Immersed-B_z Diode Research on RITS at Sandia

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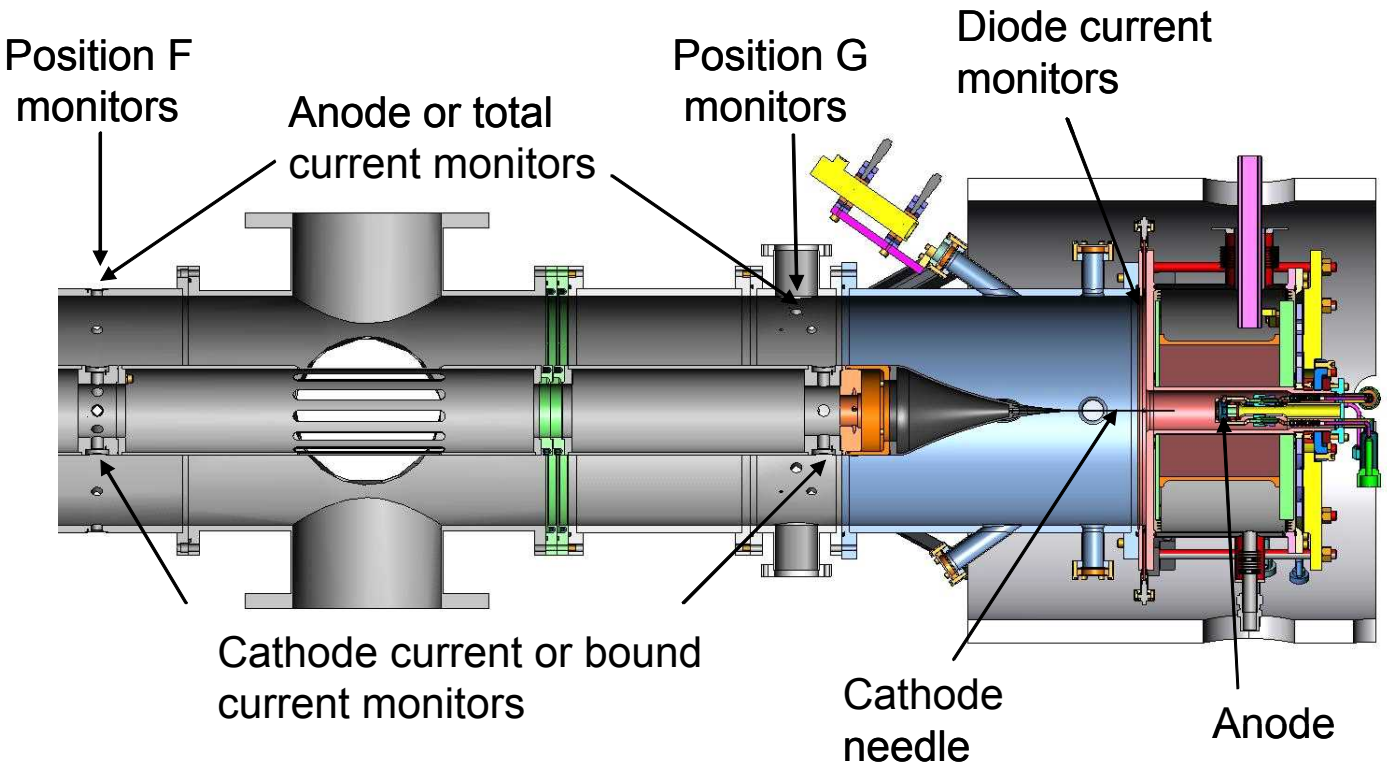
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Immersed-B_z Diode Research

- Identified two different operating regimes
  - Nominal
  - Anomalous

- Investigated the effects of cryogenic modifications to anode surface

Immersed-B_z Diode on RITS-3



RITS-3 Parameters:

V : 4 - 5 MV

I (total) : 120 – 150 kA

t: 70 ns FWHM

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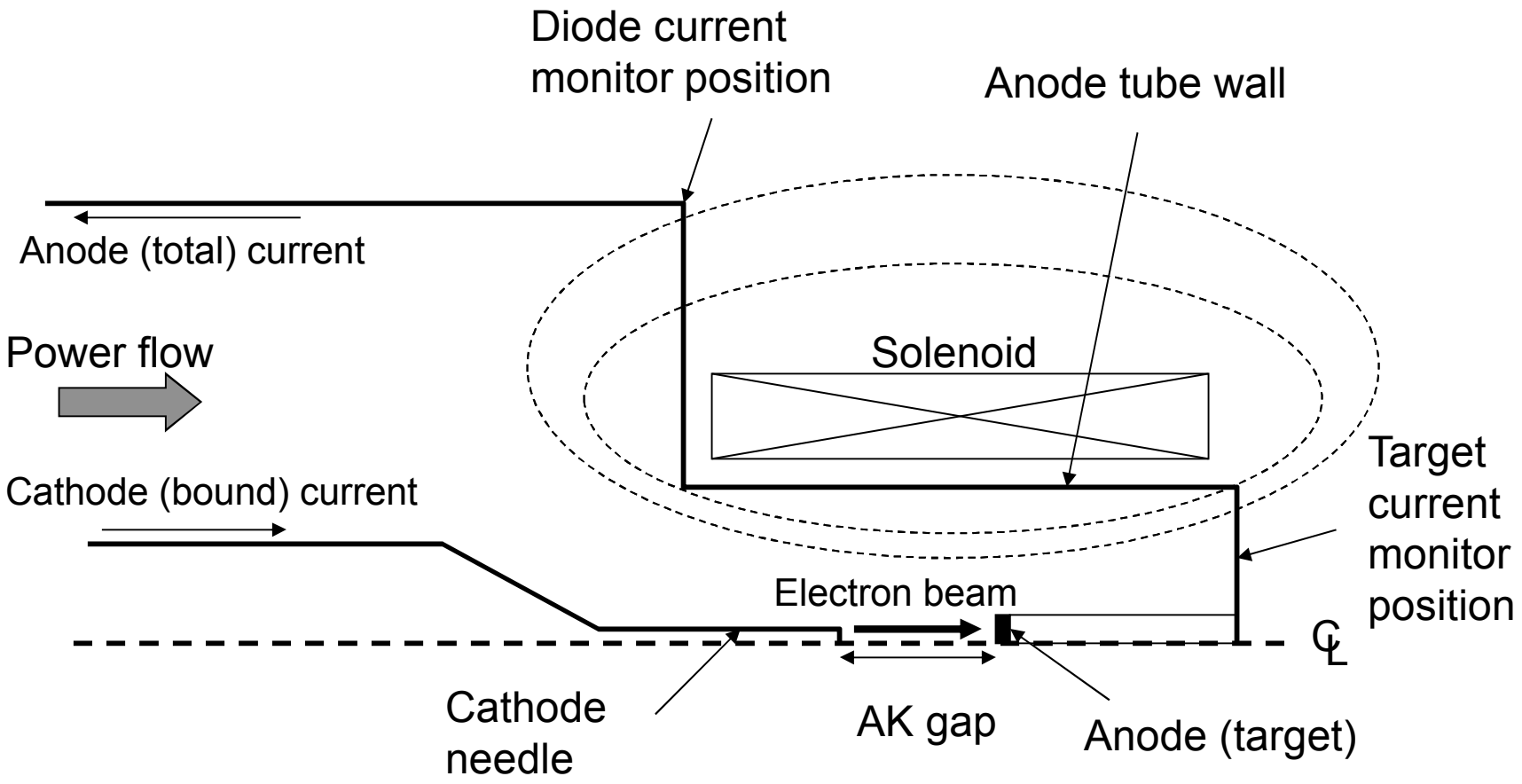
Immersed-B_z Diode Schematic



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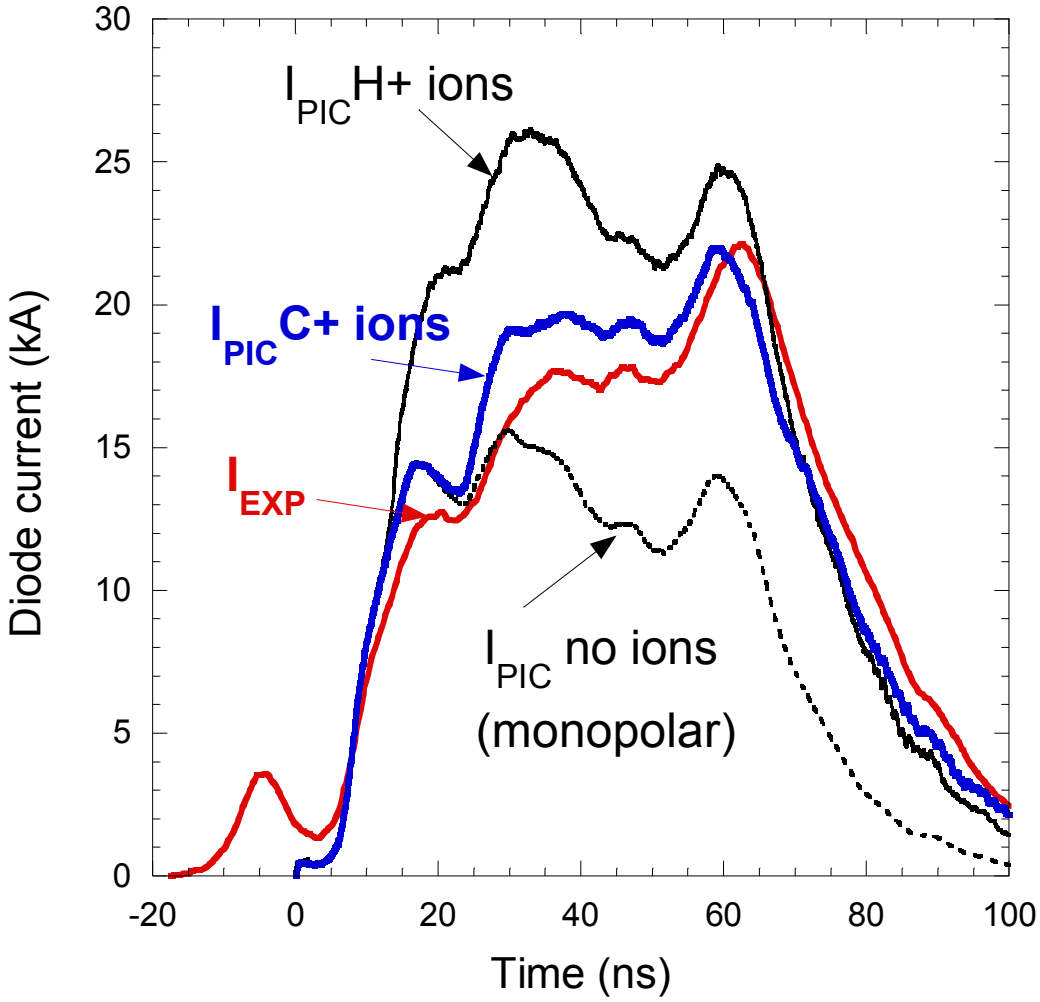
Nominal operating regime characteristics

