Measurement of Mechanical Vibration of SRILAC Cavities

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Abstract

Mechanical vibration of quarter-wavelength resonators of SRILAC, the superconducting booster of the RIKEN heavy-ion linac, was measured during a vertical cold test. The measurements were performed for fully assembled cavities as well as for bare niobium cavities without the titanium jacket. In the procedure, the instantaneous resonant frequencies were measured for 10 seconds at a time interval of 1 ms and were recorded as a time series. The frequencies were analyzed by means of conventional signal analysis. The power spectrum was deduced from the autocorrelation function calculated with the fluctuation of resonant frequencies. Although the vibration amplitudes were smaller in the cavities assembled with the titanium jacket, we could not find a clear reason for this.

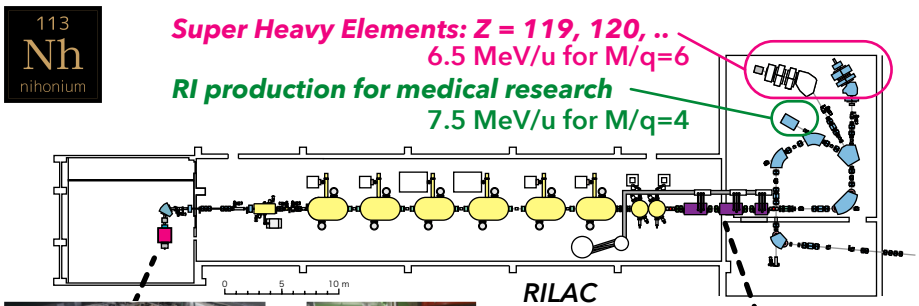
SRILAC Project

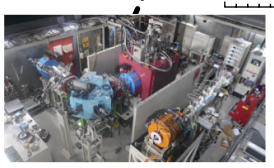
Nihonuim, the element [113], synthesized with RILAC (RIKEN Heavy-Ion Linac)

113 Nh nihonium

Super Heavy Elements: Z = 119, 120, ..
6.5 MeV/u for M/q=6

RI production for medical research
7.5 MeV/u for M/q=4



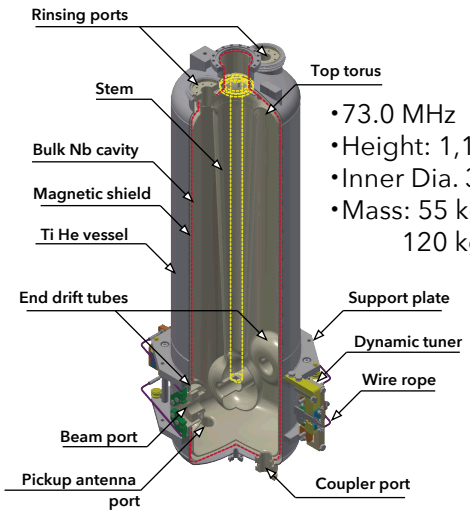


28GHz Superconducting ECR Ion Source

- Ten supercondcuting QWRs.
- Three cryomodules.
- 4.5 K operation.

Measurement Setup

SRILAC Cavity



- 73.0 MHz
- Height: 1,103 mm
- Inner Dia. 300 mm
- Mass: 55 kg (bare)
  120 kg (dressed)

