

Behavior of a Spark Gap Pulser at High Repetition Rate

J. W. Nam, H. Rahaman¹⁾, S.H. Nam¹⁾

Hankuk Academy of Foreign Studies, Yongin, Gyeonggi, 449-854 Korea

¹⁾ Pohang Accelerator Laboratory, Pohang, Kyungbuk, 790-784 Korea

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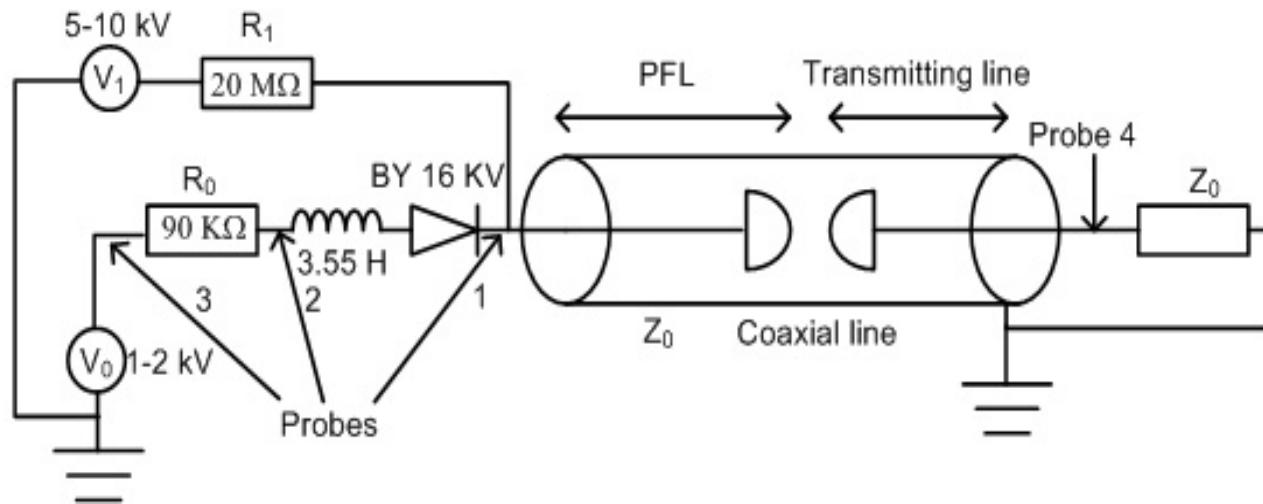
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Objectives

- Understand overall system behavior
- Develop theoretical and simulation analysis.
- Find a stable and reliable system operation conditions
- Design a high power spark gap pulser system
 - Generate pulses with sub nanosecond rise time.
 - High repetition rate ($\sim 1\text{MHz}$).

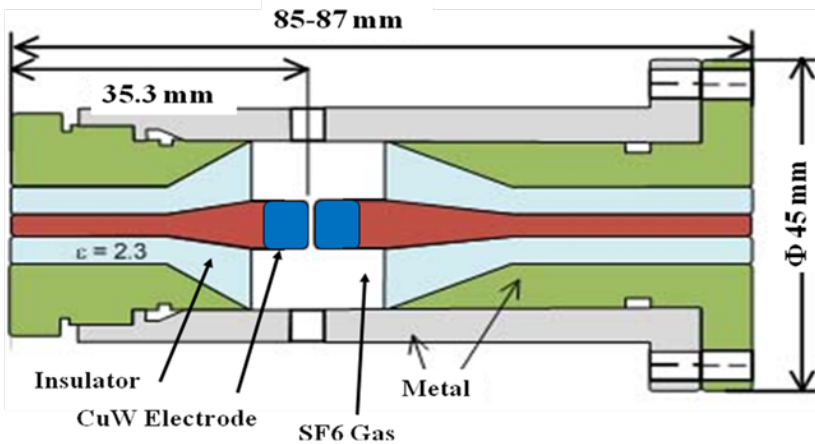
Introduction: Pulser System

- Coaxial type transmission line structure of the spark gap geometry.
- Dual power supply charging system.
- SF₆ filling gas in the spark gap geometry.

