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Triode RF Gun Project

Status Report

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- RF-Gun in use
- BB Effect
- Triode RF Gun Project
- Results
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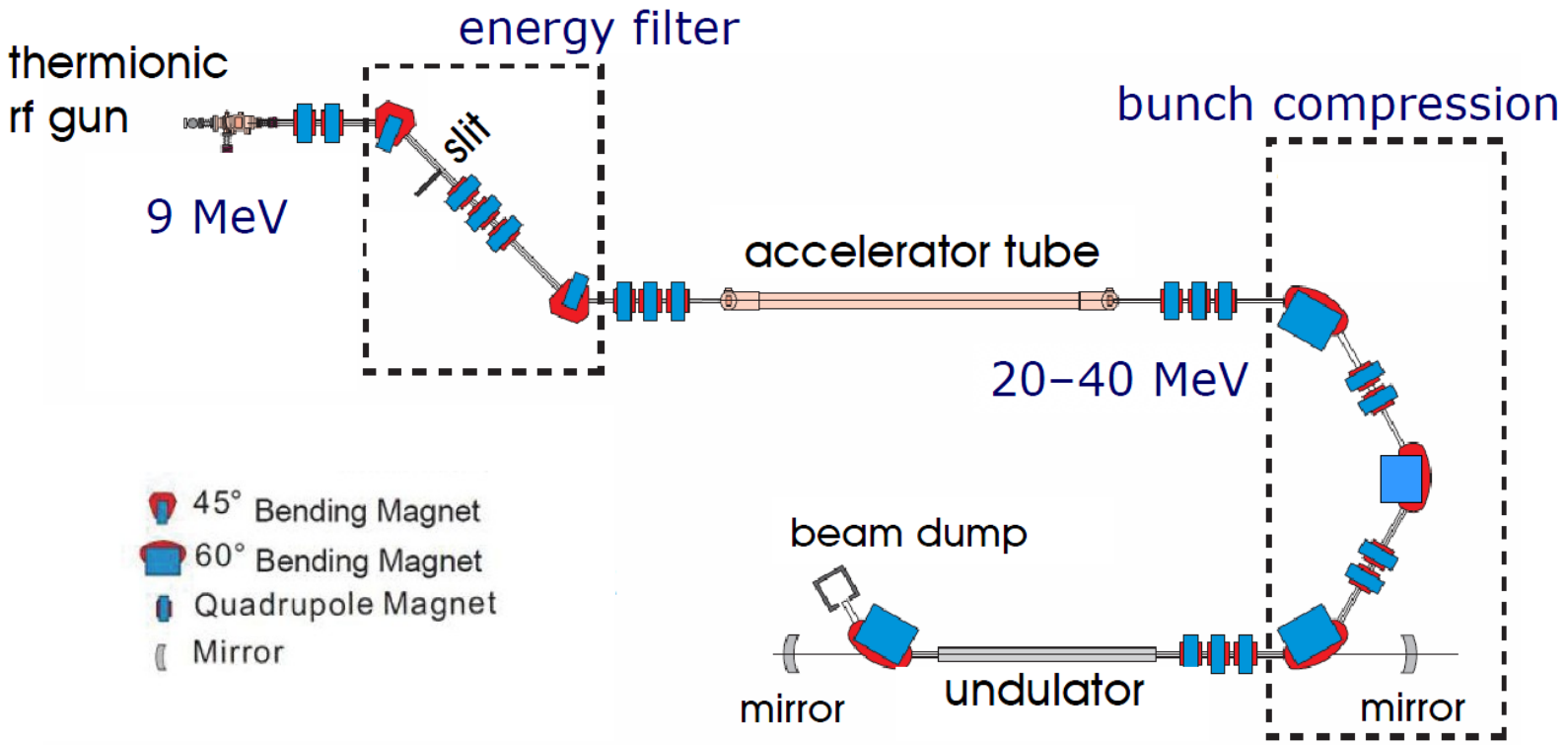
KU-FEL Facility

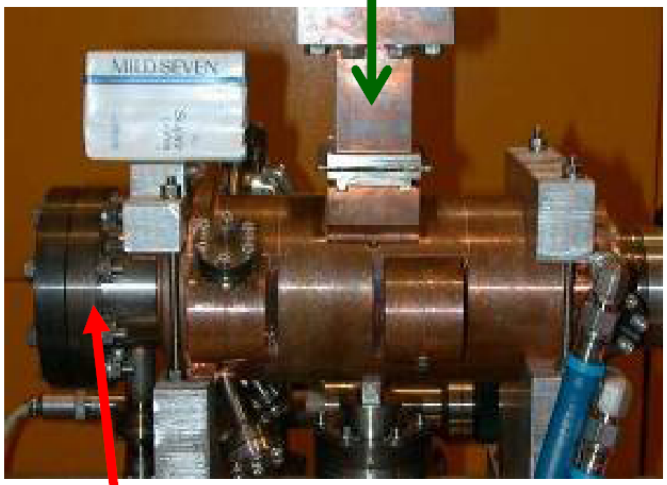
KU-FEL (Kyoto University FEL) was constructed for investigation of energy materials



