RF Experience from 6 Years of ELBE SRF-Gun II Operation

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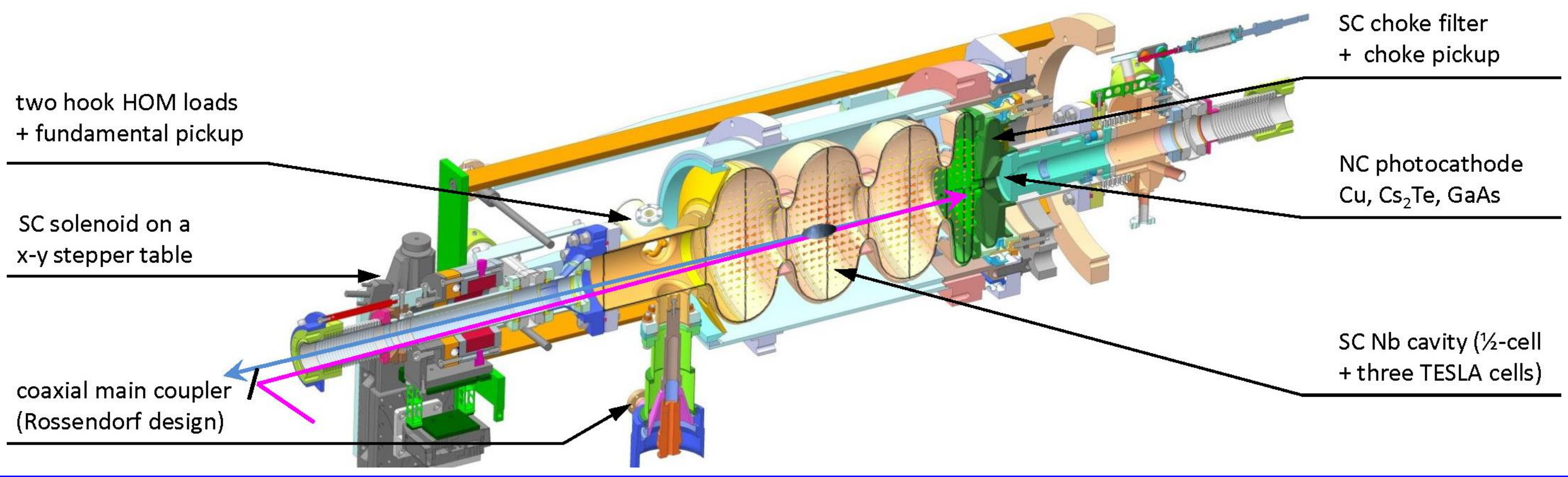
Abstract

At the electron accelerator for beams with high brilliance and low emittance (ELBE), the second version of a superconducting radio-frequency (SRF) photoinjector was brought into operation in 2014. After a period of commissioning, a gradual transfer to routine operation took place in 2017 and 2018, so that now more than 3400h of user beam have already been generated since 2019. During this time, a total of 20 cathodes (2 Cu, 12 Mg, 6 Cs2Te) were used, but no serious cavity degradation was observed. In this paper, we summarize the operational experience of the last 6 years of SRF gun operation, with special emphasis on main RF properties of the gun cavity.

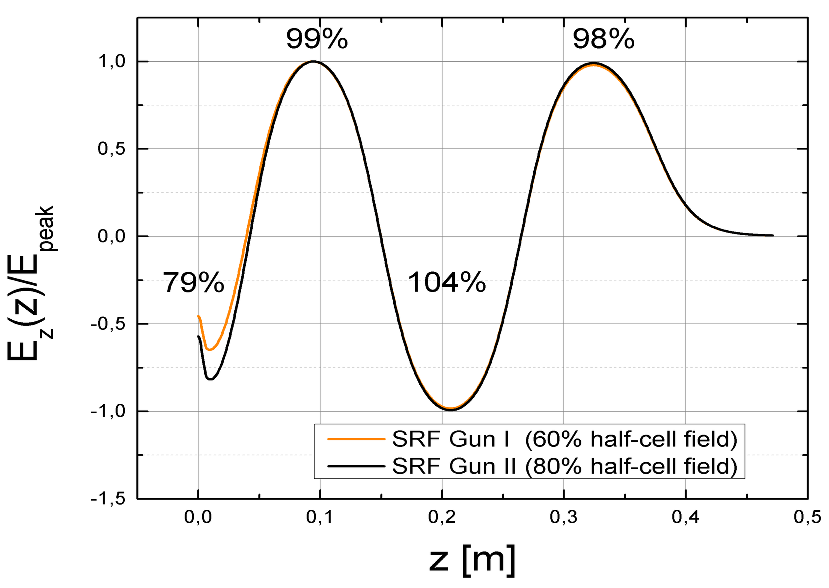


Passband, field distribution and external Q

field profile

- TM_{010} frequencies in combination with latest bead pull results used to estimate the field profile of the accelerating mode

