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New design and development for an ultrahigh-voltage short pulse switch power supply

～ For the new power supply of the J-PARC RCS kicker system ～

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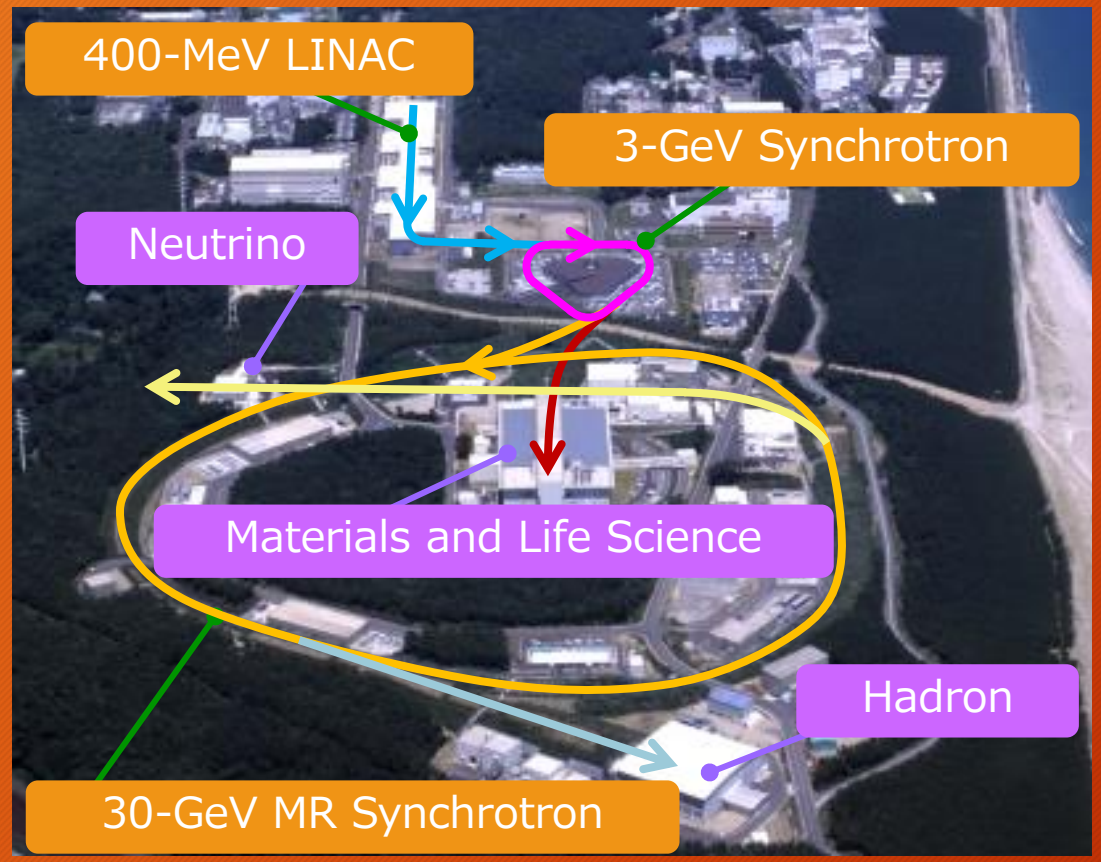
Introduction of J-PARC

J-PARC(**J**apan **P**roton **A**ccelerator **R**esearch **C**omplex)

