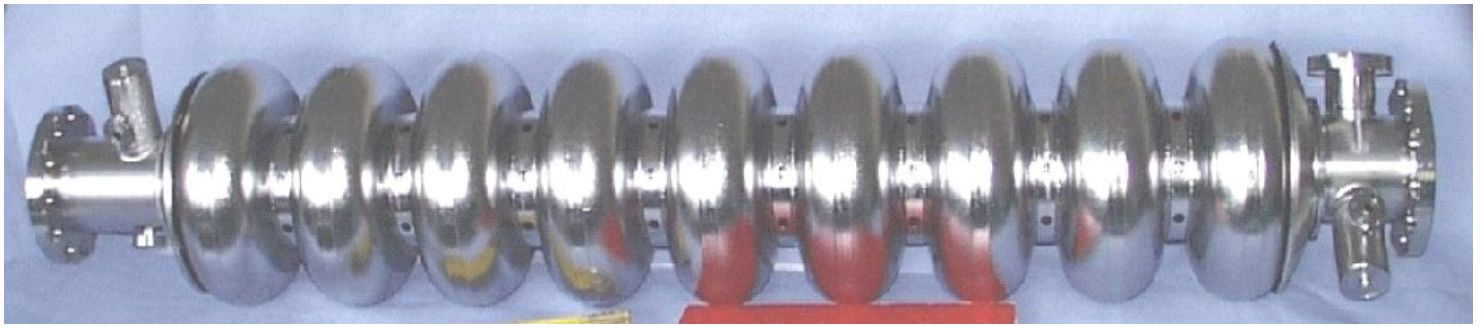
Detuning compensation during FLASH 9mA tests

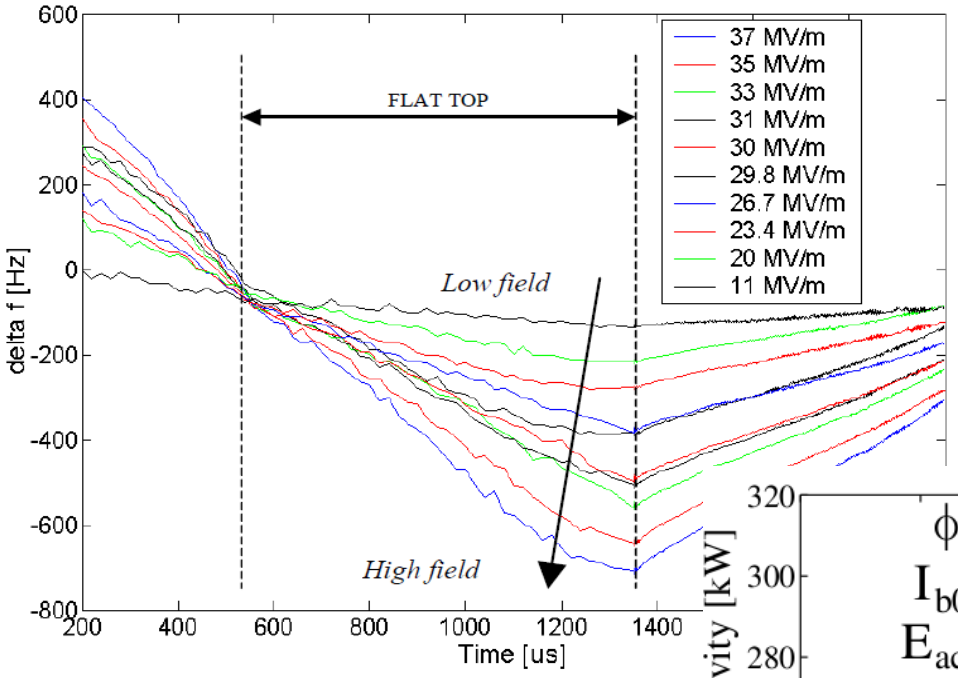
Mariusz Grecki for LLRF collaboration

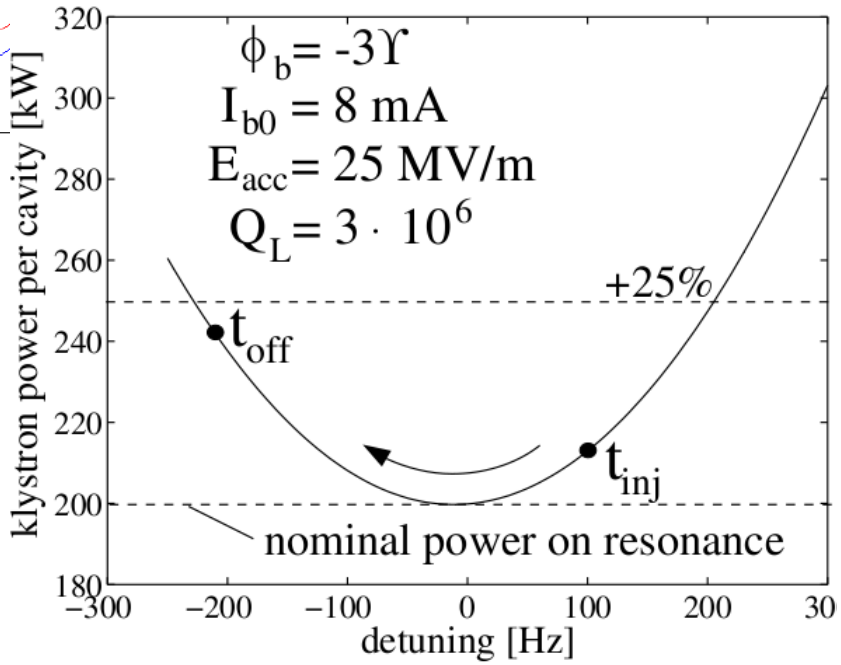


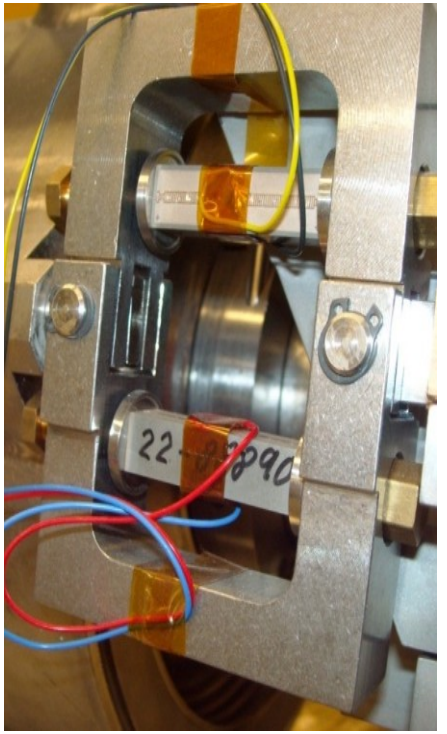
Agenda

- Lorentz Force Detuning and its compensation
- Piezo Control System at FLASH
  - Detuning calculation
  - Control algorithm
- Results of 9mA tests related to piezos
- Conclusion

