

Application of Permanent Magnet Focusing to Klystrons

First part is based on Mr. Fuwa's talk file.

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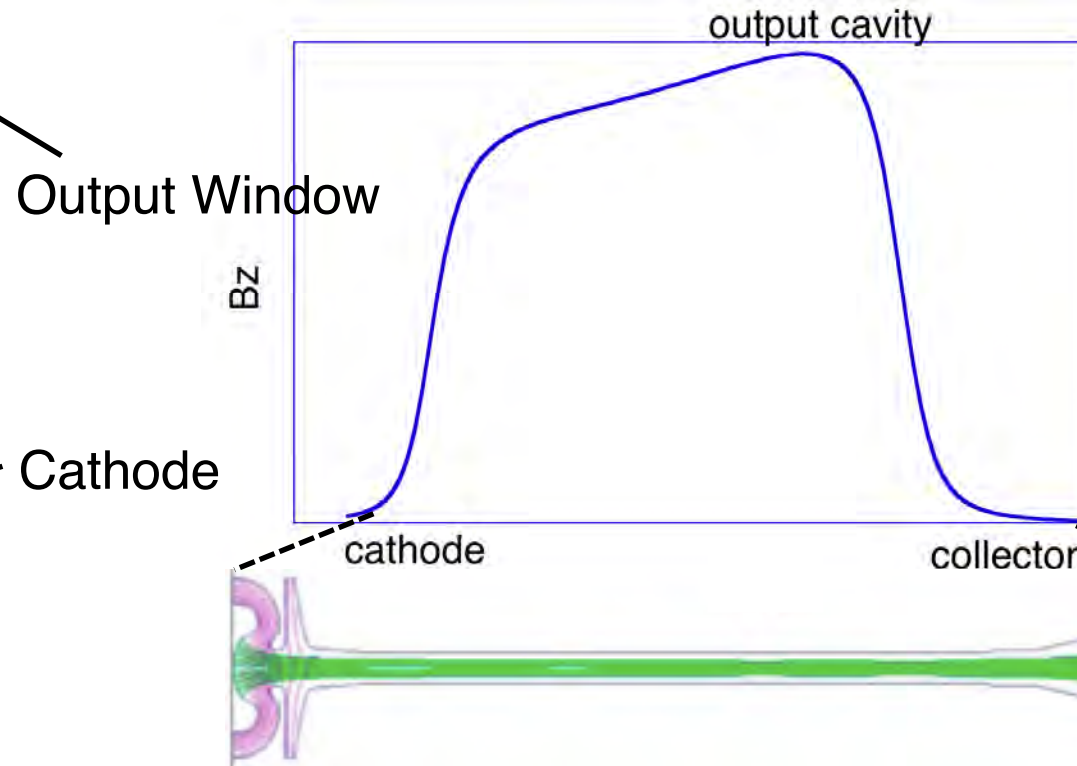
Application to 750kW klystron

Klystron for DRFS

Toshiba E37501

Frequency: 1.3 GHz、 Max Power: 750 kW


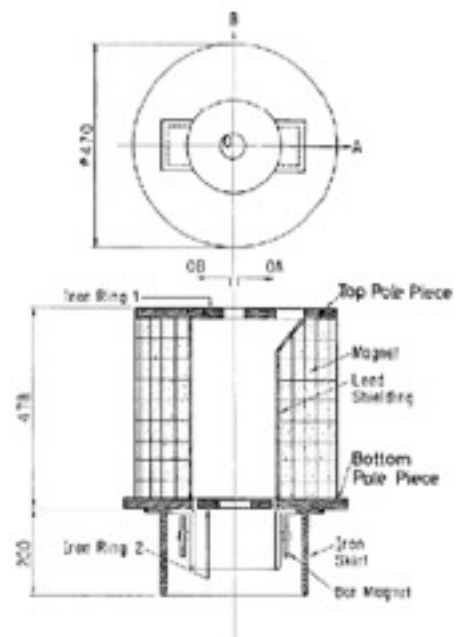
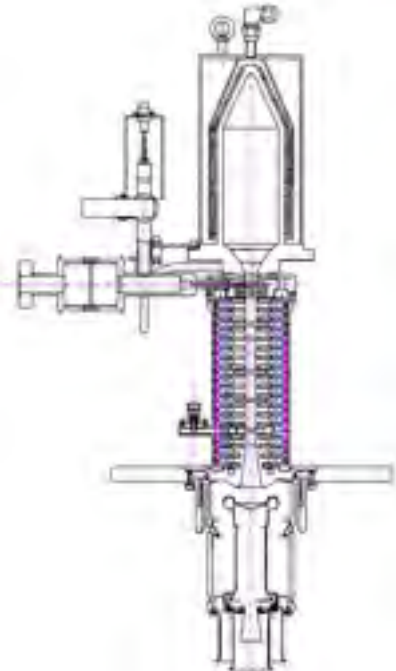
Focusing field distribution for E37501



E37501

Beam transmission Analyzed by DGUN

Former Study

		
SLAC (1960's)	KEK (1980's)	KEK (2000's)
ALNICO	ALNICO	NdFeB
Unidirection	Unidirection	PPM(periodic)

Use ALNICO

→ Small coercive force causes demagnetization, difficult adjustment.

