

Klystron Development by TETD

1. Two kinds of klystron for the J-PARC project

- 324-MHz klystron E3740A: working at the J-PARC site
- 972-MHz klystron E3766: in the final stages of developing

2. 1.3-GHz MBKs and a power coupler for the European XFEL project

- VMBK (vertically-oriented MBK): completed acceptance testing at DESY
- HMBK (horizontally-oriented MBK): under development
- Power coupler: on contract with LAL for the industrialization studies

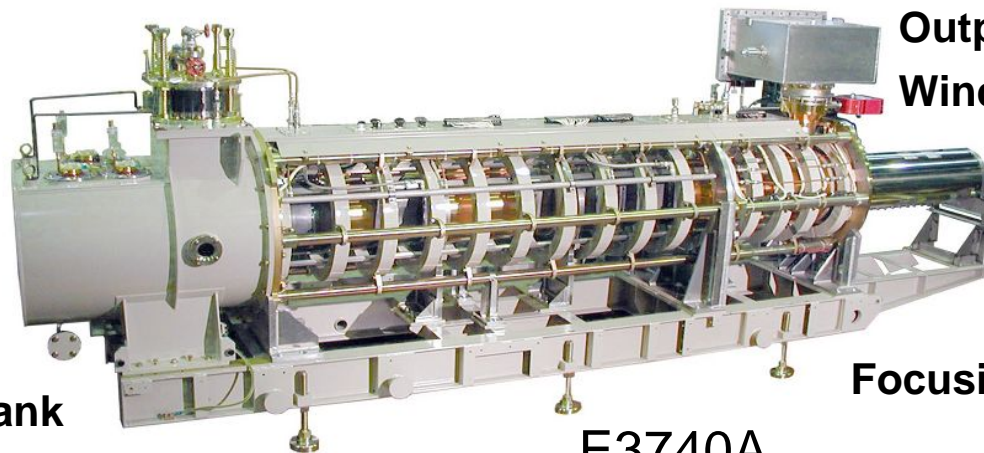
3. Application to fusion experimental devices

- Prototype E3762 of 5-GHz, 500-kW CW klystron for KSTAR
- 170-GHz, 1-MW Quasi-CW gyrotron for ITER

Klystrons for J-PARC: E3740A and E3766

	E3740A	E3766
Frequency (MHz)	324	972
Output Power (MW)		3
Efficiency (%)		50
Gain (dB)		55
RF Pulse Length (ms)		0.62
Beam Pulse Length (ms)		0.7
Repetition Rate (Hz)		50
Beam Voltage (kV)		110
Anode Voltage (kV)		94
Beam Perveance (I/V ^{1.5})		1.37×10^{-6}
No. of cavities	5	6
Window	Coaxial	Pillbox
Output Flange	WR-2300	WR-975
Tube Length (m)	4.55	2.93