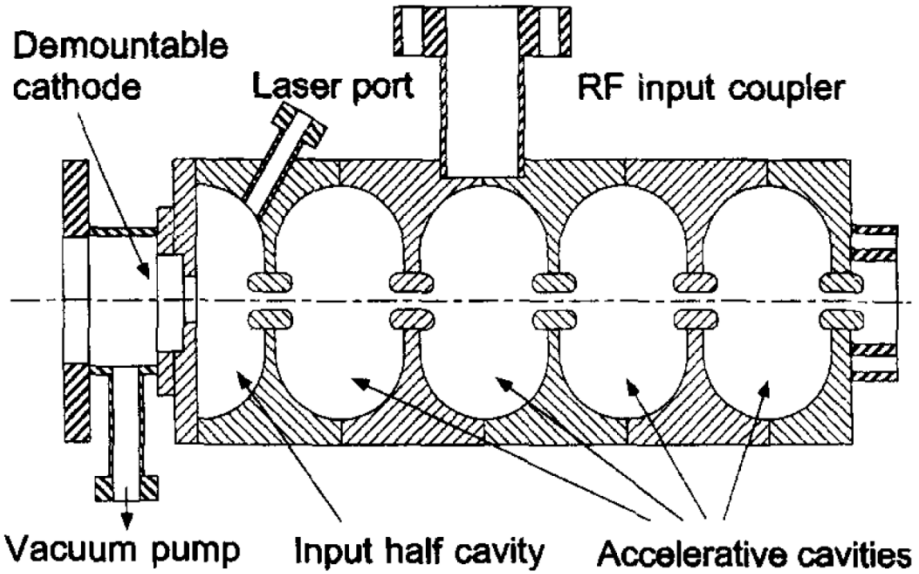
Thermionic RF Gun

KU-FEL applies 4,5 cell
thermionic RF Gun as an electron source

drive rf power <10 MW
2.856 GHz
<10 μsec
<10 Hz



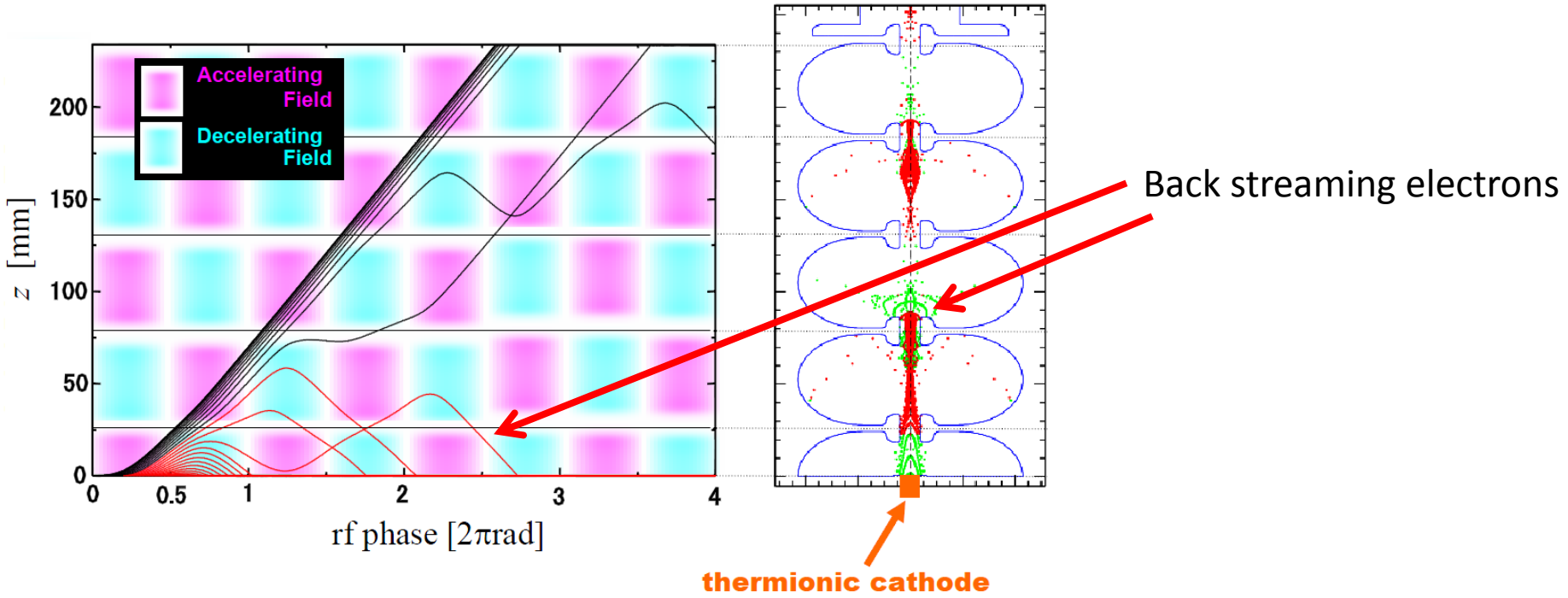
thermionic cathode mount



Resonant frequency [MHz]	2856
Coupling coefficient β	2.79
Q value	12500
R/Q [Ω]	980
Number of cells	4.5
Accelerating mode	π
Cathode radius [mm]	1
Cathode material	LaB_6
Initial cathode temperature [°C]	1545

Back Bombardement Effect

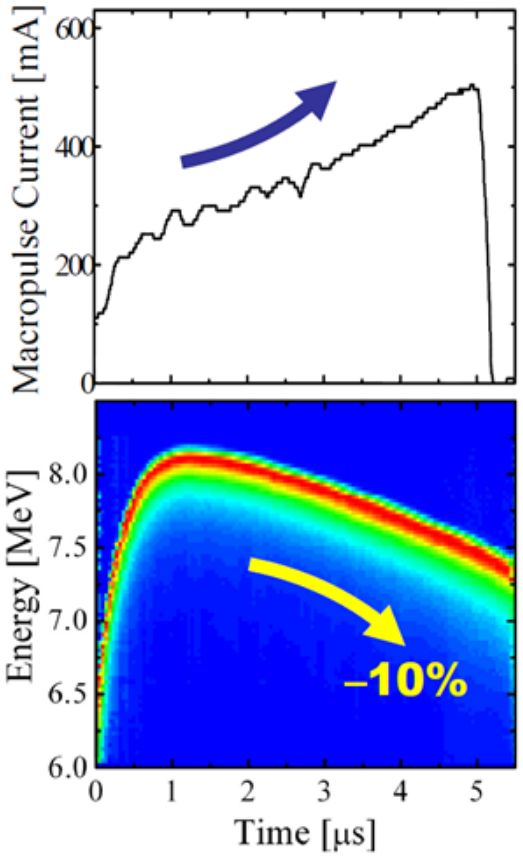
- BB effect: some electrons are “drifting” into the decccelerating rf-phase, which accelerates them back to the cathode. The back streaming electrons hit the cathode and increase its temperature
- 1-D simulation of back streaming electrons for 4.5 cell thermionic rf gun

