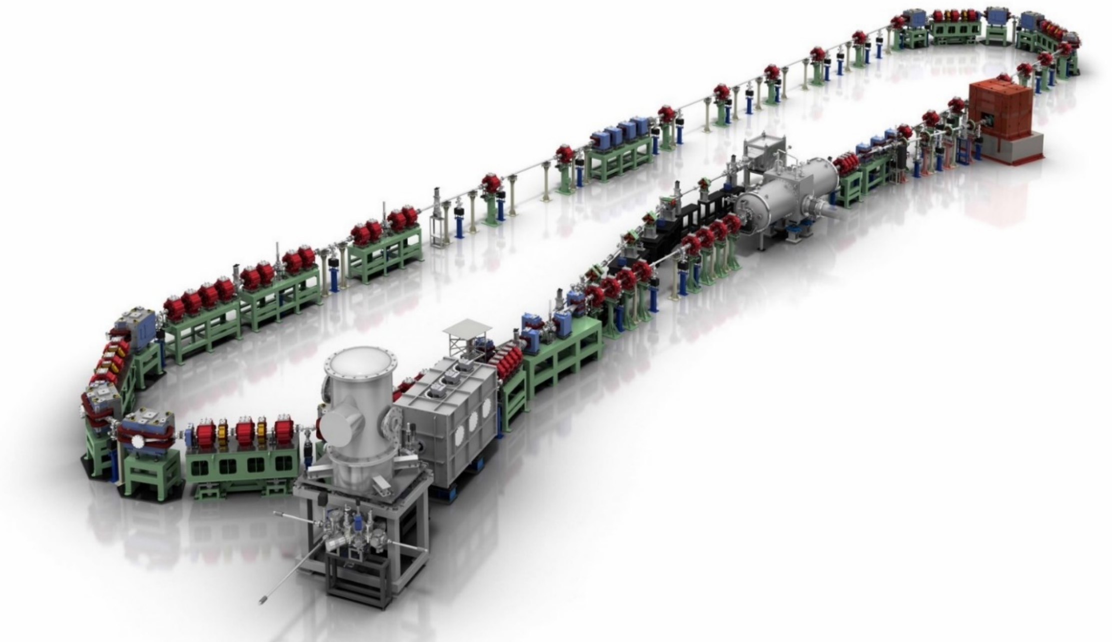
Current Status of Microphonics and LLRF at cERL



Takako Miura (KEK)

LLRF Group

Takako Miura, Feng Qiu, Shinichiro Michizono, Toshihiro Matsumoto, Hiroaki Katagiri, Dai Arakawa (KEK)

SRF Cavity Group

Eiji Kako, Takaaki Furuya, Hiroshi Sakai, Kensei Umemori, Taro Konomi, Masato Egi, Kazuhiro Enami (KEK), Masaru Sawamura (QST)

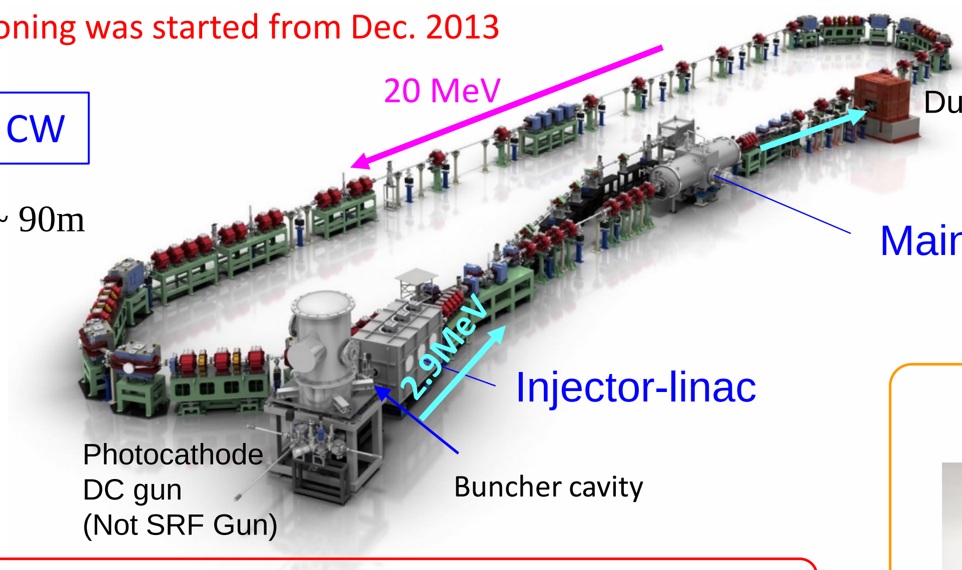
Introduction of cERL

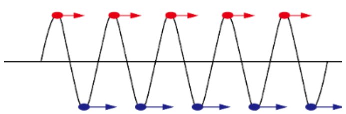
Compact Energy Recovery Linac (**cERL**) : Test facility of 3-GeV ERL Project

