Linac RF Source

S. Fukuda

Proposal from Accelerator Group.

C-band High-power Klystron.

Modulator issues---Flat-top pulse width.

Possible layout plan for C-band scheme.

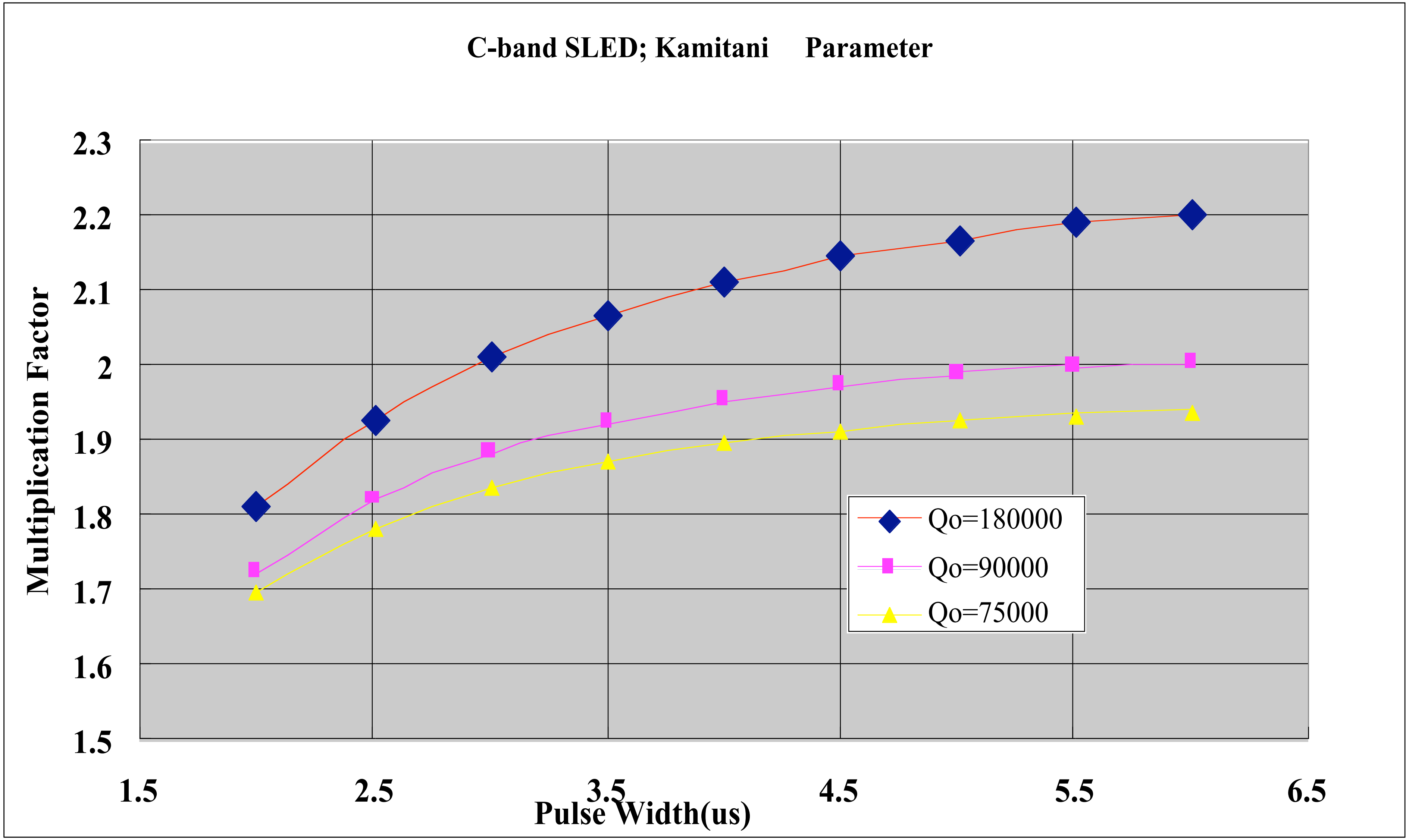
Driving system study.

Conclusion

Kamitani’s Scheme

- C-Band Scheme
- ⇒Positron Energy Up to 8GeV with Using C-band RF Source, which Comprises 3 Sectors of ＃３、＃４、＃５.
- C-band Accelerator Design and Parameters were shown
- ⇒２ｍ Waveguide x 4、42MV/ｍ
- Attenuation Factor 0.676, Filling Time 0.365μs
- Usage of SLED Type Energy Doubler
- ⇒High Q SLED Cavity Using the TE038 Mode
- ⇒Pulse Width ２μsec,
  Multiplication Factor 1.84 (at Q=180000)

C-band SLED


C-band SLED; Kamitani Parameter
Multiplication Factor
Pulse Width(us)
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.5
2.5
3.5
4.5
5.5
6.5
Qo=180000
Qo=90000
Qo=75000

Study Points of C-band RF System

- Klystron Gallery's Space is limited and All are installed there.
- Spacing, Modulator systems, Klystron Assemblies.
- ⇒Is it possible to construct C-band system with making use of the existing infrastructures such as the modulator?

  ⇒Can we get enough pulse width in the realistic case including the phase reversing interval time?
- ⇒2 C-band 50MW-Klystron in the existing 1 unit space
- Other RF(C- band) Components

  ⇒Driving System

  ⇒How serious the phase stabilities comparing with S-band case?
- Relation between the construction schedule and KEKB, PF and AR experiments.

C-band Klystron

C-band klystron developed:

- ●Output Power Maximum～50 MW、
- ●Applied Voltage 350kV, Pulsed Current 317A, Microperveance 1.5
- ●Efficiency 45%, Gain 52-54dB, Required driving power of about 300 W
- ●2 klystrons from a modulator ⇒Microperveance 3 (1.5 times larger than s-band case)

2 C-band 50 MW klystrons in the 1 unit modulator spacing.

C－Band 50-MW Klystron

TENTATIVE

TOSHIBA PULSED KLYSTORN AMPLIFIER E3746

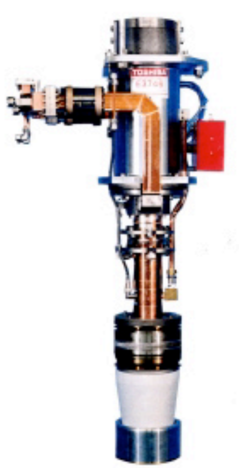
Toshiba E3746 is a C-band high power amplifier klystron designed for linear accelerators.

The E3746 delivers 50MW peak output power in 2.5 μs pulse.

Output power is extracted through two WR187 standard waveguides in parallel. One port output is also possible with the specific power combiner .