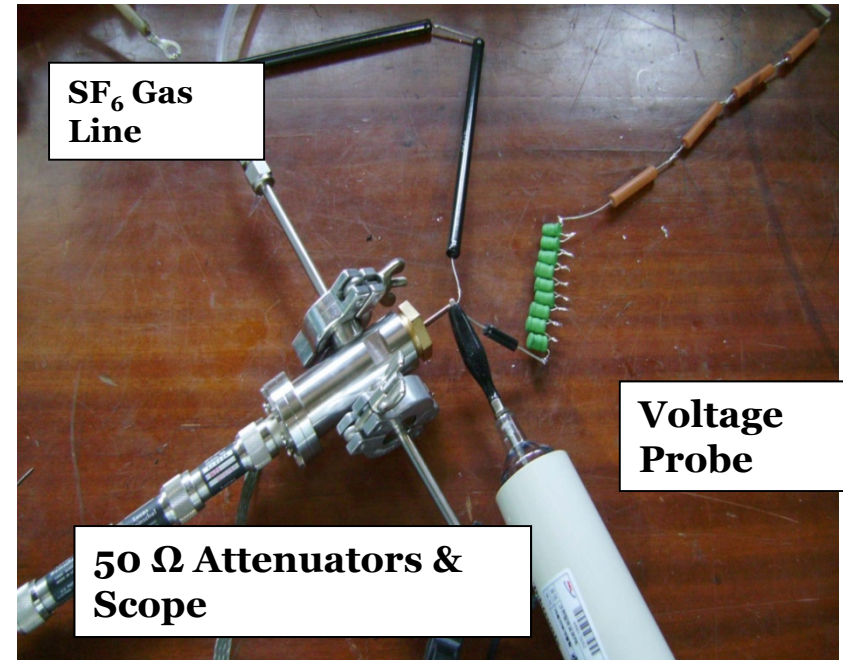


Schematic of the Pulser system

Introduction to the system



$$Z_o = \frac{377}{2\pi\sqrt{\epsilon_r}} \ln\left(\frac{D}{d}\right)$$

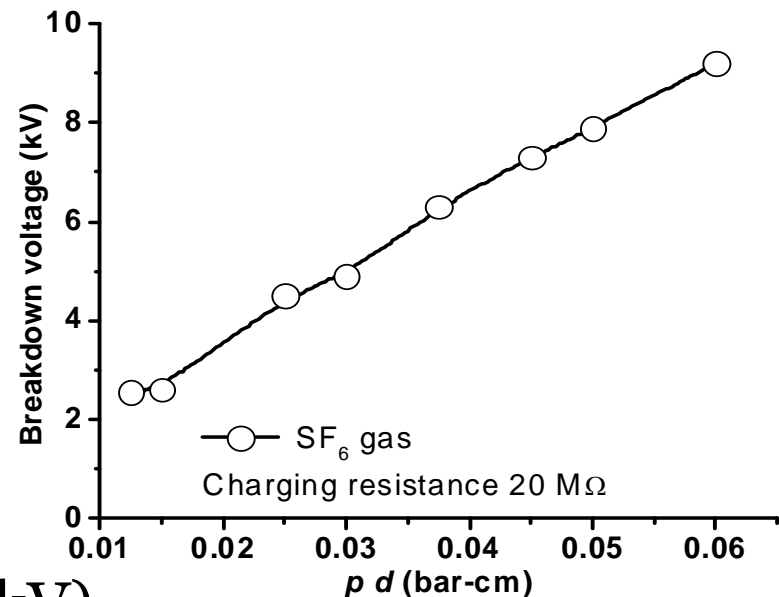


Observations on System Operation 1

- High pressure discharge.
- Spatially confined plasma with gap distance of few 100's μm .
- Pd (pressure times distance)– right hand side of the paschen curve.
- Operating range
 - Pressure(1.0 bar ~ 2.0 bar)
 - Gap distance(100~400 μm)

