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Viable Options for Reducing Impedance in a 2.5 MV Multichanneling, Multigap SF_6 Gas Switch

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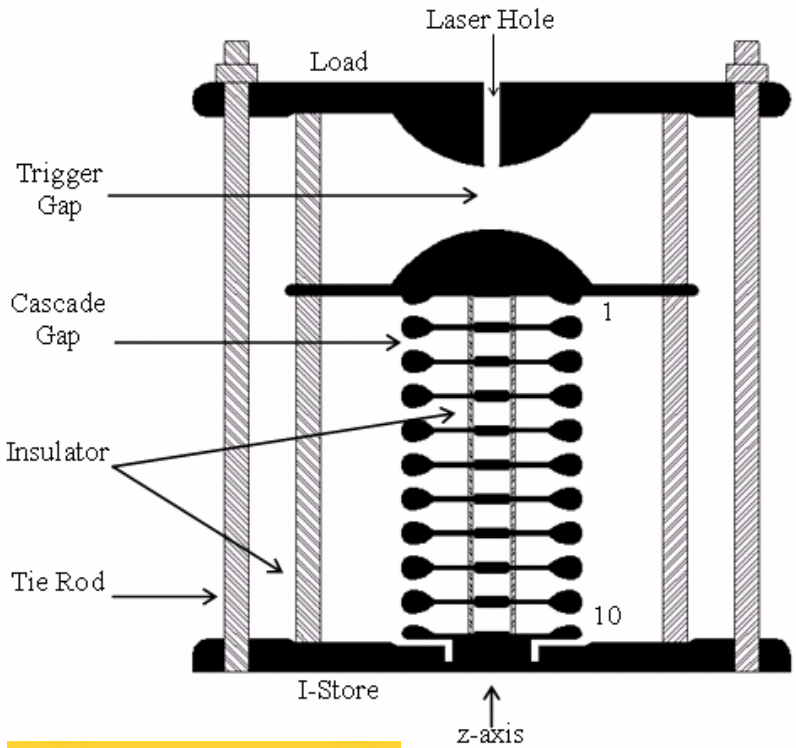
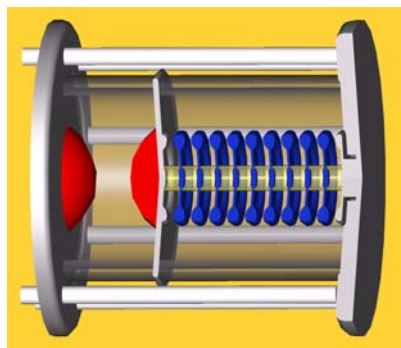
Rimfire Operation

- **Operation**
  - Relatively short laser triggered main gap
  - Short conduction lengths in multichanneling cascade section
  - Fields are uniform graded in cascade gaps
  - Scalable in voltage with length
- **Near Term Requirements**
  - 6.25 MV / 600 kA / 600 nH
  - < 4 ns jitter for 36 switches
  - 0.001% prefire/failure rate
  - 400 shot lifetime





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Experimental Arrangement

- **University of Missouri Terawatt Test Stand**
  - **SF_6, 1.5 MV, 260 ns voltage risetime, 18 psig, laser triggered 65-70% of self-break**
    - **Varying radii of cascade electrodes**
  - **Air, 1 MV, 320 ns voltage risetime, 25-35 psig, laser triggered (75-80%) and self-break**
- **Impedance Calculations**
  - **Assume a constant and calculable inductance**
  - **Obtain switch voltage and current from diagnostics**
  - **Solve for time varying switch resistance**
- **Reducing Impedance**
  - **Increase number of channels, *n***
  - **Reduce ratio of outer to inner conductors, *b/a***
  - **Reduce switch length, *l***

