

Novel High Repetitive Solid State Pulsed Power modulator

Euro-Asian Pulsed Power Conference

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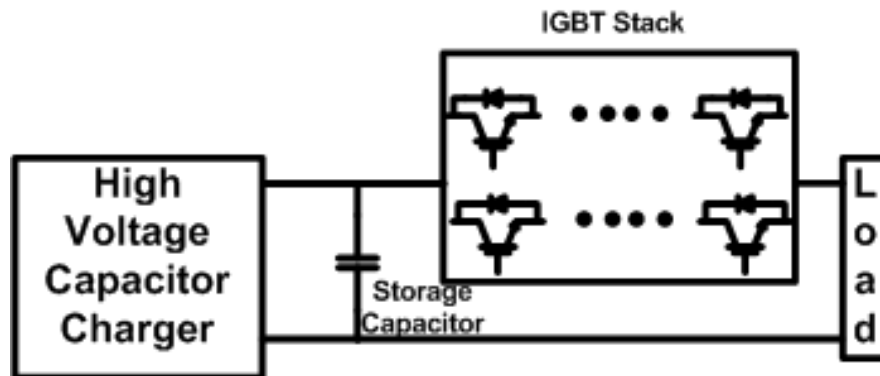
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Presentation Outline

- **Background**
- **Proposed Solid State Pulsed Power Modulator**
 - Specifications of Proposed Solid State Pulsed Power Modulator
 - Structure of Proposed Solid State Pulsed Power Modulator
 - High Voltage Capacitor Charger with IGBT Stack
 - Simple and Reliable Gate Driver Circuit
- **Experimental Results**
- **Summary and Future Study**

Background

- **Solid State Pulsed Power Modulator**
 - **Advantages of Solid State Marx Generator**
 - Long Life Span
 - Easiness of varying Pulse width and Repetition Rate
 - Rectangular Pulse Waveform
 - **Concept of Solid State Pulsed Power Modulator**



- **Requirements for Developing Solid State Pulsed Power Modulator**
 - Series or Parallel Stacking of Semiconductor Switches
 - Synchronization of IGBT turn on & off timing
 - Optimized gate driver circuit for reducing complexity

Proposed Solid State Pulsed Power Modulator

■ Specifications

- Output Voltage: 0 ~ 10 [kV]
- Output Current: 0 ~ 50 [A]
- Pulse Width: 1 ~ 10 [μ S]
- Pulse Repetition Rate: 1 ~ 50 [kHz]
- Pulse Rising Time: < 100 [ns]
- Average Output Power: 10 [kW]
- Maximum Charging Efficiency: 93 [%]
- Protections: Over Current, Over Temperature, Arc and Short
- Compactness: 26Liter (43.5cm(W)*40cm(D)*15cm(H))



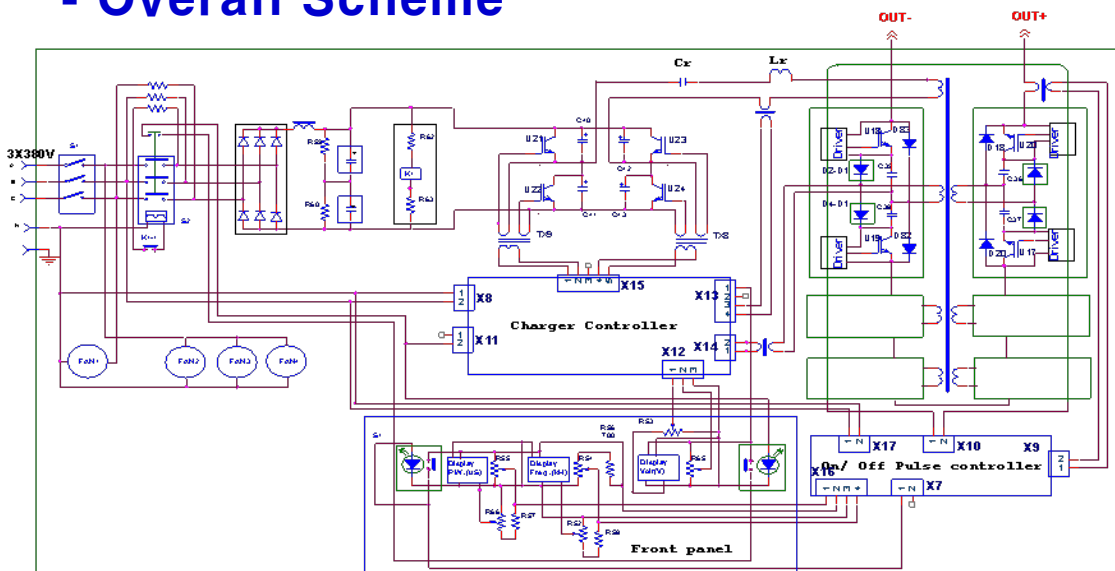
■ Advantages

- Simple & reliable gate driver circuit
- Easiness of pulse wave control(PW, PRR, PV)
- Superior arc and short protection
- Compact and High efficiency Capacitor Charger