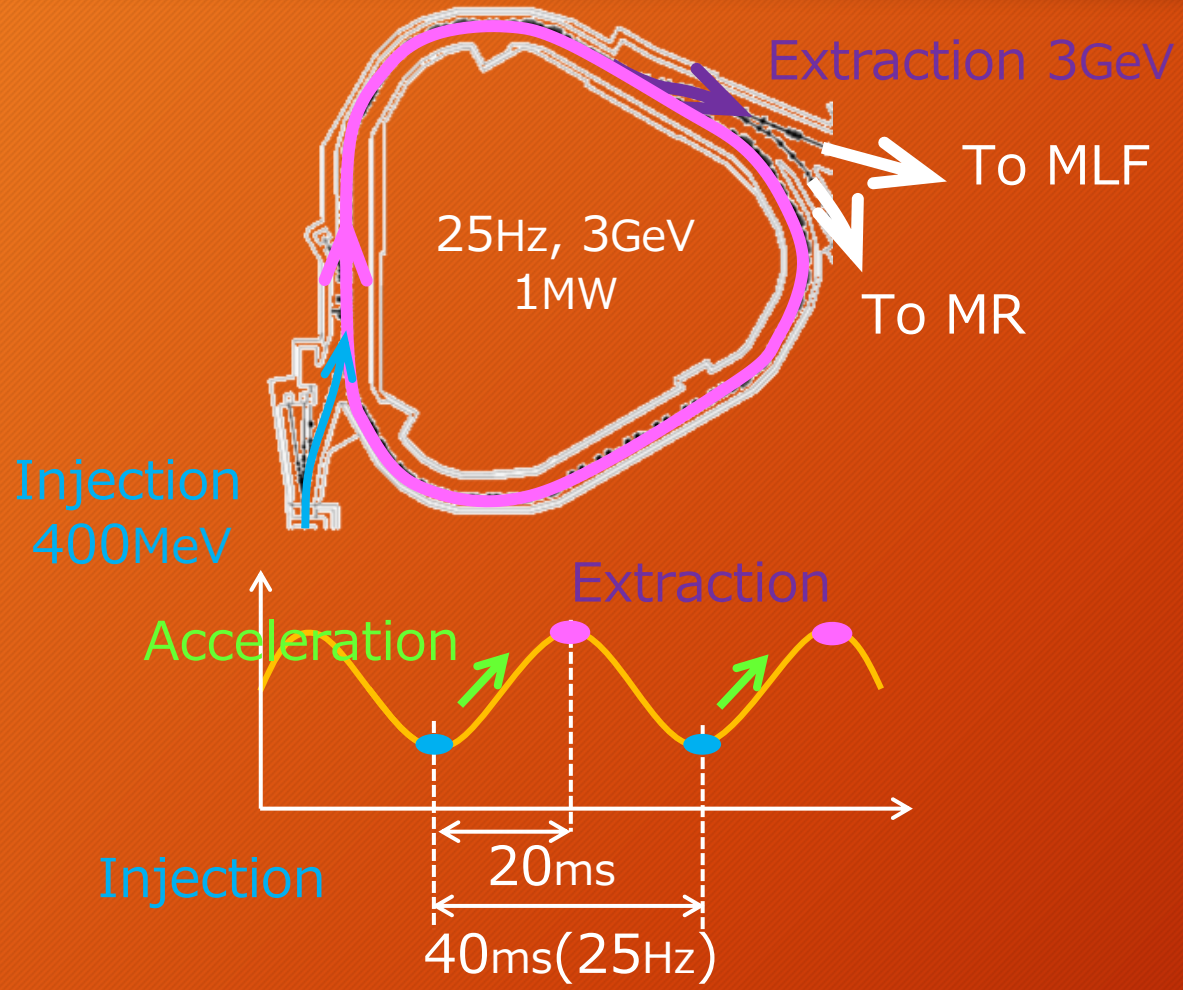


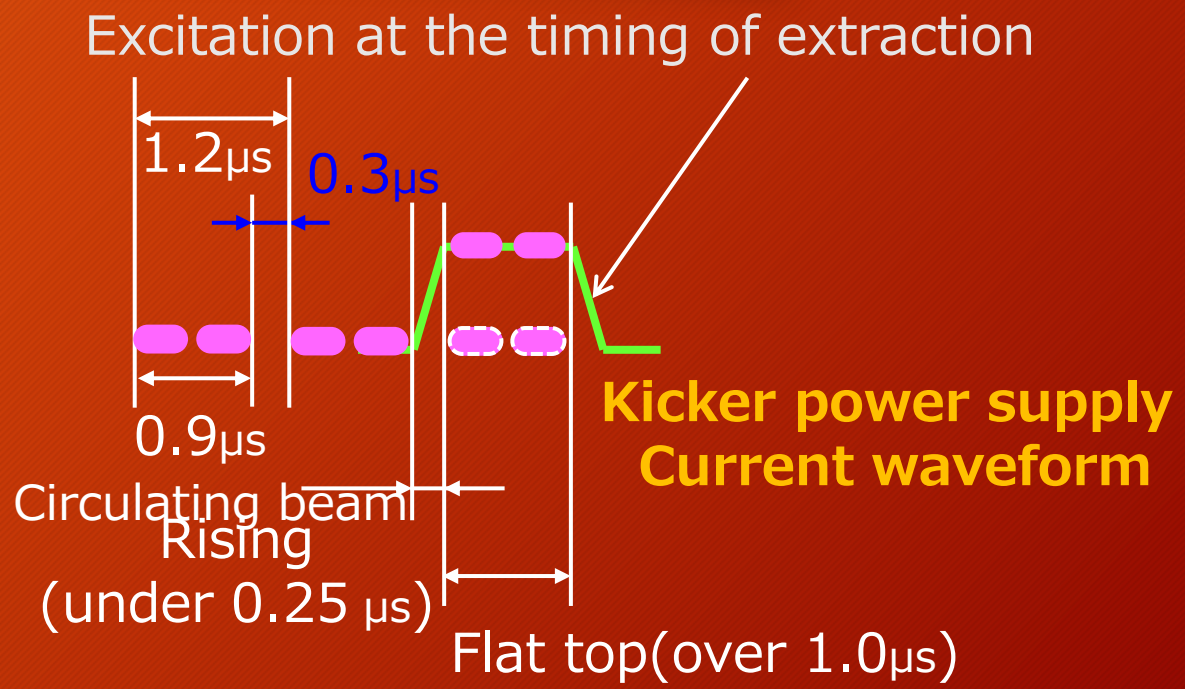
J-PARC consists of 3 world-class proton accelerators and 3 experimental facilities that make use of the high-intensity proton beams.

- **Proton accelerators**
  - 400 MeV linear accelerator (LINAC)
  - 3 GeV rapid-cycling synchrotron (RCS)
  - 30 GeV main ring (MR)
- **Experimental facilities**
  - Muon and neutron production targets in the Materials and Life Science Experimental Facility (MLF)
  - Nuclear and Particle Physics Program at the Hadron Experimental hall (HD)
  - Neutrino Experimental Facility (NU)

RCS Kicker System

RCS(Rapid-Cycling Synchrotron): Generation of 1 MW high intensity beam.





- Kick the 3-GeV beam with a short pulse.
- Outputs 80kV / 4kA using PFN circuit.
- Adopt a thyratron switch.

Motivation

Replace with a power semiconductor switch.

e2V CX1193C

Thyratron switch

Only high speed switch

Disadvantages

- Occasionally misfire
  ⇒ Stopping power supply
- Keep stable operation
  ⇒ Daily conditioning
- Limited lifetime
  ⇒ Preliminary preparation

