UPGRADE OF THE KLYSTRON MODULATOR OF THE L-BAND ELECTRON LINAC AT OSAKA UNIVERSITY FOR HIGHER STABILITY

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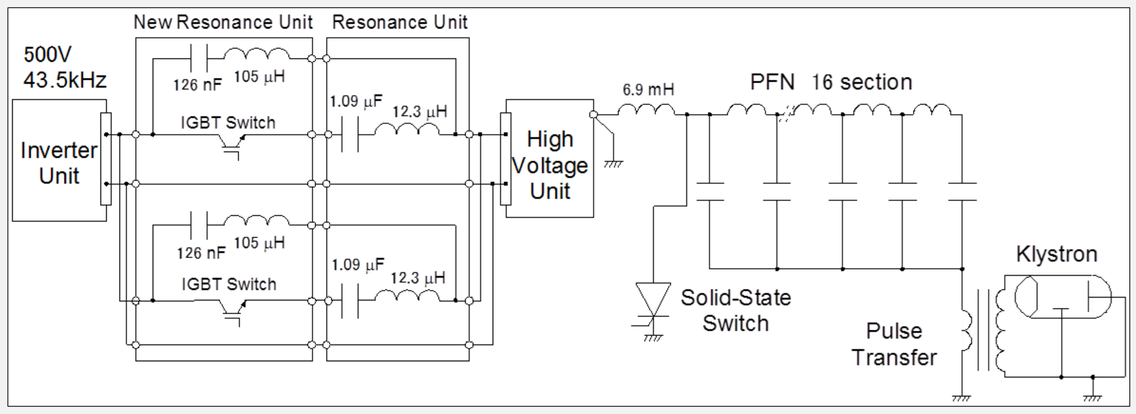
INTRODUCTION

- 40MeV L-band electron linac at the Osaka University ; used for
  - Pulse radiolysis (time range : from nanoseconds down to sub-picoseconds)
  - The development and applications of THz-FEL
  - ➢ Highly intense and stable FEL beam requires highly stable electron beam.
  - ➢ The energy stability of the electron beam is dependent on stability of high power RF pulses generated with a klystron.
- Klystron modulator
  - Maximum specifications : 25 kV, 6 kA
  - Electric charge accumulated in the PFN to a high voltage is discharged using a high-speed switch, and the generated pulse is supplied to the klystron via a step-up transformer, and then a high power RF pulse is generated.
- Development for higher stability
  - ➢ Two-step charging system for PFN using two parallel resonant lines
  - ➢ Solid-state switch using SI-thyristors used in place of a thyratron



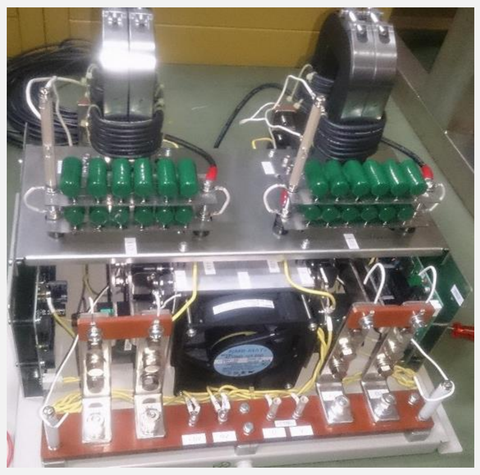
Circuit diagram of the klystron modulator

CHARGING SYSTEM

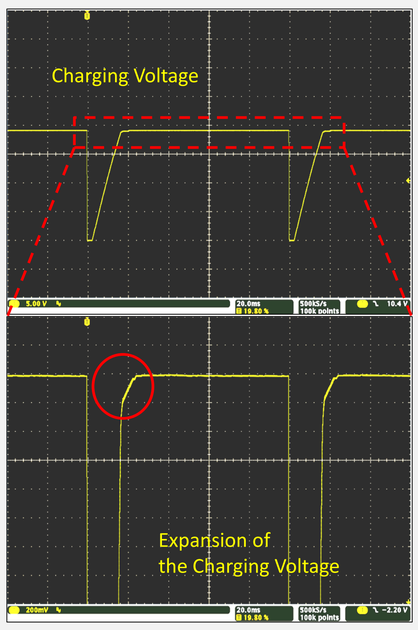
- Two-step charging system for PFN
  - The charging current of the inverter unit is determined by the inductor L and capacitor C of the resonance line.

$$I = \sqrt{\frac{C}{L}}V \equiv \frac{V}{Z_0}, \qquad f = \frac{1}{2\pi\sqrt{LC}}$$

  - A high impedance charging line was added in parallel with main resonance line.
    - ➢ The PFN is first charged via both resonance line and, when the PFN voltage approaches a setting value, the IGBT switch is turned off, so that the fine step charging via the sub line only is implemented.
  - Conventional resonance unit : C= 1.09 μF, L = 12.3 μH
  - New resonance unit : C= 126 nF, L = 105 μH
    - ➢ Fast charging mode : Z = 1.5 Ω, I = 332 A
    - ➢ Fine charging mode : Z = 14.4 Ω , I = 34.7 A
- New resonance unit
  - Upper plate : A pair of reactors and capacitors
    - ➢ Reactors : adjusted by the number of the windings and air gap
    - ➢ Capacitors : 10 nF of 12 parallel
  - Lower plate :
    - ➢ Two IGBTs for the switch
    - ➢ Heat-sink cooled by the fan
    - ➢ Circuits board for driving IGBTs