Proposed Solid State Pulsed Power Modulator

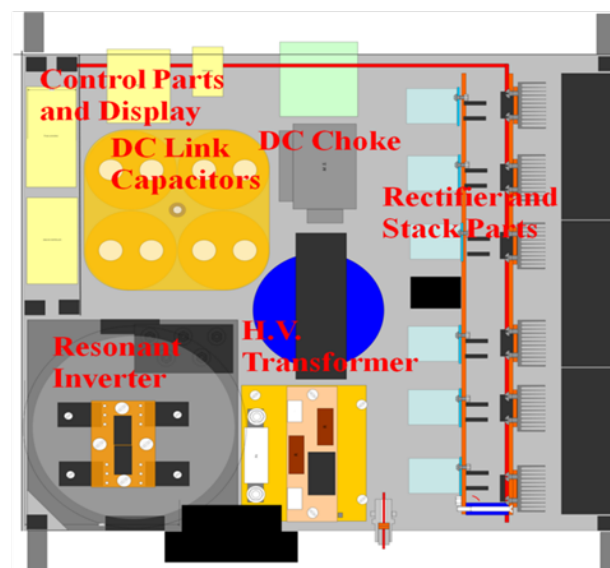
Structure of Proposed Solid State Pulsed Power Modulator

Overall Scheme

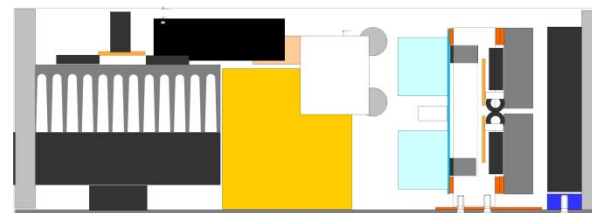


- High efficiency capacitor charger based on the phase shifted PWM converter topology
- Power cell based IGBT stack for 10kV pulse
- Gate driver circuit with on/off pulse controller

Designed Structure - Top View

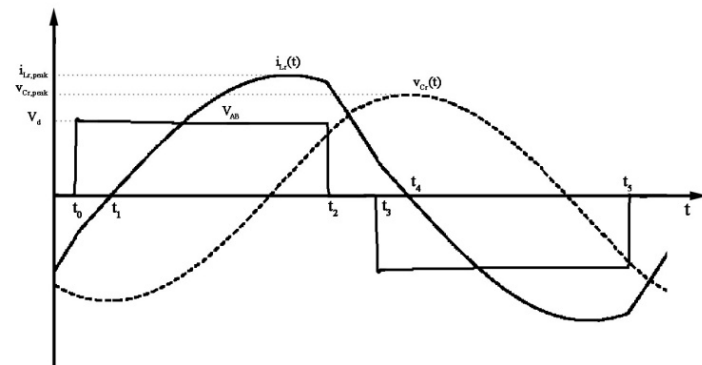
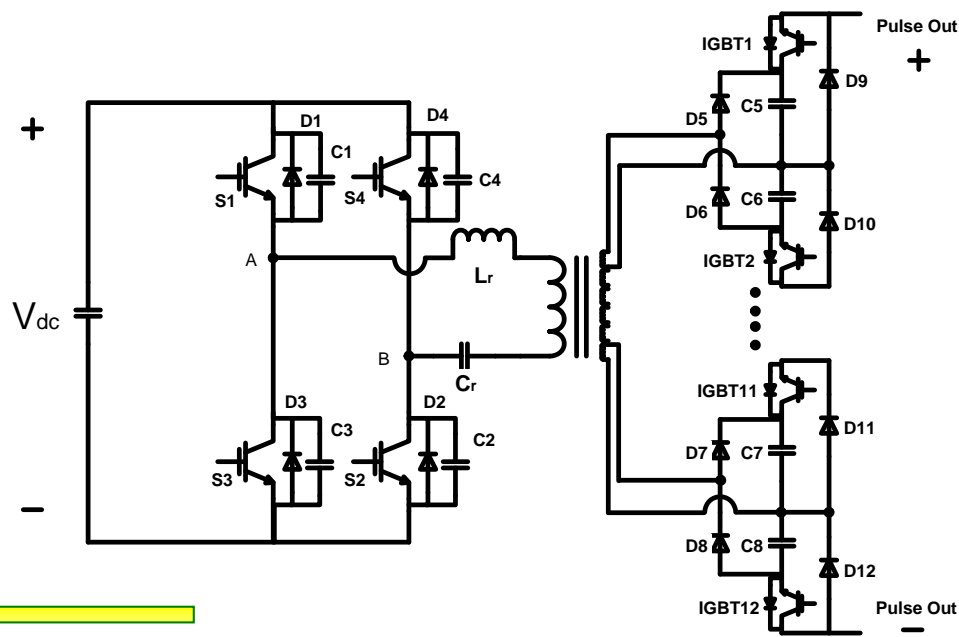


