AMPERE AVERAGE CURRENT PHOTOINJECTOR AND ENERGY RECOVERY LINAC

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The objective: Provide high-brightness, high-power electron beams.

10 mA is happening at JLAB, but 100-1000 mA requires a few new elements. We describe the development of

- Ampere class photoinjector
- Ampere class ERL cavity
- ERL (described in greater detail in Vladimir Litvinenko's talk and poster)

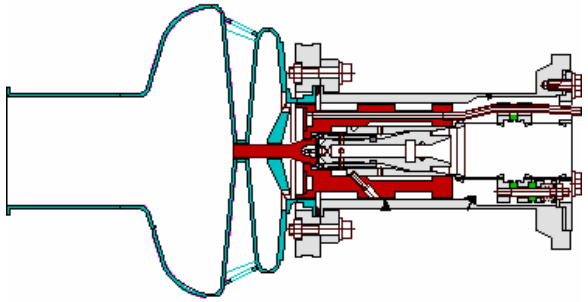
Ampere-class defined: 3000 mA ≥I >300 mA

Motivation

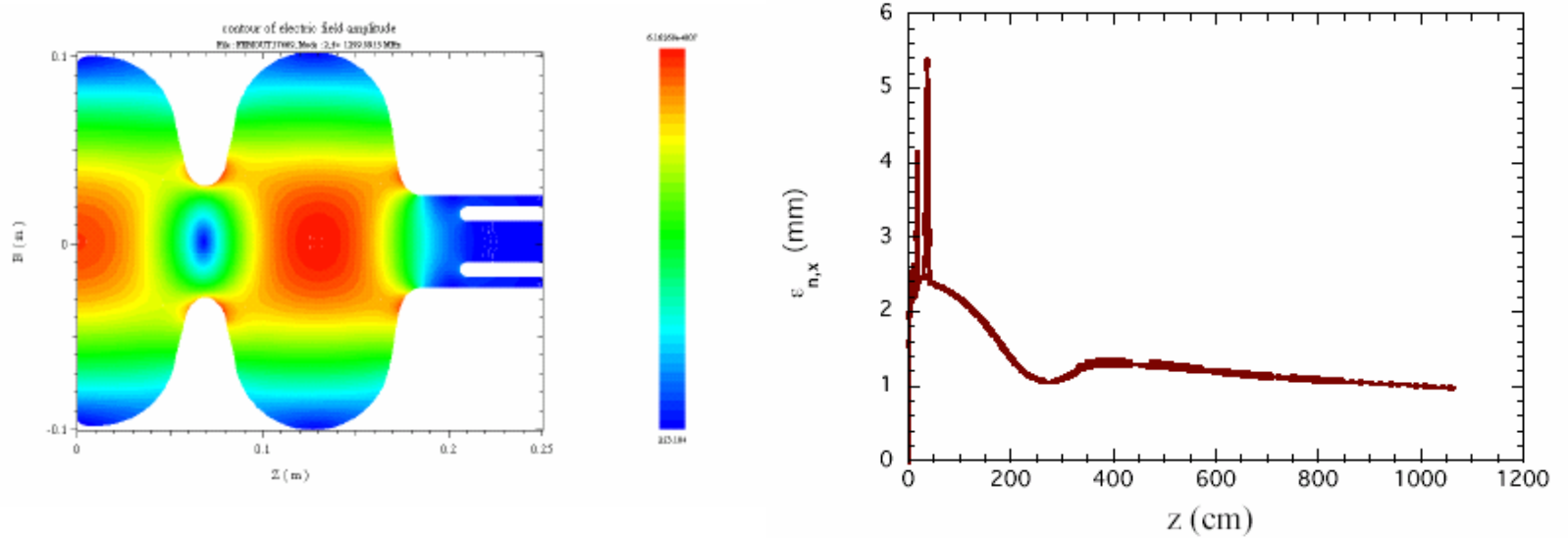
- Ultra-high power FELs
- High flux and brightness ERL light-sources
- High luminosity electron-hadron colliders
- Electron cooling of hadron colliders
- Compton X-ray sources
- THz sources

The electron gun

- We have an operational SRF gun, initial results gave 0.5 nC pulses.
- FZR demonstrated a gun with demountable cathode.
- The advantages of SRF in CW photoinjectors are obvious.



SRF Photoinjector can provide a very bright beam in CW operation!



