Superconducting Twin-Quarter Wave Resonator for Acceleration of Low Velocity Heavy Ions

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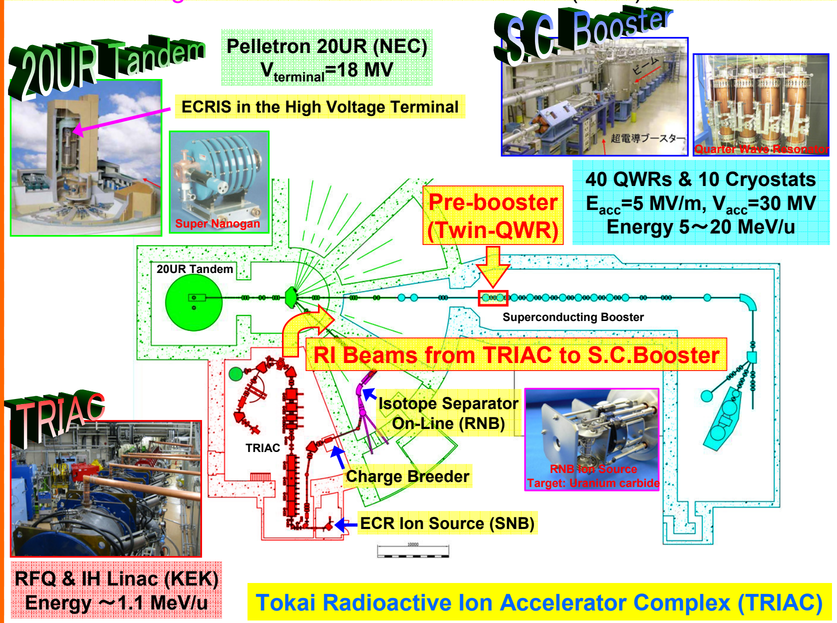
Abstract

We have developed a superconducting twin-quarter-wave resonator (Twin-QWR) for acceleration of low velocity heavy ions. The resonator has 2 inner conductors and 3 acceleration gaps which give a resonant frequency f_0 of 129.8 MHz and an optimum beam velocity β_{opt} of 6 %.
The resonator was designed to have a separatable structure by using superconducting contact-ring made of niobium.
We obtained a quality factor Q_o of 9×10^8 at 4.2 K at low electric field, and an acceleration field gradient E_{acc} of 5.8 MV/m at an RF power input of 4 W.

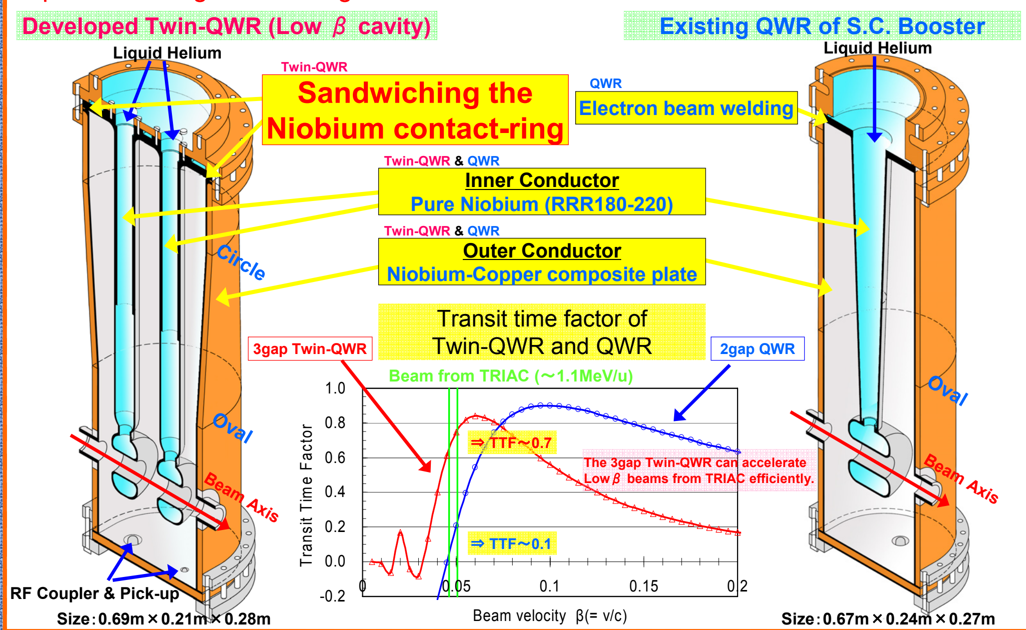
1. JAEA Tandem & Superconducting Booster