Triode-type electron gun
for anode modulating
Same beam parameters



Oil tank

E3740A

Output waveguide
Window

Collector

Focusing solenoids

Collector

Window

cavities

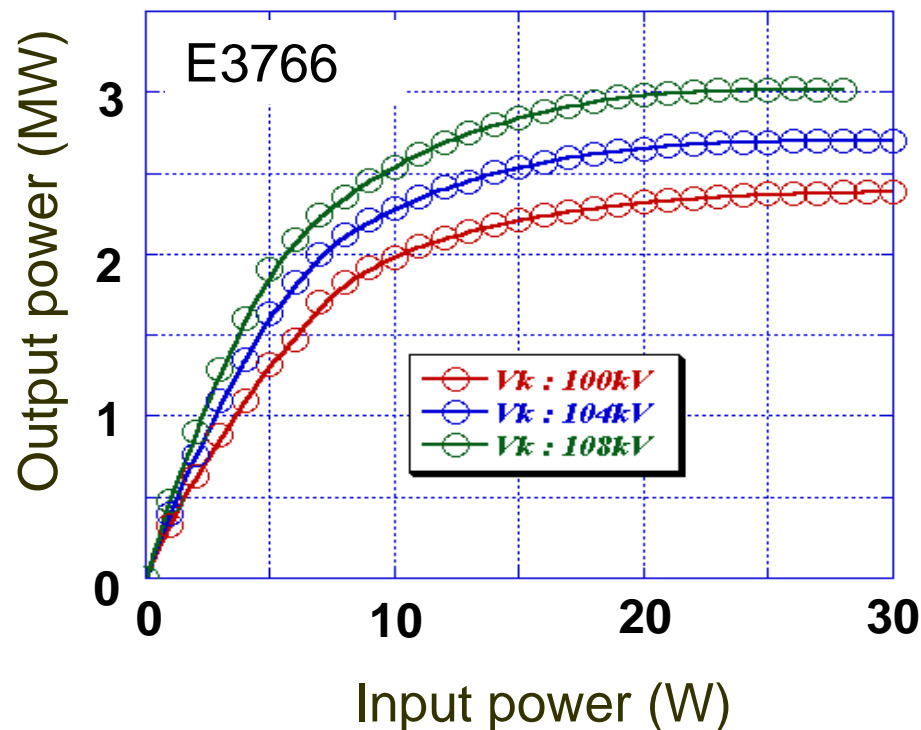
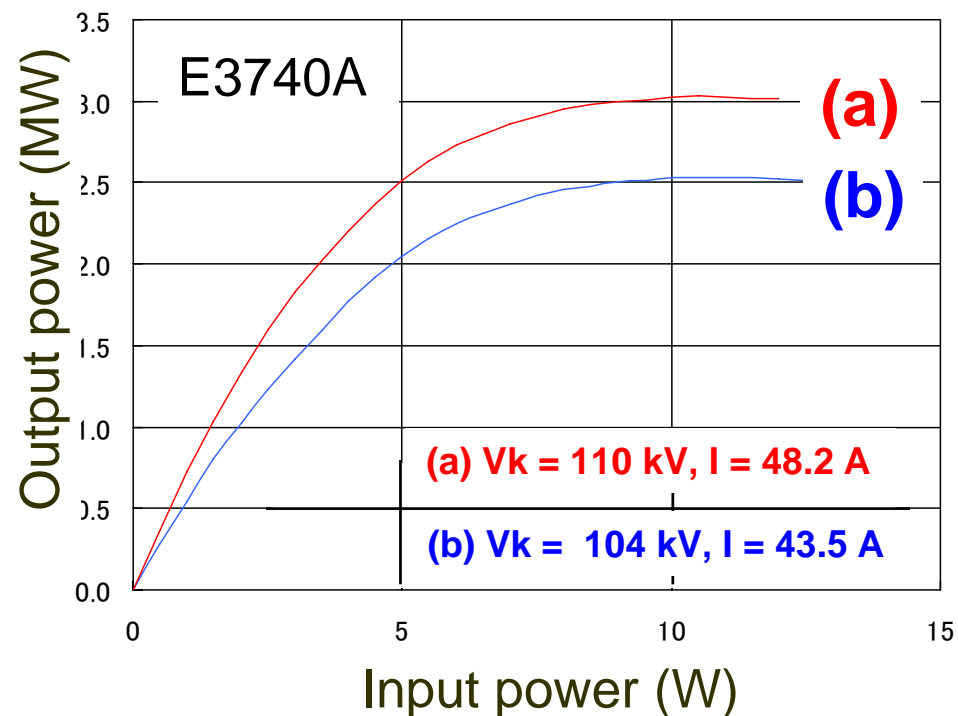
Electron gun



E3766

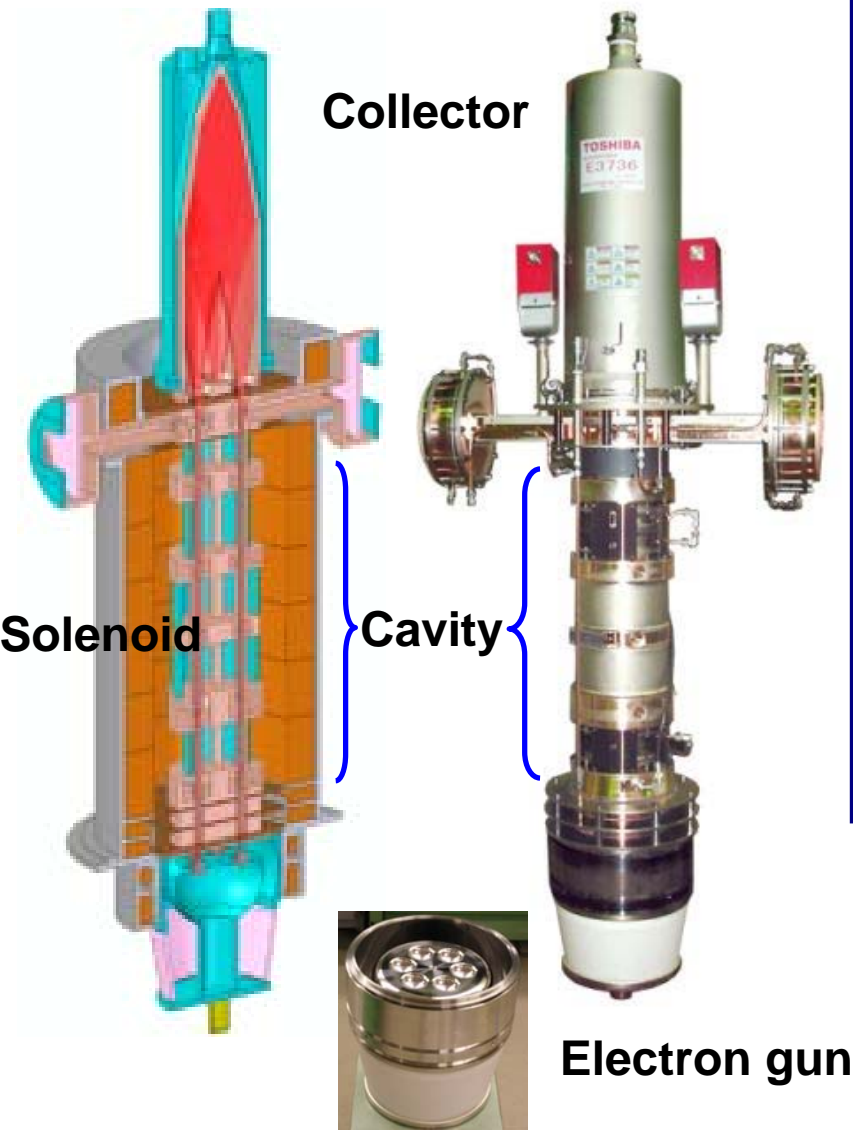
Klystrons for J-PARC: Performance of E3740A and E3766

