

TOSHIBA

Leading Innovation >>>



How to Cope with Requirements or Requests from Accelerator Projects in the Case of Klystrons

11th May, 2016

Osamu YUSHIRO

[title]

How to Cope with Requirements or Requests from Accelerator Projects in the Case of Klystrons

This talk...

will be concentrated on
mainly klystrons for national big project,
w/o design/technical matters.

[title]

How to Cope with Requirements or Requests from Accelerator Projects in the Case of Klystrons

Acknowledgement

- klystron lineup information from THALES, CPI

Outline

1. Company Introduction
2. RF source – Klystron –
3. Accelerator Project and Requirements
4. Summary

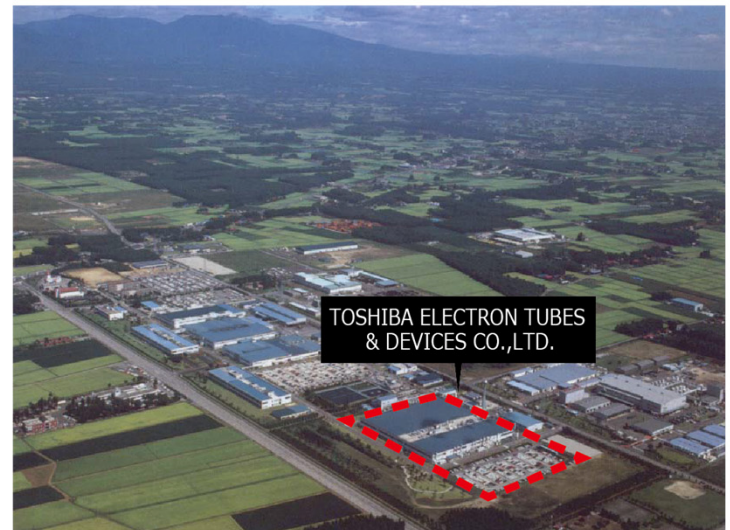
1. Company Profile

A company specializing in the design, development and manufacturing of electron tubes and devices

Company Name	TOSHIBA ELECTRON TUBES & DEVICES CO.,LTD.
Established	October 1, 2003
Headquarters	1385, Shimoishigami, Otawara-shi, Tochigi
Metropolitan Office	1-114-1, Miyacho, Omiya-ku, Saitama-shi, Saitama (ORE Omiya Building 8F)
Capital	480 million yen
CEO	Nakamuta Hironori
Number of employees	378 (as of April 1, 2016: Permanent employees)
Businesses	Development, manufacture and sales of electron tubes and applied products
Main Products	Klystrons, gyrotrons, Power Grid Tubes, X-ray tubes, X-ray Image Intensifiers, FPD (flat panel detectors)



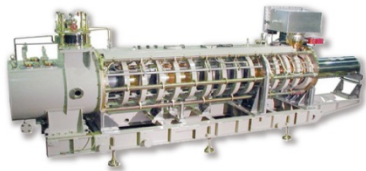
Headquarters, TOSHIBA ELECTRON TUBES & DEVICES CO.,LTD.



1. Company Profile

Development, production and sales of key components used in medical and food inspection as well as the science technology sector to contribute to the well-being of society and our customers.