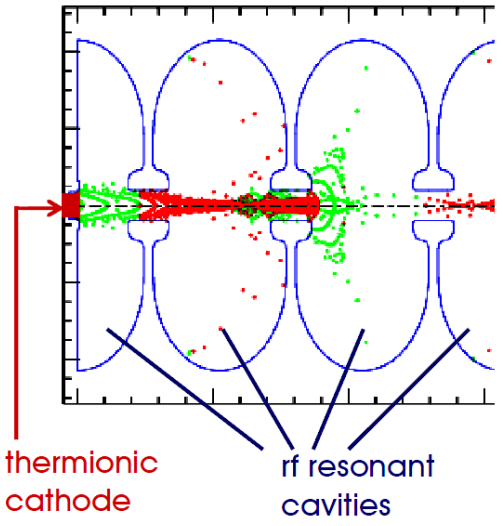


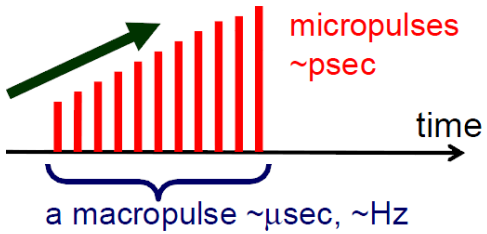
Back Bombardement Effect

The thermionic RF generates ramping current, which causes about 10% energy drop in macropulse.

The reason for the Ramping current is the back bombardemet effect.

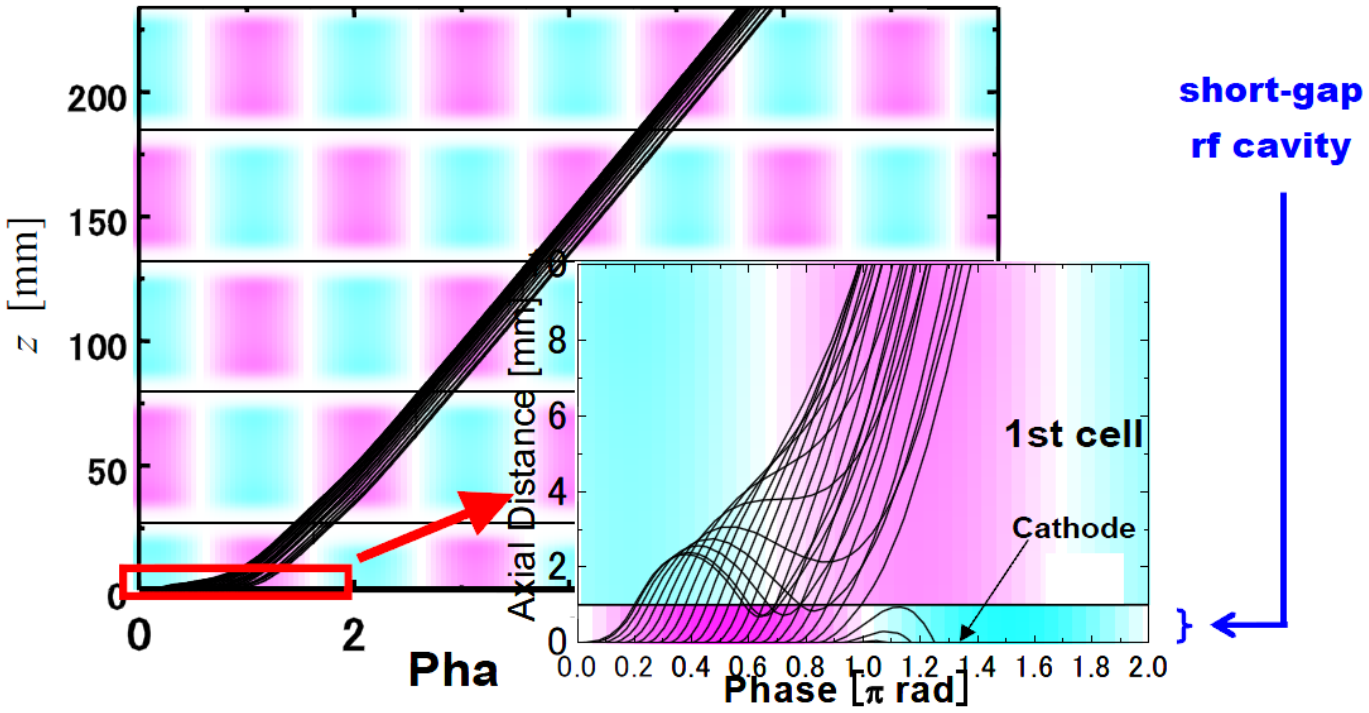






Triode Gun Approach

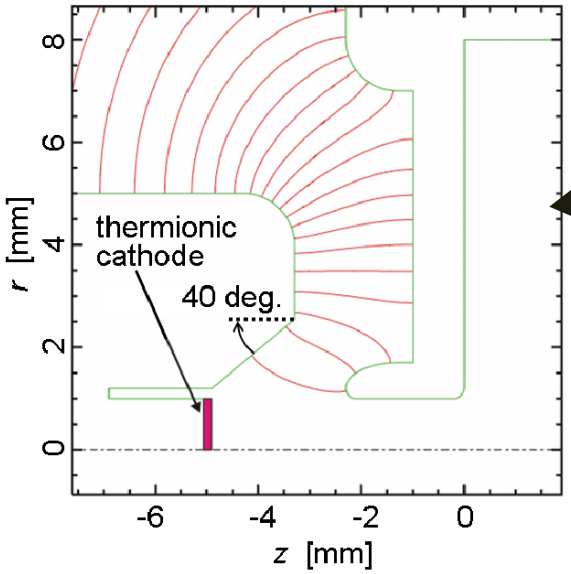
- An additional rf cavity would allow controlled electron injection into accelerating phase of the rf gun and mitigate the “drifting” into the deceleration phase