The electron beam is focused by a series-coil electromagnet. The specific focusing electromagnet VT-68926 is available.

A Scandate dispenser cathode is employed, ensuring high reliability and long tube life.



GENERAL CHARACTERISTICS

Electrical M	in.	M	ax.	Units
Heater Voltage[1]	——		110	V
Heater Current[1]	----		5.5	A
Heater Surge Current[1]	----		7	A
Heater Warm-up Time	60		----	min.
Peak Beam Voltage	----		370	kV
Peak Beam current	----		344	A
Beam Perveance	----	1.53	----	$\mu A/V^{3/2}$
Frequency	----	5712	----	MHz
Peak Output Power	30		51	MW
Efficiency	40		----	%
Drive Power	----		500	W
Pulse Duration (Beam)	----		6.2	μs
Pulse Duration (RF)	1		2.5	μs
Load VSWR	----		1.2	
Ground	Tube	Body		
Electromagnet current	30		----	Adc
Electromagnet voltage	250		----	Vdc

表4．試験結果

Parameter	2nd	3rd	Unit
Operating Frequency	5712	←	MHz
Beam Voltage	368.7	358.1	kV
Beam Current	333.0	319.2	A
Output Power	53.9	53.5	MW
RF Pulse Width	2.5	2.5	μs
Pulse Repetition Rate	50	50	pps
Drive Power	259	238	W
Power Efficiency	43.9	46.8	%
Power Gain	52.2	54.1	dB
Beam Perveance	1.49	1.49	$\mu A/V^{3/2}$
Solenoid Coil Power	4.55	5.37	kW

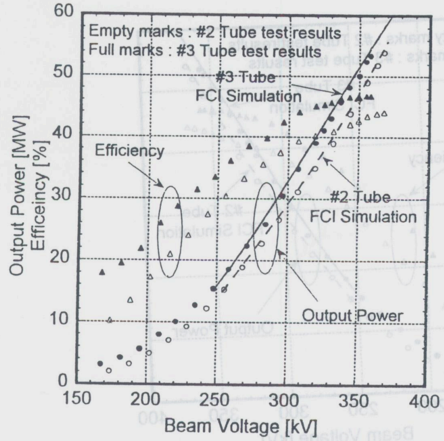


図3　2，3号管の飽和出力特性

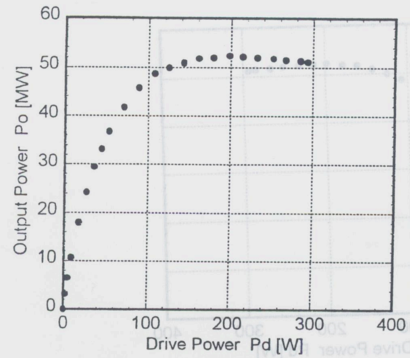


図4　3号管入出力特性
（ビーム電圧 354kV、ビーム電流 315A）

Pulse Flat-top Width

- Study of Pulse flat-top width from power consideration.
- Power Conservation

$$I_s V_s T = P V_s^{3/2} T = (1/2)\, C_{pfn} V_{pfn}^2$$

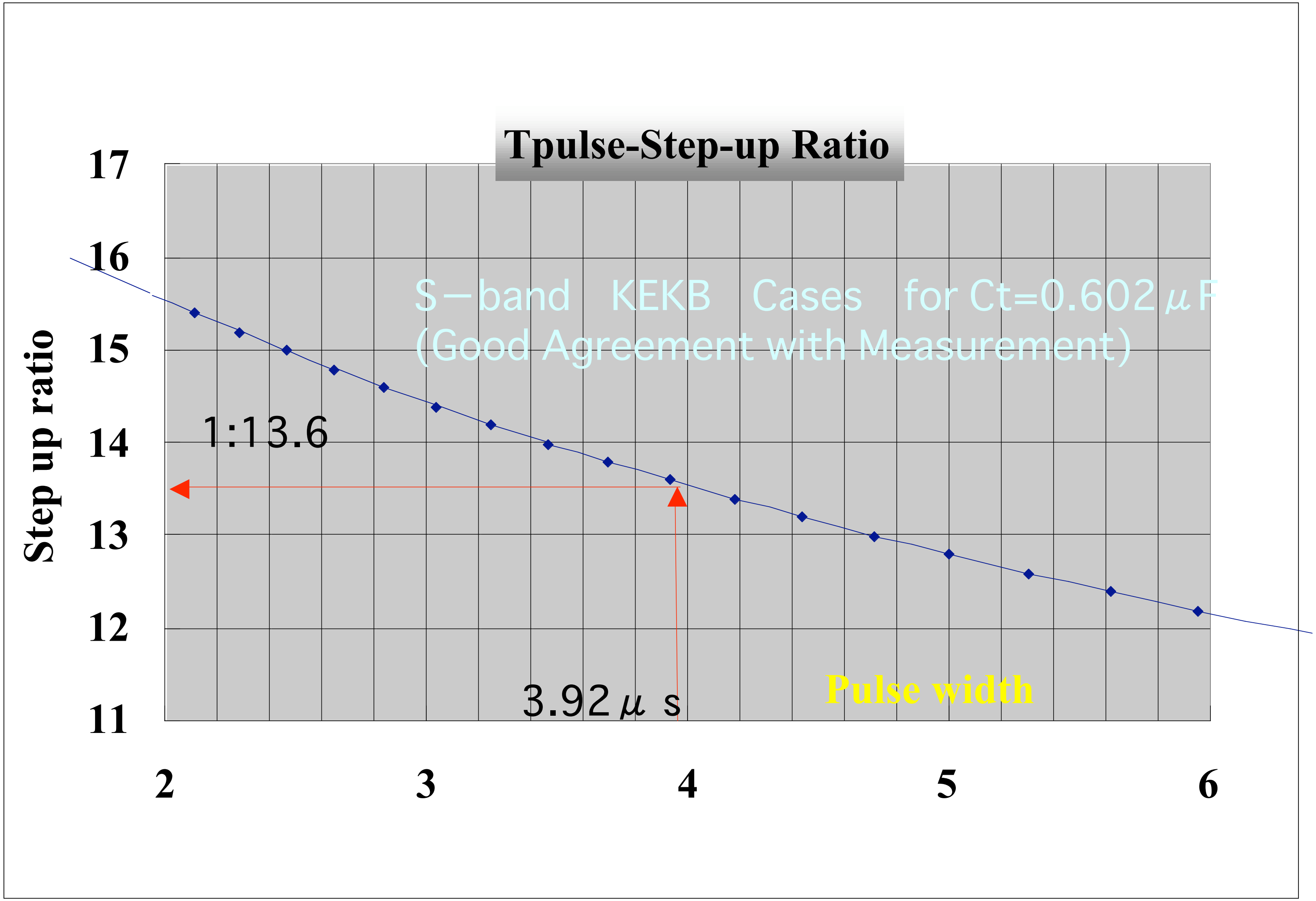
- where
- I_s : Secondary Pulse Current, V_s : Secondary Pulse Voltage、
  T : Pulse Half Width, P : Perveance of klystron
- C_{pfn} : PFN Total Capacitance, V_{pfn} : PFN Charging Voltage、
-