Lorentz Force Detuning







Dimensions: **10x10x36mm**
Manufacturer: **PI**

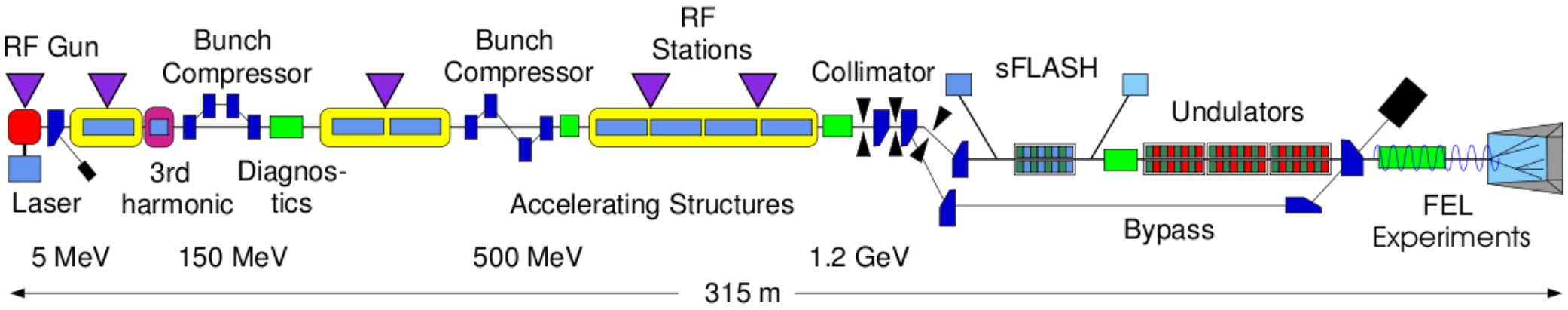
Piezos Installed in ACC1,3,5,6,7

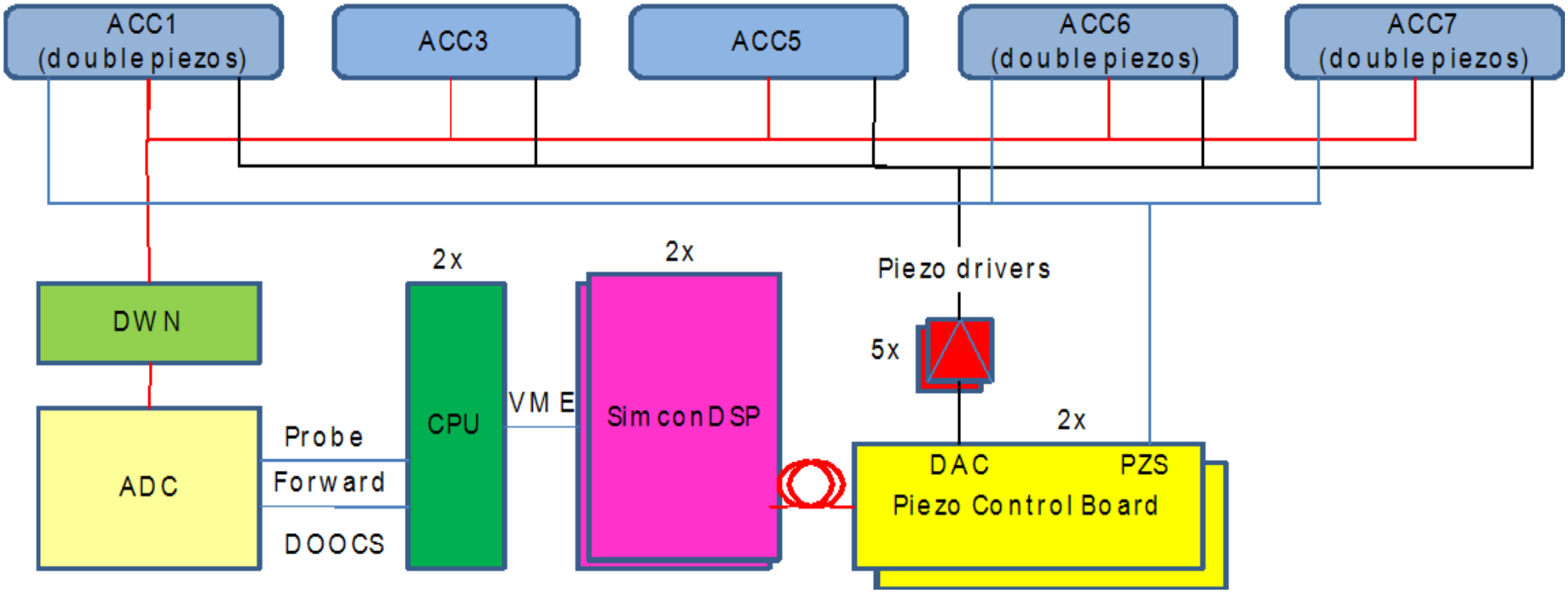
Producent ratings	Noliac	PI ceramic
Model:	SCMAS/S1/A/10/10/30/200/42/6000	P-888.90
Cells:	8	8
Voltage:	< 200 V	< 120 V
Blocking force:	6 kN	3 kN
Size:	10 mm x10 mm x 30 mm	10 mm x10 mm x 35 mm
Capacitance:	6 μF	12 μF

Piezos Capacitance (2K)

cavity	piezo	model	ACC3/M7	model	ACC5/M5	model	ACC6/M6
1	1	PI	4,93uF	Noliac	2,1uF	PI	4,13uF
	2	-	Unavailable	-	Unavailable	PI	4,45uF
2	1	PI	4,61uF	Noliac	2,22uF	PI	4,4uF
	2	-	Unavailable	-	Unavailable	PI	4,2uF
3	1	PI	4,91uF	Noliac	2,28uF	PI	4,21uF
	2	-	Unavailable	-	Unavailable	PI	4,1uF
4	1	PI	4,6uF	Noliac	3,12uF	PI	3,86uF
	2	-	Unavailable	-	Unavailable	PI	4,2uF
5	1	Noliac	2,6uF	Noliac	2,2uF	PI	4,22uF
	2	-	Unavailable	-	Unavailable	PI	4,28uF
6	1	Noliac	2,13uF	Noliac	2,13uF	PI	3,73uF
	2	-	Unavailable	-	Unavailable	PI	4,41uF
7	1	Noliac	2,22uF	Noliac	2,19uF	PI	4,69uF
	2	-	Unavailable	-	Unavailable	PI	4,41uF
8	1	Noliac	2,21uF	Noliac	2,17uF	PI	4,31uF
	2	-	Unavailable	-	Unavailable	PI	4,2uF

FLASH and Piezo Control





Detuning measurements (1)

$$\Delta f = \frac{1}{2\pi}\left(\frac{d}{dt}\varphi_c + 2\omega_{1/2}\frac{|V_{for}|}{|V_c|}\sin(\varphi_{for} - \varphi_c)\right)$$

Δf – detuning,

V_c, φ_c – field amplitude and phase,

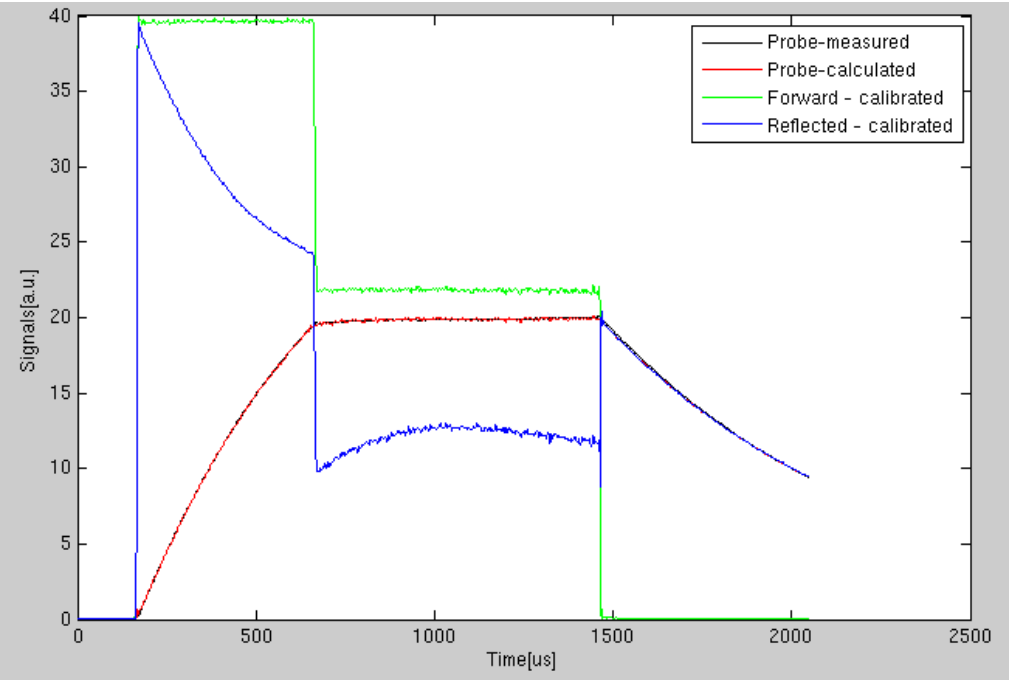
$\omega_{1/2}$ – cavity bandwidth

V_{for}, φ_{for} – forward power amplitude and phase

$$V_c = V_{for} + V_{ref}$$
$$V_{for} = a\,V_{form} + b\,V_{refm}$$
$$V_{ref} = c\,V_{form} + d\,V_{refm}$$