PPM (Periodic Permanent Magnet)

→ Small magnet volume, but with stop-band

Magnet Material

Rare Earth Magnet

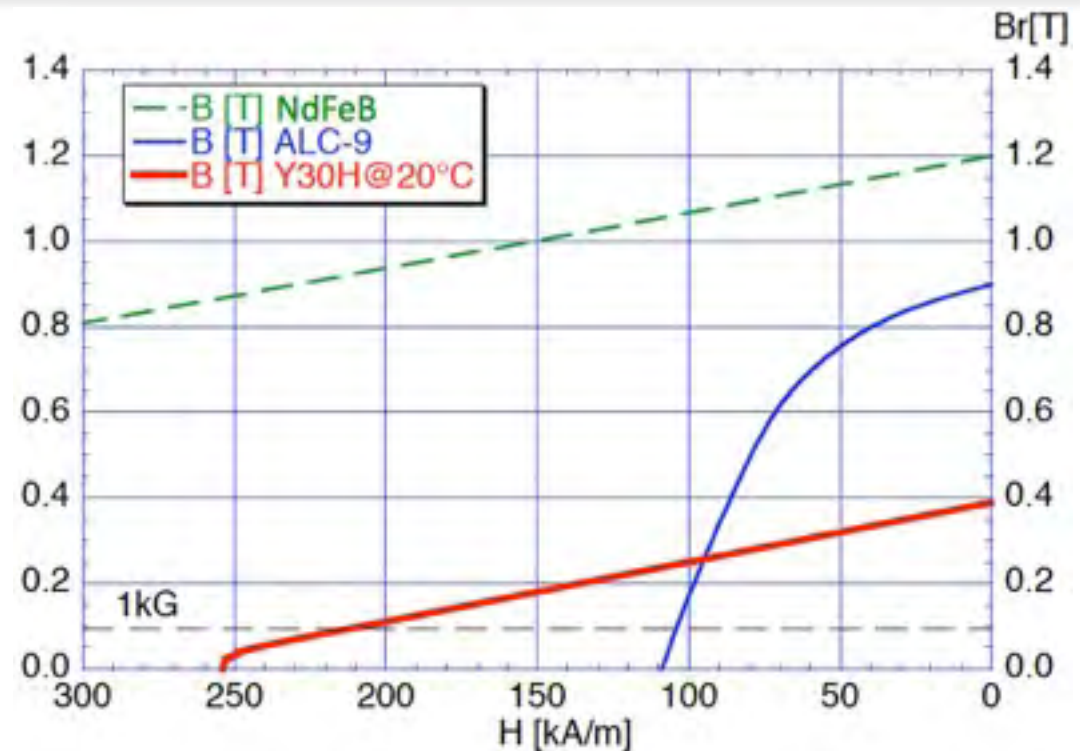
- High remnant field B_r
- High coercive force H_c
- High cost
- Limited supply

ALNICO Magnet

- Moderate B_r ,
- Less H_c
- Easily demagnetized

Anisotropic Ferrite Magnet

- Enough B_r , H_c to focusing in klystrons
- Cheap material made of iron oxide
- Enough supply



B-H curve

Required field for klystrons are of the order of 1kG on beam axis

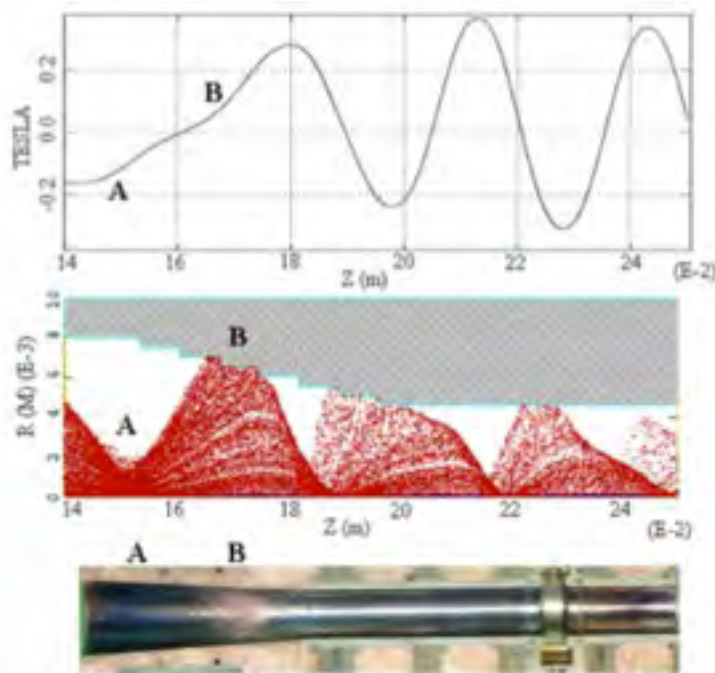
Focusing Field

For klystrons under pulse operation

For PPM(Periodic PM):

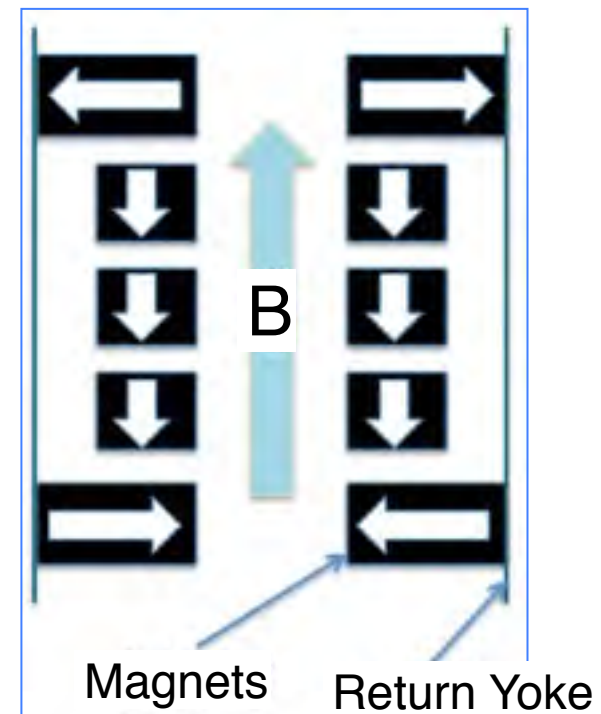
Operating point always hits stop-band at pulse raising edge.