-Side View



Proposed Solid State Pulsed Power Modulator

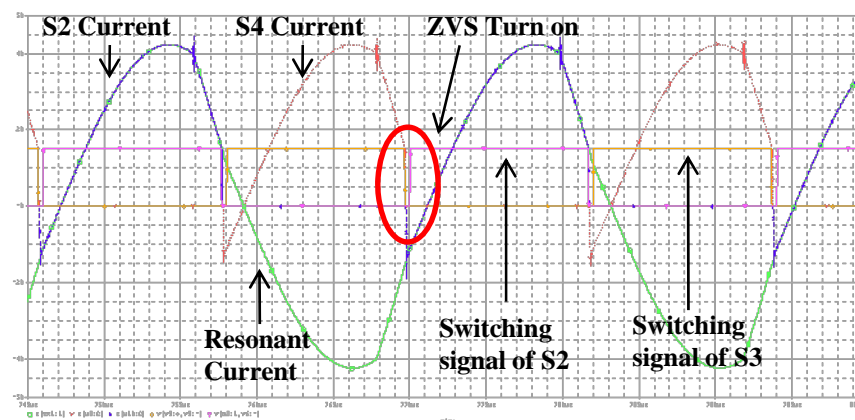
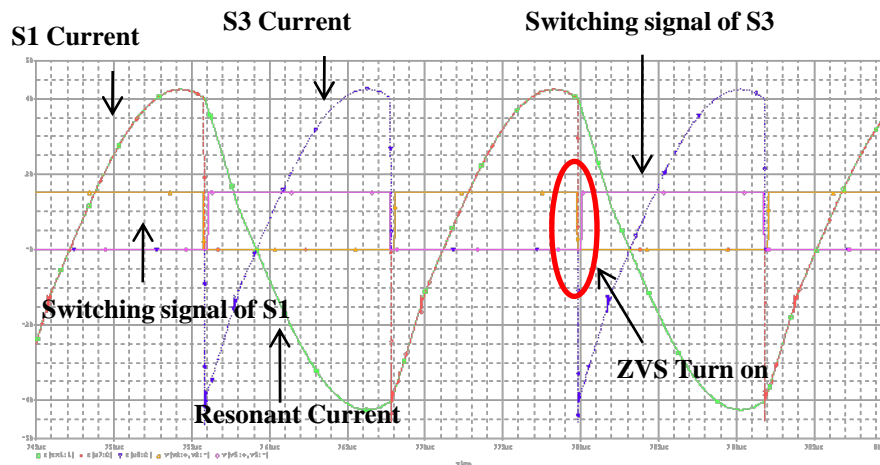
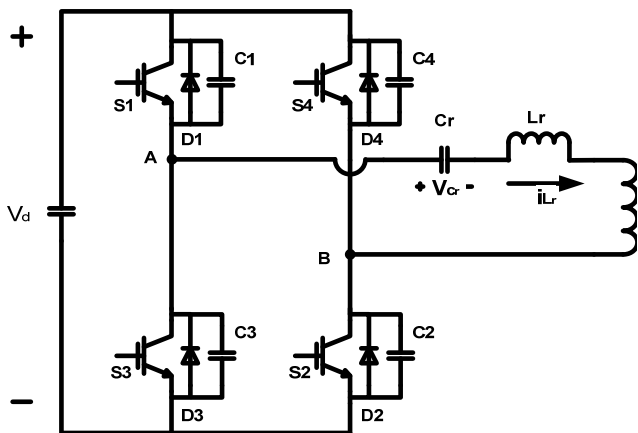
- **High Voltage Capacitor Charger and IGBT Stack**
- **Features of Proposed Capacitor Charger and IGBT Stack**
 - Phase shifted PWM converter topology with series resonant tank
 - Lossless snubber capacitor reduce the turn off loss
 - High efficiency and Compact design
 - Reliable operation of power cell based IGBT stack
- **Scheme of Charger and IGBT Stack**
- **Waveforms**



