Current Topics in Injector R&D

USPAS - 20 June 2013

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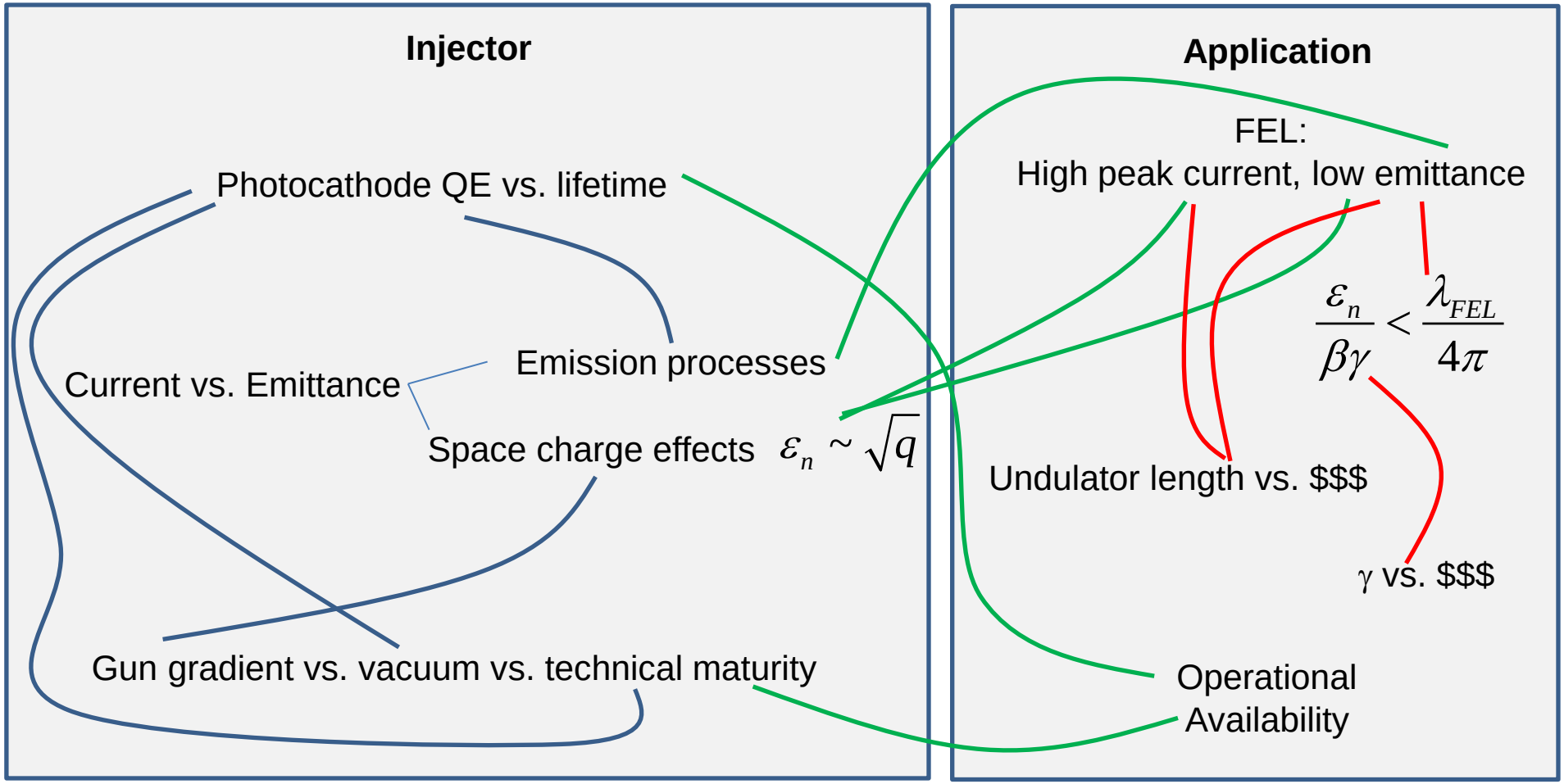
Tradeoffs