π-mode	1/4	2/4	3/4	4/4
f_0 / MHz	1267.667	1282.794	1294.762	1300
b /Hz	17	147	271	140



external Qs

- 16 kW CW main coupler with fixed coupling by bandwidth measurement
- HOM coupler and choke pickup by comparing transmitted power with known pickup antenna from vertical test
- All criteria for coupling fulfilled

	meas.	spec.
FPC:	$9.3x10^{06}$	$1.3x10^{07}$
F-Pickup:	$2.7x10^{11}$	$\sim 2x10^{11}$
Choke:	$4.3x10^{10}$	$\sim 2x10^{11}$
HOM1:	$2.3x10^{12}$	$>2x10^{11}$
HOM2:	$5.8x10^{11}$	$>2x10^{11}$

Lorentz force detuning

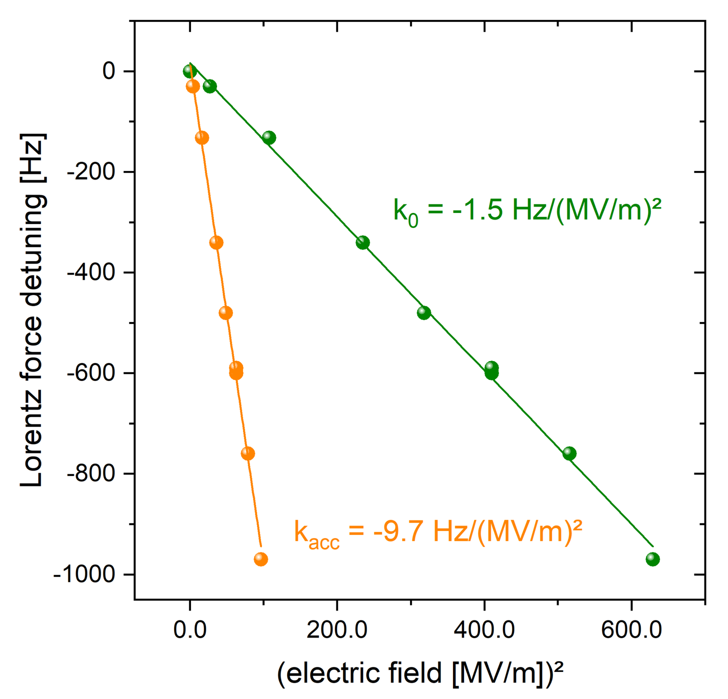
	SRF gun I	SRF gun II	TESLA
k_{acc} / Hz/(MV/m)^2	5	9.7	1
k_{peak} / Hz/(MV/m)^2	0.69	1.5	0.25

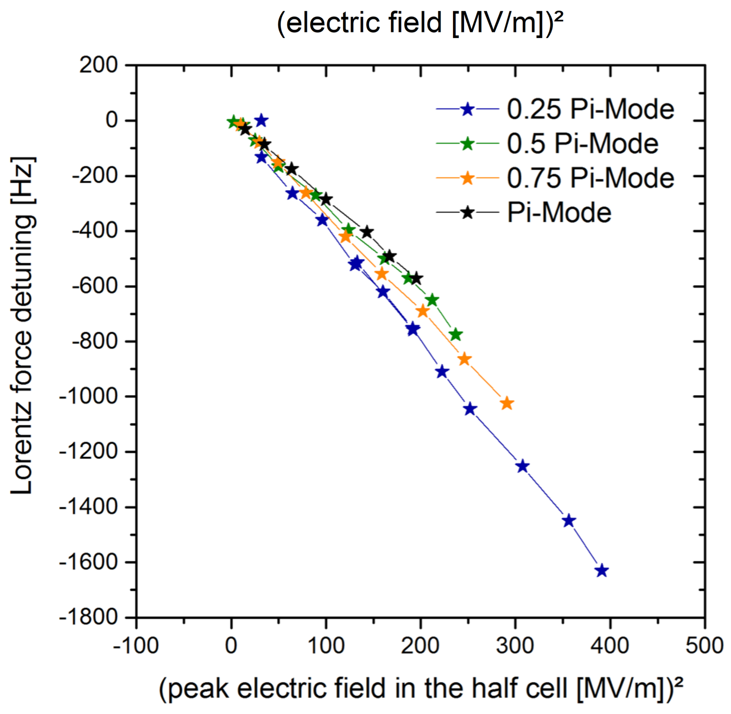
- LF coefficient is **2x higher** than for gun I
- **3x higher** than in simulation and even
- **6x higher** than for TESLA 9-cell cavities