→ Beam loss on the wall



Beam loss by stop-band

Better to have unidirectional magnetic field!!



Layout of Magnets and yoke

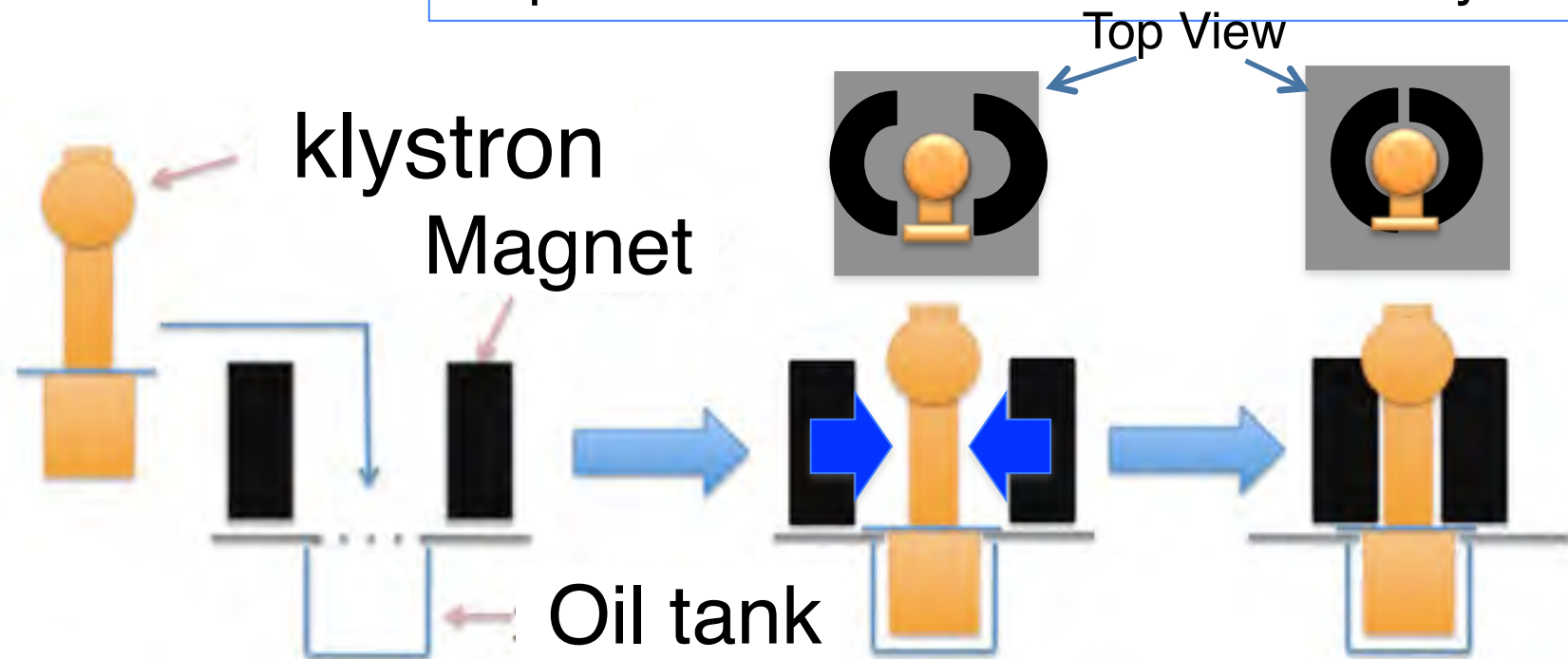
Semi-Halbach configuration and the yoke reduces the leakage stray field.

Field Adjustment with Movable Magnets

Magnetic Field Adjustment

Split the cylindrical magnets into two. Their horizontal positioning enables adjustments of magnetic field.

This also enables: Magnets can be closer to the beam axis by their displacements after the insertion of klystron.