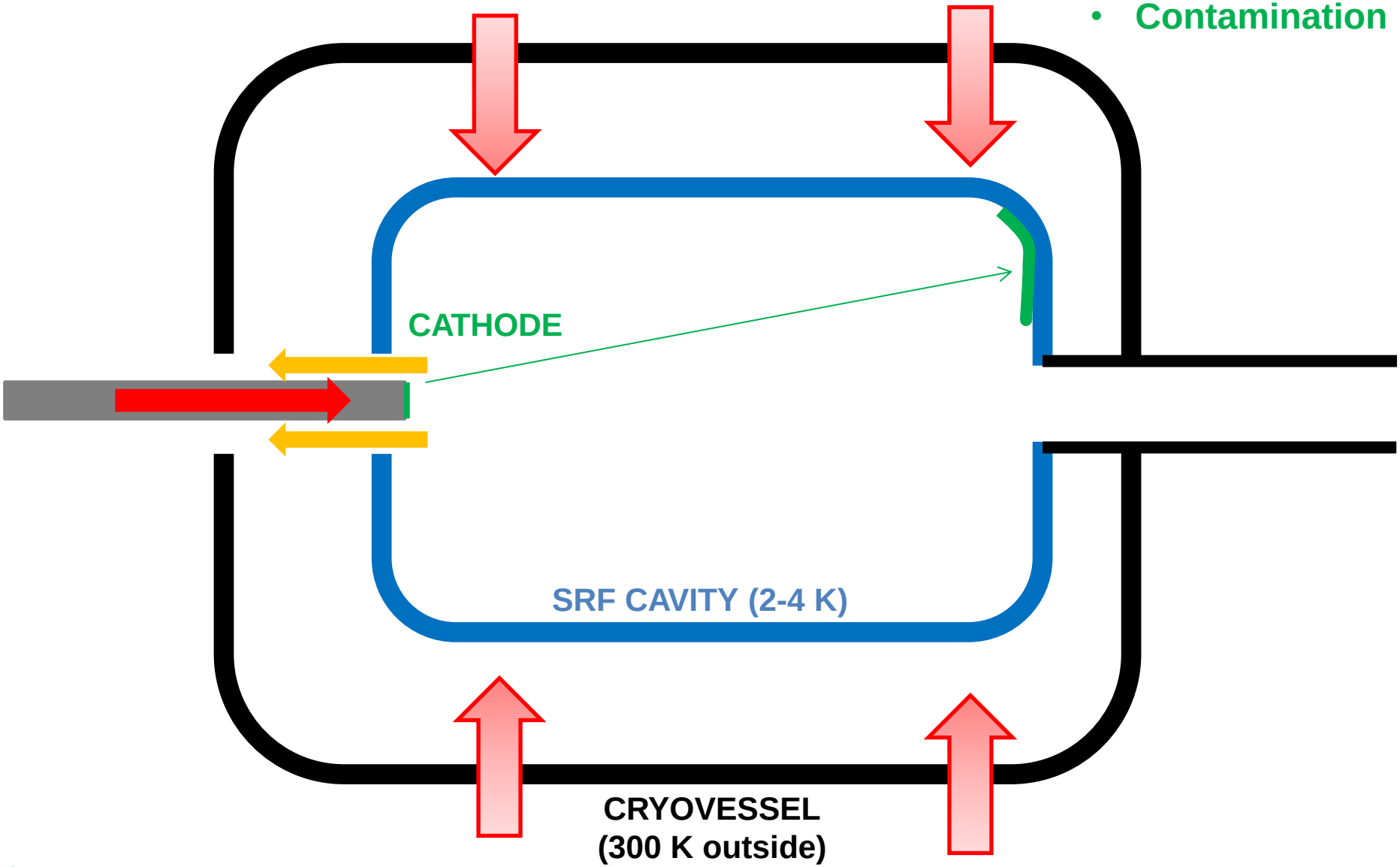


How can we relax these tradeoffs

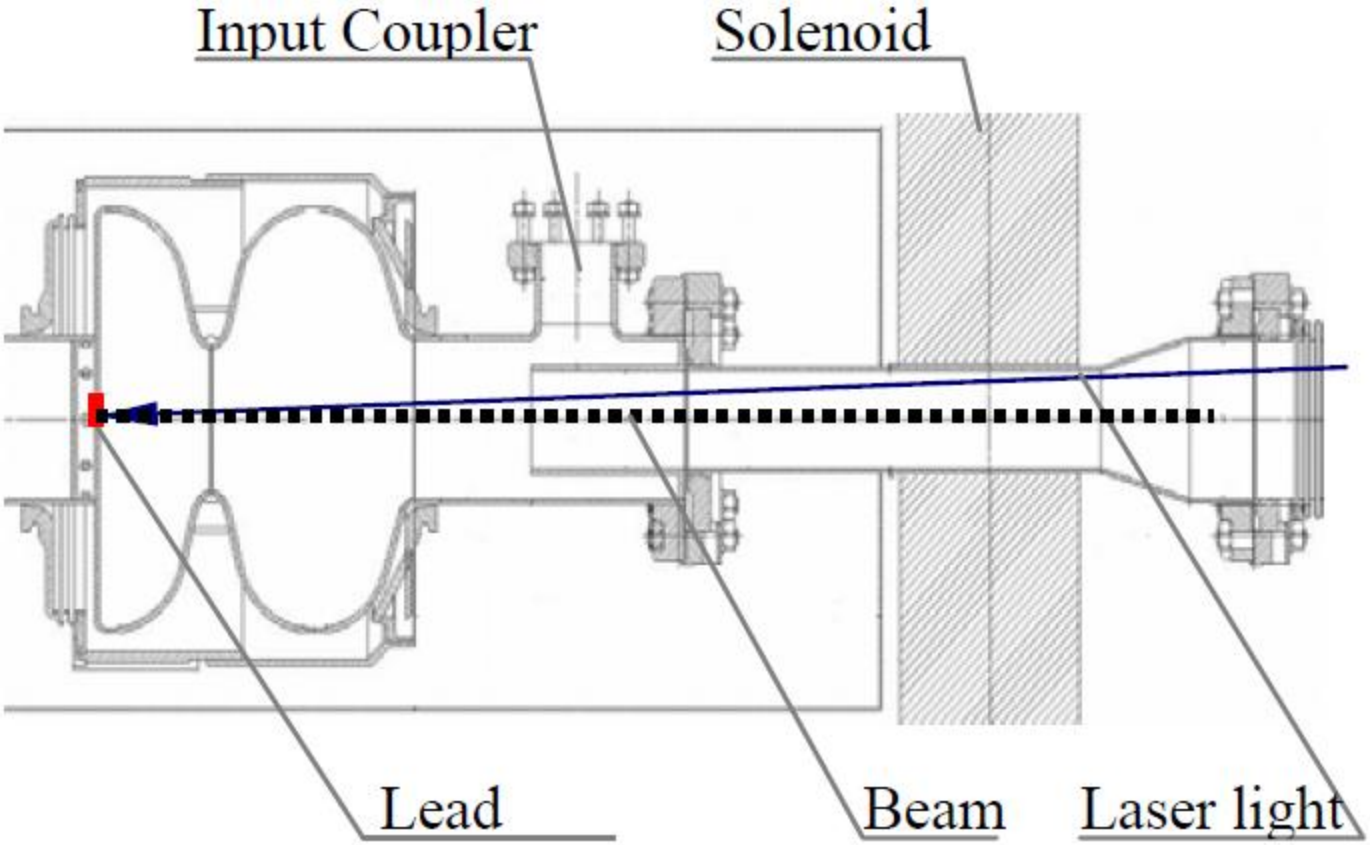
to provide more flexibility for injector designers?

Photocathodes for SRF Guns:
Integration Challenges

- Heat Leaks
- RF Leaks
- Contamination

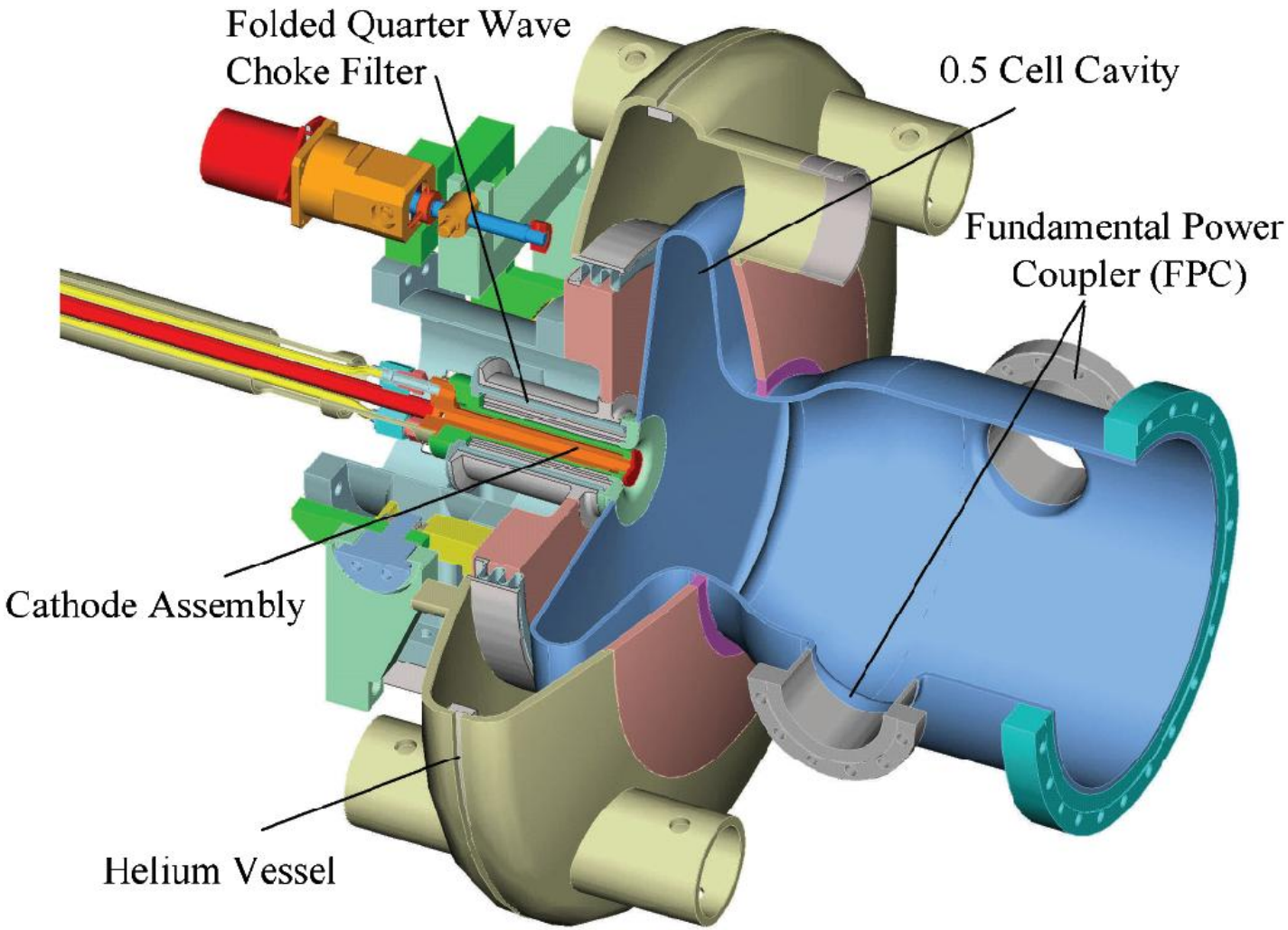


Superconducting Cathode (BNL)