Our facility consists of 3 types of accelerators which are Tandem Accelerator, Superconducting Booster, Radioactive Ion Accelerator.
Present Twin-QWR was developed as a pre-booster for re-accelerating the Radioactive Nuclear Beams (RNB) from TRIAC.



2. Design of Twin-Quarter Wave Resonator

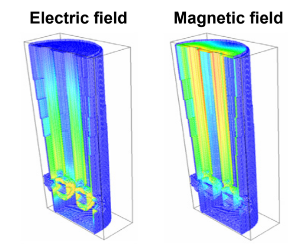
Twin-QWR is designed as a low beta cavity with 2 drift tubes and 3 acceleration gaps.
The resonant frequency f_0 is 129.8 MHz, and optimum beam velocity β_{opt} is 0.06.
The inner conductor part and outer conductor are connected by sandwiching a superconducting contact-ring made of niobium.



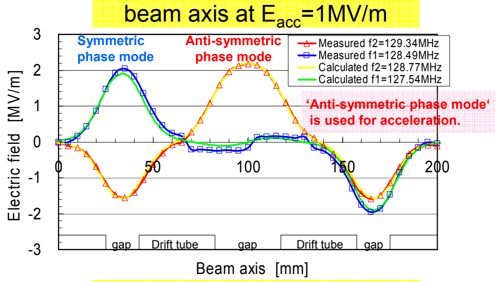
3. Electromagnetic profiles & Main parameters

The main parameters of Twin-QWR were determined from measurement and calculation. The secondary resonant frequency f_2 called 'Anti-symmetric phase mode' is used for acceleration.

