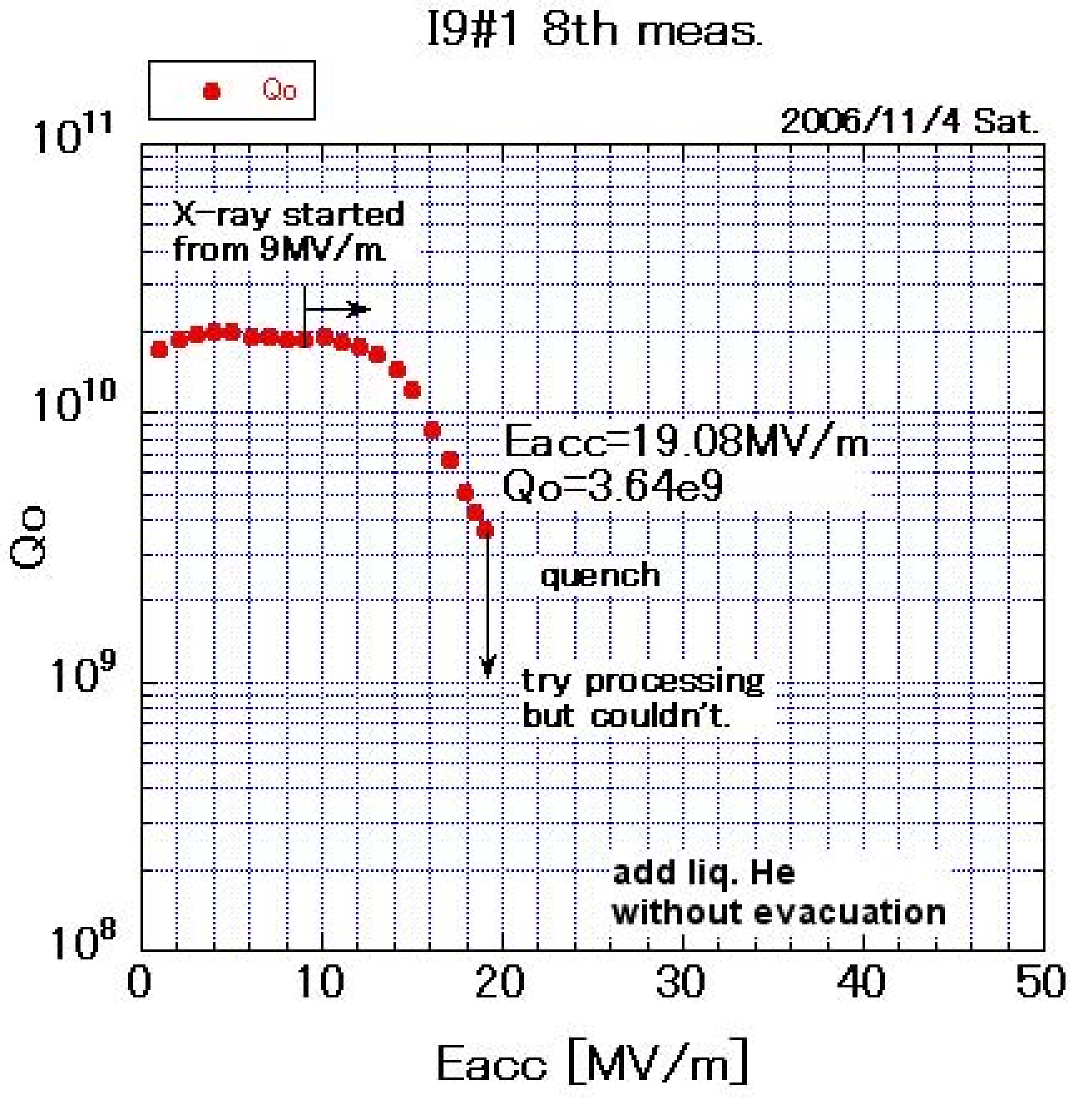
Very preliminary results of ICHIRO 9-cell cavity test in cryomodule at STF 0.5

SCRF meeting

23 April 2008

T. Saeki on behalf of ILC-Asia-WG5 group

Last vertical measurement of ICHIRO#1 9-cell cavity



History of ICHIRO#1 9-cell cavity

4 Nov. 2006 VT : Eacc = 19 MV/m @ Q0 = 3.6E9

Dec. 2006 Installation into cryomodule

Jan. 2007 Cryomodule moved into the tunnel

Feb. 2007 Leak found around the ICHIRO#1 cavity

June 2007 45 MV/m cryomodule was separated from 35 MV/m cryomodule. Some leak found in cold-box.

July 2007 Cold-box leak fixed

Aug. 2007 High-power process of CC coupler (27 hours). 45 MV/m cryomodule moved out of tunnel.

Sept. 2007 Dismantling of 45 MV/m cryomodule / cavity

Oct 2007 Leak hunting of ICHIRO#1 => No leak found

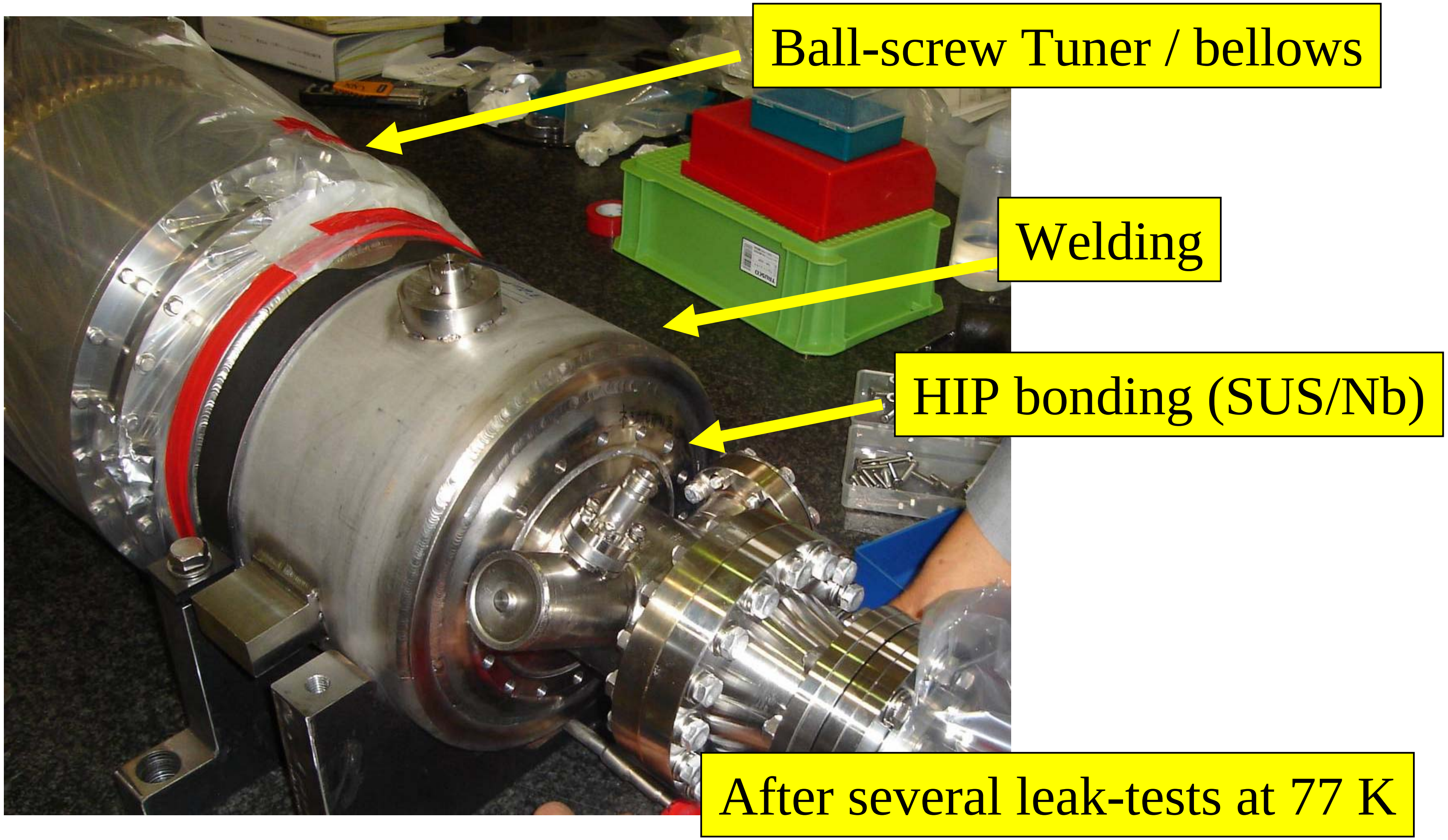
Nov 2007 Ethanol rinse + Degreasing(2%) of ICHIRO#1

Dec 2007 Installation into cryomodule

Feb 2008 Coupler processing at RT done.

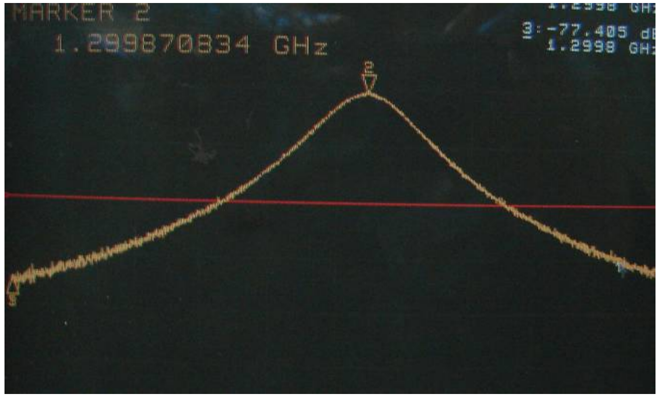
Mar 2008 Start cooling down / no leak found.

Leak Tight @ 2K!



QL measurements

QL (design) = 2.6E6
QL (target) = 2.2E6 (Antenna length +0.5mm)



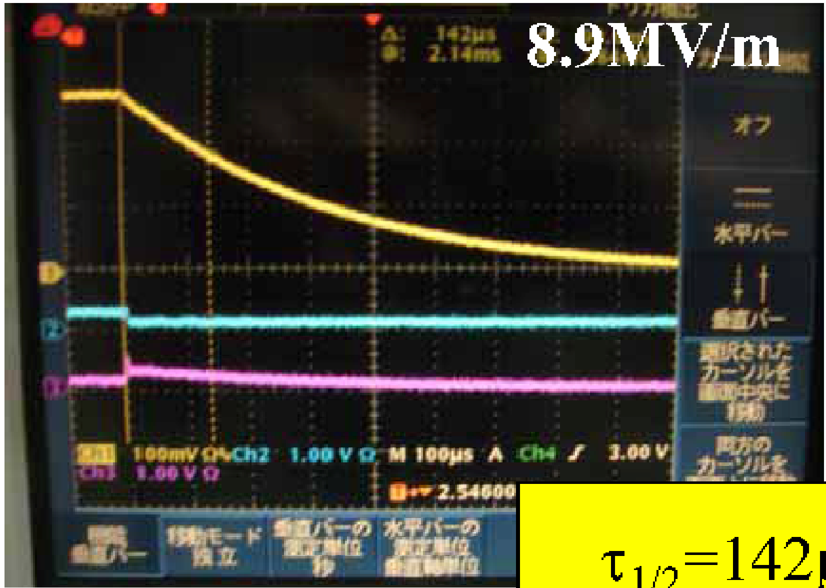
Network Analyzer (HP)
dF(BW/2) = 370 Hz
QL = 1.76E 6

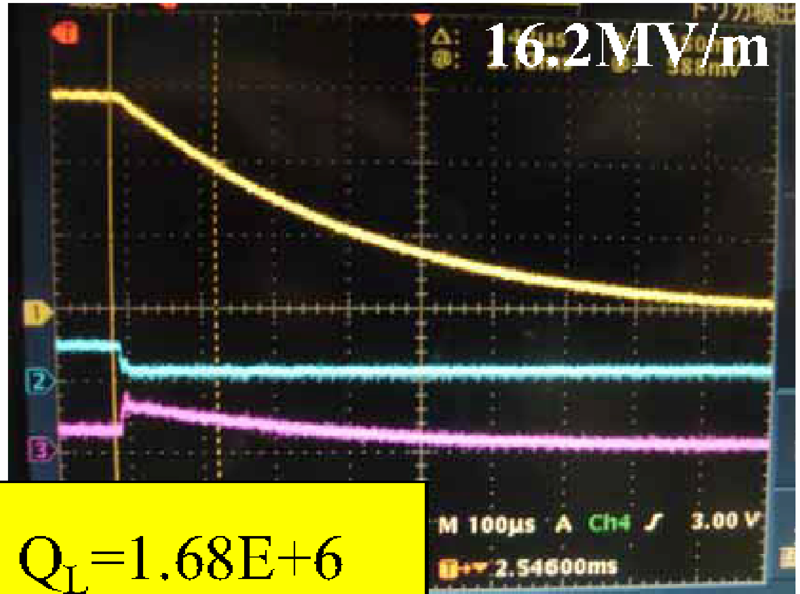
Network Analyzer (Agilent)
dF(BW/2) = 382 Hz
QL = 1.70E 6

SG (Pin, F variation)
+ Power meter (Pt)
dF(BW/2) = 363 Hz
QL = 1.79E 6

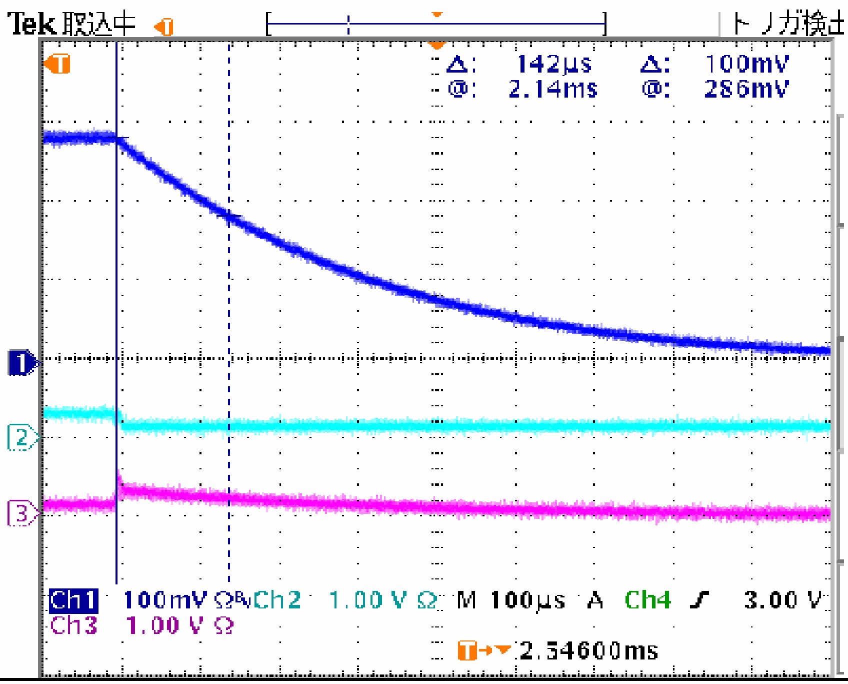
Decay time at 4K
T(1/2) = 150 us
QL = 1.77E 6