In continuous operation

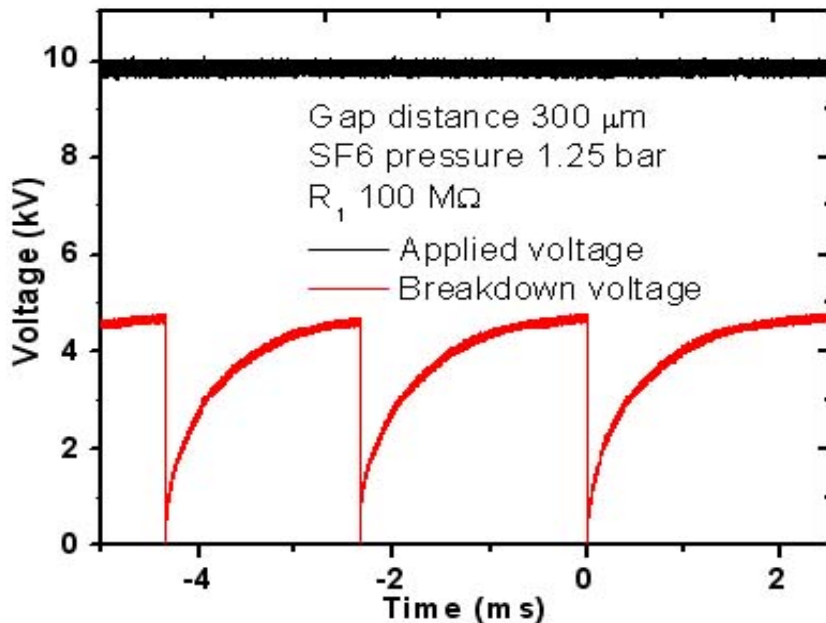
- Moderate breakdown voltage (~1kV).
- Moderate discharge current (~A).