- Large cathode diameters > 4 mm
- Diode current
  - 20 – 40 kA
  - Bipolar flow (electrons and ions)
  - Agrees well with numerical simulation
- Dose production
  - Agrees well with physics-based model
- Spot size
  - Scales with cathode diameter

Nominal regime diode current

Comparison of 2D Lsp PIC simulations with experiment



Shot 288

- Cathode dia. = 4.76 mm
- AK gap = 10 cm
- Bz field = 18 T
- Anode = RT Ta

Lsp simulation

- 2D
- 400 K ΔT ion turn-on
- Space charge limited
- Electron backscatter

Experimental current is best replicated with medium-mass ion simulation (C+ ions)

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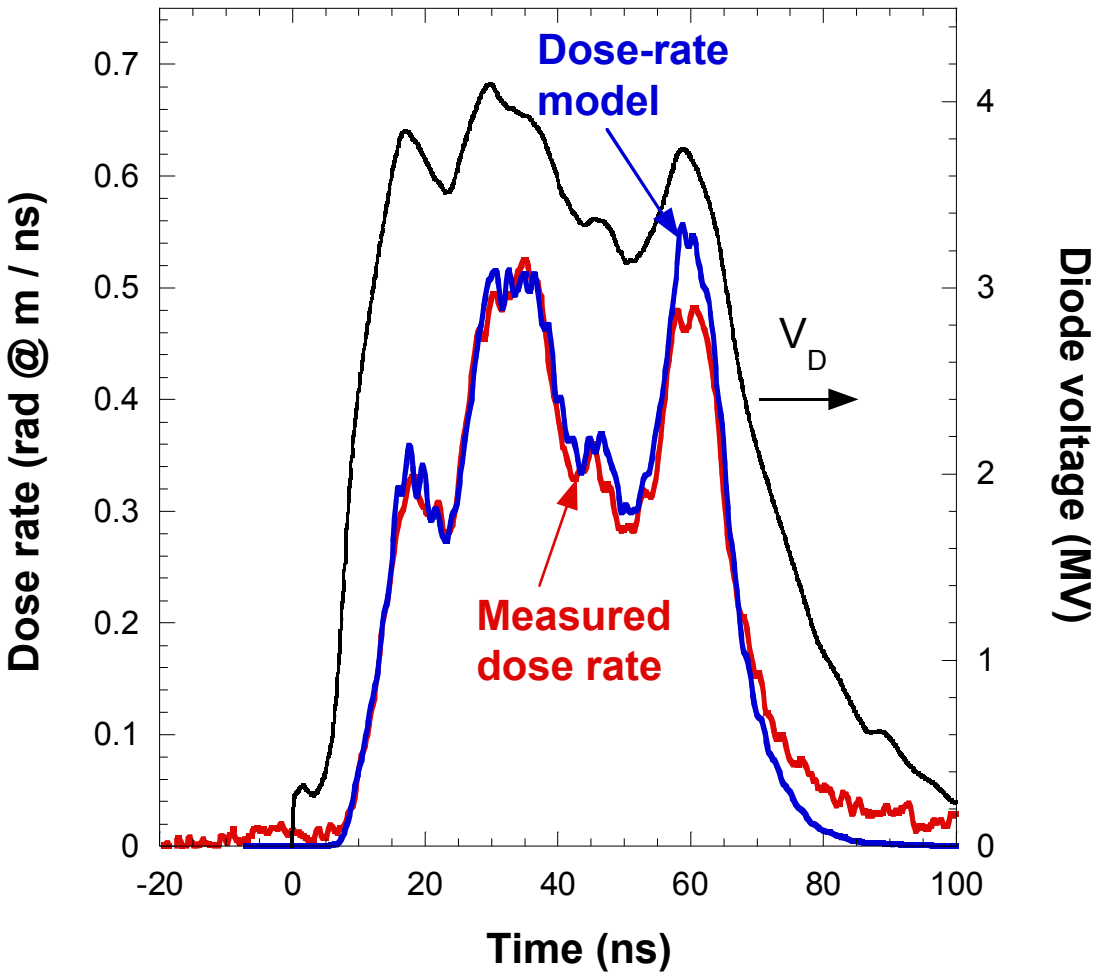
Nominal regime dose production