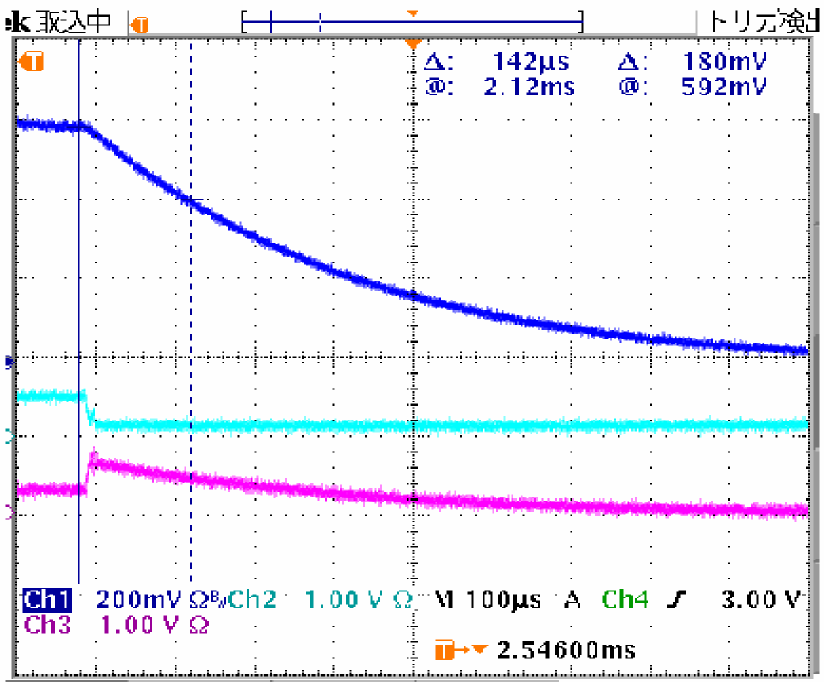
$\tau_{1/2}$ measurement for QL evaluation





$\tau_{1/2}$=142μs, Q_L=1.68E+6





Qt measurements

Pg = Input power at input-coupler
b = Coupling of input-coupler
Q0 = Q of cavity / P0 = Power loss of cavity wall
Qt = Qext of pickup antenna / Pt = Power from pickup antenna
QL = Loaded Q

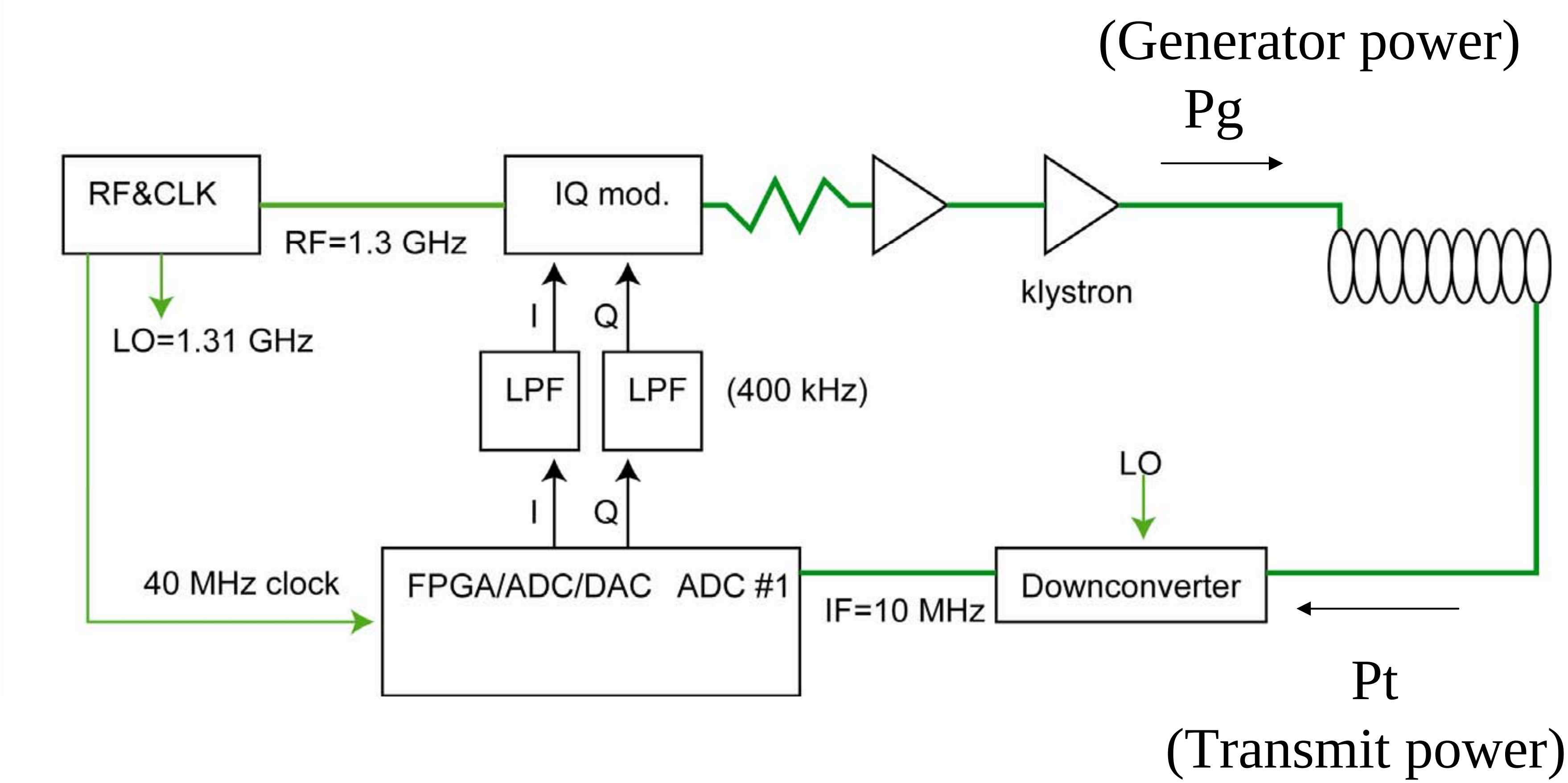
Pg = [(1+b)*P0]**2 / (4*b*P0)
If b>>1, Pg ~ b*P0/4 ----(1)

Pc = Pt * Qt / Q0, b = Q0/Qin, Qin ~ QL ---(2)

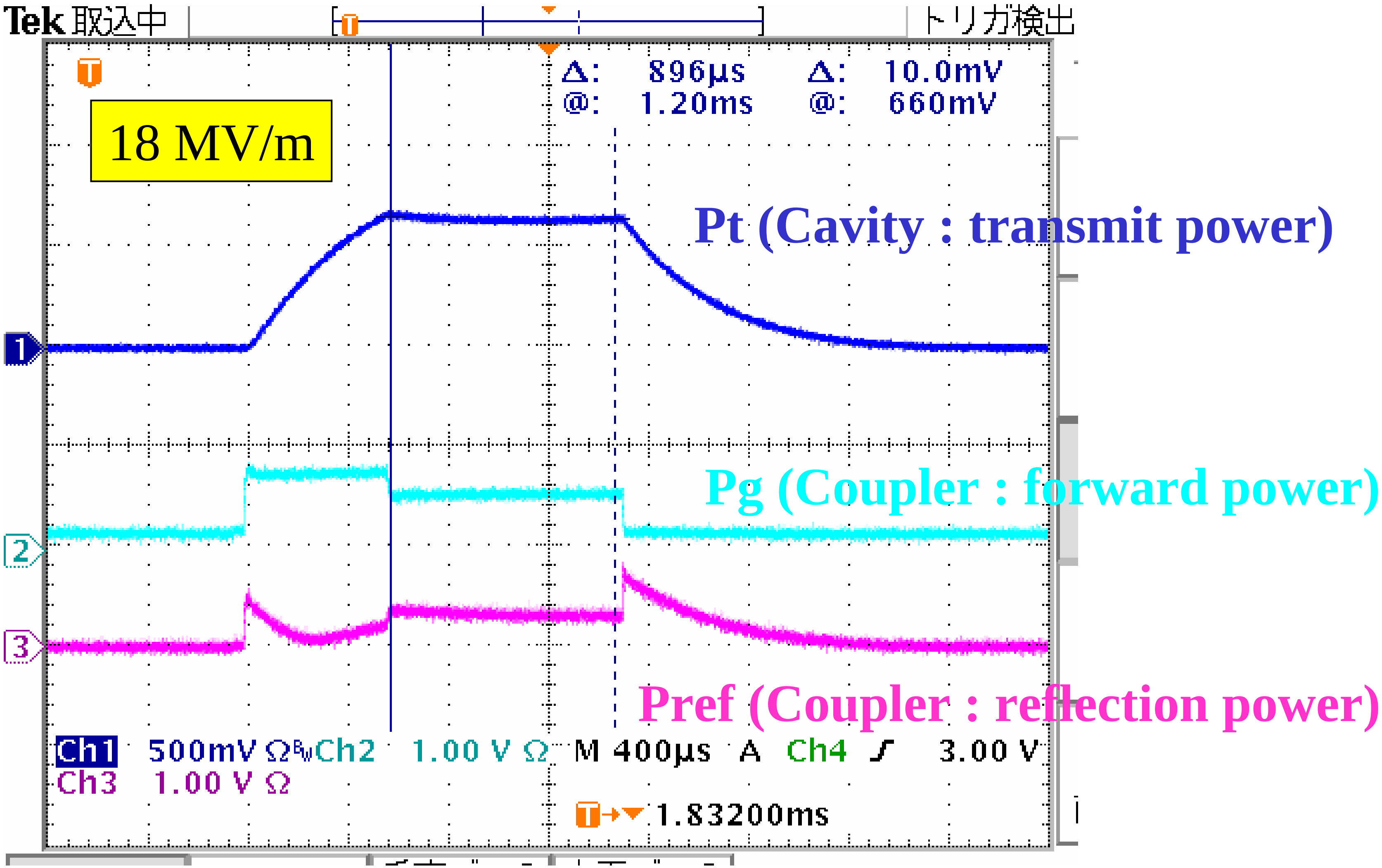
(2) -> (1)
Qt ~ 4*QL * (Pg/Pt) => Pg, Pt measurements => **Qt = 1.03E12**

Qt (target) ~ 5E11

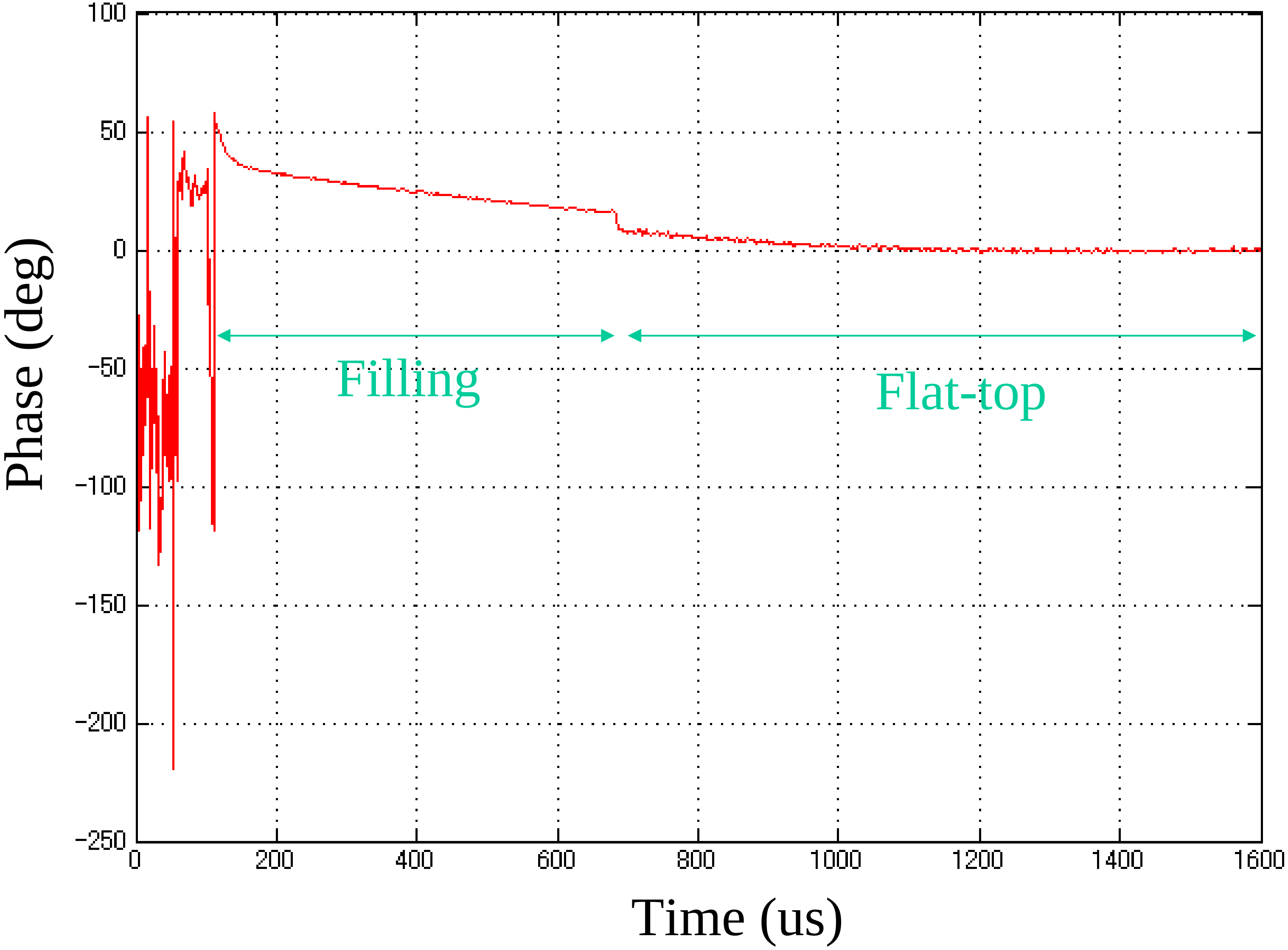
I Q measurement by LLRF



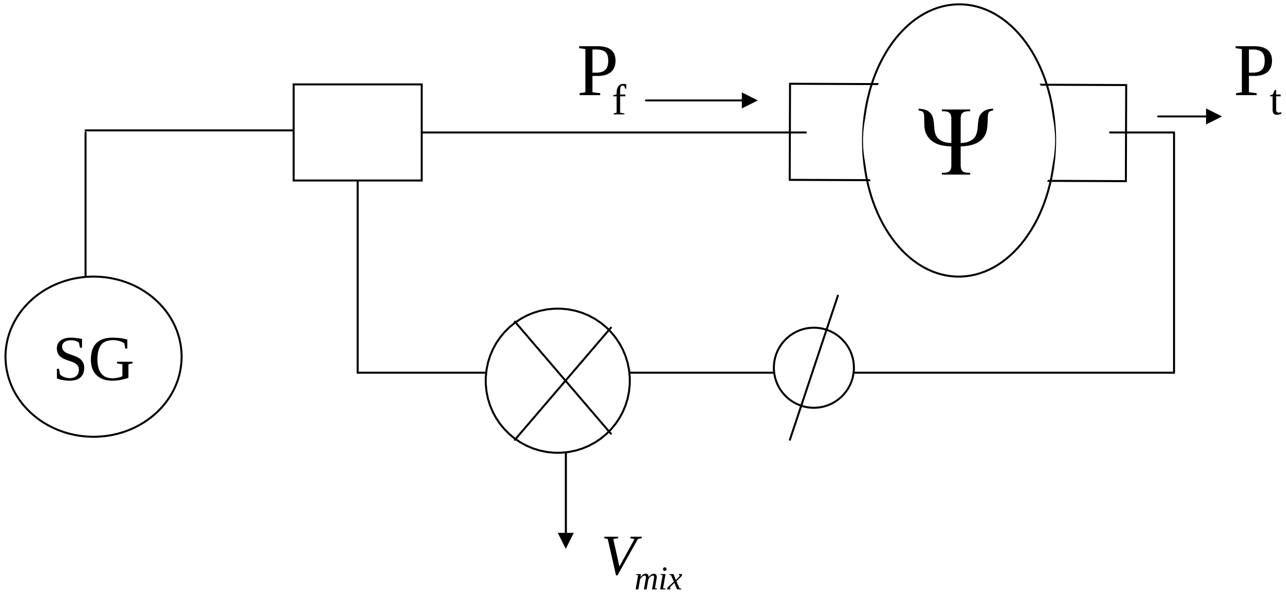
High-power tests



Phase measurements (LLRF)