- Reduction of facility utilization rate
- High running cost

Replace

ROHM SCT3030KL

SiC-MOSFET

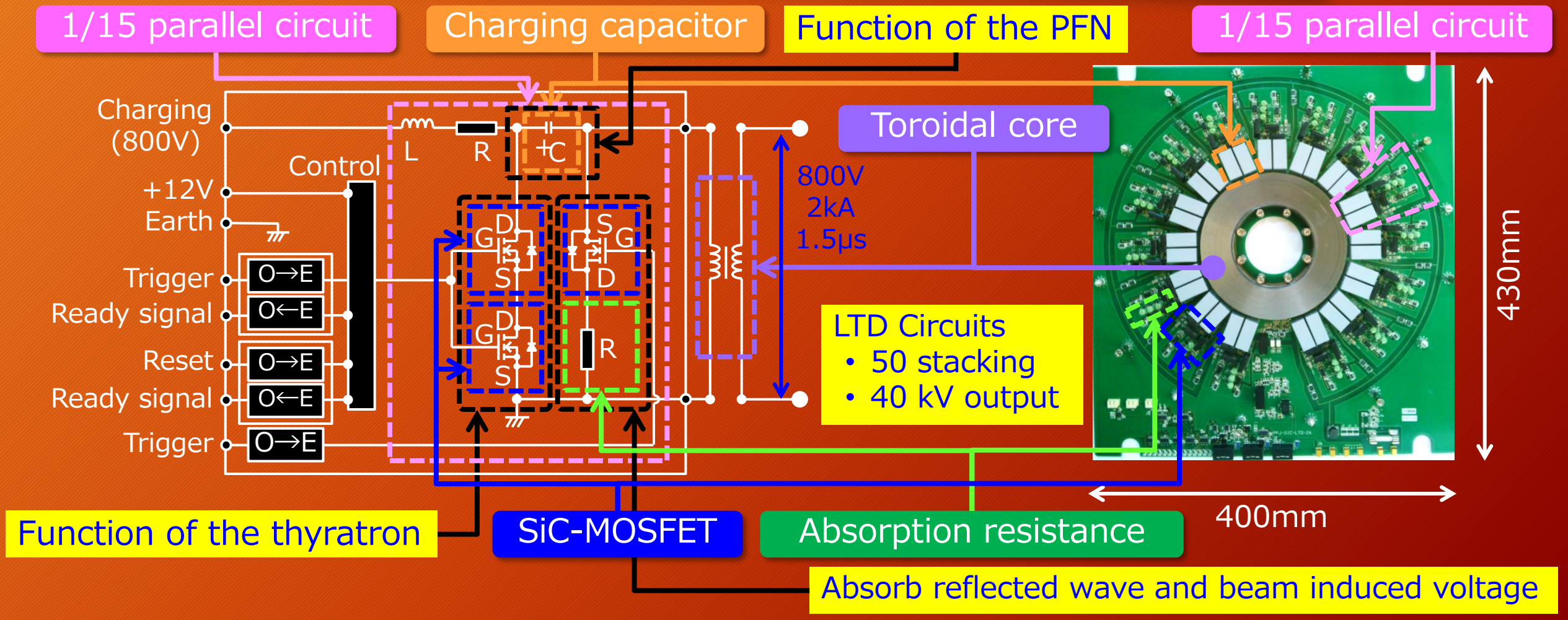
Advantages

- High speed operation
- Low switching Loss
- High withstand voltage

- Stable operation and long life operation
- Reduced running cost

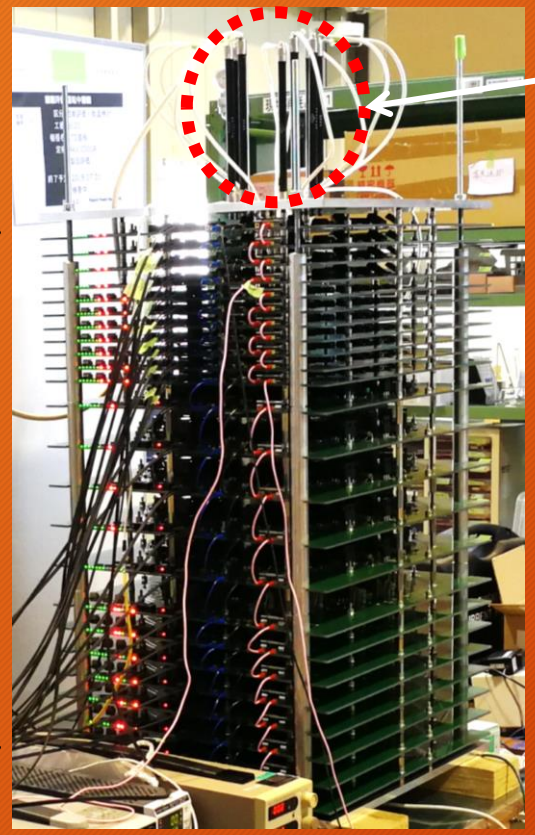
Design of New kicker supply using LTD Circuit

Combination of semiconductor switch and induced voltage superimposing circuit.