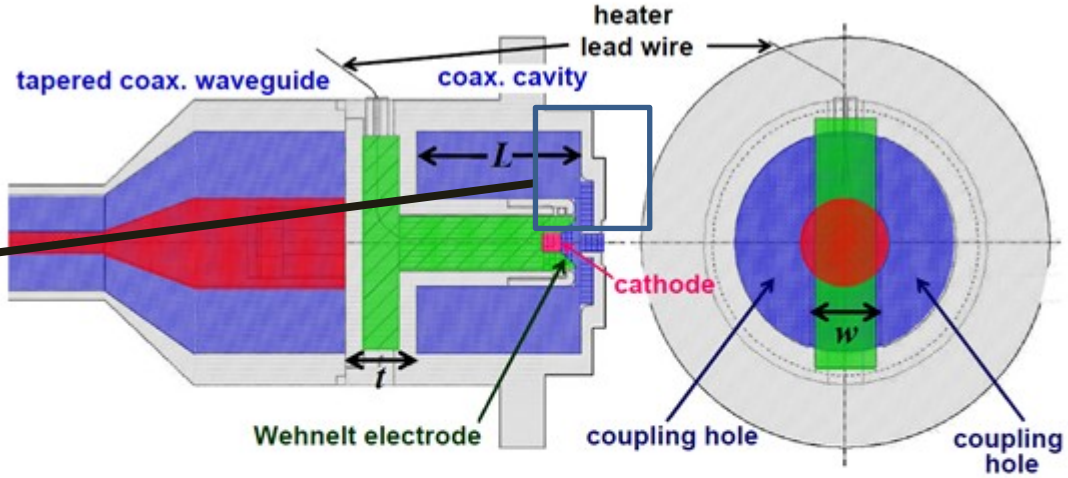


Triode RF Cavity Design

A new coaxial rf cavity is designed for high E-field density in cathode area

A steep whnelt electrode (40 deg. with respect to the axis) is adopted to minimize the transverse emittance by compensating the inherent defocusing effect induced in the rf triode configuration.





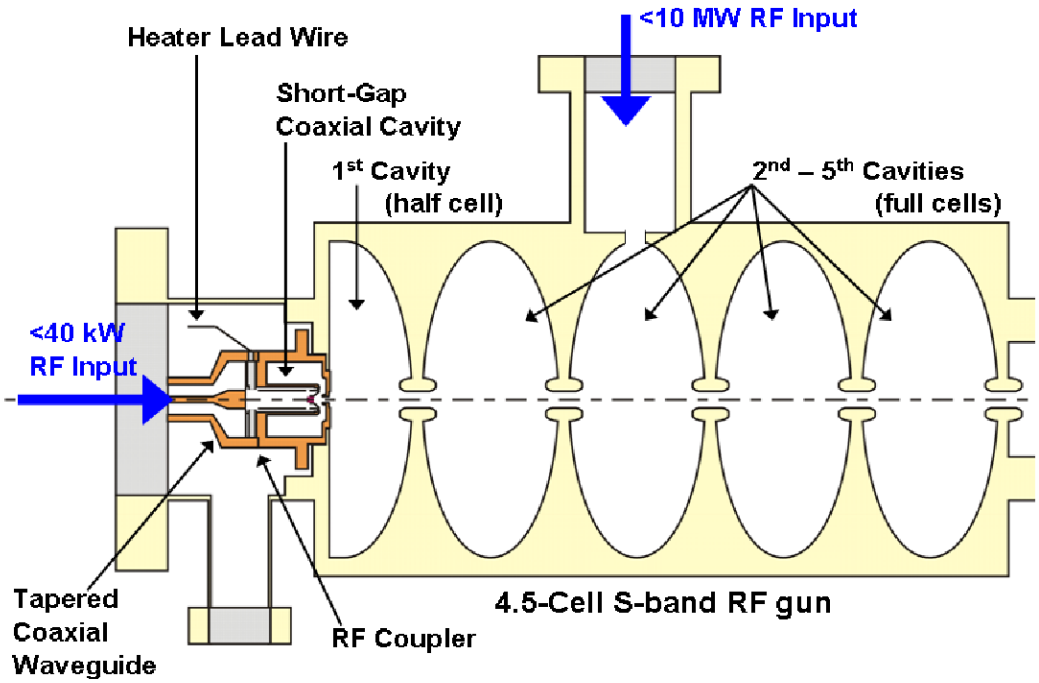
Design parameters prototype

- ☐ L cavity length — L = 19.62 → f_0
- ☐ t bridge thick. ($t \geq 6$) — t = 8
- ☐ w bridge width ($w \geq 8$) — w = 8 → β

(cavity wall material: oxygen-free Cu) → Q_0

Estimation

The coaxial triode rf cavity is to be implemented into the used thermionic rf gun body

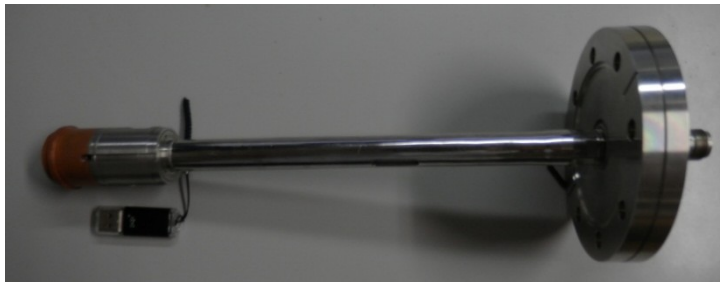


Simulation results

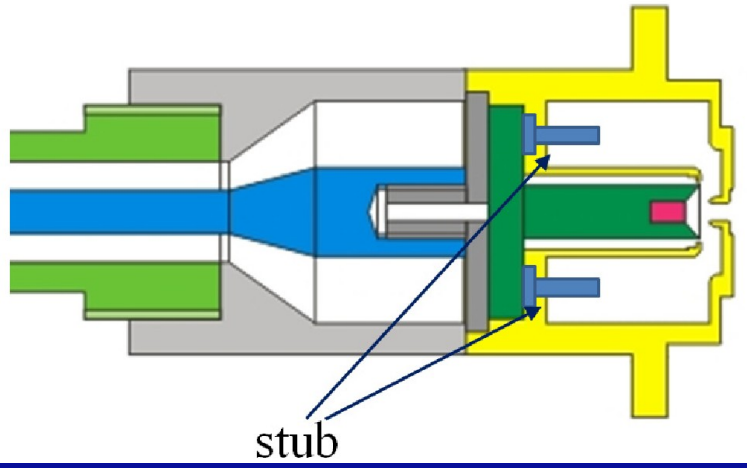
	conventional	triode
back-bombardment power	170 kW	0.8 kW
peak current	2.5 A	3.0 A
normalized emittance	0.5π mm mrad	2.0π mm mrad