Transfer characteristics

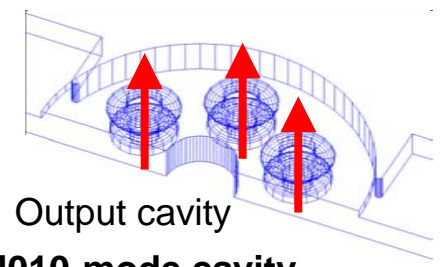
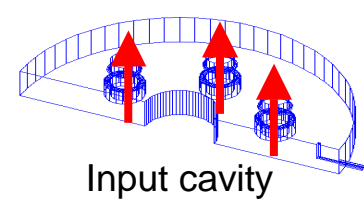


1. Twenty of the 324-MHz tubes E3740A were already installed and are working at the J-PARC linac system.
2. We achieved 3-MW stable operation for the 972-MHz tube E3766 and are in the final stages of developing the tube for volume production.

MBK for European XFEL: Design and Performance of VMBK

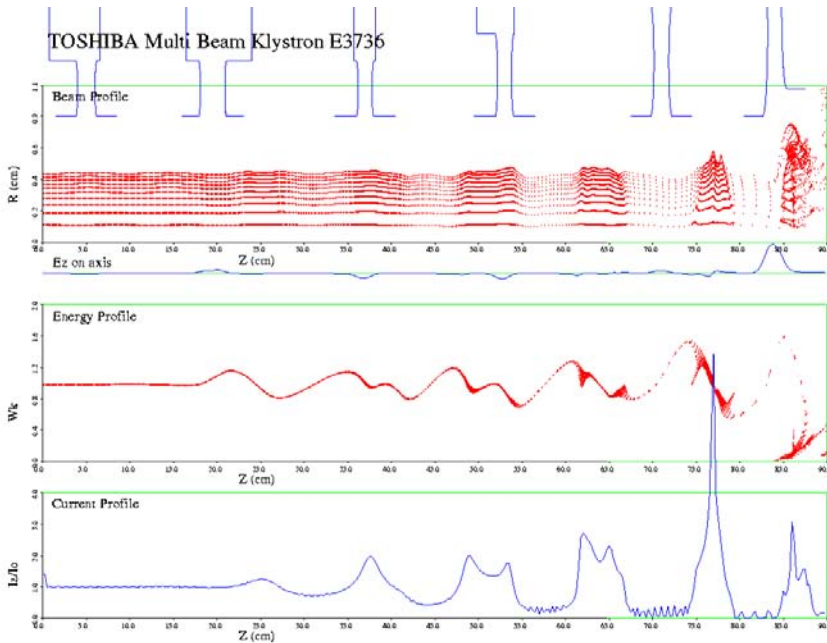


	Design	Achieved	
Frequency	1.3	1.3	GHz
Output power	10	10.2	MW
Output power (Av.)	150	153	kW
Beamvoltage	115	115	kV
Beam current	132	134	A
Efficiency	> 65	67	%
RF pulse width	1.5	1.5	ms
Repetition rate	10	10	pps
Saturation gain	47	49	dB
Number of beams	6		
Cathode loading	< 2.0	2.0	A/cm ²
Structure	6		cavities
RF window	Pill box	with WR-650	
Tube length	2270	2270	mm
Solenoid Power	< 4	3.6	kW