Proposed Solid State Pulsed Power Modulator

- High Voltage Capacitor Charger with IGBT Stack
- Designed Parameters

Design Parameters for 10kW (10kV, 1A) Capacitor Charger	
Input Voltage	380V _{ac} ±10%
DC Input Voltage, V _d	513V _{dc} ±10%
Maximum Output Power, P _{out}	10kW(10kV, 1A)
Resonant Inductance, L _r	40uH
Resonant Capacitance, C _r	0.45uF
Resonant Frequency, f _o	37.5kHz
Switching Frequency, f _s	42kHz
Transformer Turns Ratio	13 : 25*6
Snubber Capacitance for Leading Leg	1.5nF
Snubber Capacitance for Lagging Leg	1nF
Storage Capacitor (C5~C8)	15uF



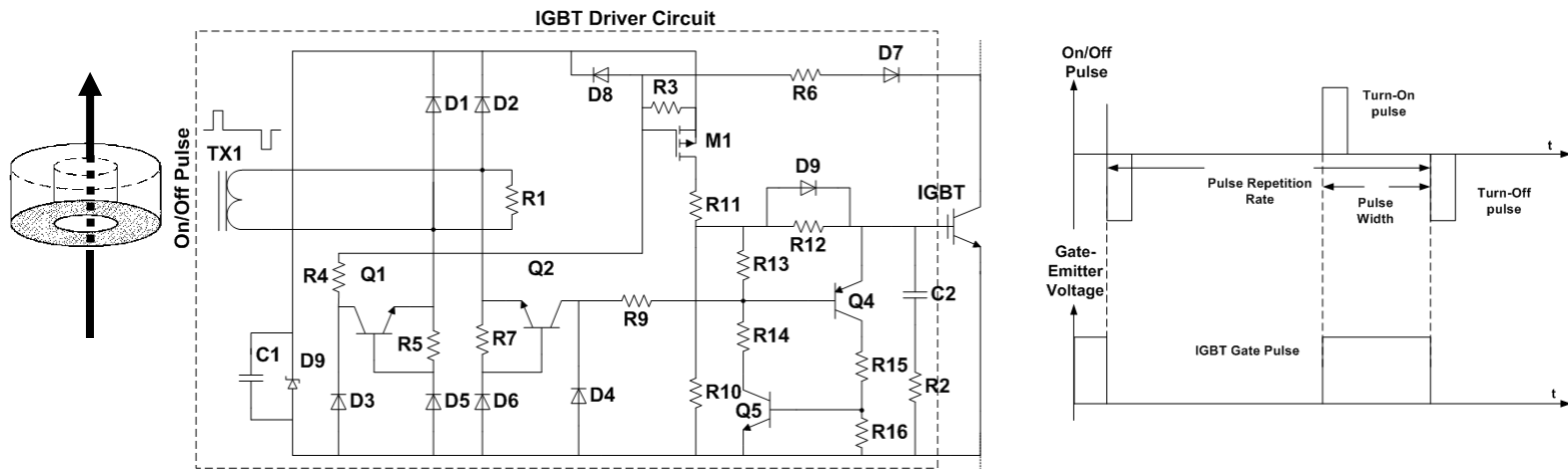
Proposed Solid State Pulsed Power Modulator