First Prototype of Coaxial RF cavity

A coaxial waveguide is used to supply rf power to the cavity

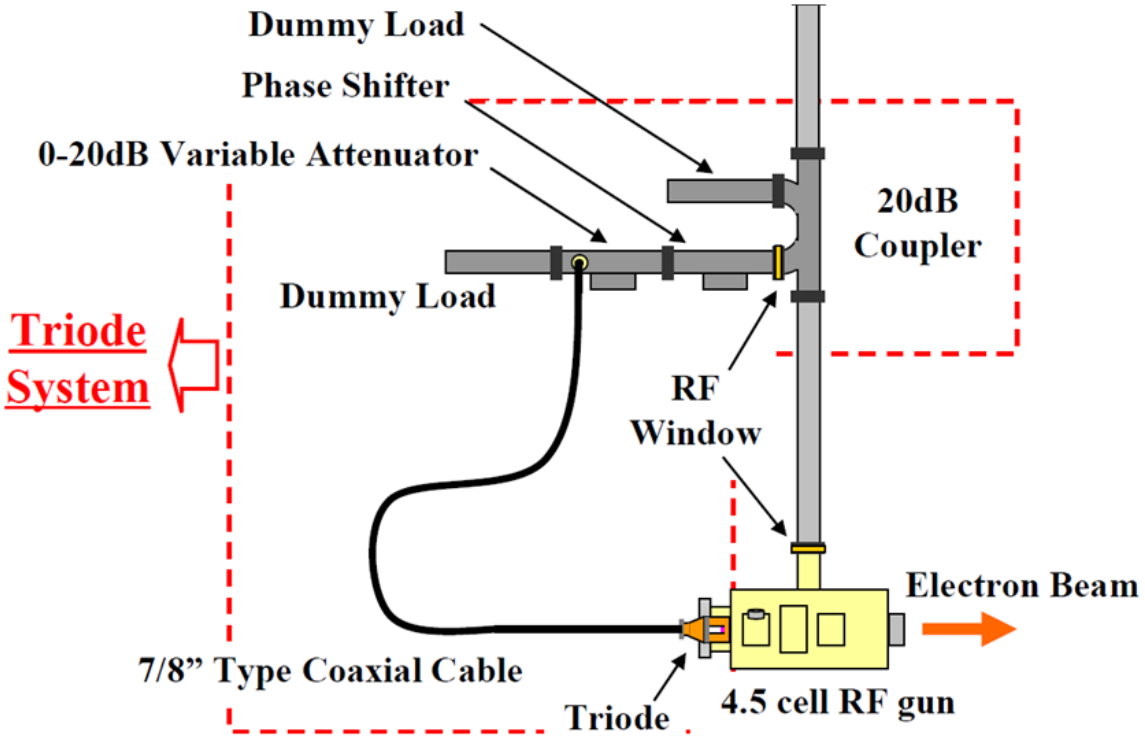


The adjustment of resonance frequency is ensured by stub tuning system



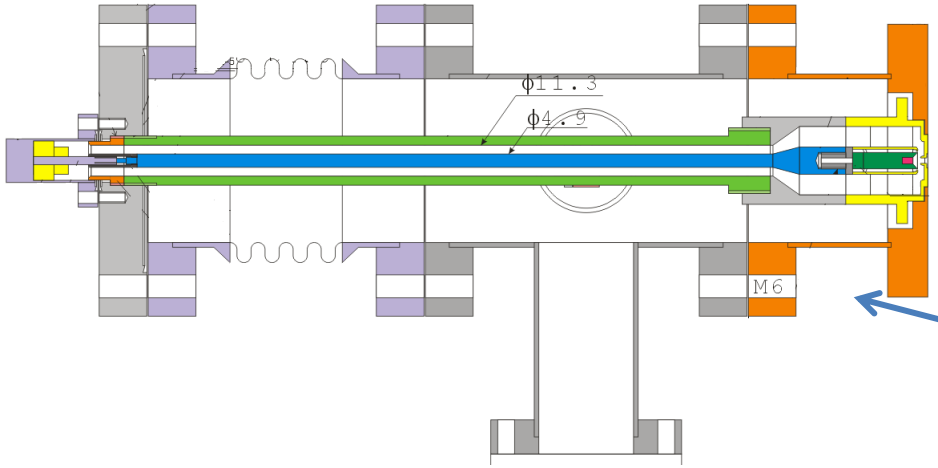
Set up

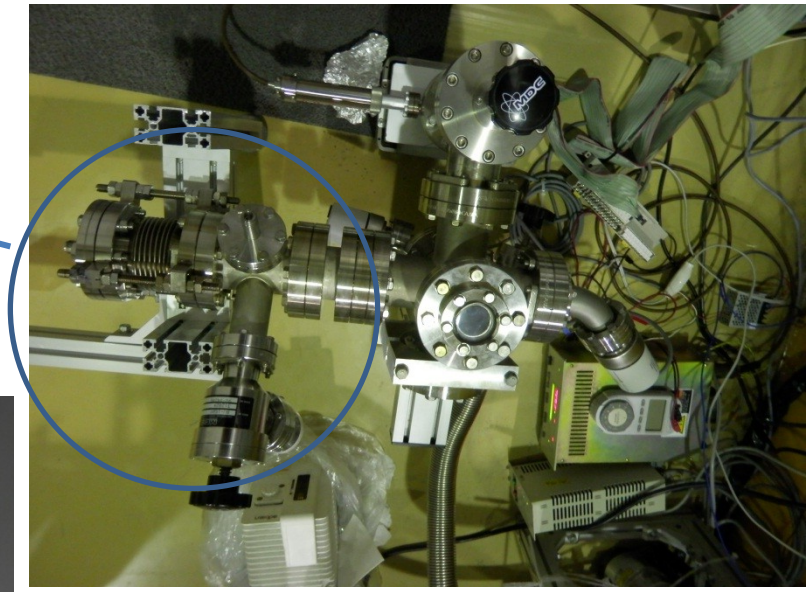
The coaxial triode rf cavity is supplied by the 20dB junction of Klystron power for the main gun. The junction has additional power and phase control

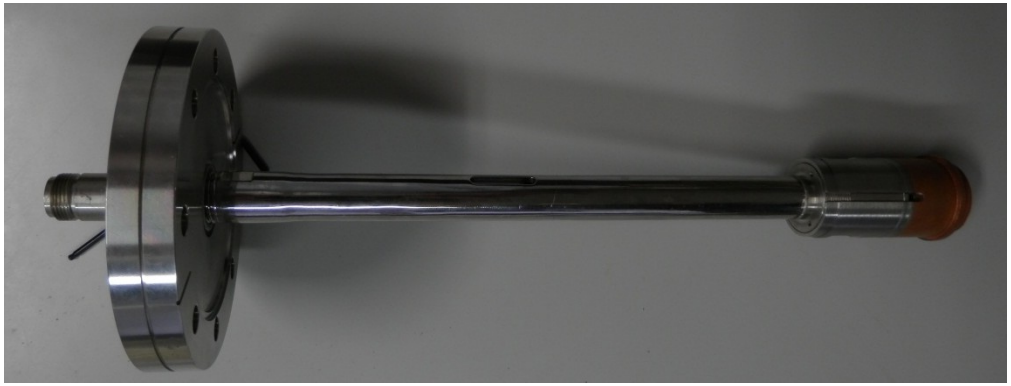


Cold Test
Low Power Test

The coaxial triode cavity has an separate vacuum chamber for “cold tests”

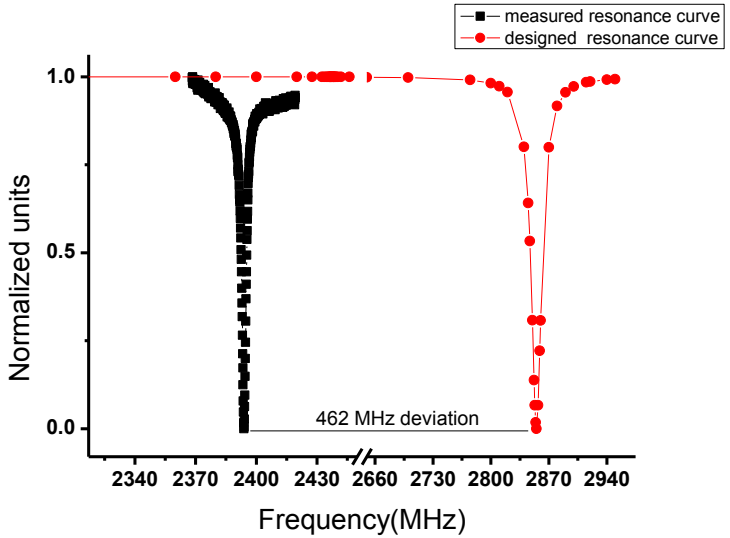


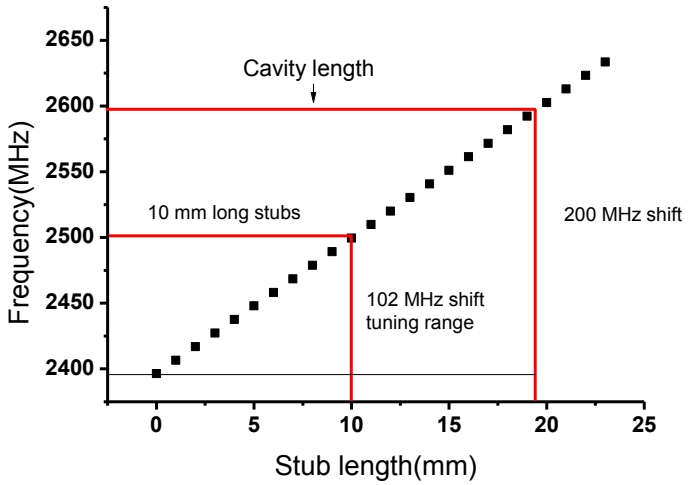