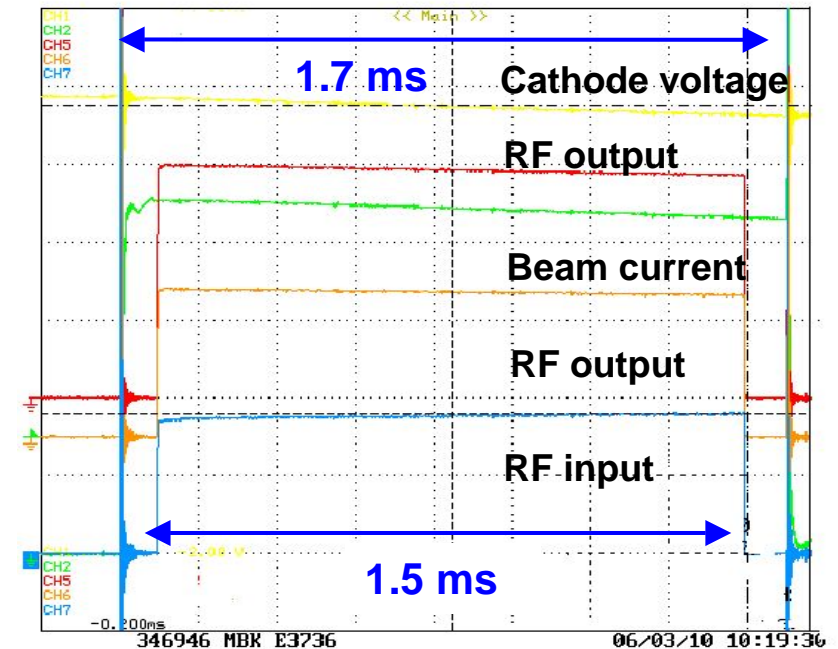


Ring-shaped TM010-mode cavity

MBK for European XFEL: Design and Performance of VMBK



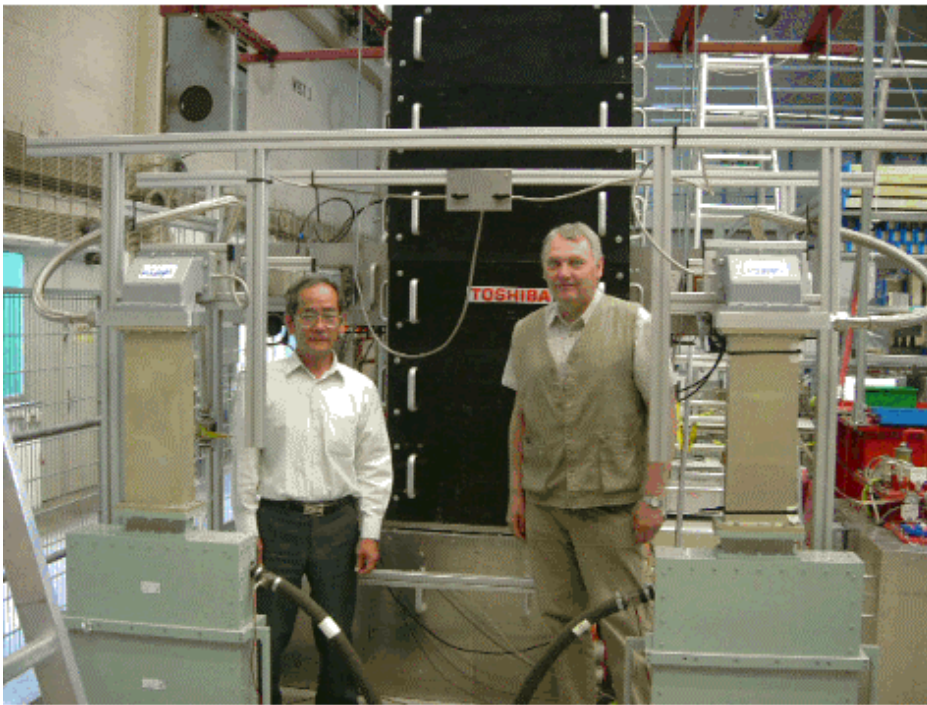
Interaction analysis by FCI code



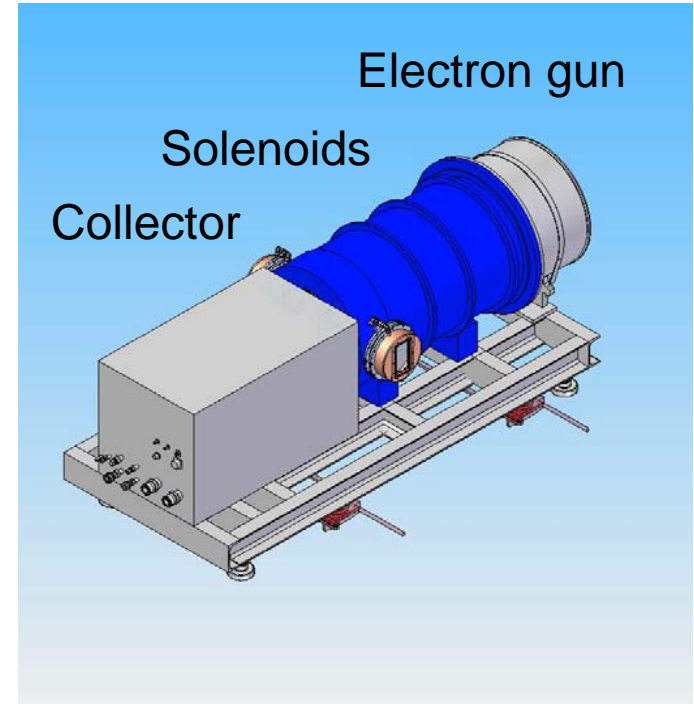
Wave forms for 10.2-MW, 1.5-ms, 10-pps operation

MBK for European XFEL: Summary

1. The final acceptance test was done at DESY in June 2006. The output power of 10.2 MW with the efficiency of 66% was demonstrated at the standard beam voltage of 115 kV at the RF pulse length of 1.5 ms and the beam pulse of 1.7 ms at 10 Hz.
2. A horizontally-oriented MBK is under development.