- plotting detuning vs. peak electric fields for each mode clearly point on half cell
- additional stiffeners are not satisfactory

$$\Delta f = -k_{acc} \cdot E_{acc}^2 = -k_{peak} \cdot E_{peak}^2$$

$$k_{peak} = k_{acc} \left(\frac{E_{peak}}{E_{acc}}\right)^2 \qquad \frac{E_{peak}}{E_{acc}} = 2.56$$





Acknowledgement

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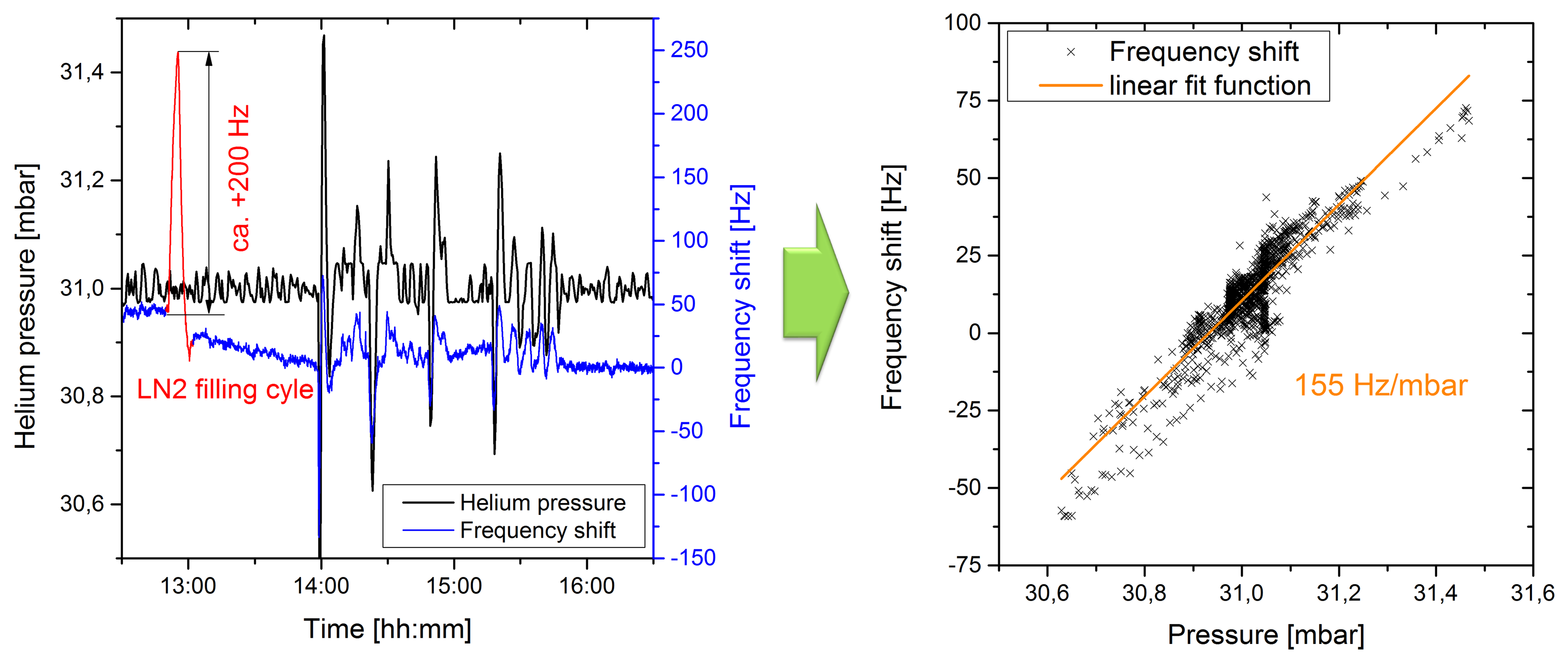
Pressure sensitivity