Cold Test
Low Power Test

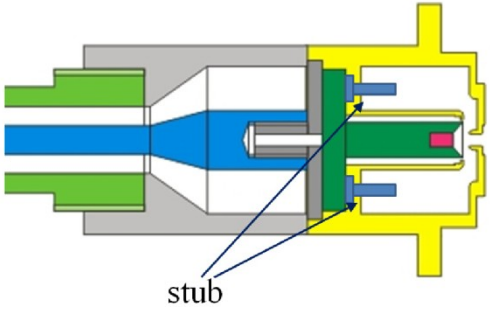
- The prototype cavity reveals 462 MHz resonance frequency and deviation
- The stub tuning system can compensate for <200 MHz resonance shift





Cold Test results

Resonance frequency [MHz]	2437
Unloaded quality factor (Q_0 value)	2600
Q value	650
Coupling coefficient β	3



Redesign of the Cavity

- Based on prototype cavity characteristics measured by cold test new cavity has been designed

	Δf_0 prototype	$\Delta f_0/f_0$ prototype	$\Delta f_{0\ new}$
Cathode temperature	-10.2 MHz	-0.42 %	- 12 MHz
Cavity temperature	-2.7 MHz	-0.11 %	-3 MHz
Beam loading effect	+1 MHz		+1 MHz
Total			-(2 - 15)MHz