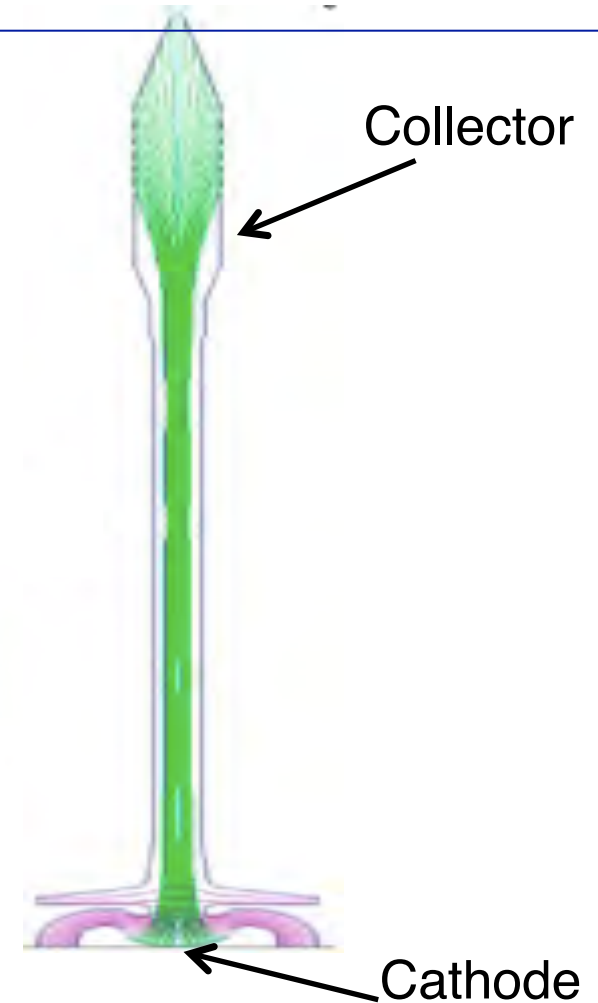
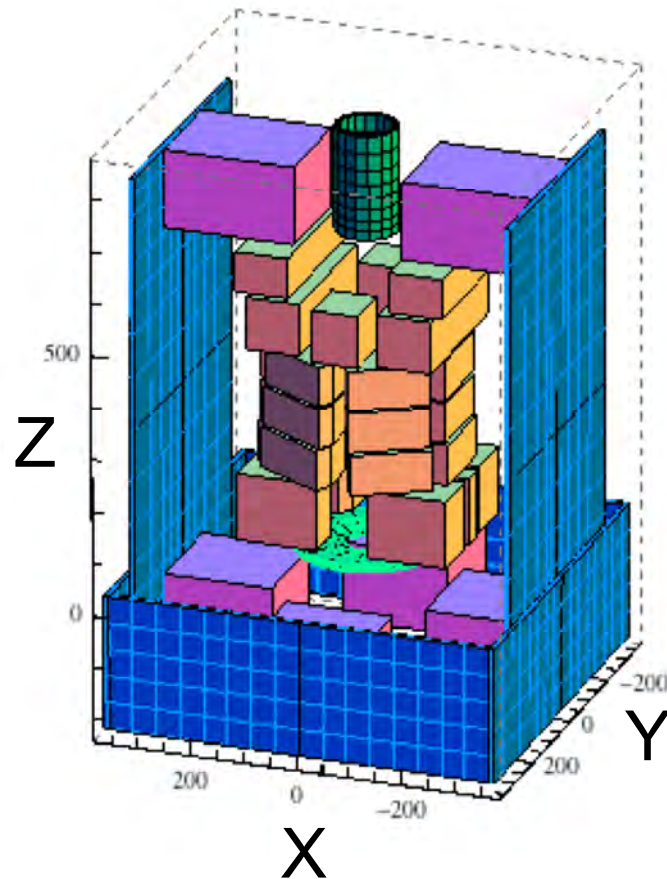
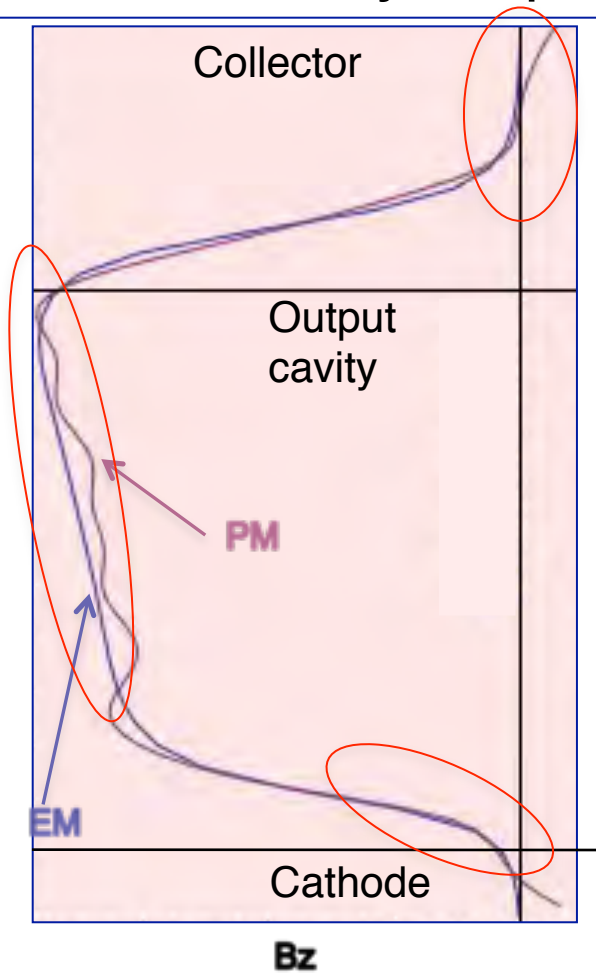


Less magnet volume!

