

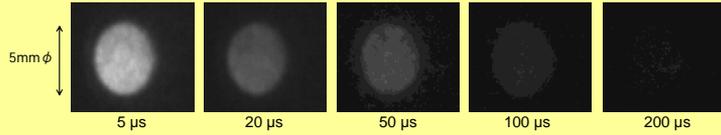
# Development of 20kHz Pulsed Power Generator to Drive Z-pinch Plasmas

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## Motivation

Highly repetitive operation of pulsed EUV source more than 10 kHz is favorable for EUV lithography process. Highly repetitive pulsed power generator (HRPPG) is one of the key technologies. Motivations of this study are:

- To see the technology limitation of highly repetitive operation more than 10 kHz ~ (Semiconductor switch?, circuit design?)
- To investigate discharge phenomena in highly repetitive operation.



Visible emission from discharge plasma

► Plasma decay ~ more than hundred microseconds

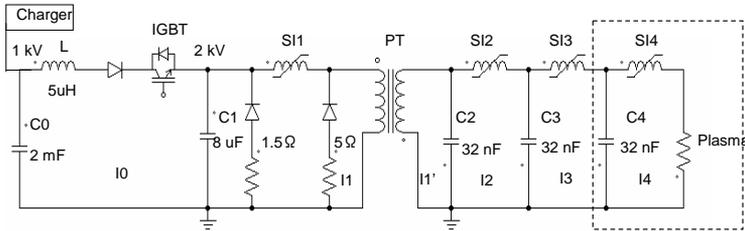
## 1. Circuit - Magnetic Pulse Compressor (MPC)

### Concept

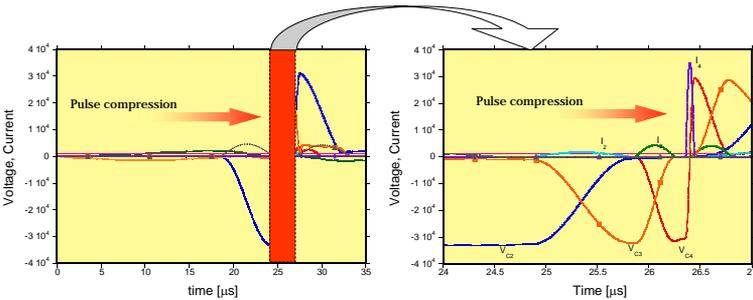
- Burst mode operation. ~ 10 pulses
  - No huge charging device, no cooling.
- High voltage charging to small capacitance capacitor bank.
- One semiconductor switch.

### Target specification

- Rep. rate > 20 kHz
- Energy per pulse:  $E_0 < 15$  J
- Number of pulses: ~10 pulses (5% voltage decrease)

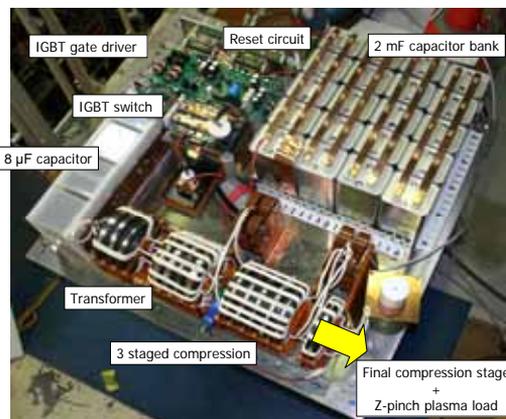


4 stage magnetic pulse compression circuit (MPC) Z-pinch



P-Spice simulation

## 2. Highly Repetitive Pulsed Power Generator (HRPPG)



Overview of HRPPG

### Components

- Power supply 8 kJ/s
- Buffer capacitor bank 2 mF
- Main capacitor 8 μF
- Capacitors (at each stage)
- IGBT switch
- IGBT driver
- Diodes
- Ferromagnetic core (FINEMET FT-3H, Hitachi Metals)
- Core reset circuit
- Resistors

### Misc. parameters

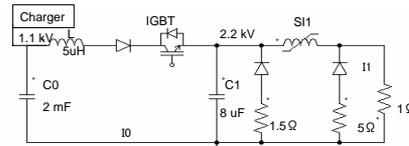
- Size : 100 x 100 cm<sup>2</sup>
- Weight : Approx. 200 kg
- Cost : Approx. \$40,000

## 3. IGBT Test - 20 kHz operation

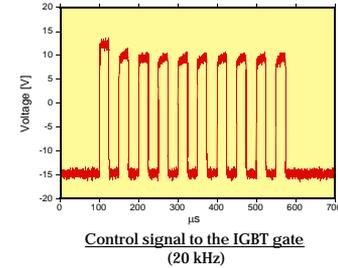


### IGBT switch (Mitsubishi Semiconductor)

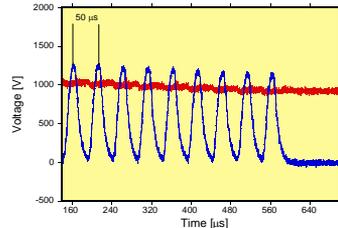
- Ic 1200 A (pulse 2400A)
- Vce 3300 V
- Turn on delay 1.6 μs
- Turn on rise time 1.0 μs
- Turn off delay 2.5 μs
- Fall down time 1.0 μs
- Recovery time 1.4 μs
- Gate input charge 8.6 μC



IGBT test circuit



Control signal to the IGBT gate (20 kHz)

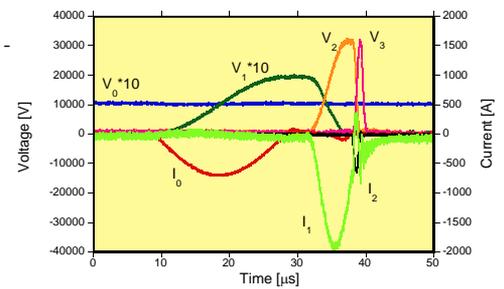


20 kHz operation,  $V_{C0}$ ,  $V_{C1}$

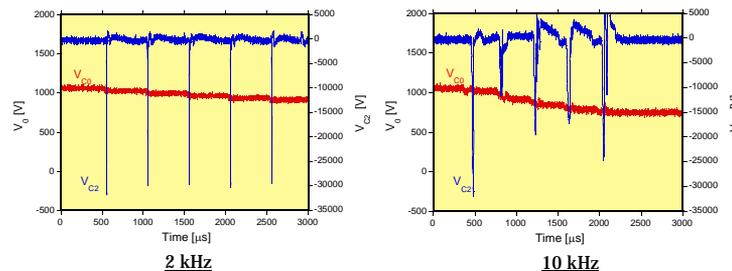
## 3. MPC - Dummy Resistive Load (10 Ω)

### (1) Waveforms

- single shot operation -



### (2) High rep-rate operation

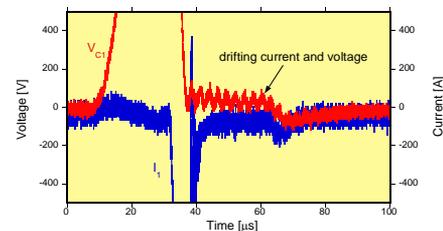


### (3) Problem

- Residual current drifts in the circuit for several hundreds microseconds and influences the magnetic switch.

### Key techniques

- Absorbing the residual current.
- Strong reset of ferromagnetic cores.



Residual current and voltage

## Summary

- IGBT switch is capable of operating at 20 kHz.
- Main circuit needs to be modified.
  - Adding an absorption circuit of the residual charge
  - Improve reset circuit.

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