Beam commissioning was started from Dec. 2013

RF = 1.3 GHz CW

Circumference ~ 90m

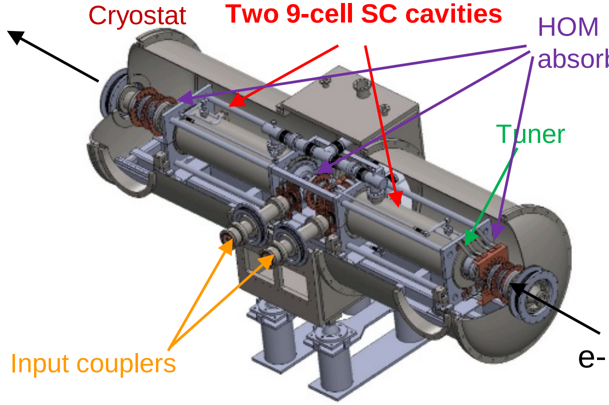




Main linac module

9-cell cavity × 2

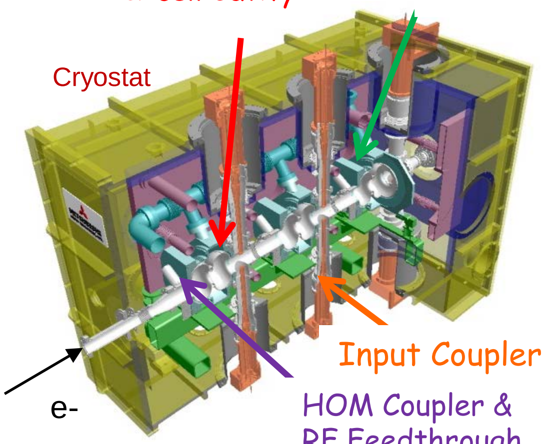
$Q_L = 1\times 10^7$



Injector module

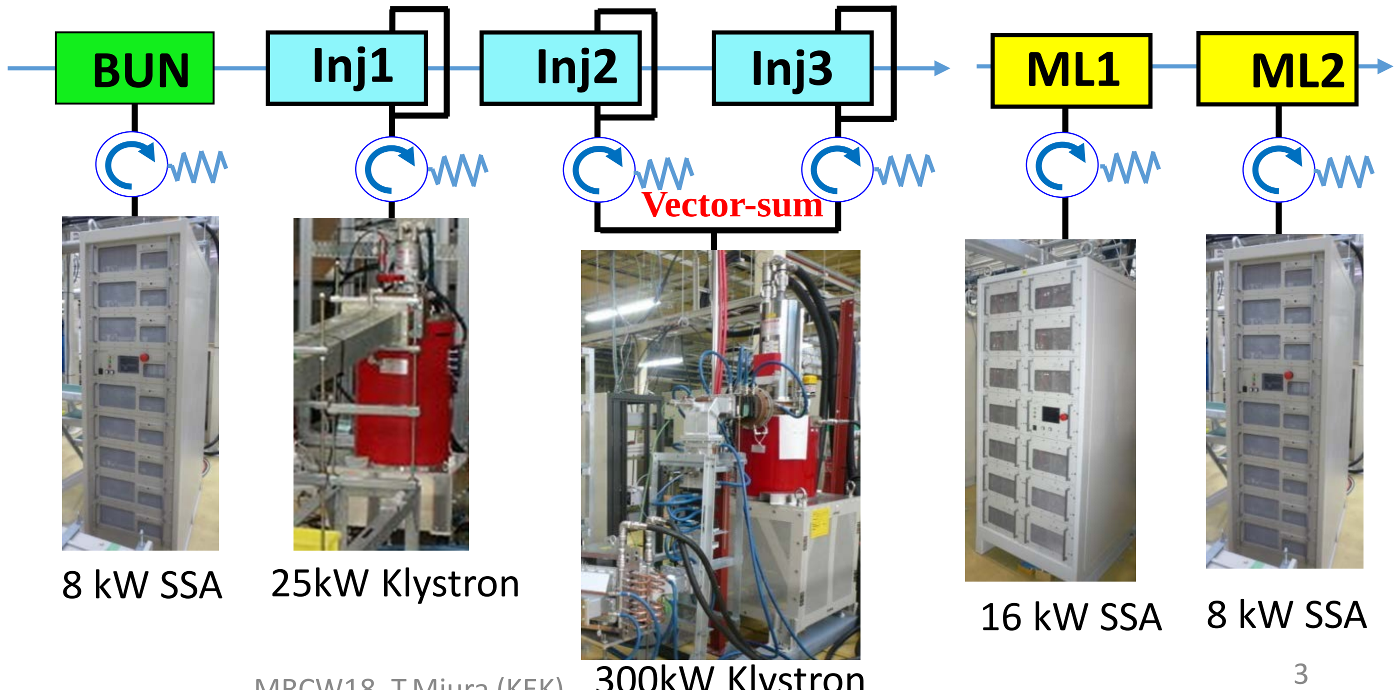
2-cell cavity × 3
Double coupler

$$Q_L = 4.8\times 10^5 \sim 1.2\times 10^6$$



Current status of high power RF sources

	Buncher	Inj-1	Inj-2	Inj-3	ML-1	ML-2
Cavity	NC	2cell-SC	2cell-SC	2cell-SC	9cell-SC	9cell-SC
Cavity Voltage	114 kV	0.7 MV	0.7 MV	0.7 MV	8.6 MV	8.6 MV
Field Gradient (Desgin)		3 MV/m (7.5MV/m)	3MV/m (7.5MV/m)	3MV/m (7.5 MV/m)	8.3 MV/m (15MV/m)	8.3 MV/m (15MV/m)
Q_L	1.1×10^5	1.2×10^6	5.8×10^5	4.8×10^5	1.3×10^7	1.0×10^7
Cavity Length	0.068 m	0.23 m	0.23 m	0.23 m	1.036 m	1.036 m
RF Power @Low beam current	3 kW	0.53 kW	2.6 kW		1.6 kW	2 kW

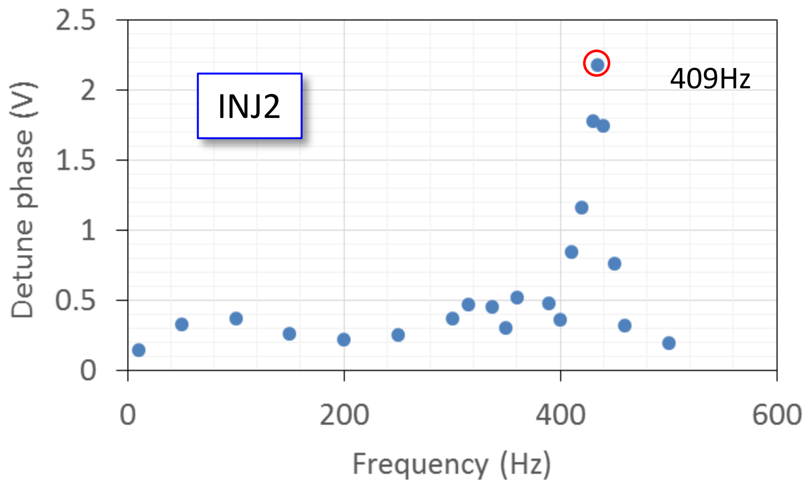


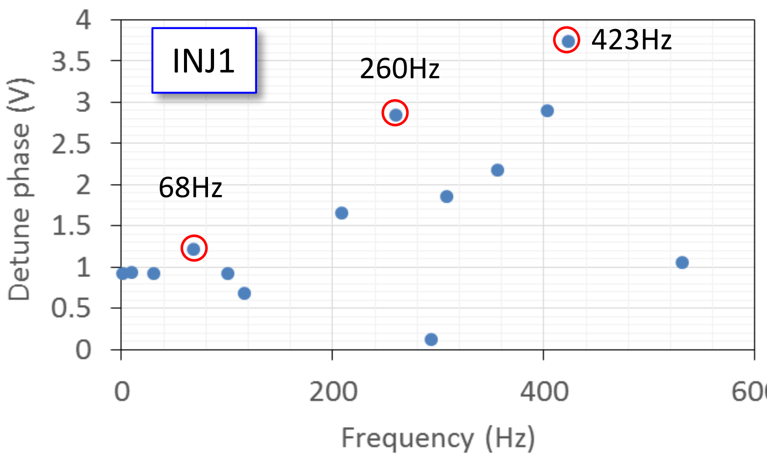
Mechanical Resonance measurement of Inj. Cavities

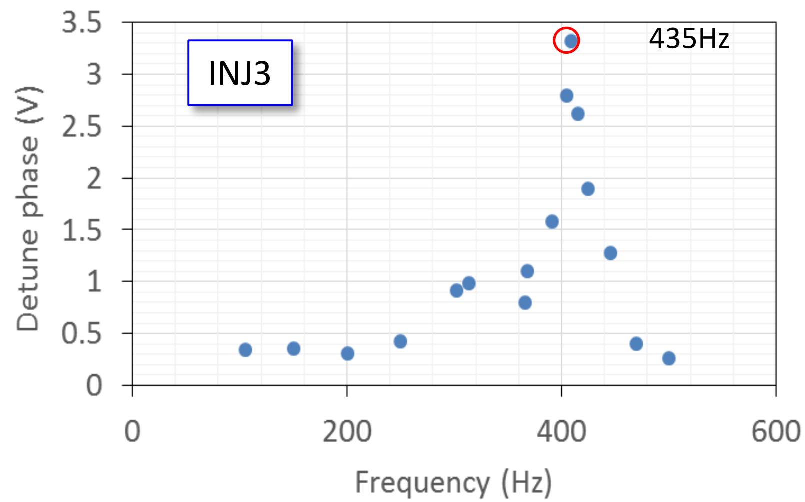
Eacc: 1MV/m

Vibration was excited by using the piezo tuner to longitudinal direction.

Sinusoidal wave ($40V_{pp}$) was fed to piezo tuner.