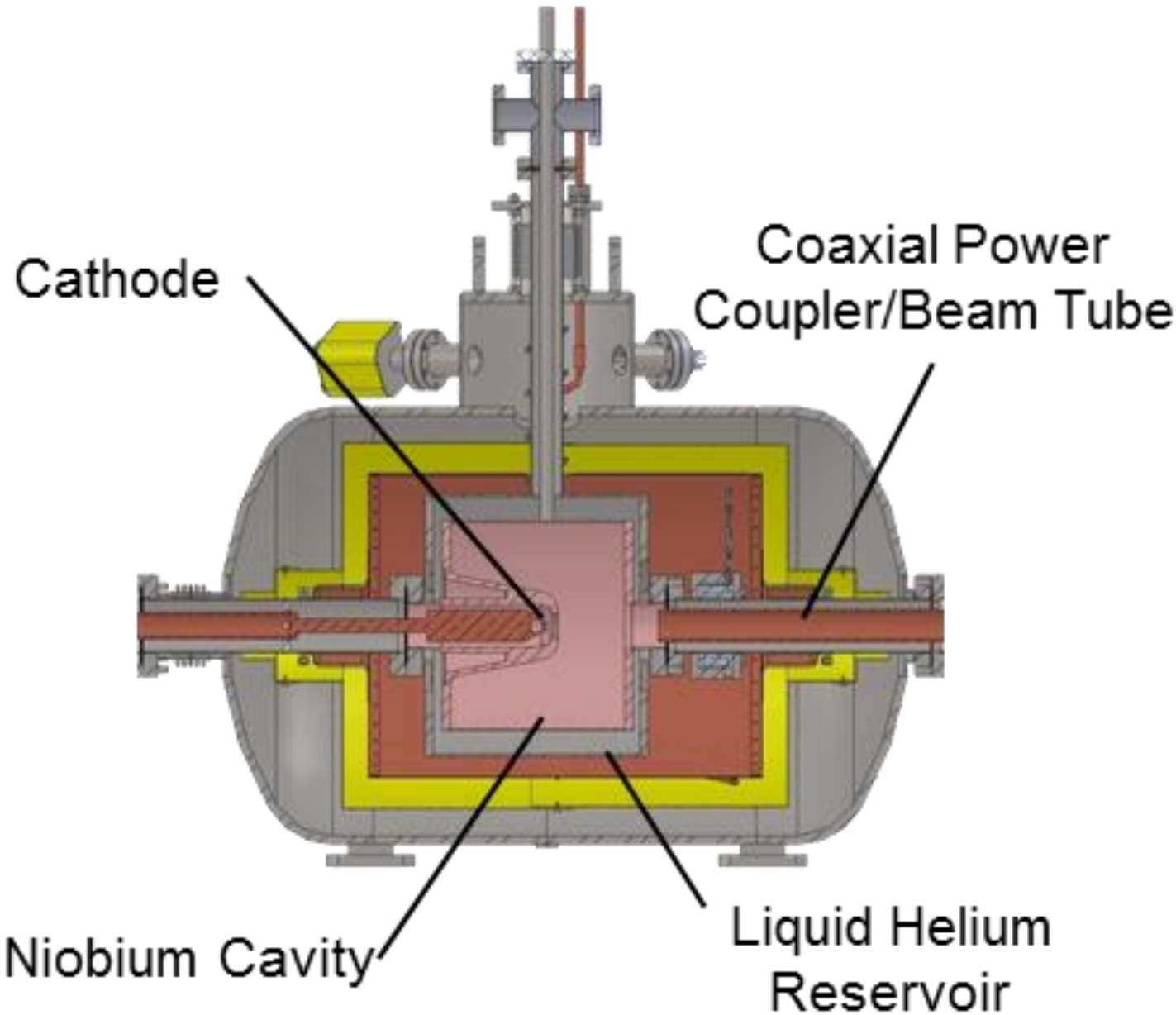
Sekutowicz, et al., “Nb-Pb superconducting RF-gun”
TESLA-FEL Report 2005-09/SLAC-PUB-11792 (2005)

Isolated Cathode with Choke Joint (BNL/AES)



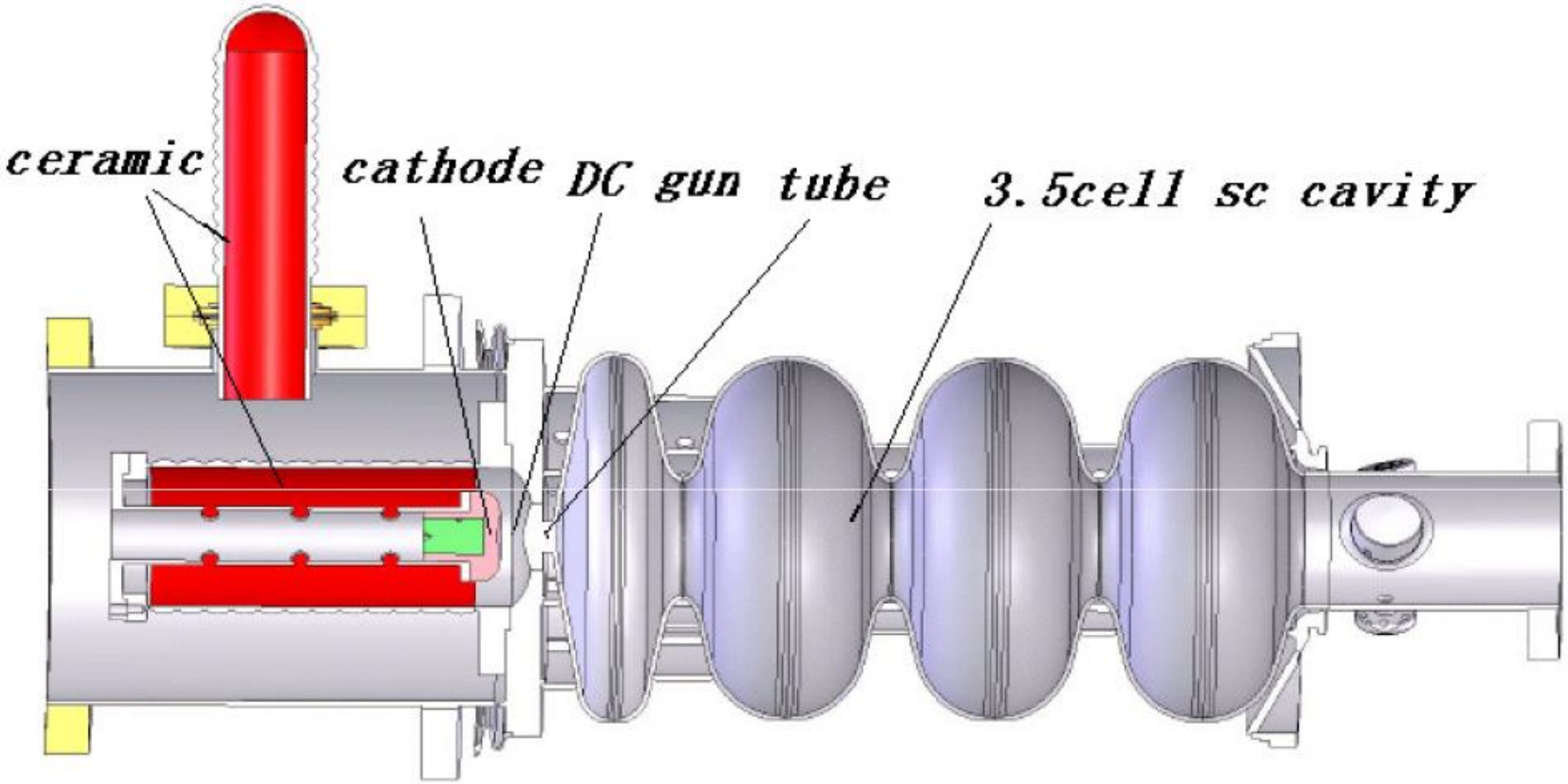
A. Arnold and J. Teichert, PRSTAB 14 024801 (2011)

Isolated Cathode, Stalk Radius Discontinuities (NPS/Niowave)



J.R. Harris, et al., PRSTAB 14, 053501 (2011)

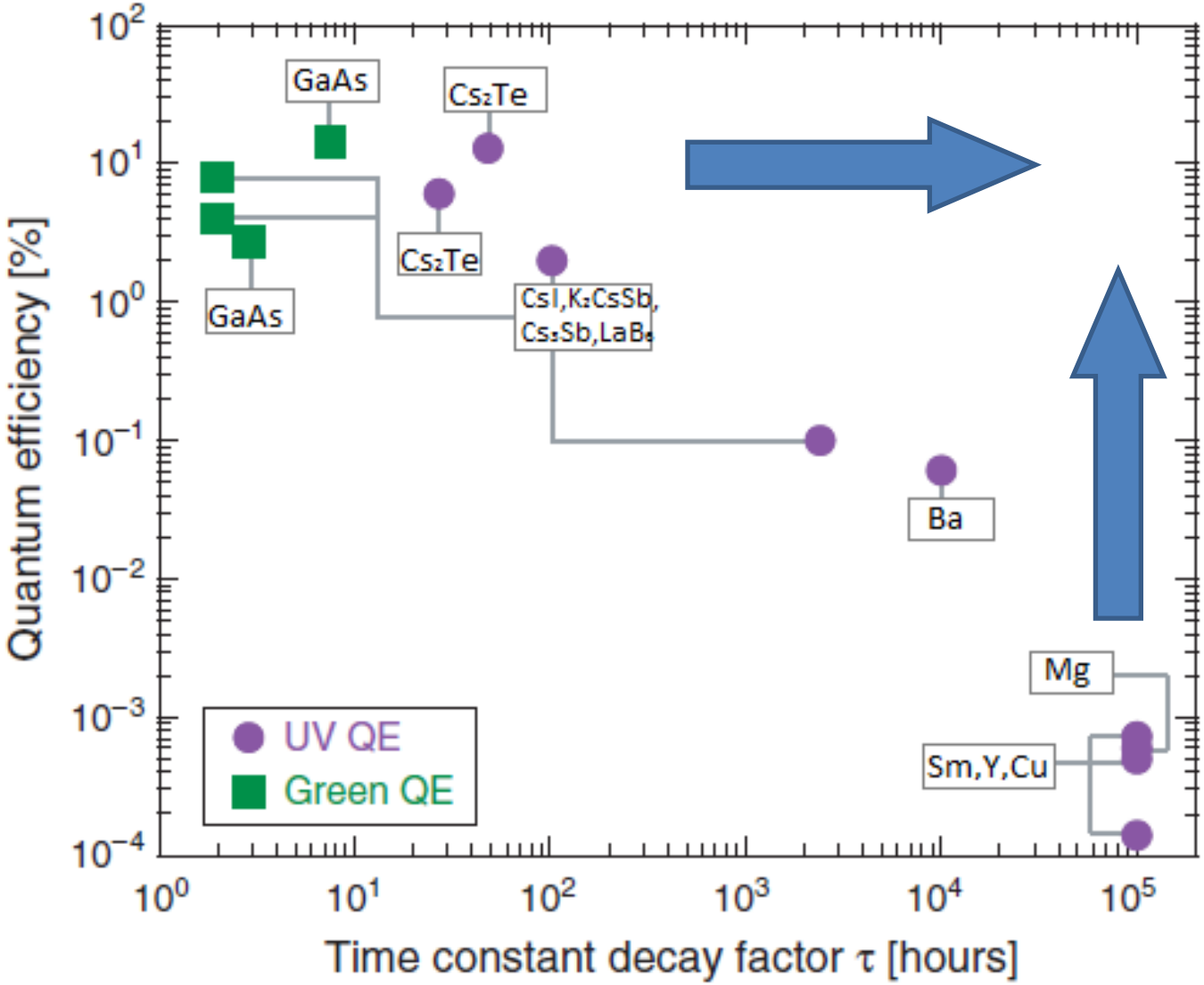
Hybrid DC/SRF (Peking University)



