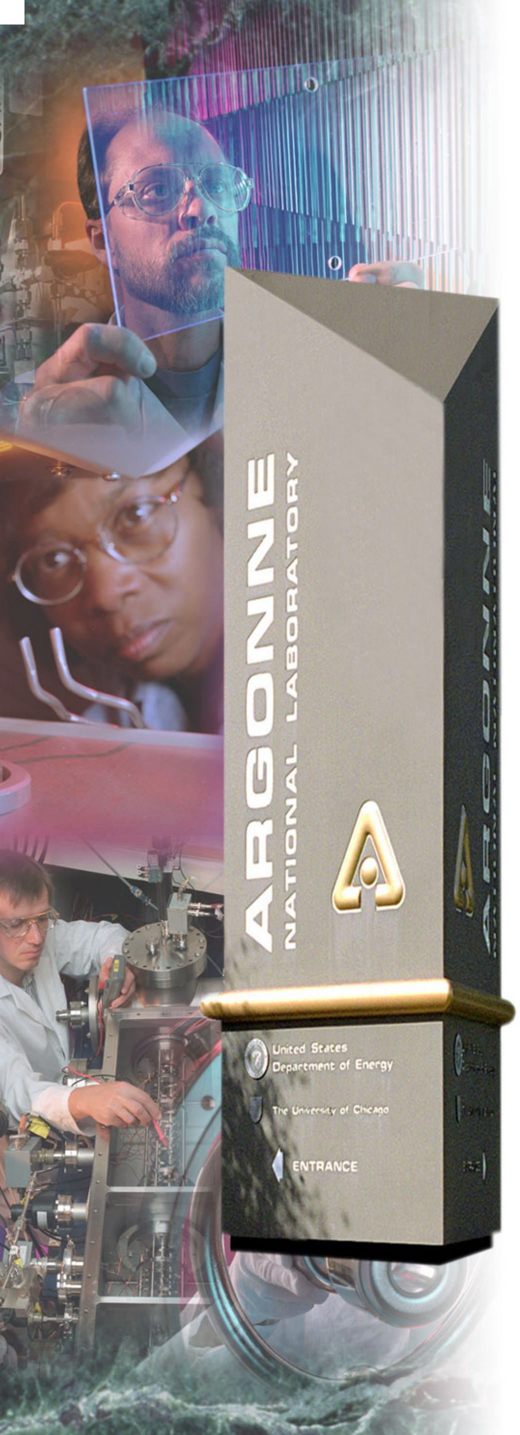

Field Emission Cathode Gating for RF Electron Guns

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A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago

Thanks and Acknowledgements

Sandra Biedron (ANL/ES)

Court Bohn (NIU)

Dave Dowell (SLAC)

Katherine Harkay (ANL/ASD)

Terry Maynard (ANL/IP)

Todd Smith (Stanford)

Various drive lasers of the authors' acquaintance, for motivation

Outline

- **Cathode Options**
- **Field Emission Cathode Gating Scheme**
- **Conclusions & Wrap-Up**

Cathode Overview

"Ideal" Cathode Checklist:

- ✓ **Long lifetime**
- ✓ **Rapidly switchable on/off**
- ✓ **Damage resistant**
- ✓ **High charge density**
- ✓ **Cryogenic compatible**
- ✓ **Simple operation**

Photocathodes

Emission mechanism: Use laser pulse to excite electrons off the cathode surface

Advantages:
- ✓ Rapidly switchable
- ✓ High charge density

Disadvantages:
- ✗ Efficiency-lifetime tradeoffs
- ✗ External drive laser required