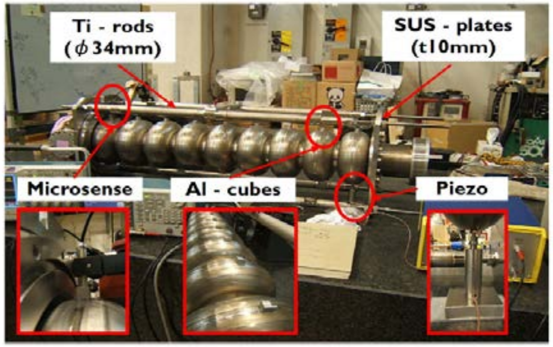


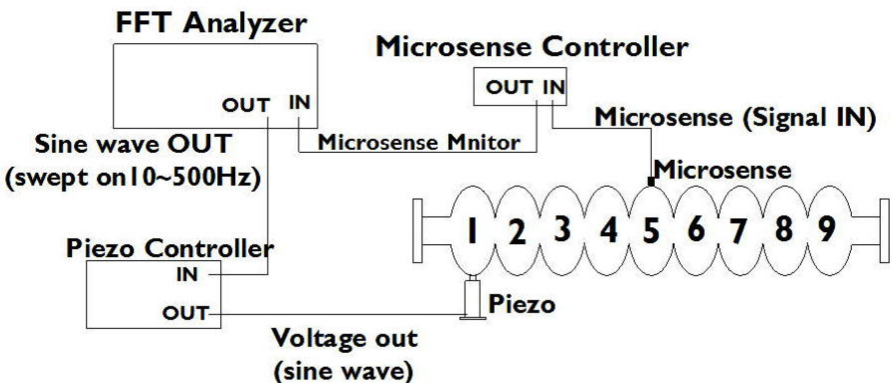


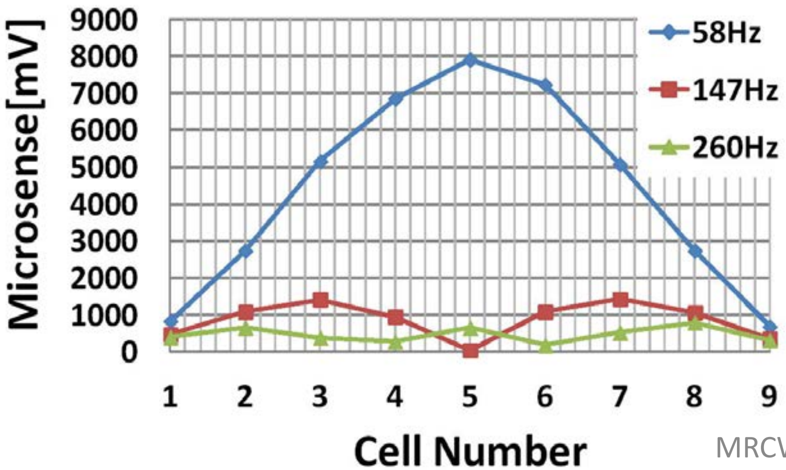


Large mechanical resonance exists around 400 Hz.