Power tubes



Research and scientific sector

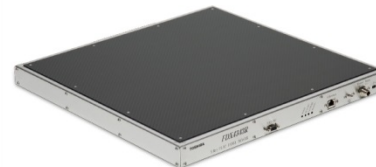
Spring-8
J-PARC
CERN

X-ray tubes



**Medical / Dental
Analytical
industry**

X-ray flat panel detectors: FPD



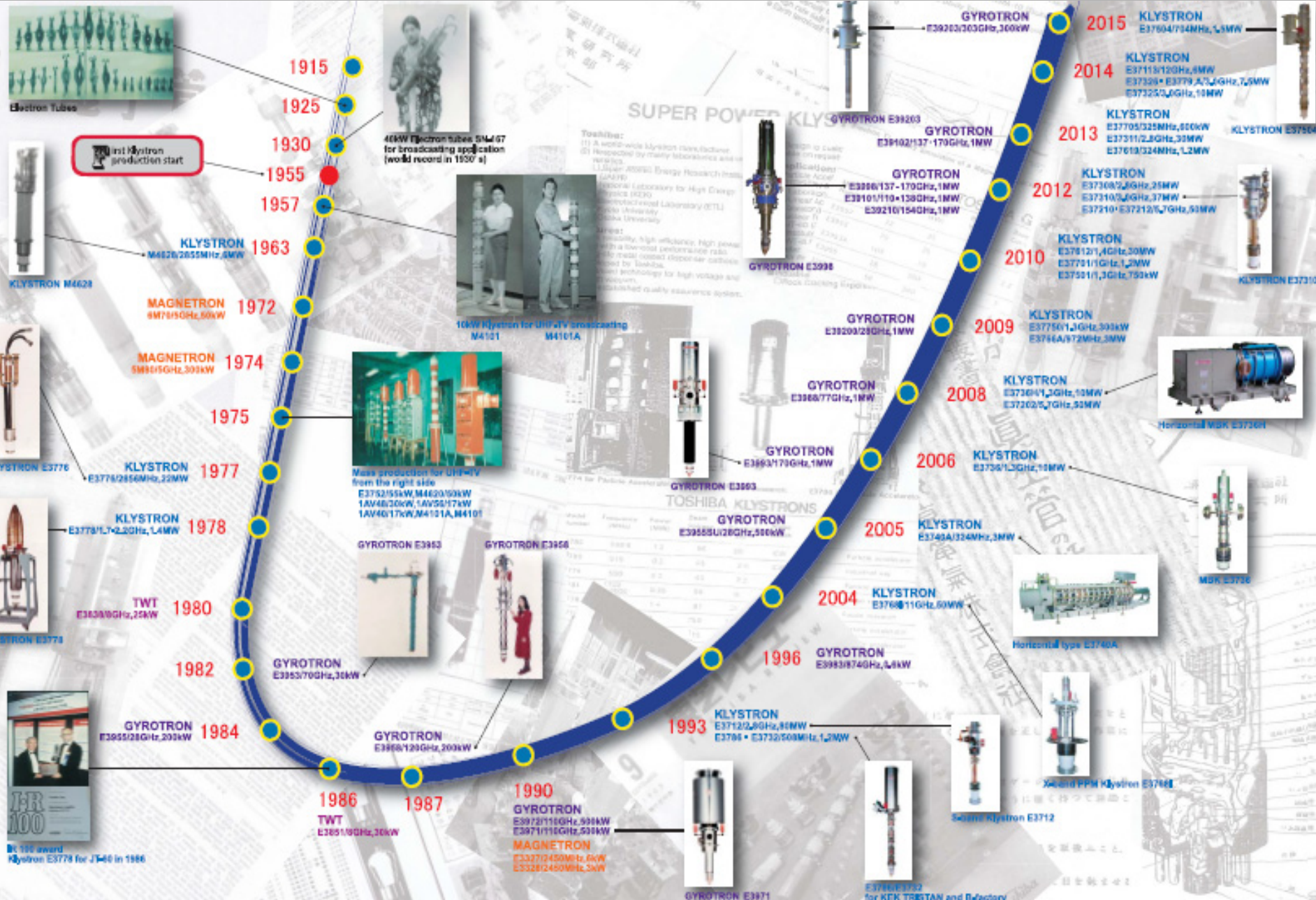
**Medical use
dynamic/
static images**

X-ray Image Intensifiers



**Medical use/
industrial use
X-ray TV**

Some history - microwave tubes --

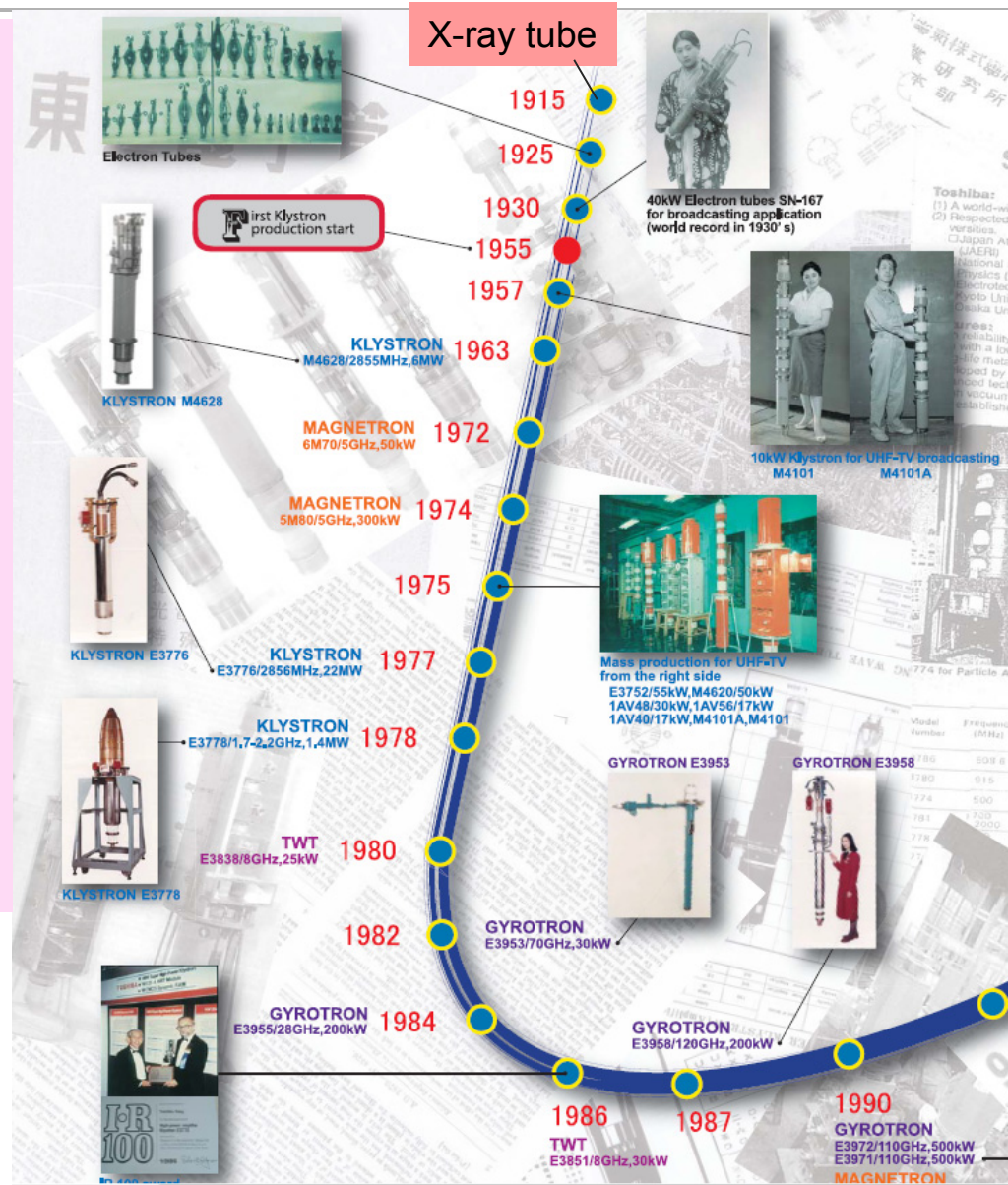


Some history – microwave tubes --

1955
Started the klystron's R&D

1957
First mass-production
for UHF-TV broadcast

1984
IR 100 award
Klystron E3778 for JT-60



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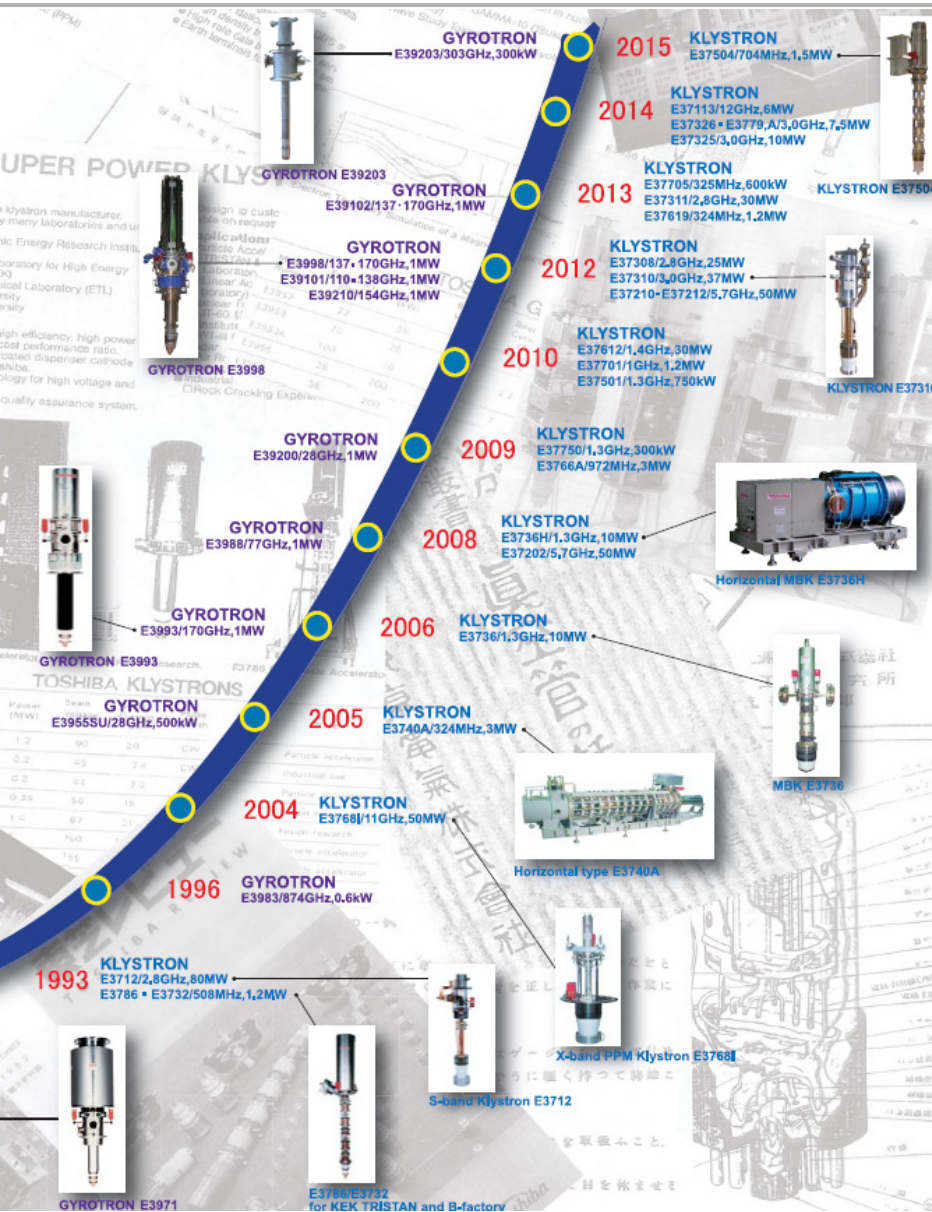