M. Ferrario, J.B. Rosenzweig, G. Travish, J. Sekutowicz, W. D. Möller, EPAC'04

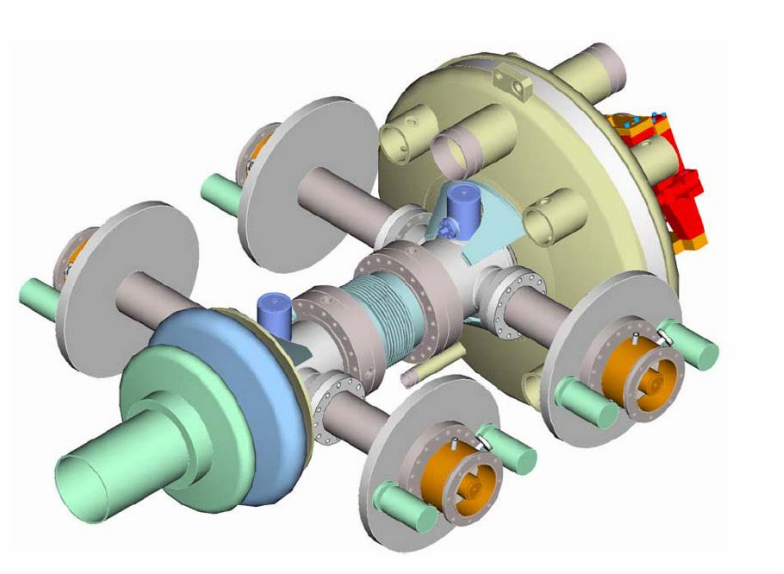
BROOKHAVEN NATIONAL LABORATORY

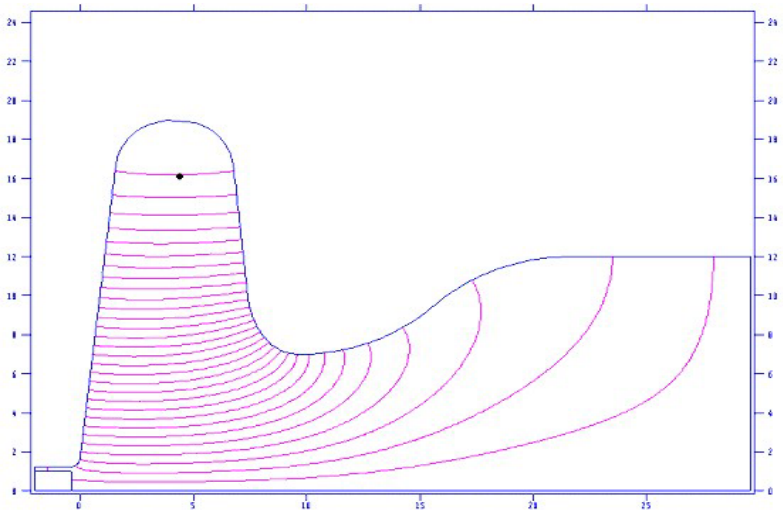
Advanced Energy Systems, Inc.

Jefferson Lab

FEL 2004 AUGUST 29 - SEPTEMBER 3 Trieste, Italy

A New SRF Photoinjector is being designed, at 703.75 MHz.





Ilan Ben-Zvi

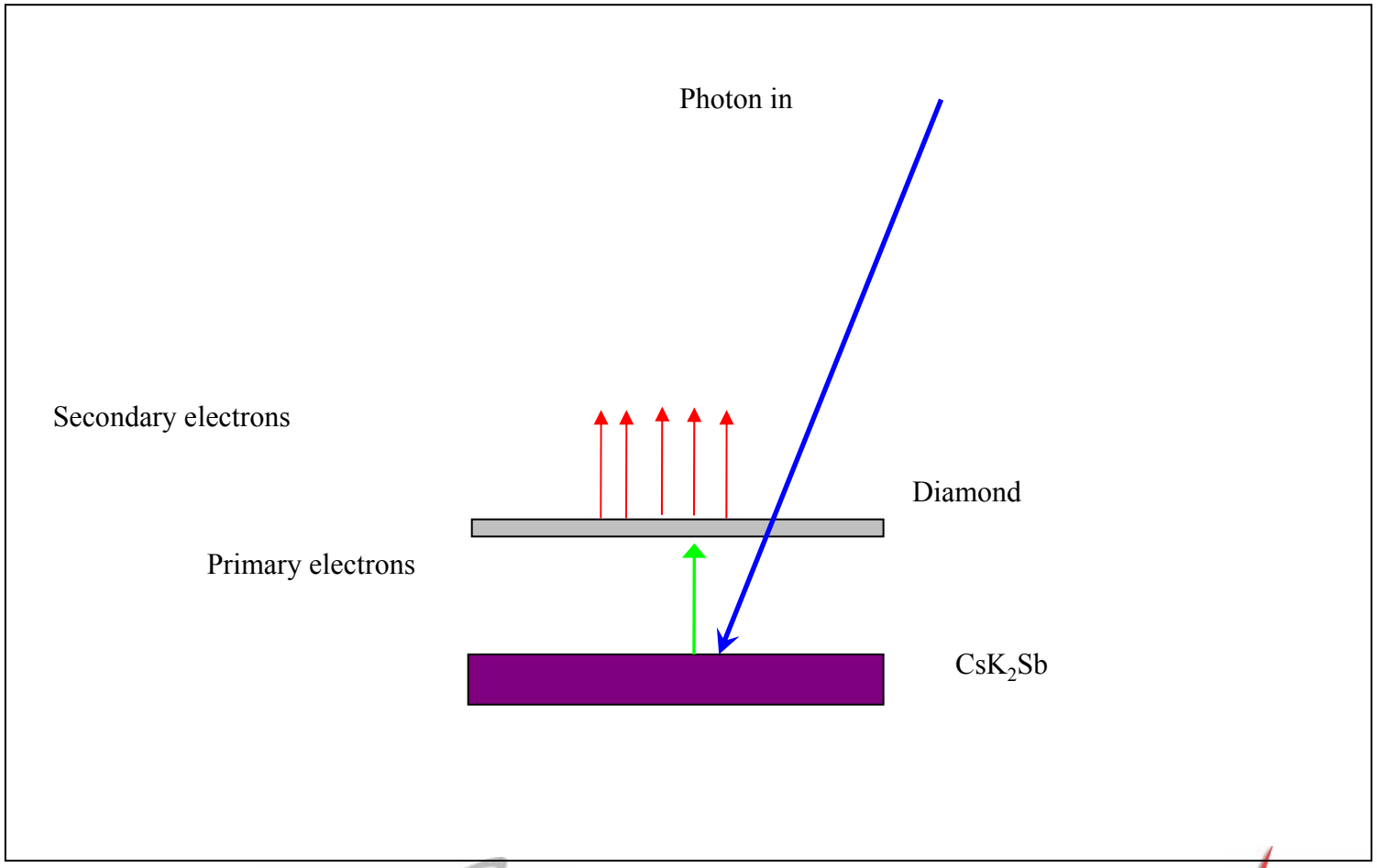
Photocathode and laser system: Arguably the critical challenge