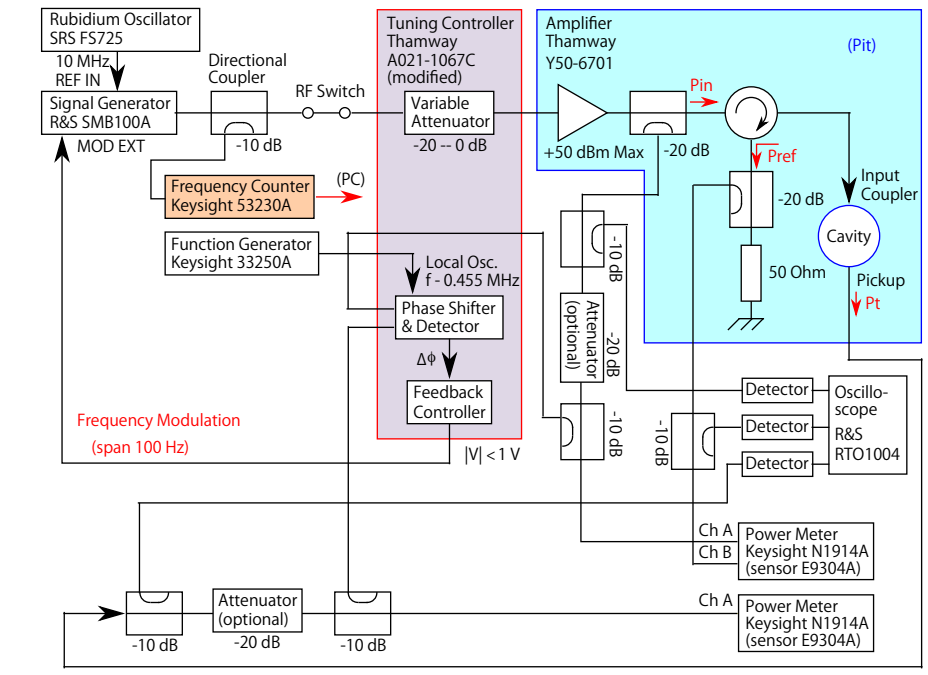
Vertical Test Stand

Equation of Frequency Fluctuation

$$\delta\ddot{\omega}_\mu + \frac{2}{\tau_\mu}\delta\dot{\omega}_\mu + \Omega_\mu^2\delta\omega_\mu = -2k_\mu\Omega_\mu^2 V_0{}^2\delta v + \underline{n(t)}$$

source of microphonics

Measurement Circuit

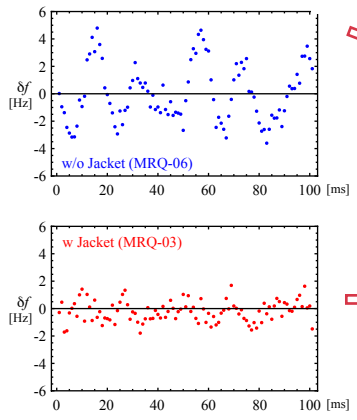


- Generator frequency is always tuned to resonant frequency with Δϕ feedback loop.
- Instantaneous frequencies were measured at a time interval of 1 ms during a period of 10 seconds.

Data Analysis

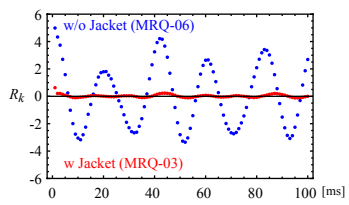
Fluctuation

$$\delta f(n\tau) \equiv f(n\tau) - \frac{1}{N}\sum_{n=1}^{N} f(n\tau)$$



Autocorrelation

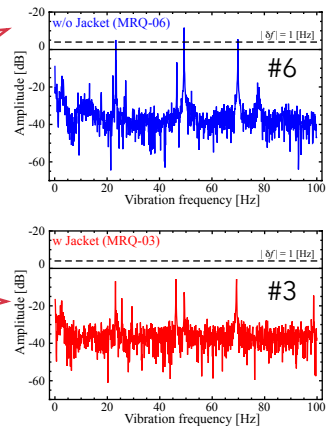
$$R_k = \frac{1}{N}\sum_{n=1}^{N-k} x_n x_{n+k}$$



Power Spectrum

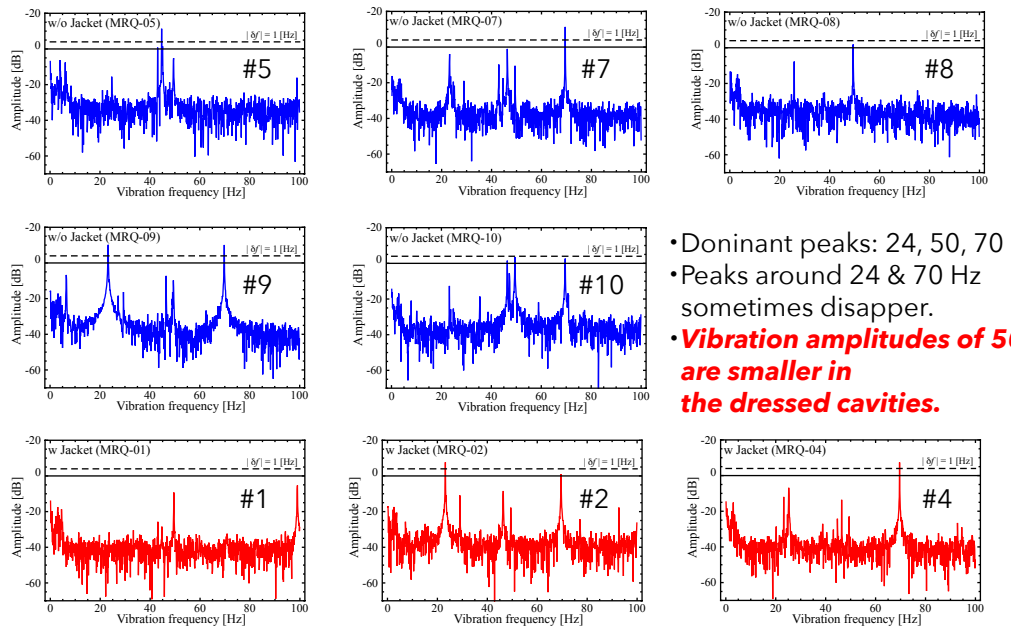
$$S(f) = \tau\sum_{k=-(N-1)}^{N-1} R_k \exp\left[-\mathbf{j}\cdot 2\pi f k\tau\right]$$