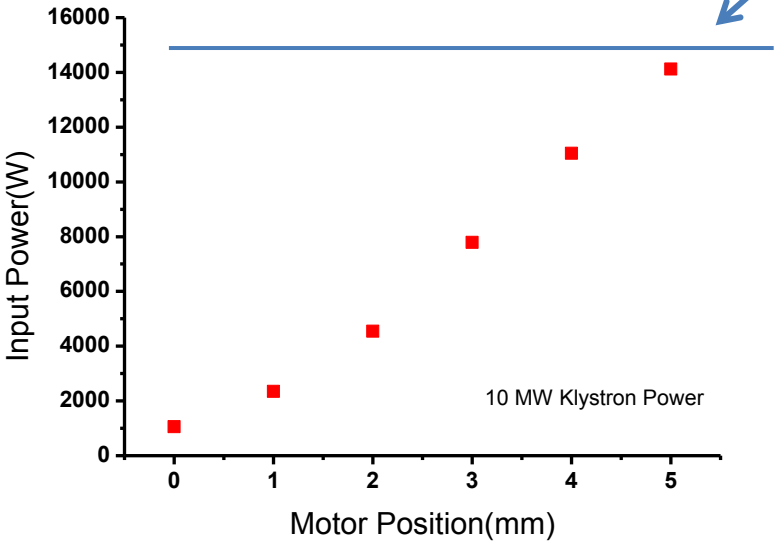
	prototype	new design
cavity length, L	19.20 mm	16.27 mm
Resonance frequency	2437	2848

Required f_0 = 2856 MHz
Designed f_0 = 2848 MHz
Stub tuning 10 MHz

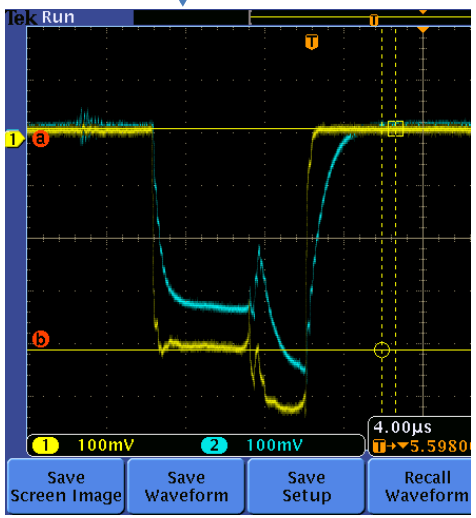
Cold Test
High Power Test

High power test is performed with reflecting plate(no coupling to cavity)
The power limit, which can be supplied to the device is about 15 kW . Beyond this value discharge occurs

High Power Test results



Power instability



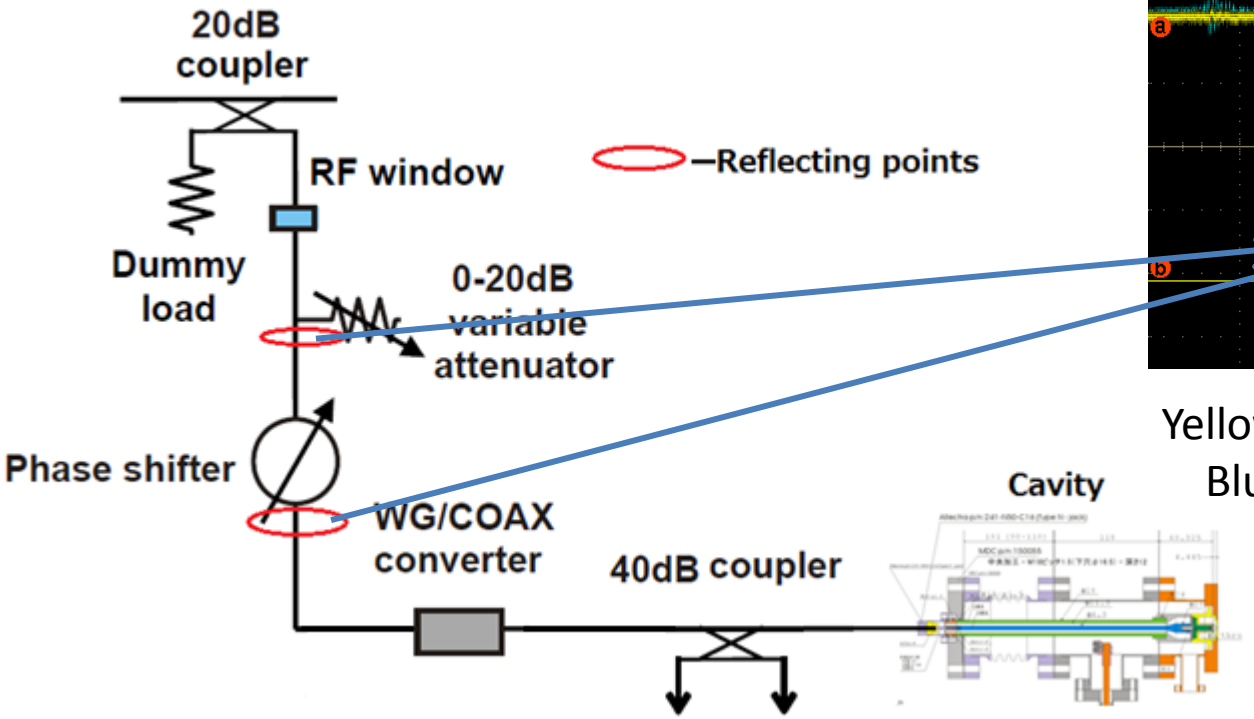
Discharge trace

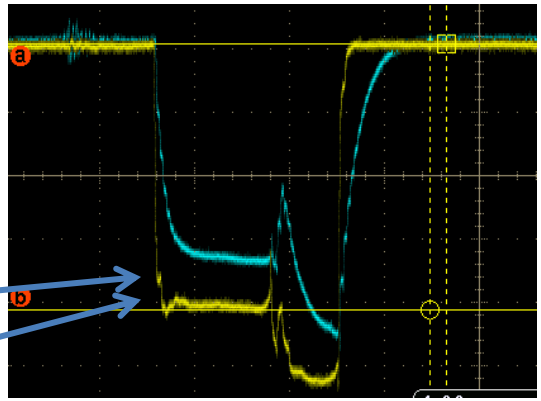
Coaxial feedthrough is not suitable for high power

Input/Reflected Power Coupling

By power >15 kW the input as well as reflected signal is not stable.