- Cathode quantum efficiency – tied to the laser size and complexity.
- Cathode lifetime (contamination) and vacuum requirements.
- Gun contamination by cathode materials.
- Complicated load-lock mechanisms.
- Thermal emittance, promptness.

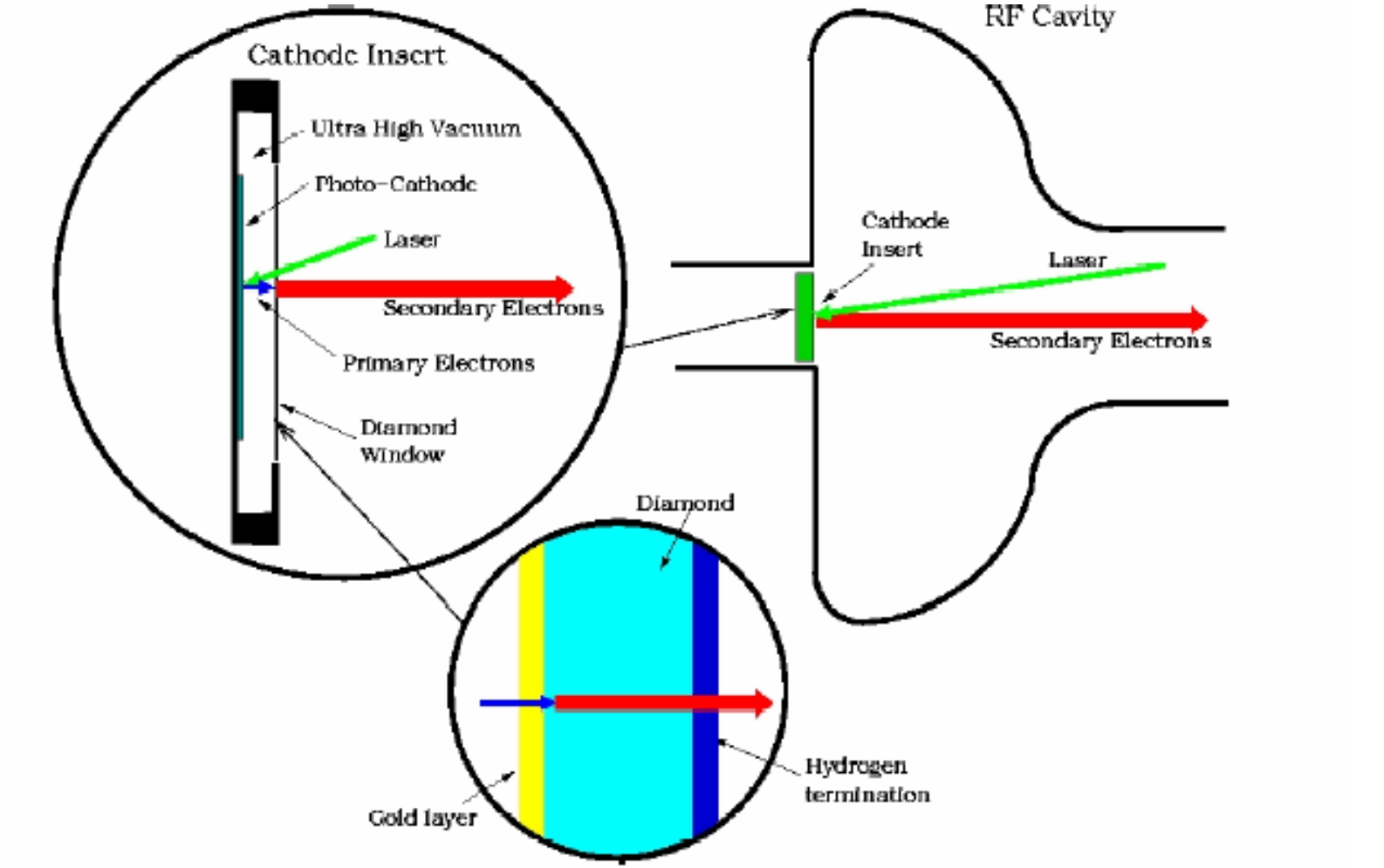
Desirable photocathode properties

- Be compatible with a superconducting gun.
- Have high quantum efficiency.
- Have long life.
- Have prompt emission.
- Sealed cathode capsule, exposable to air.
- Have a low thermal emittance.