Thermionic cathodes

Emission mechanism: heat the cathode to "boil" the electron sea in the metal

Advantages:
- ✓ Long lifetime
- ✓ Robust
- ✓ Simple to operate

Disadvantages:
- ✗ Not rapidly switchable
- ✗ High temperature required

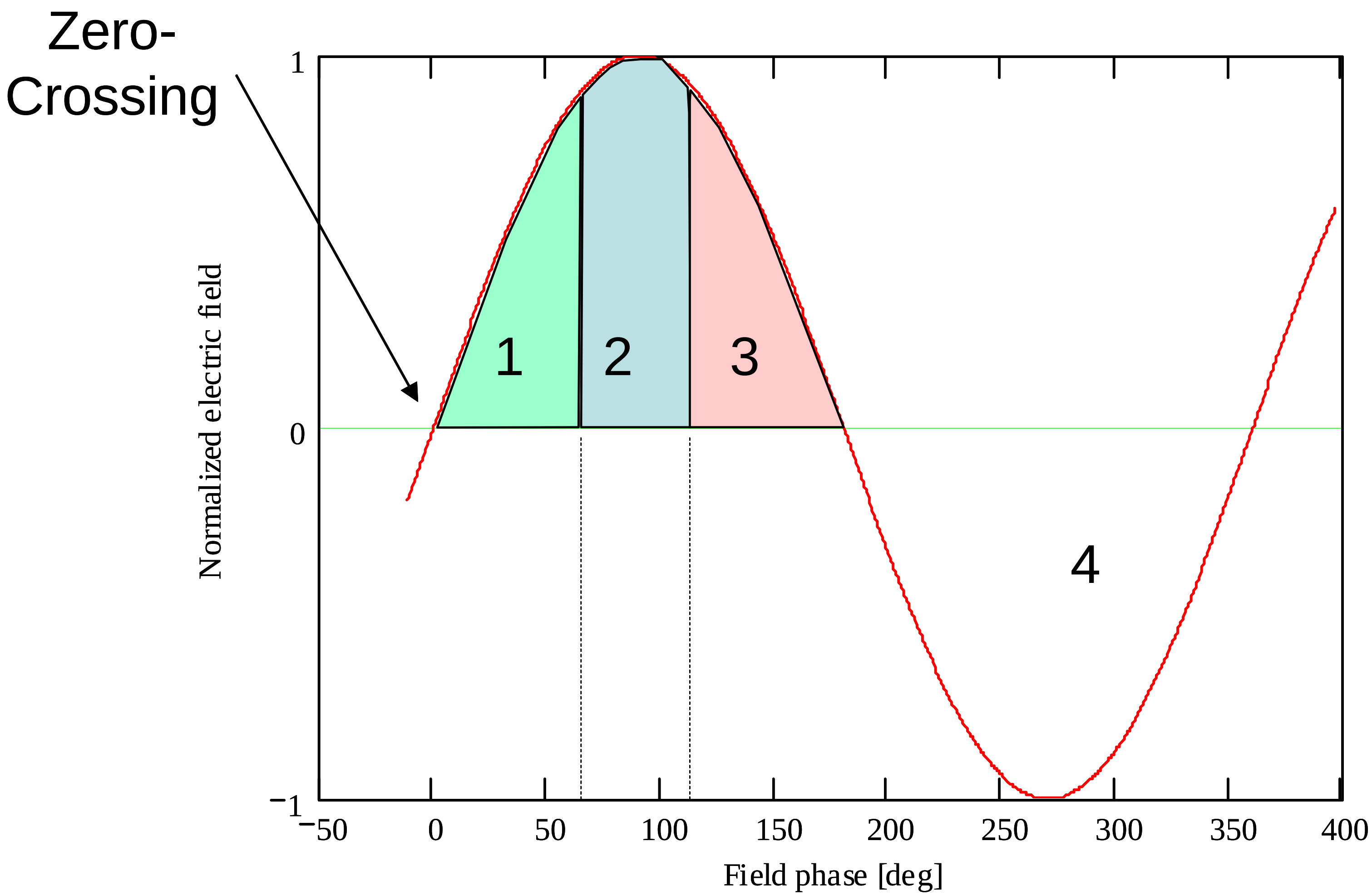
Field-emission cathodes

Emission mechanism: Electric field pulls electrons from cathode surface

Advantages:
- ✓ Very simple
- ✓ High charge density