Klystron / Gyrotron
New development

Klystron
L-band to X-band

Gyrotron
For plasma heating
especially for ITER

Some history – microwave tubes --

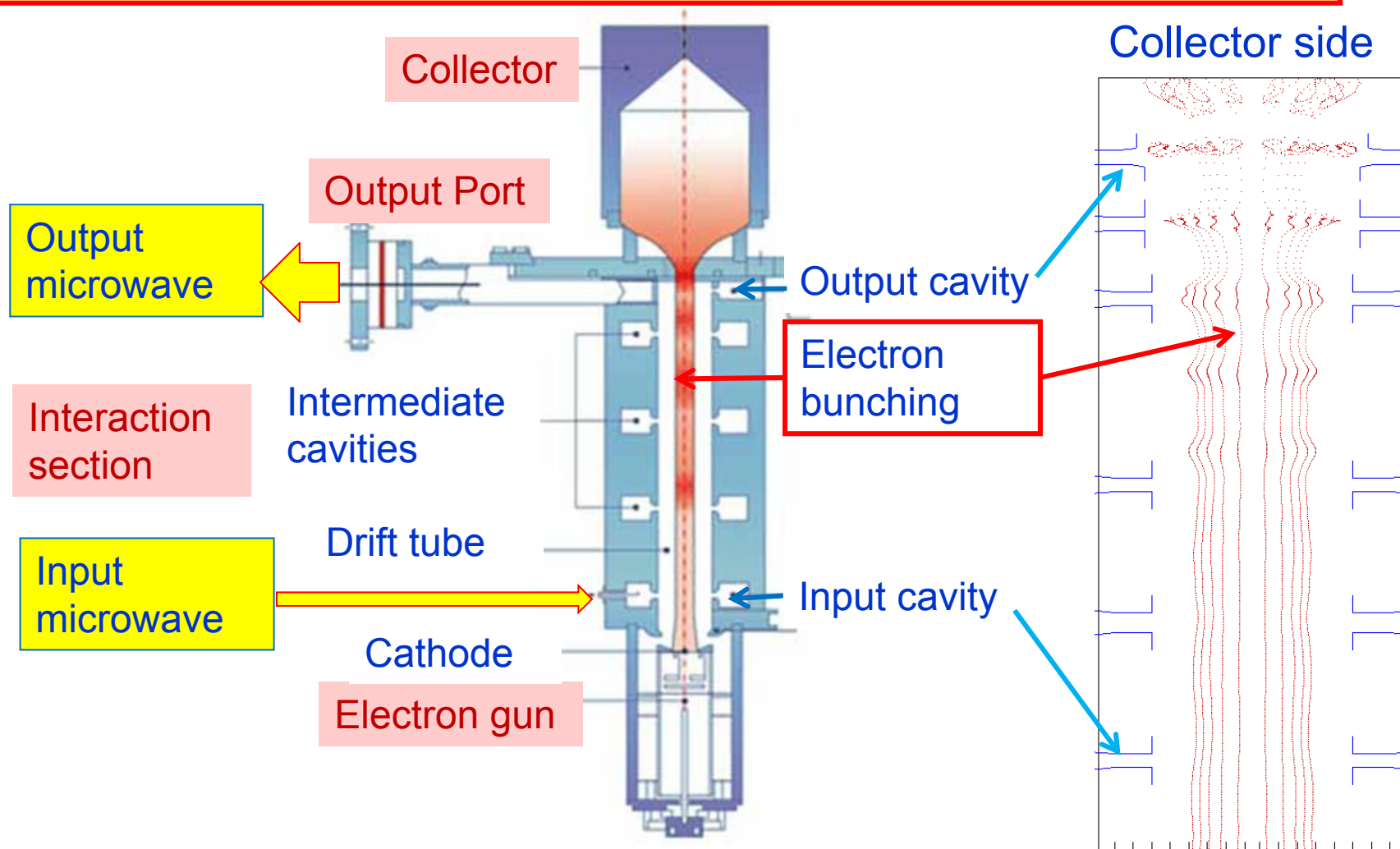


{new development}

- ESS/Sweden : E37504
- CERN/Swiss: E37113
- Max-IV/Sweden: E37310
- ITER/France: E39102
- E-XFEL/Germany: E3736H
- SwissFEL/Swiss: E37212
- IHEP/China: E37705
- KSTAR/Korea: E3762
- SACLA/JPN: E37202, E37612
- CLS/Canada: E37300
- IHEP/China: E37311
- PAL-XFEL/Korea: E37320
- SSRF/China: E37302