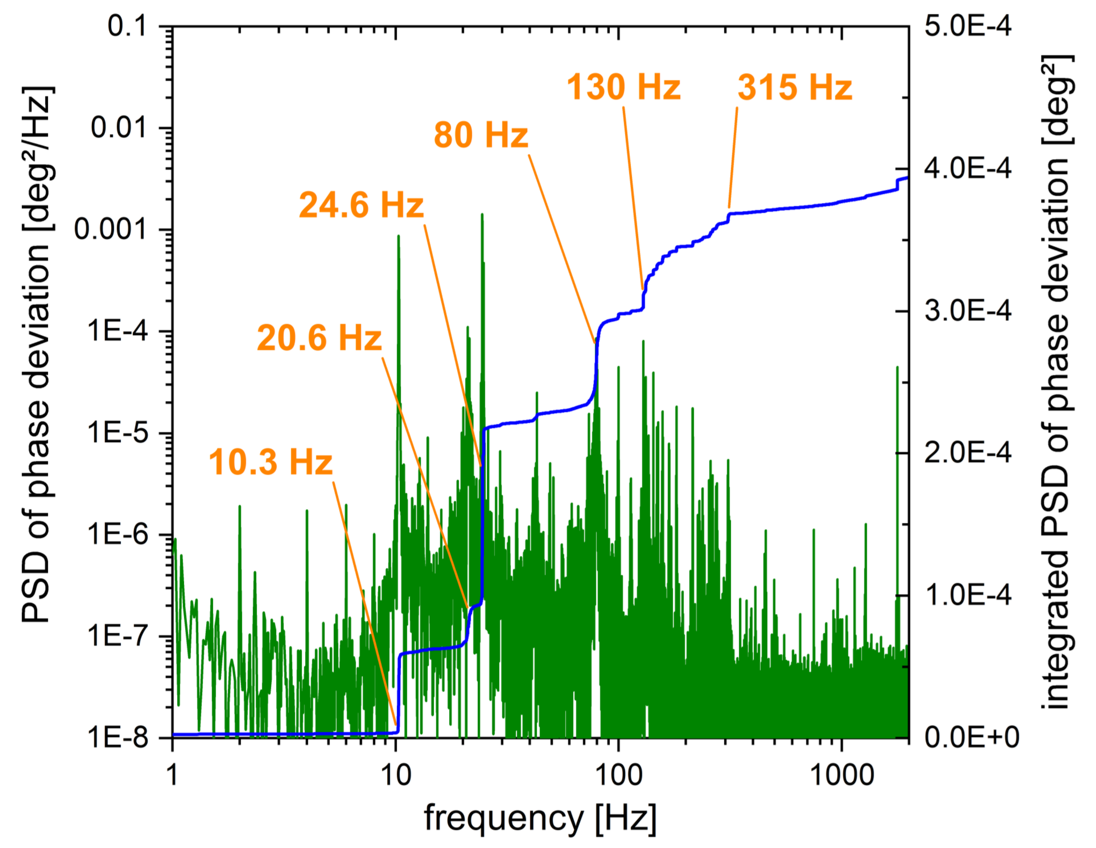


Microphonics

Parameters
- loop gain: 127
- bandwidth: 300 Hz
- gradient: 9 MV/m

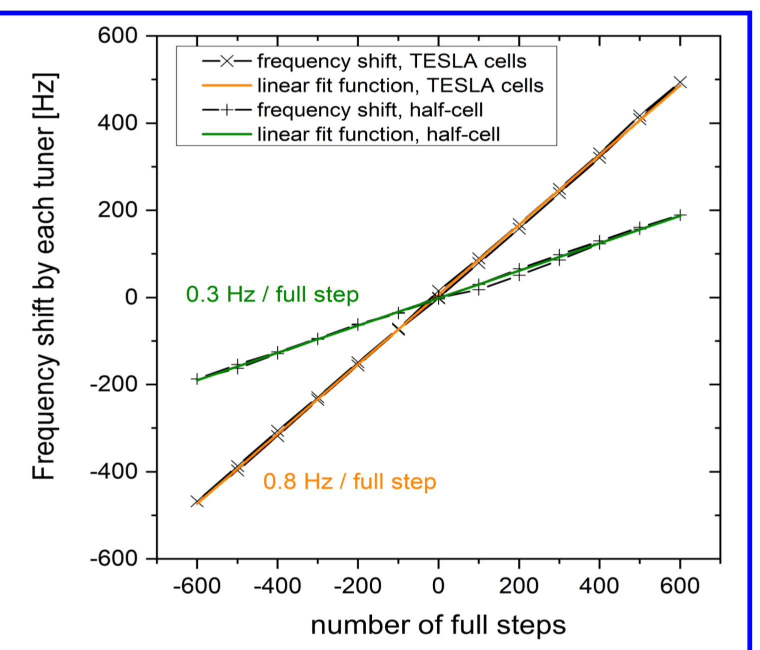
Results