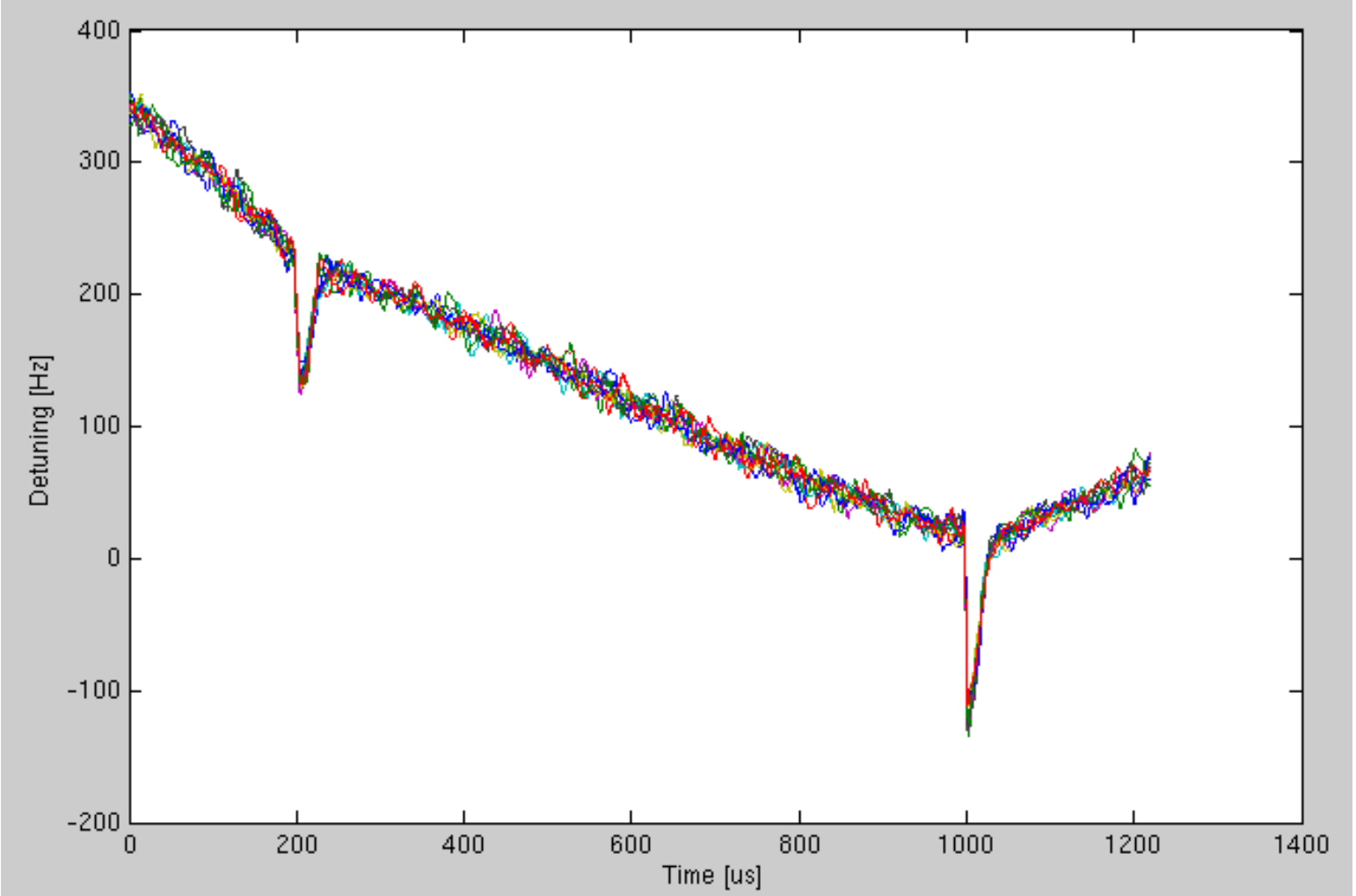
V_{form} – measured forward power

V_{refm} – measured reflected power



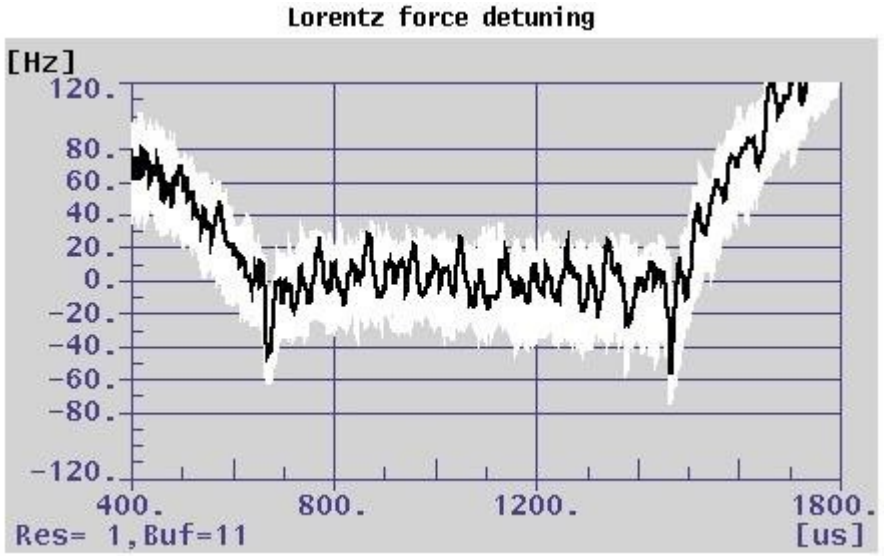
02-05-2011 11:33:29 – 11:34:11

Detuning measurements (2)



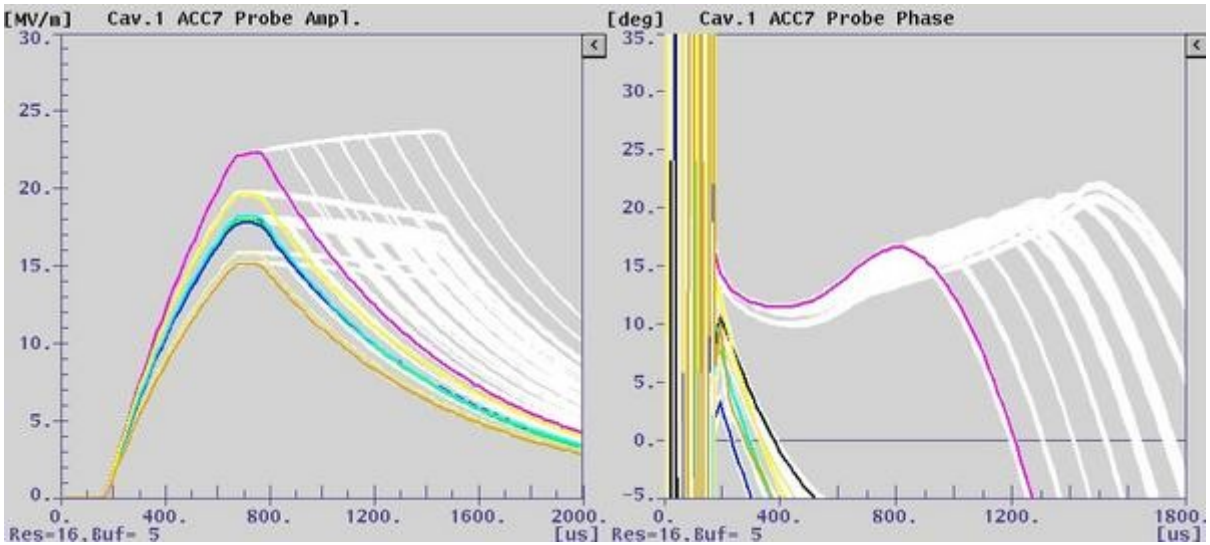
Detuning calculated for 10 pulses
(c1@acc7 02-05-2011 11:33:29)

Detuning calculation (3)