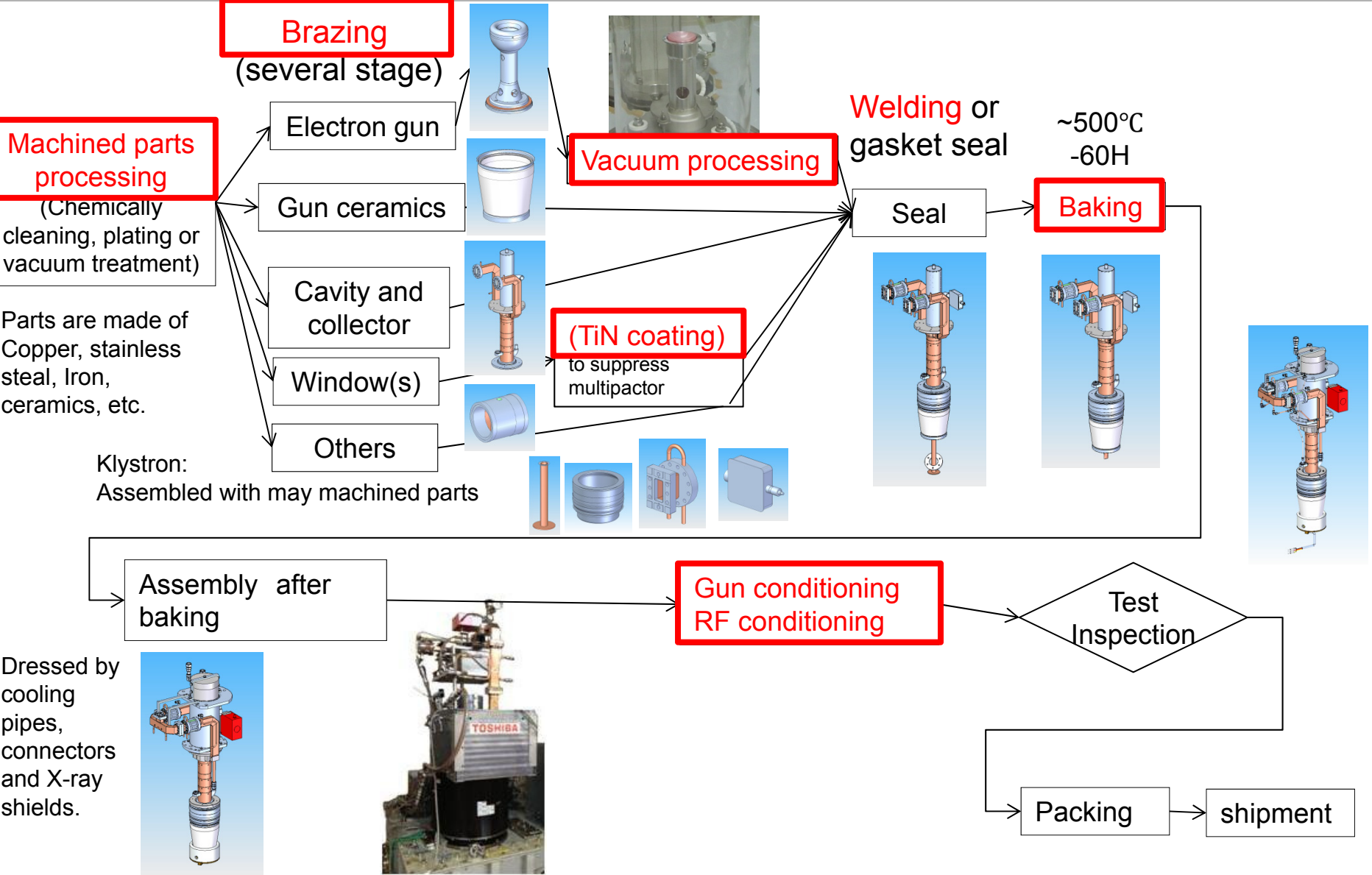
2. RF source - Klystrons -

KLYSTRON : Microwave Amplifier
apply the “electron bunching” → high gain RF Power

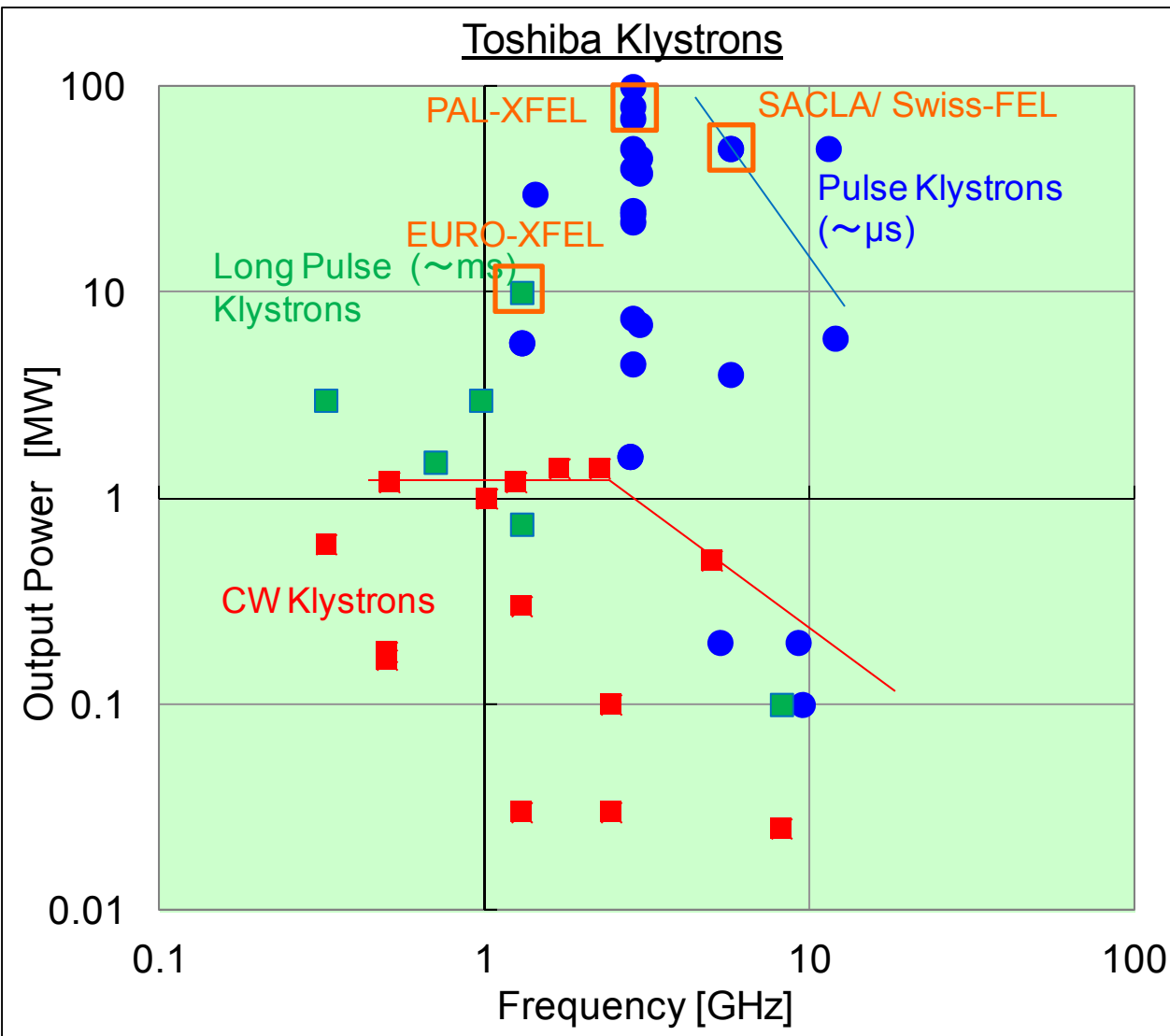


2. RF source - Klystrons -

Fabrication process example



2. RF source - Klystrons -



Amplifier

Frequency:

0.324 ~ 12GHz

Output power:

~1.2 MW (CW)

~100 MW (Pulse)

Application:

- Science -
Linear accelerator,
Synchrotron radiation,
Collider, Plasma heating
- Industrial -
Medical, Sterilization
(Linac), Heating
- Radar -

3. Accelerator Project and Requirements

This talk...

will be concentrated on
mainly klystrons for national big project.

3. Accelerator Project and Requirements

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mainly klystrons for national big project.

Klystrons have been developed deeply
collaborating with many research institutes.