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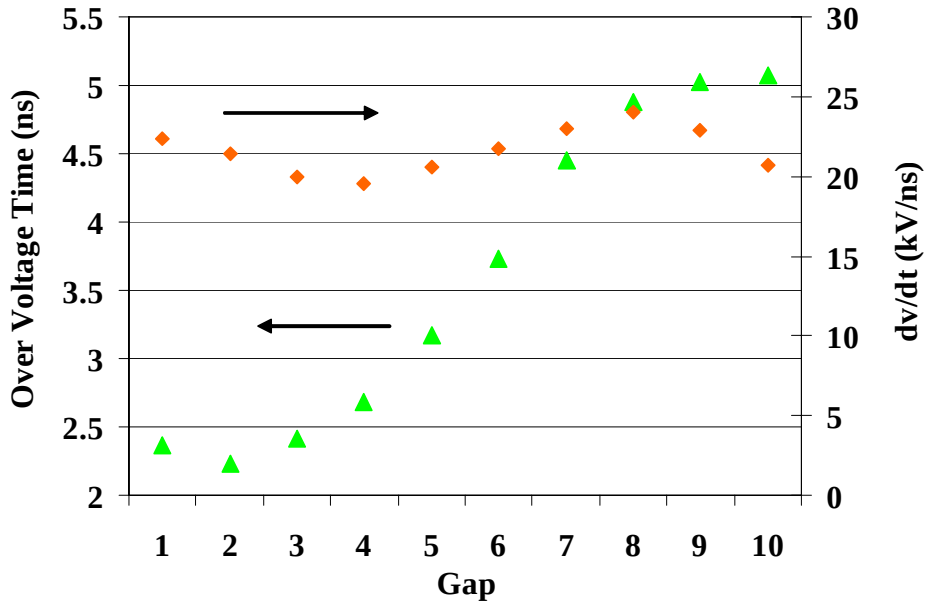
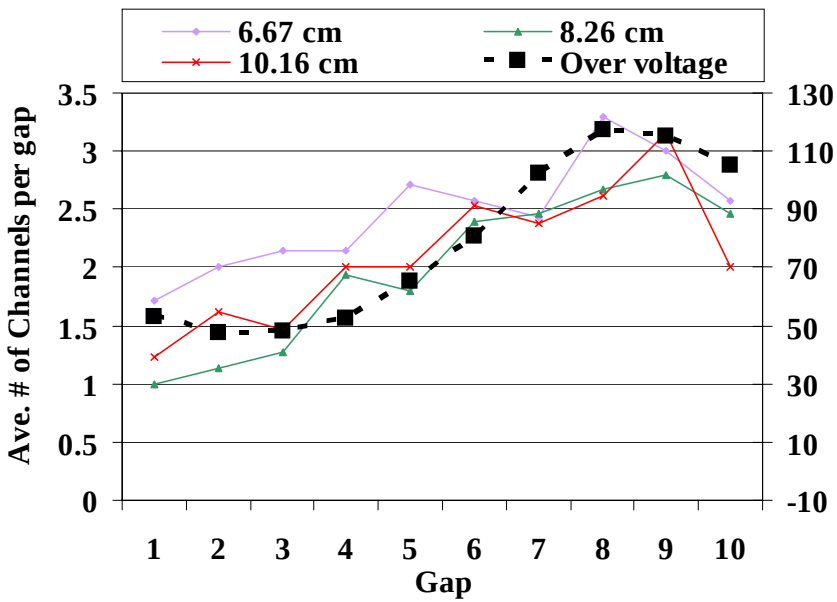
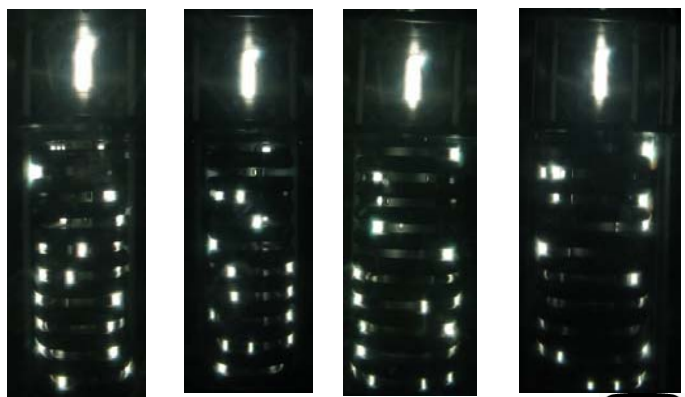
Number of Channels (*n*)