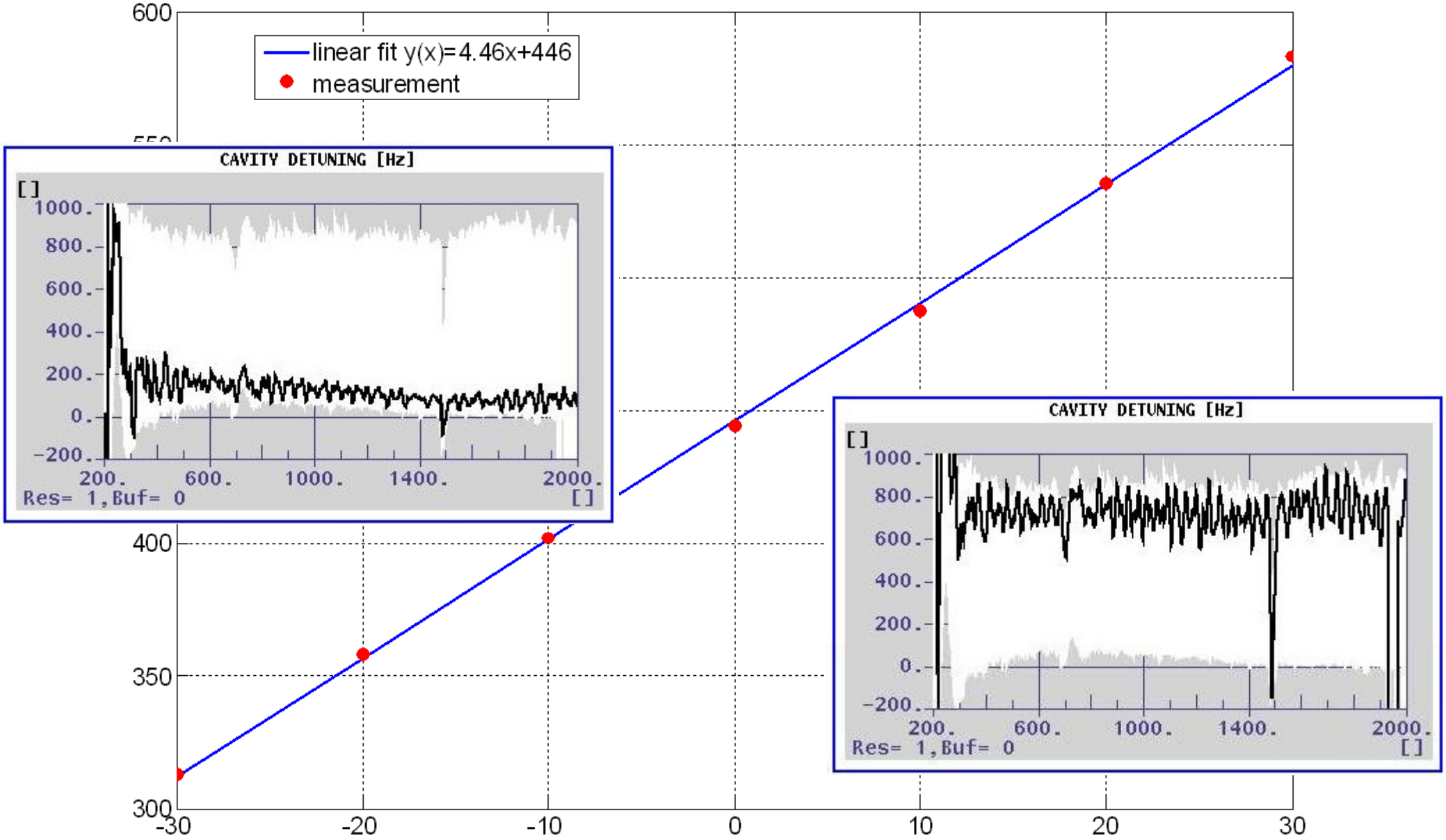


c5@acc7 - cavity well tuned by piezos

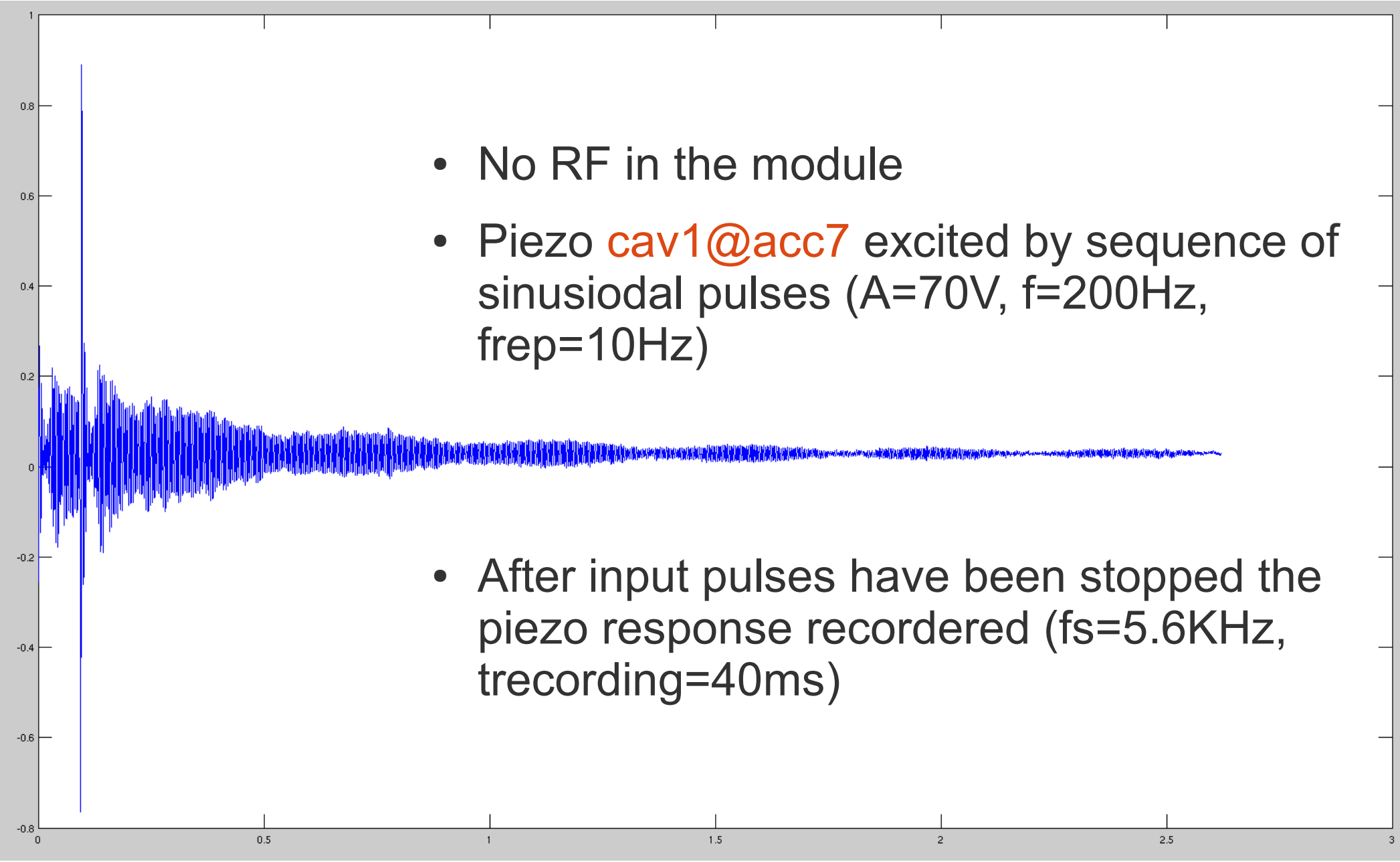
c5@acc7 - shortening the RF pulse



Transfer function (ACC6 cav. 1)