3. Accelerator Project and Requirements

Collider accelerator	Frequency	Peak Power	Rep. Rate	Pulse Length	Ave. Power
SLAC	2856MHz 476MHz	45,65MW 1.2MW	180pps CW	3.5usec	41kW
KEK-B	2856MHz 508MHz	50MW 1.2MW	50pps CW	4usec	10kW
BEPC II	2856MHz 500MHz	50MW 250kW	50pps CW	4usec	10kW
LHC	401MHz	300kW	CW		
Tevatron	805MHz	15MW			

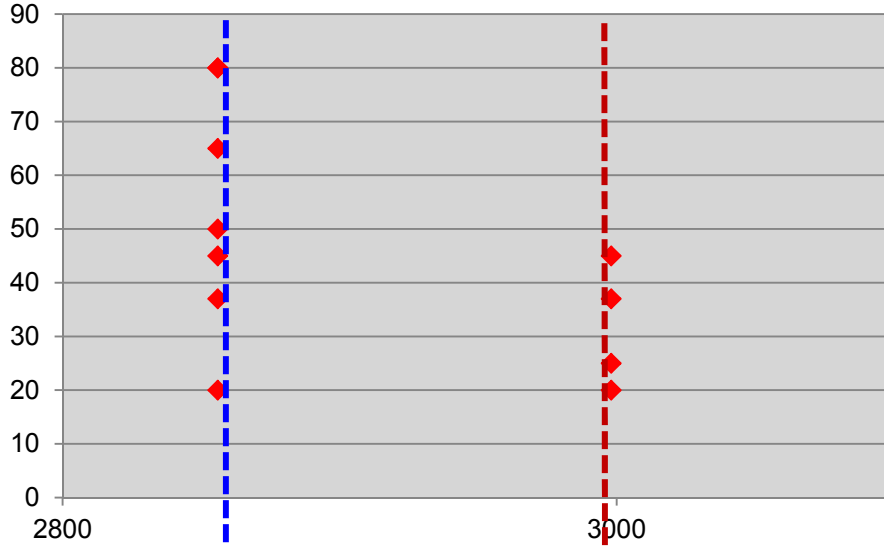
3. Accelerator Project and Requirements

Light sources	Frequency	Peak Power	Rep. Rate	Pulse Length	Ave. Power
KEK-PF	2856MHz 500MHz	50MW 180kW	50pps CW	4usec	10kW
SPring-8	2856MHz 500MHz	80MW 1.2MW	50pps CW	4usec	16kW
PAL	2856MHz 500MHz	80MW 150kW	50pps CW	4usec	16kW
CLS	2856MHz 500MHz	25MW 80kW	10pps CW	4usec	1kW
SLS	2998MHz 500MHz	45MW 180kW	10pps CW	3usec	17kW
ESRF	2998MHz 352MHz*	35MW 150kW	10pps CW	1usec	1kW
MAX-IV	2998MHz 100MHz	37MW 120kW	100pps CW	4.5usec	15kW

