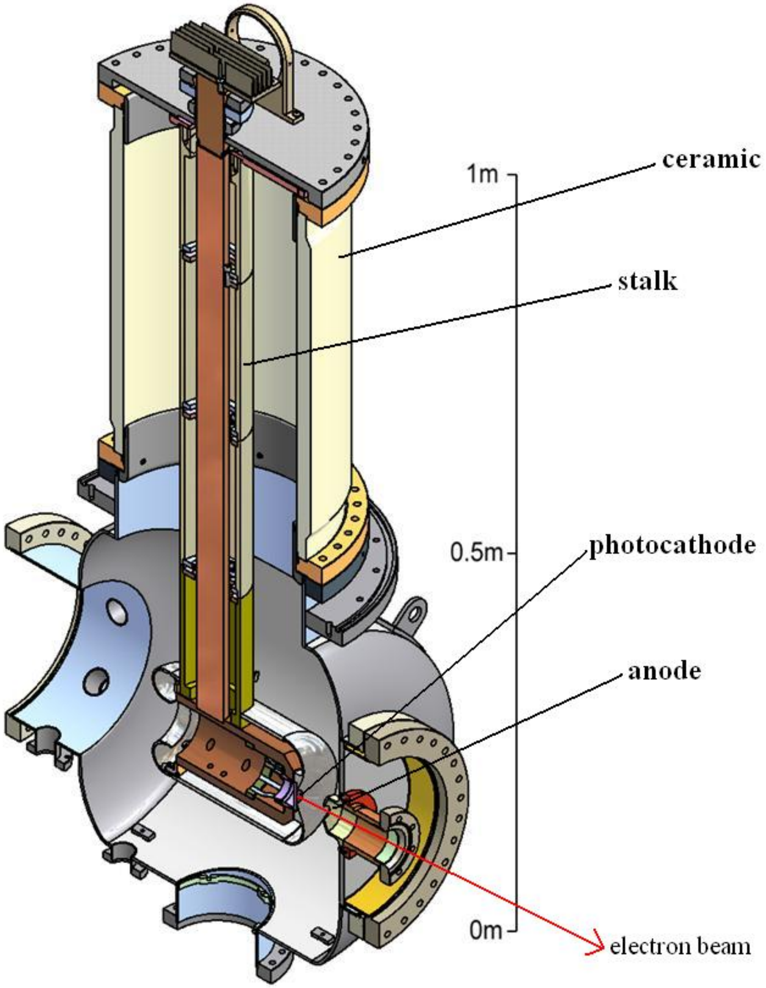
Reducing (?) Field Emission from Large Area, High Voltage Electrodes

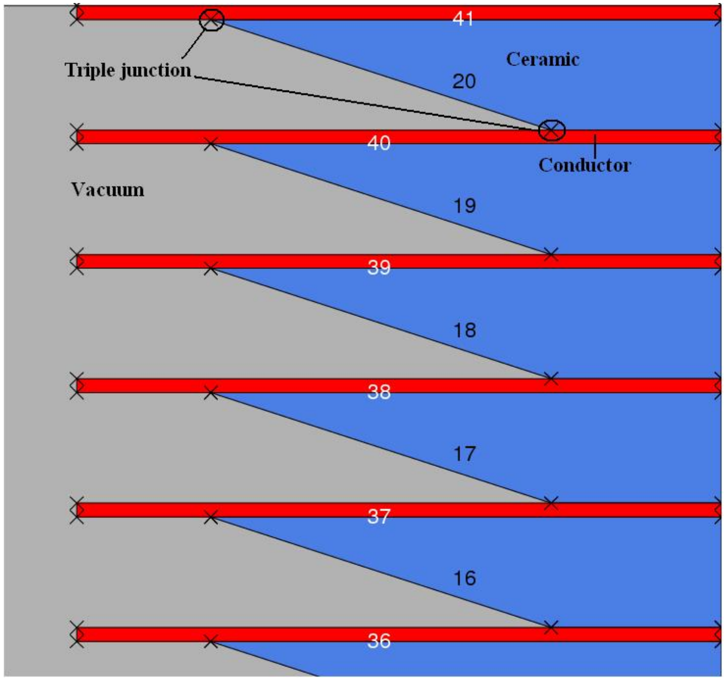
David Stone
Carnegie Mellon University
Advisors: Karl Smolenski and Bruce Dunham
Cornell University
Laboratory for Elementary-Particle Physics