Comparison of dose-rate model with experiment



Shot 288
Cathode dia. = 4.76 mm
AK gap = 10 cm
Bz field = 18 T
Anode = RT Ta

Dose-rate model:
$dD/dt = 1.25\ I\ V^{2.3}$

Measured dose rate agrees well with model

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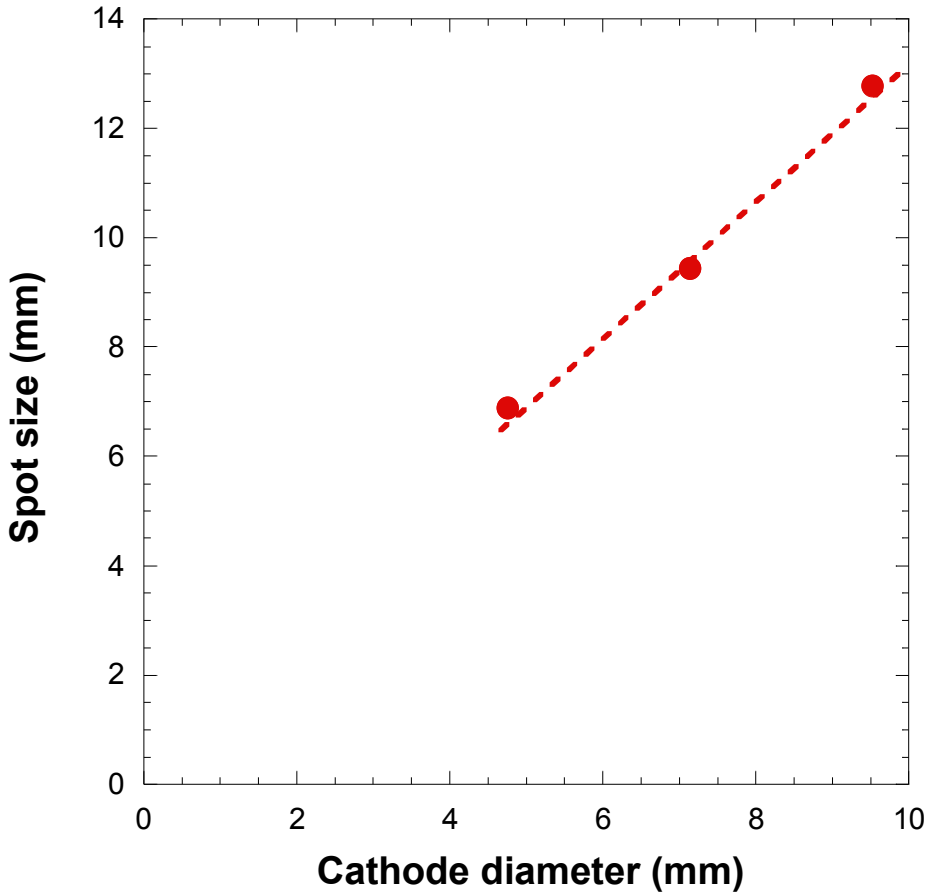
Nominal regime spot size

Spot size scales with cathode diameter



Shots 288, 339, 345
V = 4 MV
AK gap = 10 cm
Bz field = 18 T
Anode = RT Ta

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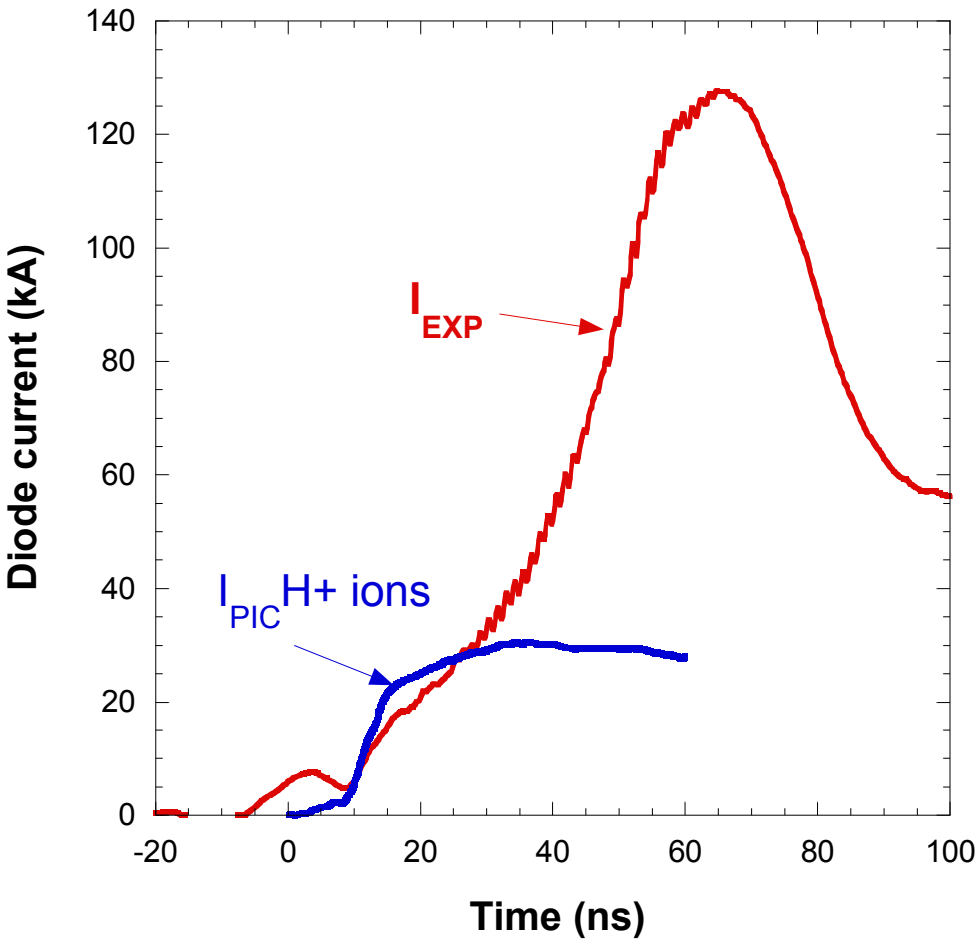
Anomalous operating regime characteristics

- Small cathode diameters < 3 mm
- Diode current
  - > 80 kA
  - Rapidly exceeds bipolar current
  - Dramatic impedance collapse
- Dose production
  - Narrow pulse
  - Rapid departure from physics-based model
- Spot size
  - Does not scale with cathode diameter

