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High-brightness CW ERL Gun R&D

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APS/Users Monthly Operations Meeting

Dec. 13, 2006

Introduction

- ERL requirements ***very*** demanding on electron gun
- Grand challenges:
  - Extremely low emittance AND
  - High average current
- Physics and engineering of high brightness guns have long been pursued – performance achieved but at low duty factors
- Interest in high-average-power FELs and ERLs is driving a vigorous CW gun R&D effort world-wide

Thanks to Manoel Conde, John Lewellen, Yuelin Li, Ali Nassiri, Yin-e Sun, and Marion White for discussions and input

Representative ERL gun requirements

Cornell ERL Parameters[1] Scaled to 7 GeV

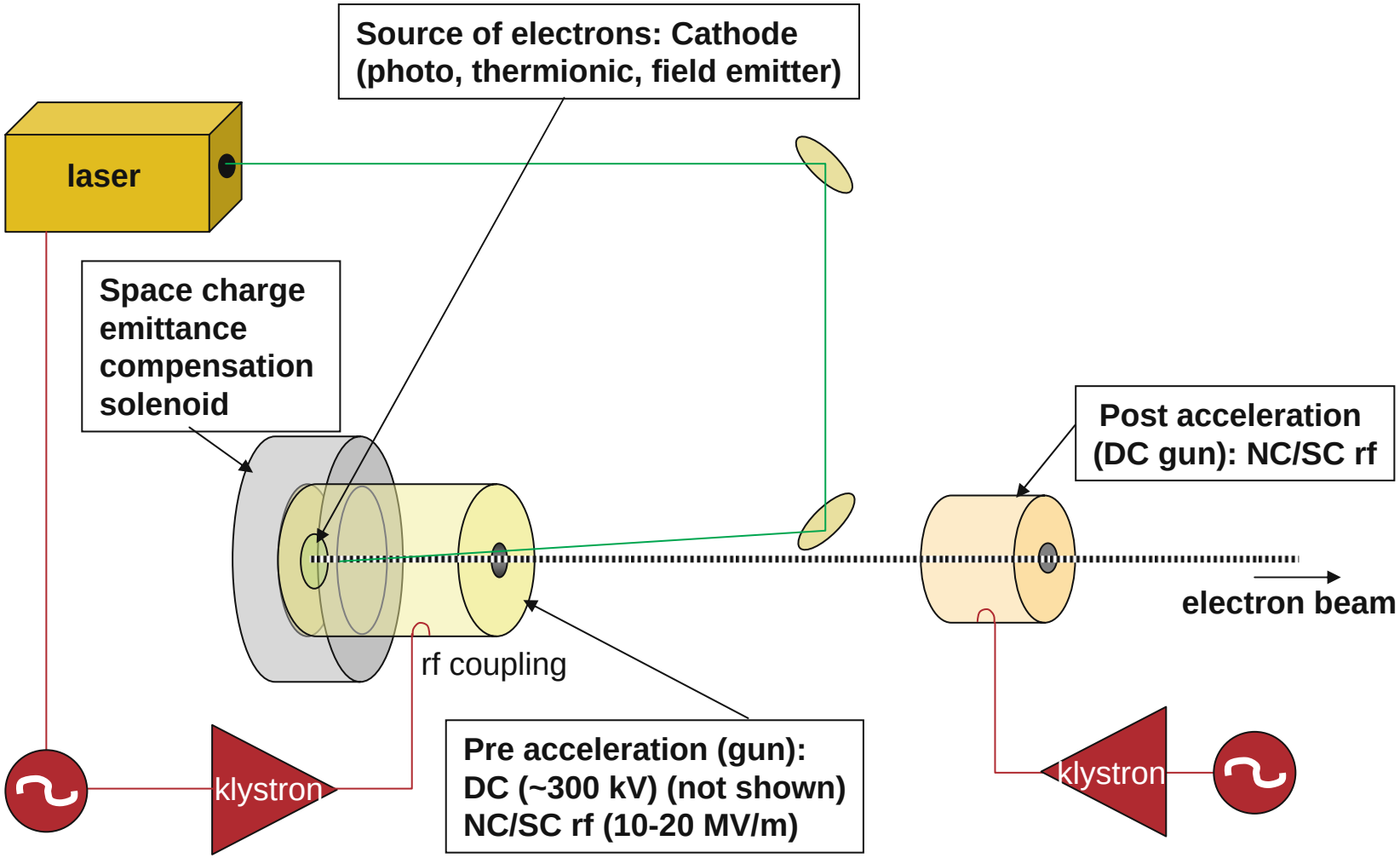
	APS	ERL		
	now	High flux	High coherence	Ultrashort pulse
Average current (mA)	100	100	25	1
Repetition rate (MHz)	0.3~352	1300	1300	1
Bunch charge (nC)	0.3~60	0.077	0.019	1
Emittance (nm)	3.1 x 0.025	0.022 x 0.022	0.006 x 0.006	0.37 x 0.37
Rms bunch length (ps)	20 ~ 70	2	2	0.1
Rms momentum spread (%)	0.1	0.02	0.02	0.3