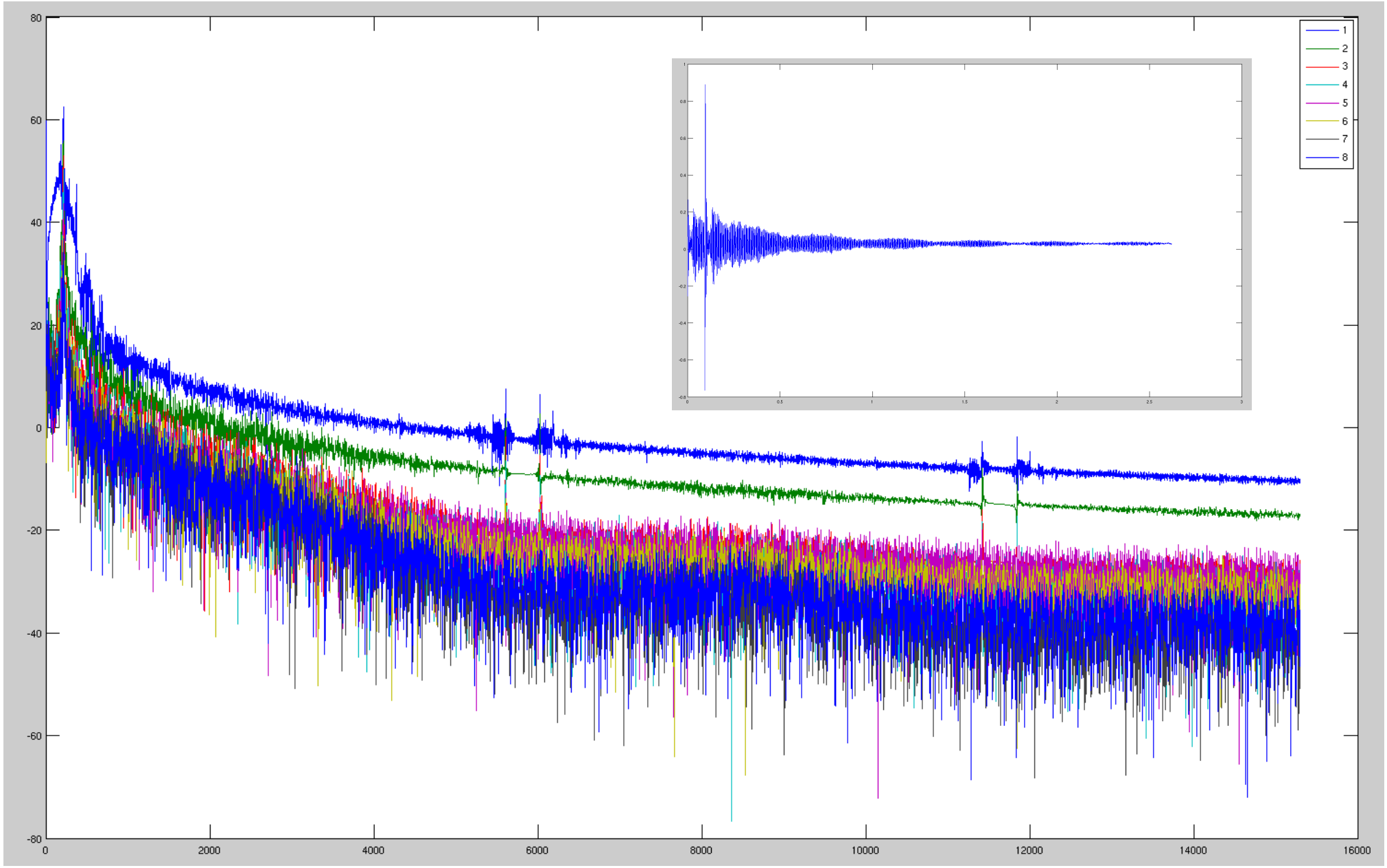


Dynamic response of piezo

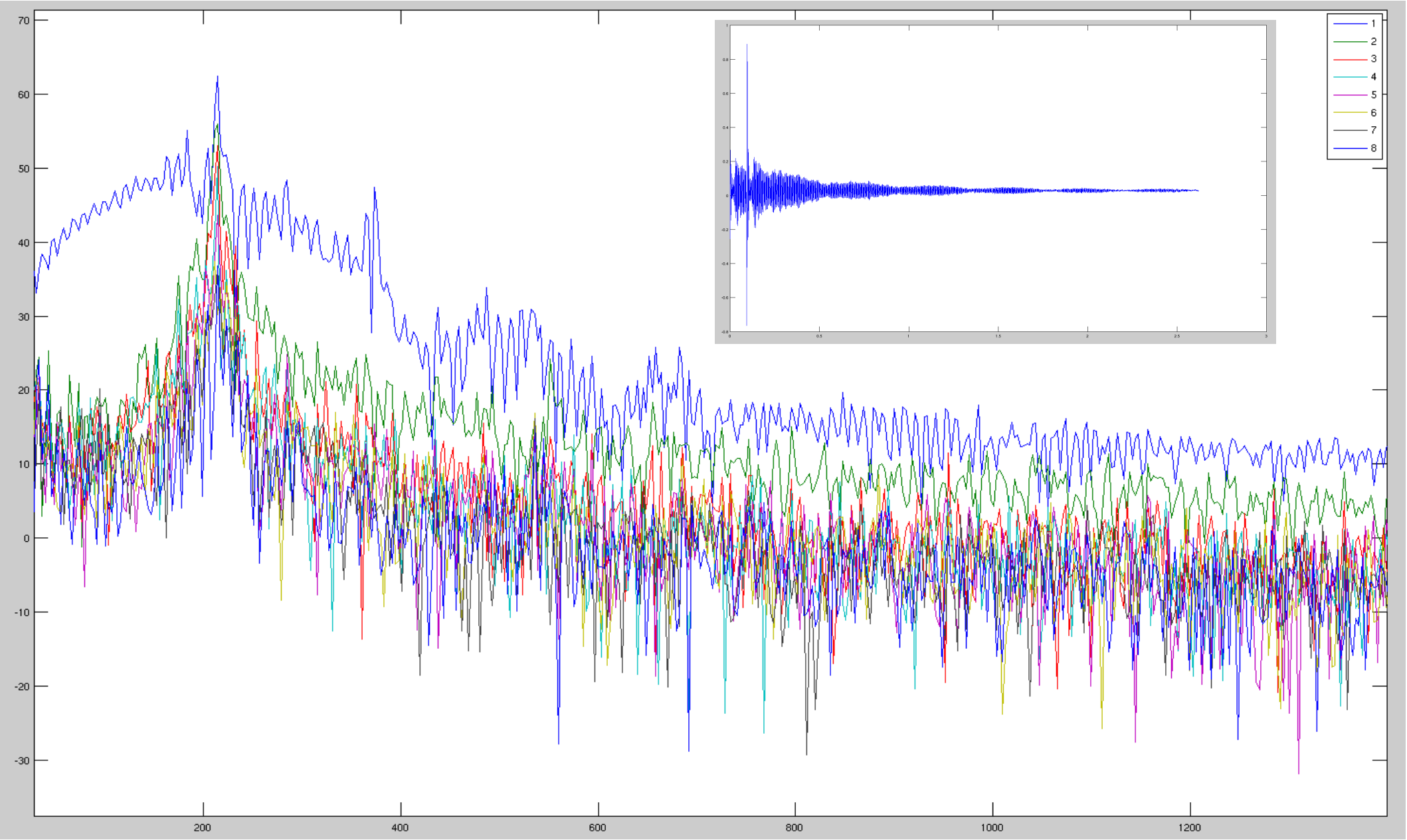


- No RF in the module
- Piezo cav1@acc7 excited by sequence of sinusiodal pulses (A=70V, f=200Hz, frep=10Hz)
- After input pulses have been stopped the piezo response recordered (fs=5.6KHz, trecording=40ms)

FFT ot the piezo sensor response (1)

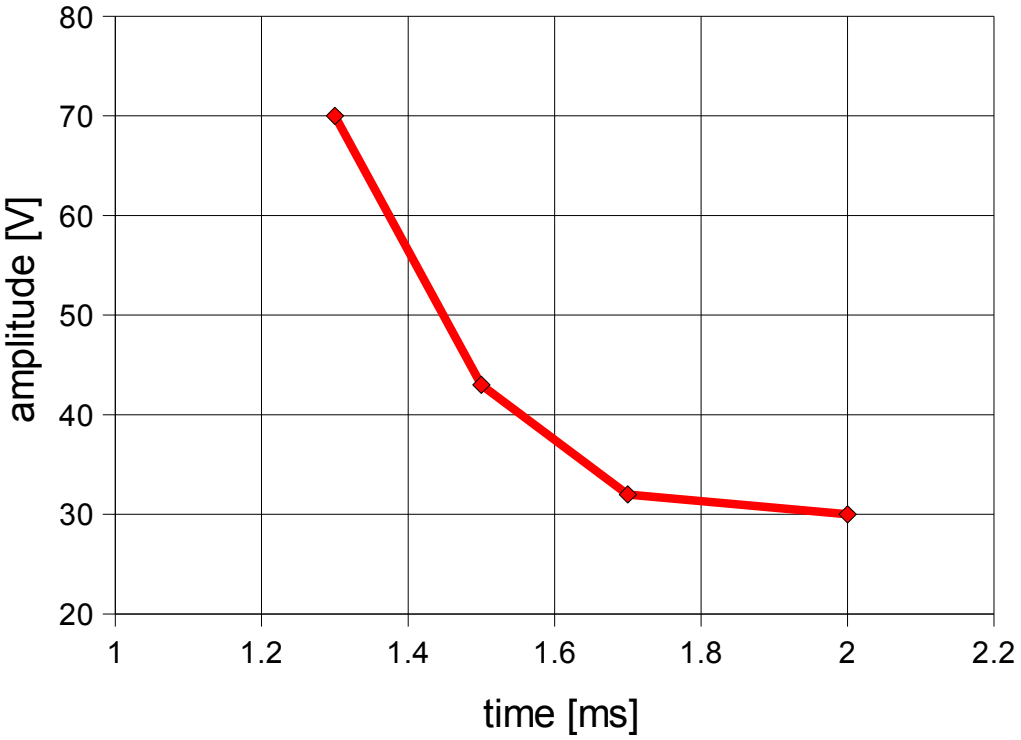


FFT ot the piezo sensor response (2)