Background

- Electron gun:
  - Photocathode, pulsed laser, stalk, ceramic
  - All under vacuum
- Cathode Voltage
  - Ideally at -750 kV w.r.t. anode (at ground)
  - Cathode must use conditioning, HPR, electrochemical polishing, etc. to decrease imperfections (which become important at high voltage)



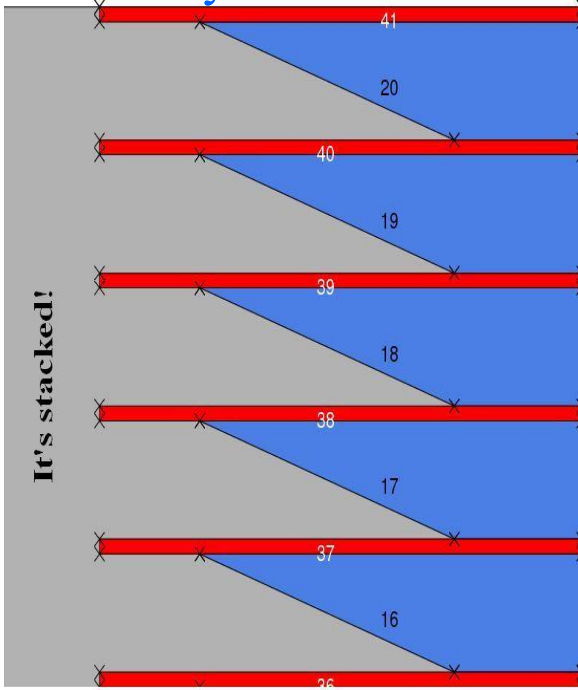
Problems



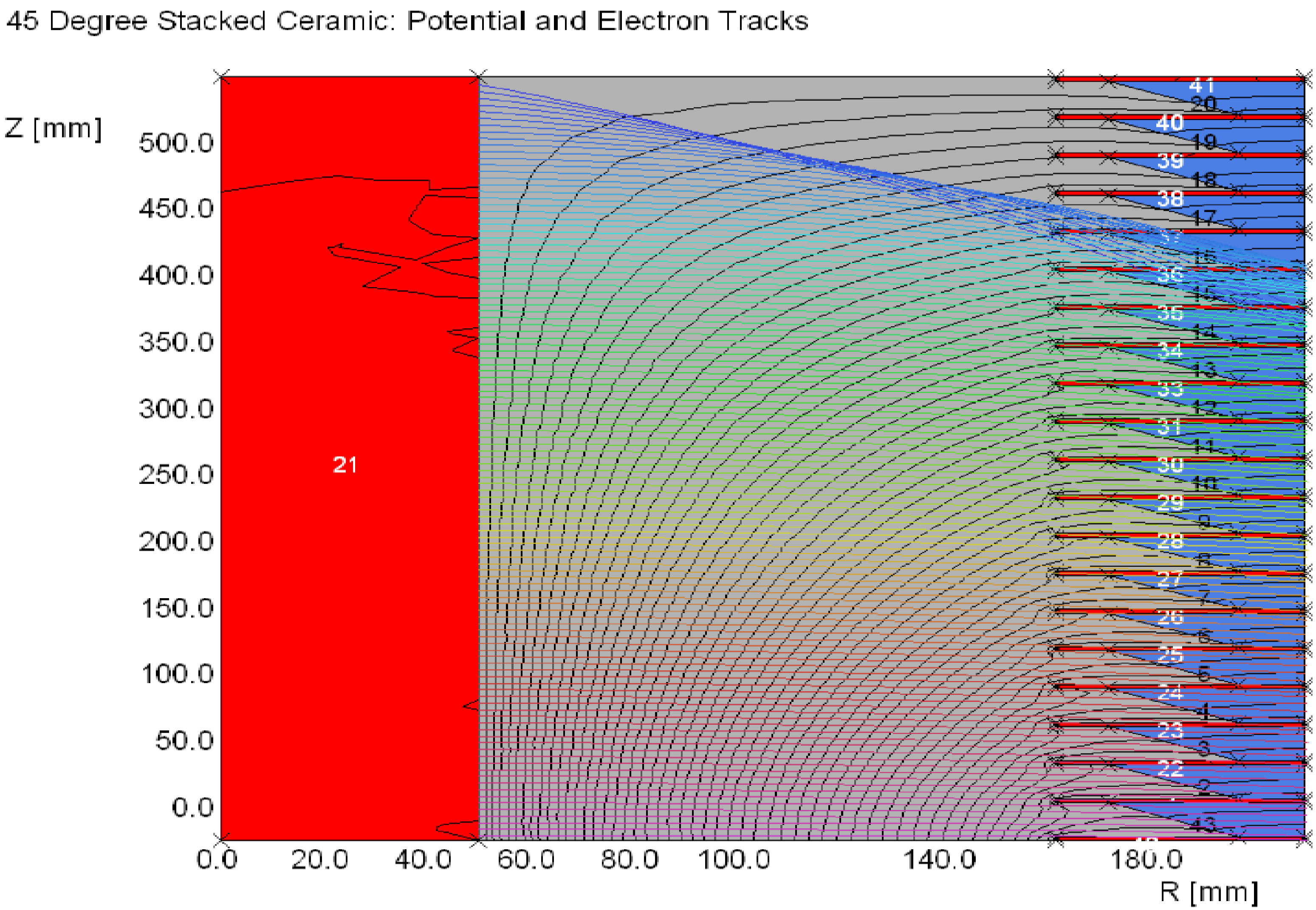
- Ultra-High Vacuum (UHV)
  - Maintained to prevent voltage breakdown- desorbed or leftover gas can initiate breakdown
  - In gun, p $\approx 10^{-11}$ torr to prevent decay of QE in photocathode
- High Voltage (HV)
  - Breakdown occurs in most gaps w/ excess field strength > 20 MV/m
  - Initiated by microprotrusions and other e^- emission sites, strong fields at triple junctions, desorbed gas, small gap separations, etc.
  - Once initiated, if electron current impacts ceramic, secondary emission and electron avalanches can occur, irreversibly destroying ceramic

The Project- So far

- Ceramic Design
  - Stacked/graded insulator design (J.G. Leopold, et al.)
    - Varied ceramic angle (45°) & thickness, conductor length & protrusion, etc.
    - Not much difference in any design in reducing field strengths in ceramic
    - But ***geometries*** are very important for reduction of secondary electron emission (need an $E_\perp$ to ceramic surface)
  - Modeling with Opera-2d electrostatics module
    - Electron path tracking, equipotential visualization, fields along lines (graphical comparisons)
- Electrode Design
  - Electrochemical polishing of niobium discussion



The Project- So Far



UNITS
Length : mm
Flux density : C m-2
Field strength : V mm-1
Potential : V
Conductivity : S mm-1
Source density: C cm-3
Power : W
Force : N
Energy : J
Mass : kg

PROBLEM DATA
C:\Documents and Settings\dstone\Opera Models\stackLong.st
Linear elements
Axi-symmetry
Scalar potential
Electric fields
Static solution
Scale factor: 1.0
9769 elements
5017 nodes
43 regions