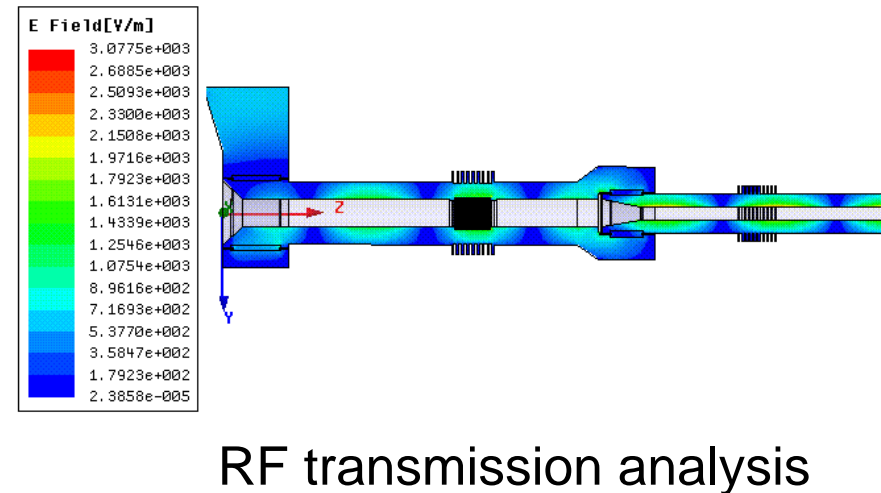
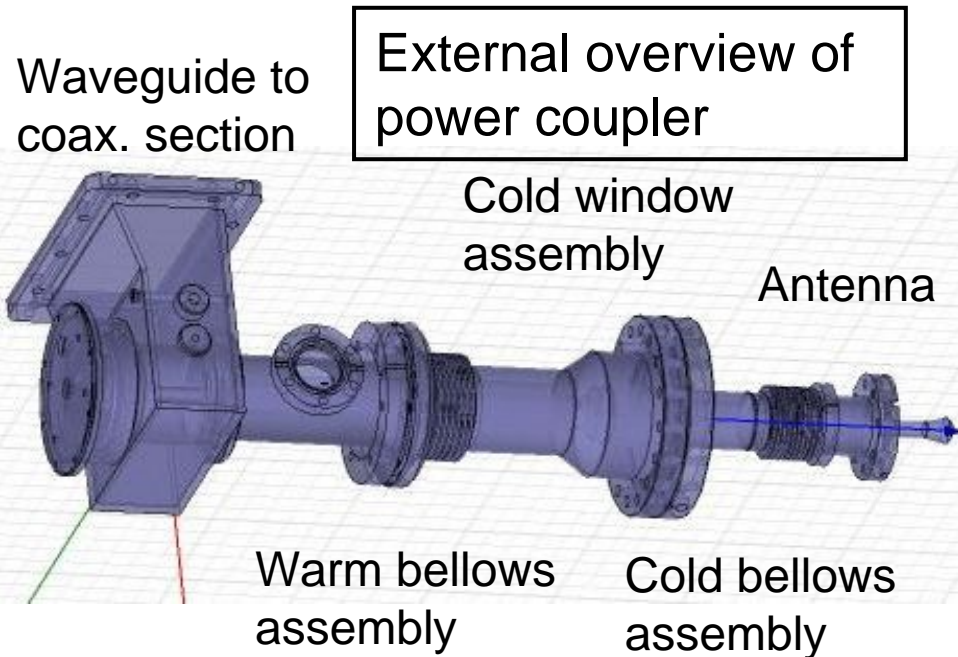
Acceptance test at DESY



External view of HMBK

Power coupler for European XFEL: Industrialization studies

We are on contract with LAL (Orsay - France) for the industrialization studies of the XFEL power couplers.



In order to achieve competitive cost and high reliability for volume production, we adopted all vacuum-brazed metallic joints and decreased parts and junctions of the bellows.

Application to Fusion Experimental Devices

Prototype of 5-GHz, 500-kW CW klystron for KSTAR

KSTAR: Korea Superconducting Tokamak Advanced Research

We demonstrated 350-kW CW, 455-kW, 10-s and 510-kW, 0.5-s operations for the prototype. We will achieve 500-kW CW operation for the next tube.