- σ_{phase} = 0.02° (RMS)
- $\sigma_{frequency}$ = 6.6 Hz (RMS)

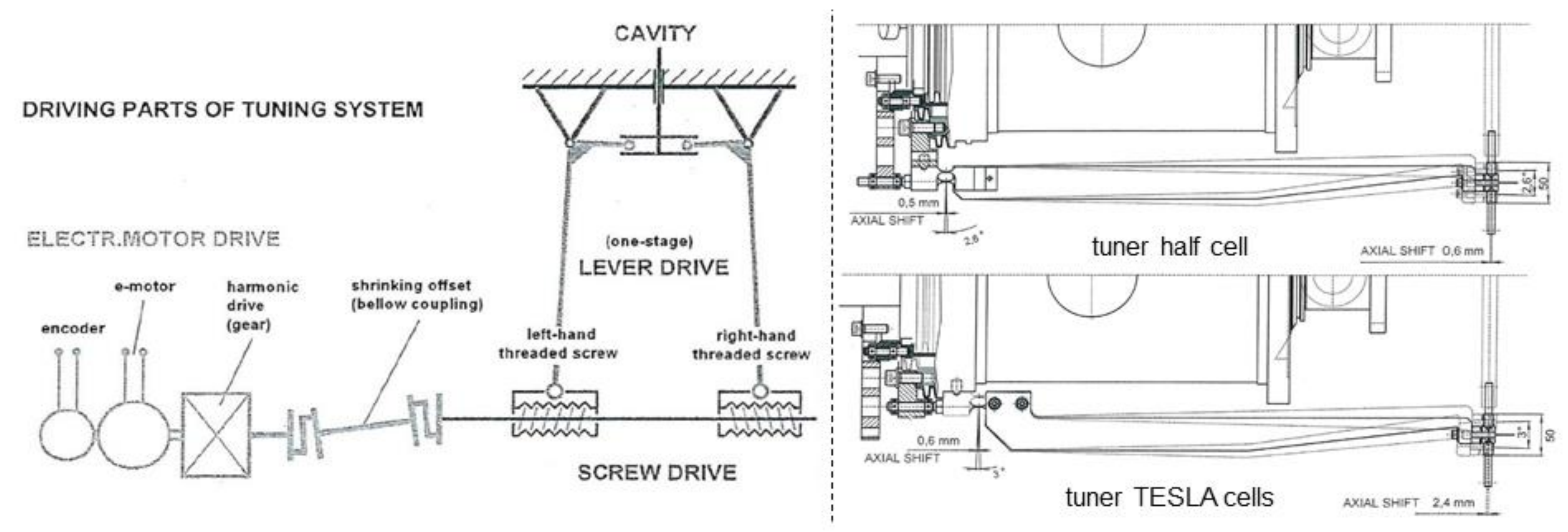
- main contributors:
  - 10 Hz, 24 Hz (pumps)
  - 20 Hz, 80 Hz (unknown)