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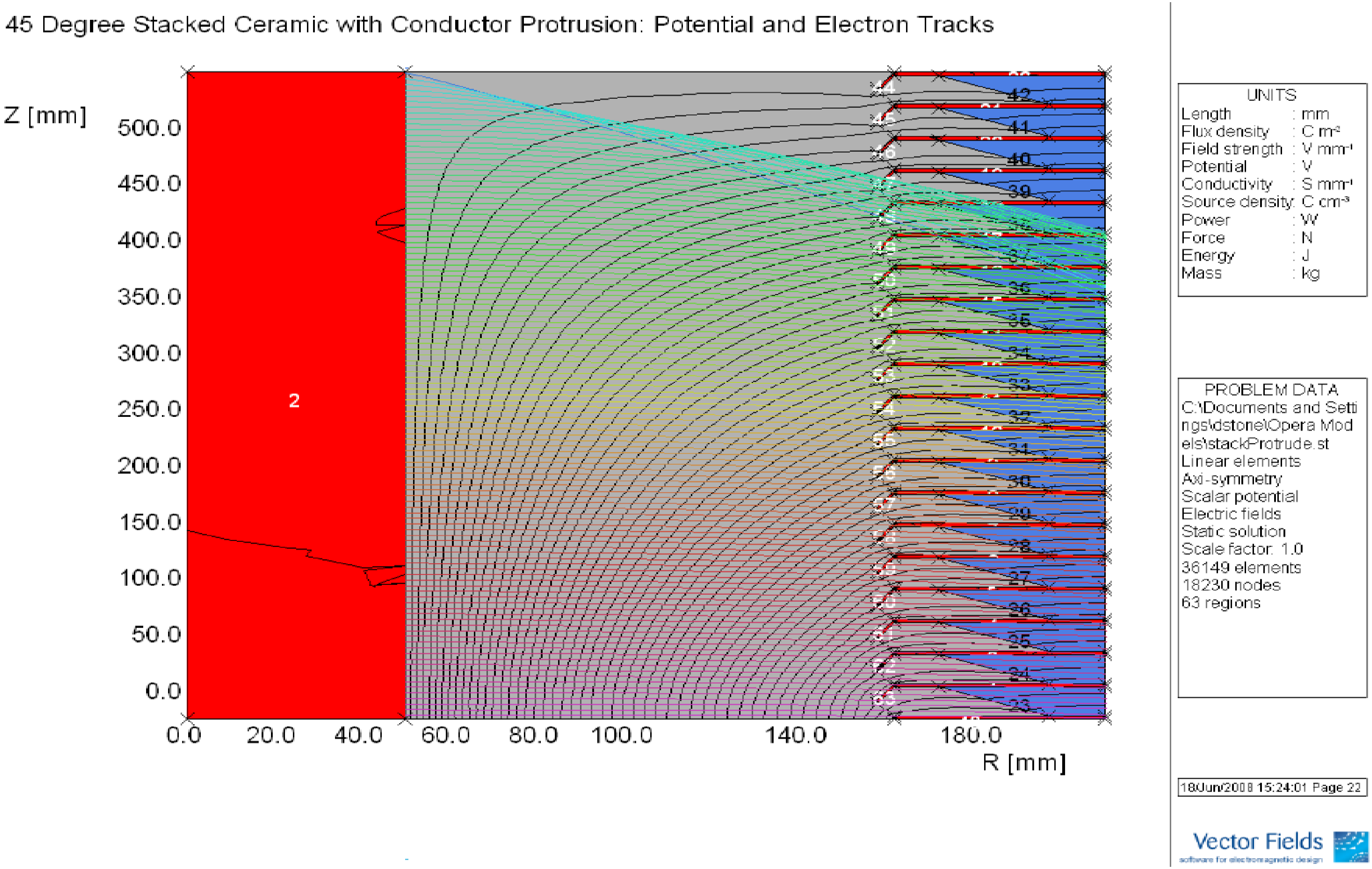
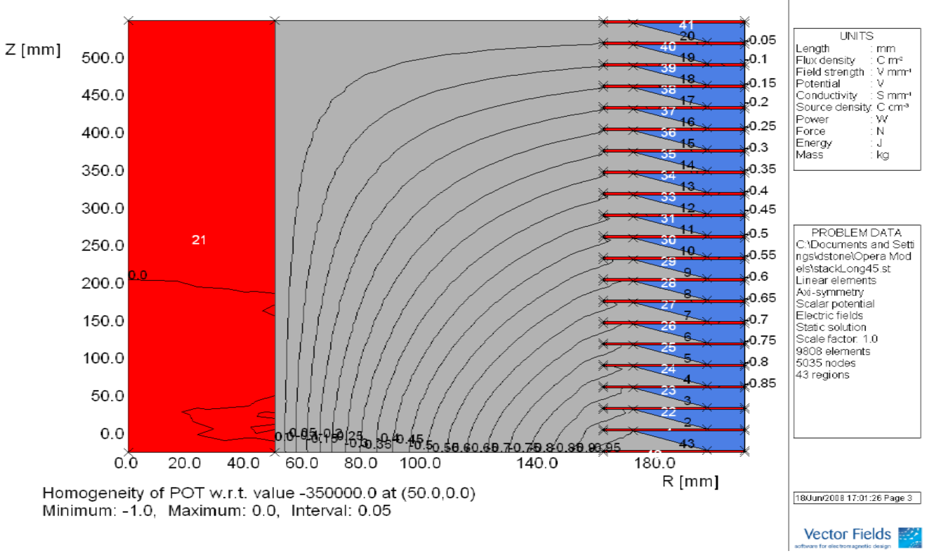
Vector Fields
software for electromagnetic design