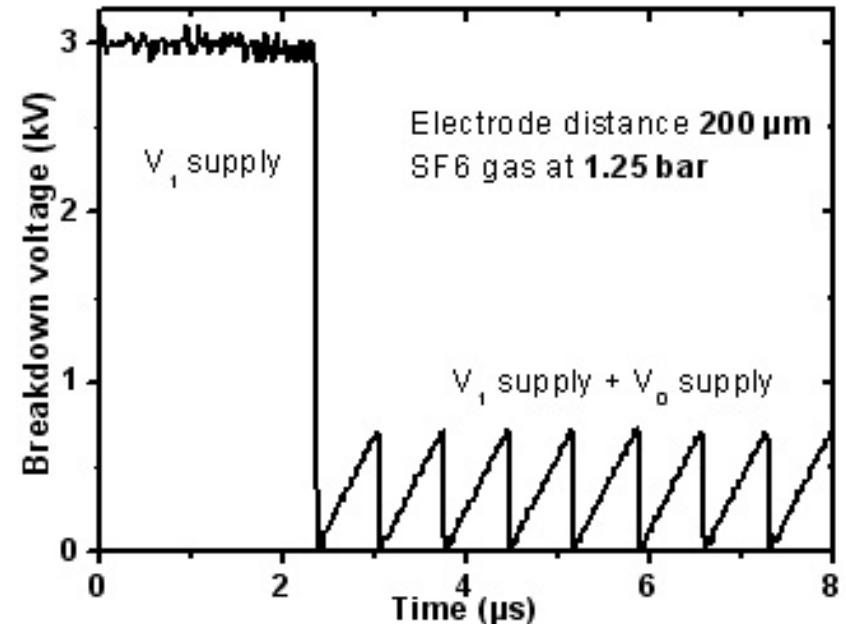
Paschen curve

Observation on System Operation 2

- Two power supplies play distinct role



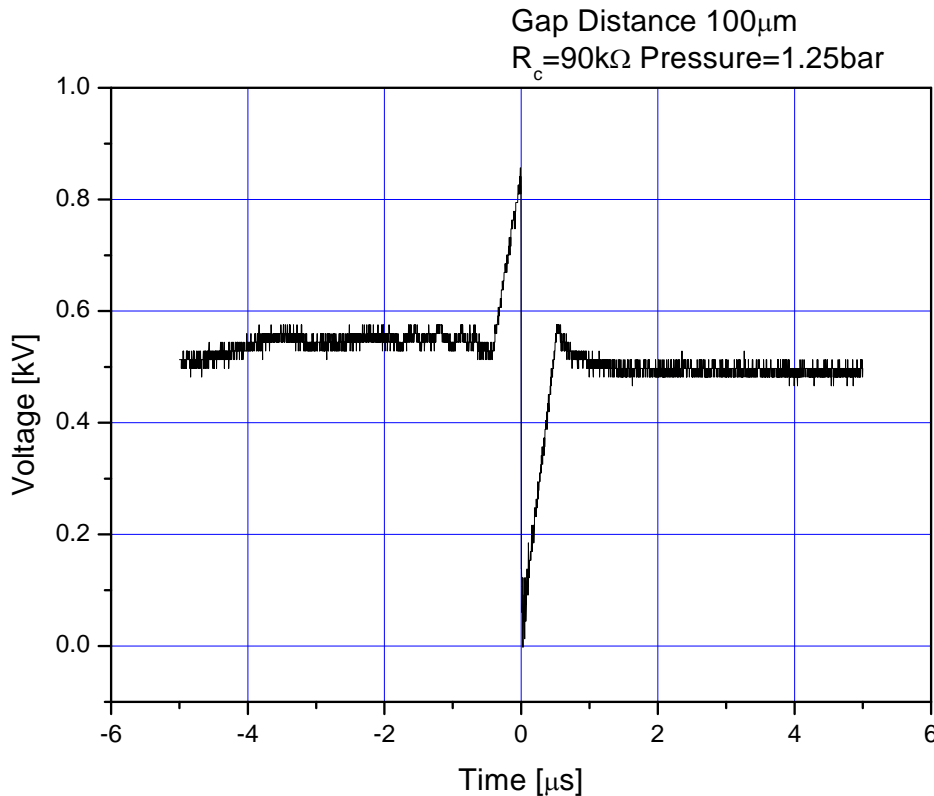
▫ High voltage (5~10kV) power supply initiates the slow breakdown of the system with small current



▫ Low voltage ($\sim 1\text{kV}$) power supply provides most of the current/energy for fast repetition ($\sim 1\text{MHz}$)

Observation on System Operation 3

- However, system sometimes had instabilities, failing to work as a switch.