Mechanical Resonance Measurement of ML Cavity

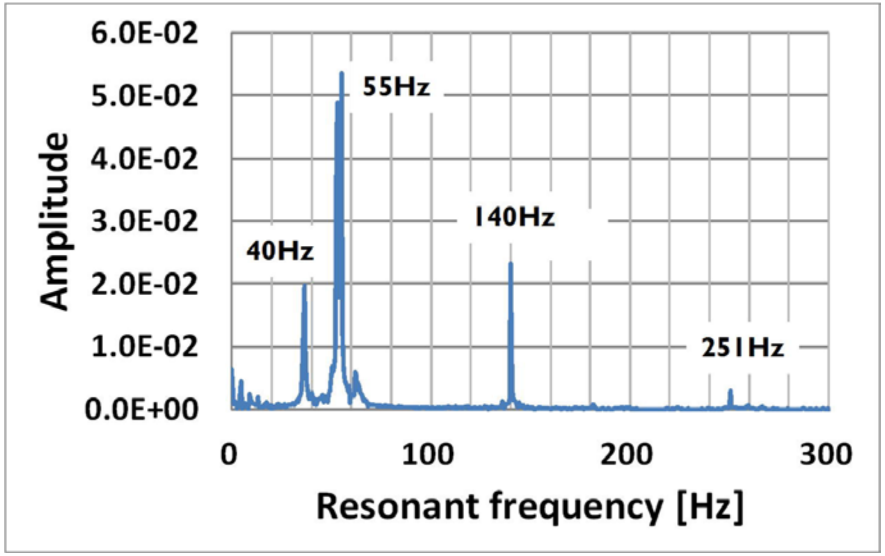






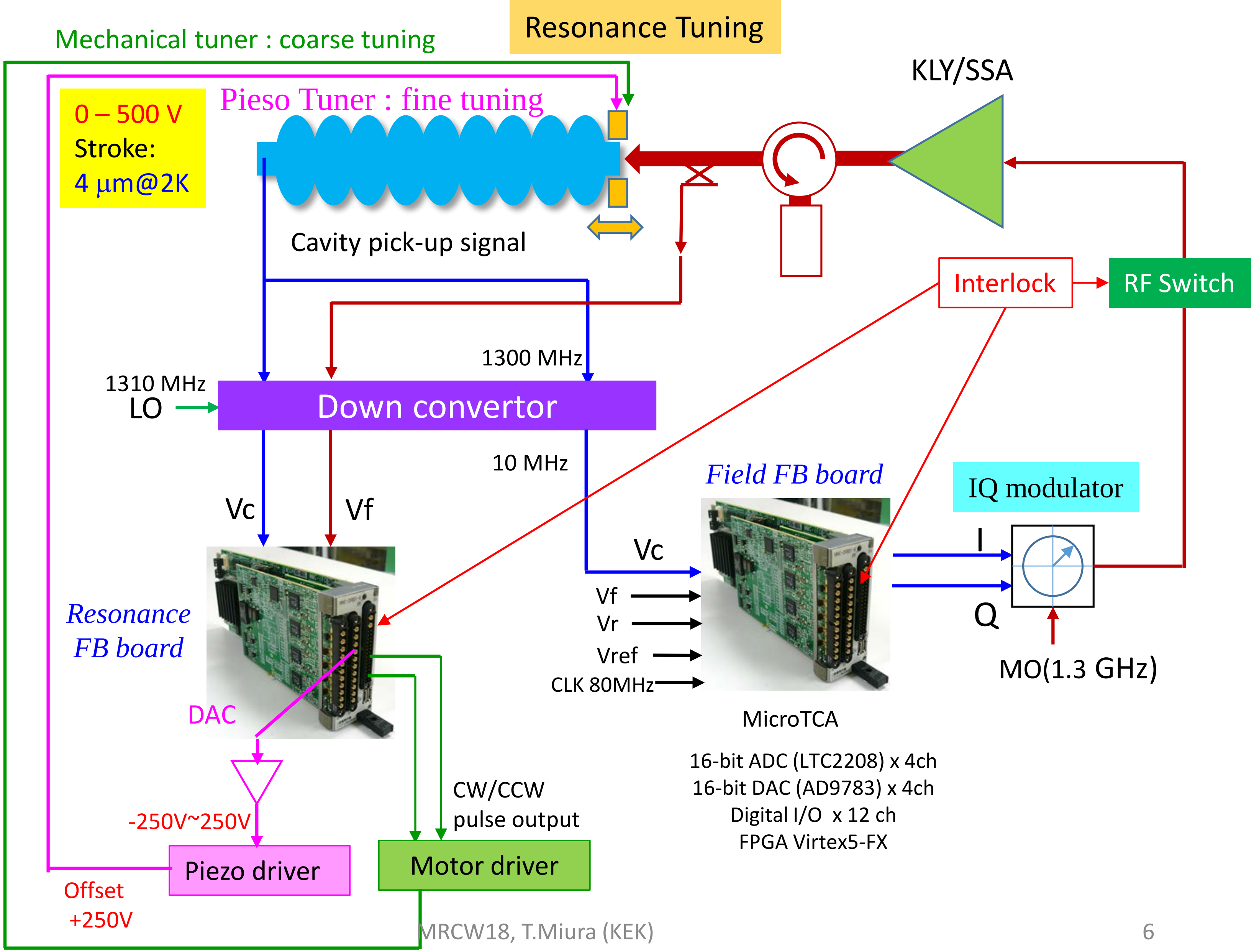
M. Satoh, IPAC2014
PASJ2013

Impulse hammer response with piezo



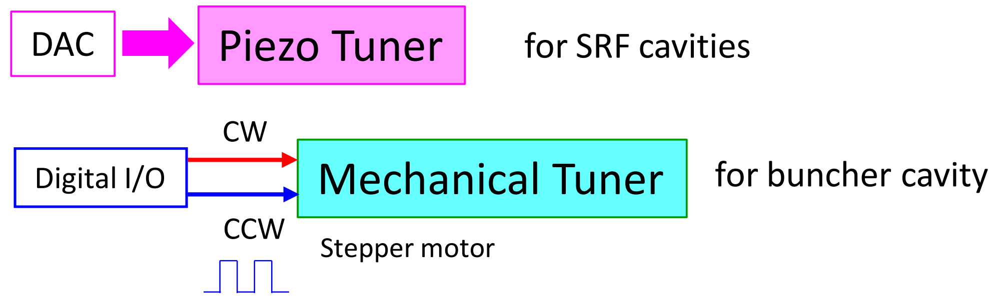
Large mechanical resonance exists near 50 Hz

Digital LLRF System at cERL

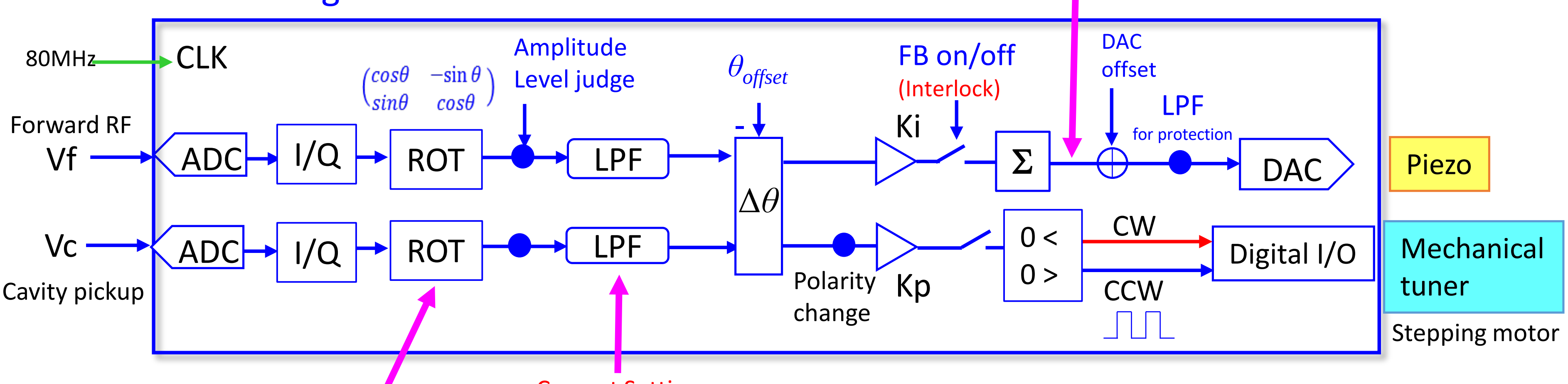


Resonance Control

Feedback Control: $\Delta\theta = \theta_f\,(\text{input RF}) - \theta_c\,(\text{cav}) - \theta_{offset} \Rightarrow 0$



Block diagram of Tuner Control Board



Phase is calibrated
by resonance scan

Current Settings:
fc=100 Hz for INJ Cav
fc=20 Hz for ML Cav

*100Hz analog LPF is equipped
in ML Piezo driver.

Waveforms of ML Cavities

T. Miura, IPAC2014 @Dresden

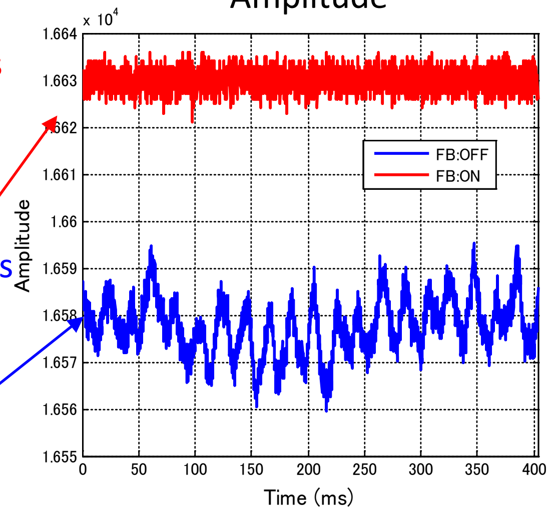
ML1

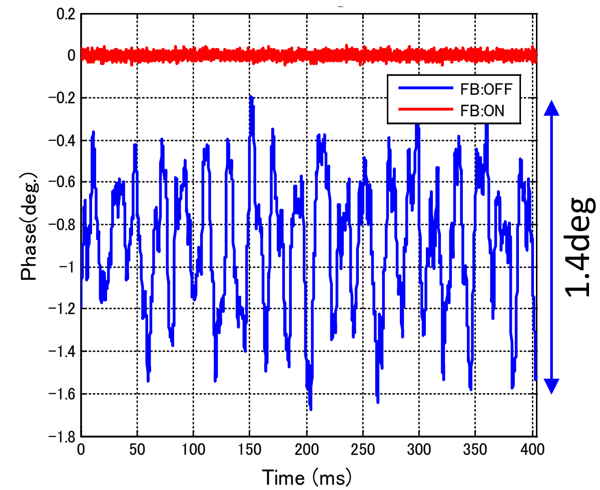
ΔA = 0.012% rms
$\Delta\theta$ = 0.014° rms