Magnetic Field Design

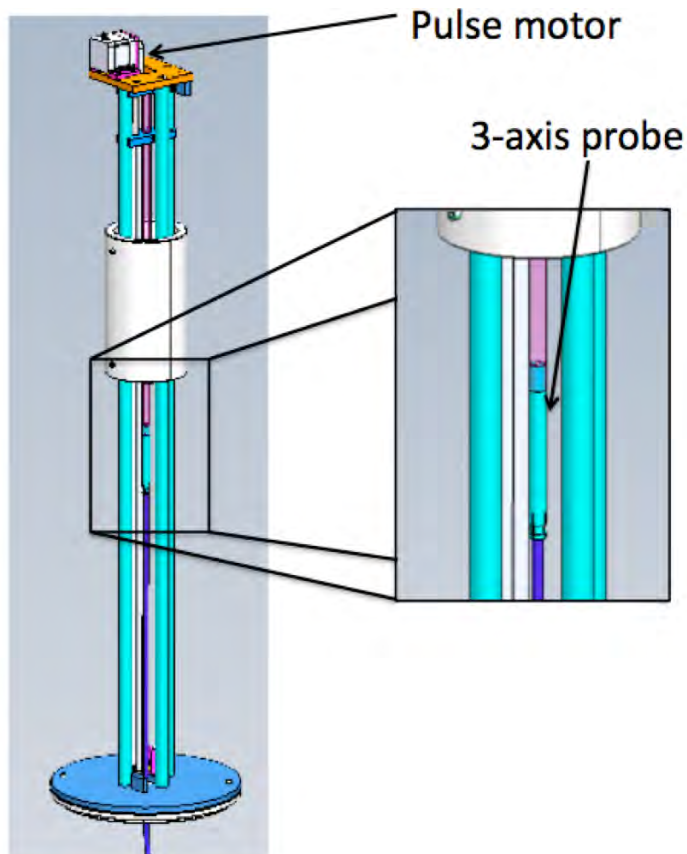
RADIA4.29 is used

Shapes and positions are parameterized and optimized to fit the EM distribution by simplex method.



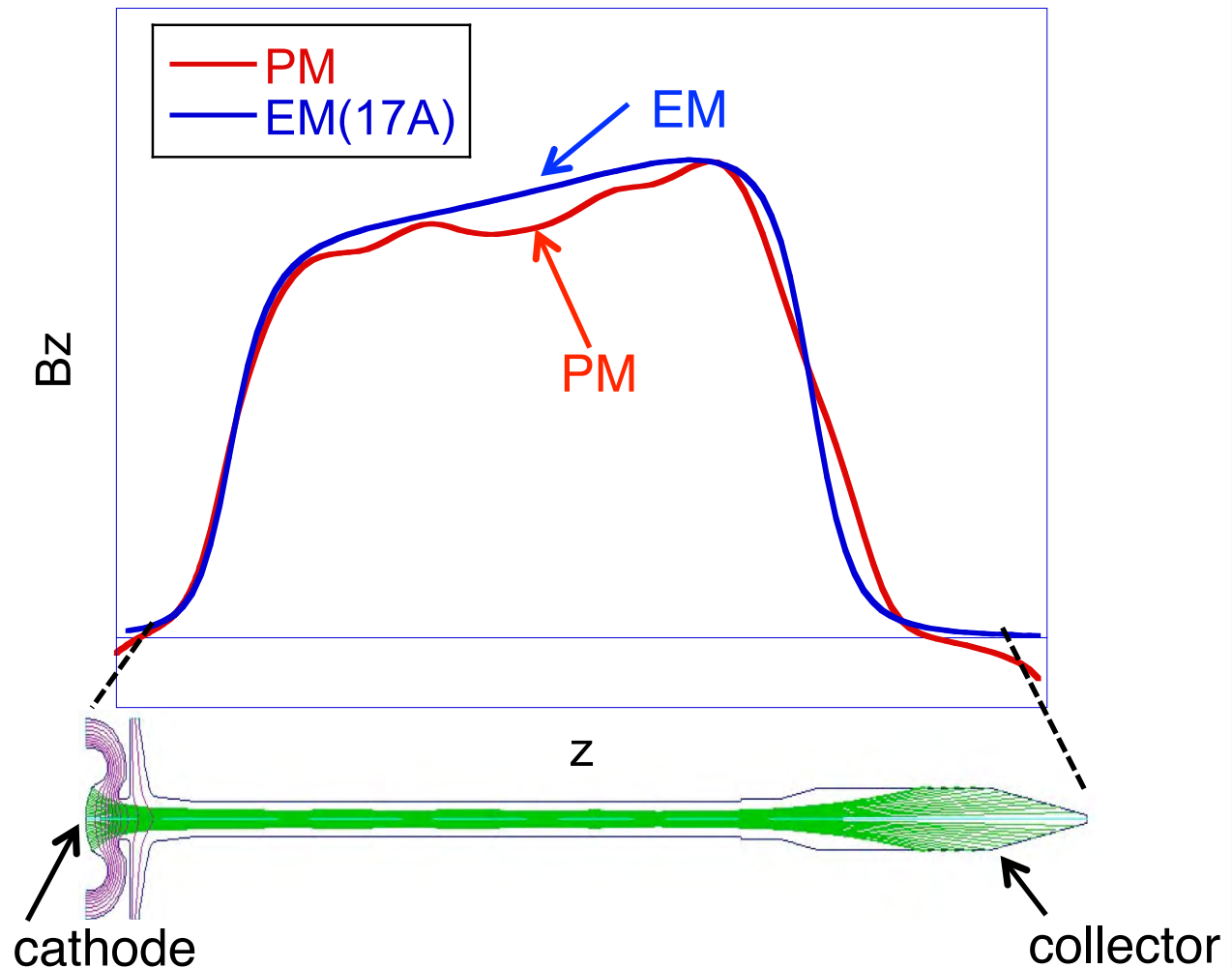
Simulated by DGUN from cathode to collector