[1] G. Hoffstaetter, FLS 2006 Workshop, DESY

- Promise of very high brightness due to very low emittance & energy spread, even for 25 mA
- Different modes may not use the same gun

Slide courtesy M. Borland, MAC presentation

Anatomy of an ERL gun/injector



Schematic adapted from D.C. Nguyen, LANL

Compiled by Y.-E. Sun

	Operational ERL guns			ERL guns under commission	
Facility	**JLab ERL FEL**	**JAERI ERL**	**BINP ERL FEL**	**Daresbury ERLP**	**Cornell ERL**
Gun type	DC	DC	DC	DC	DC
Voltage (kV)	350	230	300	350	300 (750)*
Cathode	photocathode (GaAs)	thermionic	thermionic	photocathode (GaAs)	GaAs or GaAsP
Average current (mA)	10	5	20 ~ 40	6.5	100*
Beam energy after booster (MeV)	7~10	2.5	2	8.35*	5 ~ 15*
Booster type	SC rf	SC rf	NC rf	SC rf	SC rf
Booster frequency (MHz)	1497	499.8	180	1300	1300
Norm. rms emit (μm)	<10	30	32	1.5*	<1*
Note				first beam in 08/2006	first beam 09/2006

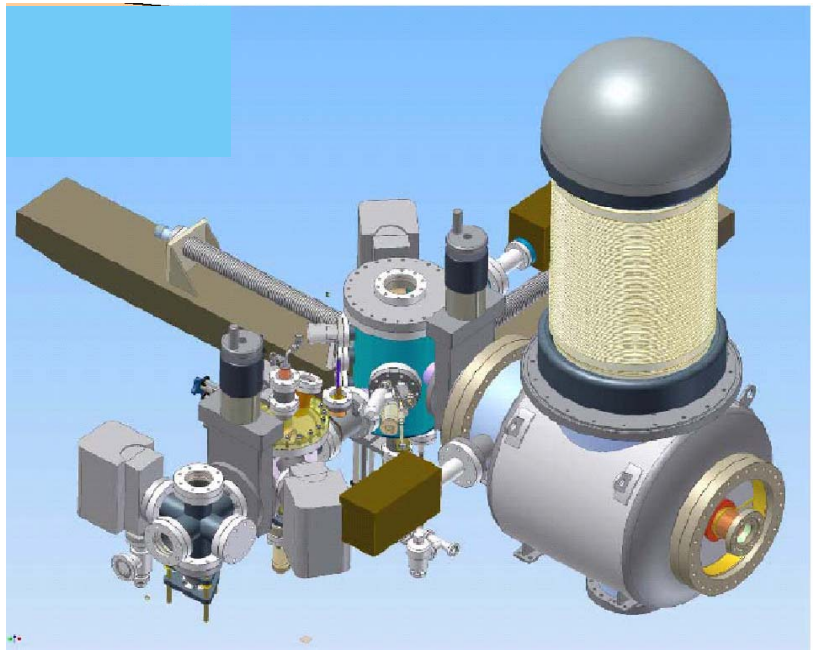