Phase measurements / Mixer Output vs. Phase



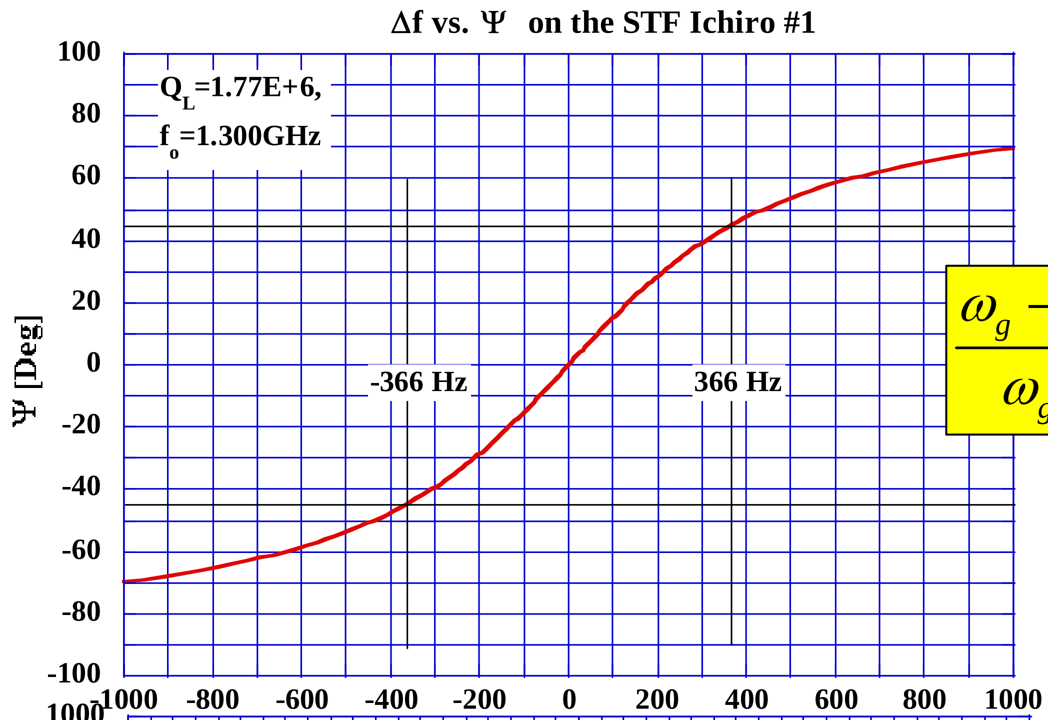
$$V_{Mix} \propto \sin(\Psi)$$

$$= A \cdot \sqrt{P_f} \cdot \sqrt{P_t} \cdot \sin(\Psi)$$

$$= B \cdot P_f \cdot \sqrt{BW} \cdot \sin(\Psi) \quad \because \; P_t \propto U, \quad U = \frac{4P_f / f_0}{(1/Q_L)^2 + (f/f_0 - f_0/f)^2}$$

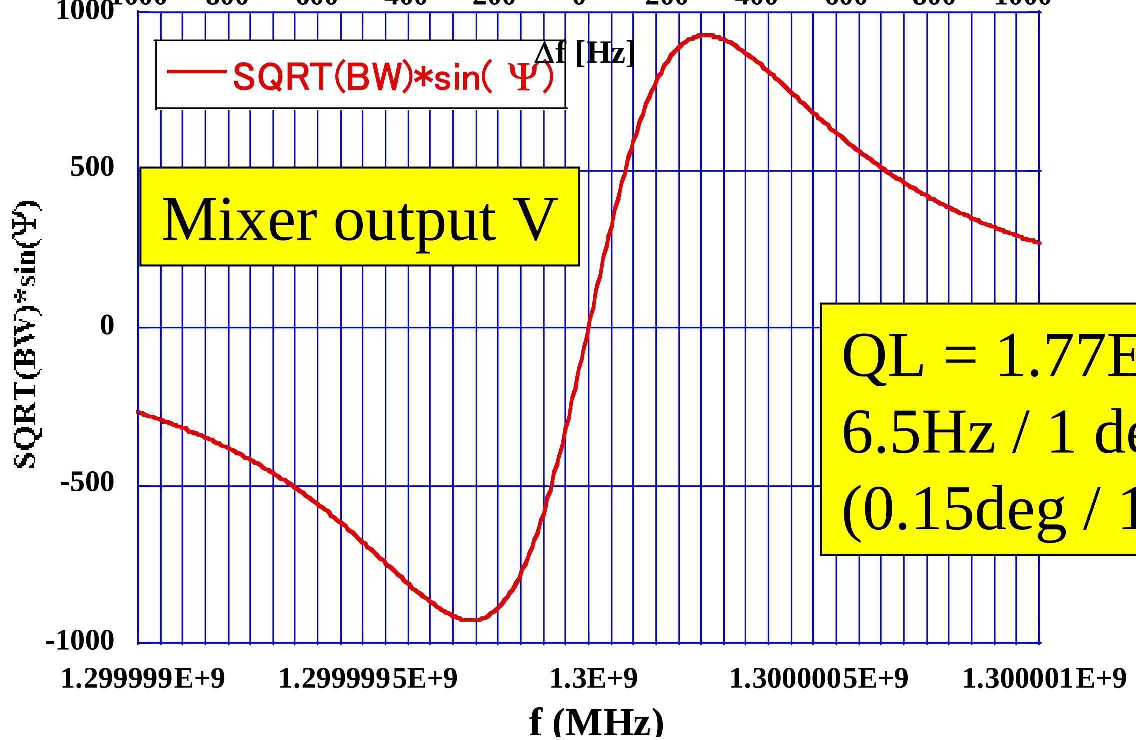
$$BW \equiv \frac{1/f_0}{(1/Q_L)^2 + (f/f_0 - f_0/f)^2}$$

Calculation



$$\frac{\omega_g - \omega}{\omega_g} = \frac{\tan(\Psi)}{2Q_L}$$

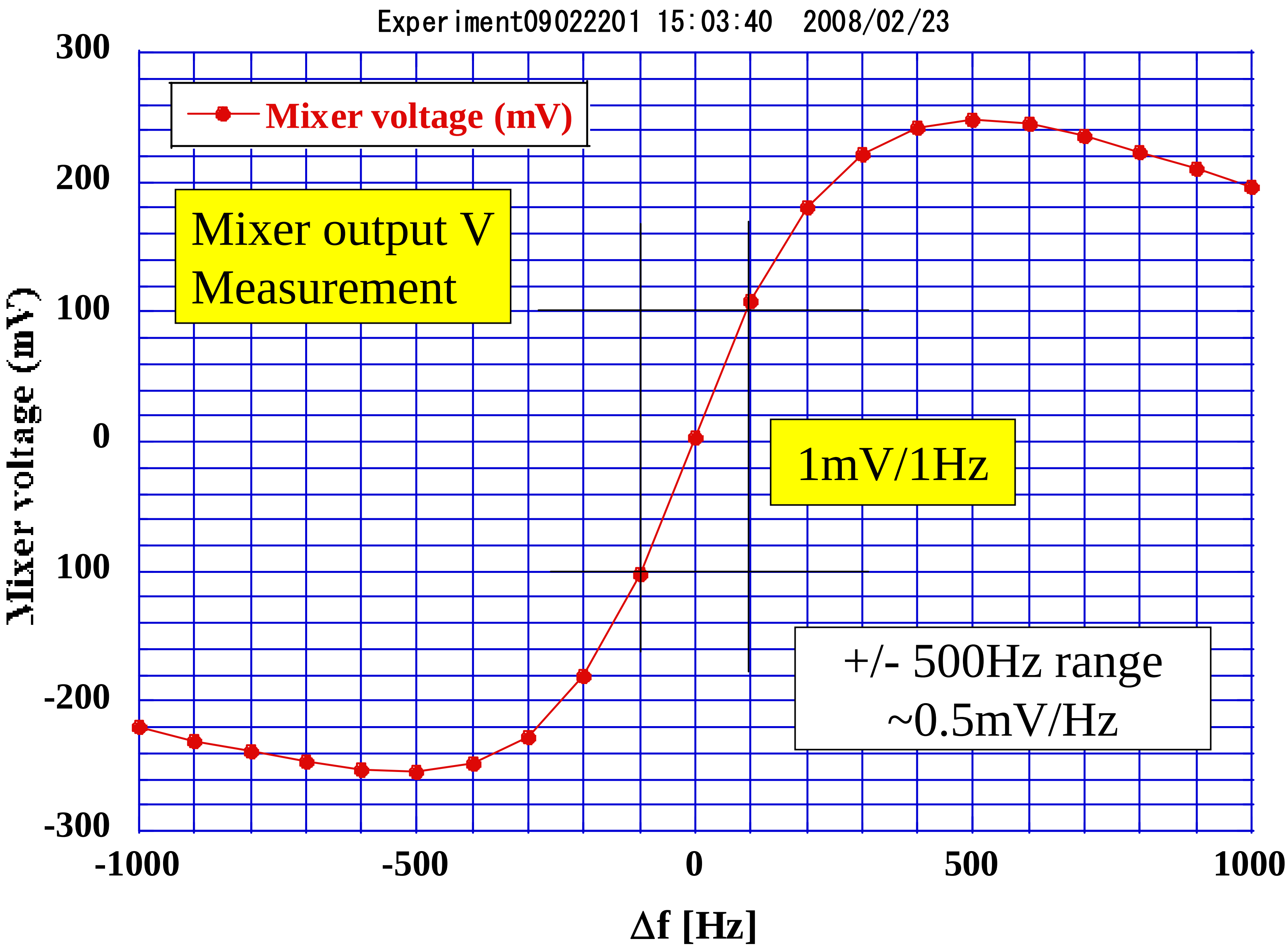
$$\sqrt{BW} \cdot \sin(\Psi)$$



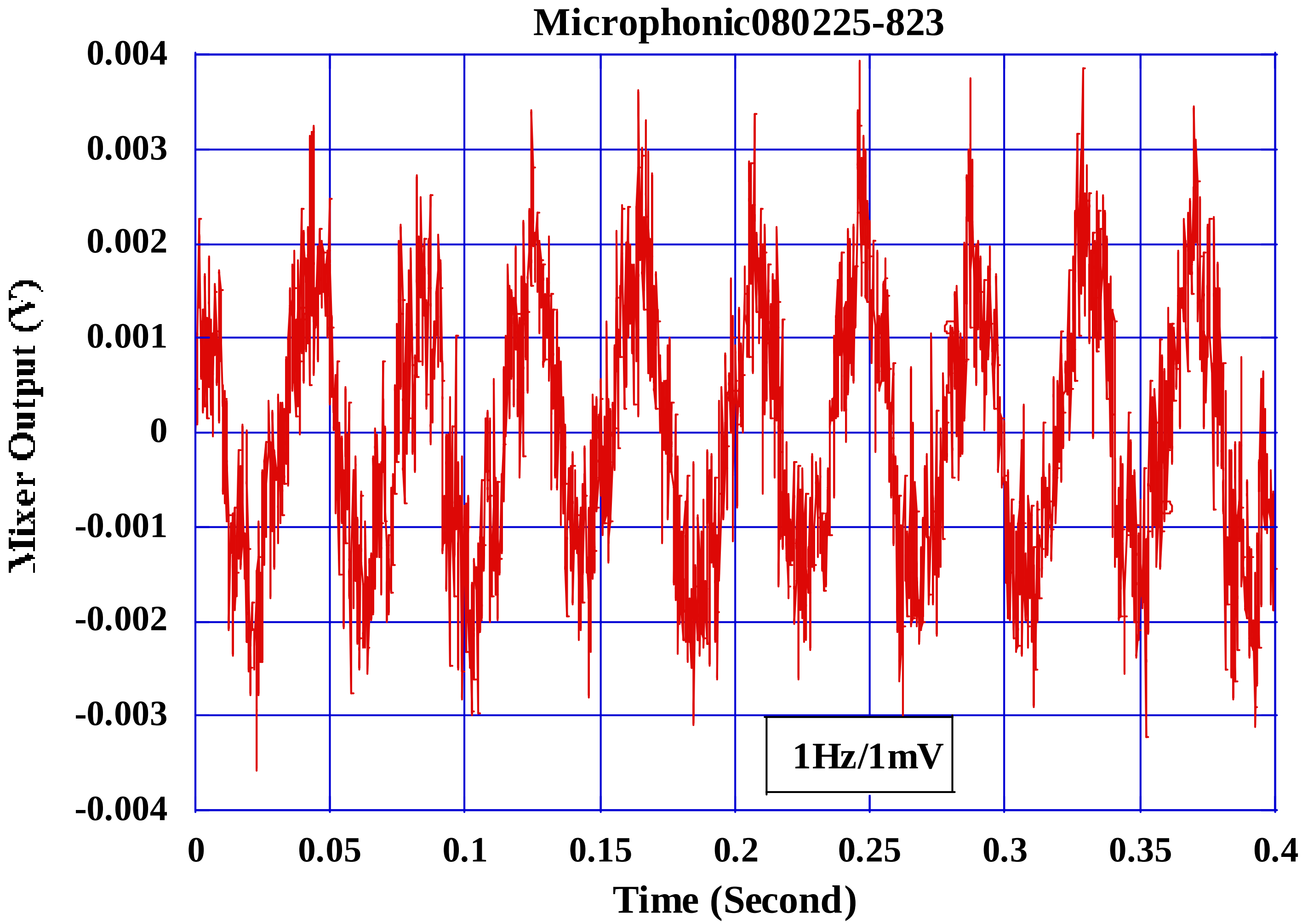
Mixer output V

QL = 1.77E6
6.5Hz / 1 deg
(0.15deg / 1 Hz)

Mixer Output Signal @ 25dBm (Pg)

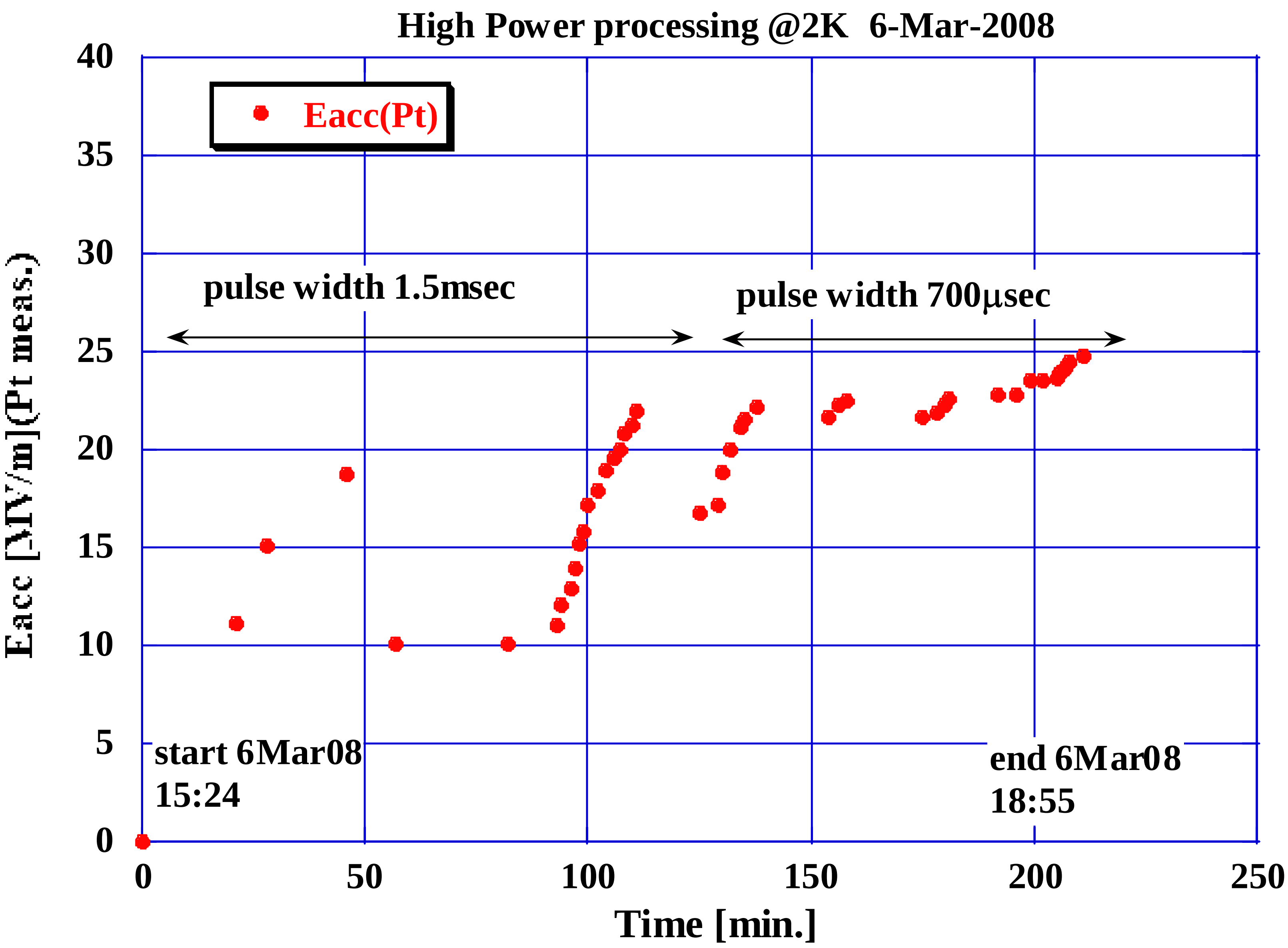


Evaluation of Microphonics



Microphonics is ± 3mV,

which corresponds to ± 3Hz in frequency and ±0.5^{O} in phase variation


High Power processing @2K 6-Mar-2008
Eacc(Pt)
pulse width 1.5msec
pulse width 700μsec
start 6Mar08
15:24
end 6Mar08
18:55
Eacc [MV/m](Pt meas.)
Time [min.]
0
5
10
15
20
25
30
35
40
0
50
100
150
200
250

13:30 ~

Radiation Measurement

Eacc= 1 – 17MV/ @ 1.9ms, 18-25MV/m @700ms, f=1300.133342Hz @ -300Hz off-set, Fig.1.