3. Accelerator Project and Requirements

electron
accelerator

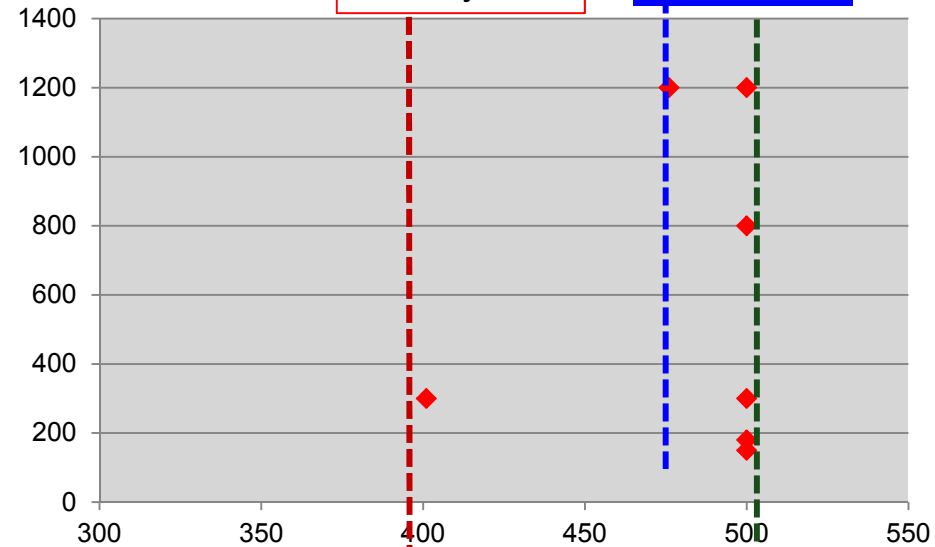
Pulsed Klystron



2856MHz

2998MHz

CW Klystron



476MHz

401MHz

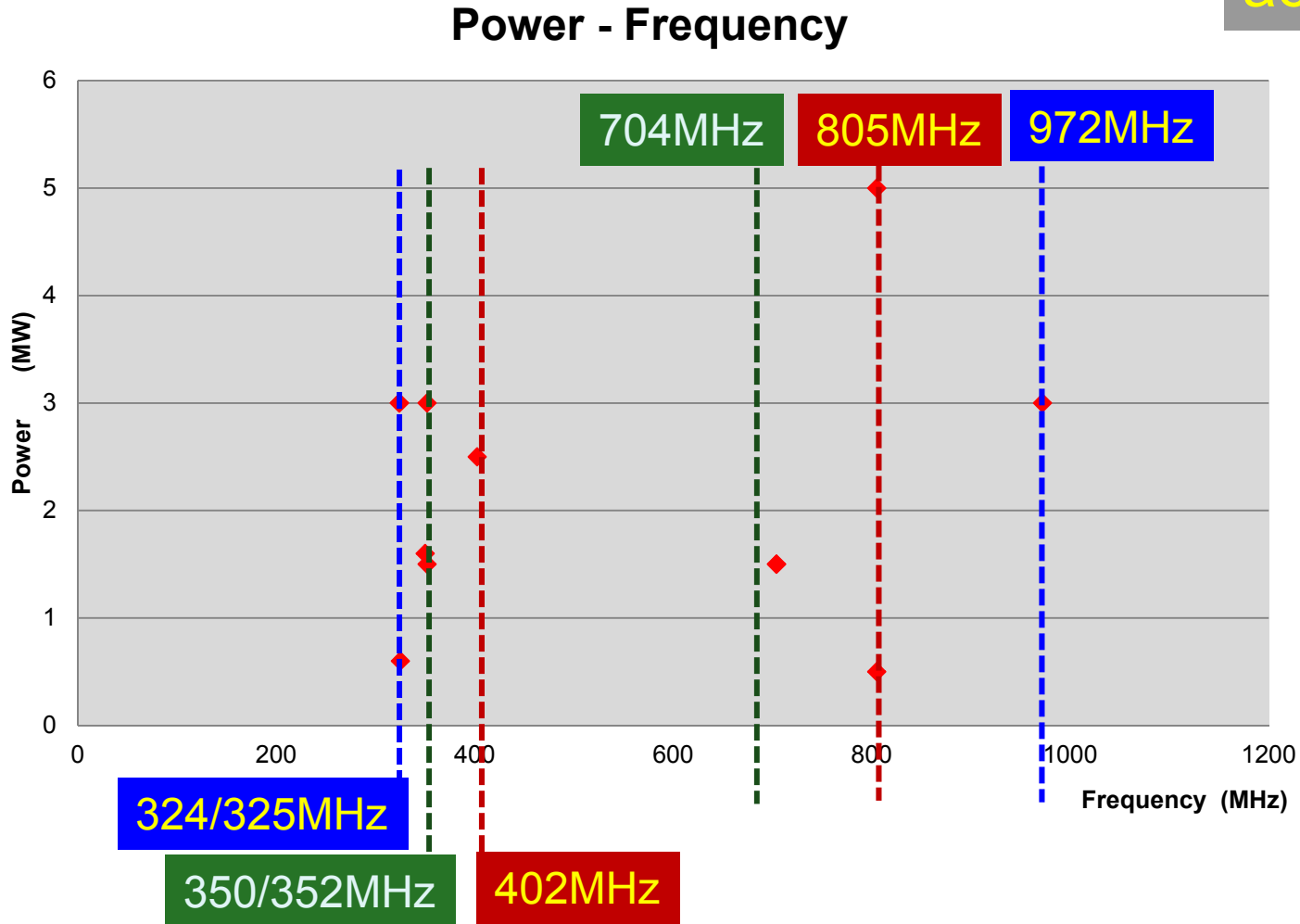
500/508MHz

3. Accelerator Project and Requirements

Proton accelerators	Frequency	Peak Power	Rep. Rate	Pulse Length	Ave. Power
LANS	805MHz	1.25MW	120pps	100usec	15kW
FNAL	201MHz(*)	5.0MW	15pps	450usec	34kW
SNS	402.5MHz	2.5MW	60pps	1msec	150kW
	805MHz	5MW	60pps	1msec	300kW
		0.55MW	60pps	1msec	35kW
JPARC	324MHz	3.0MW	50pps	620usec	93kW
	972MHz				
ESS	352MHz	1.5MW	14pps	3.5msec	73.5kW
	704MHz				
LINAC4 SPL	352MHz	3.0MW	2pps	1.2msec	150kW
	704MHz	1.5MW	50pps	1.7msec	
CSNS	324MHz	3.0MW	25pps	650usec	50kW
KOMAC	350MHz	1.6MW	60pps	1.5msec	144kW

3. Accelerator Project and Requirements

Proton
accelerator

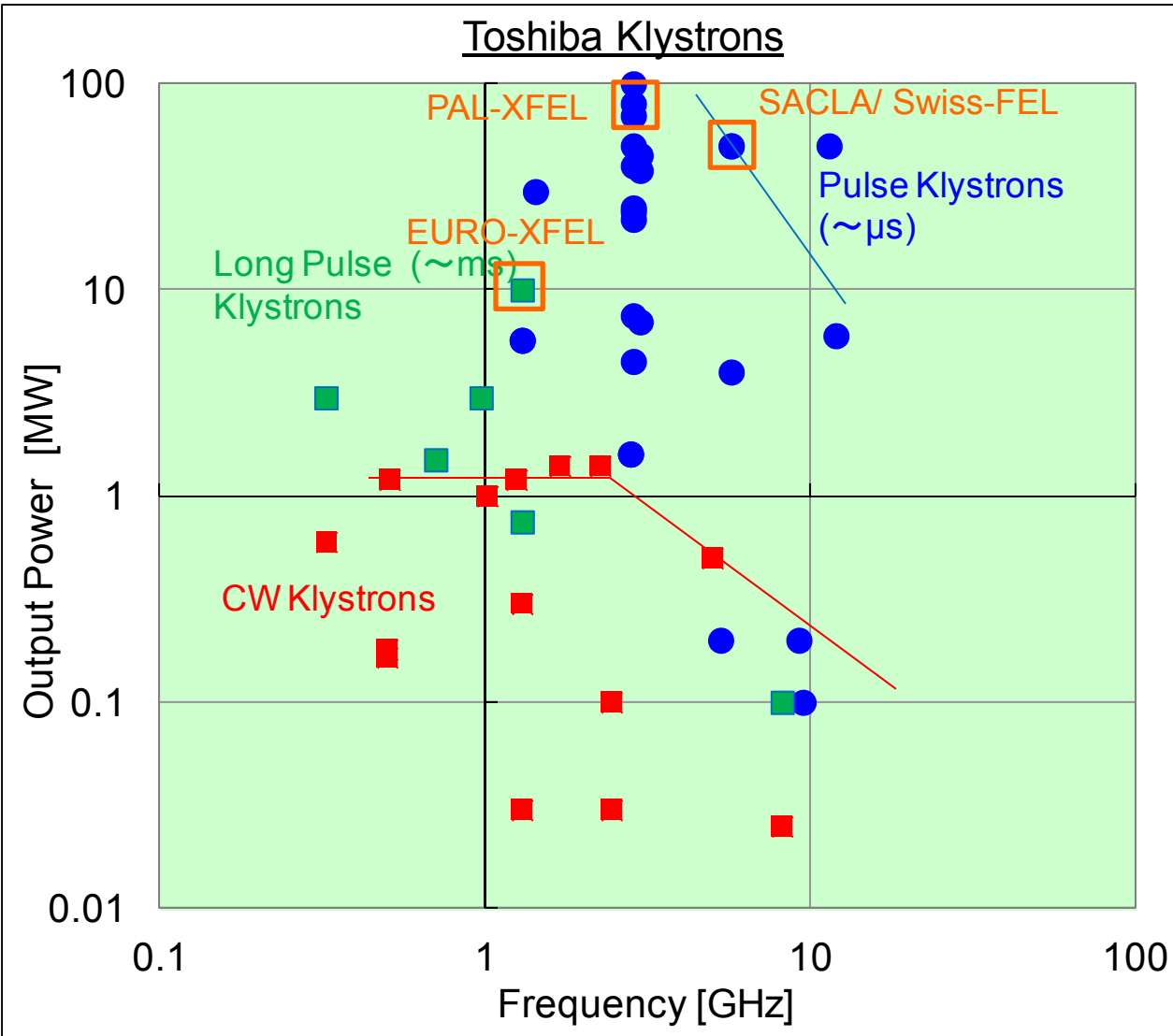


3. Accelerator Project and Requirements

Superconductive accelerators	Frequency	Peak Power	Rep. Rate	Pulse Length	Ave. Power
E-FEL	1300MHz	10MW 5MW	10pps 10pps	1500usec 1500usec	150kW 75kW
ILC	1300MHz	10MW	5pps	1500usec	75kW