Electromagnetic field profiles calculated with MAFIA



Electric field profiles along the beam axis at E_{acc}=1MV/m



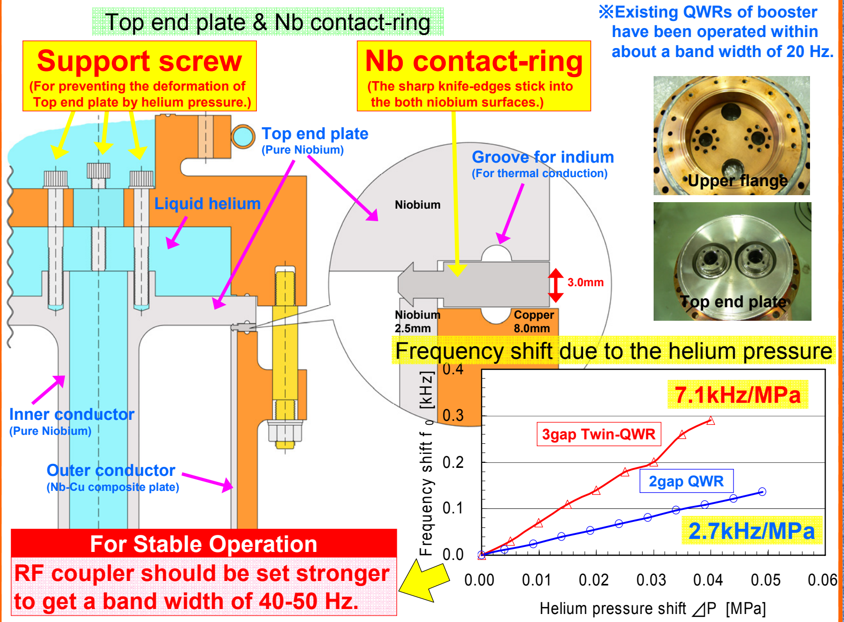
Model Twin-QWR made of aluminum

Main parameters

		Developing Low β cavity	Existing S.C. Booster
Type		Twin-QWR	QWR
Optimum beam velocity	β_{opt}	0.06×c	0.10×c
Frequency [MHz]	f_0	129.80	129.80
RF stored energy [Joule/(MV/m)^2]	U_0/E_{acc}^2	0.039	0.046
Peak surface electric field	E_p/E_{acc}	4.2	4.6
Peak surface magnetic field [mT/(MV/m)]	H_p/E_{acc}	12.5	7.5
Acceleration gap length [m]	L_g	0.0175, 0.035, 0.0175	0.04, 0.04
Acceleration field gadient E_{acc} @ RF 4W [MV/m]	E_{acc} @4W	5.8	4.0～5.0 (average)

4. Frequency Stability

The frequency instability happens due to the deformation of top end plate by helium pressure. The 2 inner conductors of Twin-QWR largely swing compared to a single center conductor in QWR.

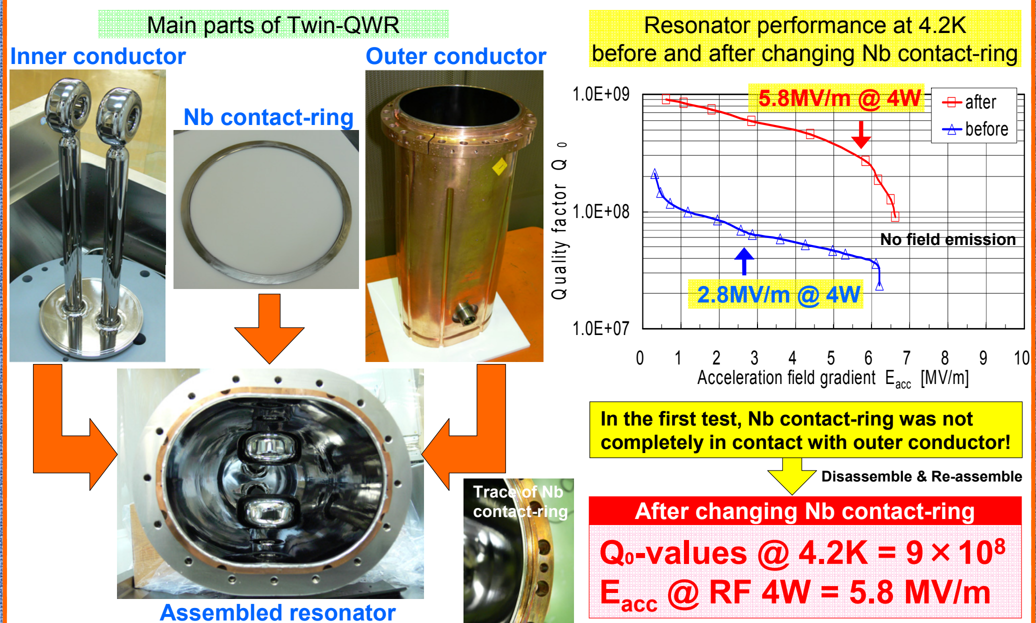


For Stable Operation
RF coupler should be stronger to get a band width of 40-50 Hz.

5. Off-line performance test at 4.2K

This resonator has a separatable structure so that we can give 600℃ heat-treatment for inner conductor apart from outer conductor in the case of niobium is polluted with hydrogen heavily.

※The RF power dissipation of 4W per resonator is determined from the cooling capacity of refrigerator.



6. Summary

Design

Superconducting Twin-QWR of f_0=129.8MHz, β_{opt}= 0.06

Resonator performance

Quality factor Q_o was 9×10^8 @ 4.2 K @ low E_{acc}
Acceleration field gradient E_{acc} was 5.8 MV/m @ RF4 W

Niobium contact-ring

It worked as a good superconducting current contact.

Frequency stability

Stable beam operation will be secure by setting the RF coupling stronger at a band width of 40-50Hz.

More information http://triac.kek.jp