ΔA = 0.035% rms
$\Delta\theta$ = 0.3° rms

Vc: w field Feedback

Vc: w/o field Feedback

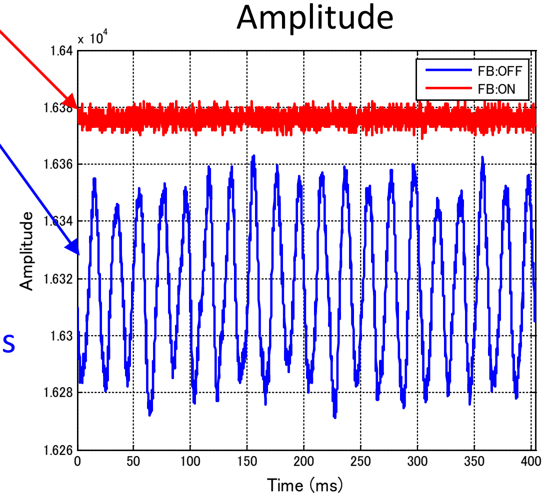


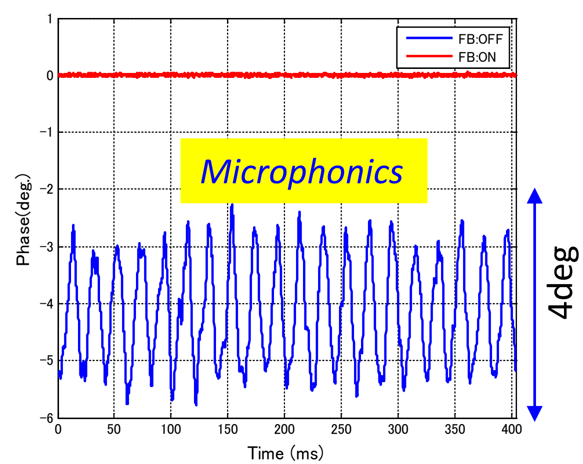


ML2

ΔA = 0.013% rms
$\Delta\theta$ = 0.015° rms

ΔA = 0.15% rms
$\Delta\theta$ = 0.6° rms



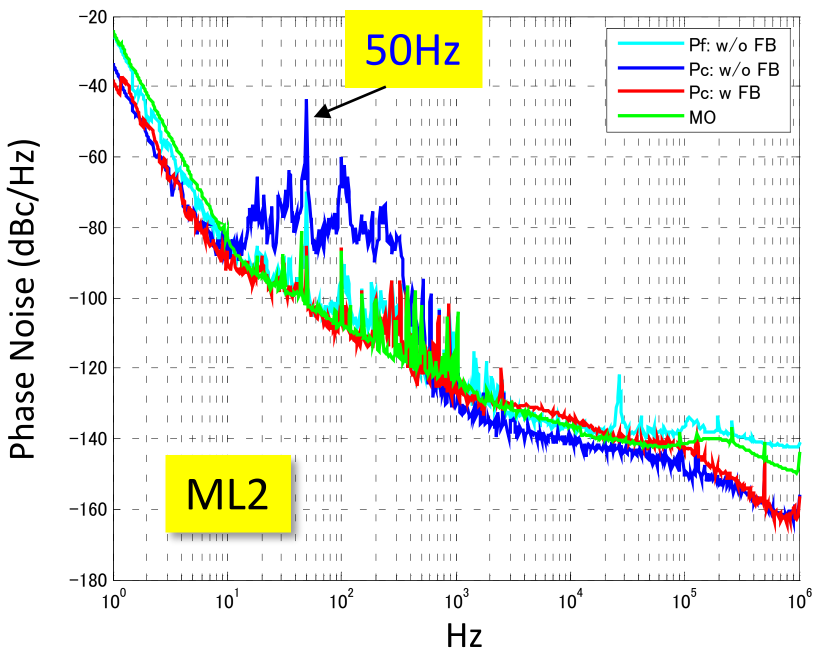


Field fluctuation by Microphonics is stabilized by RF Feedback

Phase noise measurement using Signal Source Analyzer

T. Miura, IPAC2014 @Dresden

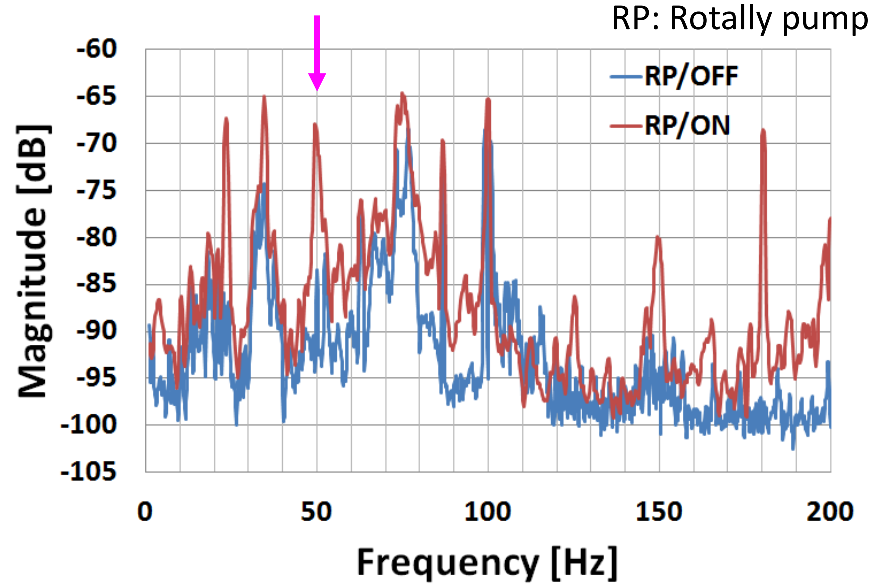
Agilent E5052B



Microphonics is observed at 10 Hz - 400Hz.

M.Egi, IPAC2014, PASJ2016

Floor vibration around Main Linac



Vc Phase Noise w/o RF FB (10Hz- 1MHz)=0.73 deg

Vc Phase Noise with RF FB (10Hz-1MHz)=0.017deg

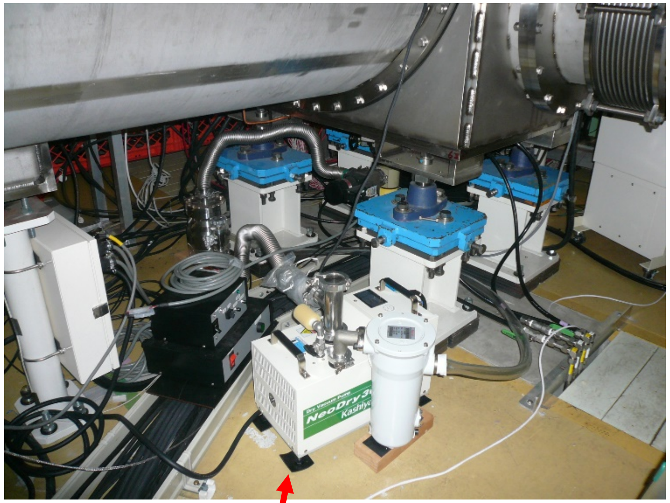
Phase noise by Microphonics was suppressed well by RF FB.

Phase noise of Vc with FB was almost the same as that of Master Oscillator.

Countermeasure against Scroll Pump Vibration

9-cell SC cavity: $Q_L = 10^7$

Field gradient
8.3 MV/m : Operation point
(15 MV/m : Design)



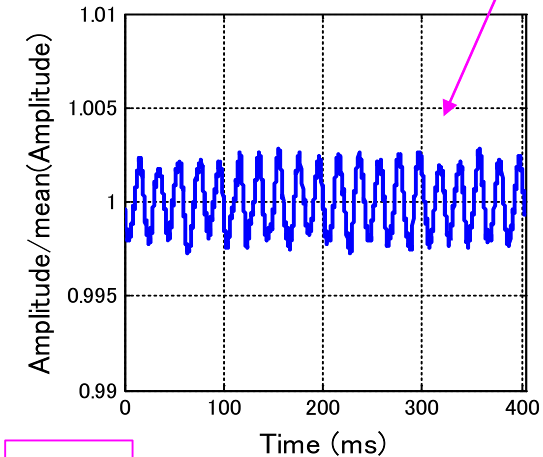
The rubber sheet was inserted under the scroll pump.
The 50 Hz vibration is suppressed.