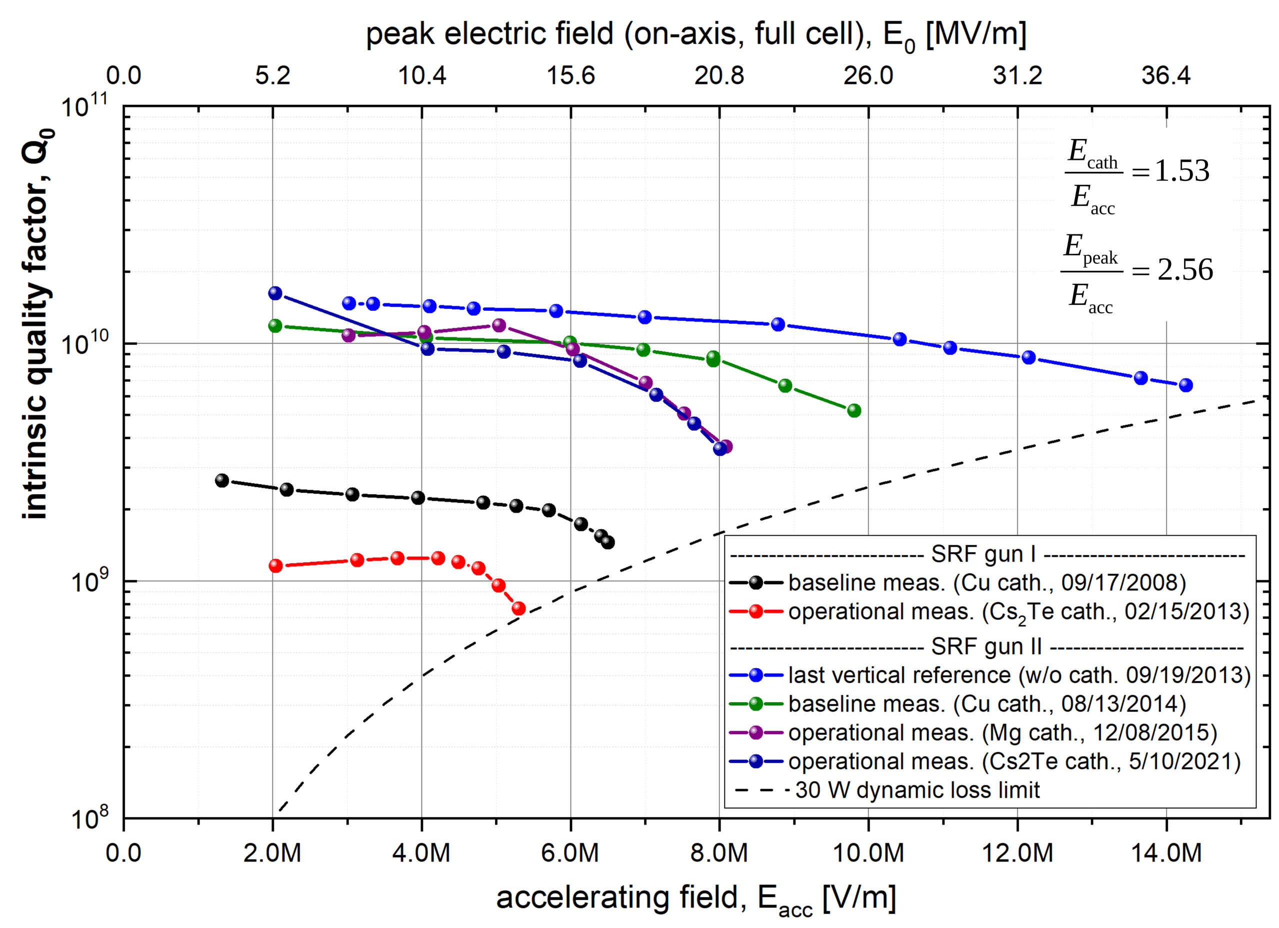
Tuning system

tuner parameter	unit	cold test	
		half cell	full cells
force path	mm	±15	
load path	mm	±0.30	±0.30
frequency const.	kHz/mm	257	650
tuning range	kHz	±77	±195
mech. resolution	nm/step	1.25	1.25
frequ. resolution	Hz/step	0.31	0.80





Q_0 vs. E_{acc}



Formulas:

$$E_{acc} = \frac{1}{L}\sqrt{2r_s Q_t P_t}$$

$$Q_0 = \frac{Q_t P_t}{P_{diss}}$$

Constants:

$$r_s = 167.5\ \Omega$$

$$Q_t = 2.68e11$$

$$L = 0.5\ m$$