$$T = T_{trj} + T_{flat} = T_{0trj} N + T_{flat}$$

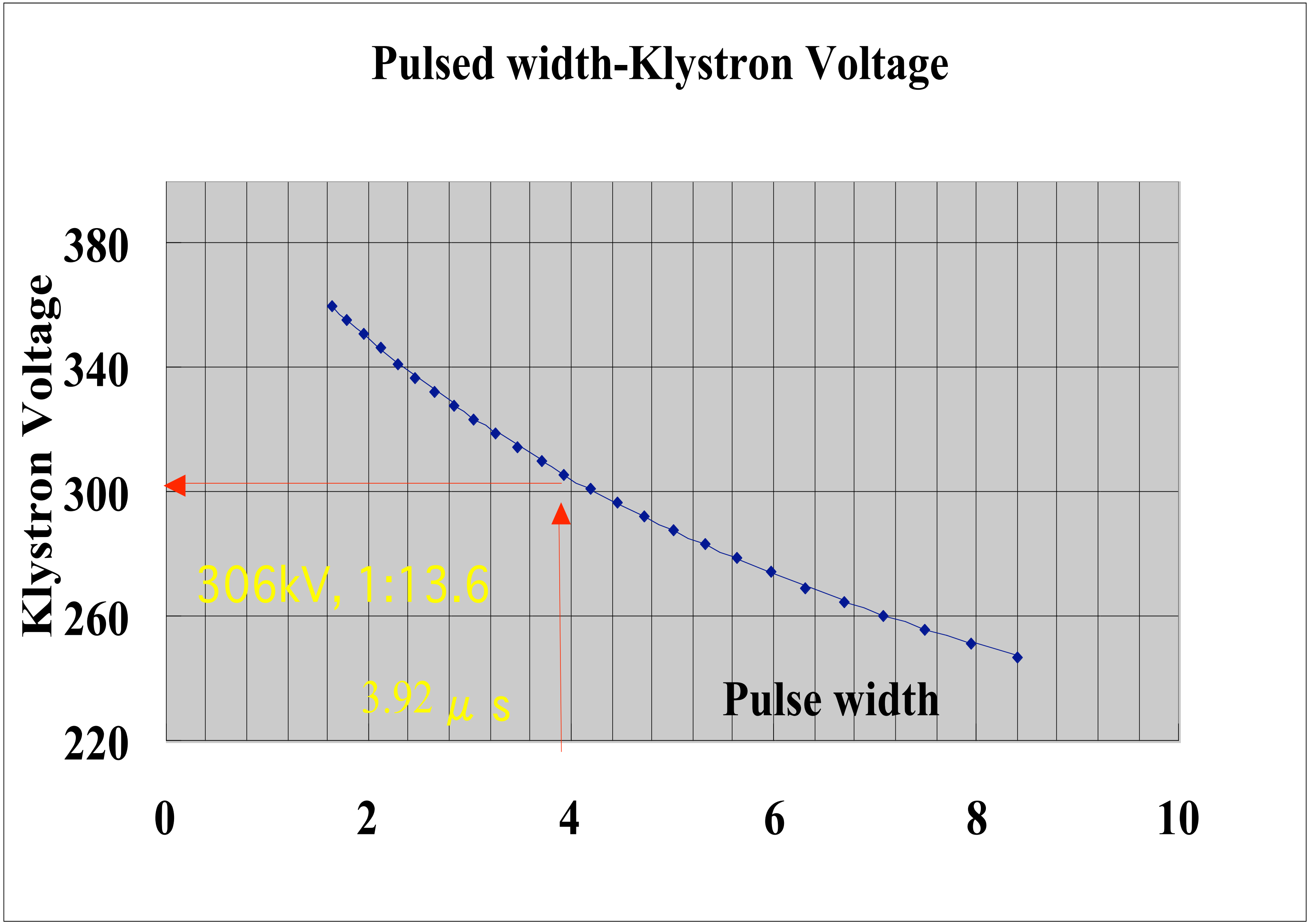
$$V_s = (1/2)\, V_{pfn} N$$

- T_{trj} : Rising and falling time, T_{flat} : Pulse flat-top time,
  T_{0trj} : T_{trj} / a turn, N : Step-up ratio of pulse transformer