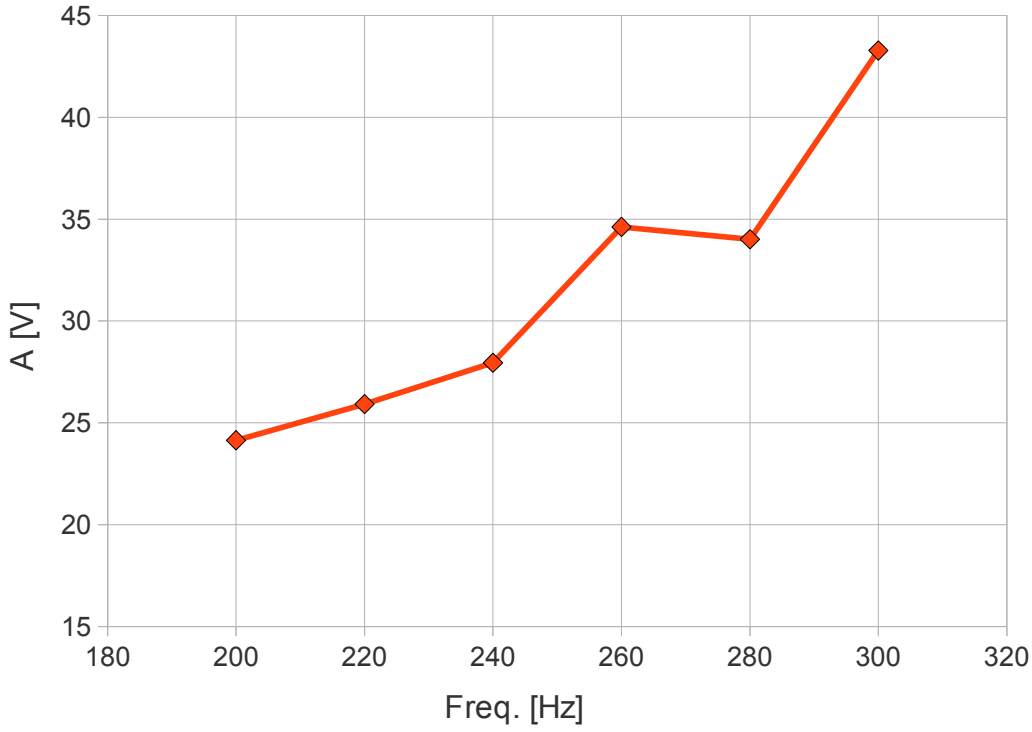


Piezo control characterization

Pulse amplitude vs time before RF



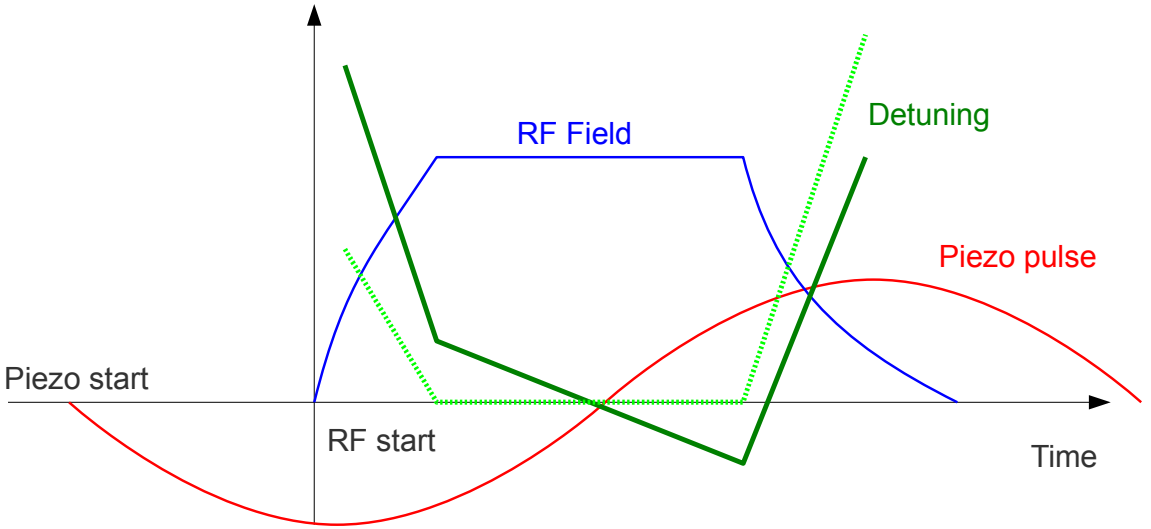
Pulse amplitude vs frequency



cav1@acc6

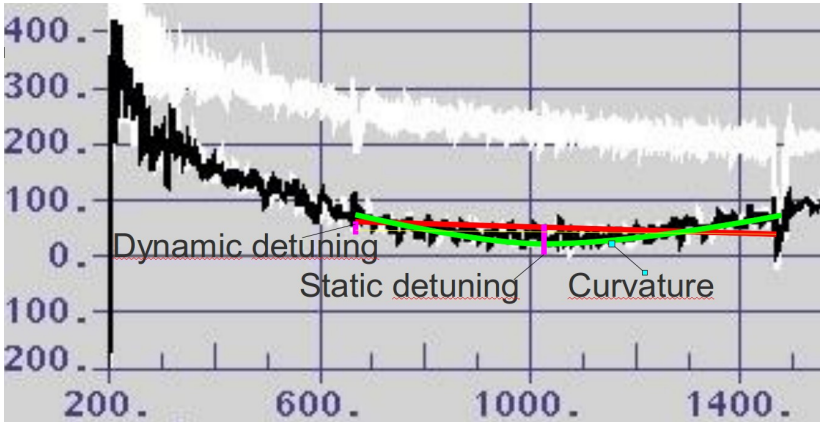
Piezo control for LFD compensation

- Sinusoidal excitation with adjustable
  - Frequency
  - Pulse number
  - Amplitude
  - Time position
  - DC pedestal