Anomalous regime diode current

Comparison of 2D Lsp PIC simulations with experiment



Shot 765

- Cathode dia. = 2 mm
- AK gap = 7.1 cm
- Bz field = 20 T
- Anode = RT Ta

Lsp simulation

- 400 K ΔT ion turn-on
- Space charge limited
- Electron backscatter

Experimental current quickly exceeds calculated bipolar current (H+ ions)

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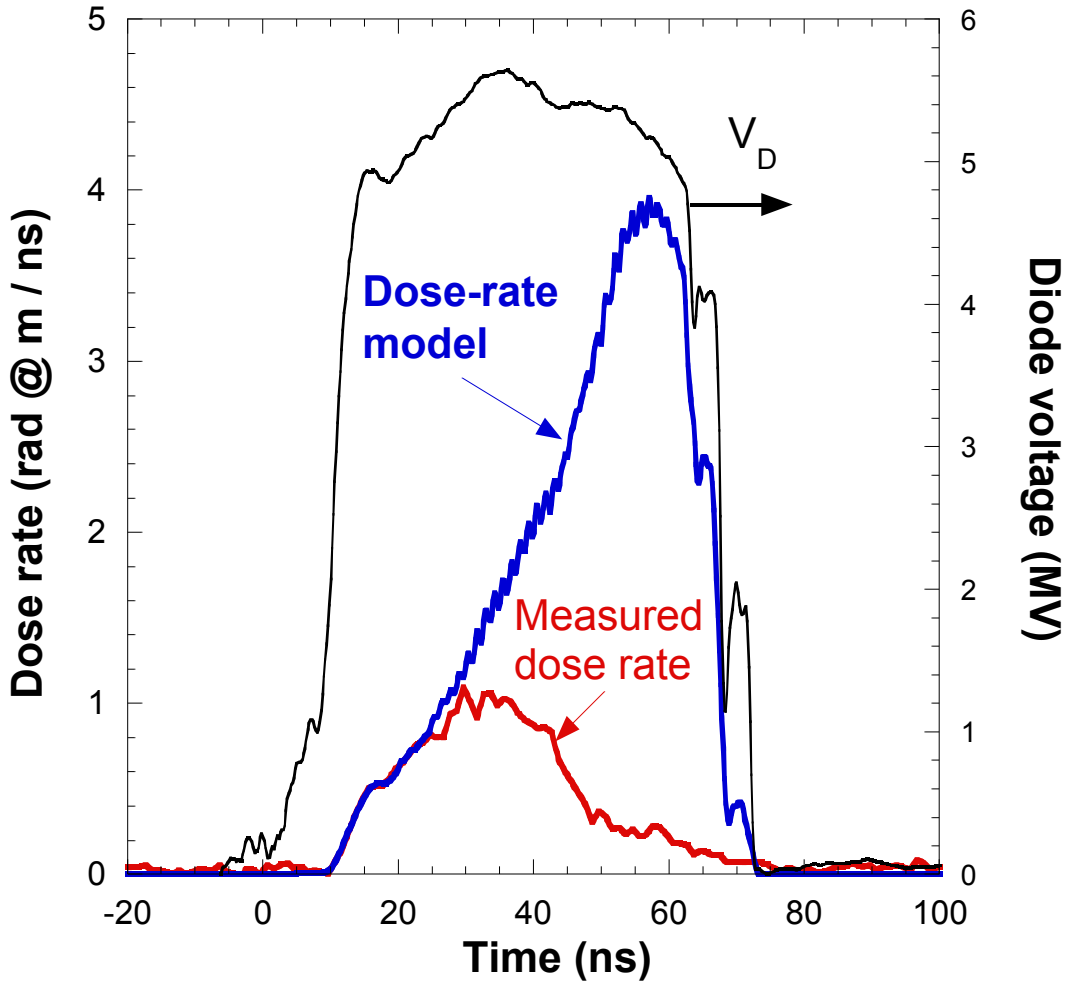
Anomalous regime dose production