- ✓ Rapid turn-on/off

Disadvantages:
- ✗ Problematic gating (for rf app.)
- ✗ Damage questions

Beam Emission Timing

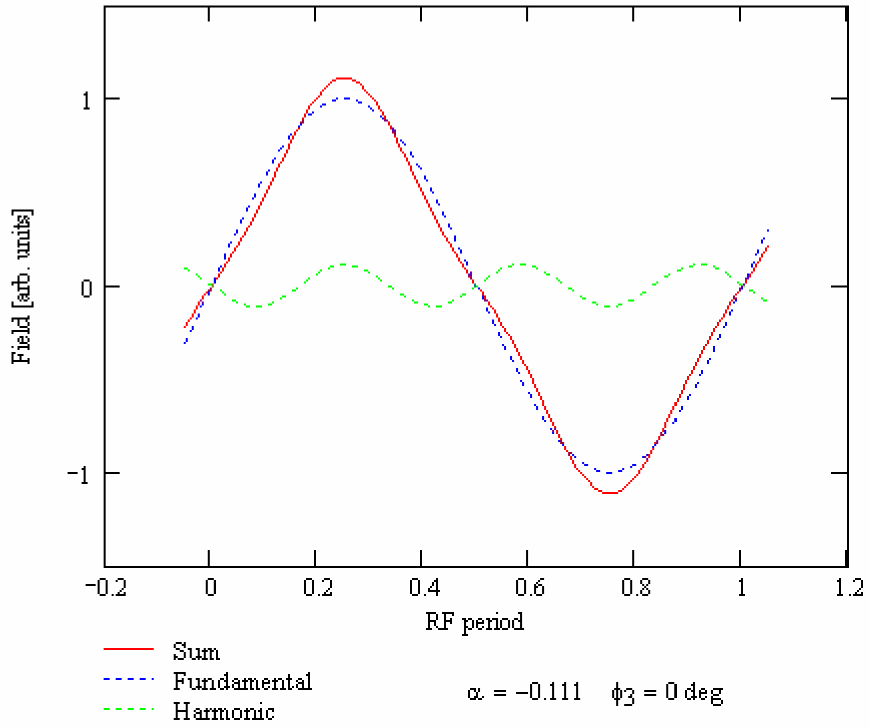


Field Emission Cathode Gating Scheme

FE cathodes emit electrons when the field is high enough

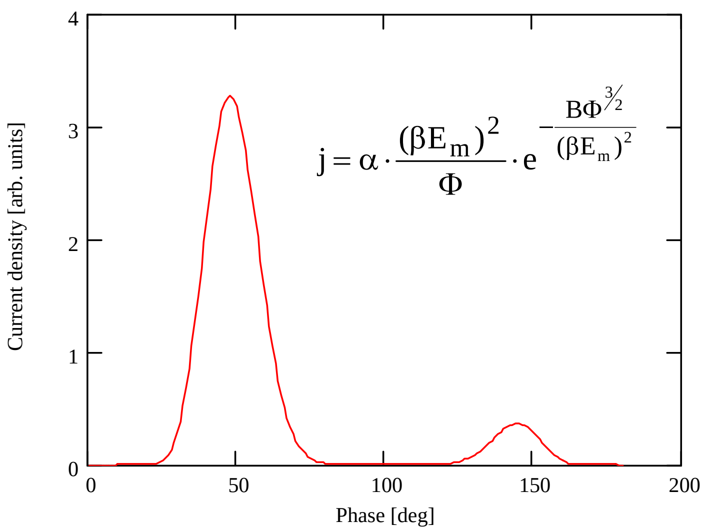
- **operate at low temperature (unlike thermionic cathodes)**
- **emit only under "internal" influences (unlike photocathodes)**