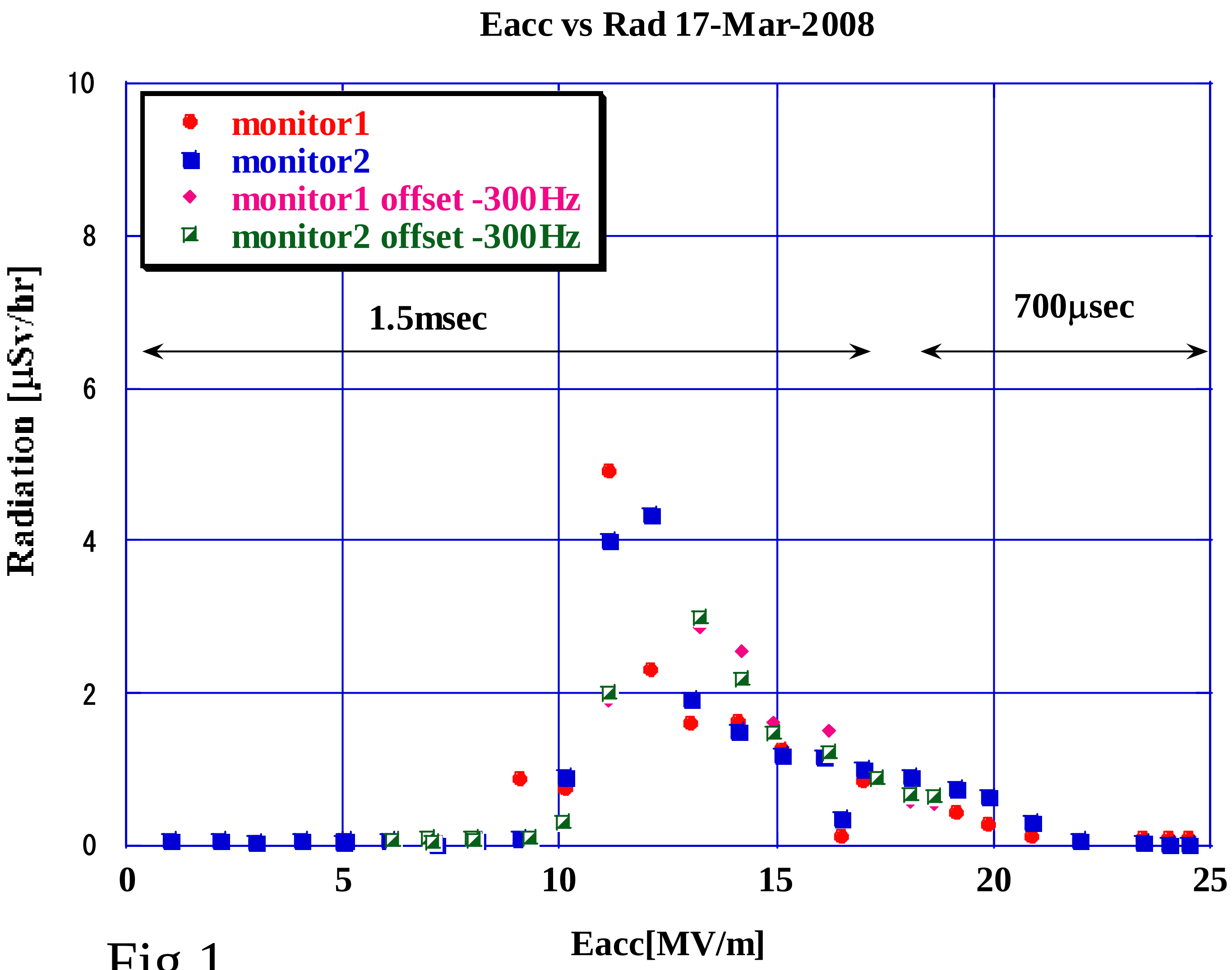
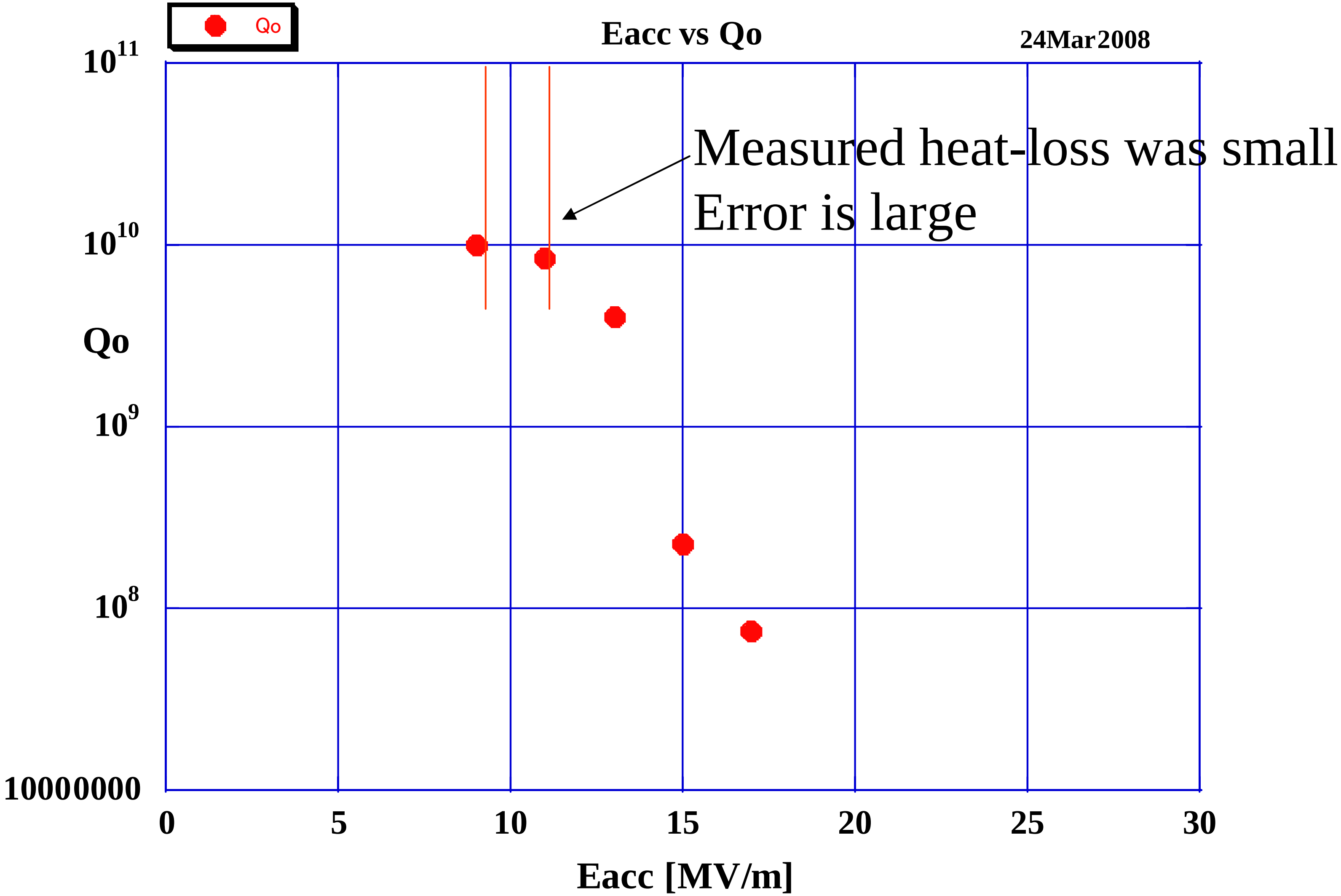


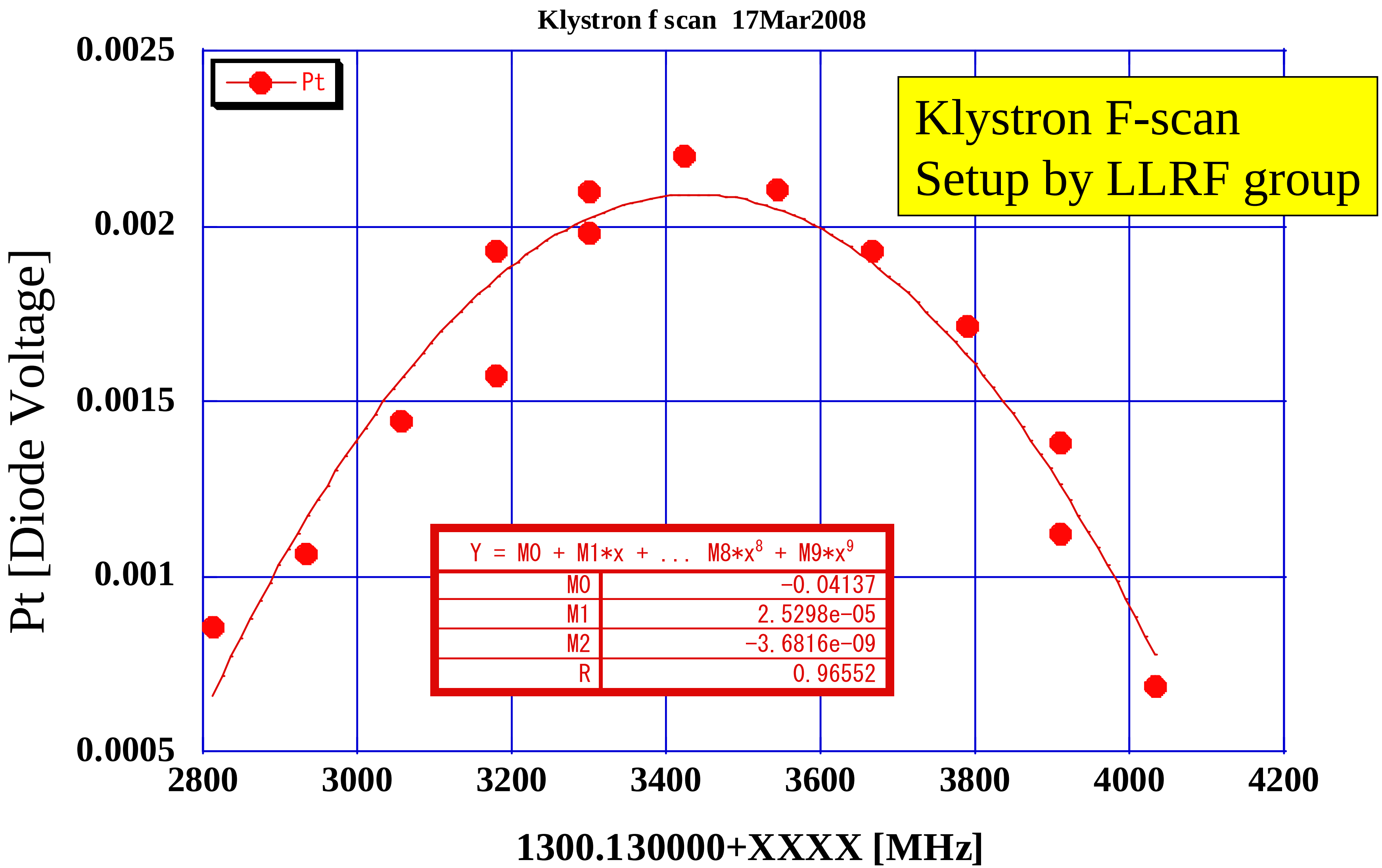
Fig.1

Radiation is very small, less than 5mSv/hr.