3. Accelerator Project and Requirements

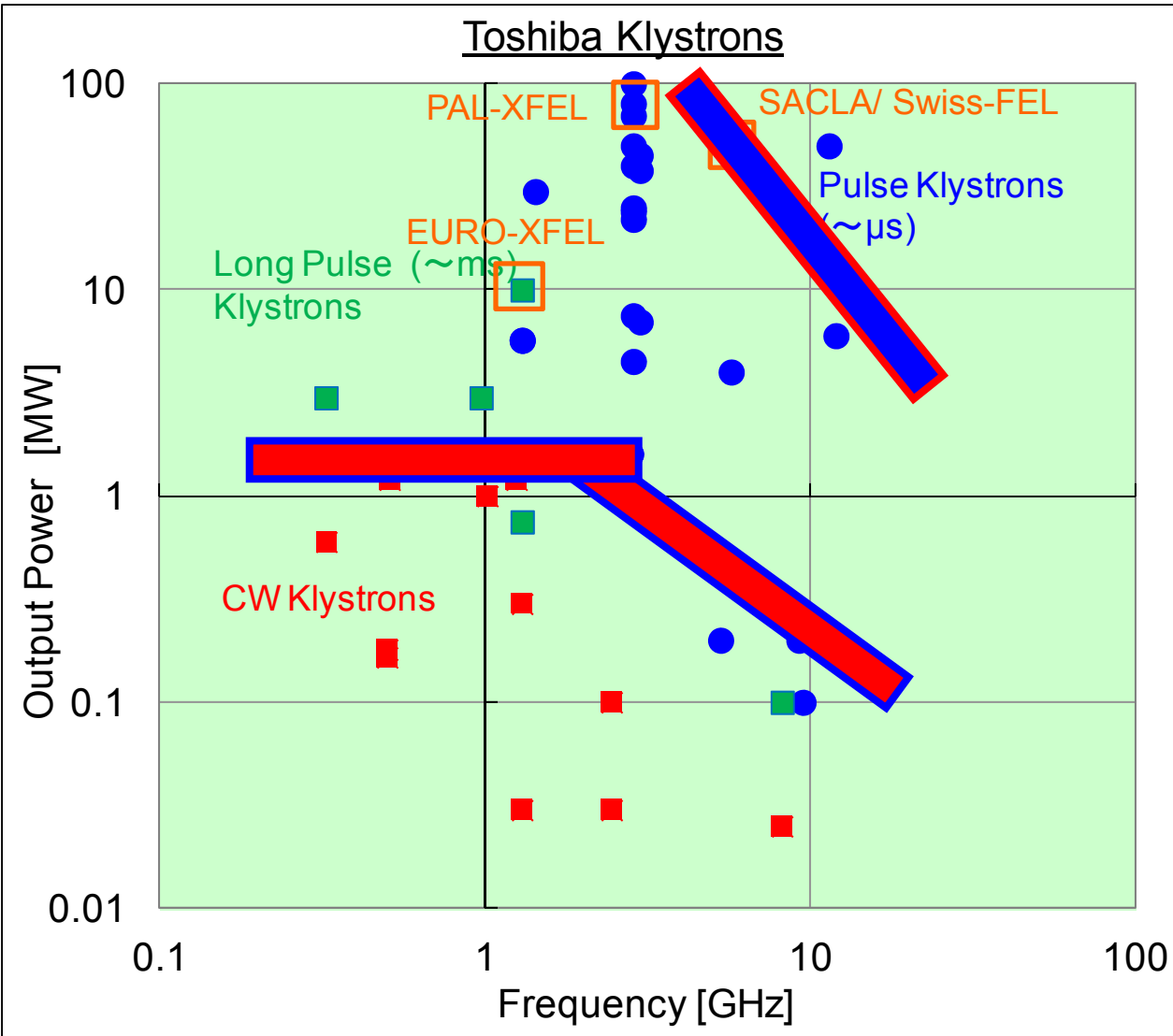
Frequency vs Power



- Short pulsed
- Long pulsed
- CW

3. Accelerator Project and Requirements

Frequency vs Power



- Short pulsed
- Long pulsed
- CW

3. Accelerator Project and Requirements

Manufactures points of view - Linac -

- Frequencies

[electrons]

S-band	C-band	X-band
2856MHz --	5712MHz --	11.4GHz
2998MHz --		12GHz

[protons]

201MHz	
324/325MHz --	972MHz
350/352MHz --	704MHz
402.5MHz	-- 805MHz

[SCRF]

325MHz -- 650MHz -- 1300MHz

3. Accelerator Project and Requirements

Manufactures points of view - Linac -

- Frequencies

[electrons]

S-band	C-band	X-band
2856MHz --	5712MHz --	11.4GHz
2998MHz --		12GHz
		9.3GHz

[protons]

201MHz	
324/325MHz --	972MHz
350/352MHz --	704MHz
402.5MHz	-- 805MHz

[SCRF]

325MHz --	650MHz --	1300MHz
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3. Accelerator Project and Requirements

Manufactures points of view - Linac -

- Peak Power

Upper Limit

[electrons] S-band 2856/2998MHz 80MW/4usec

100MW/1usec

C-band 5712MHz 50MW/2.5usec

X-band 11.4/12GHz 50MW/1.5usec

6MW/4.5usec

[protons] 201MHz 5MW/450usec

324/325MHz -- 972MHz 3MW/650usec

350/352MHz -- 704MHz 1.5MW/3.5msec

402.5MHz -- 805MHz 2.5MW/5MW/1msec

[SCRF] 325MHz/650MHz/1300MHz ~~~> high duty & CW

3. Accelerator Project and Requirements

Manufactures points of view - Linac -

- average power (pulth length)

Upper Limit

[electrons] S-band 5MW

4usec/200pps (4kW)

5MW

18usec/667pps (60kW)

C-band 4MW

4usec/250pps (4kW)

50MW

2.5usec/100pps(12.5kW)

X-band 6MW

5usec/400pps (12kW)

50MW

1.5usec/50pps (3.8kW)

[protons] 3MW

650usec/50pps (98kW)

1.5MW

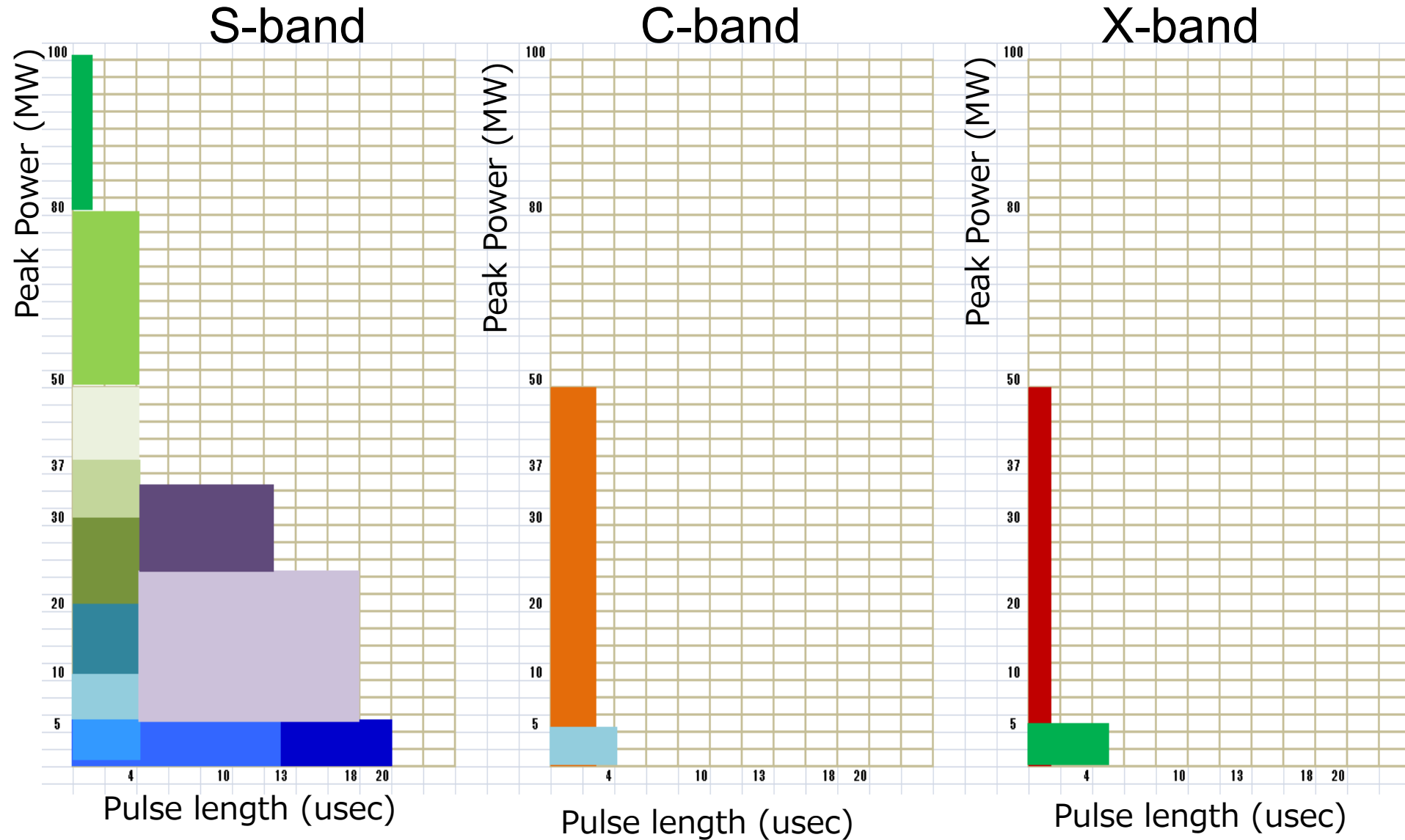
3.5msec/14pps (74kW)