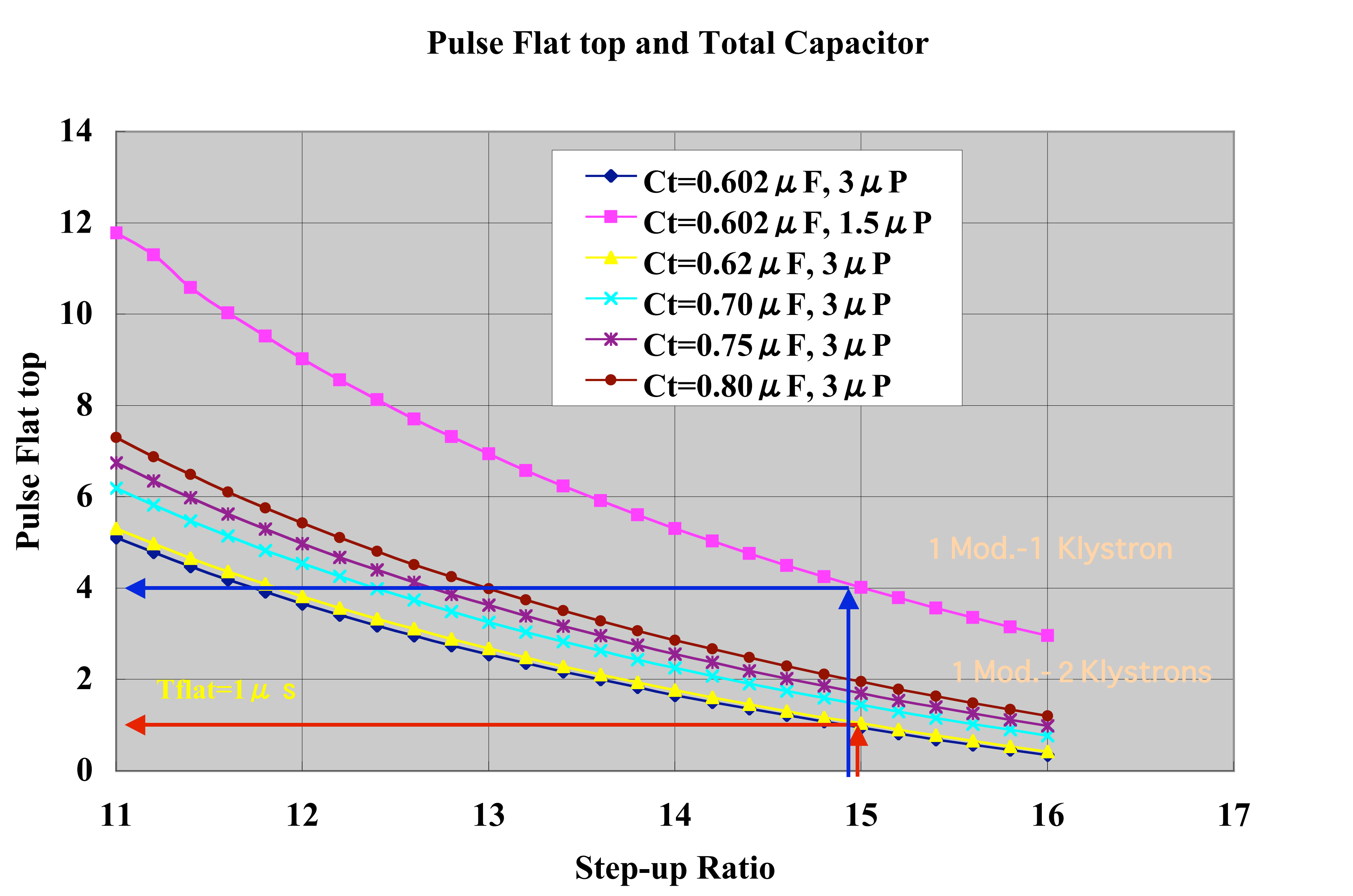
S-Band（KEKB/Pulse width vs PT Step-up Ratio)



KEKB S-Band(Pulse width vs Klystron Voltage)



Pulse Flat-top（Cband Klystron）



Problem for 1 modulator 2 klystrons

It is necessary to increase the total PFN capacitance of 30% to get the 2μs Flat.

●30% increase to the vertical direction⇒Adding PFN capacitors

●30% increase in length ⇒Exchanging whole PFN capacitors

○Increase the packing factor of the Capacitor element⇒ Exchanging whole PFN capacitors

◎Change the capacitor element⇒Exchanging whole PFN capacitors

◎Adopting the commercial compact capacitors ⇒Exchanging whole PFN capacitors

Larger Thyratron

Step-up ratio １：１５, Secondary Voltage 350kV,634A⇒Primary23.3kV、9510A。

It is necessary to use larger thyratron

Is it possible to use other components for PFN capacitance increase of 30%?

Charging Choke?————ＯＫ？(For the recently revised version)

ＩＶＲ————————It is necessary to change

Facility electricity?

How about the compact inverter HV P/S? ———— exceed 30kW average power, need more than two module.

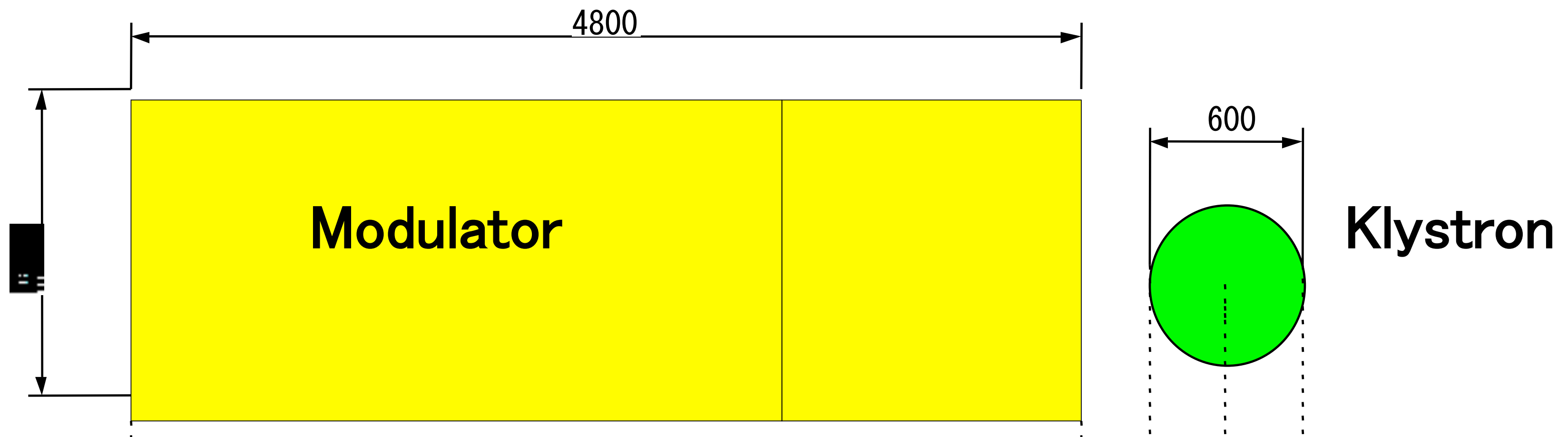
The case of 1 modulator 1 klystron

- It is possible to decrease 30% of total capacitance to get 2μs flat in the case of 1 modulator 1klystron.