- **Comprehensive circuit model**
  - dv/dt
  - Time gap exceeds V_b
- **Overvoltage value**
  - Product of dv/dt and t_b
  - Criteria for calculating an expected *n*







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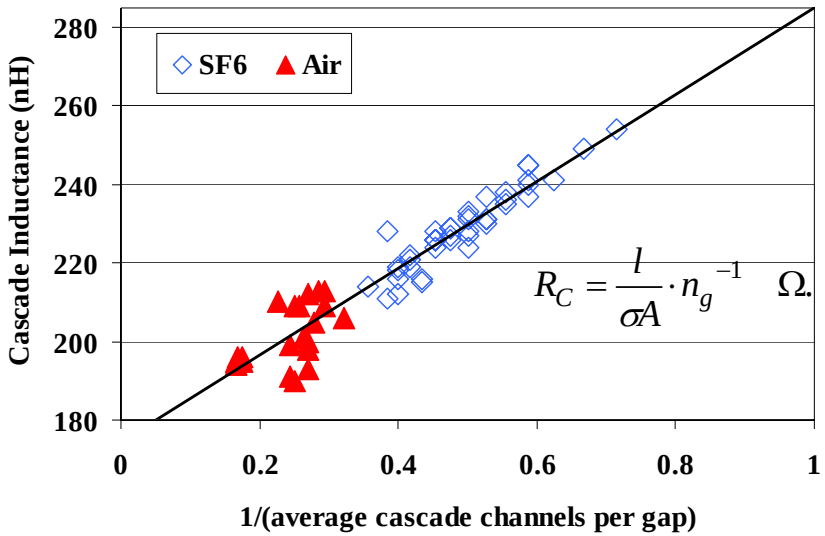
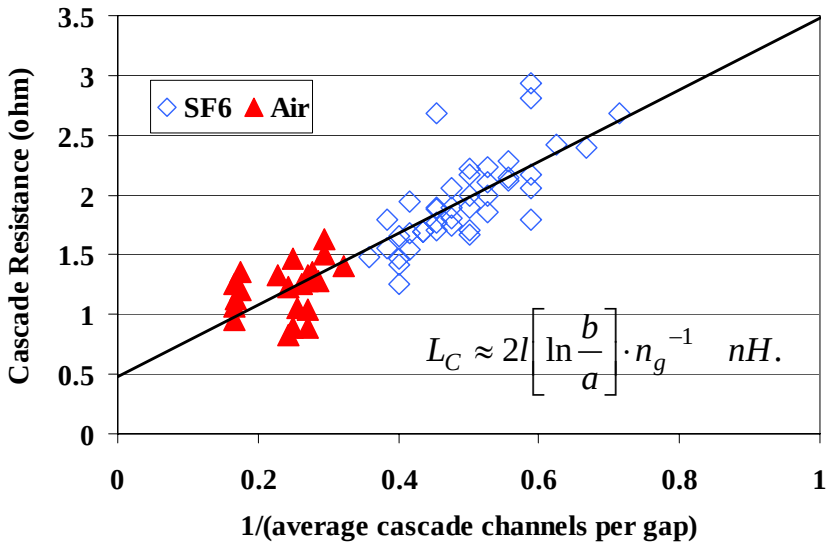
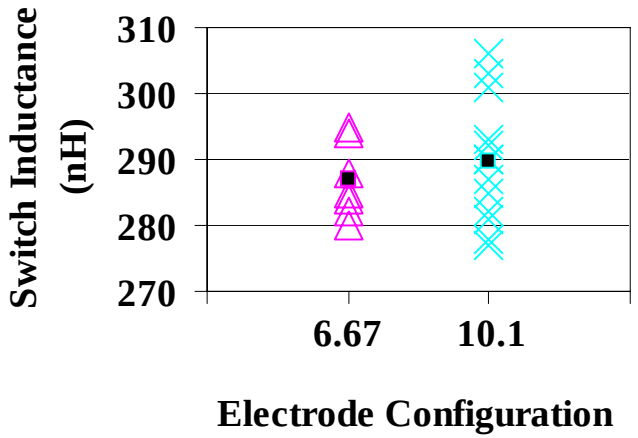
Reducing *n* and *b/a* to lower impedance by a factor of two compared to a single channeling arc of the same length