100KV DC gun and 3+1/2 cell cavity

Zhao & Liu, Proc. ERL 2009

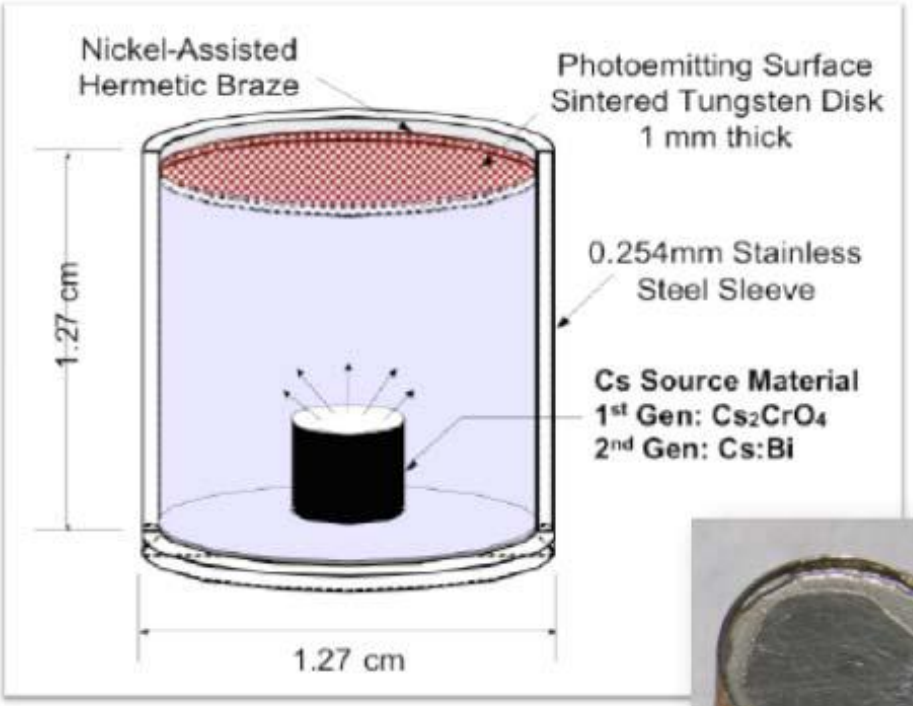
Photocathode Lifetime vs. QE

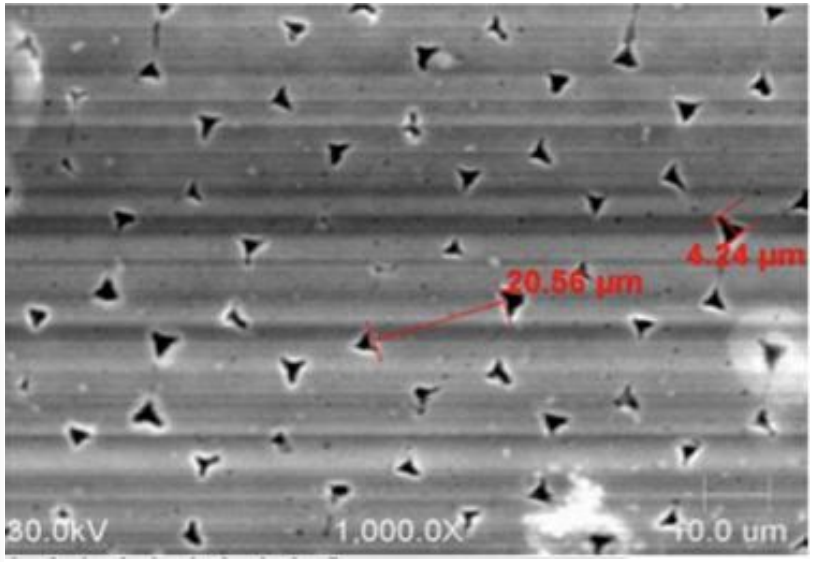


Jensen & Montgomery, J. of Comp. and Theo. Nanosci. **6**, 1754-1769 (2009).

Dispenser Photocathodes (UMD/Calabazas Creek)

Self-Healing Cathodes to Extend Lifetime

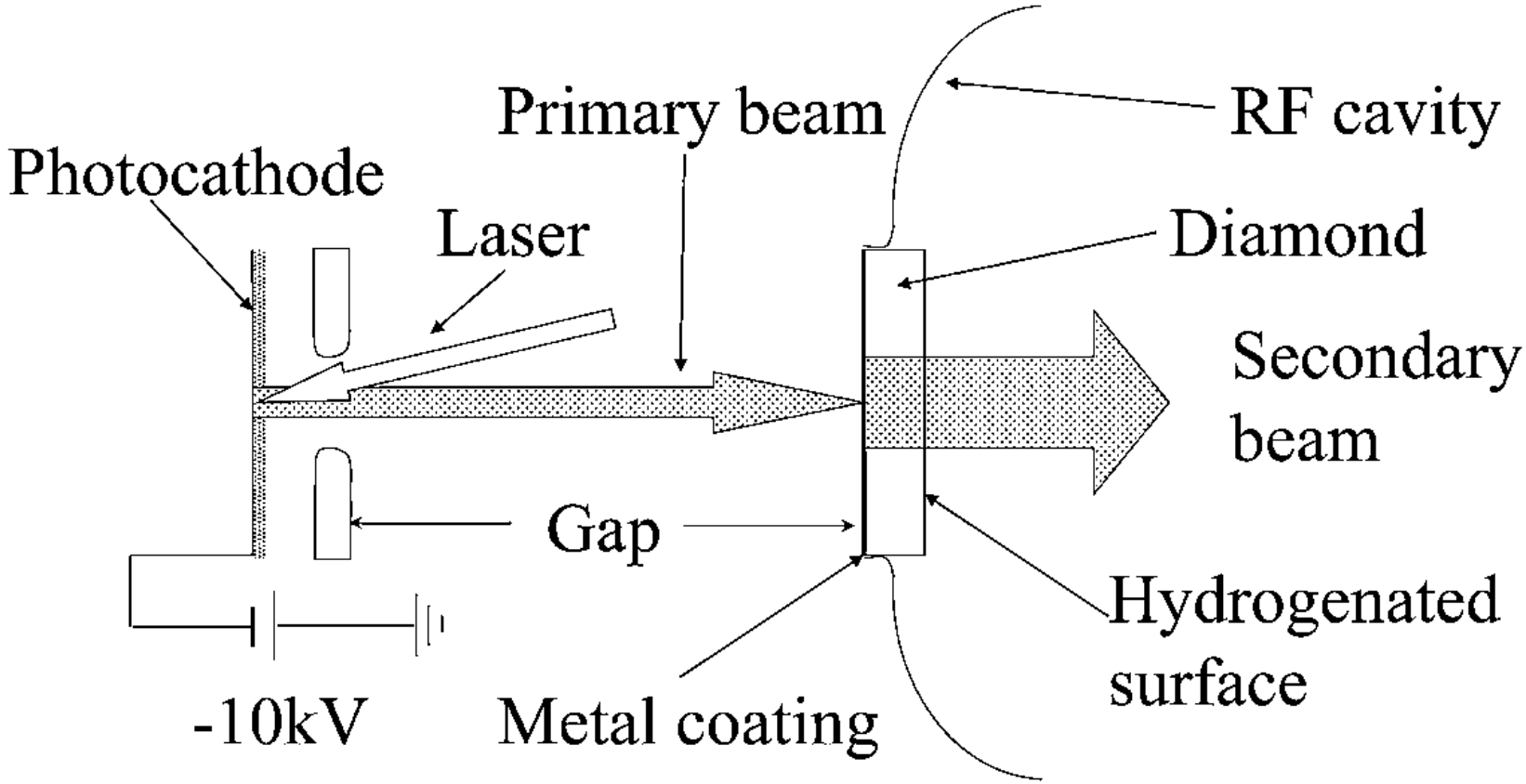




E.J. Montgomery, Ph.D. Dissertation, UMD (2010)
J.C. Jimenez, M.S. Thesis, NPS (2010)
Pan, et al., APL 100 034102 (2012)