Diamond window amplification: The basic idea



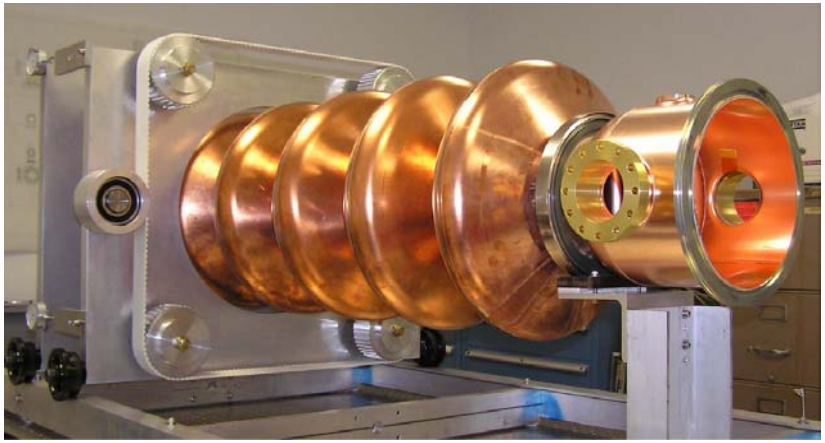
Schematic Arrangement of the System



Diamond as a Secondary emitter:

- High gain amplification: 100 or more.
- Good thermal conductivity (~300W.cm^{-1}.k^{-1} at low T).
- Negative electron affinity
- Strong mechanically (sealed capsule)
- Thickness dictated by
  - Transport time (100 ps across 10 microns)
  - Temporal spread (<5 ps for 1 nC bunches)
  - Thermal properties (about 30 watts for 0.5 amperes)
  - Mechanical properties

The Ampere-Class ERL Cavity

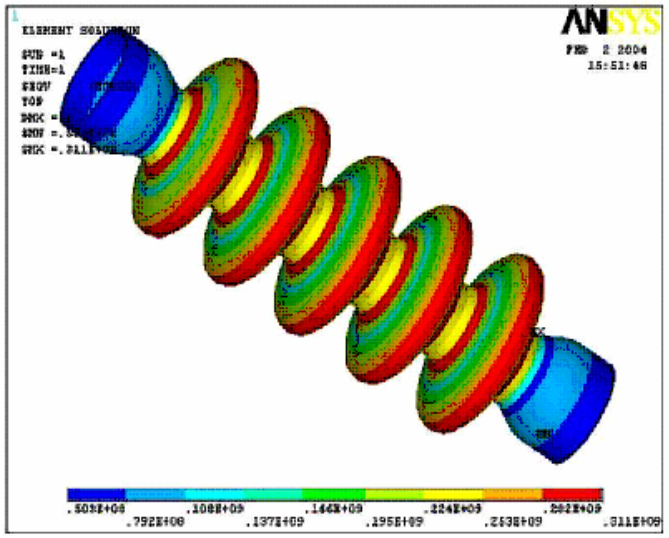


Copper model of the 703.75 MHz
high-current ERL cavity.
The niobium cavity is under construction