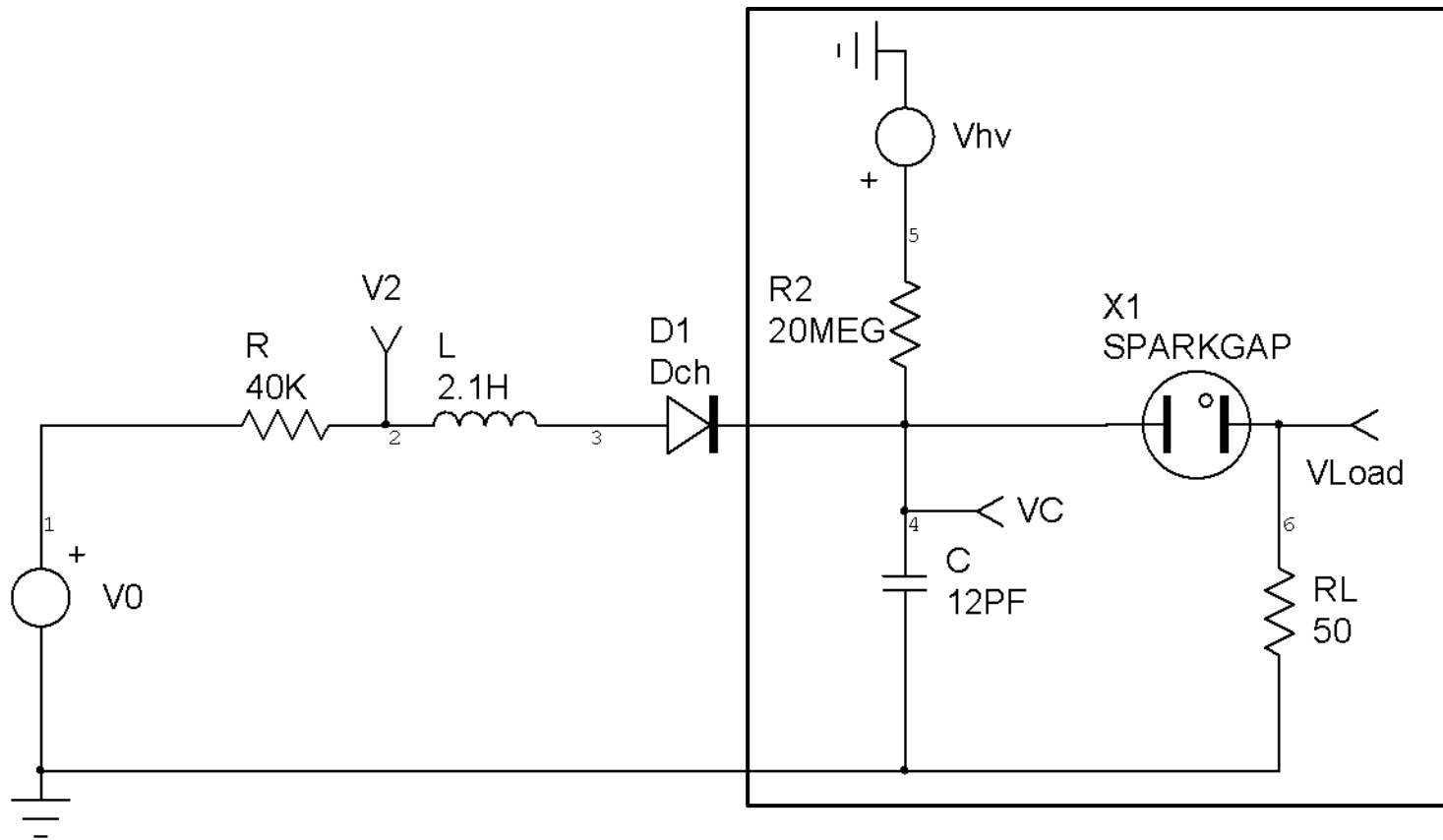


**THUS, NEEDED OPTIMIZATION
FOR STABLE AND SUSTAINABLE
SYSTEM OPERATION!!**

Simulation and Theoretical Analysis: Objectives

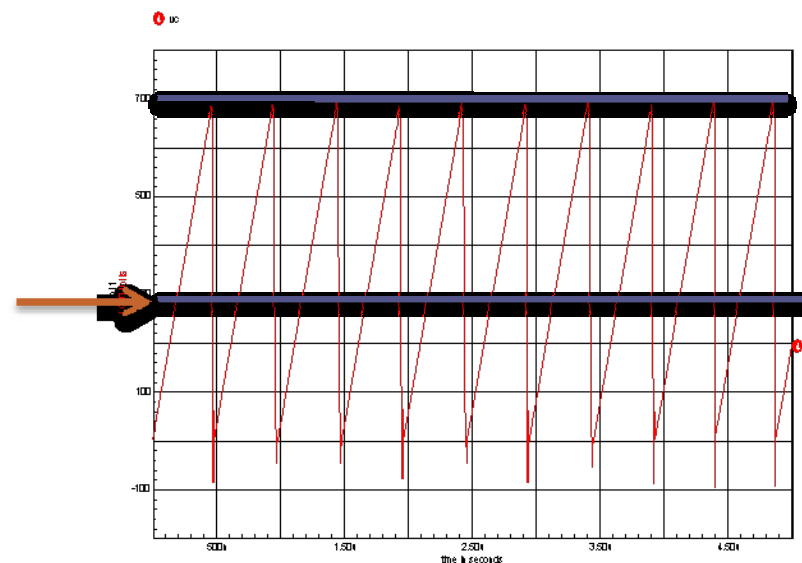
- Understand the system circuit more thoroughly
- Develop theoretical tool for calculation of system performance
- Optimize the circuit parameters with the better understanding

Simulation and Theoretical Analysis: Equivalent Circuit



Black box of the system (what we know is that this system continuously uses energy), consequently substituted with a resistor

Simulation and Theoretical Analysis: Simplified Circuit



- Known constants: V_o , R , L , C , V_c (breakdown voltage)
- Breakdown Voltage is assumed to have a constant value
- Unknown Values: R_z , i , PRR, Efficiency

Simulation and Theoretical Analysis

PRR Calculation

$$Q = \int i dt = i\tau = CV_{br}$$

$$i_0 = \frac{V_0 - V_{av}}{R_C} = \frac{2V_0 - V_{br}}{2R_C}$$

$$PRR = \frac{1}{\tau} = \frac{i}{CV_{br}} = \frac{2V_0 - V_{br}}{2R_C CV_{br}}$$