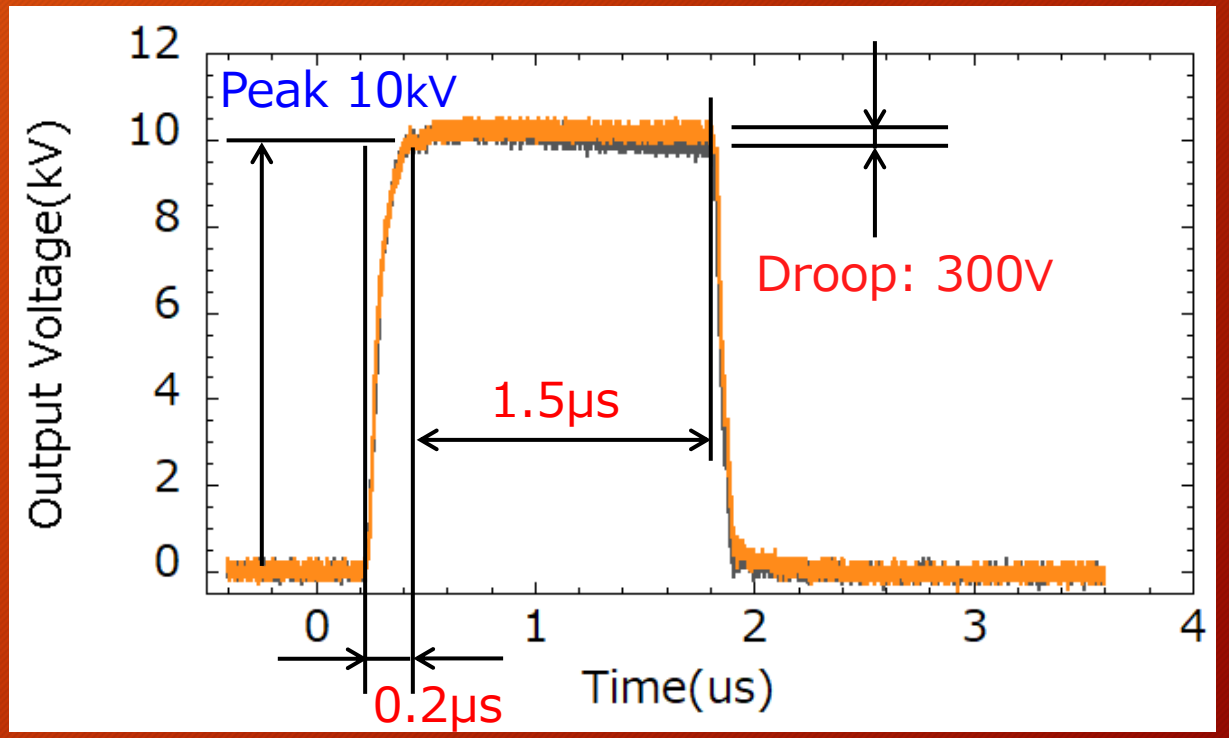
Experimental result

Preliminary test of LTD circuit for new kicker power supply



Stacked evaluation test

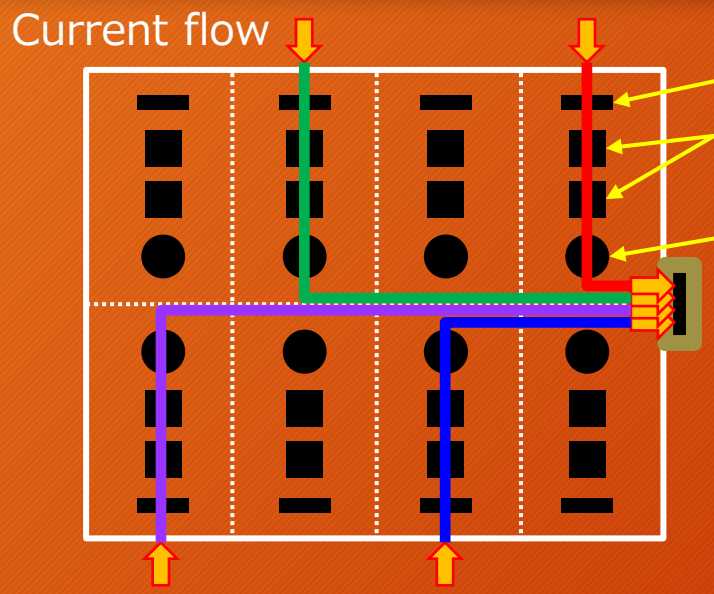
Charging voltage
Main: 800V×13
Sub : 40V×11