ε = 0.07 nm @ 7 GeV

Normalized emittance $\varepsilon_N = \varepsilon\gamma = \varepsilon(14000)$

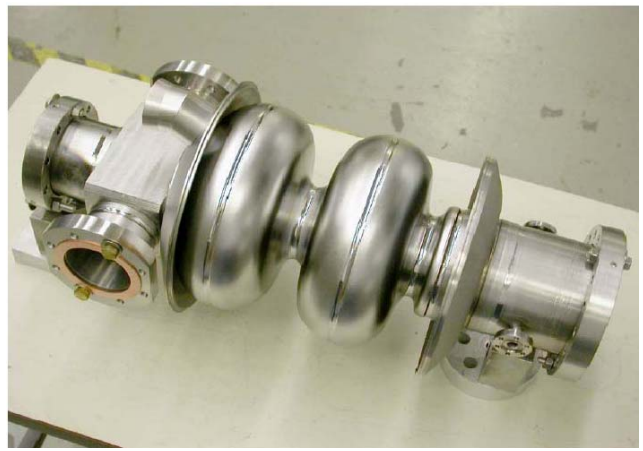
*** design values**

DC gun challenges

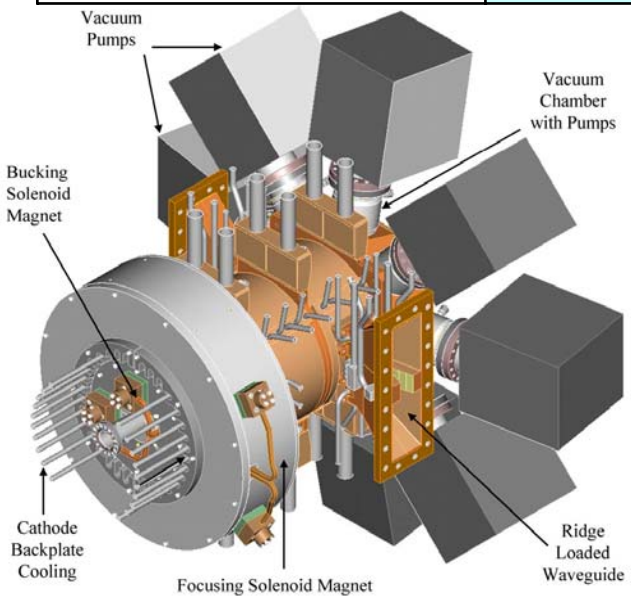
- Photocathode QE, lifetime
- XUHV req'd, < 0.1 nT
- Space charge emittance compensation (solenoid)
- Voltage breakdown issues – high standoff ceramic
- Power supply: 100mA x 750kV = 75 kW
- Drive laser or high voltage pulser or buncher
- Safety, reliability, stability



Cornell DC gun + SC rf booster (S. Gruner)



	ERL guns under development			
Facility	**Rossendorf, Germany**	**LANL/AES**	**BNL/AES**	**Peking Univ., China**
Gun type	SC rf	NC rf	SC rf	DC + SC rf
Gun frequency (MHz)	1300	700	703.75	1300
Cathode	Cs_2Te	multi-alkali	multi-alkali /diamond	Cs_2Te
Average current (mA)	1	100	500	1.6 -- 5 (0.27 achieved)
Norm. rms emit (μm)	0.5 – 2.5	6	2	3 – 5 (achieved)
Energy at gun exit (MeV)	9.5	2.5	2	2.6 (1.1 achieved)