The reflected signal seems to affect the input signal(feedback).





Yellow: Input power

Blue: Reflected power

Outgoing Work

- Next cavity prototype with corrected cavity length will arrive in December
- The coaxial waveguide will be modified for a high power feedthrough
- A Isolater will be included into the power line in order to exclude the reflection

Summary

- The concept of triode thermionic RF gun has been developed
- The cold test of prototype of coaxial rf cavity reveals deviations from designed parameters
- The coaxial cavity can be feeded with max. 15 kW at present conditions
- An high power insulator will be implemented in order to avoid the coupling of input and reflected power
- A new designed cavity will be tested in December

Triode RF Gun Group

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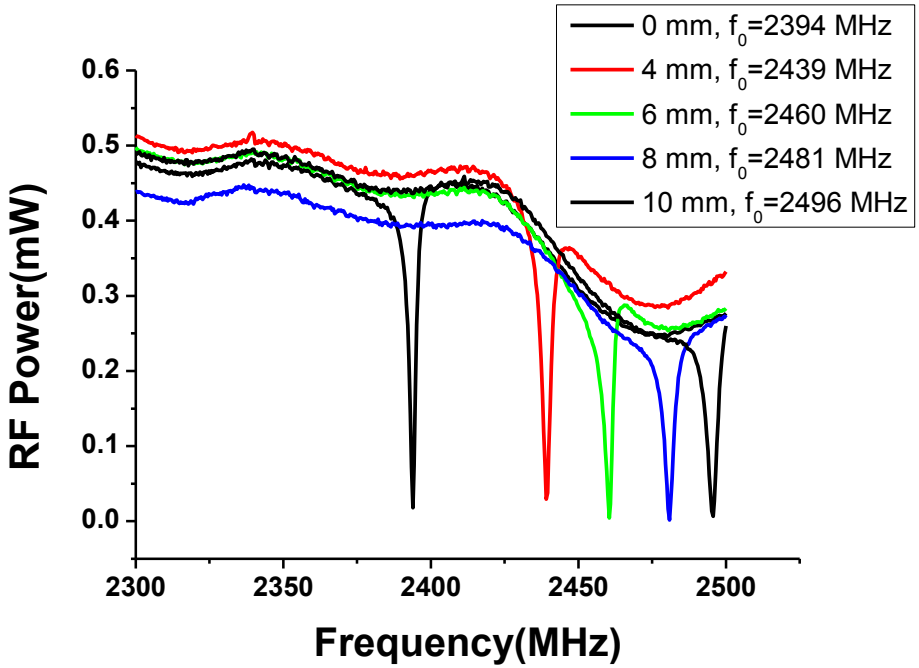
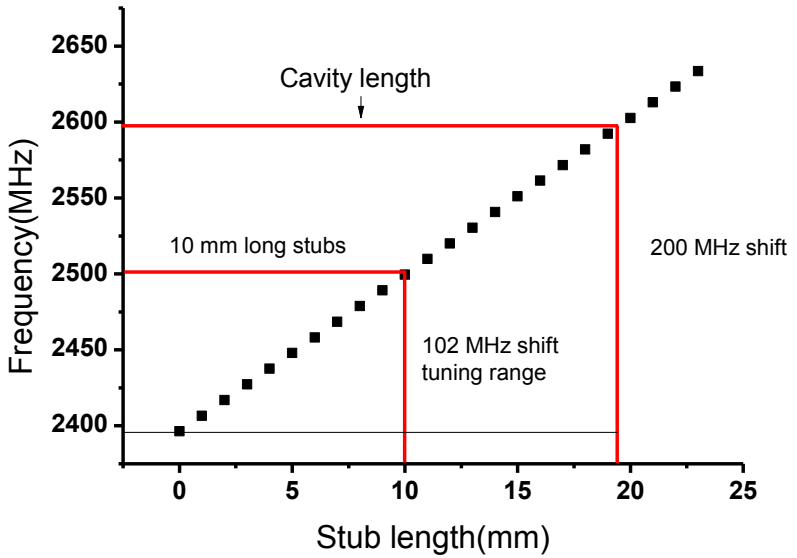
ご清聴ありがとうございました

(Danke für Ihre Aufmerksamkeit)

Cold Test
Low Power Test





Triode gun

An coaxial rf cavity with a thermionic cathode on the inner rod of the coax was designed and fabricated, which is to be installed in an existing conventional rf gun to configure the rf triode structure.

The rf coupler geometry between the coaxial cavity and the rf waveguied was designed by use of a 3-D electromagnetic field solver.

Expected macro-pulse duration by the triode rf gun is twice as long as the conventional gun with ~10 times higher peak current without degradation in emittance.

BBE: which eventually leads to rapid energy drop of the output beam and limits the macro-pulse duration by changing the thermal electron emission

A wehnelt structure was designed by 2-D particle-in-cell (PIC) simulations

the quality factor and the coupling coefficient of the additional coaxial cavity with an rf feed coaxial cable were determined based on an equivalent circuit model to ensure both the induction of the required cavity voltage and a wide frequency acceptance

These predicted beam properties could contribute to FEL performance improvement to a great extent.

Table 1: Parameters of the RF gun used the numerical simulation code.

Resonant frequency [MHz]	2856
Coupling coefficient β	2.79
Q value	12500
R/Q [Ω]	980
Number of cells	4.5
Accelerating mode	π
Cathode radius [mm]	1
Cathode material	LaB_6
Initial cathode temperature [°C]	1545