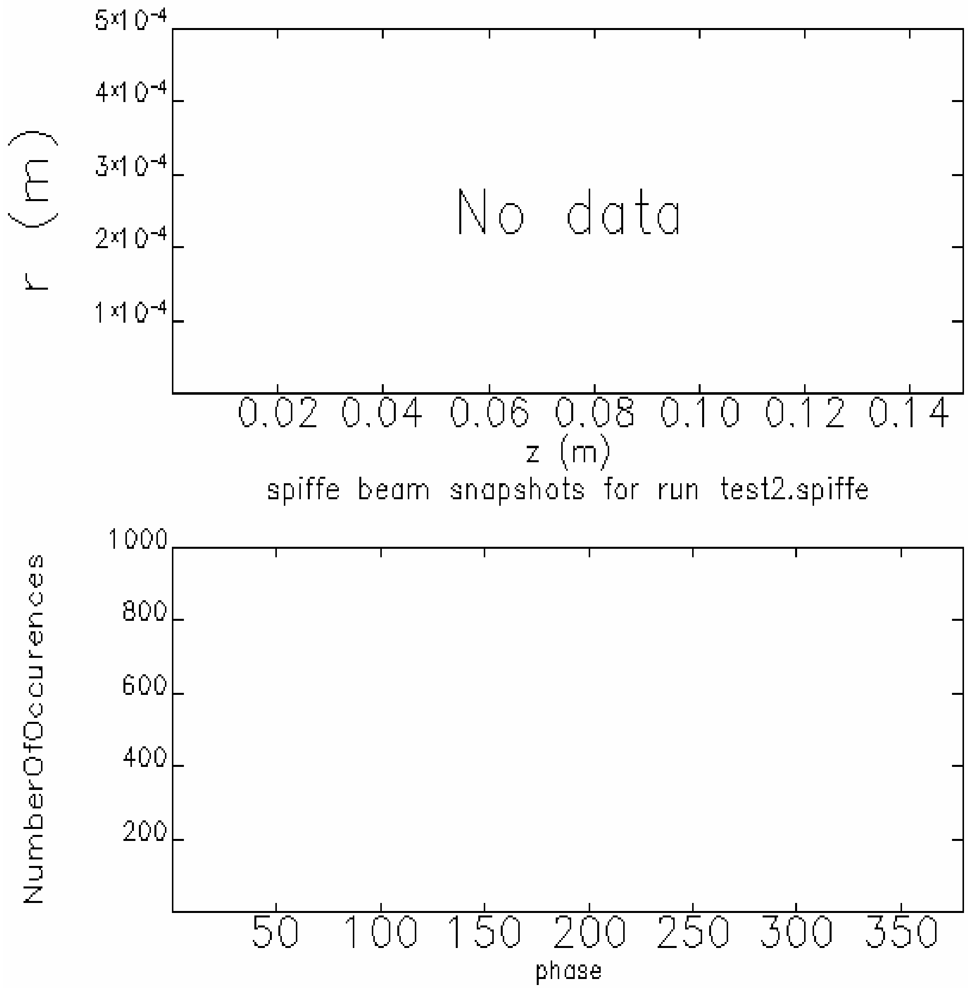
$$\mathrm{Sum} = E_0 \cdot \sin(2 \cdot \pi f \cdot t) + \alpha \cdot E_0 \cdot \sin(2 \cdot \pi \cdot 3 \cdot f \cdot t + \phi_3)$$



Will it work?

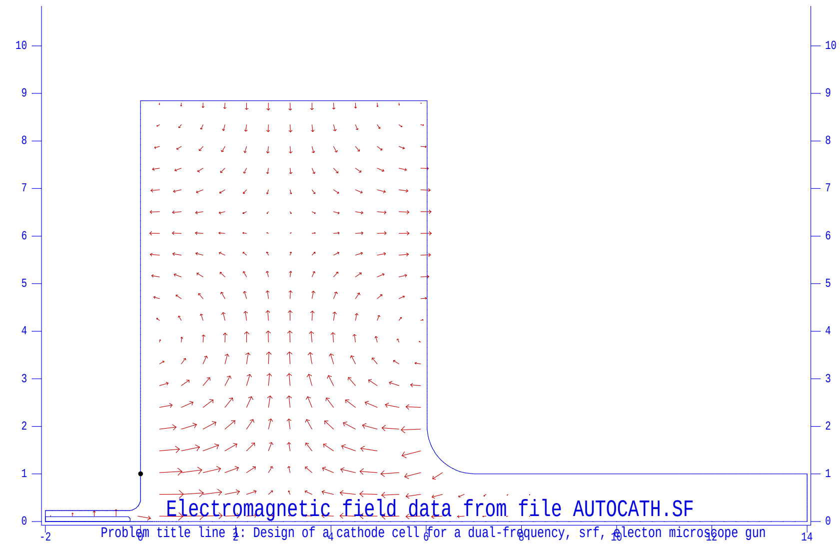
- **Simulation:**
  - Incorporated the Shottky emission model directly
  - Also includes space-charge effects