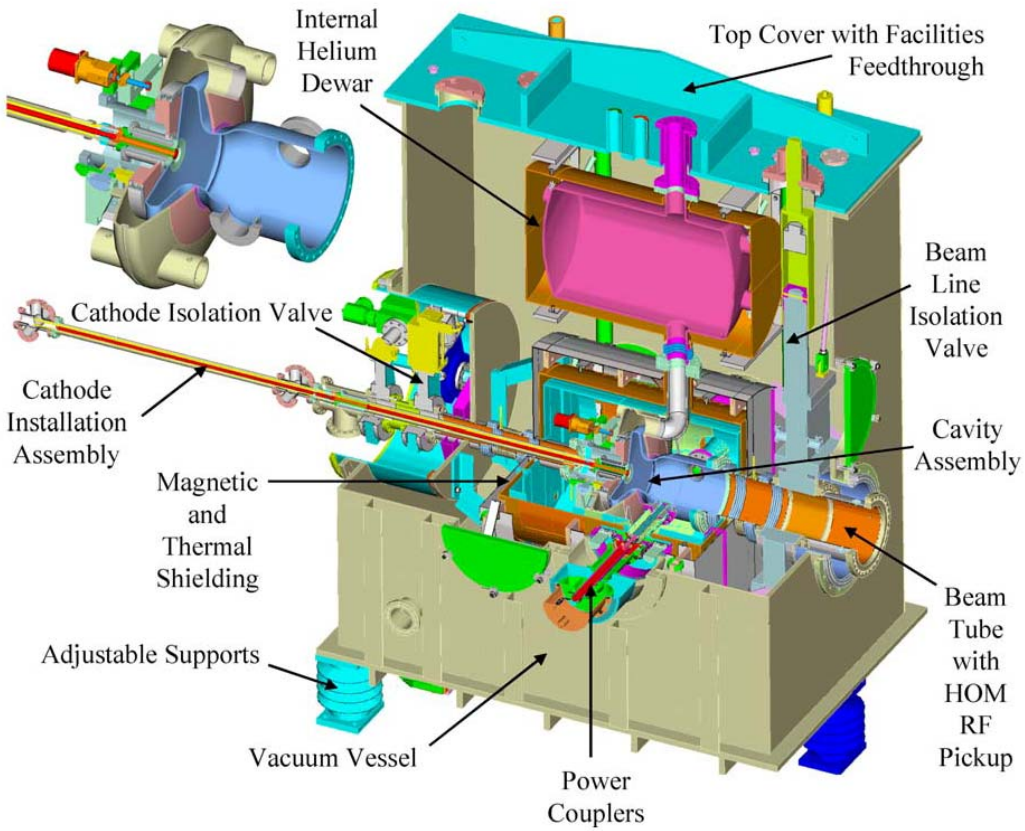
Compiled by Y.-E. Sun

Predecessor holds record: 32 mA, ε_N ~7μm

Thermal/vacuum management:
100 mA NC rf gun dissipates 800 kW!

SC RF gun challenges

- Least mature, most promising
- Cathode compatibility with rf and SC environment
- Thermal isolation and integration of cathode (laser power) with cavity
- Emittance compensation: magnetic shielding req'd, can't use solenoid
- Drive laser
- Reliability
- …



AES/BNL SC rf gun (A. Burrill et al)

Towards R&D program at APS: expertise/facilities

- APS
  - Laser physics, gun dynamics theory and modeling, NC/SC rf, Injector Test Stand, photocathode NC rf gun operation for LEUTL, engineering, photocathode theory
- Argonne
  - HEP, Advanced Wakefield Accelerator group: high QE photocathodes, NC rf gun, modeling and design
  - PHY: SC rf
  - AST-ONR: CW guns, high avg power FELs (Navy)
  - MSD: cathodes, ceramics
- Local area
  - FNAL: high brightness injector, ILC R&D, dynamics, SC rf
  - Universities: NIU, …

Summary

- ERL CW guns extremely challenging: pushing significantly beyond present state-of-the-art
- Performance goal: to achieve very low emittance and high average current
- R&D is vigorously being pursued world-wide; planning at APS underway
- All are welcome to attend ERL Journal Club (send me email): http://www.aps.anl.gov/Accelerator_Systems_Division/Accelerator_Physics/