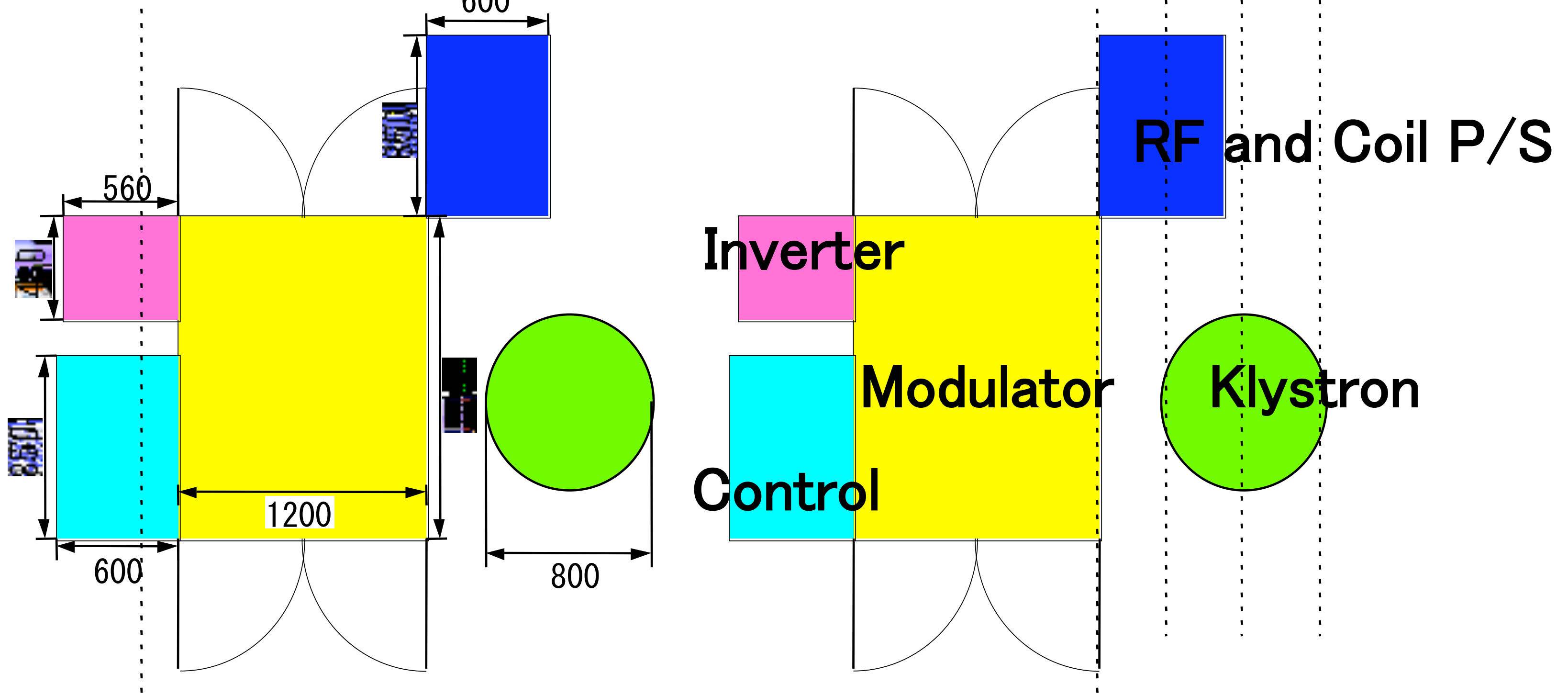
Klystron gallery' s spacing is important.
⇒Usage of Compact inverter DC HV power supply eliminates the use of IVR, charging choke and de' Qing circuit.
Possibility to use the discharging cabinet of existing modulator.
(see the plan of configuration)

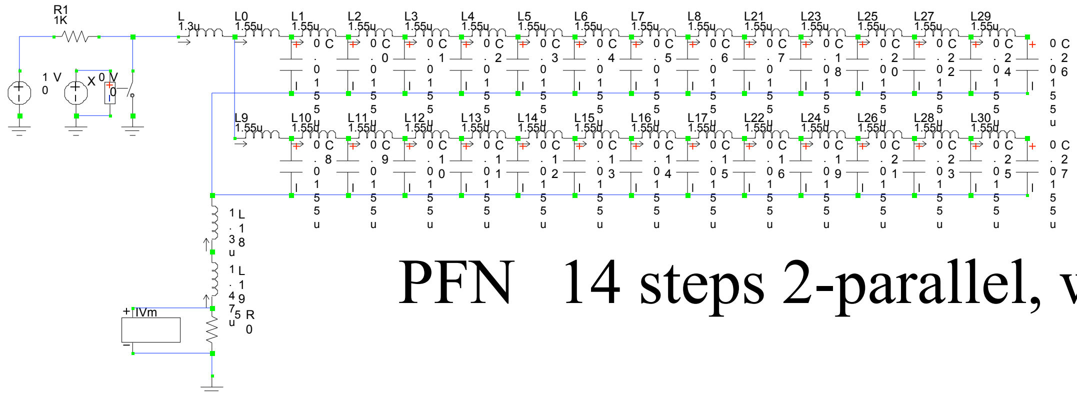
Existing PFN Capacitors are possible to be used again.
⇒ example, 14 steps, parallel PFN circuits
C_i=0.0155μF, L_i=1.5μH
↓
Flat pulse width of 2μs, half width of 4.8μs
(see simulation)