Cavity parameters

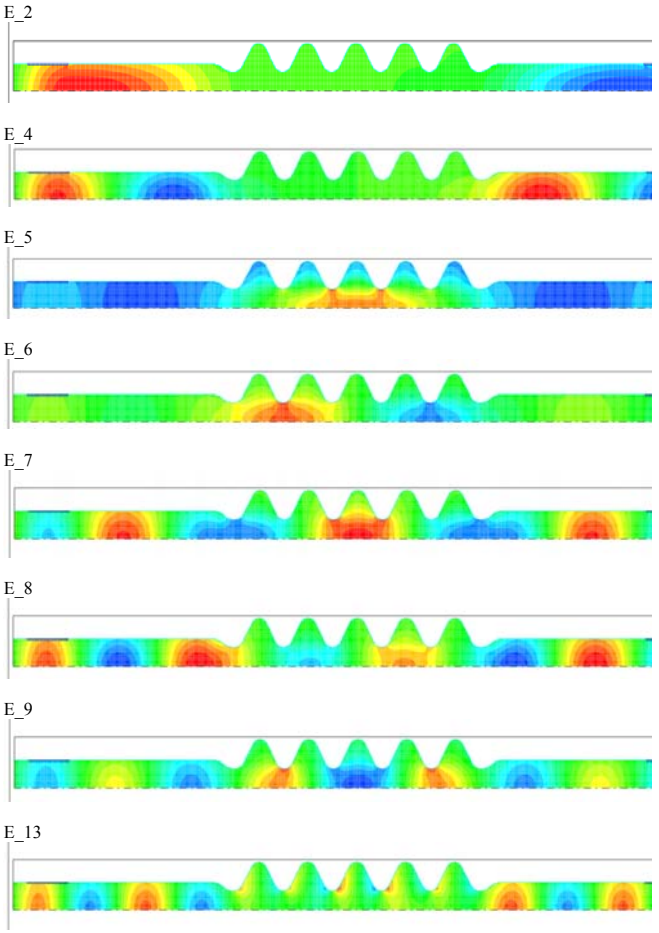
Property	Units	Value
Frequency	MHz	703.75
E_p/E_a	-	2.0
H_p/E_a	mT/(MV/m)	5.8
R/Q	Ω	807
Geometrical factor	Ω	225
Cell-to-cell coupling	%	3
Expected unloaded Q	-	$2x10^{10}$
Dynamic power loss	Watt	22
External Q	-	$2x10^{7}$
Max. amplifier power	kW	50
1st Mechanical resonance	Hz	96
Lorentz detuning	$Hz/(MV/m)^2$	1.5
Loss factor	V/pC	1.2