Simple and Reliable Gate Driver Circuit

Features of Proposed Gate Driver Circuit

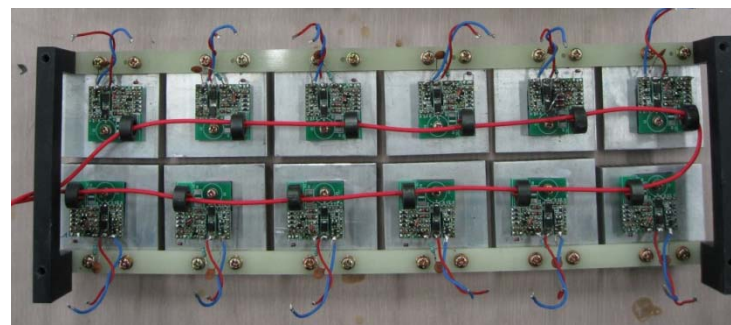
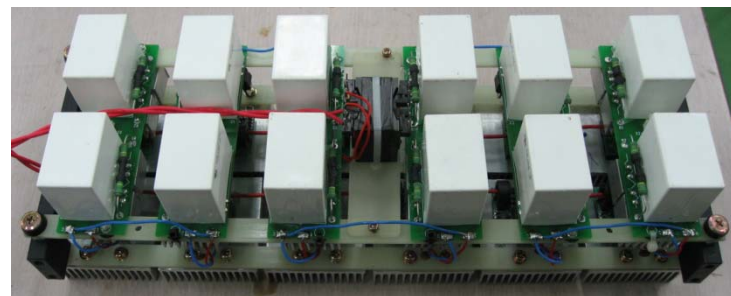
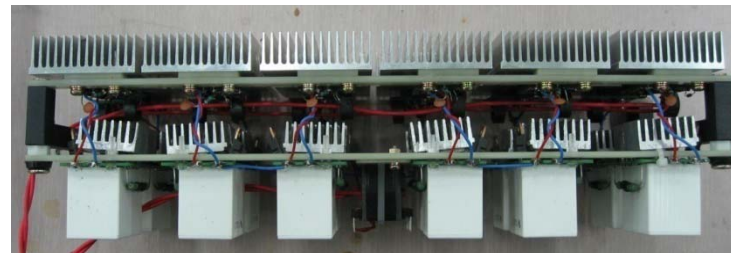
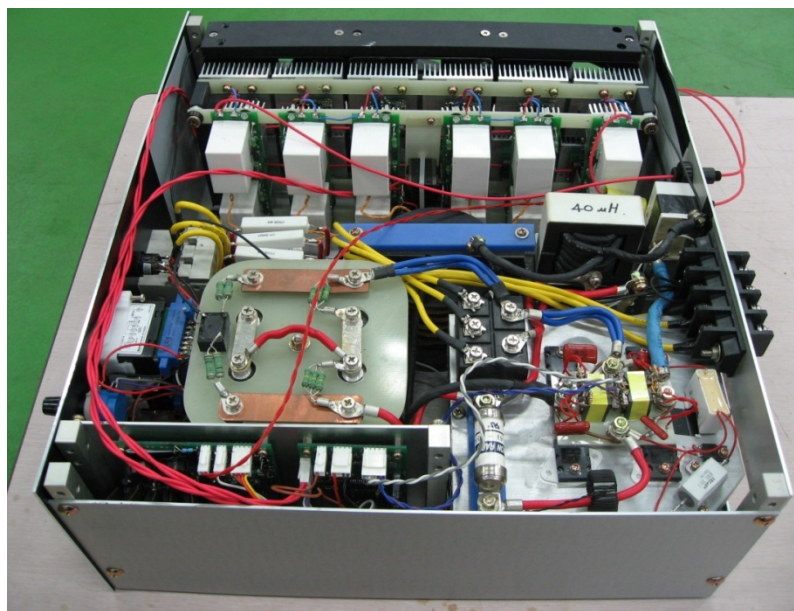
- Receive the power and signal simultaneously
- A new charging process for IGBT input capacitance
- Three kinds of operation modes
- Protection against arc and short circuit