Present Configuration of Modulator and Klystron

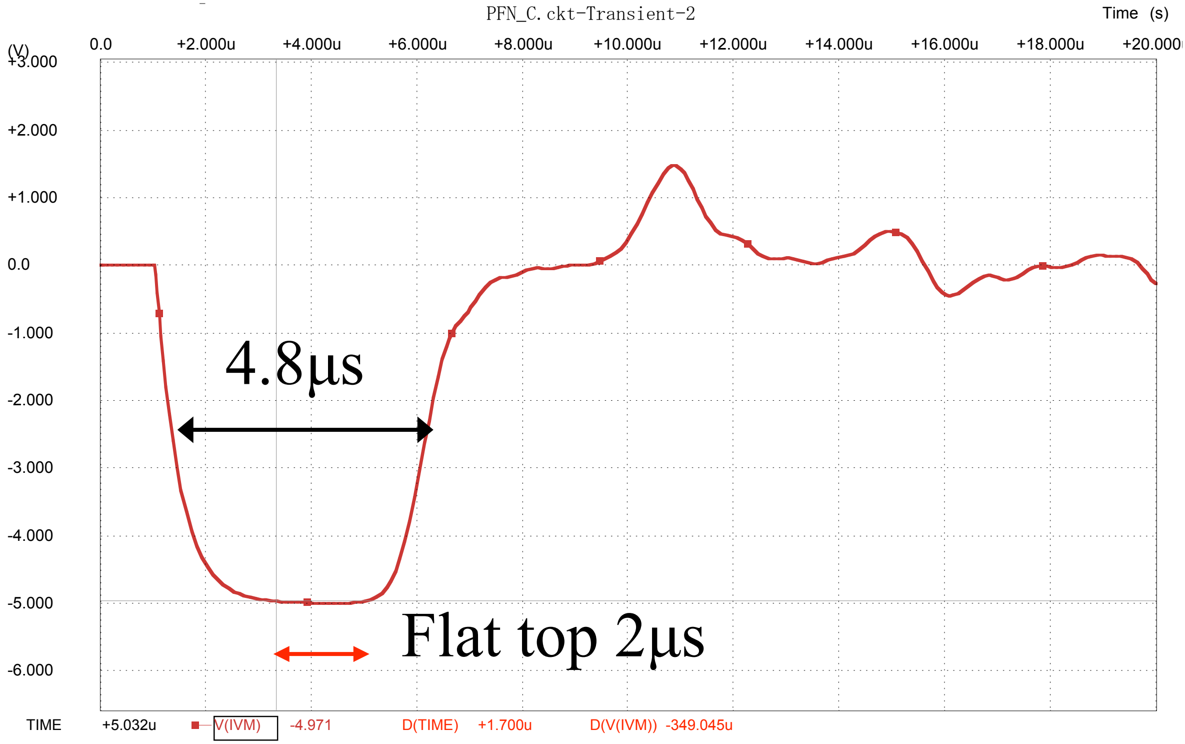


Proposed C-band Configuration





PFN 14 steps 2-parallel, with R_p=5Ω



Klystron Assembly

- Step-up ratio of １：１５ Pulse transformer

⇒Is it possible to use the existing pulse transformer?

⇒Is it possible to use the existing pulse transformer tank?

（the focusing magnet is fatter than the old one.）

- Assemblies configuration has been already shown.
- Cost of the C-band klystrons per present one unit is twice as much high as the one of S-band case.

totally 48 sockets!

It is necessary to compete the klystron quality among the several vendors.

Scheme of Driver System

Possible scheme for the Driving RF to the high power klystrons

(1) **Similar as the present sub-booster system- Driving 8 units from a SB klystron**

・deliver S-band to each sector⇒amplification⇒2-times multiplier SB klystron ⇒driving 16 C-band klystrons.

・deliver S-band to each sector⇒amplification⇒2-times multiplier ⇒amplification ⇒ C-band SB klystrons ⇒driving 16 C-band klystrons.

・deliver C-band to each sector⇒amplification⇒ C-band SB klystrons ⇒driving 16 C-band klystrons.

Constructing a sector (8 modulators, 16 tubes) in every fiscal year.

(2) **Similar as the present sub-booster system- Driving 4 units from a SB klystron**

・deliver S-band to each sector⇒amplification⇒2-times multiplier SB klystron ⇒driving 8 C-band klystrons.

・deliver S-band to each sector⇒amplification⇒2-times multiplier ⇒amplification ⇒ C-band SB klystrons ⇒driving 8 C-band klystrons.

・deliver C-band to each sector⇒amplification⇒ C-band SB klystrons ⇒driving 8 C-band klystrons.

Constructing half sector (4 modulators, 8 tubes) x n in every fiscal year.

It is easy to co-use S-band and C-band in the Tangent period.

Scheme of Driver System(Cont)

（３）One large klystron feeds all of 48 C-band klystrons.

⇒ How to construct? It is not easy to adjust the beam acceleration timing with the RF timing from SLED which delays gradually.

（４）Semiconductor C-band amplifier for each 50 MW C-band klystron.

・Merit ――― Easy feedback system, easy phase adjustment, no middle-power class phase shifter.

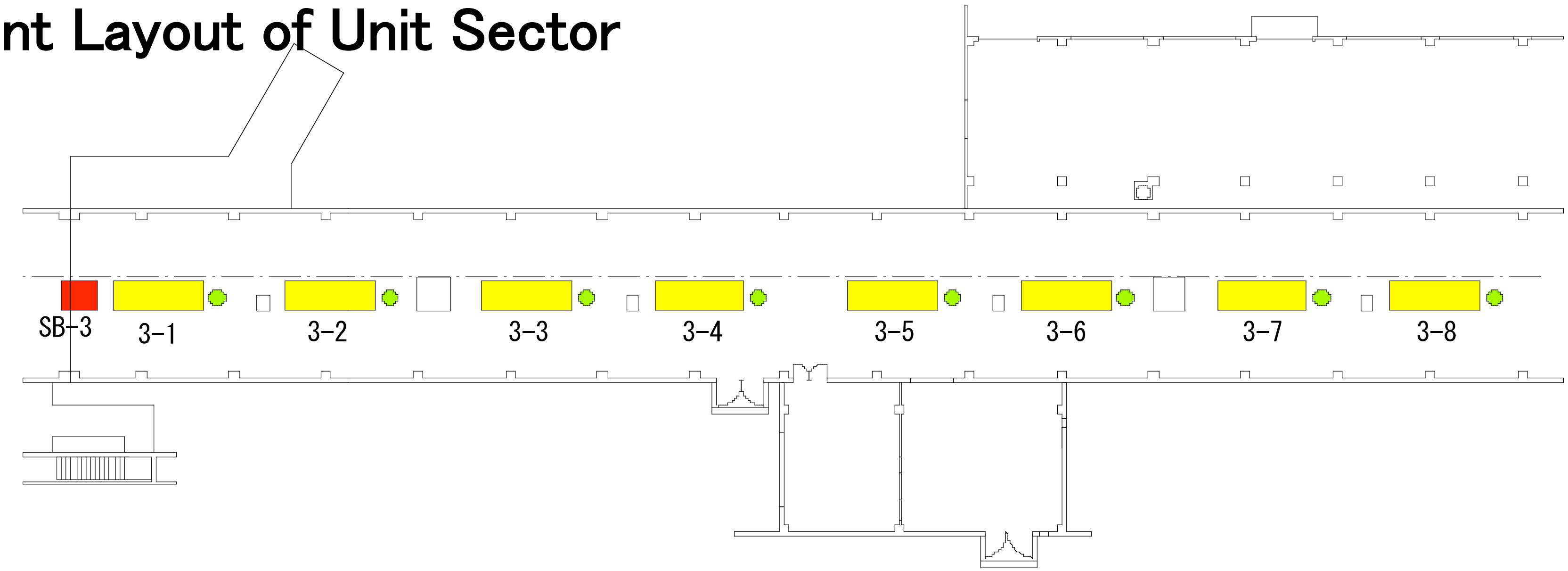
・Demerit―――Amplifier output power of about 500W×48
or amplifier output power of about 1 kW x 24
Price is roughly equal or more than a SB klystron.