For constant input RF power

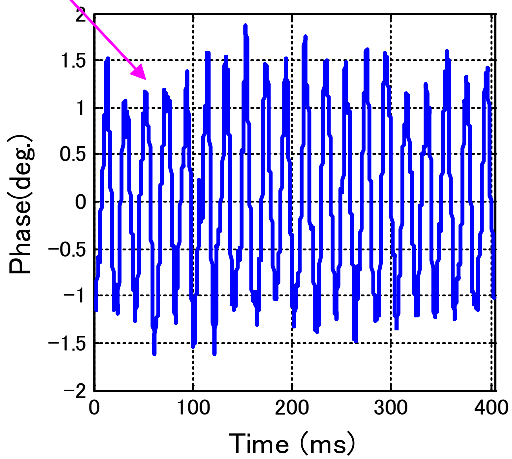
Before

50 Hz vibration by scroll pumps

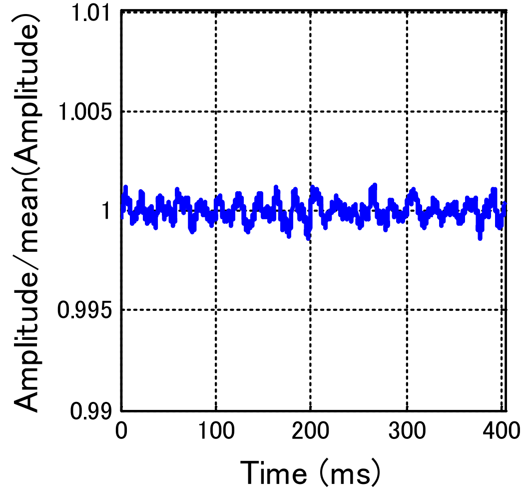
Amplitude

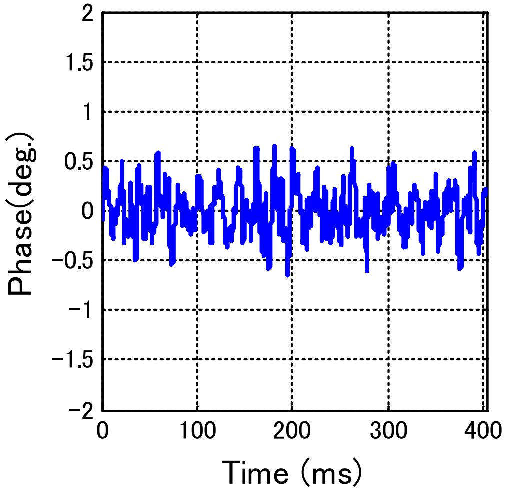


Phase



After





RF Performance

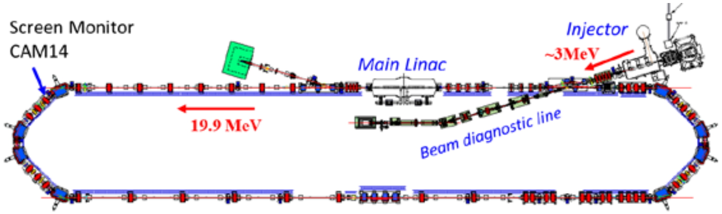
RF Stabilities for Short Time

	Inj1	Inj2 & Inj3	ML1	ML2
Amplitude	0.010% rms	0.012% rms	0.004% rms	0.004% rms
Phase	0.018° rms	0.022° rms	0.010° rms	0.009° rms

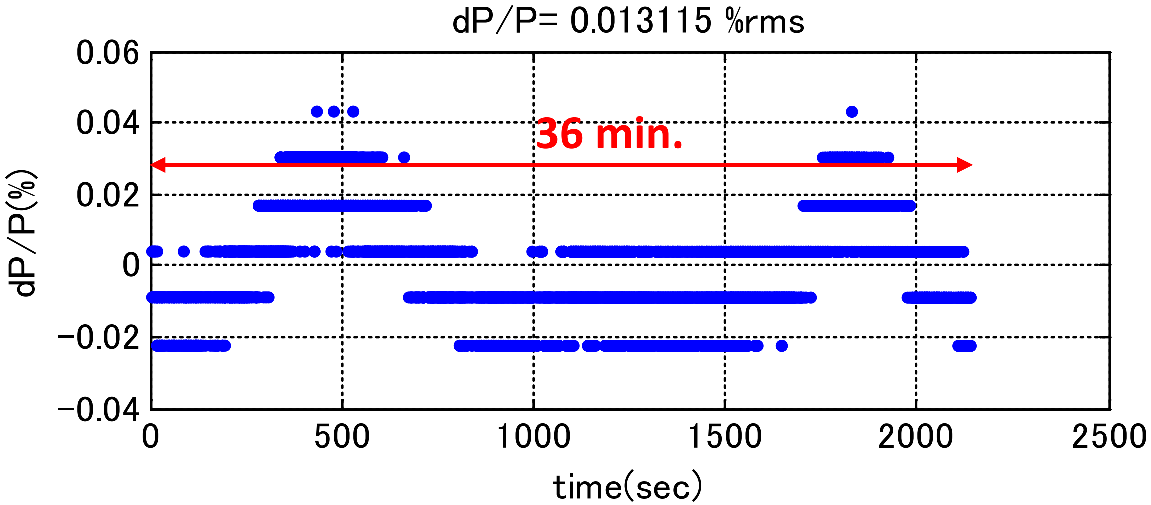
Almost satisfied the requirement of 3-GeV ERL

Measurement of Beam Momentum Stability

for confirmation of RF stability



<Measurement condition>
Beam: 5Hz, 3ps rms, 23 fC, total
Energy=19.9 MeV



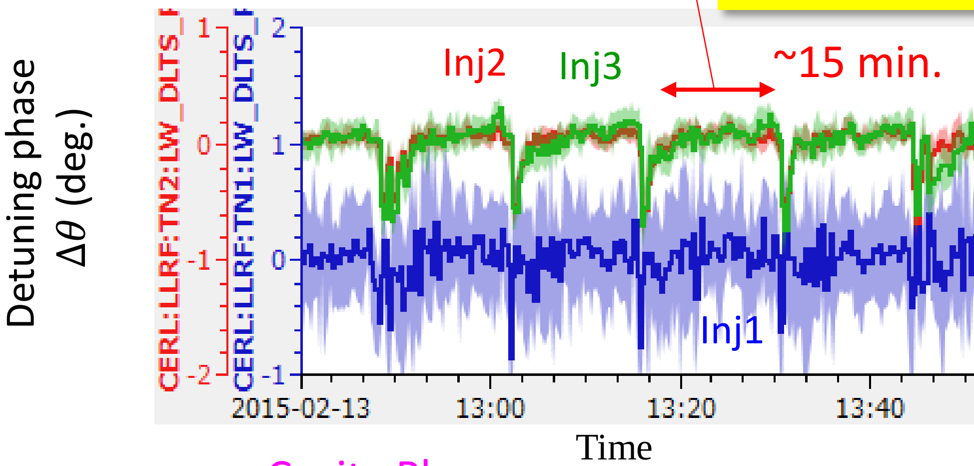
Momentum stability = 0.013% rms

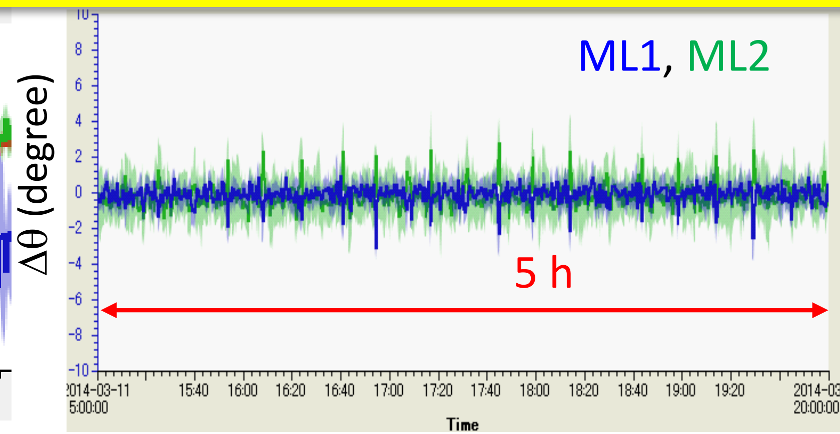
Momentum drift of ~15 minutes period was observed.