Diamond-Amplified Photocathode (BNL/NRL)

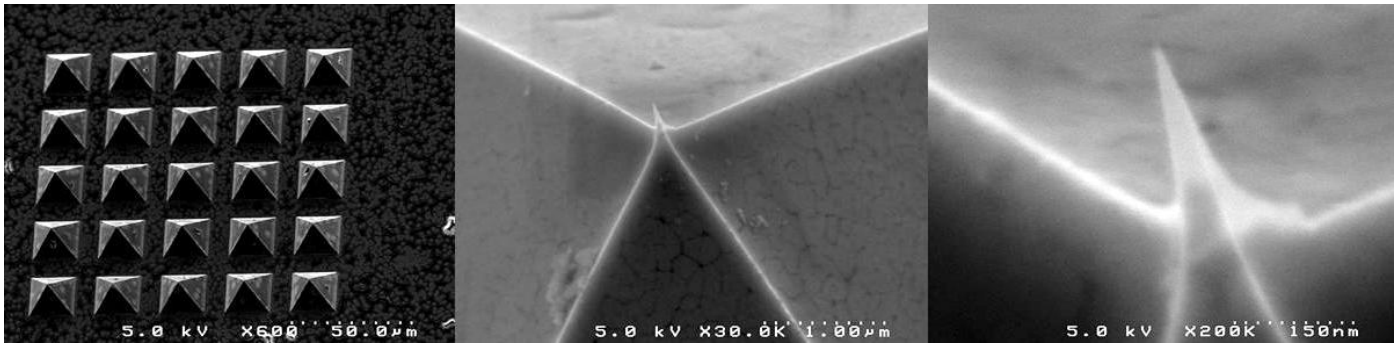
Isolate and Amplify



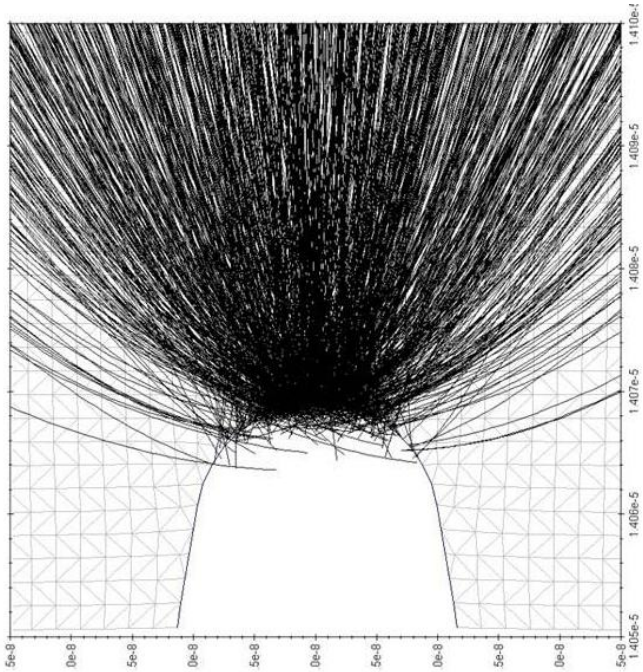
Chang, et al., PRL 105 164801 (2010)

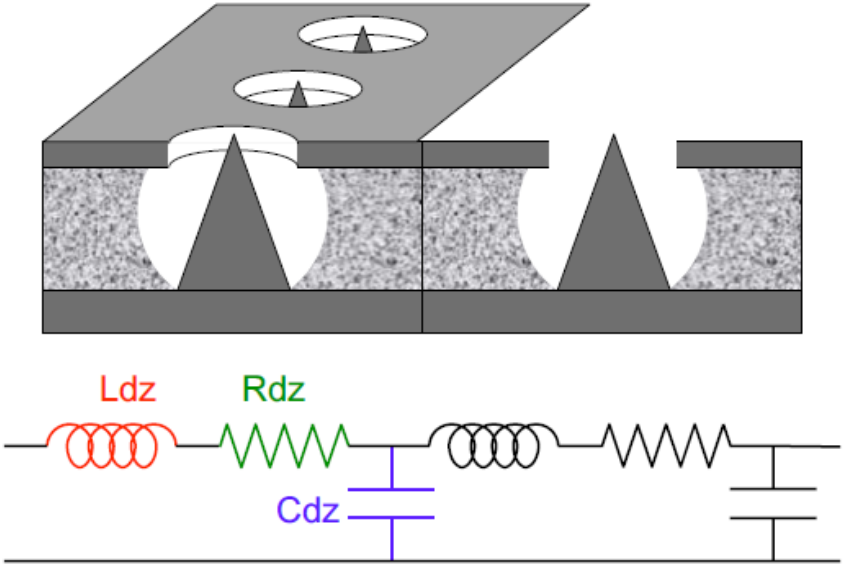
Diamond Field Emitter Arrays (Vanderbilt)

Laser? *Laser?* We don't need no stinking *laser*!



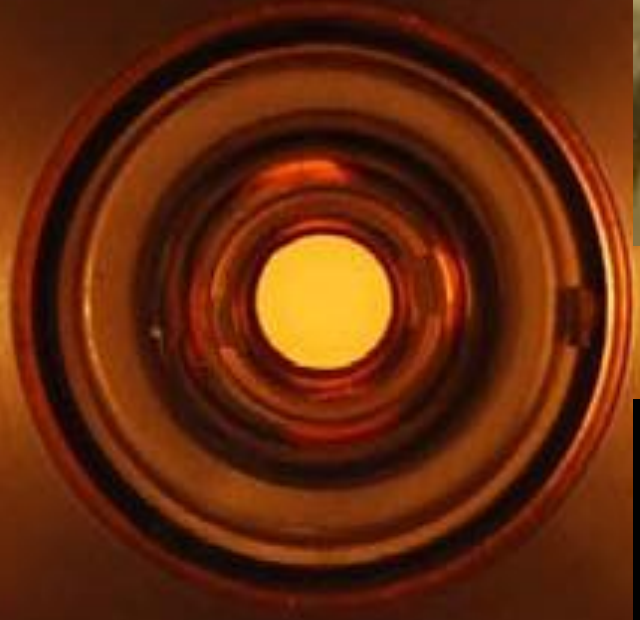
1µm



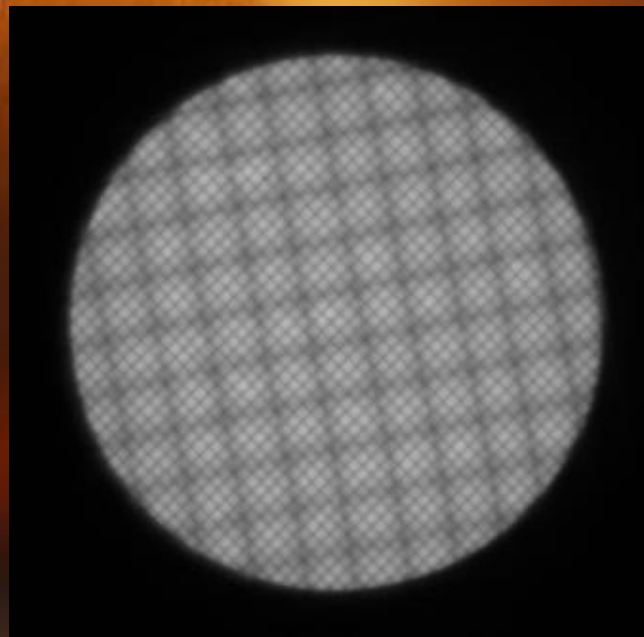


Jarvis, et al., Proc. FEL 2008
Jensen, et al., J. Appl. Phys. 107 014903 (2010)