Comparison of dose-rate model with experiment



Shot 765
Cathode dia. = 2 mm
AK gap = 7.1 cm
Bz field = 20 T
Anode = RT Ta

Dose-rate model:
$dD/dt = 0.75\ I\ V^{2.3}$

Measured dose rate quickly diverges from dose-rate model

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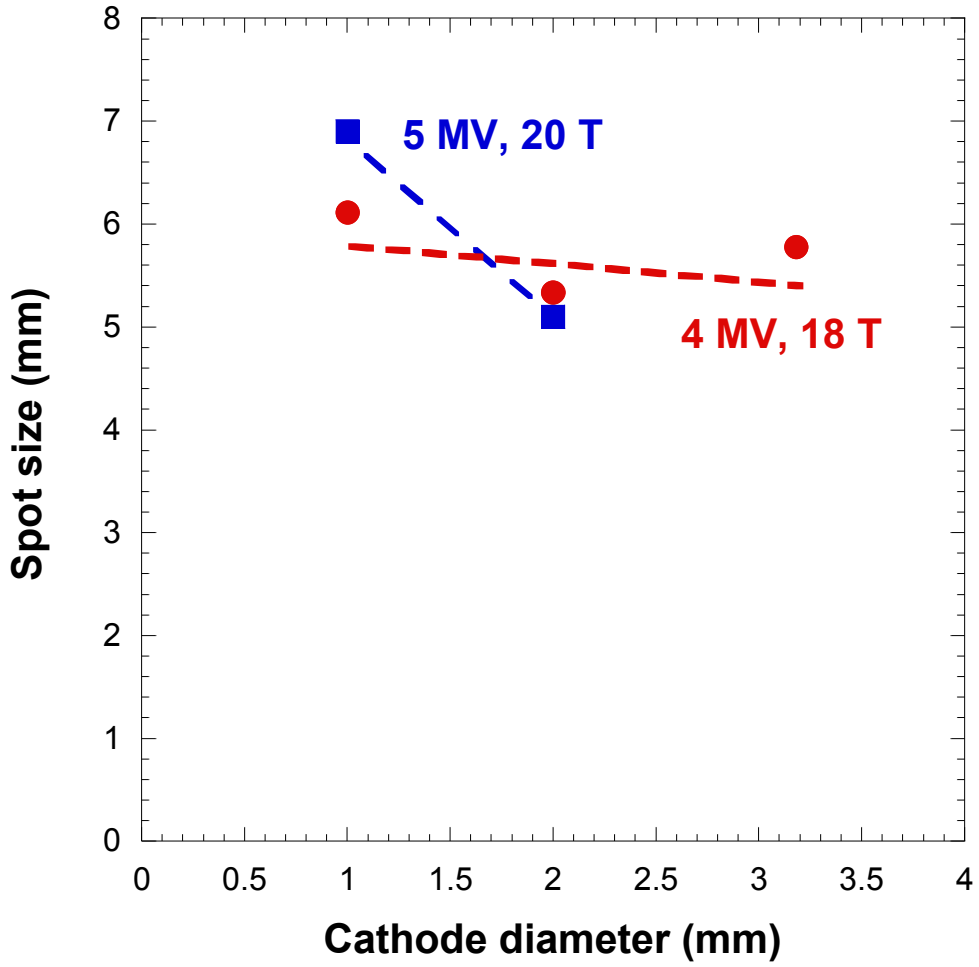
Anomalous regime spot size

Spot size does not scale with cathode diameter



4 MV, 18 T
Shots 287, 291, 341
AK gap = 10 cm
Anode = RT Ta

5 MV, 20 T
Shots 765, 766
AK gap = 7.1 cm
Anode = RT Ta

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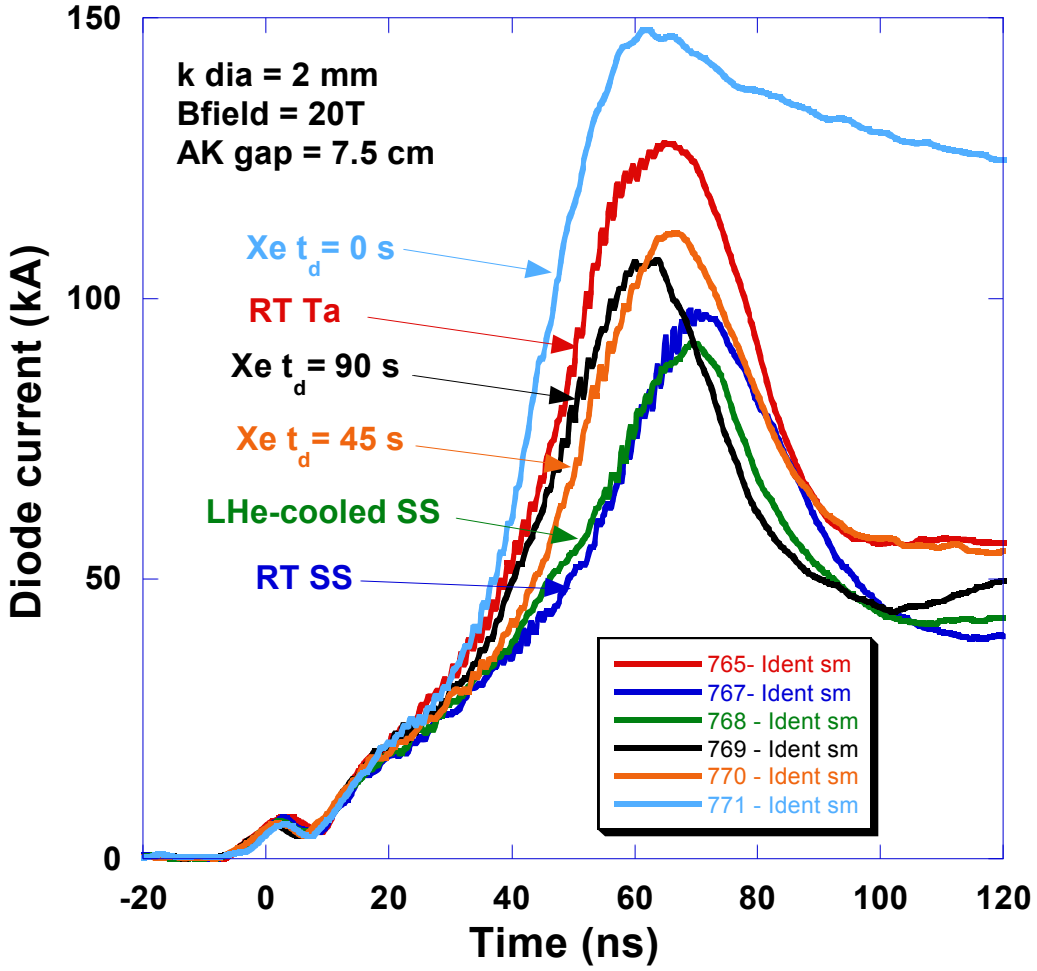
Cryogenic Modification of Anodes