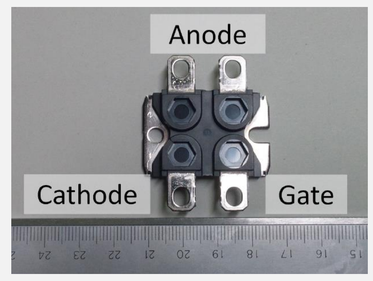
New Resonance unit



Wave form of the charging voltage

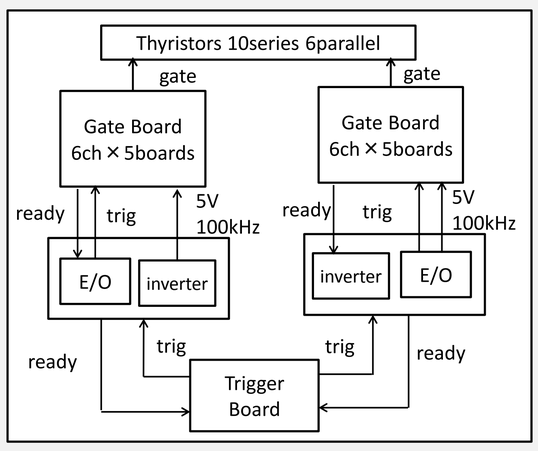
SOLID-STATE SWITCH

- Static induction thyristor
  - Manufacture's specifications
    - ➢ Blocking voltage : 3.2 kV
    - ➢ Average current : 50 A
  - Specifications after performance test
    - ➢ Restriction voltage : 2.5 kV (due to the leak current)
    - ➢ Pulse current : 1 kA @ 10 μS
- Solid-State Switch
  - The total amount of the thyristors : 60
    - ➢ 10 series (to tolerate 25 kA)
    - ➢ 6 parallel (to flow 6 kA)
  - Gate board :
    Including trigger and error detection circuits
    Power supply :
    5 V, 100 kHz isolated DC-DC converters
    Trigger signals are sent via optical links.
  - Cooling
    - ➢ Air flow of Cooling fan: 7.35 x 2 m^3/min
    - ➢ Heat resistance of heat-sink: 0.45 K/W
    - ➢ Temperature rise at 10Hz : 4 ℃
  - By changing wiring 20 series and 3 parallel, the solid-state switch can deal with the 50 kV 3 kA driving of the general klystron modulator of the S-band linac.

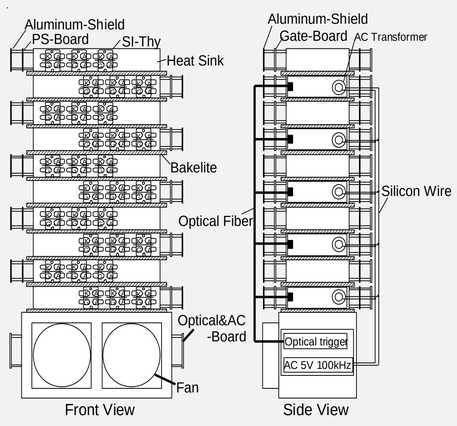


SI thyristor

Solid-state switch using SI thyristors



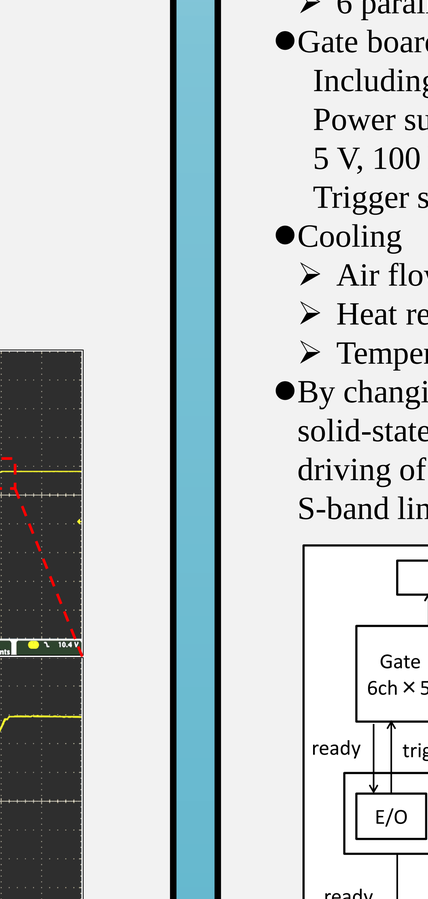
Outline of the control system



Outline drawing of the Solid-state switch

MEASUREMENT

- To evaluate the performance of the solid-state switch and the charging system, we measured the stabilities of the voltage applied to the klystron.
- Measurement conditions
  - ➢ The charging voltage of the PFN : 20 kV
  - ➢ Repetition : 10 Hz
  - ➢ Differential amplifier: DA1855A, Teledyne Lecroy
    - ➢ A low input noise level and high sensitivity enough to measure small fluctuations.
- Fluctuation of the klystron voltage
  - ➢ The expansion waveform is overlaid 532 pulses.
  - ➢ The standard deviation of the expansion waveforms: 0.00078 % (7.8 ppm)



Voltage and current waveforms of klystron and solid-state switch

CONCLUSION

- We upgraded the charging system and developed the solid-state switch for higher stability of the klystron modulator of the L-band linac.
- The new charging system uses a two-step charging scheme for finer charging steps near the setting with the single inverter power supply.
- The solid state switch with the maximum specifications of 25 kV and 6 kA were developed using 60 SI thyristors, ten of which were connected in series with six such series connected in parallel.
- ➢ The accuracy and precision of the klystron voltage were measured to be 7.8 ppm, and it is used without any serious problems in the regular operation of the linac.