What causes Energy Drift ?

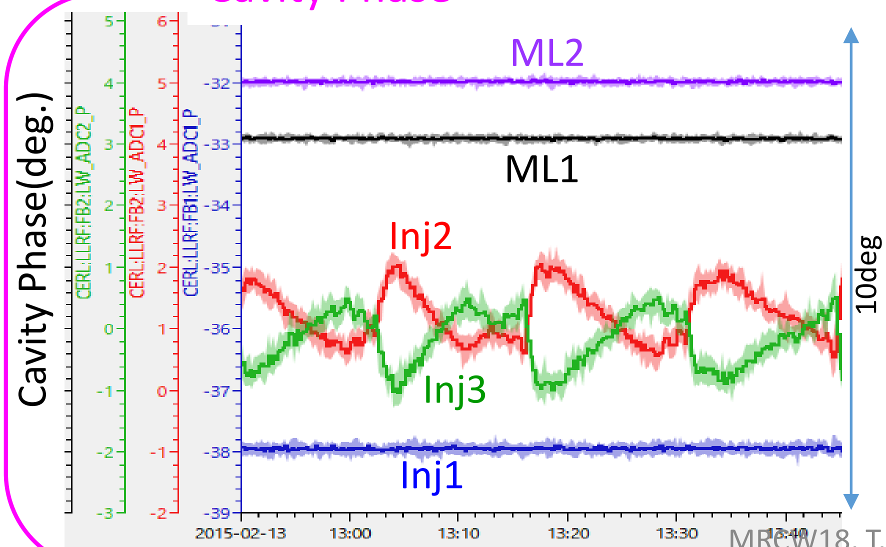
Time interval of detuning is similar to the interval of energy drift.

Large detuning was caused by valve control for liquid N_2.





Cavity Phase



<RF source : cavity =1:1 >

Cavity phase is stabilized by RF FB.

<Vector-sum operation>

Vector-sum is constant.

But each cavity phase fluctuates.

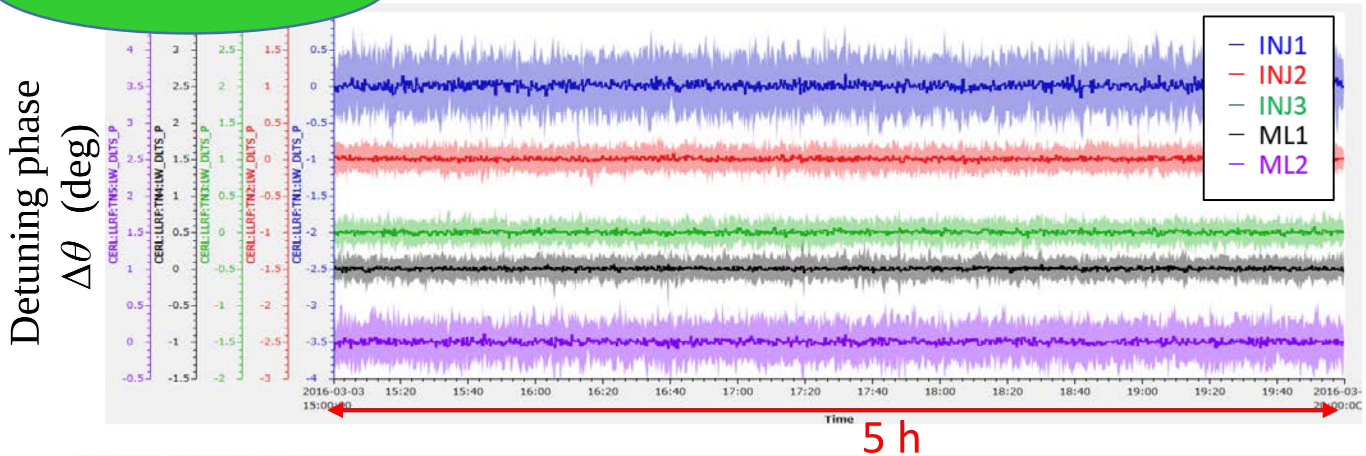
Vector-sum error may cause energy drift.

β<1 @ Injector

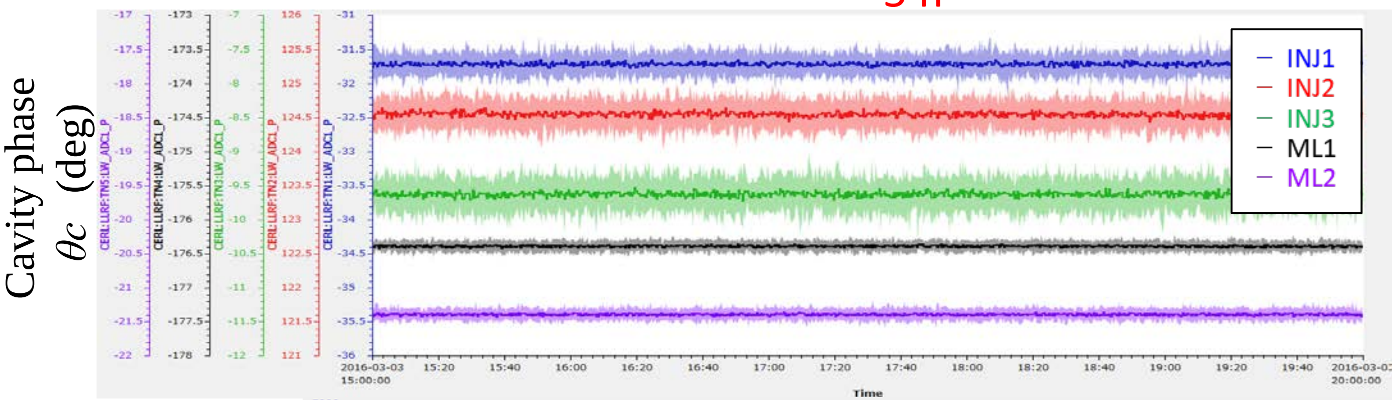
Result of Resonance FB Control Improvement

Detuning Phase

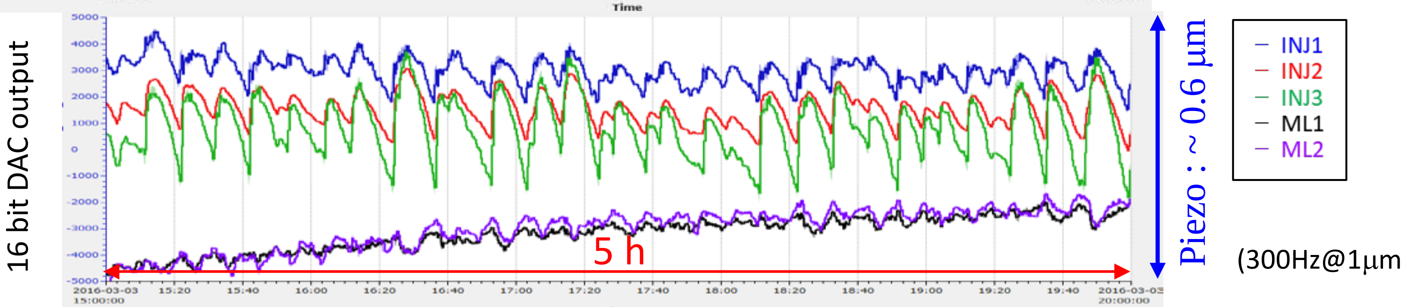
By adopting high gain, the detuning due to liquid N_2 was improved.