- **Reducing *n* for inductance**
  - **Limit of 3 channels per gap in SF_6 (6 for air)**
  - **18% reduction for 3 channels**
  - **Additional 6% decrease for 6 chan.**
- **Reducing *b/a* for inductance**
  - **5% decrease for 3 channels per gap**
  - **7% decrease for maximum theoretical inner diameter**



$$\ln\left[\frac{b^{(1-x)}a_1^{\,x/n}}{a_2^{\,1/n}}\right] = K\cdot(1-x)$$

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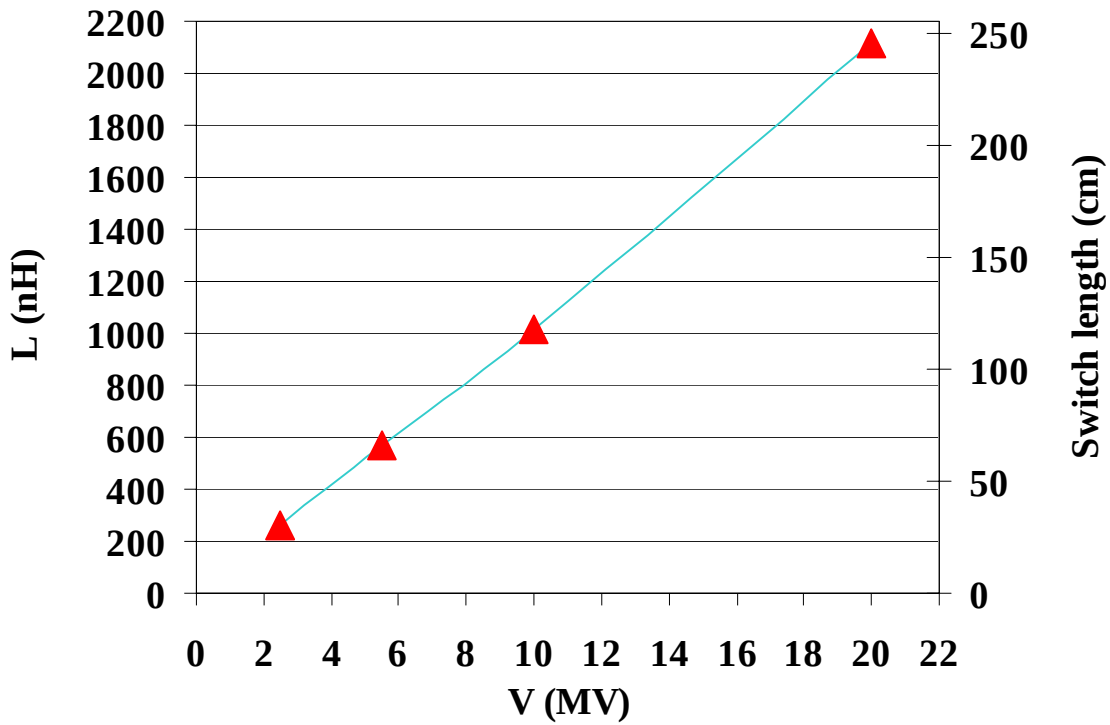
Reductions in length to reduce impedance

- Other parameters
  - 25% reduction max
- Reduce length
  - Linear relation
- Effects of reducing switch length
  - Insulators more aggressively stressed
  - Force larger operating pressures
    - Area becomes a larger factor for reliabilities



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Conclusions

- Future switch requirements
  - 20 MV
  - <10 ns jitter for hundreds of switches
  - 10^7 shot lifetime
  - <1 μH inductance
- Reducing impedance
  - No substantial benefit for parallel switching
  - Solid dielectric between inner and outer conductor required to maximally reduce *b/a*
  - No less than 3 channels for impedance concerns
    - Potentially more for wear concerns
    - Field perturbations out for SF_6
      - Must be forced by innovative trigger methods for SF_6
  - Low surface area
  - New gas dielectrics
    - Operating at >100 psi