170-GHz, 1-MW quasi-CW gyrotron for ITER

ITER: International Thermonuclear Experimental Reactor

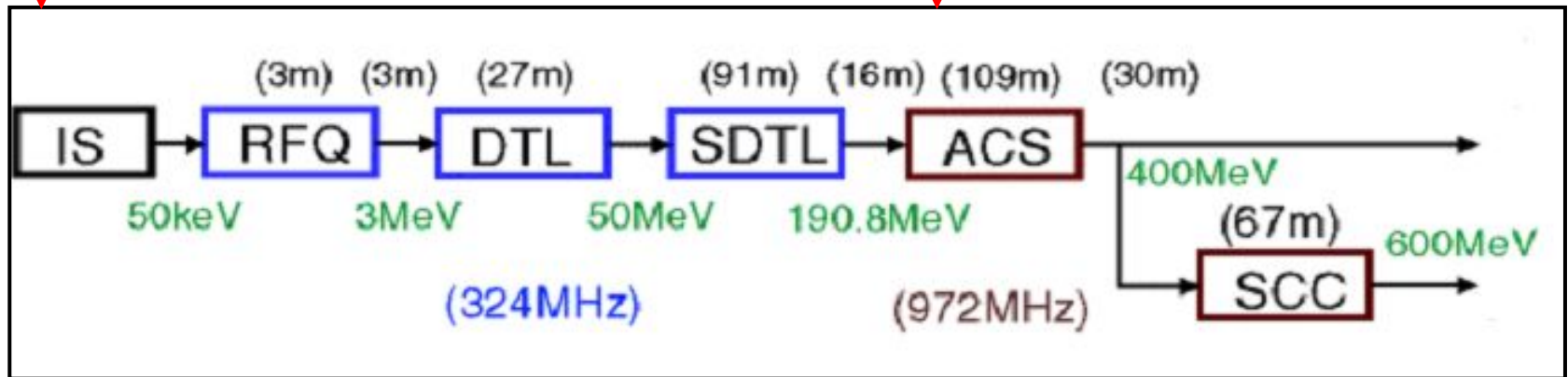
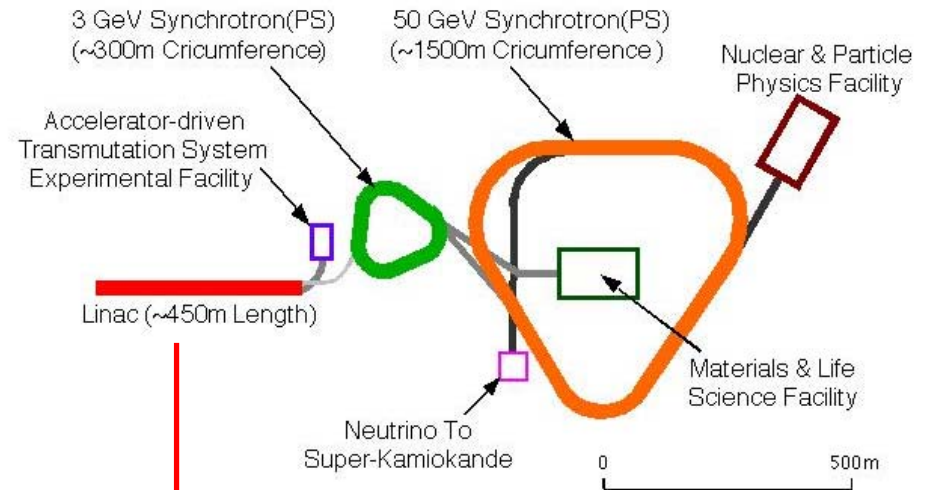
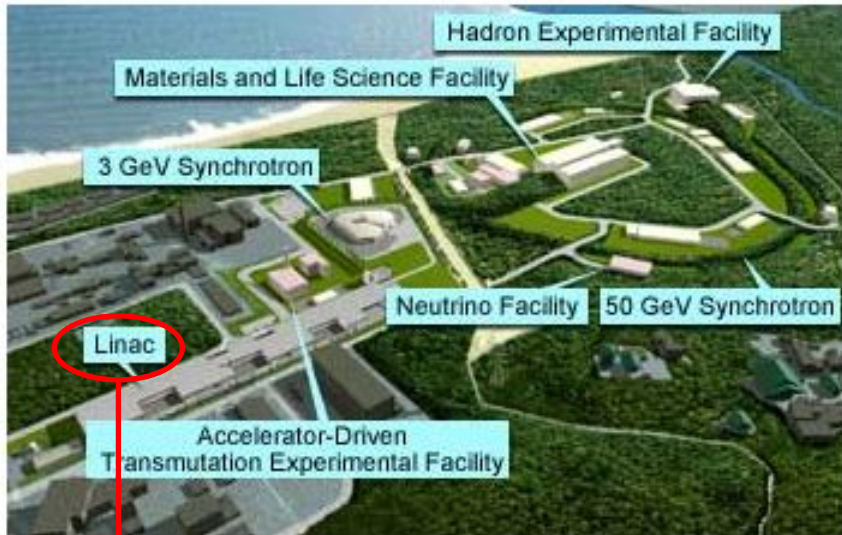
JAEA and TETD has achieved a 1-MW, quasi-CW operation with an efficiency of 55% by active control of the electron-beam parameters during the oscillation.