Magnetic Field Measurement



Measurement jig

Measured field and DGUN simulation



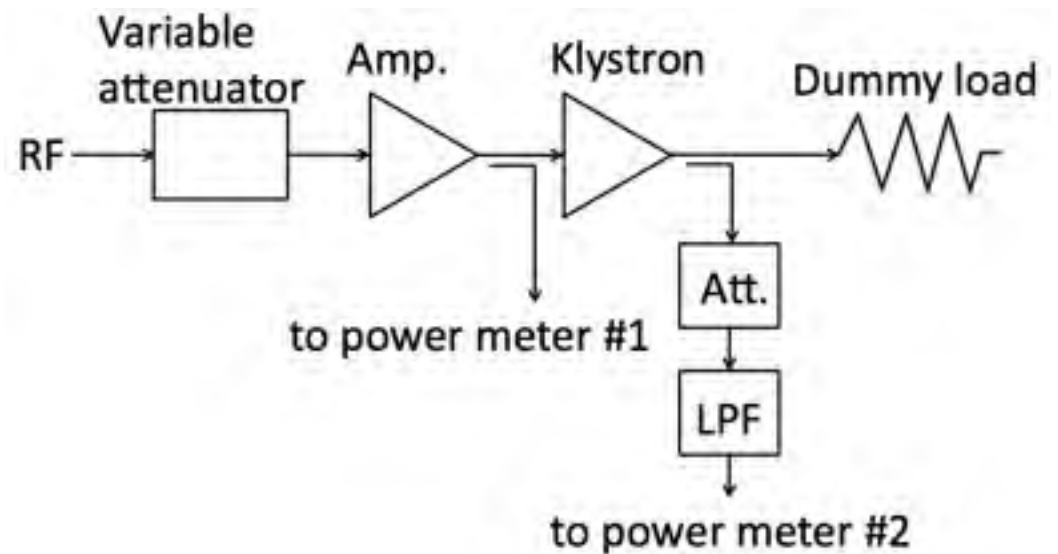
Power Test with Klystron



Klystron

Dummy Load

- KEK STF
- Dummy Load



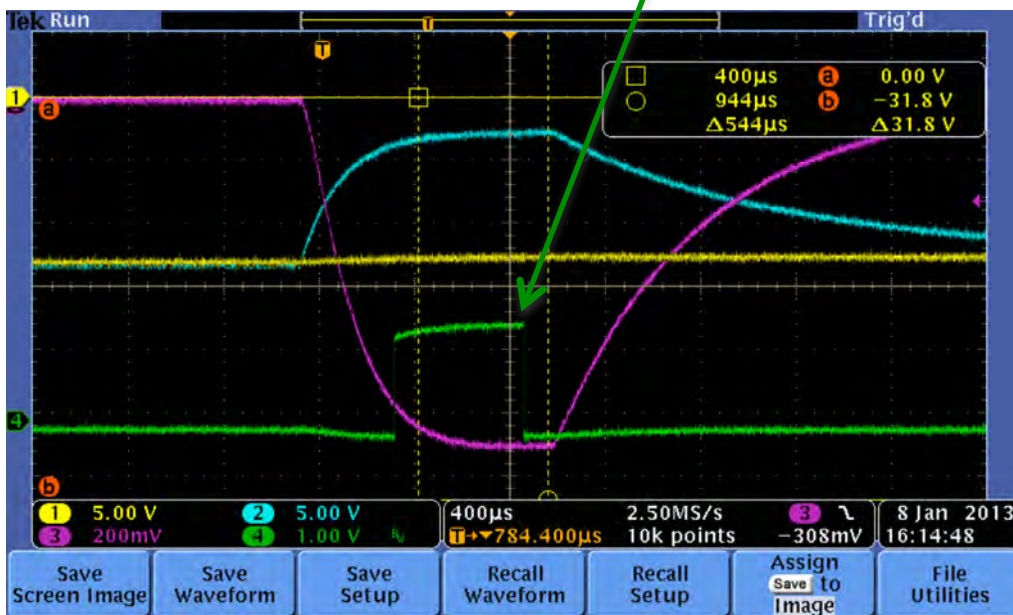
Block diagram

Compared power test results
with EM and PM

Power Test

Peak power with PM reached 94% of that with EM
(595 kW / 635 kW)

595kW!!



Waveform of RF output power

Yellow: V_{cathode}, Blue: V_{Mod Anode}

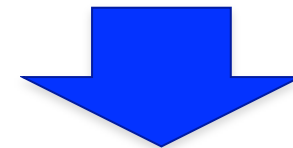
Red: Beam current, Green: RF power

Efficiency including EM
power consumption

PM: 42.2 % / EM: 41.8%

Possible reason of discrepancy

1. Transverse magnetic field
2. Multipole component



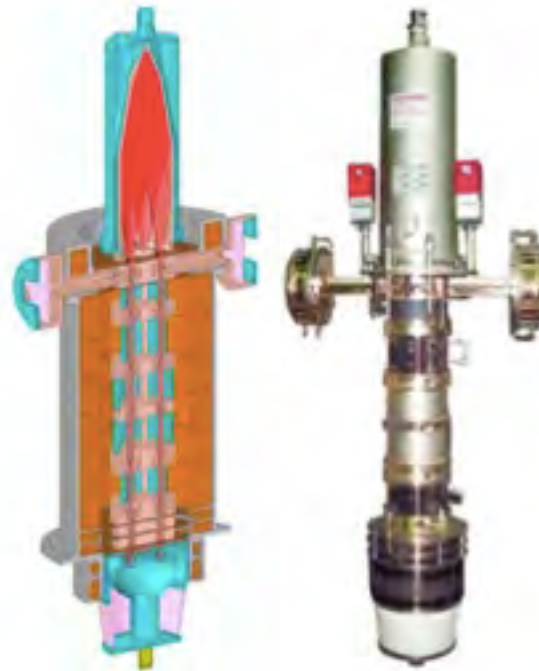
- Beam loss at wall
- Less coupling at output cavity

Distributed Klystron Scheme

One Multi-Beam Klystron (MBK) feeds RF to 26 cavities.