（５） Driving Line consideration

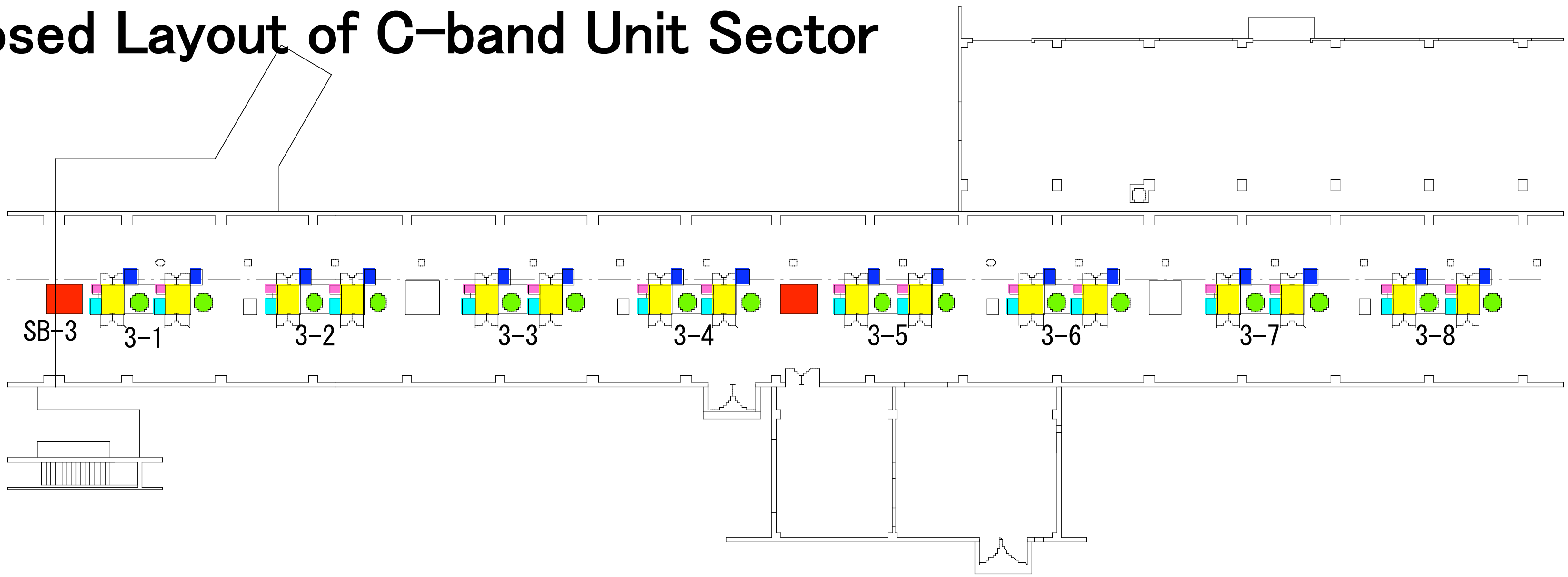
Phase stabilized co-axial line presently used is not available.
Attenuation, Higher mode, Stop manufacturing

⇒Rectangular waveguide with well temperature controlled.