- Attempt to modify behavior of small cathodes by controlling ion species from anode
  - Frozen Xe coated anodes

- No significant change in diode behavior, i.e. no change in
  - Diode current
  - Dose production
  - Spot size

- Dramatic change observed in cathode activation
  - Suggests significant decrease in protons from anode

Effect of cryogenic modification of anode on diode current



Xenon coatings:

Effective thickness > 300 microns
Effective coating rate > 0.5 μm / s

t_d: Time delay between gas supply shut-off and experiment

No significant effect on diode current

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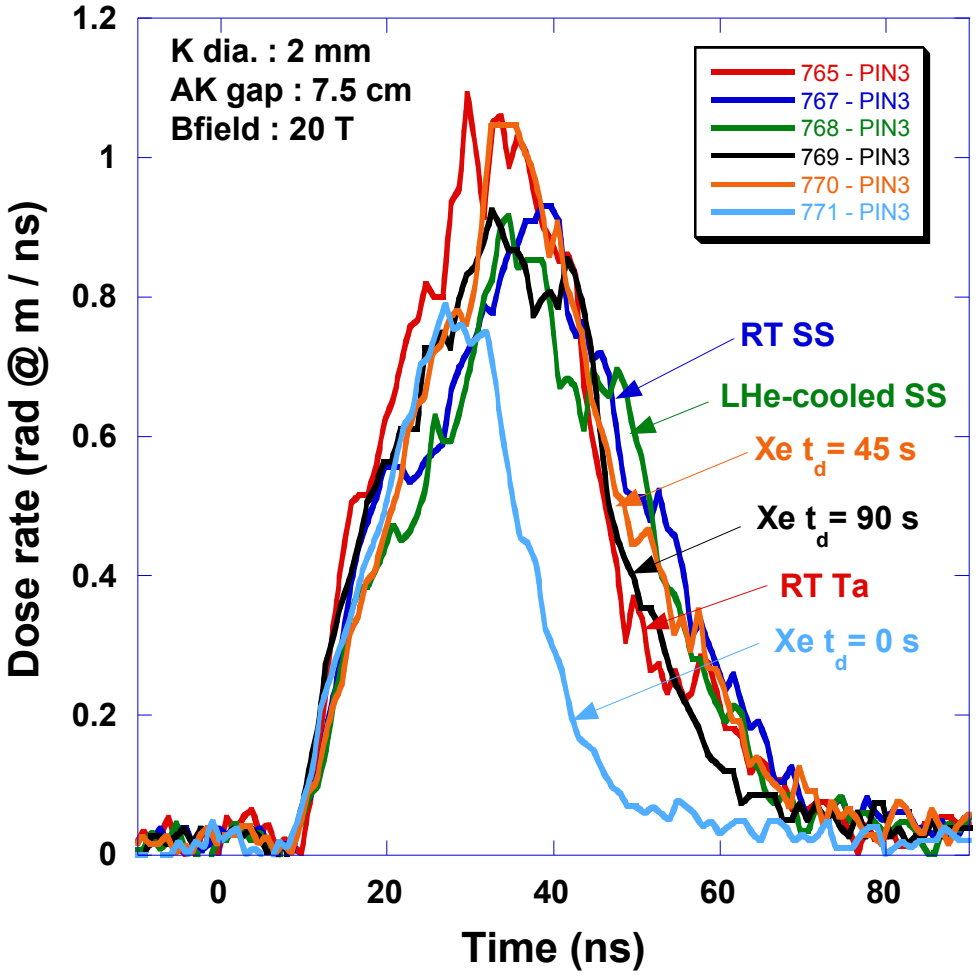
Effect of cryogenic modification of anode on dose production



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Effective coating rate > 0.5 μm / s

t_d: Time delay between gas supply shut-off and experiment

No significant effect on dose production

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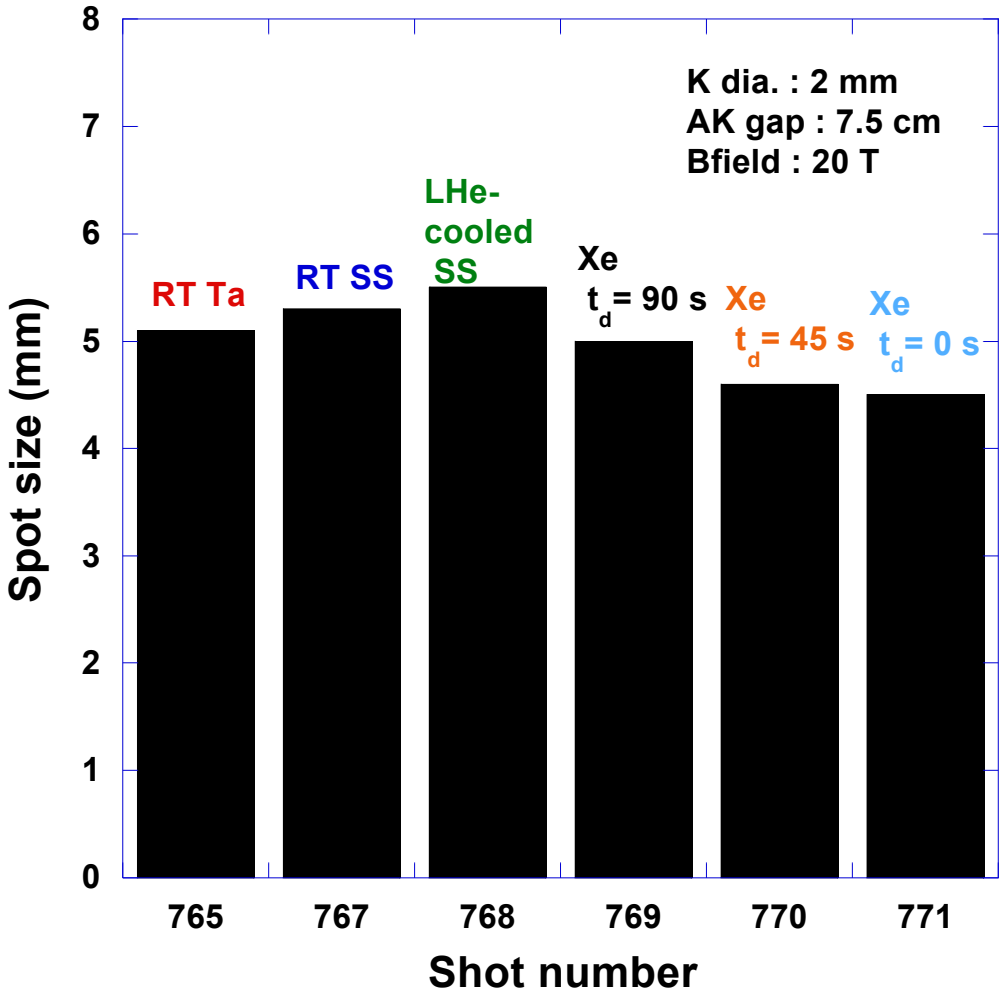
Effect of cryogenic modification of anode on spot size