2.5MW/ 5MW

1msec/60pps (150kW300kW)

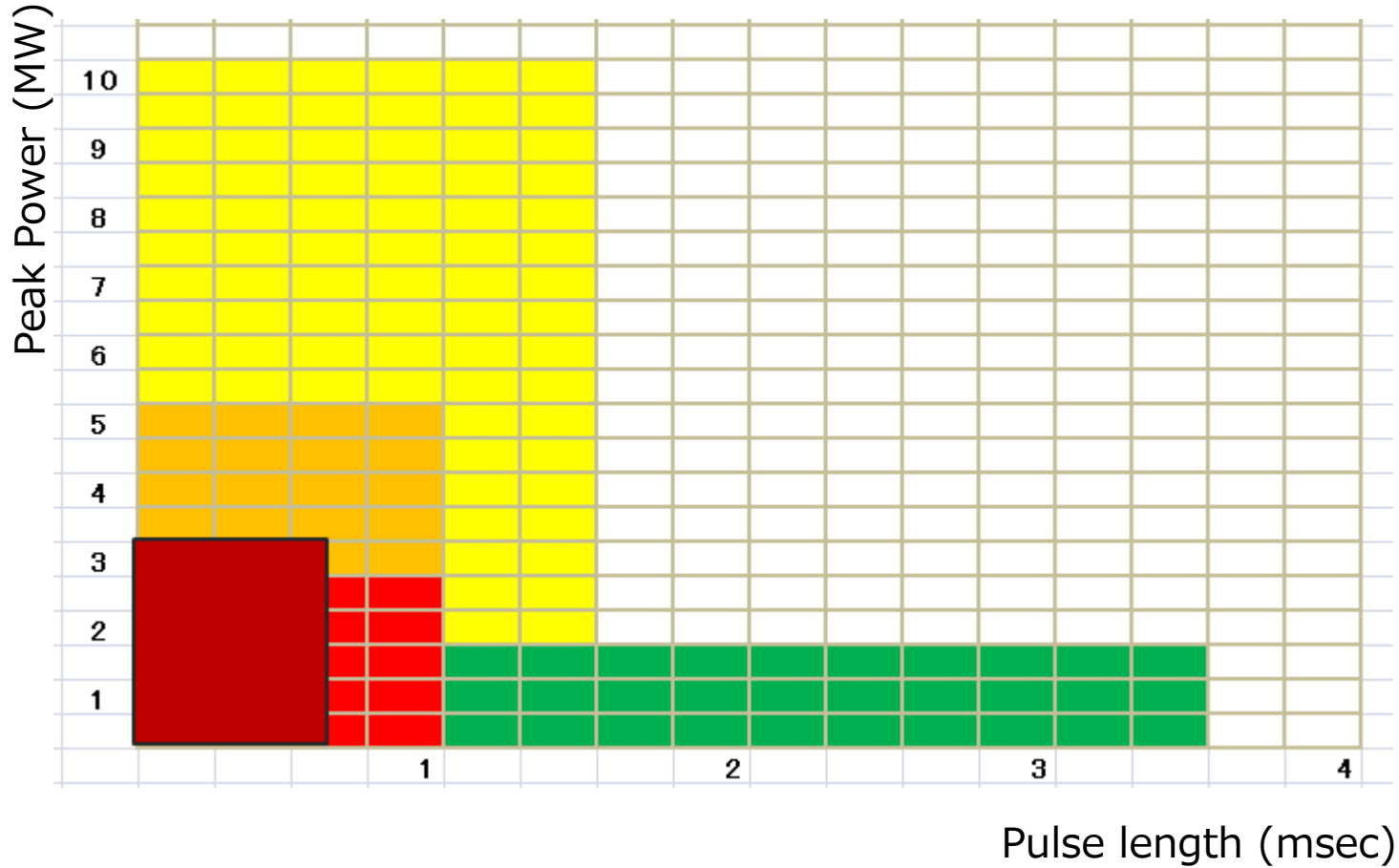
[super] 600kW to 1MW ~-> high duty & CW

3. Accelerator Project and Requirements



3. Accelerator Project and Requirements

L-band



3. Accelerator Project and Requirements

Accelerator power consumption		
Project	Estimated consumption [MW]	remarks
LHC	120	
HL-LHC	140	
CLIC 500 GeV	240	
ILC 500GeV	200	RF 70MW
FCC e+e-	300	RF ~ 150MW
FCC pp	250	

RF sections energy consumption : 1/3 to 1/2 of total energy consumption



It's very important to improve efficiency.

3. Accelerator Project and Requirements

Manufactures points of view - efficiency -

pulsed CW	current value
	40-55% 55-65%



pulsed CW	future value
	70, 80%?? 75, 85%??

(note: these numbers doesn't include the beam rise/fall time and klystron itself value.)

4. Summary

- 1) RF source manufactures will be deeply keep in touch with many laboratories and universities in the future also.
 - ➔ Researchers = human being need to discover new particles, law of nature, and origin of the universe/human...
- 2) To explore these mysteries, every time, we need best solutions.
 - ➔ huge accelerators, new concept RF sources.

4. Summary

should be

- 1) RF source manufactures ~~will be~~ deeply keep in touch with many laboratories and universities in the future also.
 - Researchers = human being need to discover new particles, law of nature, and origin of the universe/human...
- 2) To explore these mysteries, every time, we need best solutions.
 - huge accelerators, new concept RF sources.

4. Summary

3) RF source manufactures will be supplying you the best solution RF sources.

→ every frequencies, powers ...
new concept RF sources,
high efficiency

4) Requirements are widely from customers to customers.

→ RF source manufactures have been flexible and will/should continue to be flexible in order to cope with customers' requirements.

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