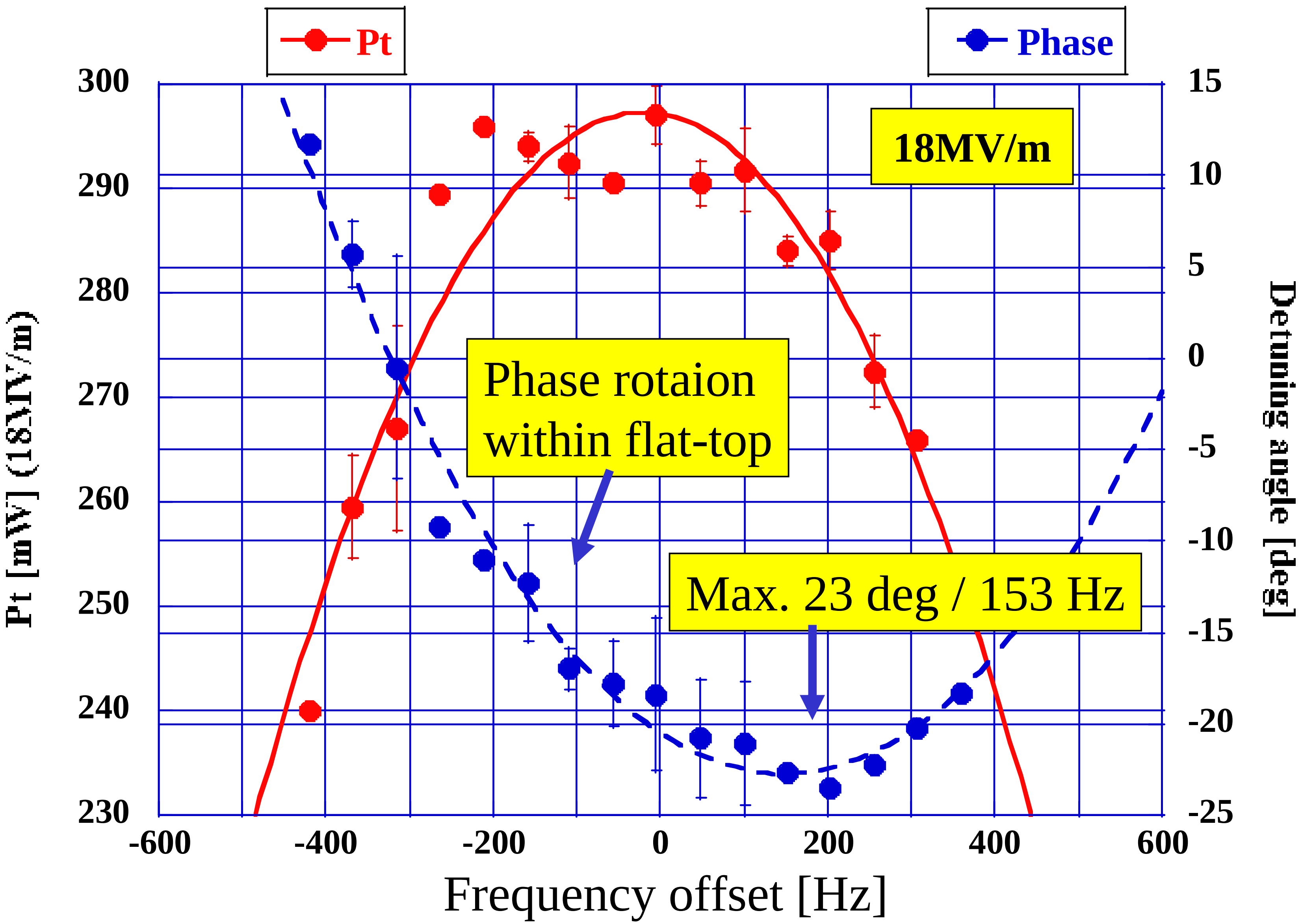
Q0 measurements



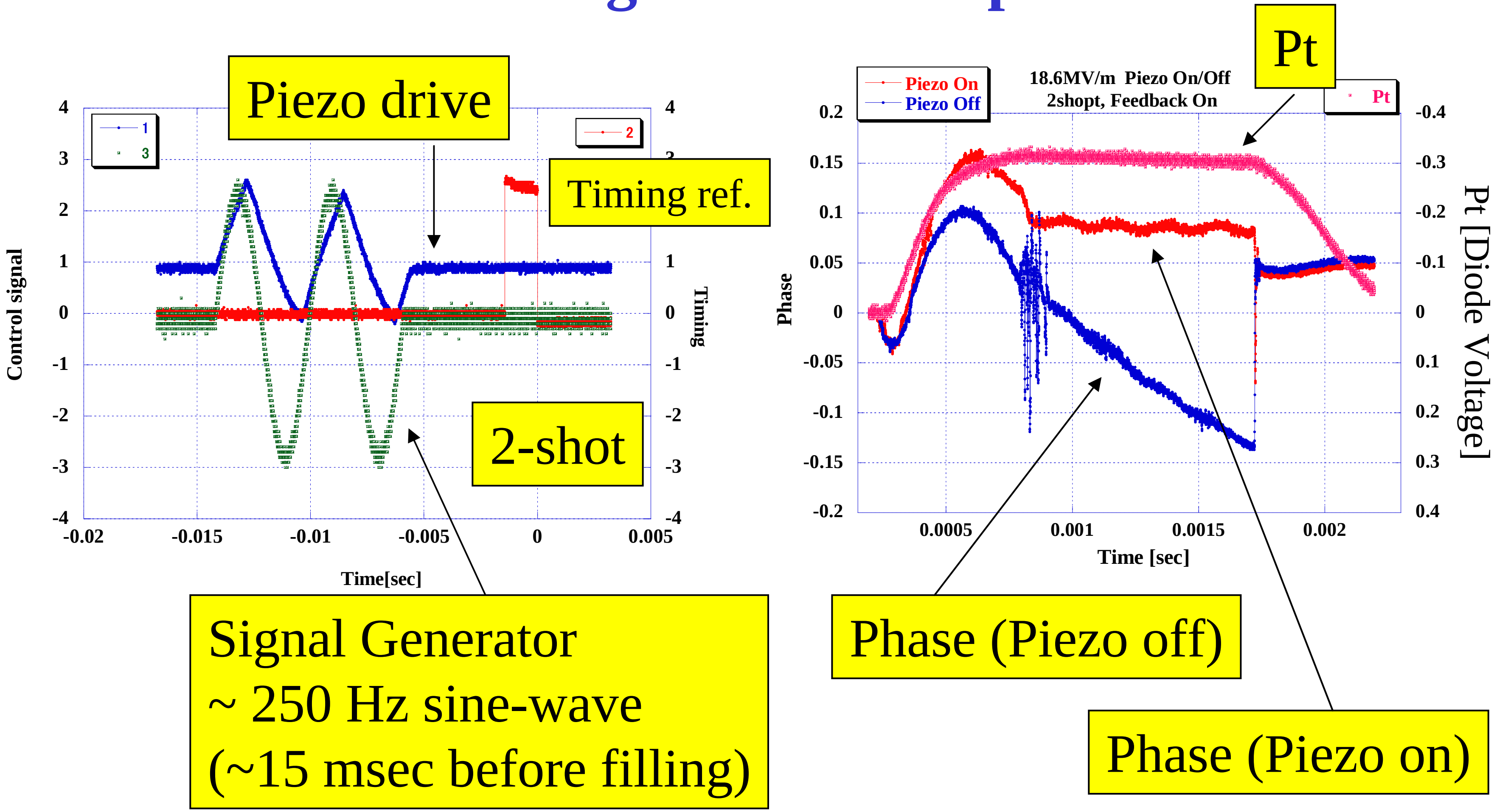
Pt vs. frequency by Klystron f-Scan



Frequency offset vs. Pt / detuning @ 18MV/m

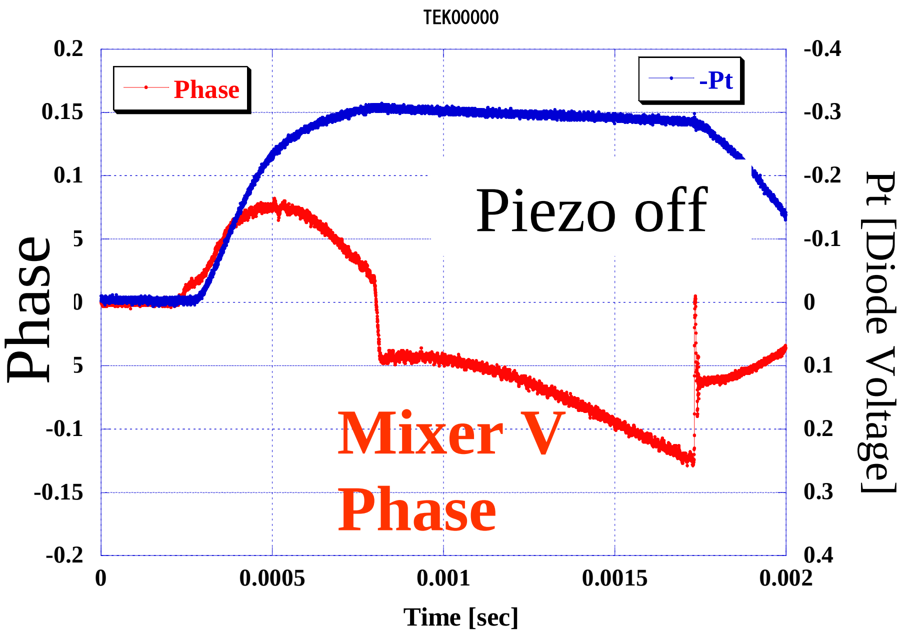


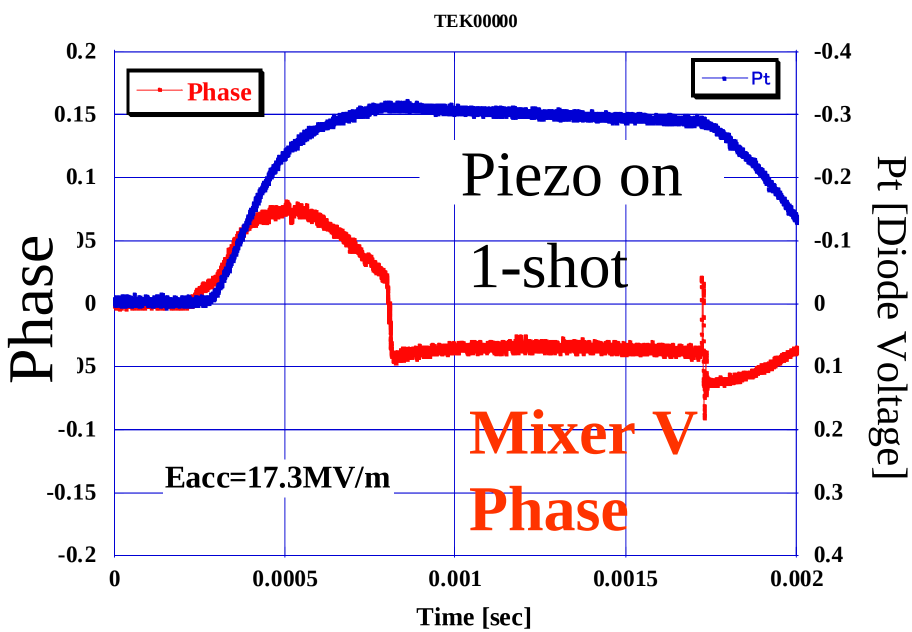
Piezo drive voltage / Piezo compensation

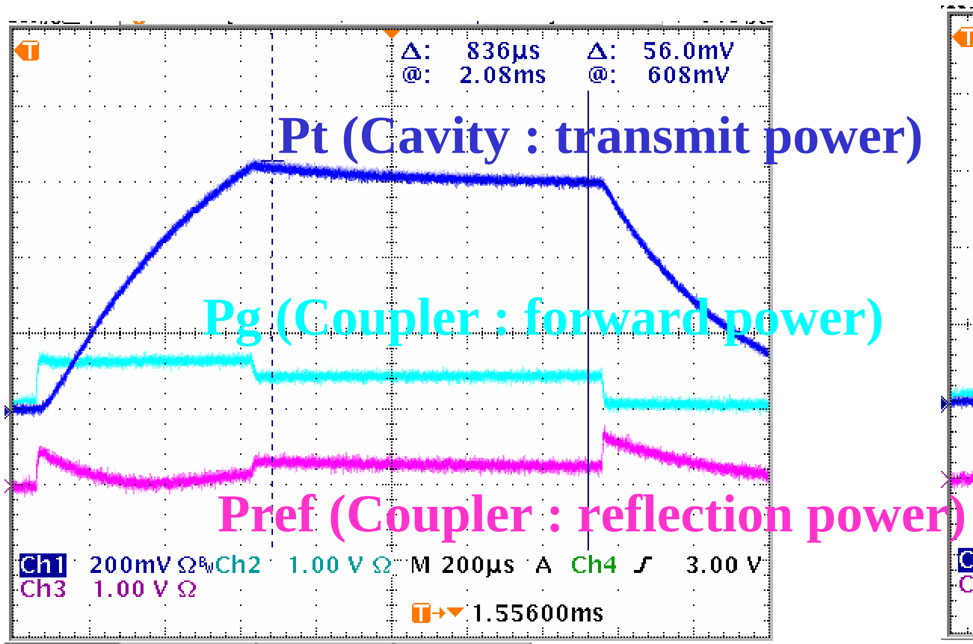


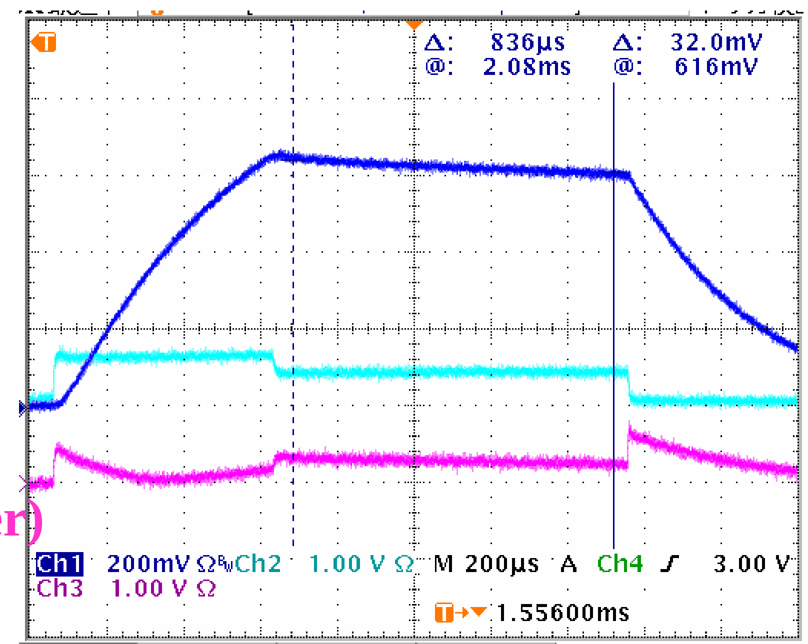
Combination of slow-tuner offset + Piezo (1-shot, 2-shot, 3-shot) could compensate Lorentz Force Detuning appropriately.
Below the Eacc of 20 MV/m, only 1-shot piezo was enough to compensate Lorentz Force Detuning.