TOSHIBA

Leading Innovation >>>

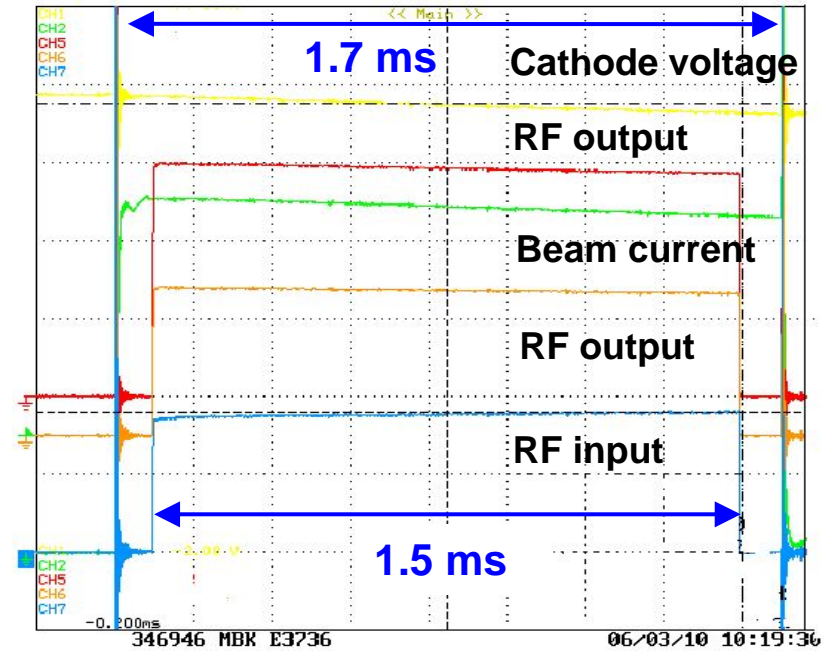
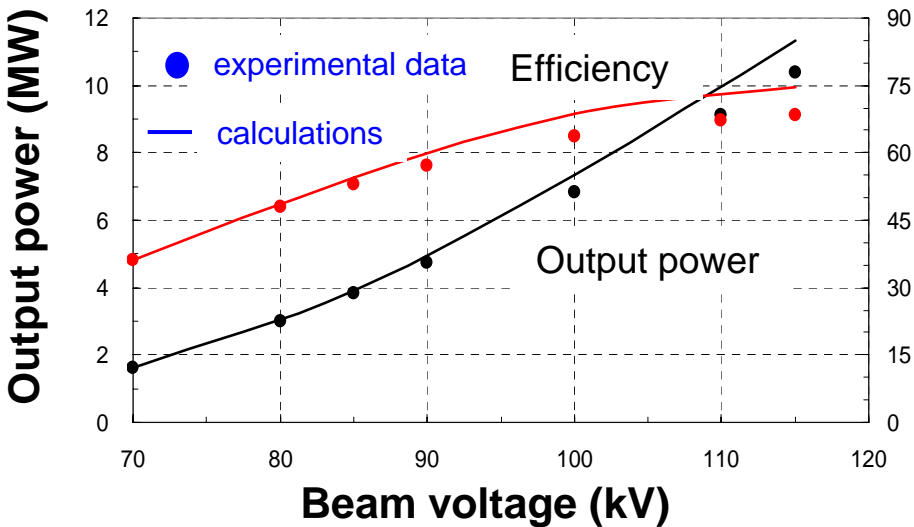
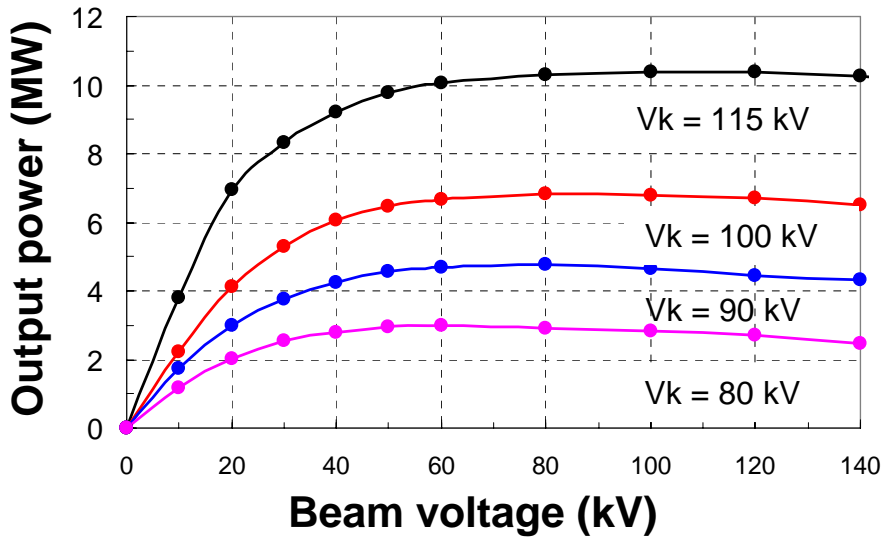
Klystrons for J-PARC: Where the klystrons are used?