Eimac Y-845/Y-646B Gridded Thermionic Dispenser Cathodes



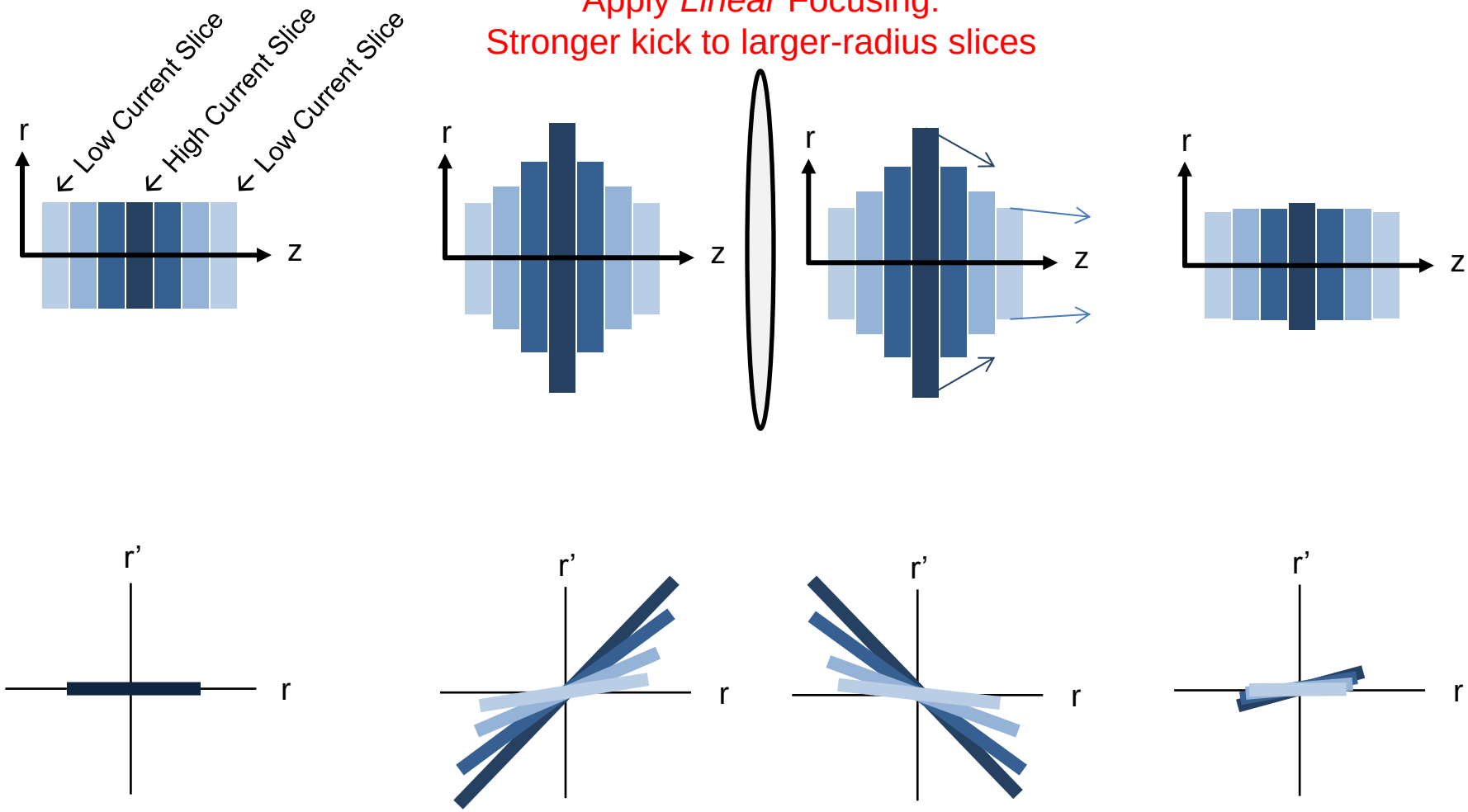
"Insel Bildung"



J.C. Jimenez, M.S. Thesis, NPS (2010)
J.R. Harris, Ph.D. Dissertation, UMD (2005)

Emittance Compensation Concept

Apply *Linear* Focusing:
Stronger kick to larger-radius slices

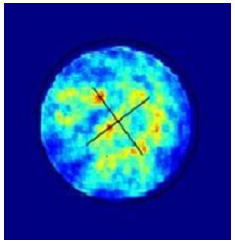


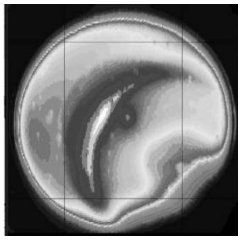
Focusing realigns slices in trace space,
reducing projected emittance

B.E. Carlsten, NIM A 285 313-319 (1989)

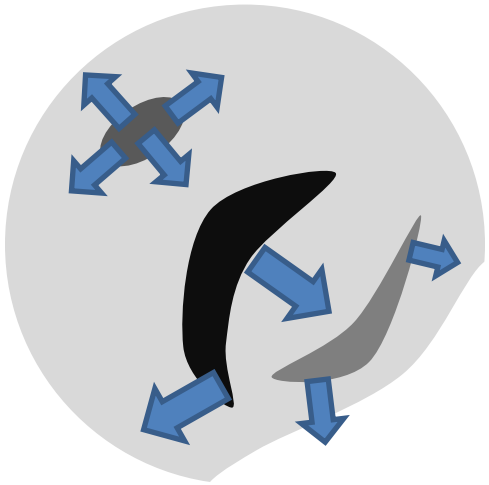
Photocathodes: Need for Transverse Uniformity to Linearize Forces