$$S(f) = \frac{1}{N\tau}\left|\tau\sum_{n=1}^{N} x_n \exp\left[-\mathbf{j}\cdot 2\pi f n\tau\right]\right|^2$$



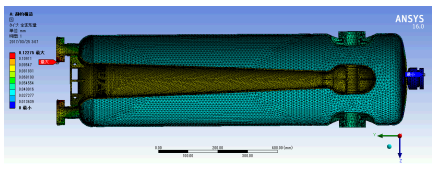
Discussions

Power Spectrum @ 6 MV/m



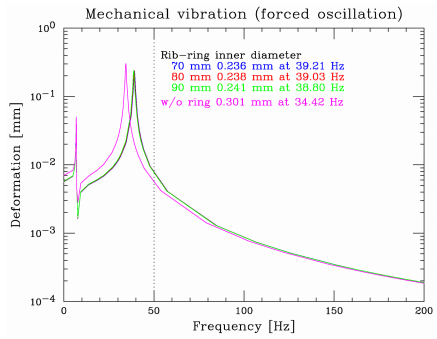
- Donimant peaks: 24, 50, 70 Hz.
- Peaks around 24 & 70 Hz sometimes disapper.
- ***Vibration amplitudes of 50 Hz are smaller in the dressed cavities.***

Structural Analysis

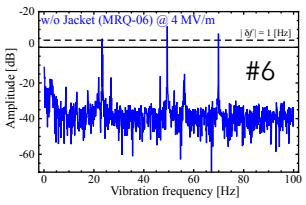


- Stem vibration around 40 MHz.
- No vibration mode around 24 & 70 MHz.

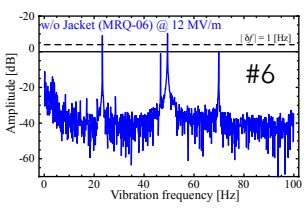
Mode#	[Hz]
1	6.9
2	30.2
3	38.8
4	42.1
5	170.7
6	181.1
7	187.6
8	224.1
9	234.8
10	241.9



Origin of the Peaks



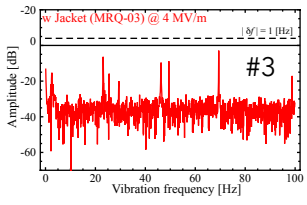
4 MV/m



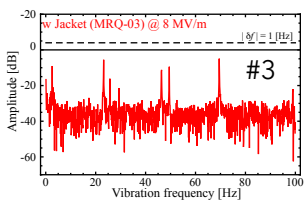
12 MV/m

Amplitudes of dominant peaks are not strongly dependent of Eacc.

- All dominant peaks are microphonics.
- 24 & 70 Hz might come from outside of cavities.

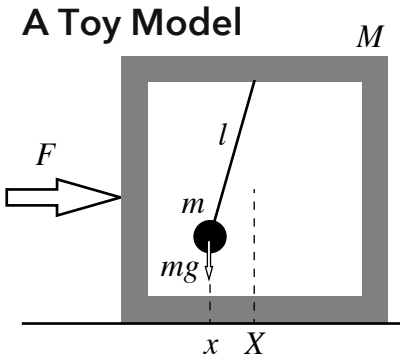


4 MV/m



8 MV/m

A Toy Model



When $M \gg m$,

$$m\ddot{r} + \frac{mg}{l}r = \boxed{-m\cdot\frac{F}{M}}$$

Impact = Inertial force
Inversely proportional to M

where $r \equiv x - X$

Smaller amplitude for larger mass ..?

Acknowledgments

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