Cav	Δθ deg (rms)	Δ*f* Hz (rms)
INJ1	0.23	2.2
INJ2	0.10	2.0
INJ3	0.09	2.1
ML1	0.09	0.08
ML2	0.16	0.18

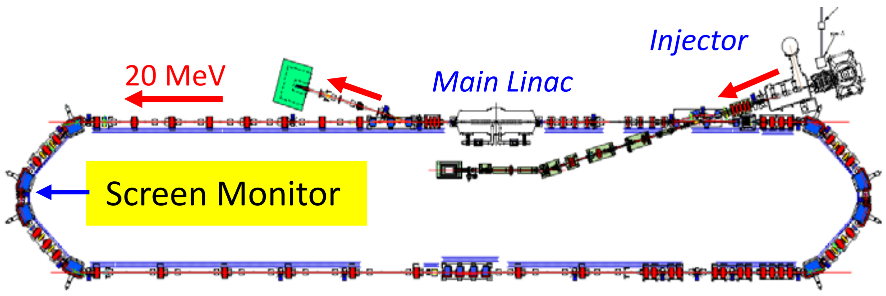


Inj2&Inj3 cavity phases became stable.

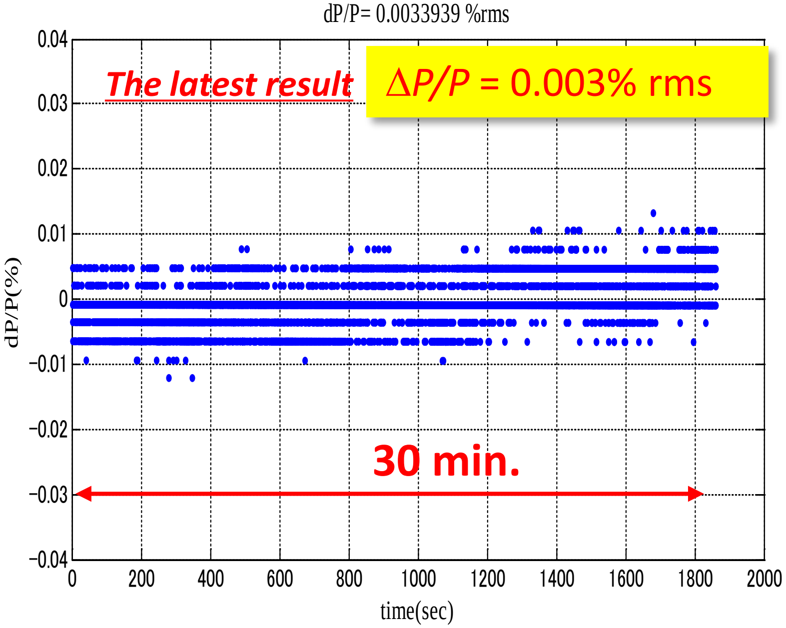


Stability of Beam Momentum (2)

Measurement after modification of tuner feedback gain



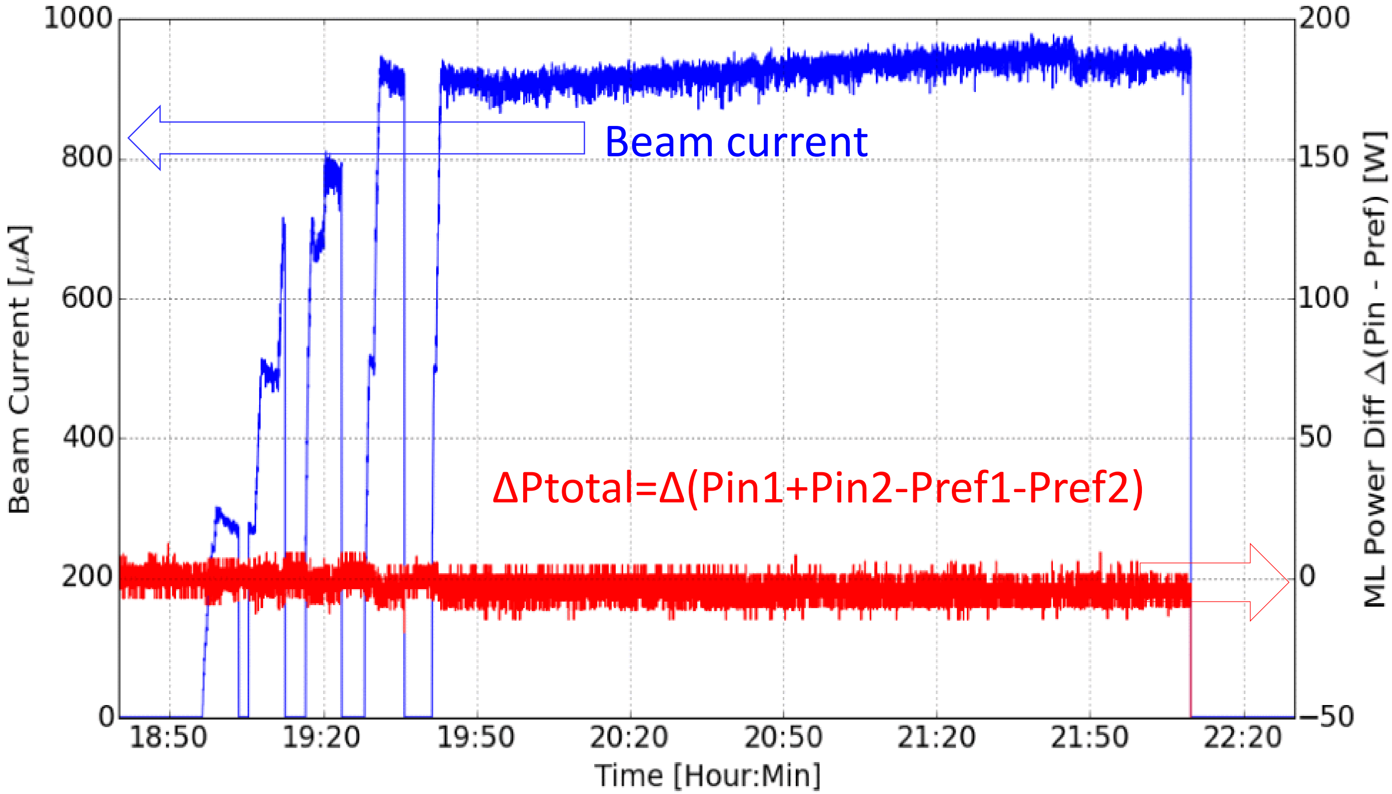
beam condition: 5 Hz, 300uA peak, 0.23pC/bunch, 1usec pulse width,
Cam15: 62.6um/pixel, Dispersion: -2.387422 m@cam15



Large momentum drift disappeared.
=> Beam momentum jitter ΔP/P =0.003% was achieved.

ERL Operation for 0.9 mA (1mA) Beam

H. Sakai



Power differences caused by beam loading was not observed.
For 0.9 mA beam operation, 100±0.03 % energy was recovered.

Summary

For ML cavities, large Microphonics of 50 Hz was excited by the scroll pump.
By using rubber sheet, the vibration was significantly decreased.

Detuning caused by valve control of liquid Nitrogen was observed.
By improving resonance control gain, the detuning was suppressed.
As a result, beam energy drift caused by the vector-sum error was also improved.

Beam momentum jitter $\Delta P/P$ =0.003% was achieved.

ERL operation for 0.9 mA beam was performed successfully.