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No significant effect on spot size

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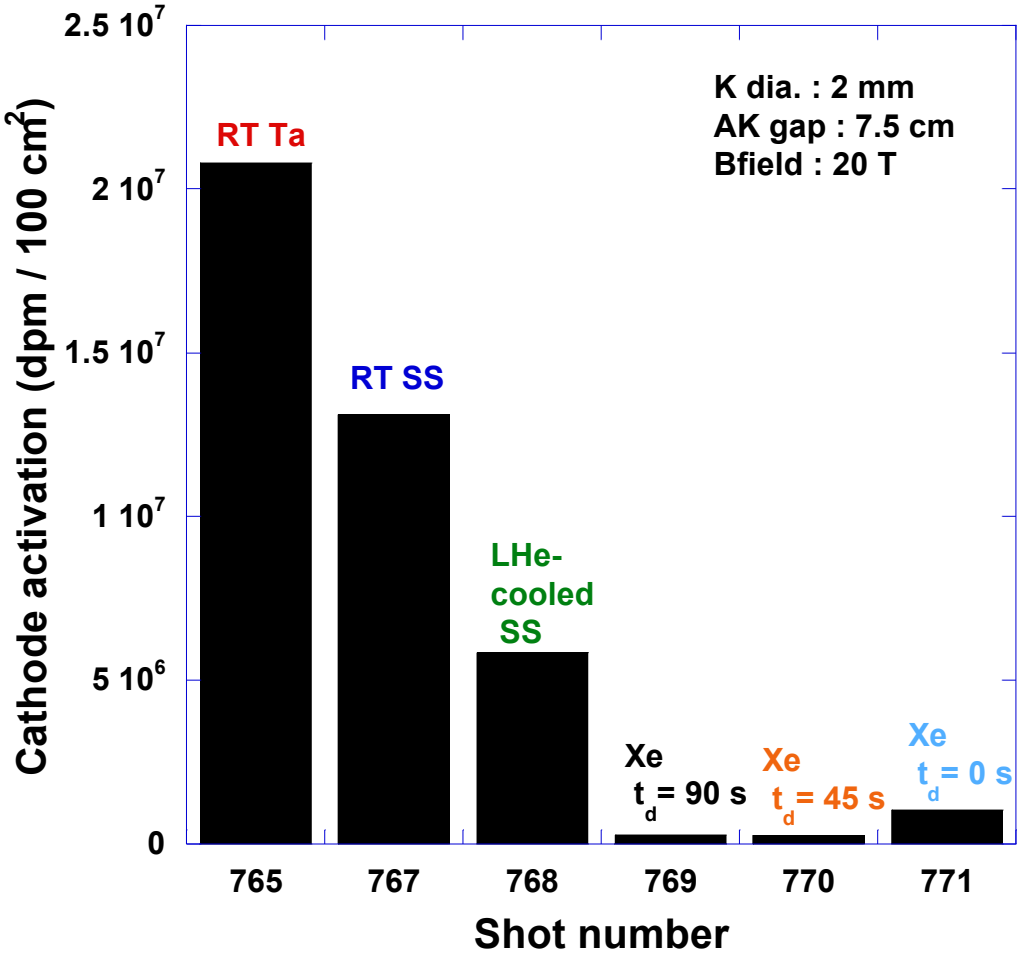
Effect of cryogenic modification of anode on cathode activation



Xenon coatings:
Effective thickness > 300 microns
Effective coating rate > 0.5 μm / s

t_d: Time delay between gas supply shut-off and experiment

Cathode material:
Titanium alloy: Ti-6Al-4V

Dramatic decrease in cathode activation suggests decreased proton content from anode

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Summary

- Identified two different operating regimes
  - Nominal
  - Anomalous
- Nominal diode currents agree well with medium-mass ion simulations
- Anomalous diode behavior remains unchanged with cryogenic modifications to anode
- Cause of anomalous diode behavior remains unclear
- Improved understanding will require increased utilization of plasma diagnostics