The Project- So Far

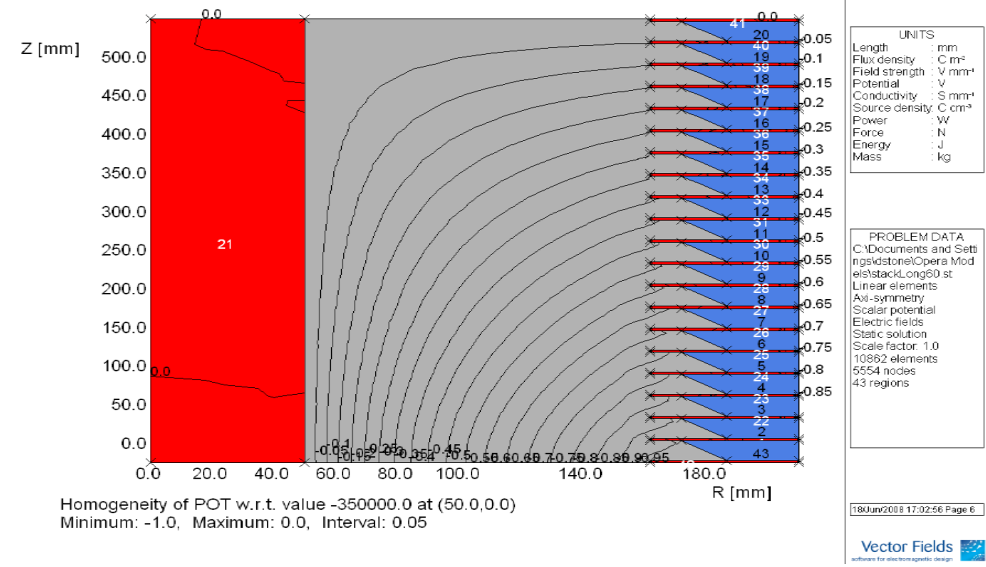


The Project- So Far

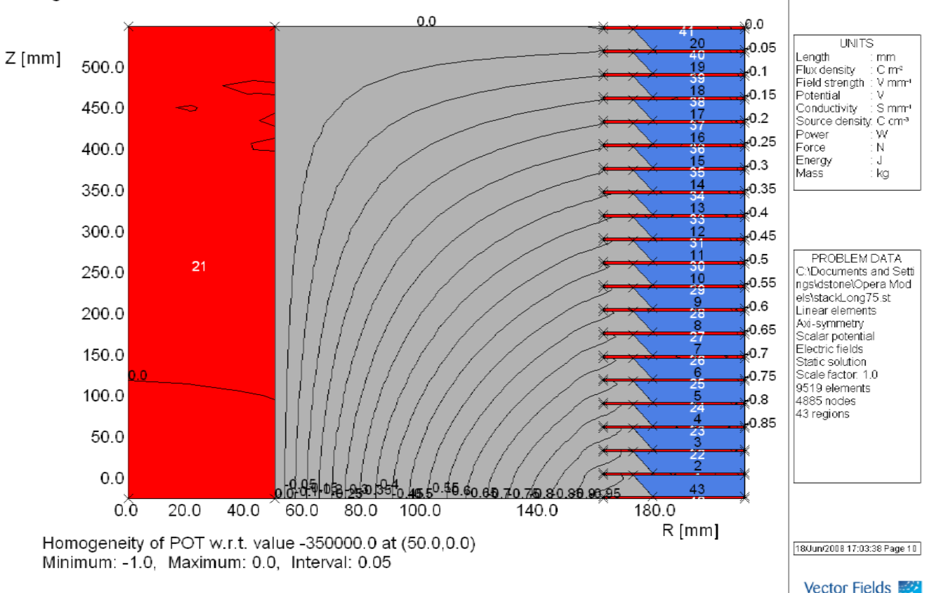
45 Degree Stacked Ceramic: Potential



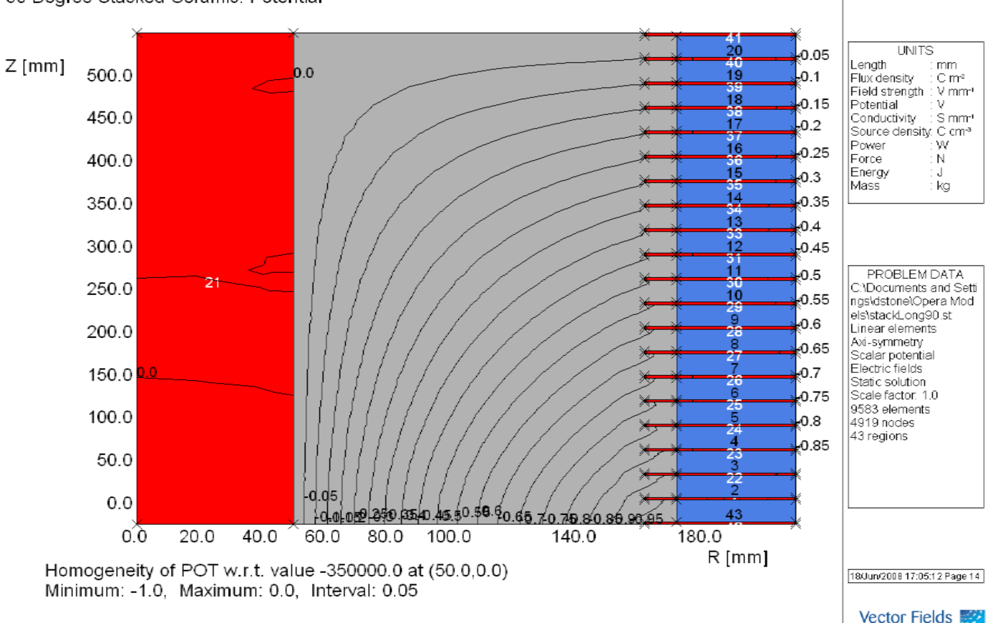
60 Degree Stacked Ceramic: Potential



75 Degree Stacked Ceramic: Potential

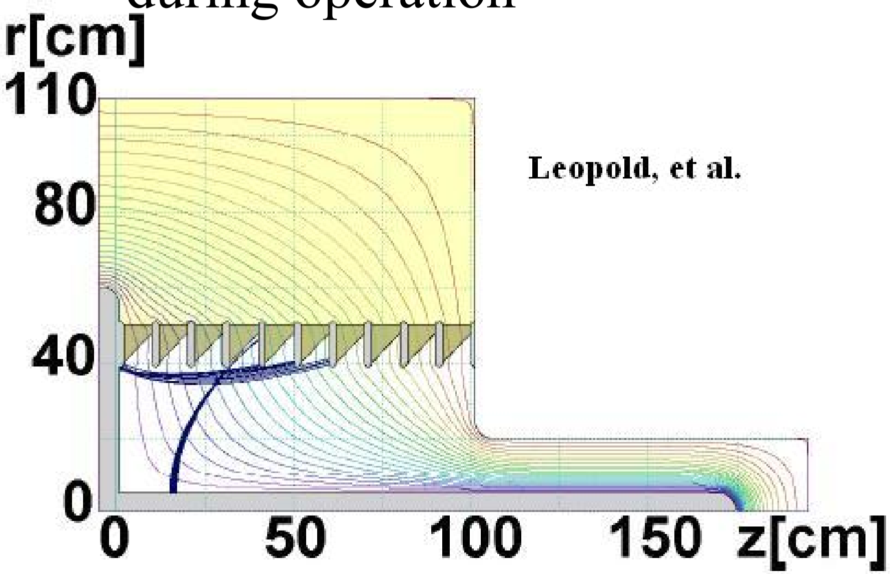


90 Degree Stacked Ceramic: Potential

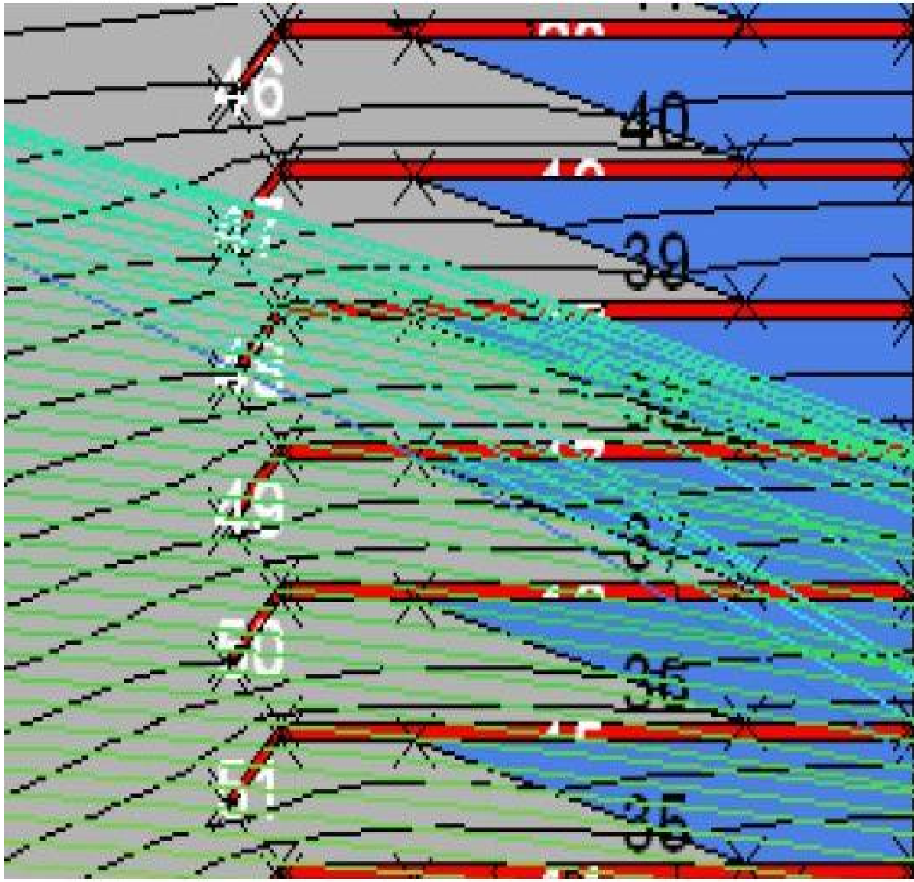


The Project- So Far

- Change in Project Direction
  - Instead of field emission *reduction*, we focus more on:
    - Field shaping
    - Electron trajectory shaping
  - Attaining mastery over these will significantly decrease breakdown during operation



Leopold, et al.



The Project- What's Next

- Ceramic Design
  - Further development and testing of stacked design
  - Writing Opera-2d scripts to do complex models
  - Try out new materials, coating?
- Modified ERL Gun Design
  - Try new geometries such as inverted design (Breidenbach, et al.)?
  - Implement new ceramic design
- Electrode Testing/Development
  - Conditioning, electrochemical polishing
  - Reducing electrode surface area to reduce possible e^- emission sites

Works Cited

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- **Pierce, J.R. "Rectilinear Electron Flow in Beams." J. Appl. Phys. 11, 548 (1940); DOI:10.1063/1.1712815**

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- **Sinclair, C.K., "Very high voltage photoemission electron guns," Particle Accelerator Conference, 2003. PAC 2003. Proceedings of the , vol.1, no., pp. 76-80 Vol.1, 12-16 May 2003.**