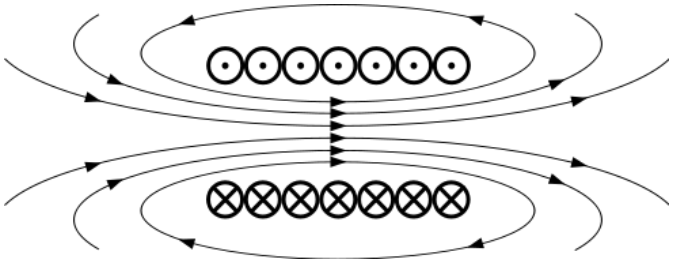
$P(x, y, (t))$

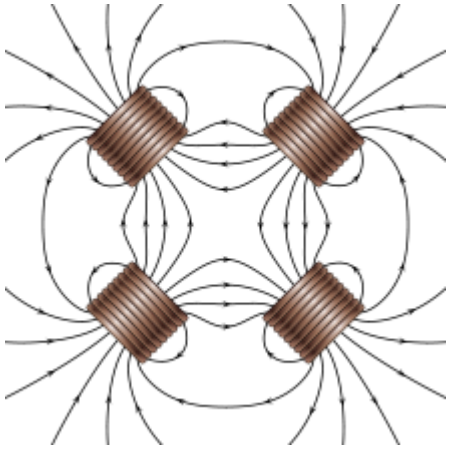




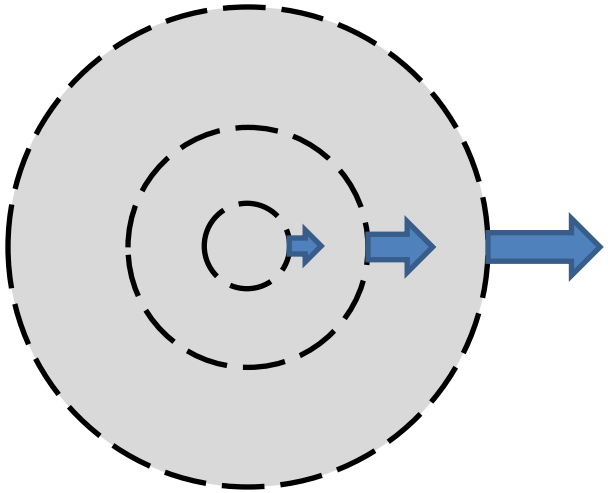
$QE(x, y, (t))$

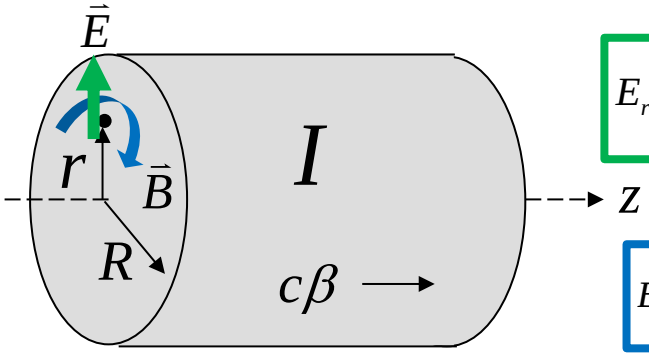






Photocathodes: Need for Transverse Uniformity to Linearize Forces

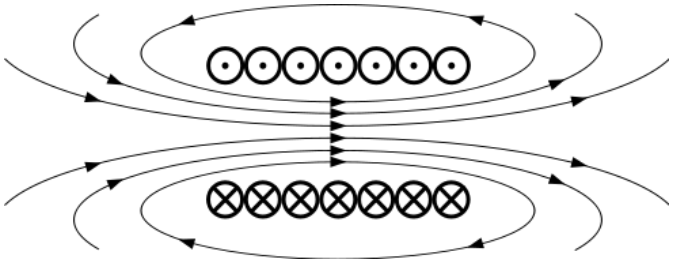


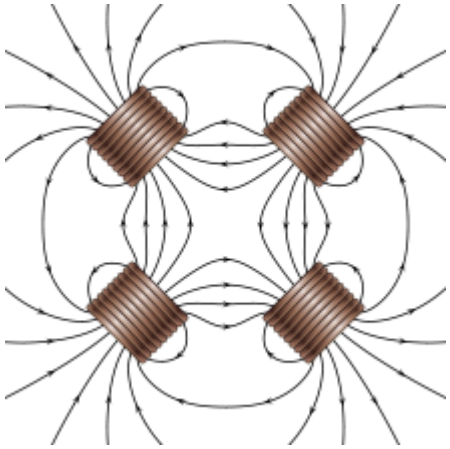


$$E_r = \frac{I}{2\pi\varepsilon_0 c\beta}\frac{r}{R^2}$$

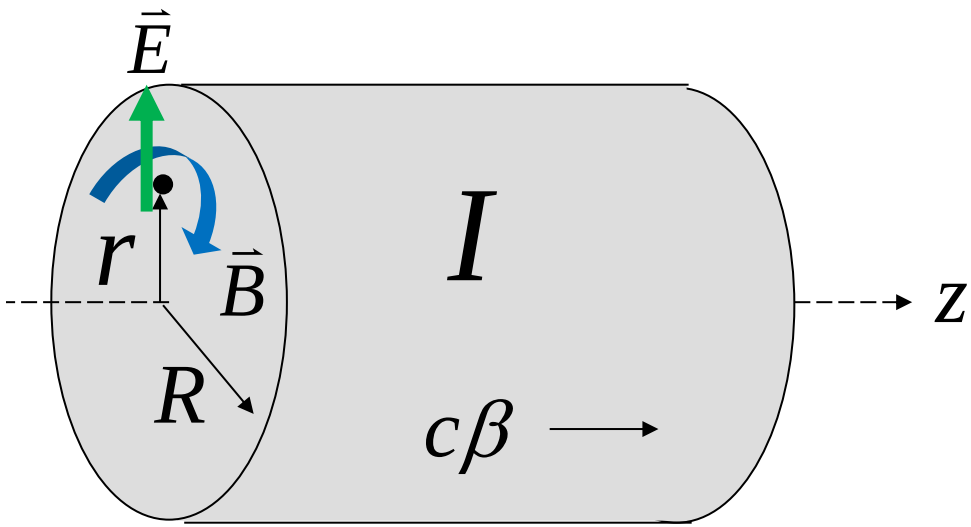
$$B_\theta = \mu_0 \frac{I}{2\pi}\frac{r}{R^2}$$

$$r'' = \frac{qI}{2\pi\varepsilon_0 mc^3\beta^3\gamma^3}\frac{r}{R^2} = \frac{Kr}{R^2}$$

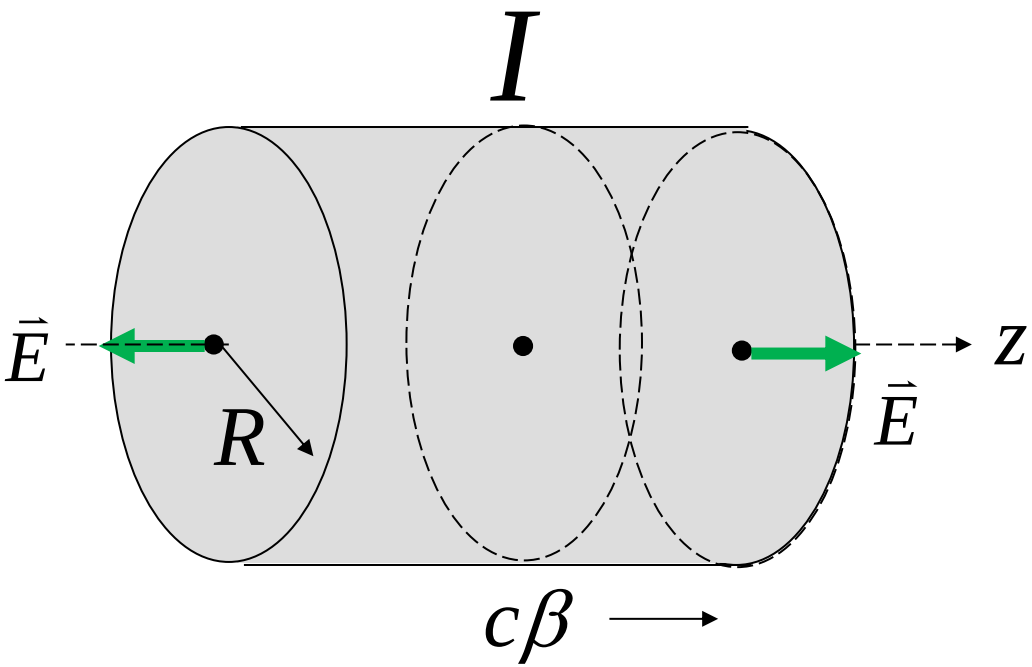




Photocathodes: Need for Transverse Uniformity to Linearize Forces

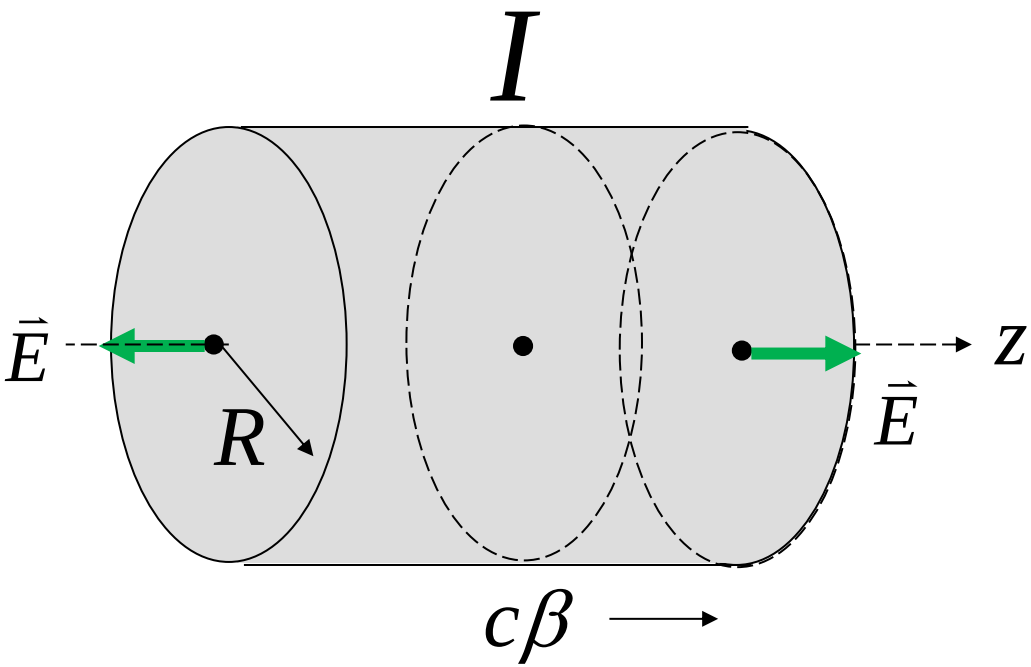


Photocathodes: Need for *Longitudinal* Profiling to Linearize Forces



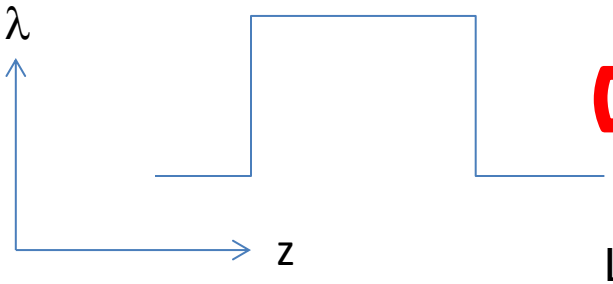
$$E_z = -\frac{g}{4\pi\varepsilon_0\gamma^2}\frac{\partial\lambda}{\partial z}$$