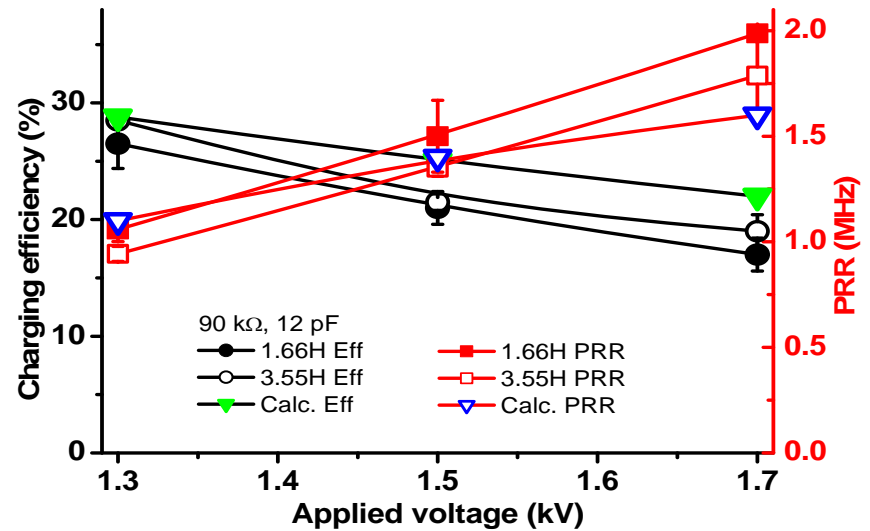
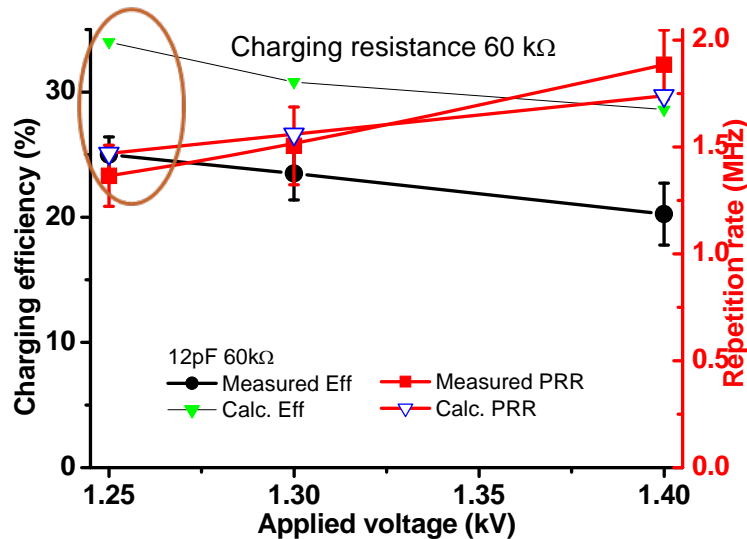
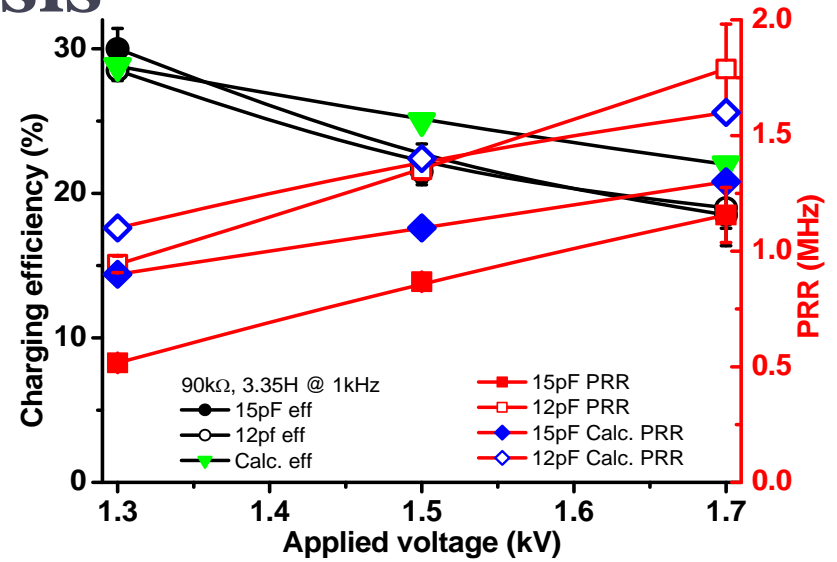
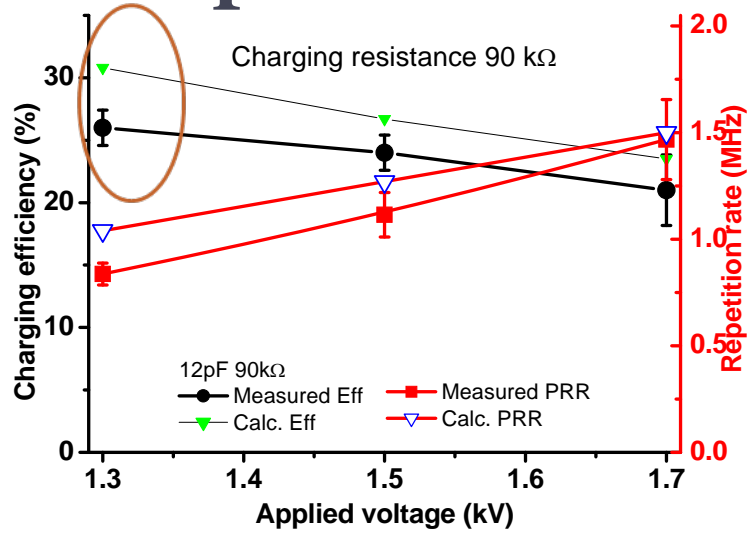
Efficiency Calculation