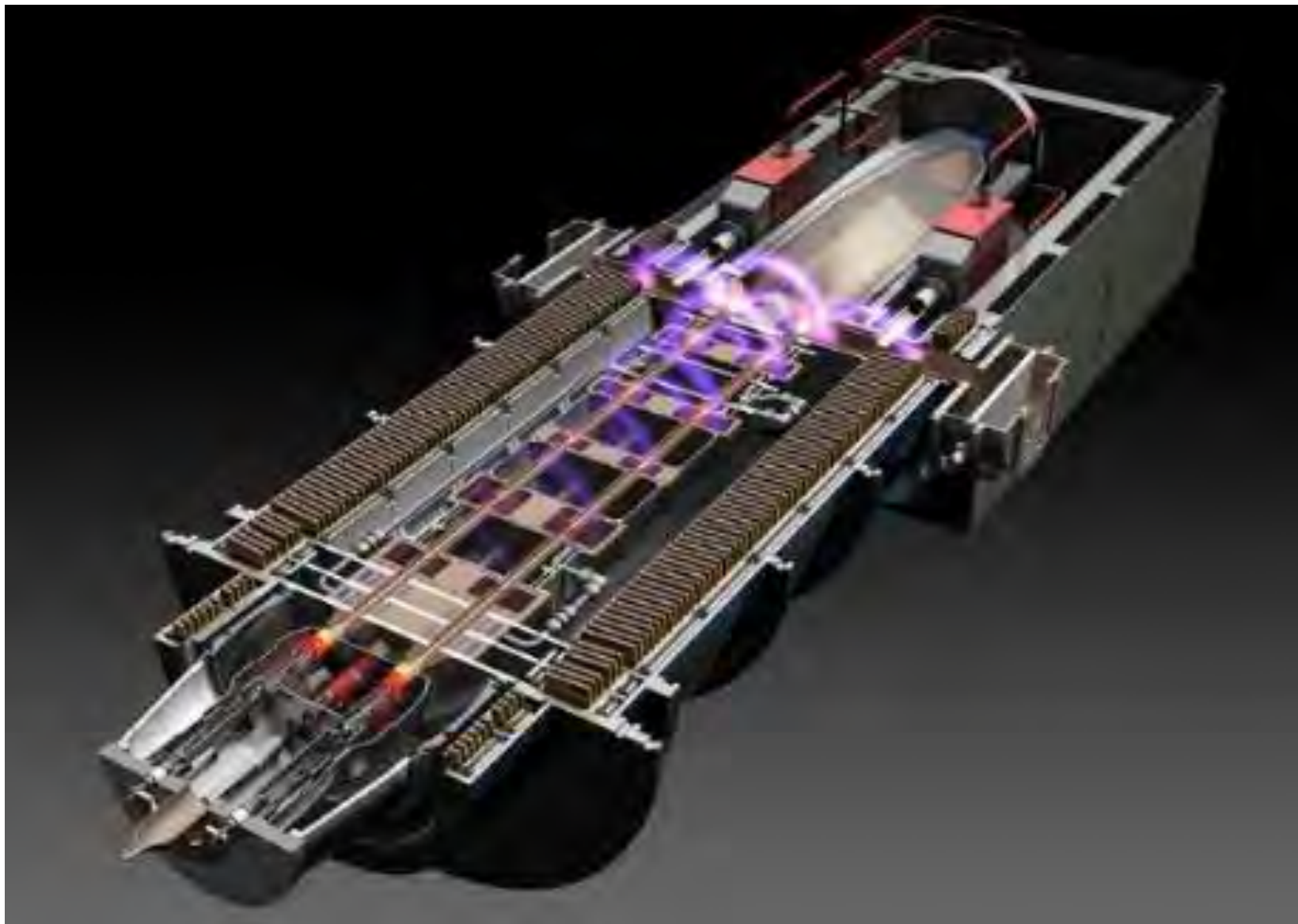
Multi-beam klystron

Use many beamlets to decrease space charge effect
→ Push up efficiency



Application of the PM focusing on MBK is under study:

MBK



Power Consumptions

	E37501	E3736
Peak Power	750kW	10MW
Av. Power	11kW	150kW
Efficiency	55%	>66%
HV	66kV	115kV
Beam Current	50A	132A
Coil Power	80V x 20A = 1.6kW	80V x 55A = 4.4kW

1.5ms/1.7ms x 10pps **4.4kW x 436 ~ 2MW**



Merit of PM Focusing

● Coil: No power consumption

➡ No cooling water

➡ Less water leak risk to HV oil tank
(Klystron still needs coolant)