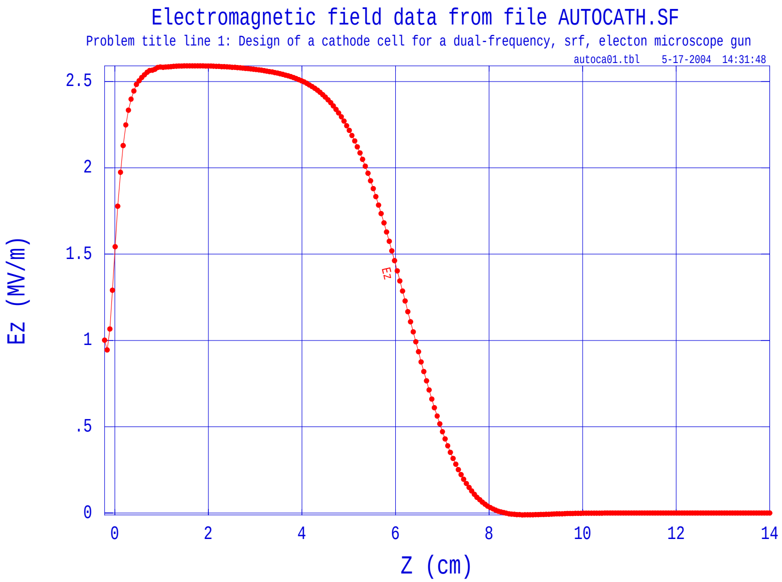


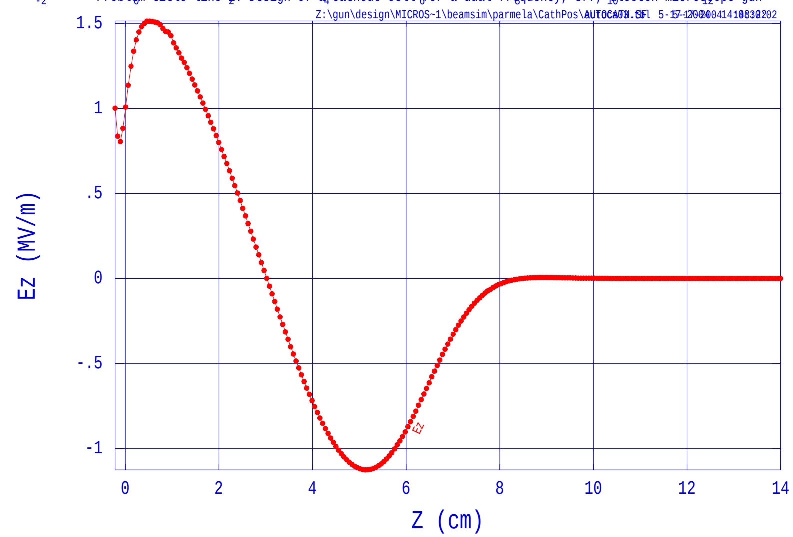


FE Cathode Gating: Other Comments

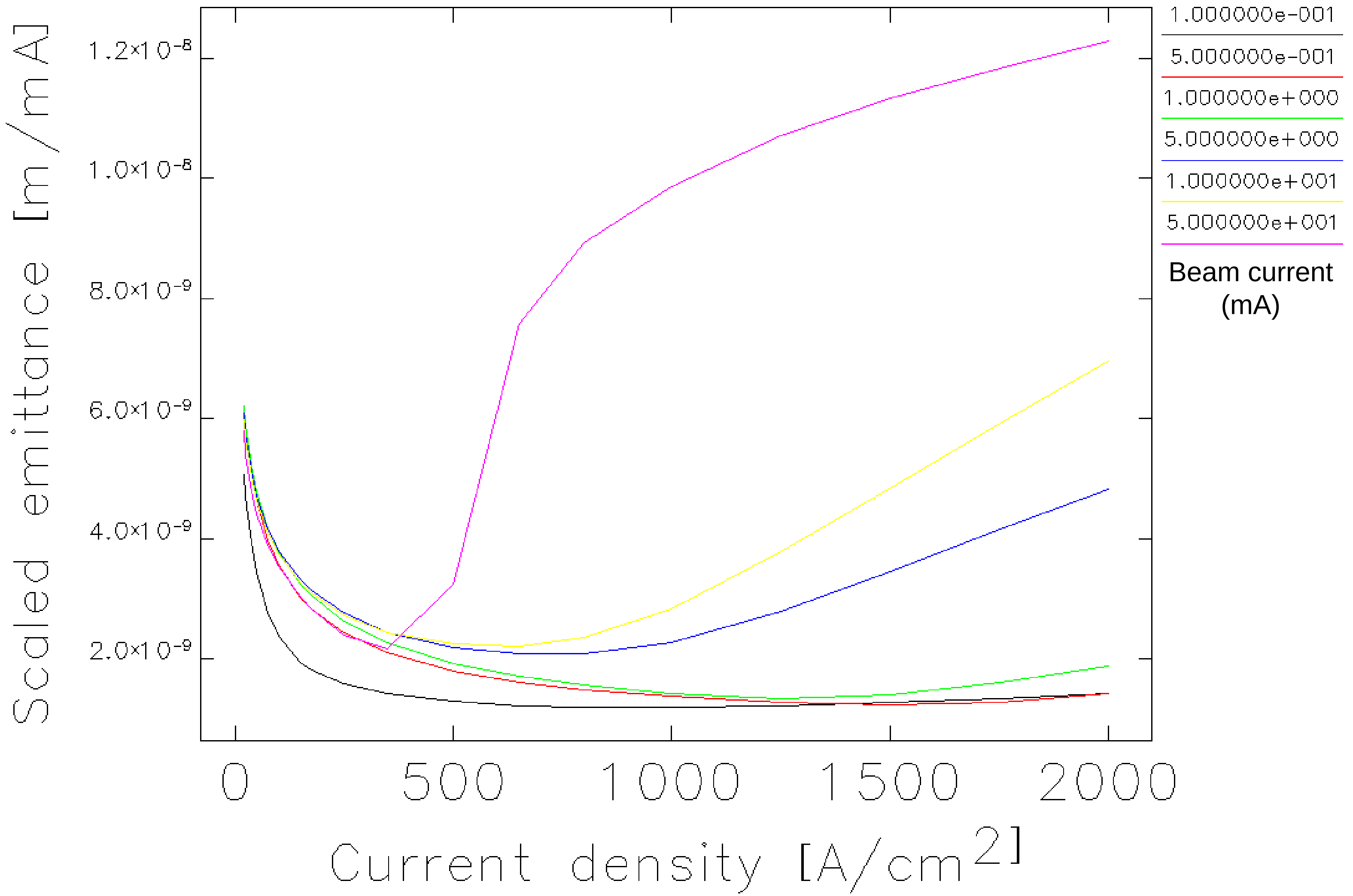
- **Proper field addition in both space and time → special gun geometry**
- **Scales well to ~ 50 mA beam current without special focusing**
- **Superconducting version highly desirable for efficient use of rf power, true CW operation potential**







Scaled Performance



Comments

- **Basic idea**
  - Strong 3rd harmonic at the cathode to launch the beam
  - Fundamental dominates in body of gun for more conventional dynamics
  - Details of emitter tbd; there are possibilties
- **Initial studies aimed at electron microscopy**
  - Low beam currents
  - Low space charge
- **Extensions to higher currents?**
  - Theoretically possible
  - Cathode-region focusing needed

Conclusions & Wrap-Up

- **Field-emitter cathodes are now a possible choice for rf gun use**
  - first- and third-harmonic field combination to gate emission
  - proper selection of recess depth and other factors to ensure good beam propagation through the gun

- **Moderate (1 – 50 mA) *average* beam currents appear possible**

- **Beam energies of 1.5 – 2 MeV appear possible**

- **This gun design, in combination with standard phase-space manipulations to reduce the energy spread etc., can drive a number of relatively high-volume applications**