Scheme of Proposed Gate Driver Circuit



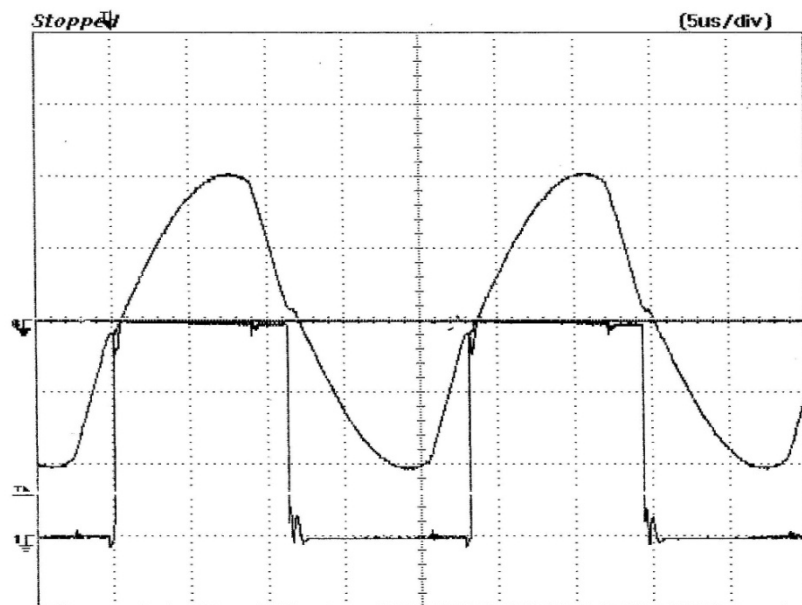
Experimental Results

- Picture of Developed Solid State Pulsed Power Modulator



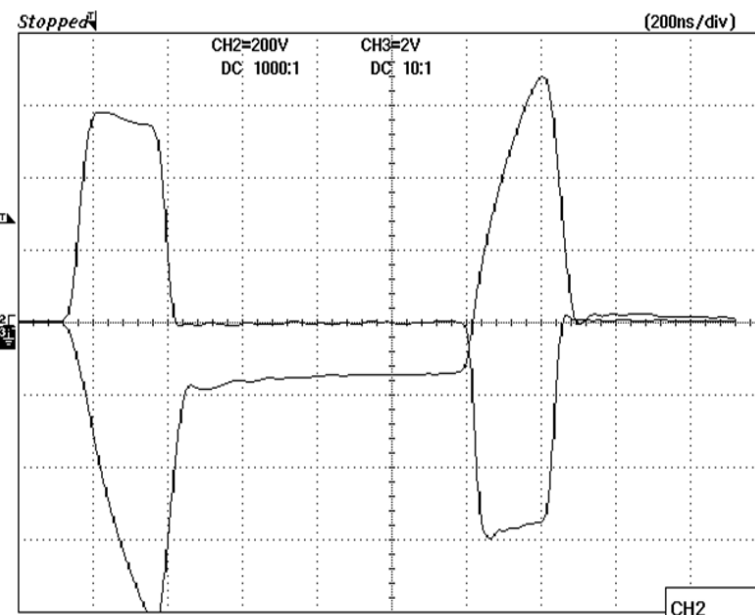
Experimental Results

Capacitor Charger



Resonant Current : 20A/div.
Switching Signal : 5V/div.

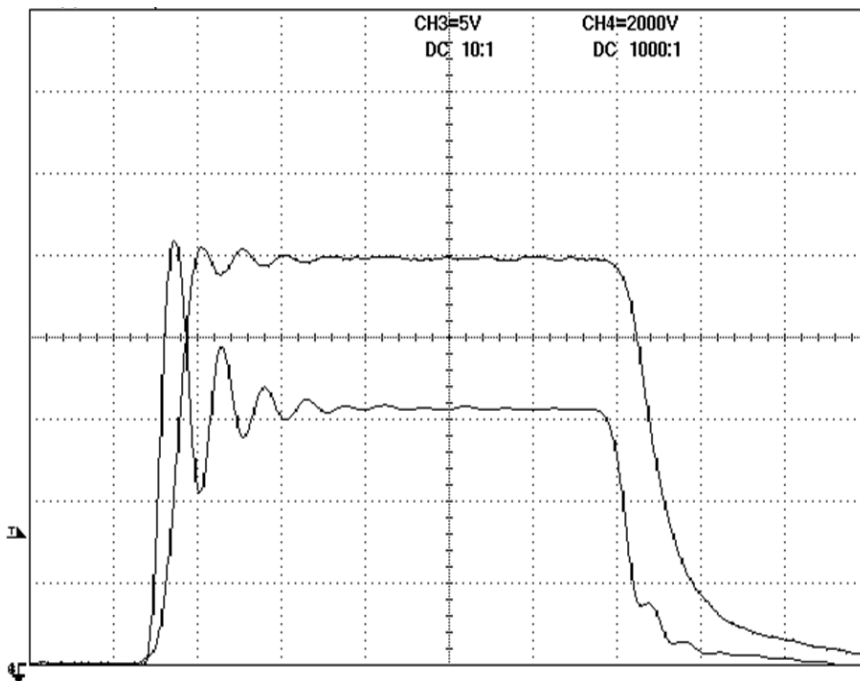
Turn On/Off Pulse



Voltage : 100V/div.
Current : 2A/div.