L.D compensation by Off-set (+150Hz) + Piezo (~200Hz) @ 17 MV/m

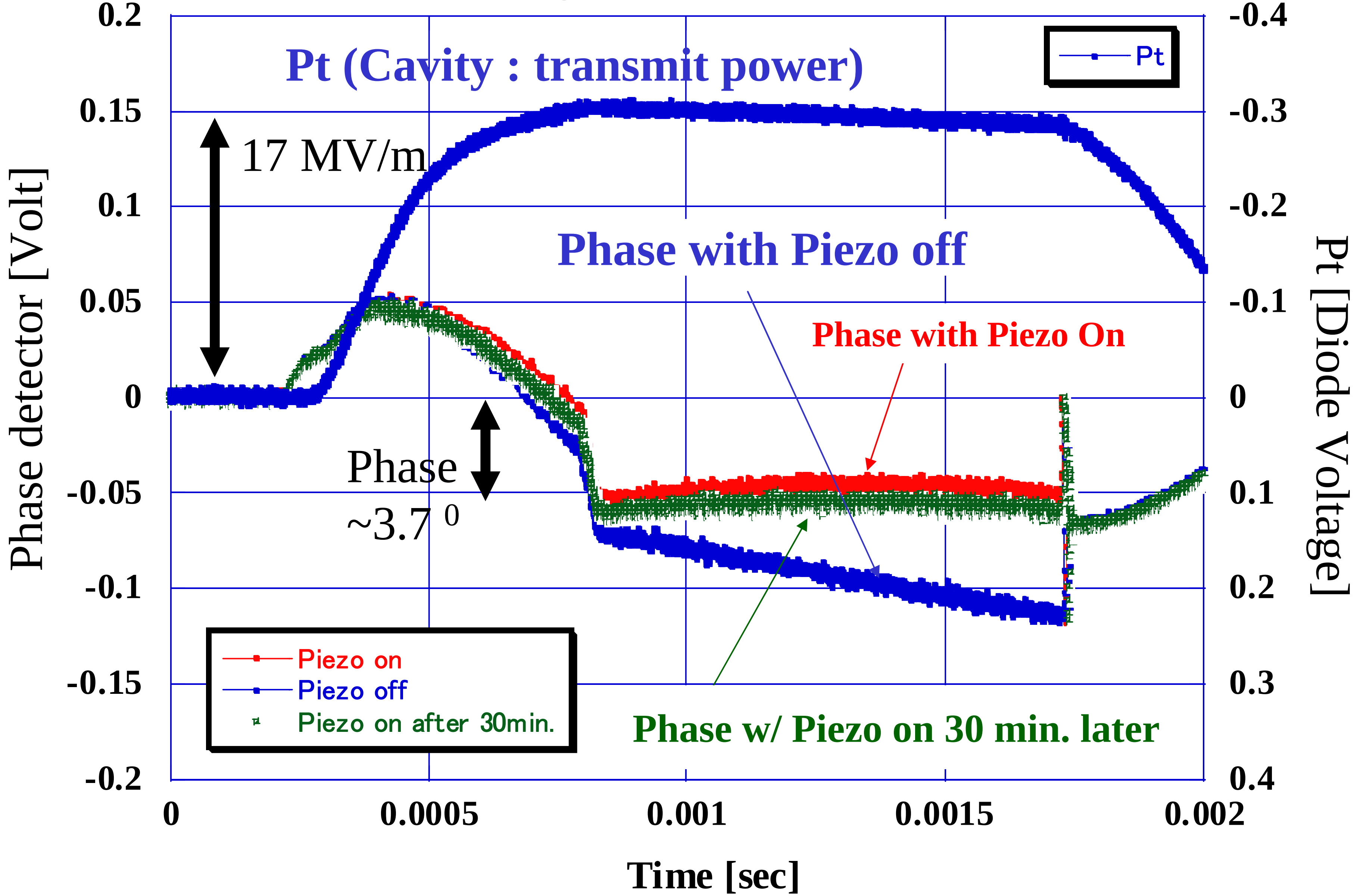




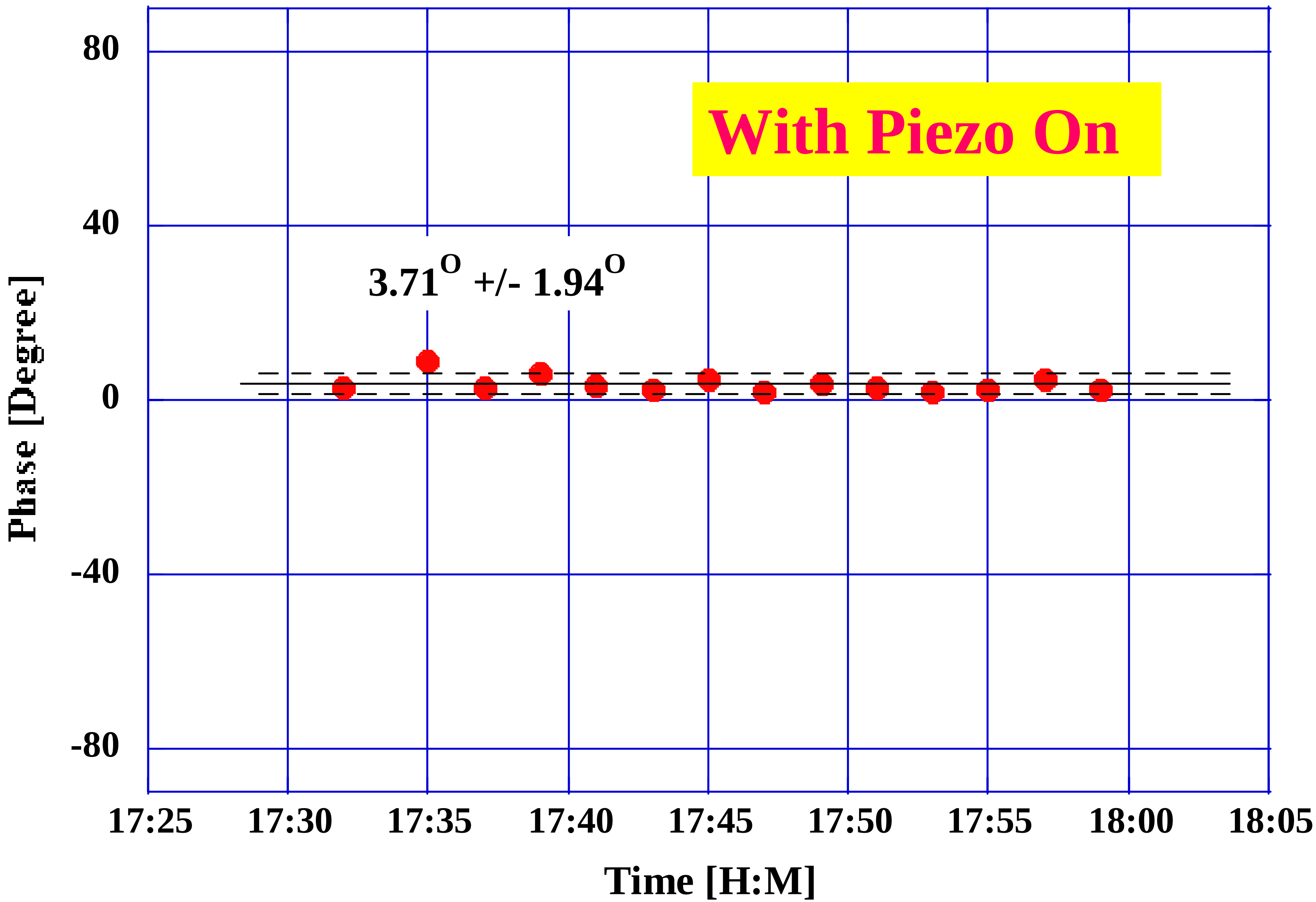




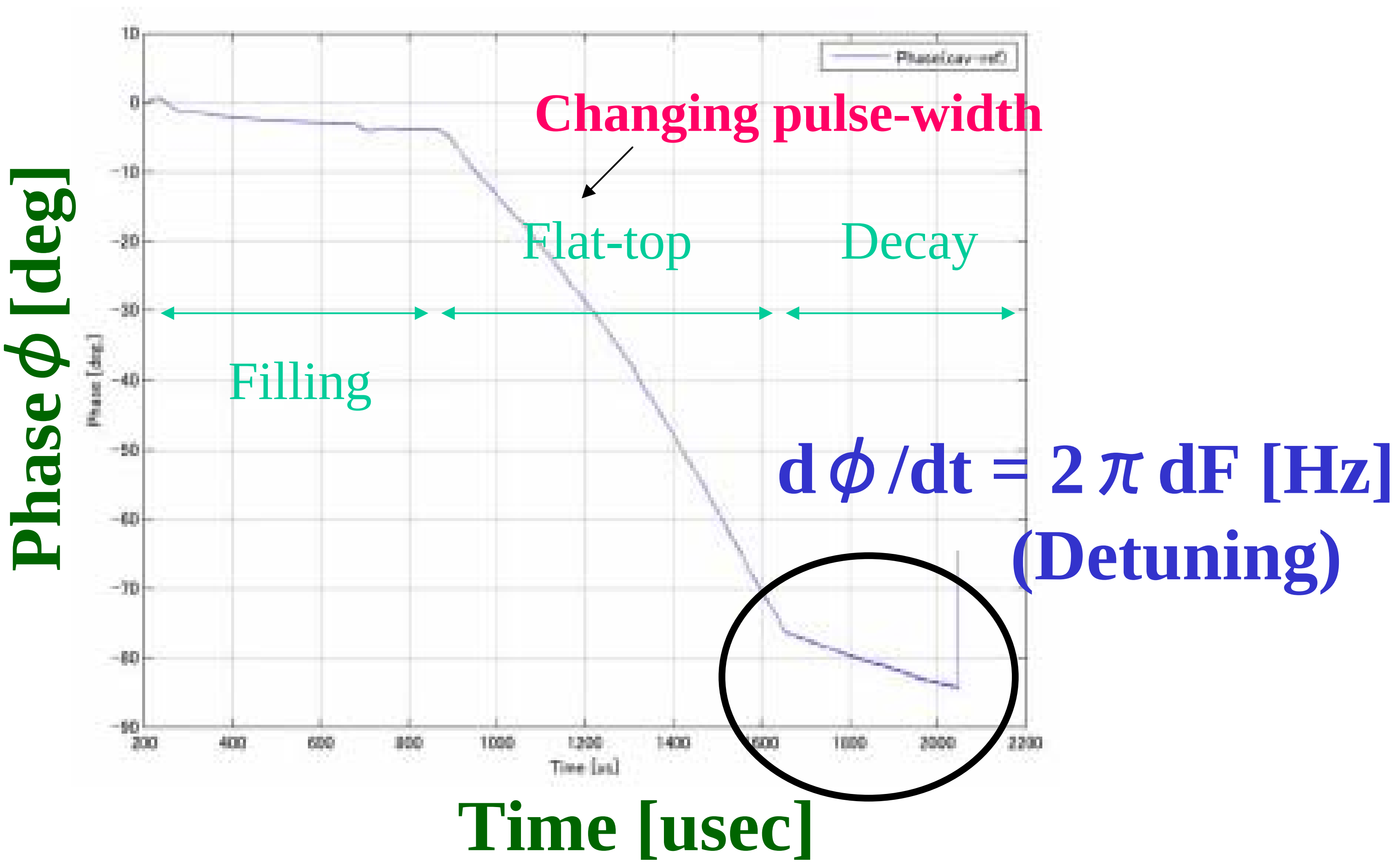
Phase stability during 30-mim operation @ 17MV/m

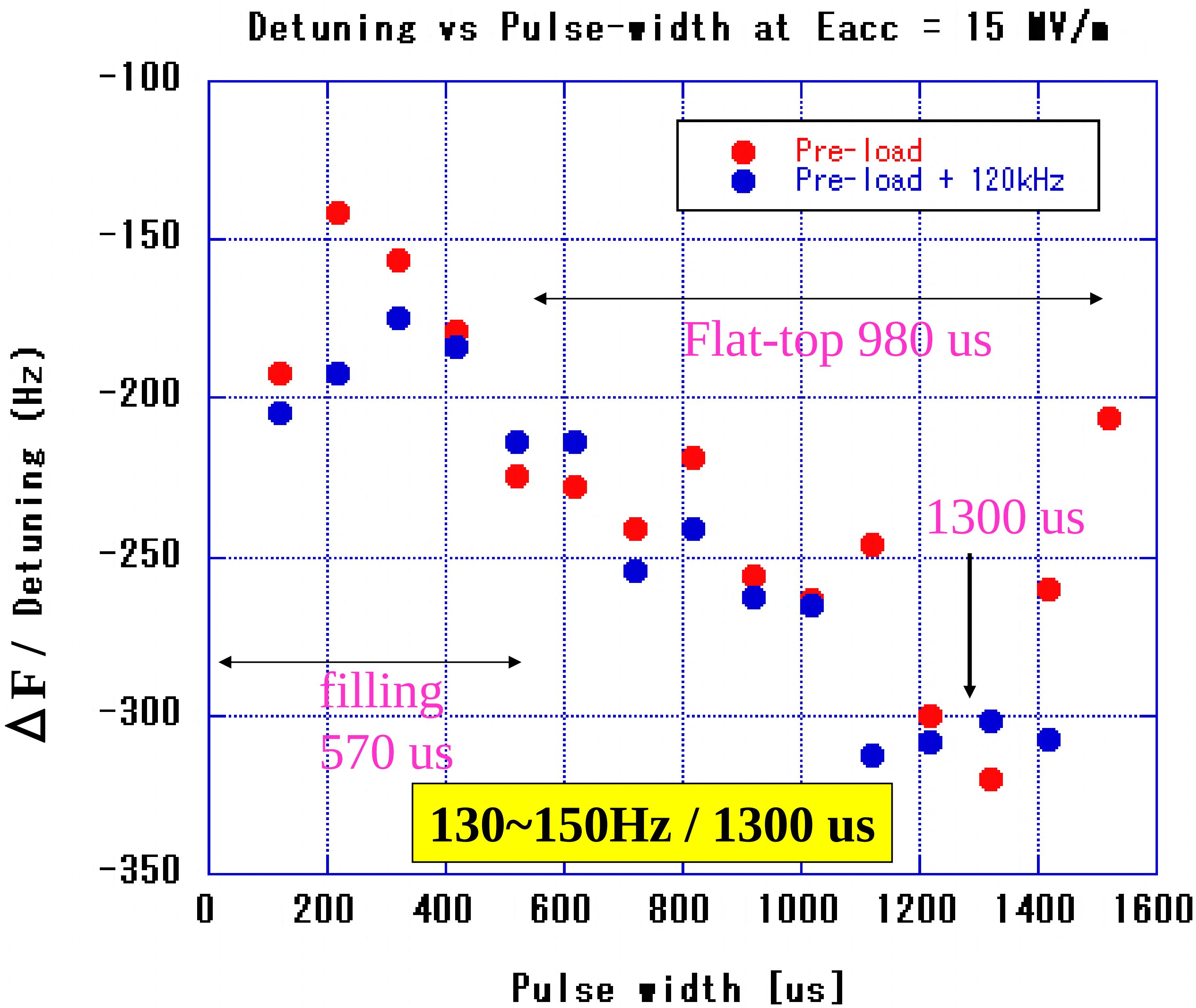


Phase stability during 30-minutes operation @ 17MV/m



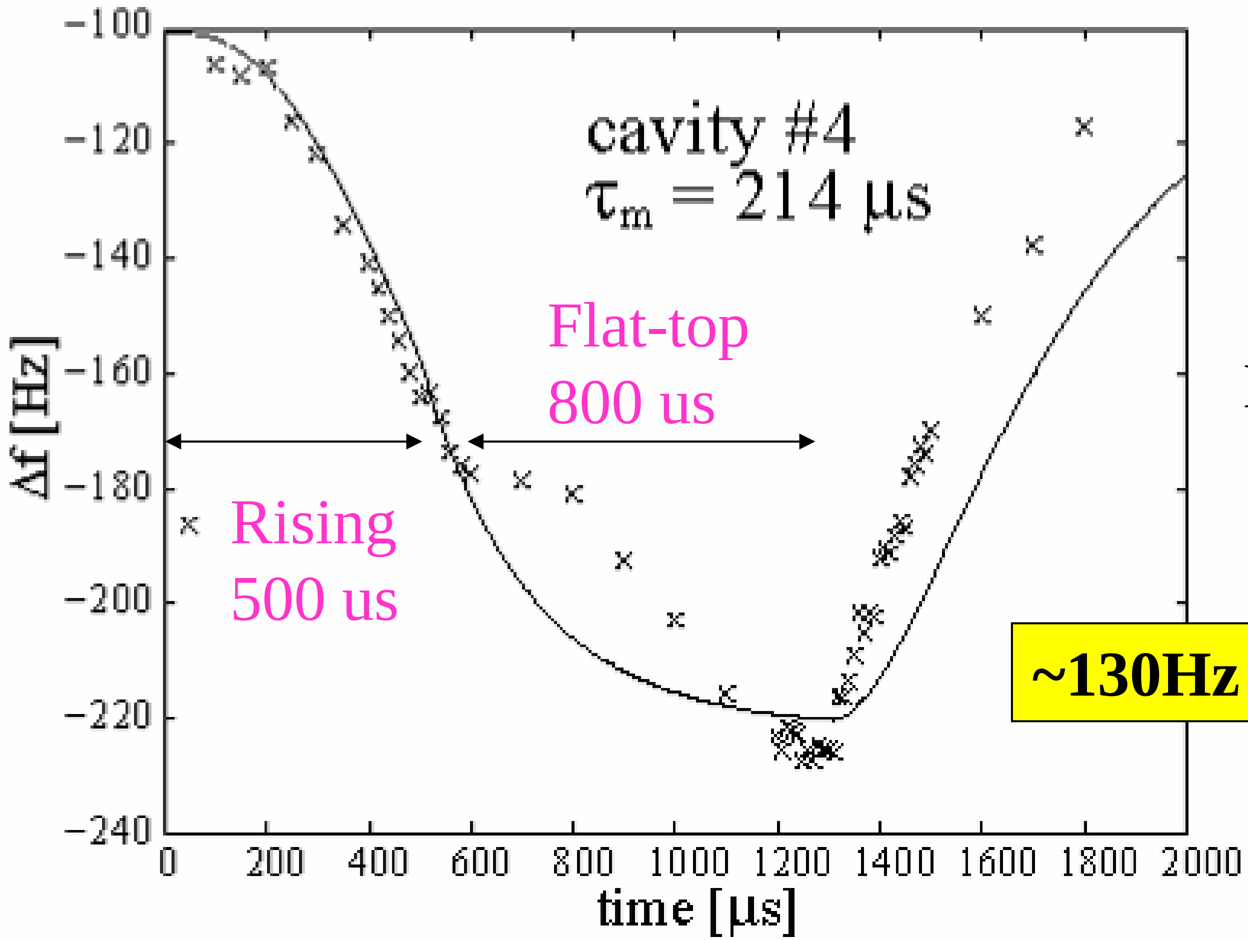
dϕ/dt analysis





Detuning vs Pulse-width at Eacc = 15 MV/m
Pre-load
Pre-load + 120kHz
Flat-top 980 us
1300 us
filling
570 us
130~150Hz / 1300 us
ΔF / Detuning (Hz)
Pulse width [us]
-100
-150
-200
-250
-300
-350
0
200
400
600
800
1000
1200
1400
1600