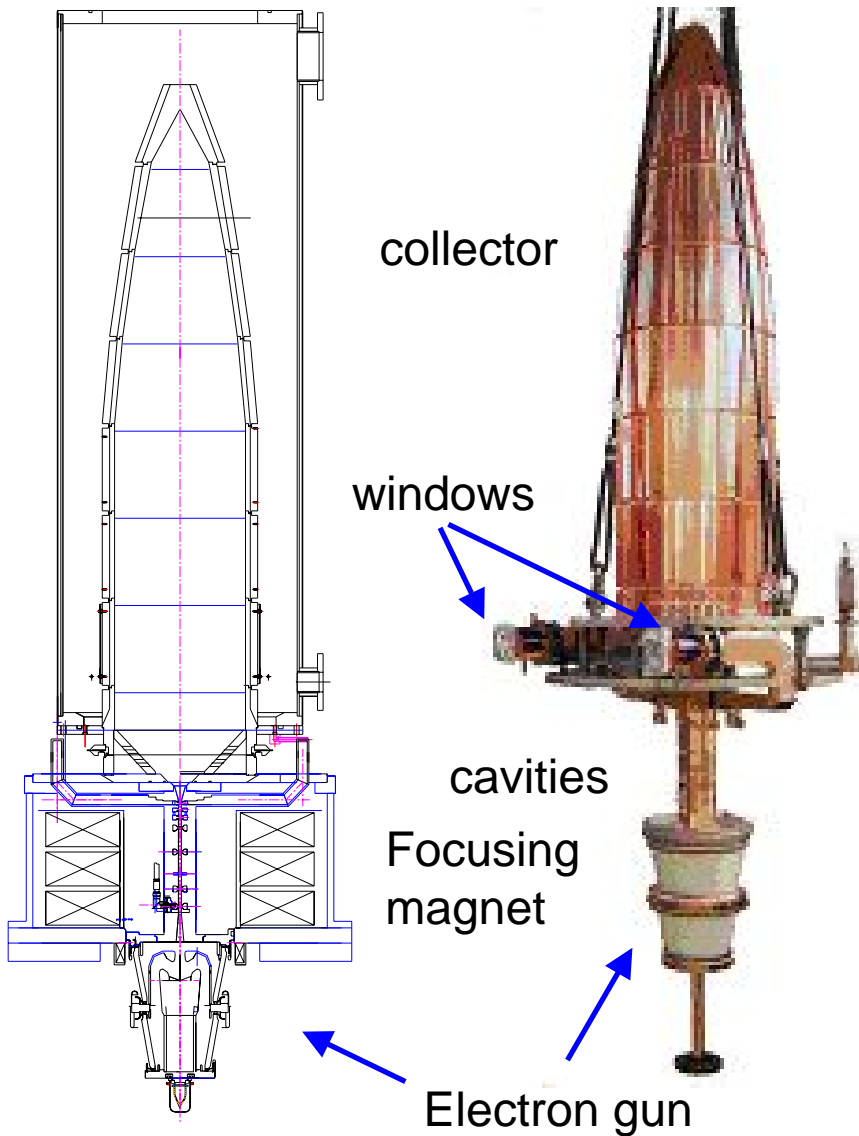
Twenty 324-MHz tubes E3740A are working.

Twenty-three 972-MHz tubes E3766 will be used.

MBK for European XFEL: Test results of VMBK



Prototype of 5-GHz, 500-kW CW Klystron for KSTAR

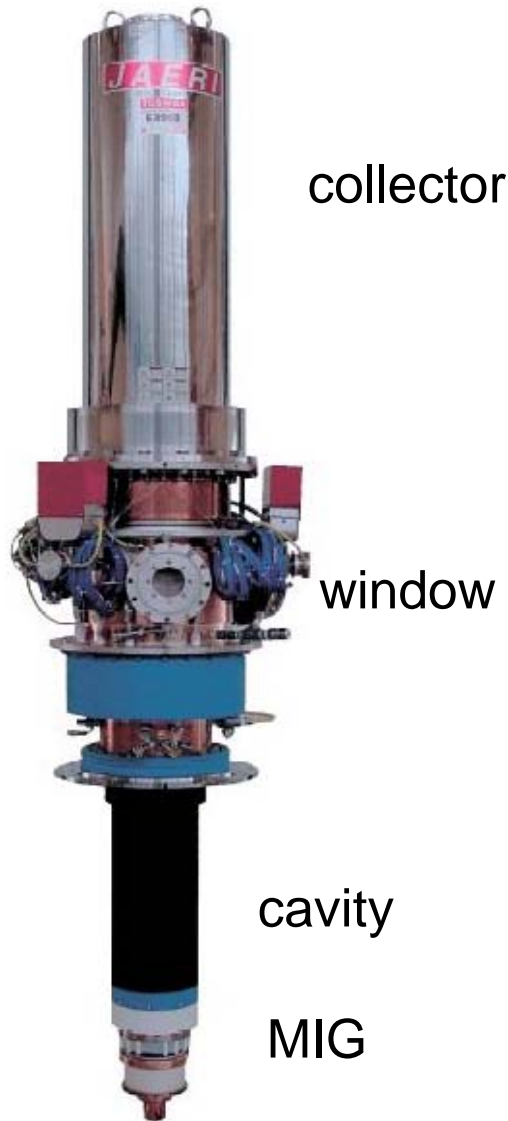


	Specs	Design
Frequency (GHz)	5	
Output power (kW)	400	500
Pulse length (s)	10	CW
Beam voltage (kV)	< 70	68
Anode voltage (kV)	< 66	61
Beam current (A)	< 17.5	15.5
Efficiency (%)	> 30	> 50
Drive power (W)	< 30	< 20
Number of cavities		6
Dissipation (kW)	800	800
Length (m)	2.6	
Weight (kg)	800	
Number of windows	2	2 (BeO)

1. $1.5\text{-}\pi$ three-cell output cavity
2. two BeO windows
3. Evaporative cooling

KSTAR: Korea Superconducting Tokamak Advanced Research

170-GHz, 1-MW quasi-CW gyrotron for ITER



- 1. Volume mode (TE_{31,8} mode) oscillation**
- 2. Depressed collector**
- 3. Diamond window**

JAEA and TETD has achieved a 1-MW, quasi-CW operation with an efficiency of 55% by active control of the electron-beam parameters during the oscillation.

**ITER: International Thermonuclear
Experimental Reactor**

JAEA: Japan Atomic Energy Agency