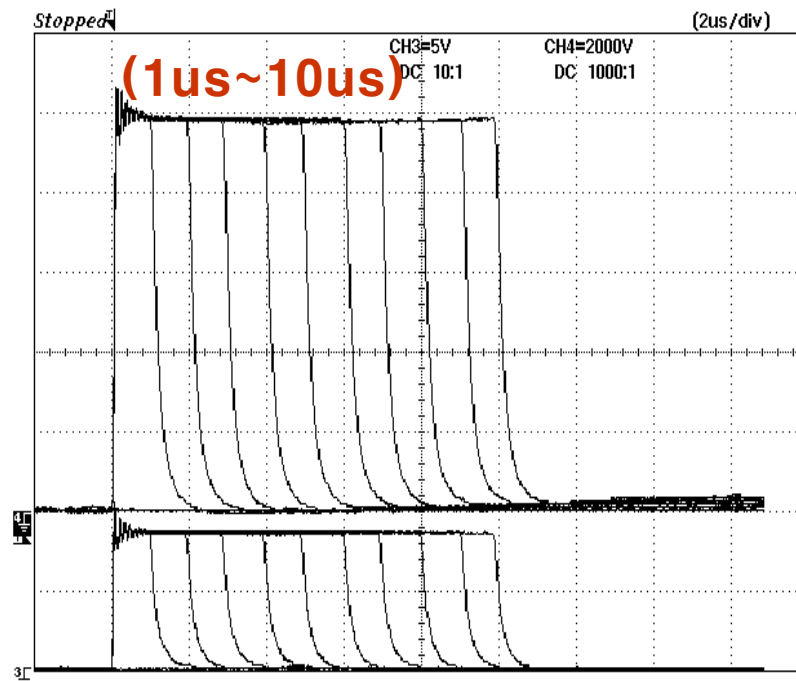
Experimental Results

Maximum Output Voltage



Output Voltage : 2kV/div.
Output Current : 5A/div.
Time Division : 200ns/div.

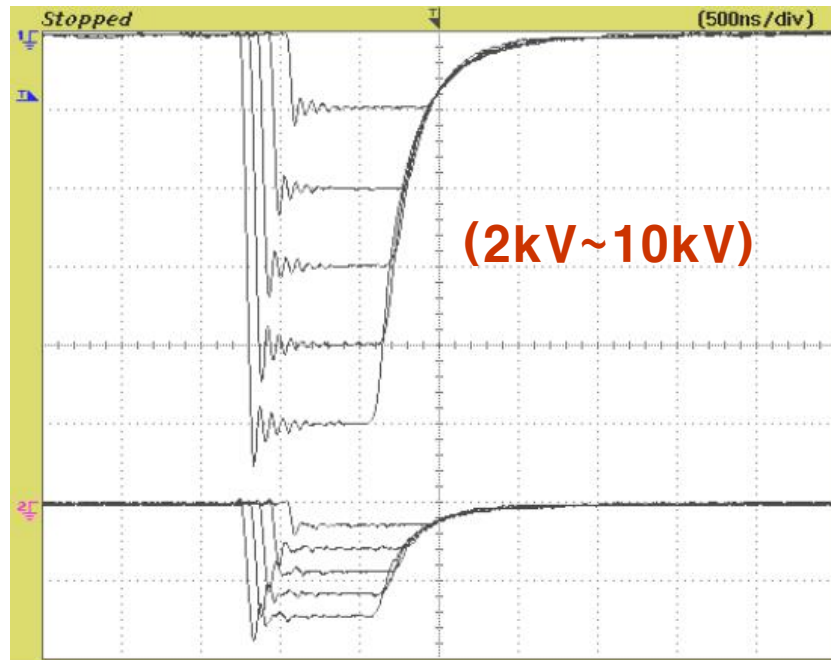
Pulse Width Variation



Output Voltage : 2kV/div.
Output Current : 5A/div.