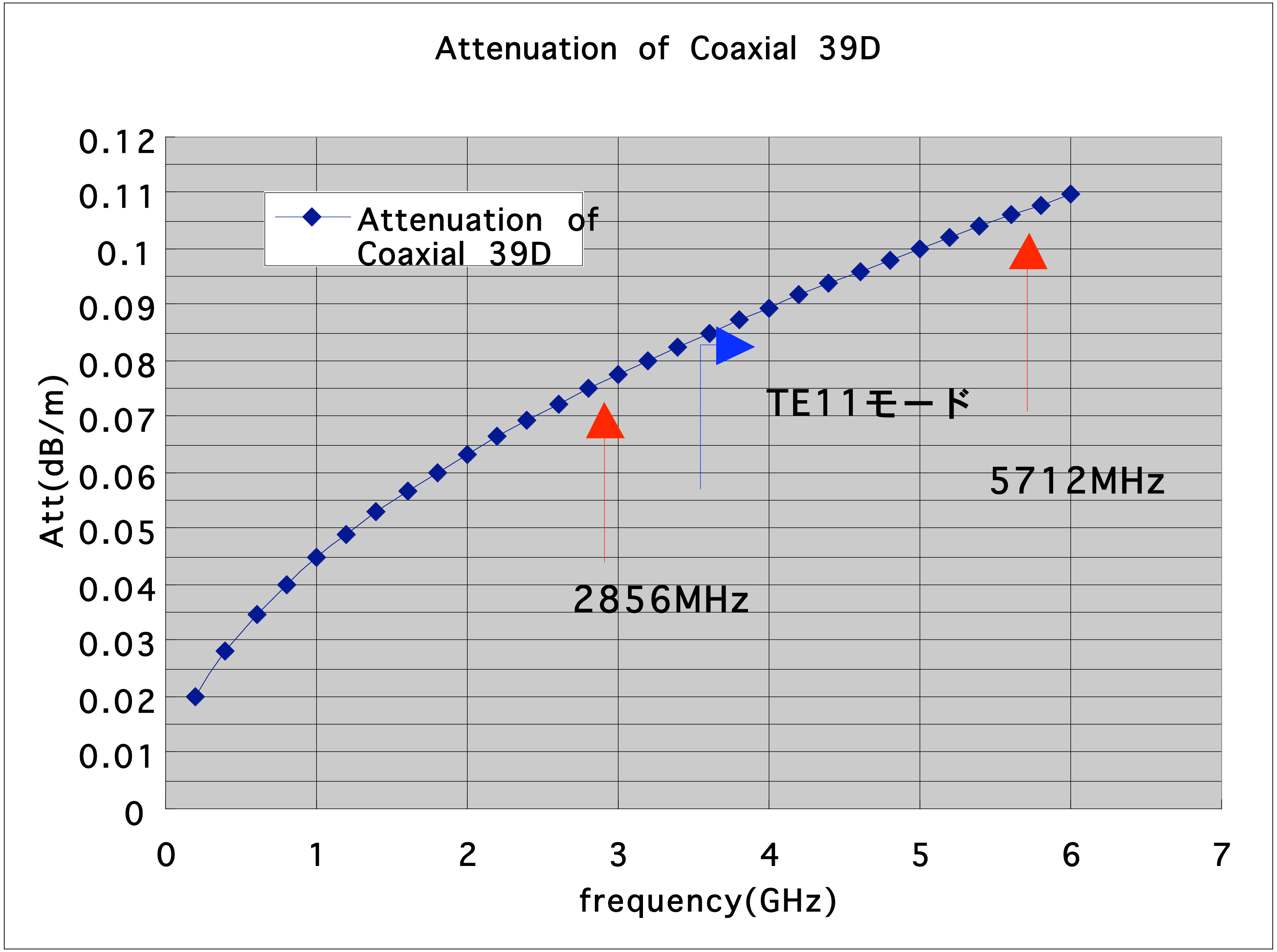
Present Layout of Unit Sector



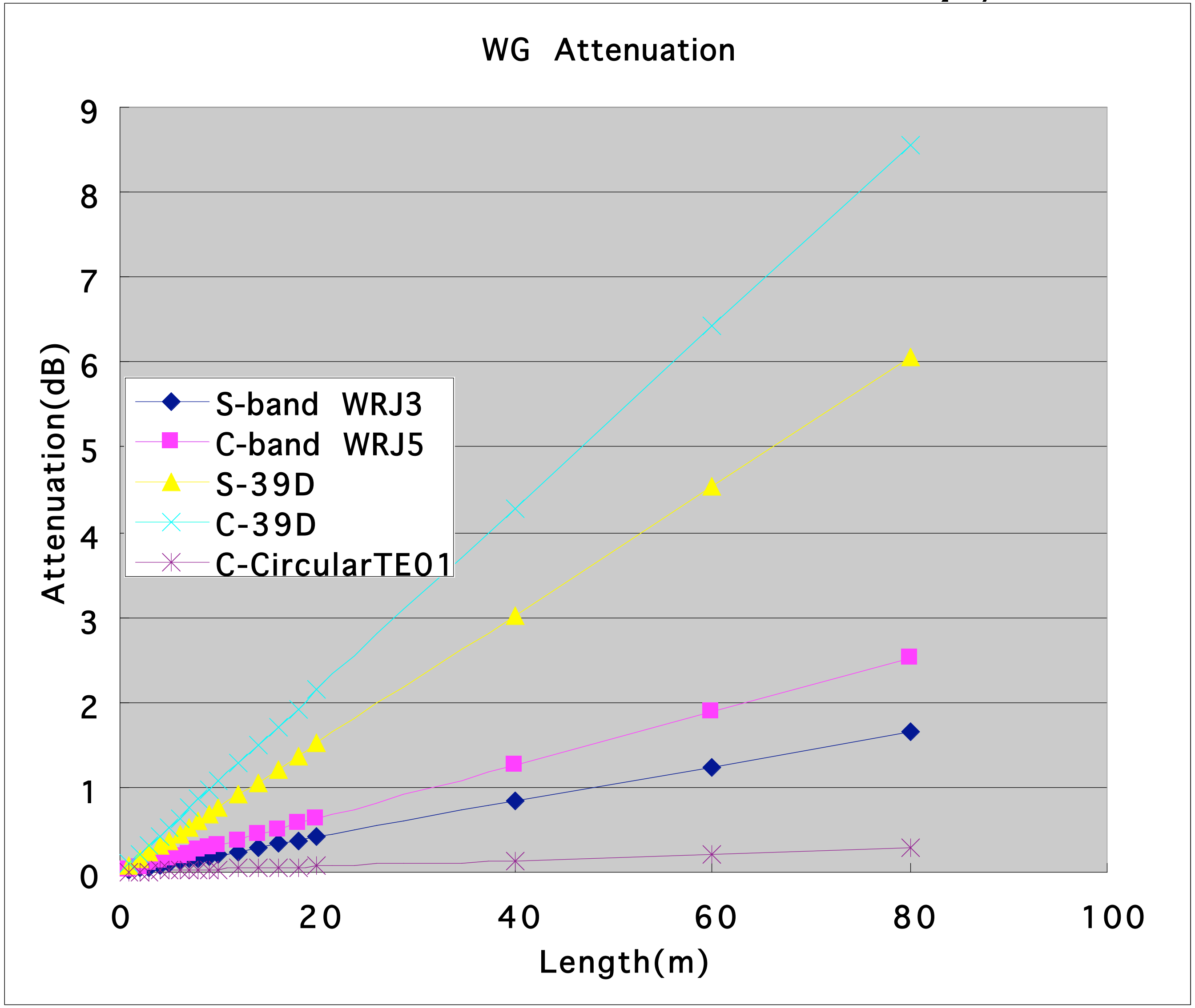
Proposed Layout of C-band Unit Sector



Attenuation of 39D Coaxial Line



Attenuation comparison between the various waveguide



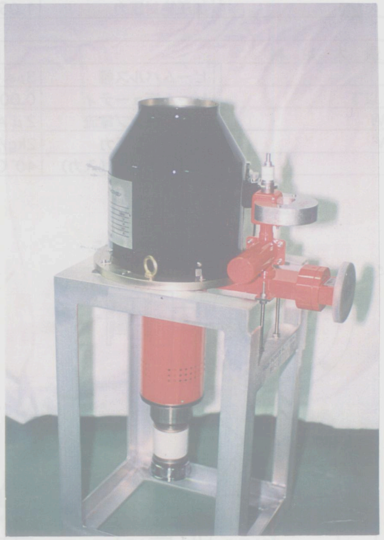
TM-X4035B

技術がつくる高度なふれあい SOCIO-TECH

MITSUBISHI

三菱クライストロン

PV−5101



PV-5101は、Cバンド、レーダー用、のパルスクライストロンです。強制空冷方式で、高帯域、小型、高出力を特長とし、DRAWシステムに最適なマイクロ波増幅管です。

- 周波数5250MHzから5350MHz内の1波で動作するクライストロンです。
- ピーク出力200kW以上（デューティ0.005、飽和利得40dB以上、効率35%以上）が得られます。
- 陰極には、バリウム含浸型陰極を採用しているため、長寿命を実現します。
- 集束磁界には、専用の電磁石（強制空冷方式）を用います。
- イオンポンプが付属しており、使用中に放出されるガスを吸蔵すると共に、管内真空度を監視することができます。

代表的動作例

ビーム電圧	50kV	効率	35%
ビーム電流	12A	飽和利得	40dB
ピーク出力	200kW	RFパルス幅	1.0μs
平均出力	0.4kW	RFデューティー	0.002

三菱電機株式会社

Existing C-band 200kW klystron (MELCO) ⇒Retune to **5712MHz**

Similar operating scheme performed by the present sub-booster（100kW at the 30kV) is expected.

It is possible to feed C-band klystrons if the rectangular waveguide (WRJ-5 or 6) is used.

⇒Good cost performance

Constant-temperature water is necessary to keep the drive line constant.

(±0.1 degree fine controlled water)

Phase stability, Minimum phase jitter is required for the C-band case.

⇒It is necessary to study the phase stability intensively.

Conclusion

- 2 klystrons and 2 modulators are installed in the present one unit space.
- Each modulator comprises a pulse discharging circuit and a compact inverter P/S.
- Existing modulator components are possible to be reused.
- C-band 50-MW klystron is used as main RF source..
- C-band 200kW klystron is used as the SB amplifier.
- Drive-line WG is kept constant temperature using highly controlled water.
- Consideration for the phase stability is very important.