Data of TESLA cavity from Schilcher (1998)

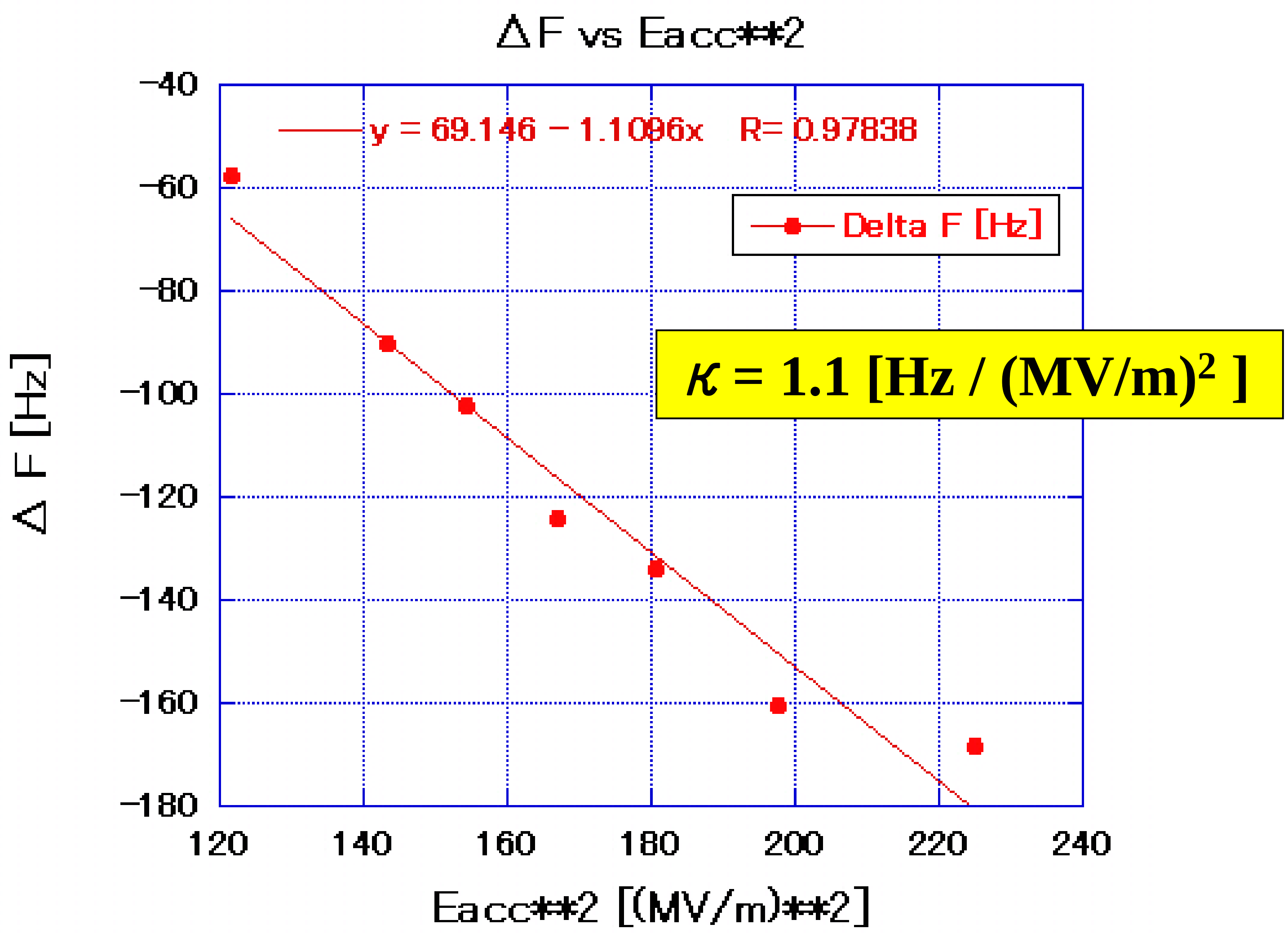


Eacc =
15 MV/m

~130Hz / 1300 us

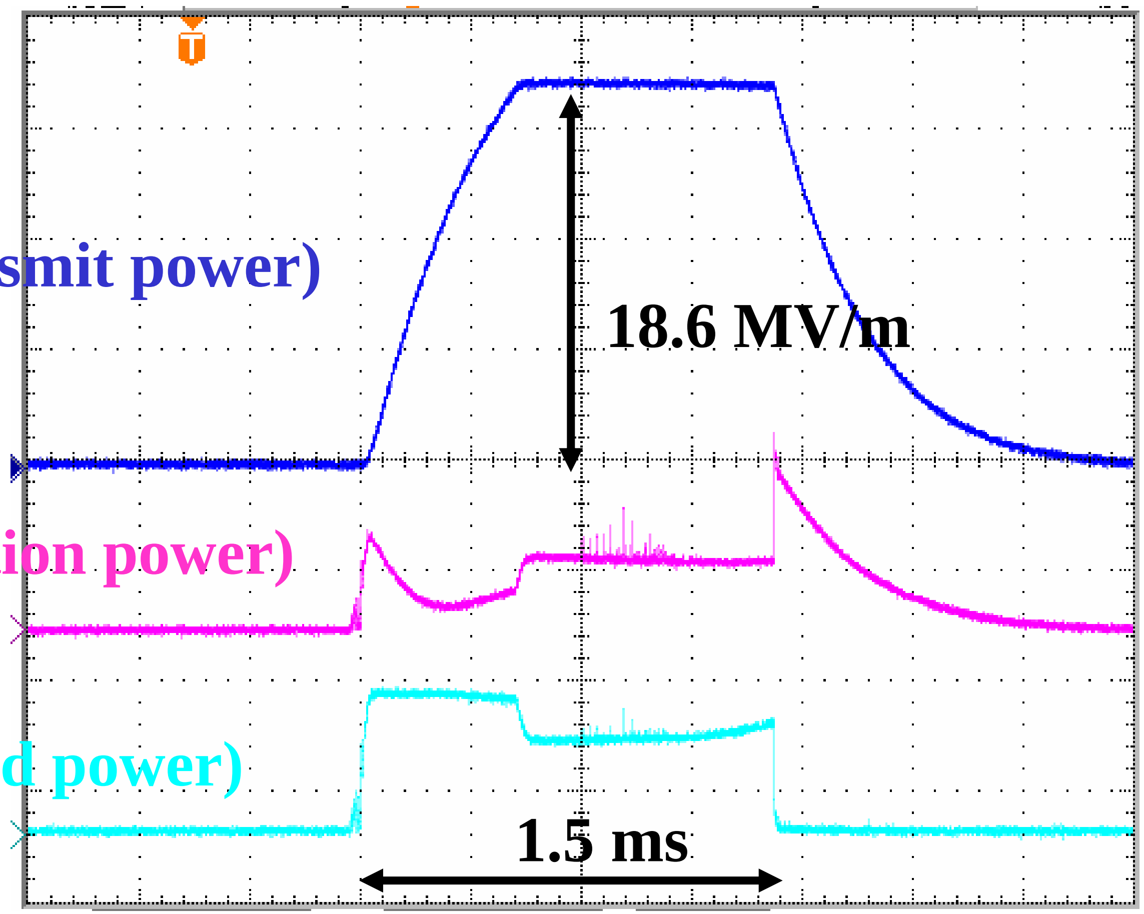
Vector Sum Control of Pulsed Accelerating Fields in Lorentz Force Detuned Superconducting Cavity, Thomas Schilcher (1998) P109 Fig 6.7

Δ F vs. Eacc^2 (Filling + flat-top)



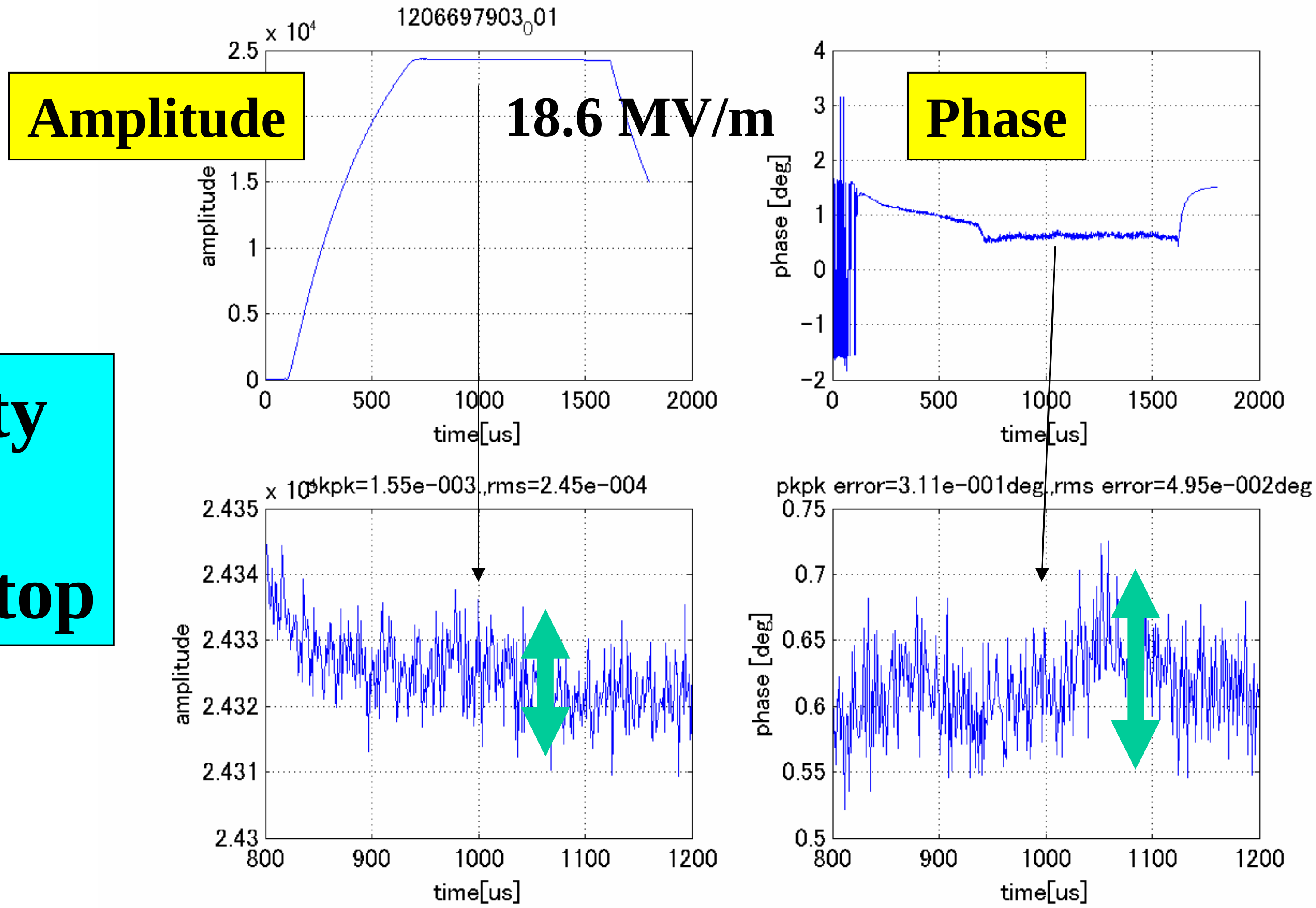
Stable operation at Eacc=18.6 MV/m

Digital Feed-back On & Piezo On



Digital Feed-back applied by LLRF Group

Stability at flat-top



Δ Amp. < 3.1 E -4 (rms)

Δ phase < 5.0 E -2 (rms)

Summary

- Leak-tight at 2K / HIP bonding (SUS/Nb)
- QL = 1.7E6 / dF(BW/2) = 380 Hz / Qt = 1.0E12
- Microphonics ~$\pm 0.5^{0}$ ($\pm$3 Hz)
- High-power processing : 22 MV/m / 1.5 ms
- No X-ray if Eacc > 20 MV/m, Quench limited
- LFD ~ 23 deg /153 Hz (within Flat-top) @ 18 MV/m
- Slow-tuner offset / Piezo worked successfully
- Stability of phase w/ Piezo-on < 2 deg @ 17 MV/m
- LDF = 130–150 Hz / 1300 us (filling+flat-top) @ 15 MV/m
- ΔAmp.< 3.1E-4 (rms), Δphase < 5.0E-2(rms) by FB of LLRF group
- See more at http://lcdev.kek.jp/ILC-AsiaWG/WG5notes/