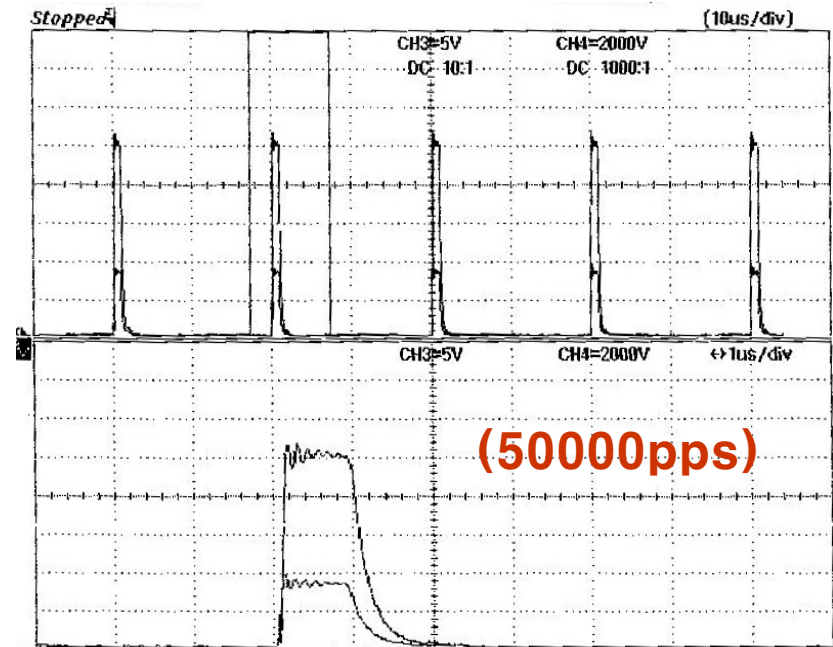
Experimental Results

▪ Pulse Voltage Variation



Output Voltage : 2kV/div.
Output Current : 5A/div.

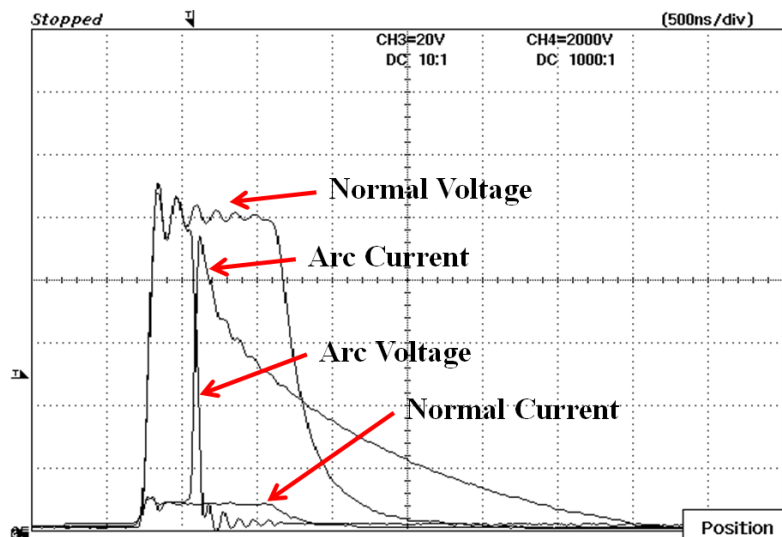
▪ Maximum Repetition Rate



Output Voltage : 2kV/div.
Output Current : 5A/div.

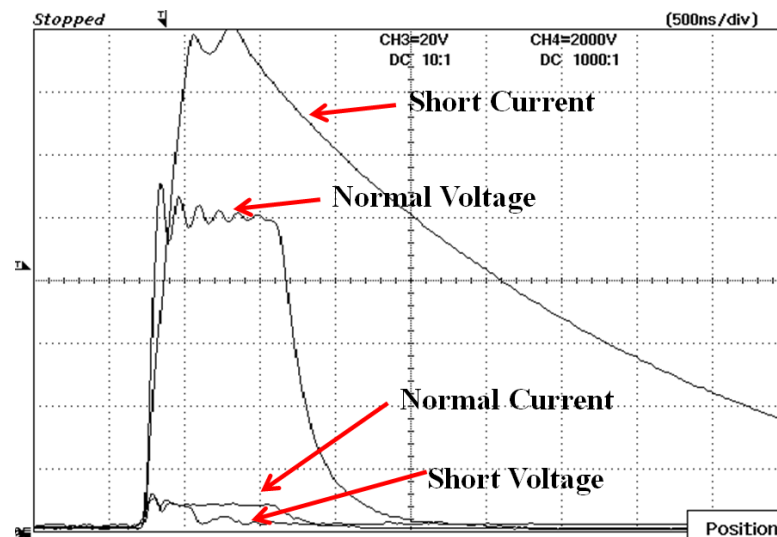
Experimental Results

▪ Arc Protection Mode



Output Voltage : 2kV/div.
 Output Current : 20A/div.

▪ Short Protection Mode



Output Voltage : 2kV/div.
 Output Current : 20A/div.

Summary and Future Study

■ Summary

- High Repetitive Solid State Pulsed Power Modulator (10kV, 50A, ~50000PPS, ~10us with 10kW Average Power)
- Fast Rising Time (80ns)
- Power Cell Based IGBT Stacking Structure
- Compact and High Efficiency Capacitor Charger Design
- High reliability for arc and short condition
- Easiness of pulse control (PRR, PW)

■ Future Study

- Application of Developed Pulsed Power Modulator such as DLC
- Design of Solid State Pulsed Power Modulator with 40kV Output voltage and More Fast Rising Time for Water and Gas Treatment Applications

Thank You !