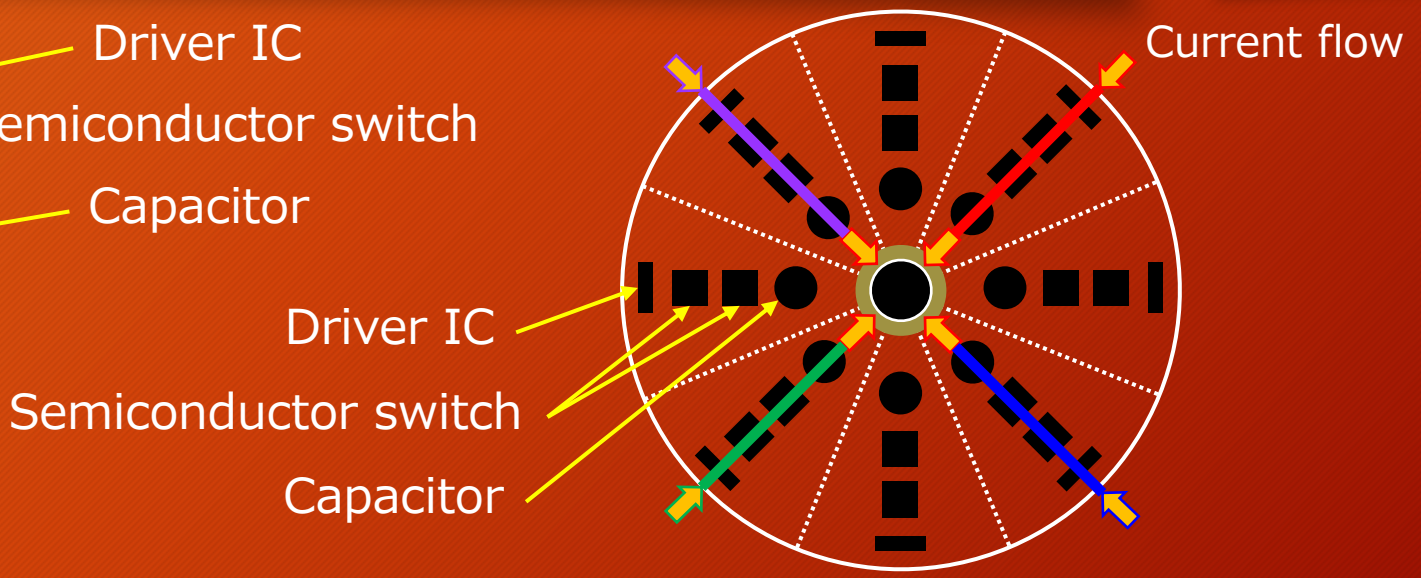
- Droop of 300V was compensated by sub board.
- Satisfying specifications of kicker power supply.

Design of parallel multiplexing circuit

Advantages of symmetrical circuit adopted in LTD circuit board



Line Symmetric Circuit



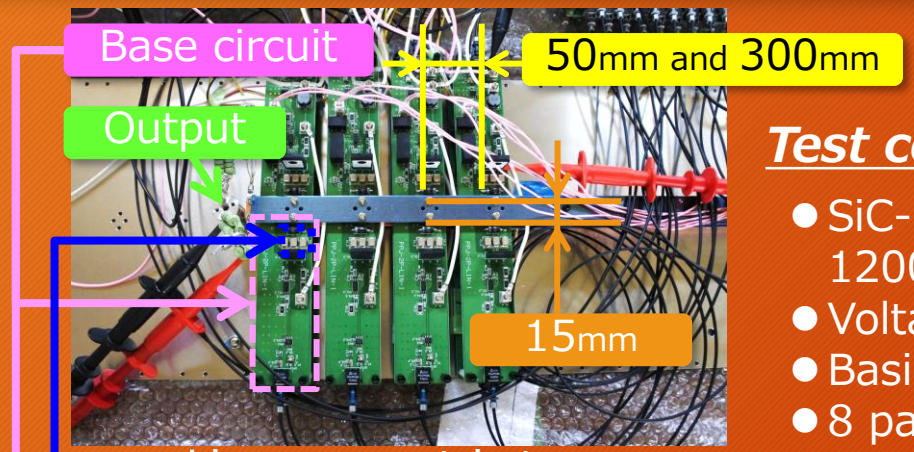
Radially Symmetric Circuit

Distance difference due to the increase in parallel circuits.
⇒ Difference in current propagation distance and time.
Waveform distortion due to the parasitic impedance.
⇒ No be adjust by switching timing.