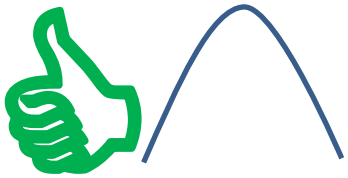
Photocathodes: Need for *Longitudinal* Profiling to Linearize Forces



$$E_z = -\frac{g}{4\pi\varepsilon_0\gamma^2}\frac{\partial\lambda}{\partial z}$$

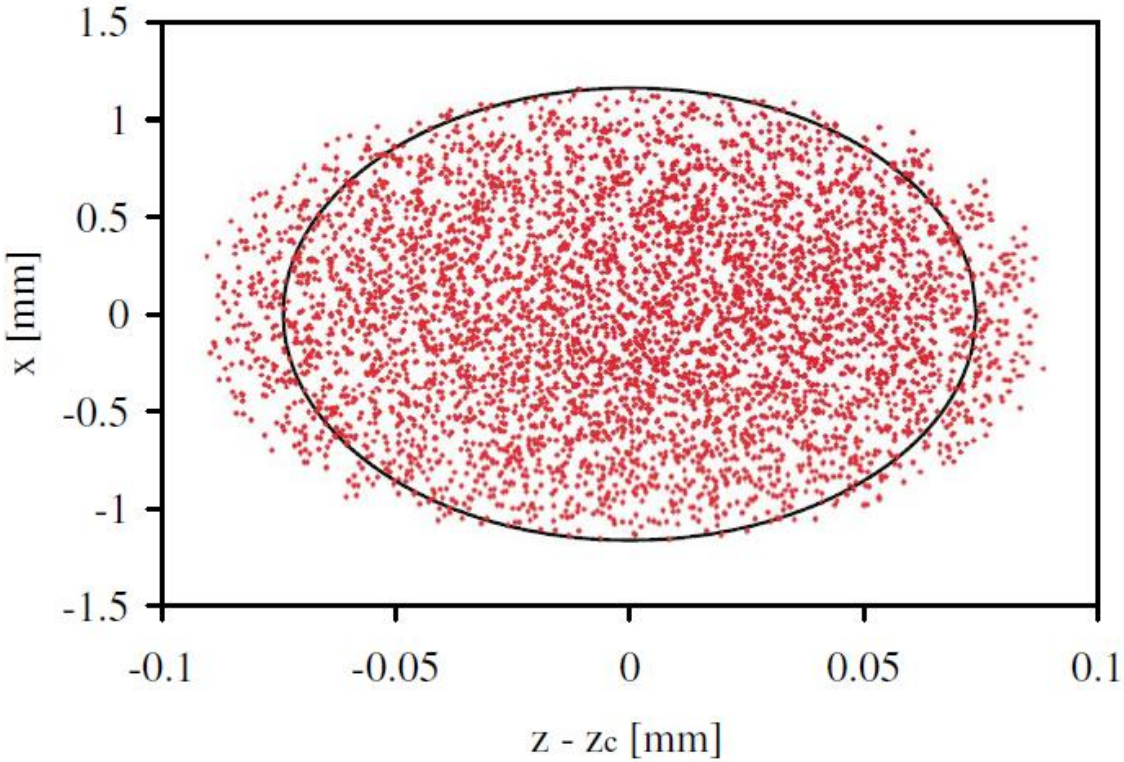
$$\lambda(z) = \lambda_0\left(1-\frac{z^2}{z_m^2}\right)$$





Linear longitudinal forces require parabolic longitudinal profile

Photocathodes: Need for *Longitudinal & Transverse* Profiling to Linearize Forces

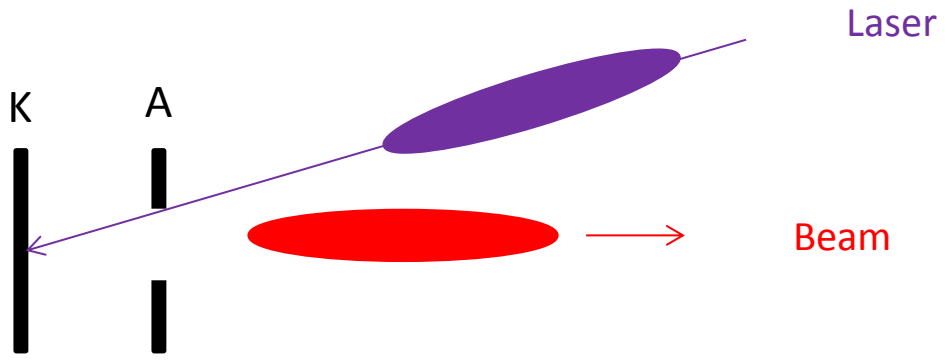


<u>Uniformly-Populated 3D Ellipsoid:</u>

- Uniform density in each slice → Linear radial force
- Parabolic line charge density → Linear longitudinal force

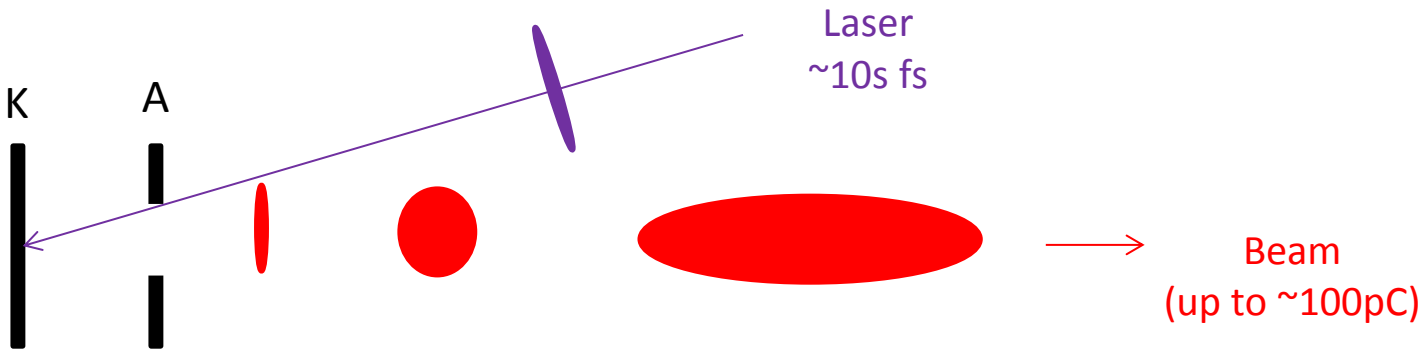
Luiten et al., PRL 93 094802 (2004)

3D Laser Pulse Shaping



Li, et al., PRL 100 074801 (2008)

Blowout Regime



Musumeci, et al., PRL 100 244801 (2008)

Blowout Regime

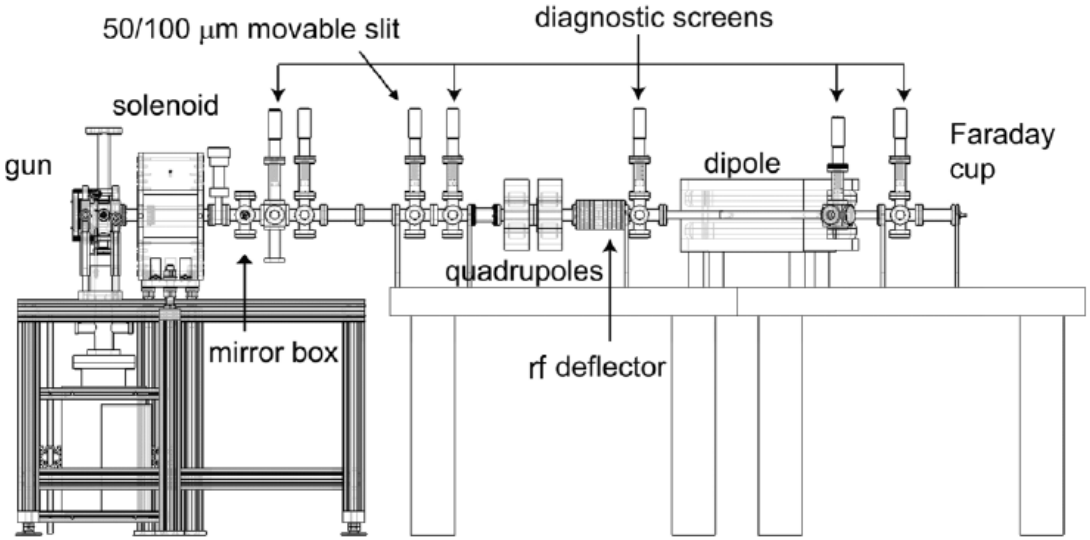


FIG. 1. Layout of Pegasus blowout regime experiment.

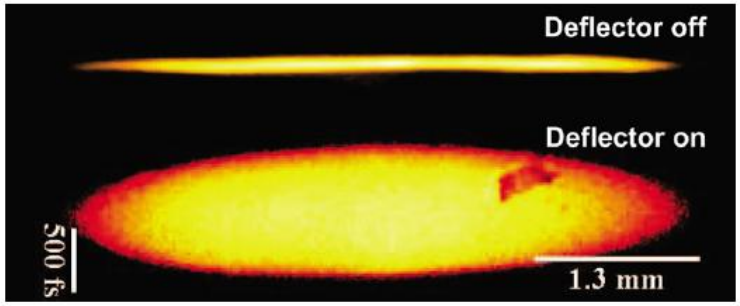


FIG. 2 (color online). Beam images after vertically focusing lens and rf deflector; cases with deflecting voltage off and on.