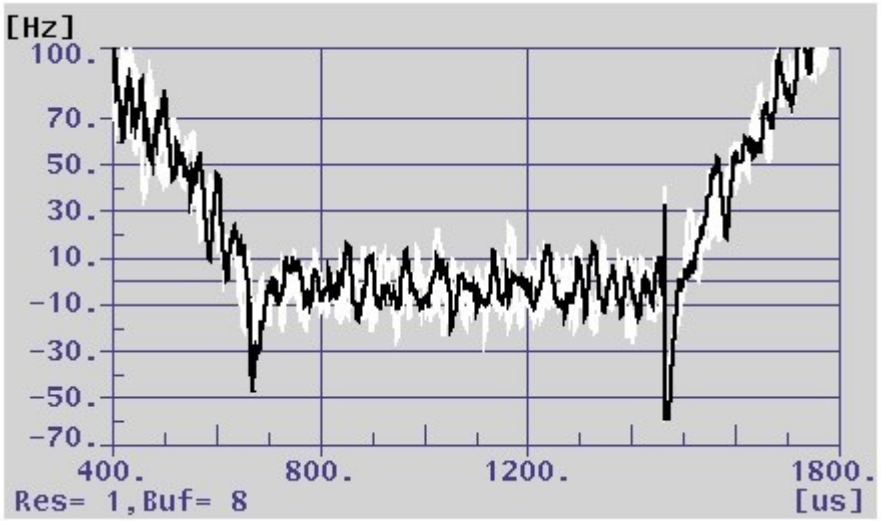


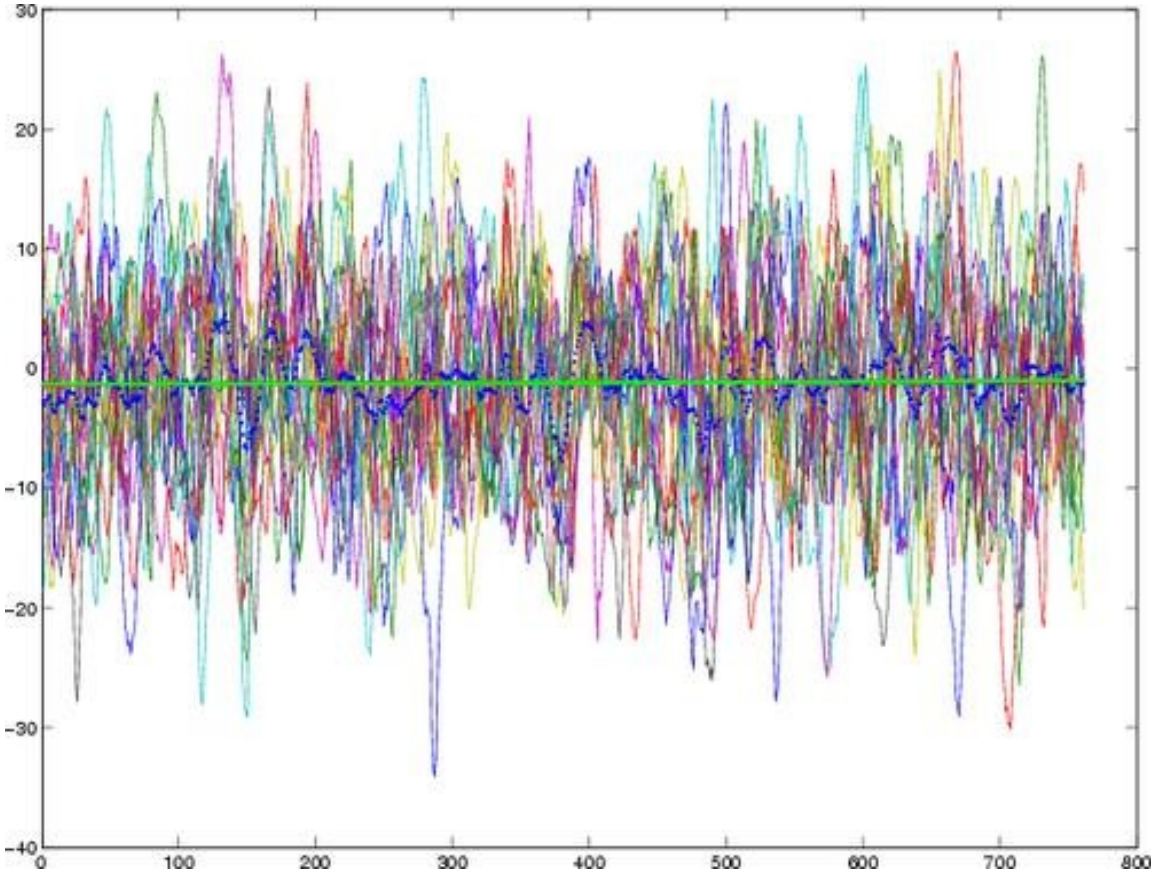
- Amplitude → dynamic detuning
- DC pedestal → static detuning
- Time position → curvature

Detuning compensation result



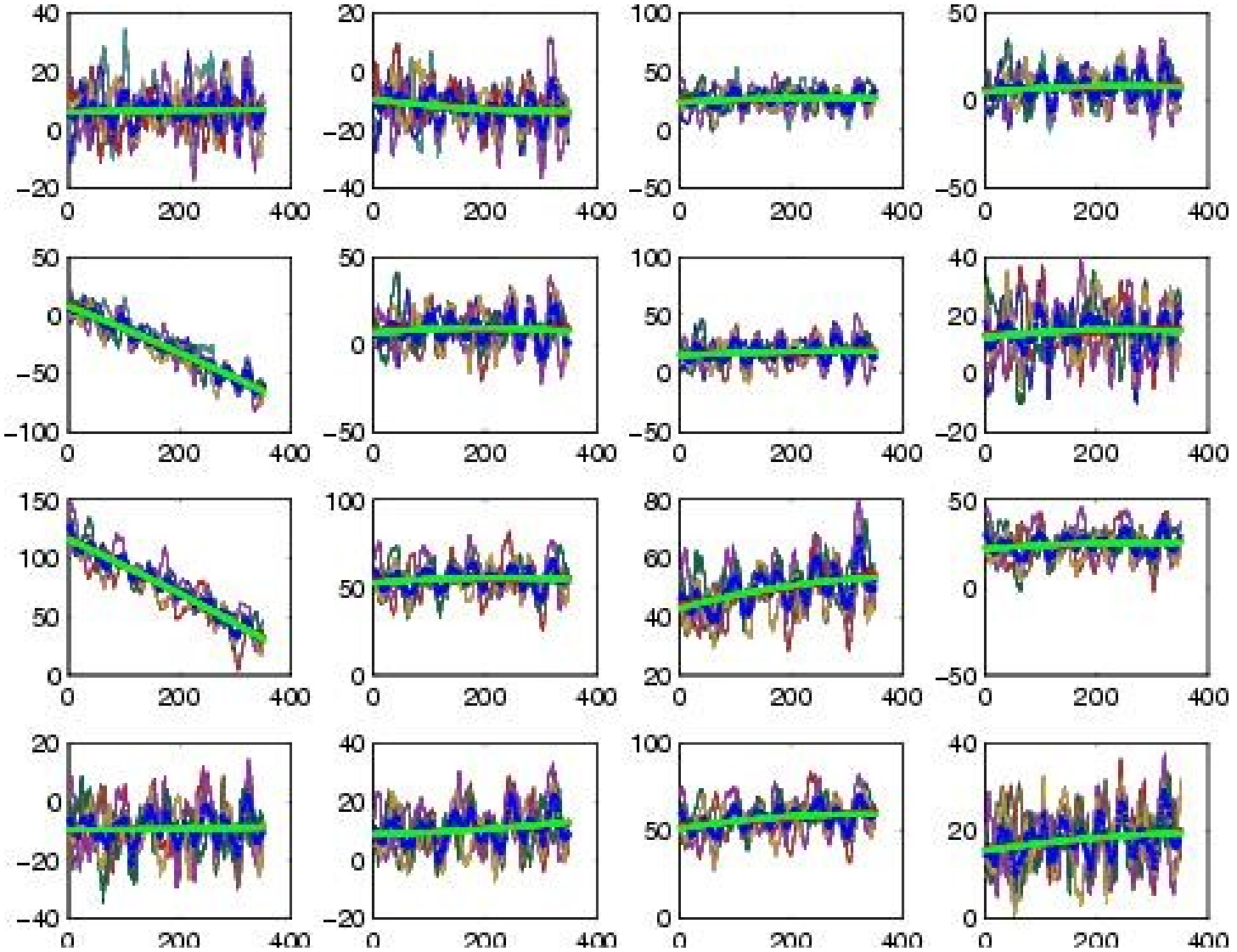
Lorentz force detuning





c1@acc6: measured over 20 pulses. The achieved parameters: dynamic detuning 0.3190Hz static detuning: -1.1760Hz, curvature: 0.1774 a.u. (linear and quadratic approximation covers in the picture). Settings for the piezo: 200Hz, 1 pulse, 19.12ms after A2, amp=-23.06V, DC off=-36.62V

Automatic tuning procedure for 2 modules



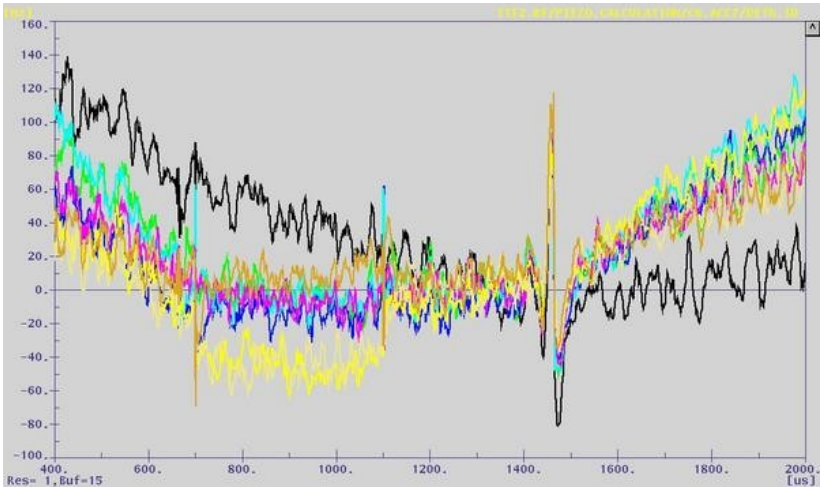
Detuning measurements with beam

$$\Delta f = \frac{1}{2\pi}\left(\frac{d}{dt}\varphi_c + 2\omega_{1/2}\frac{|V_{for}|}{|V_c|}\sin(\varphi_{for}-\varphi_c) + 2\omega_{1/2}\frac{|V_b|}{|V_c|}\sin(\varphi_b-\varphi_c)\right)$$