Detailed Computer Simulation



MAFIA:
All modes
well damped

ANSYS:
Cavity very
stiff. Lowest
mode (no
LHe tank)
is ~100 Hz

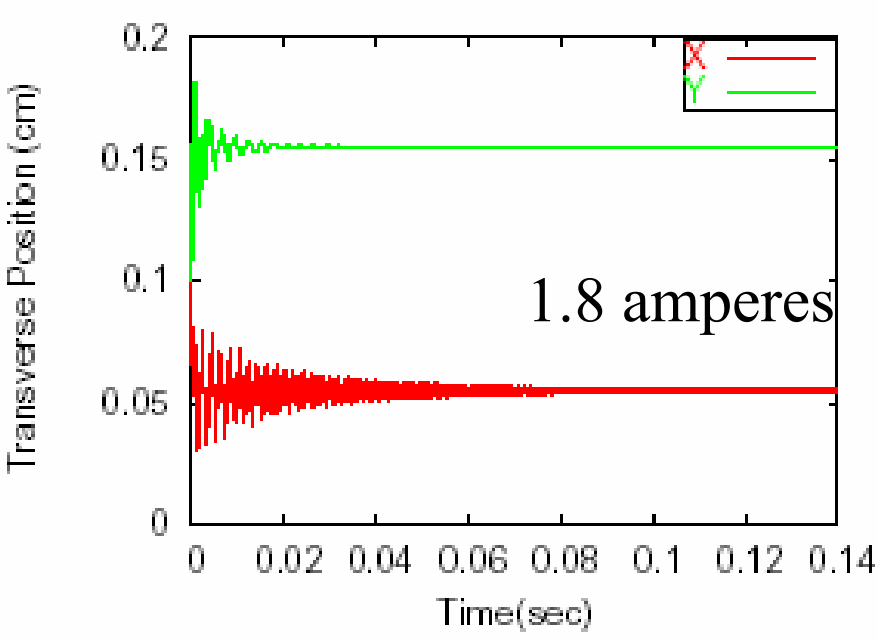


Other codes used:
BUILDCAVITY / SUPERFISH
ABCI, TDBBU, MATBBU

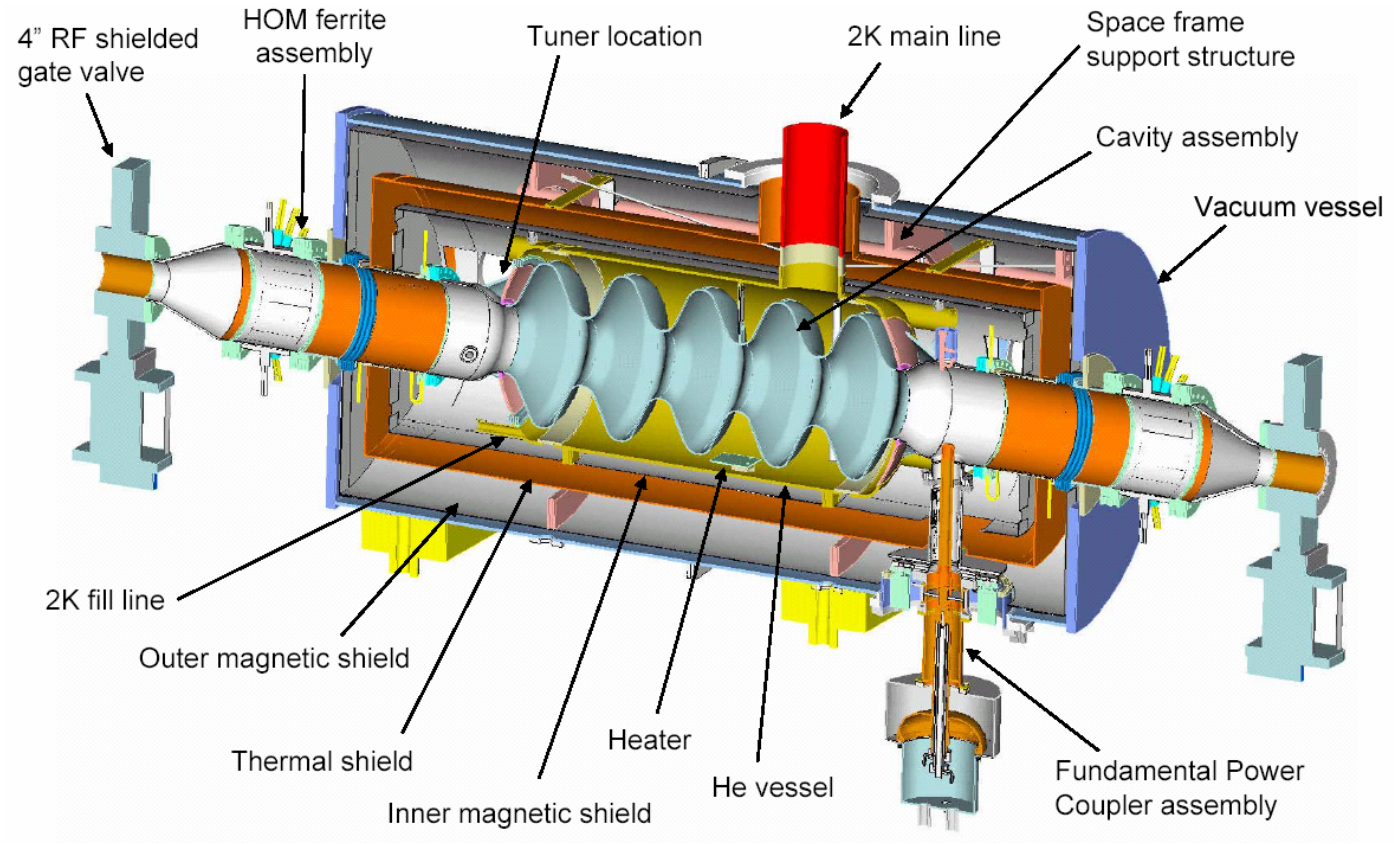
How to make a linac cavity capable of over 1 ampere?

- Good cavity / HOM design, using very large beam ports to guide HOM to ferrite absorbers.
- Design has excellent SRF cavity properties, low loss factor and high BBU threshold

TDBBU:

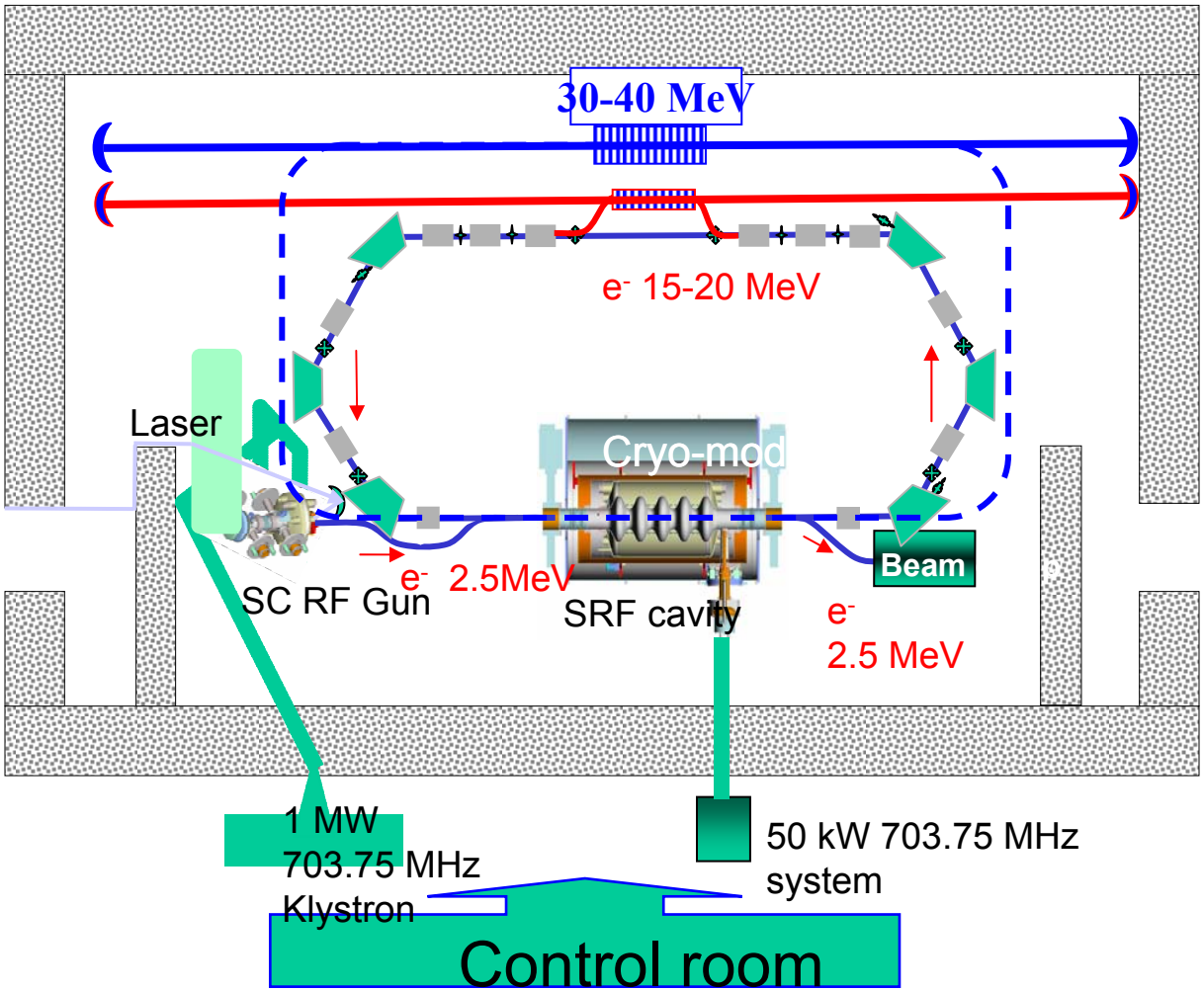


Cryomodule design passed Final Design Review



ERL Program

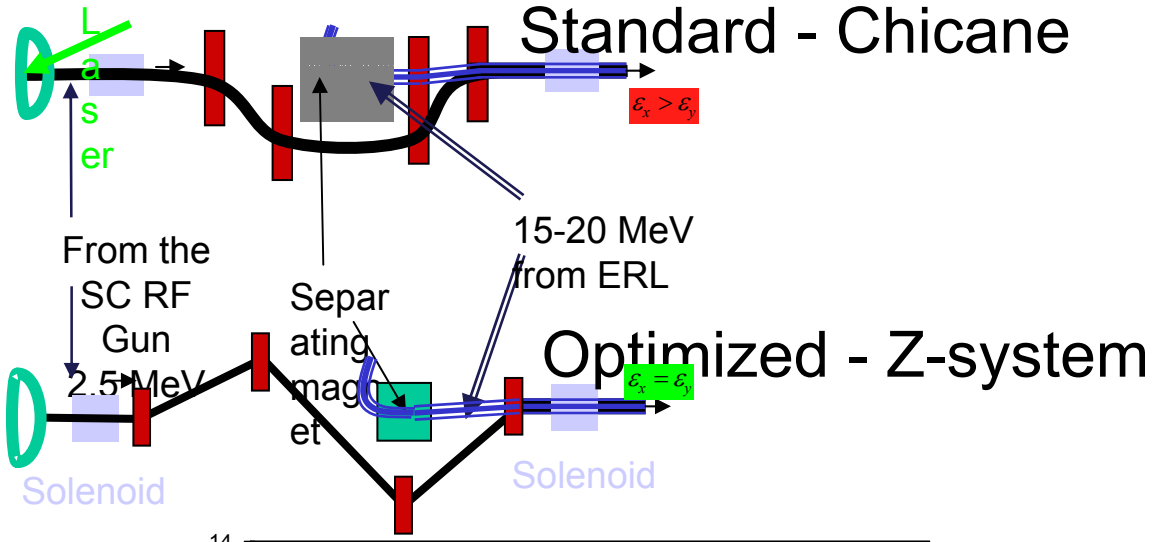
- The components described above will be used to construct a R&D ERL.
- **We plan to start commissioning of the R&D ERL in late 2006/early 2007**
- The prototype ERL will demonstrate the main parameters of the e-beam required for e-cooling
- The prototype will also serve as a test bed for studying issues relevant for very high current ERLs and high power FELs

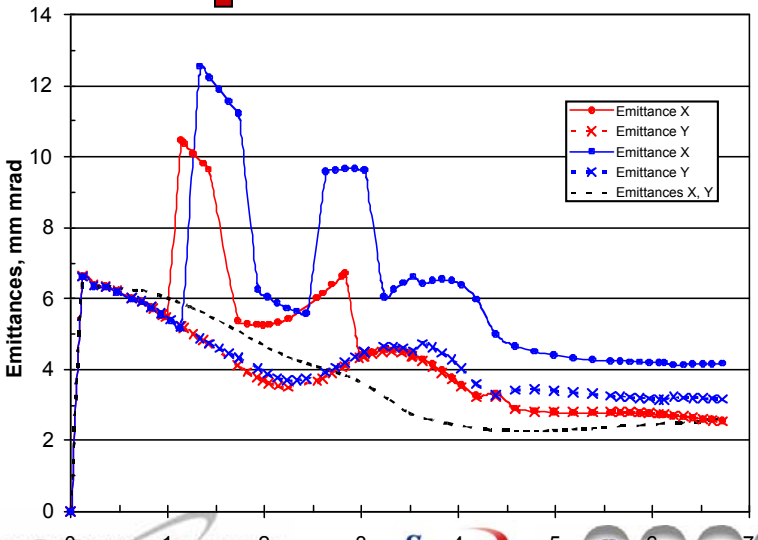

30-40 MeV
e- 15-20 MeV
Laser
Cryo-mod
Beam
e- 2.5MeV
SC RF Gun
SRF cavity
e-
2.5 MeV
1 MW
703.75 MHz
Klystron
50 kW 703.75 MHz
system
Control room

