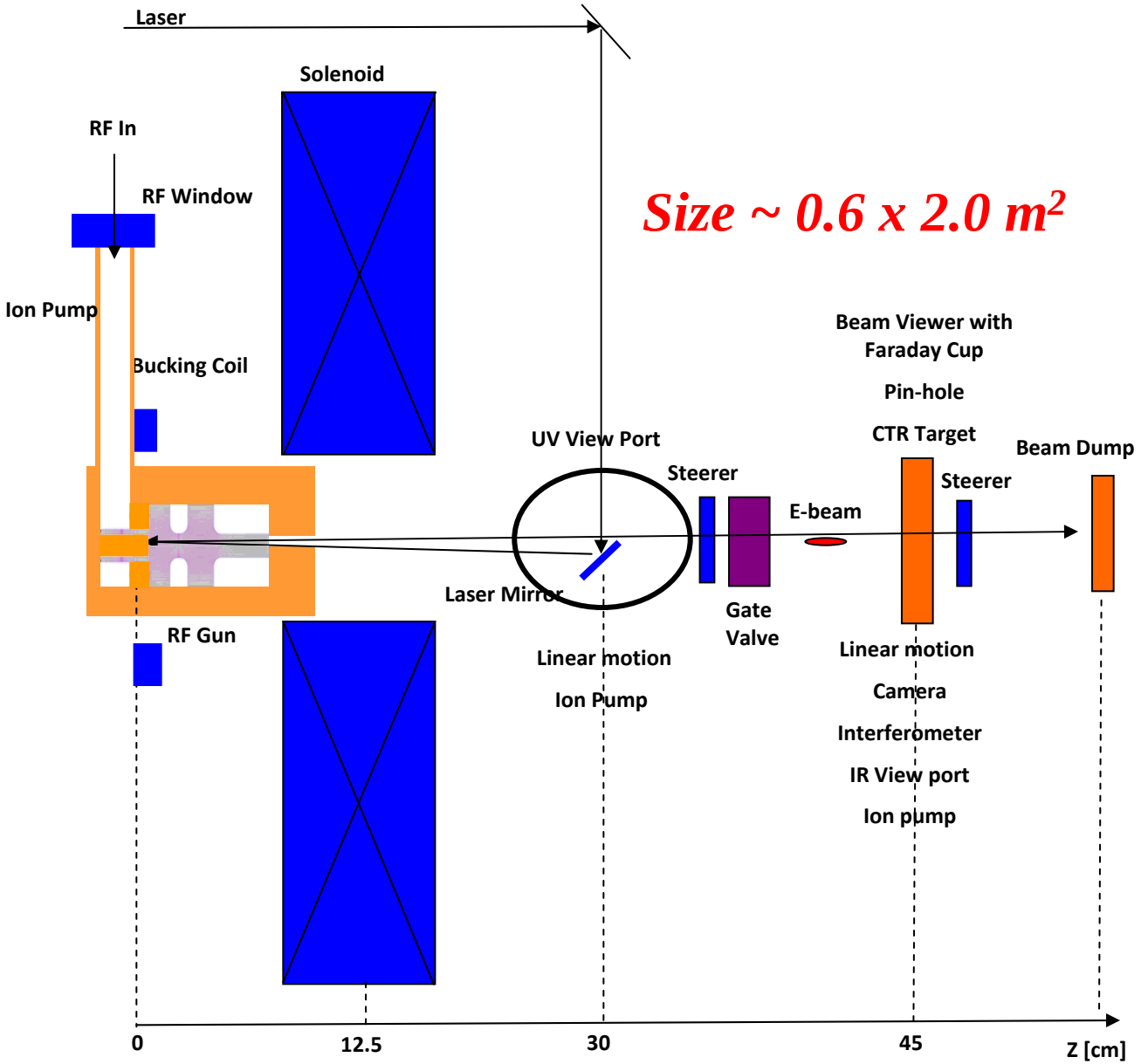
Thermo-Structural Analysis

- Frequency Shift determined on model shown below
- Waveguide not included
- Geometry as per SUPERFISH
- Frequency shift -524. kHz - Requires coolant temperature decrease of 2.8°C
- The geometry needs to be designed for an initial coolant inlet temperature of 25°C to 30°C