Δf – detuning,
V_c, φ_c – field amplitude and phase,
$\omega_{1/2}$ – cavity bandwidth
V_{for}, φ_{for} – forward power amplitude and phase
V_b, φ_b – forward power amplitude and phase

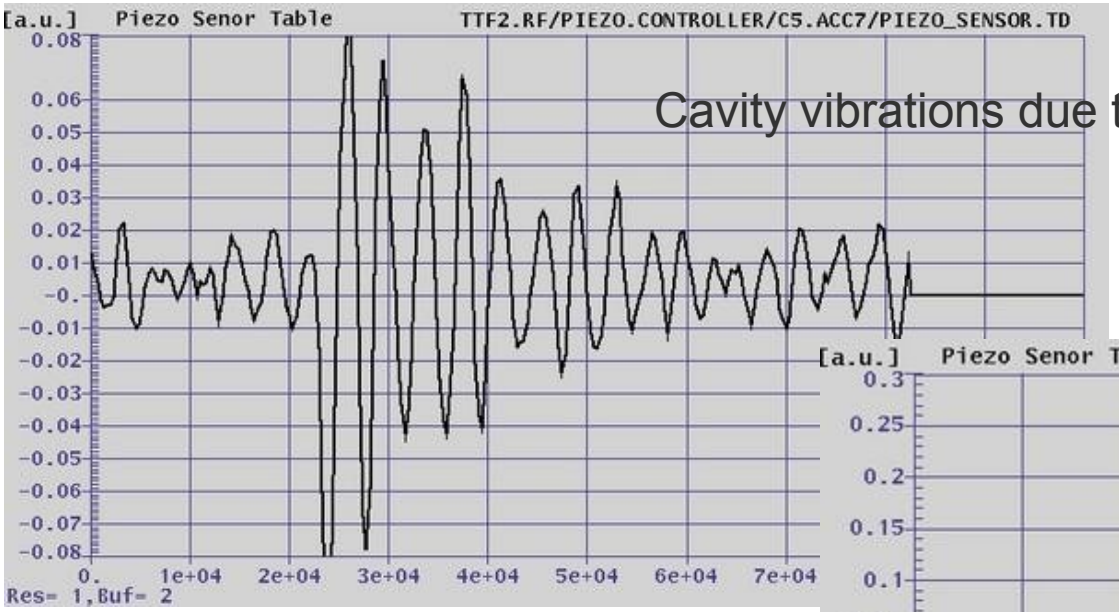
$$V_b = C_b I_b$$

C_b – calibration factor
I_b – beam current (measured at toroid)

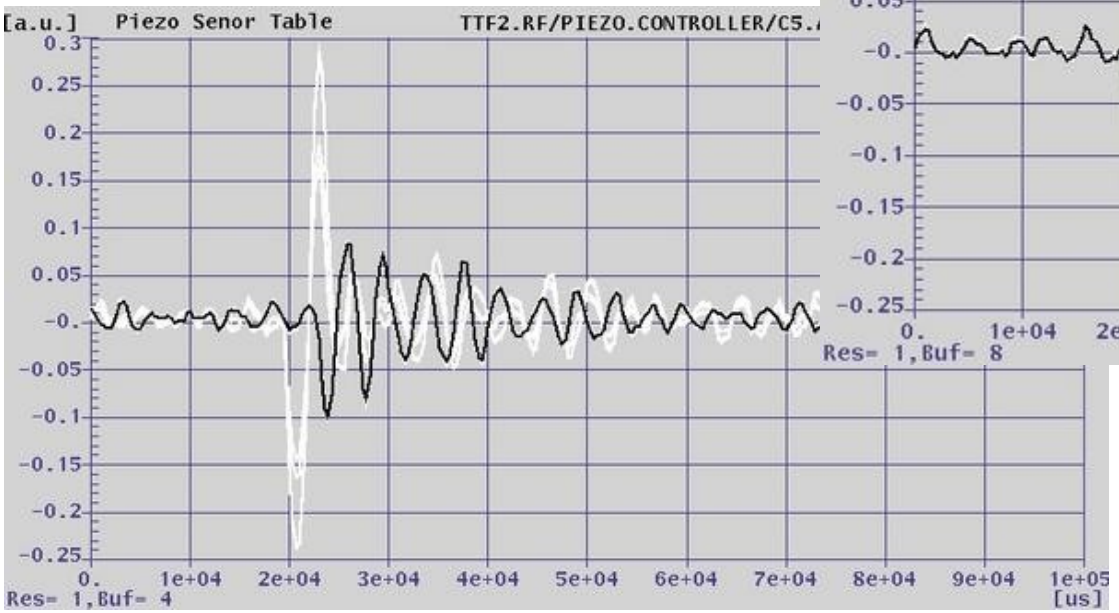


02-05-2011 11:33:29 – 11:34:11

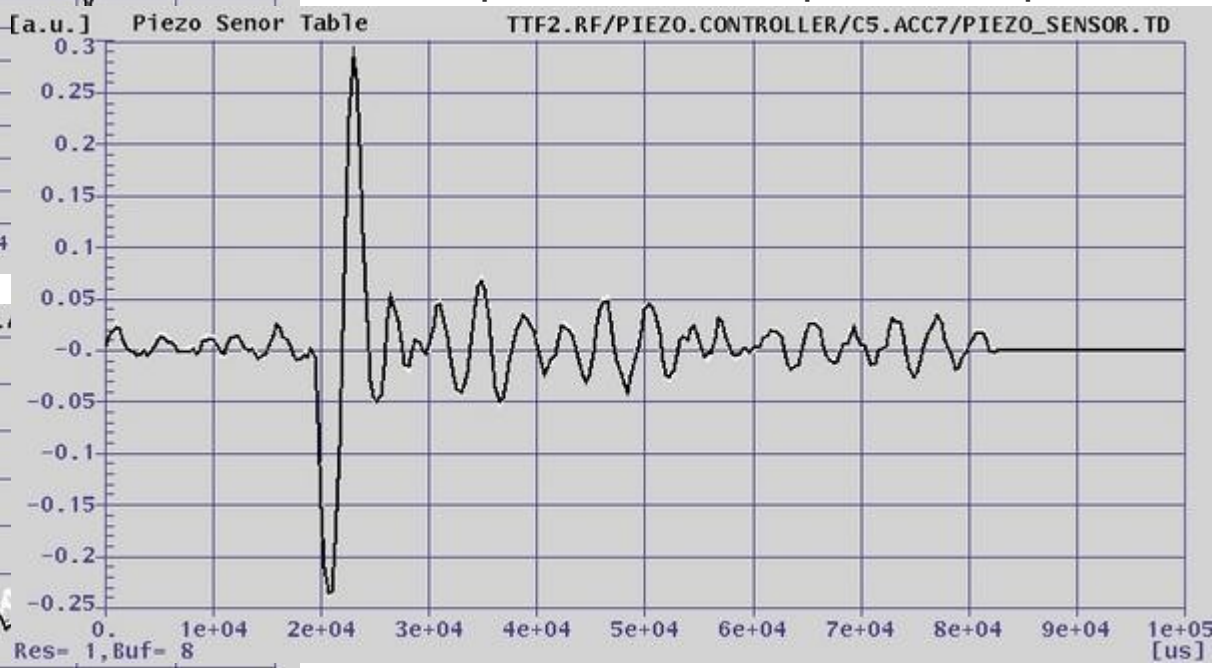
Piezo sensors signals



Cavity vibrations due to RF only



Cavity vibrations due to RF only
Plus piezo LFD compensation pulse



Conclusion

- Piezos can tune the LFD up to few hundreds of Hz. They can be used also to tuning cavities in the limited range.
- In the frame of 9mA experiment the automatic procedure for LFD compensation has been developed.
- Detuning calculation without beam agrees well with detuning measured at the end of the RF pulse. Detuning calculation in the presence of the beam requires calibration of the beam transients.
- The meaning of the sensor signals (how it relates to detuning) is still not clear. It requires further analysis.