ERL / FEL parameters

• **Energy [MeV]**	**20 → 40**
• Charge/bunch (nC)	1.3
• Bunch frequency (MHz)	352
• **Wavelength [μm]**	**10 → 2.5**
– *with micro-wiggler*	*(5 → 1)*
• Beam Power (MW)	**10 → 20**
• FEL ext. efficiency	**1%**
• **FEL power (kW)**	**100 → 200**

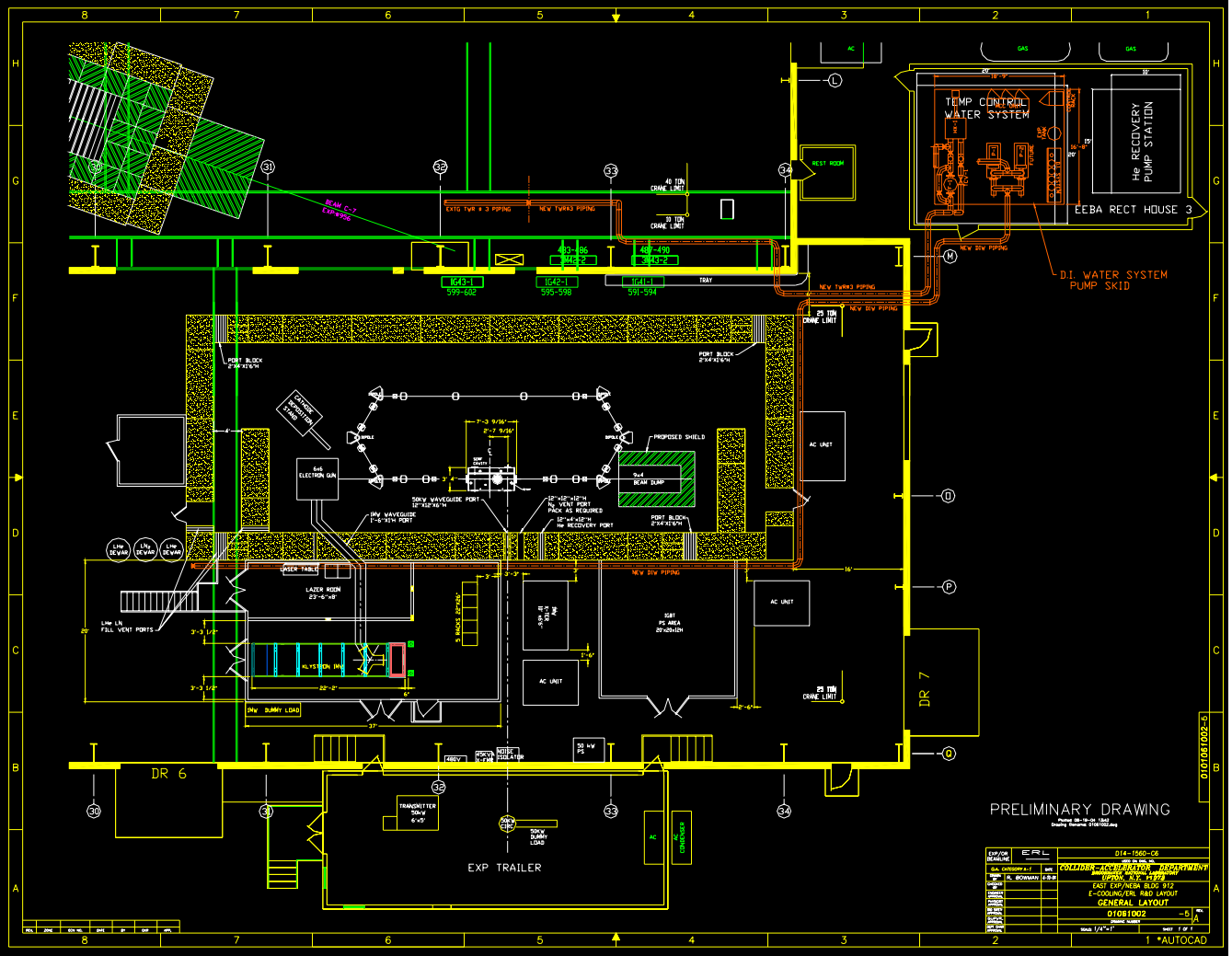
Improved beam merging optics





Bldg 912 July 04

50 kW amplifier



Conclusions

- A number of new developments are followed towards the production of ampere-class high-brightness electron beams. These include:
  - Gun
  - Photocathode
  - ERL cavity
  - ERL
- A construction and experimental program are in place with a goal of commissioning in late 2006 or early 2007.