UED Experimental Setup

Ultrafast High-Brightness Electron Source



Size ~ 0.6 x 2.0 m²

Beam

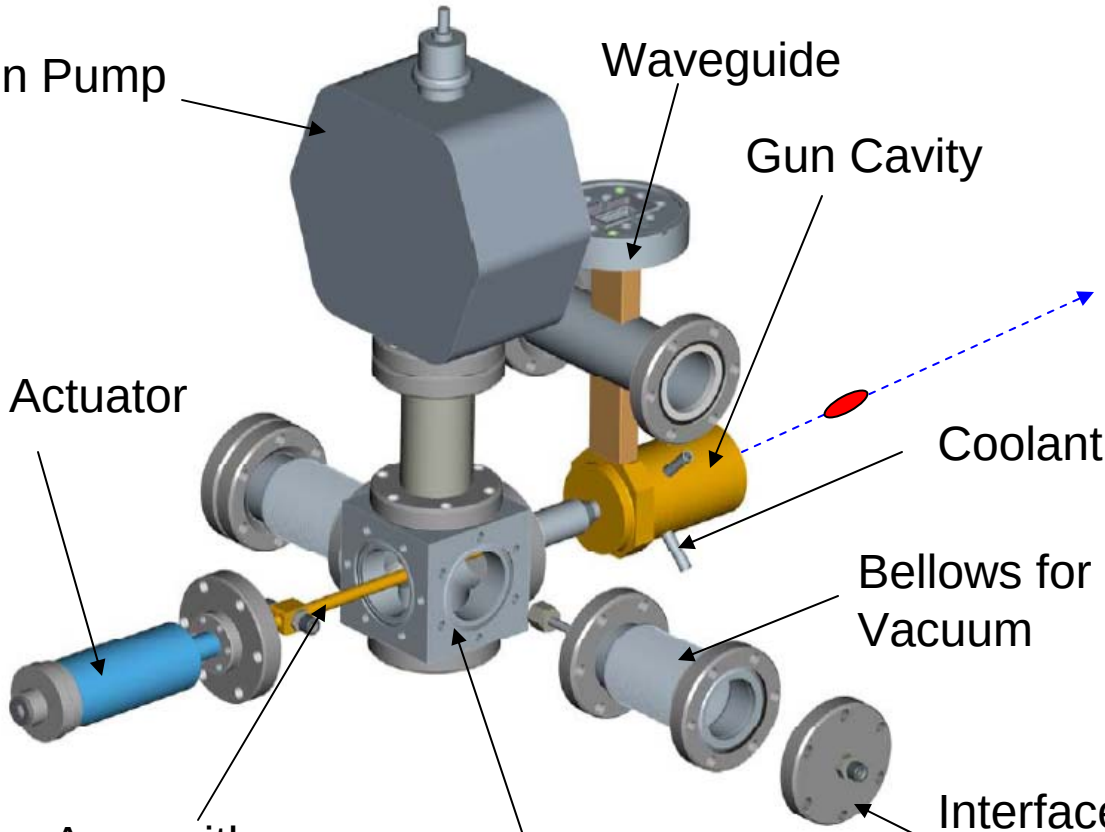
- < 50 pC
- < 2.7 MeV
- < 100 fsec
- < 3 Hz
- < 250 MV/m

RF

- ~6 MW
- 200 nsec macropulse

Laser

- < 10 μ J on cathode
- ~ 50fsec


10 l/s Ion Pump
Waveguide
Gun Cavity
Linear Motion Actuator
Coolant Inlet/outlet Tube
Bellows for Coolant Tube in Vacuum
Co-ax Probe Assy with Coolant Attachment
Blank Flange for 6-way Cube (Port not used)
Interface for CF Flange for Coolant Passage (Typ Both sides)

Ultrafast Electron Diffraction (UED) Summary

- AES is developing an ultrafast, high-brightness, electron source as an advanced X-band accelerator injector and for an ultrafast electron diffraction system
- The feasibility of an X-band, ultrafast, RF gun with a contoured copper cathode has been simulated => more than an order of magnitude beam brightness performance gain over existing S-band systems
- Rapid acceleration at high gradient in X-band coupled with cathode shaping => greatly improved brightness
- Thermo-structural analysis has verified that the modestly-cooled gun is robust and will achieve a duty factor > 4×10^{-5}
- Fabrication and installation are ongoing under a DOE SBIR Phase II grant
- Testing will be performed at the BNL ATF in 2015