➡ Less water supply & power for pump

➡ Maintenance Free

● PS: No power supply

➡ No power consumption on PS

➡ Free from PS failure

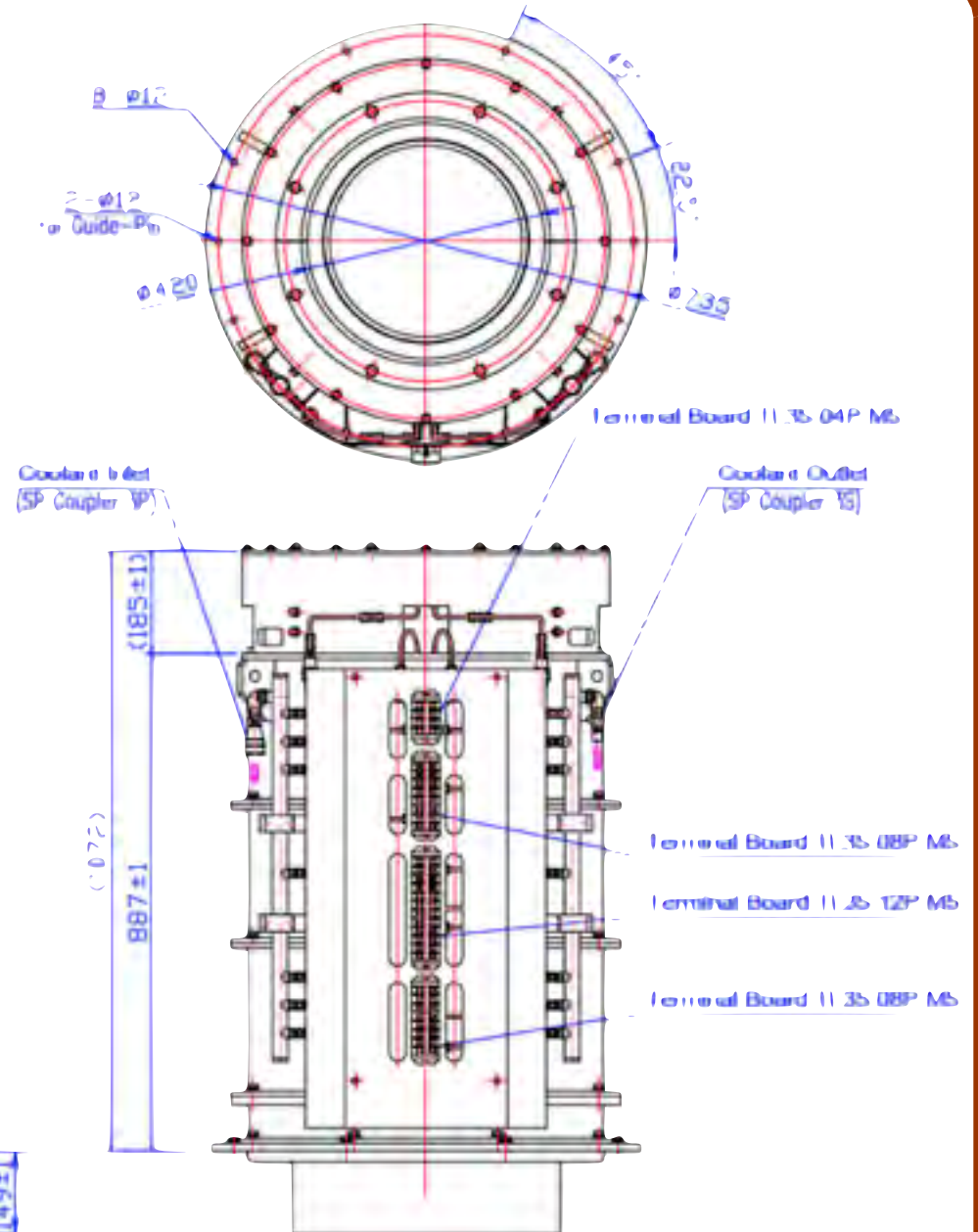
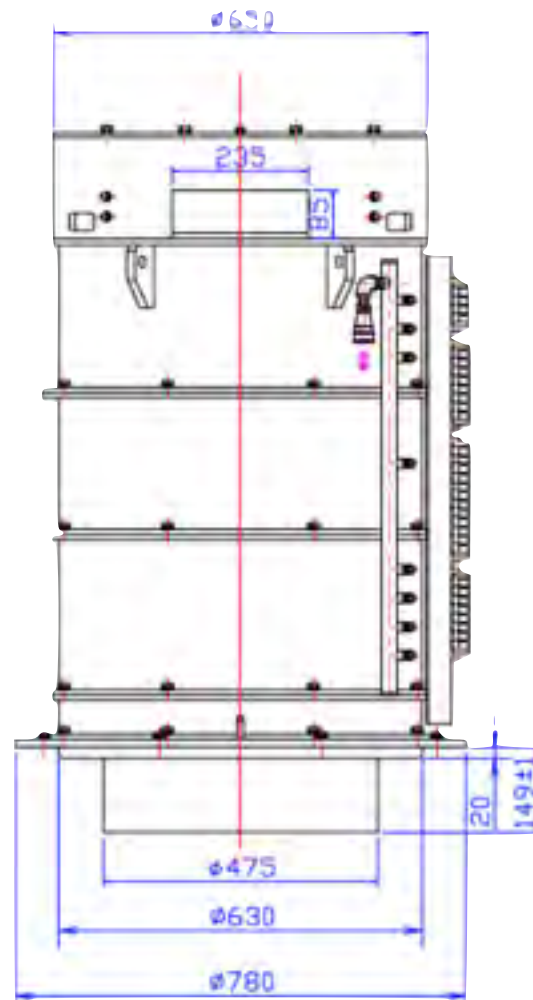
MBK

Multiple beams have to be kept going on their beam axes.

➡ Field distribution has to be uniform in the middle area.

➡ Most of power consumed in the area
External stray field has to be minimized

Focusing Solenoid for MBK



			Type
Coolant Inlet	Nitto kuhki	SP Coupler 1/2"	4S
Coolant Outlet	Nitto kuhki	SP Coupler 1/2"	4P

Summary

● Merits include:

- ➡ No coil power consumption
- ➡ No cooling water
- ➡ Less risk on water leak to HV oil tank
- ➡ Free from power supply failure
- ➡ Maintenance Free

● Design of PM focusing coil for MBK just started based on the previous work.