Some slides of ball-screw tuner for discussions

Tuner Specification

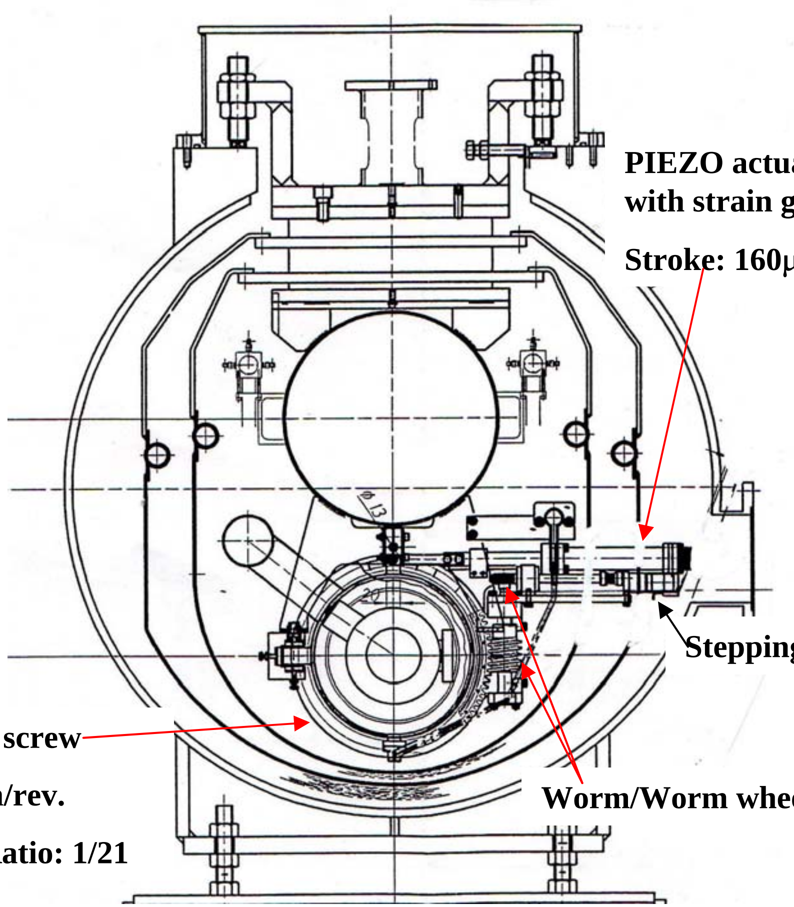
Power transmission

Basically transforms azimuthally rotation in the longitudinal direction

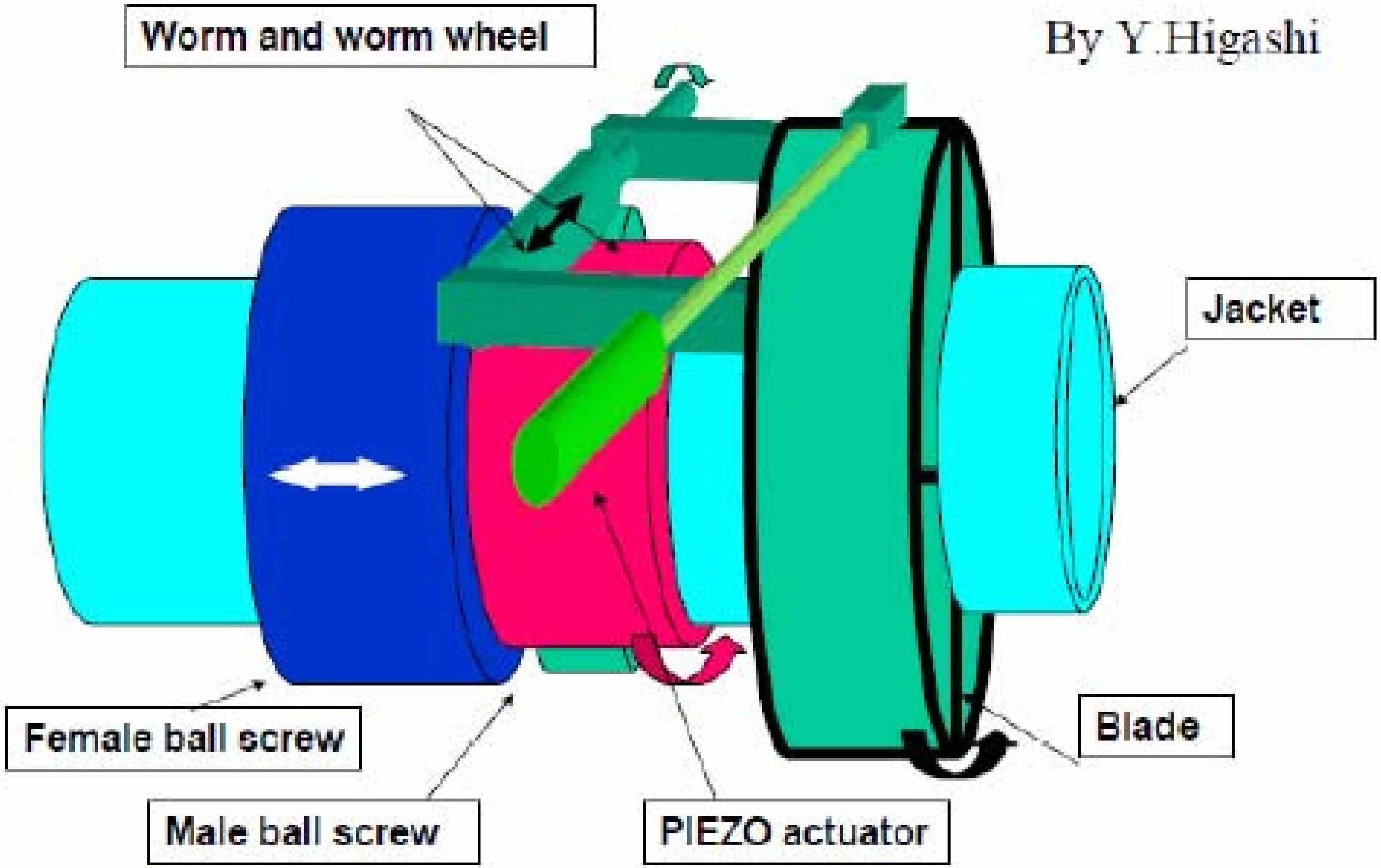
Slow Tuner: pulse motor → worm/wheel → ball screw

Fast Tuner: PIEZO → push worm gear shaft → wheel → ball screw

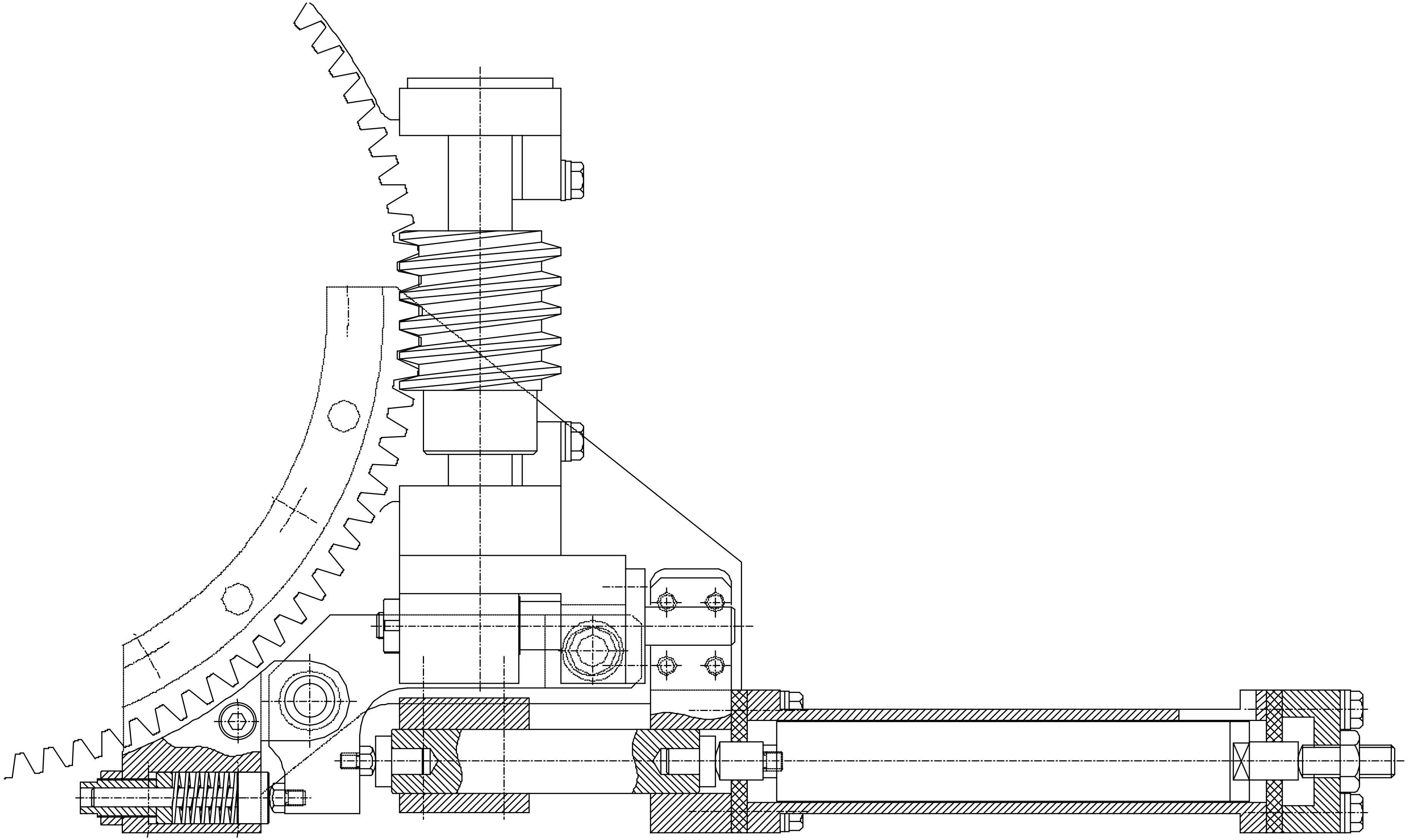
Tuner mechanism	Ball screw
Motor location	Outside 80K shield
Motor power	0.1 W
PIEZO location	Outside 80K shield
Slow tuning range	+/- 1.5 MHz
Fast tuning range	1.5 kHz
Resolution Slow/Fast	< 0.1Hz/ < 0.1Hz
Payload (dressed cavity)	125 kGw

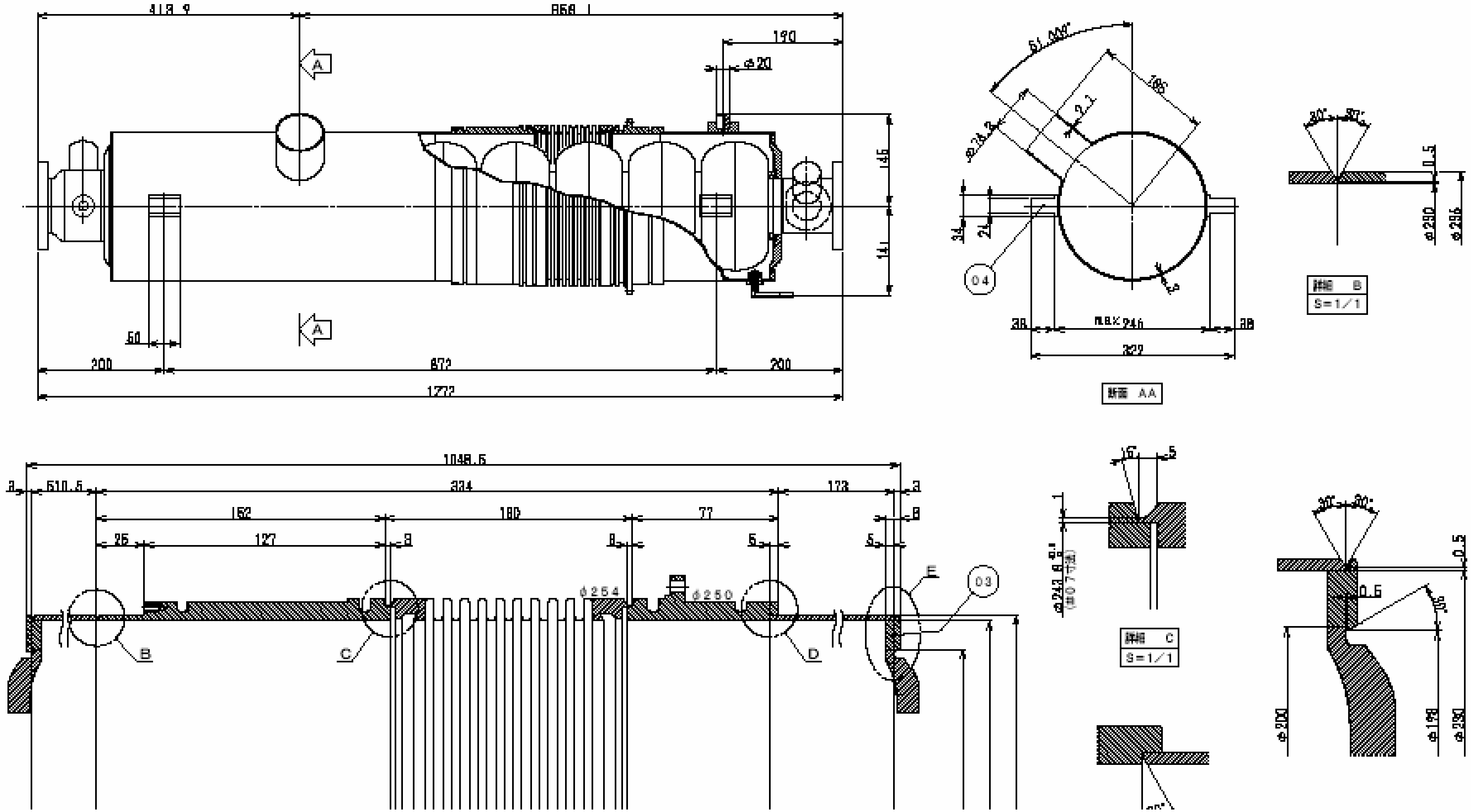


Coaxial ball screw tuner principle

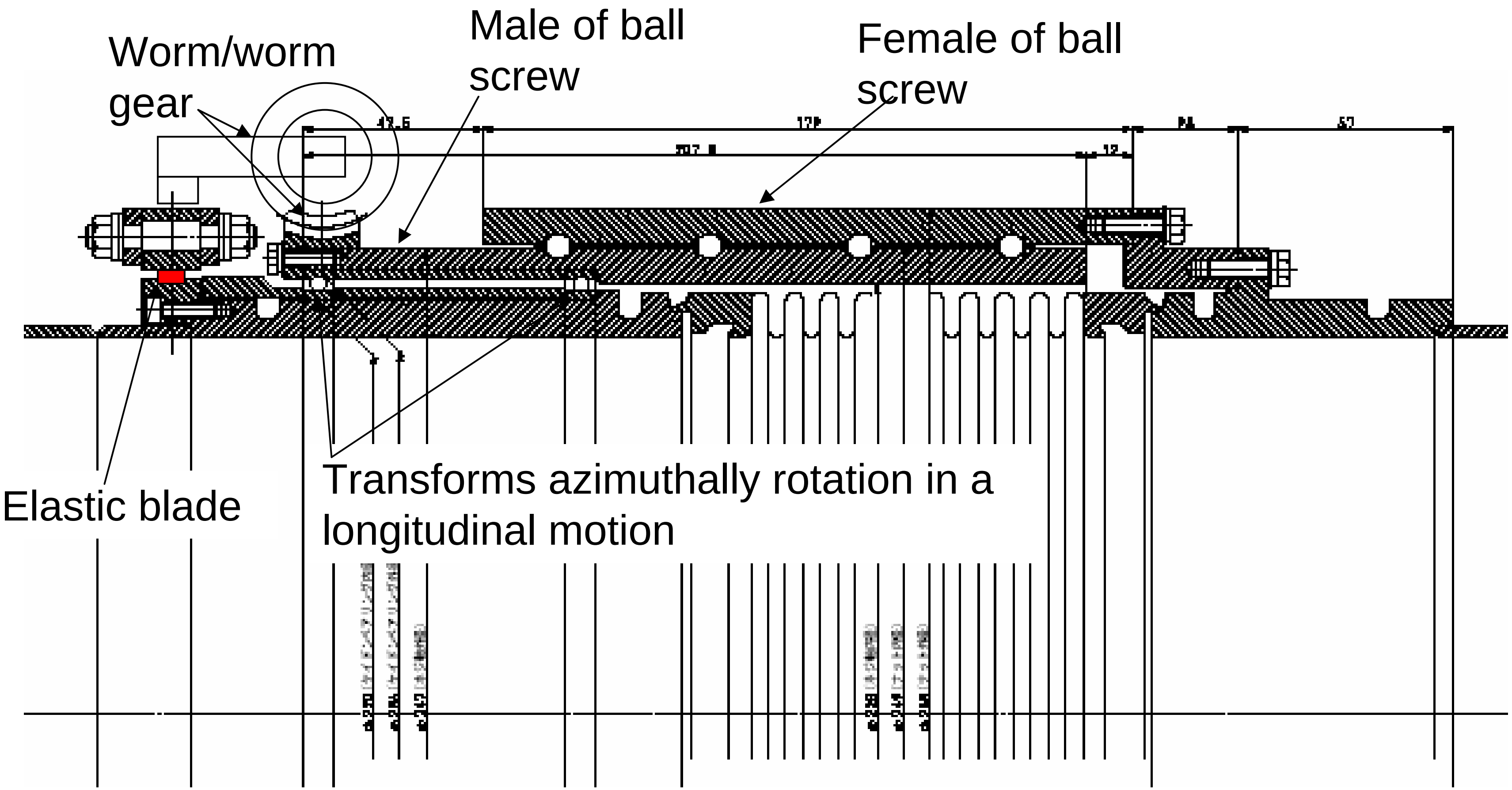


Mechanical booster mechanism





418.9
858.1
190
φ20
A
146
141
50
200
872
200
1272
185
2.1
34
24
04
38
max 246
38
322
断面 AA
30°
30°
0.5
φ290
φ296
詳細 B
S=1/1
1048.5
3
334
173
152
180
77
25
127
8
5
φ254
φ250
B
C
D
E
03
5
1
詳細 C
S=1/1
0.5
φ200
φ198
φ230



1.35 μm/1000pulse (for Pulse motor)