$$\eta_{eff} = \frac{(1/2)CV_{br}^2 \cdot PRR}{V_0 i} = \frac{V_{br}}{2V_0}$$

- Q : accumulated charge
- τ : pulse repetition period
- V_{br} : breakdown voltage
- C : spark gap geometry capacitance.

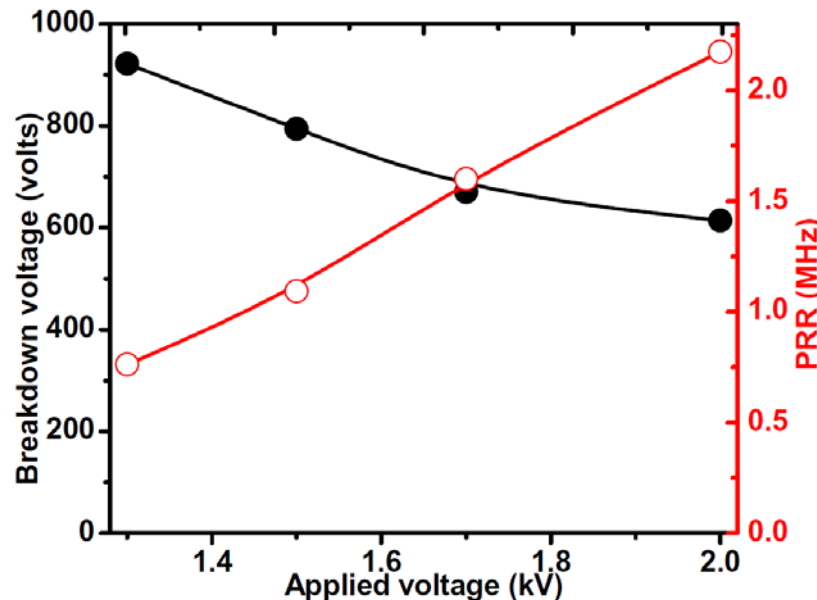
- Known constants: V_0 , R , L , C , V_c (breakdown voltage)
- Breakdown Voltage is assumed to have a constant value
- Unknown Values: R_z , i , PRR , Efficiency

Comparison and Analysis



Comparison and Analysis

- Calculated PRR matches well with the actual data
- PRR can be improved by optimizing R_c & C
- Some discrepancy between calculated and measured efficiency
- In reality, breakdown voltage varies as applied voltage and R_c change.



$$V_{br}(T) = \frac{V_{br}(T_0)n}{n_0} = \frac{V_{br}(T_0)T_0}{T}$$

V_{br} : breakdown voltage

T : elevated gas temperature

T_0 : the initial gas temperature

n : gas densities at T

n_0 : gas densities at T_0

Conclusion

- Developed a unique pulser system
- Understood the system operation behaviors
- Performed circuit simulation using PSPICE
- Developed analytical tool
- Optimized the system