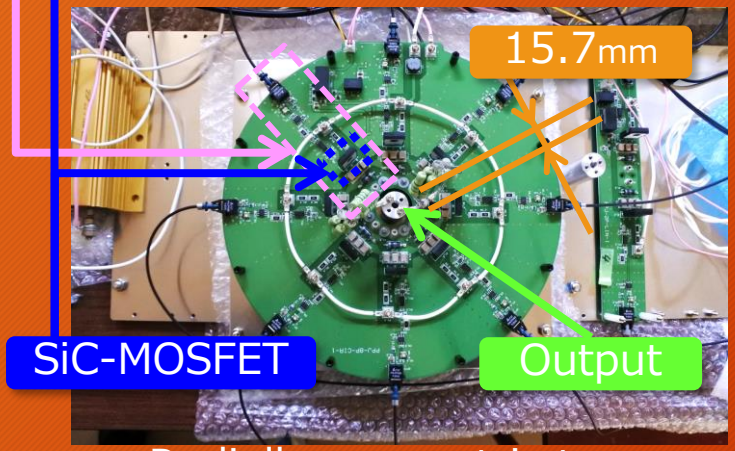
Distances of all parallel circuits are equal.
⇒ No difference in current propagation distance and time.
No difference in the parasitic impedance of all circuits.
⇒ Waveform distortion is unlikely to occur.

Experimental result

Confirmation of superiority of radially symmetric type circuit



Line symmetric type

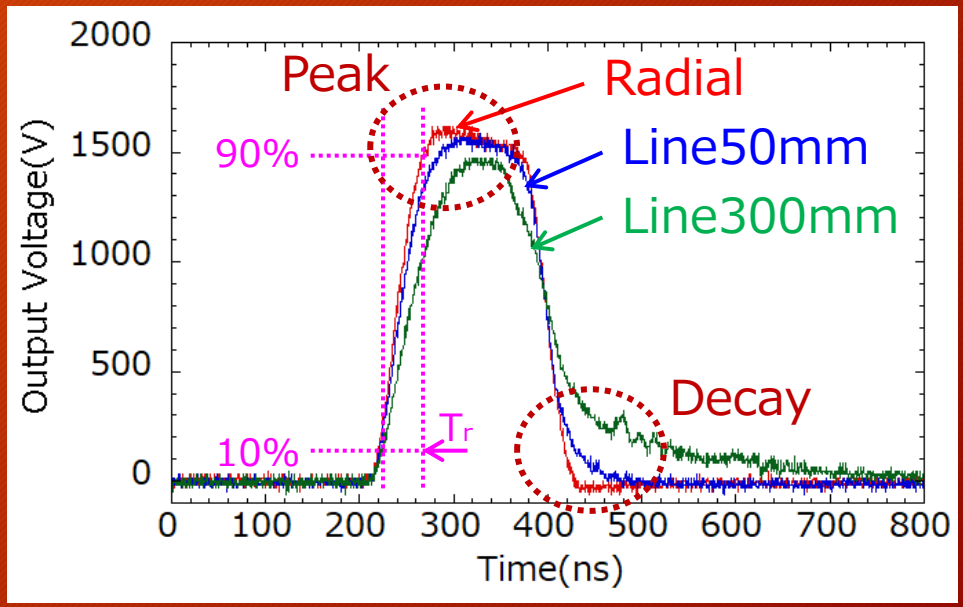


Radially symmetric type

Test conditions

- SiC-MOSFET (Rohm) 1200V/72A
- Voltage doubled on two boards
- Basic circuit is common
- 8 parallel circuits with 1 board
- Each parallel circuit distance L:15mm, R:15.7mm
- Inter-circuit distance (Only Line symmetric type) 50mm and 300mm

Type	One boards	Two boards
Radial	48ns	45ns
L:50mm	54ns	52ns
L:300mm	74ns	70ns



Radiation symmetric type circuit board

- Rise time (Tr) is fast.
- Peak and decay waveforms are steep.
- Suppress waveform distortion.

Summary

- We are developing a new switch system by considering replacement from thyratron to semiconductor switch.
- Semiconductor switch power supply for RCS kicker system of LTD circuit adopting SiC-MOSFET was developed.
- Preliminary tests showed excellent results. In the next step, we plan to test with a higher rating of 40 kV and an actual machine operation.
- Experimentally proved that the radially symmetric structure of the LTD circuit is an excellent system without waveform distortion in short pulse output.

Acknowledgments

Thank you for the teaching of Professor Weihua Jiang and the cooperation of Mr. Tokuchi and PPJ.