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Proposed High-Power Test of the ESS Spoke Cavity at the FREIA Facility

Vitaliy Goryashko
E-mail:vitaliy.goryashko@physics.uu.se

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- Why we need high-power tests of the spoke cavity?
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Why we need high-power tests of the spoke cavity?

FREIA

- The spoke LINAC is a low-energy machine and and each MeV is important;
- Multipacting in cavity coupler is a factor limiting the accelerating gradient;
- The ESS LINAC is a pulsed machine;
- Lorentz detuning and mechanical vibrations are expected to be strong;
- During the pulse the surface resistance can change substantially;
- The piezo-compensation system has to be tested in a realistic situation.

Example of the high-power test: TESLA cavity

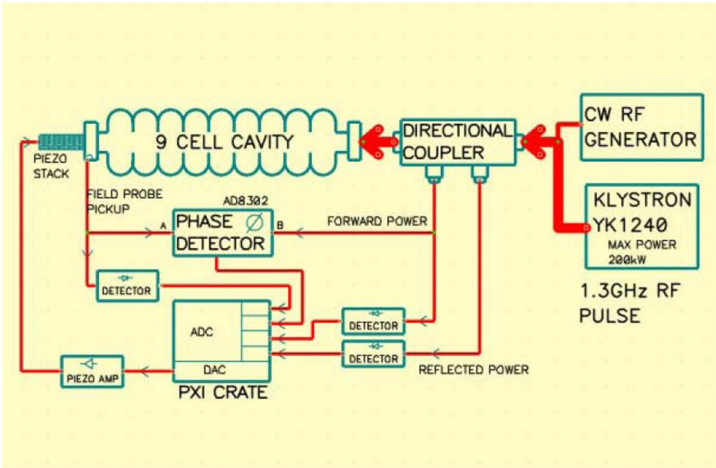


Figure 2: Experimental setup of CCII Lorentz force detuning compensation study.

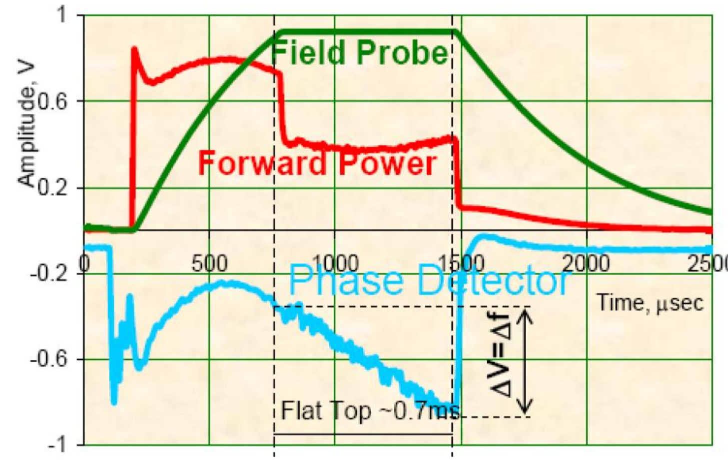


Figure 3: The forward power, field probe and phase detector signals from CCII, at a gradient of 26MV/m.

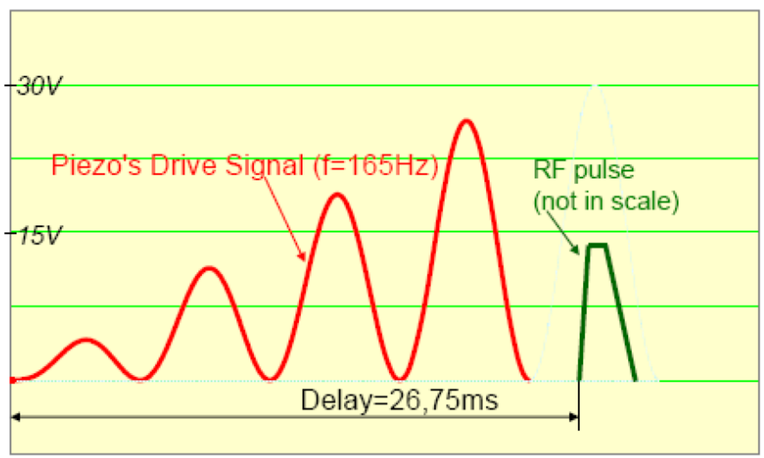


Figure 4: Piezo drive waveform used to compensate for Lorentz force detuning.

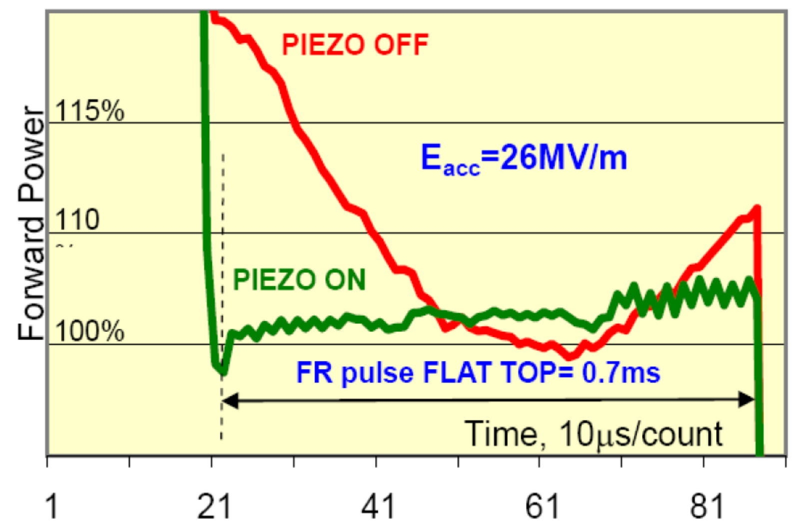
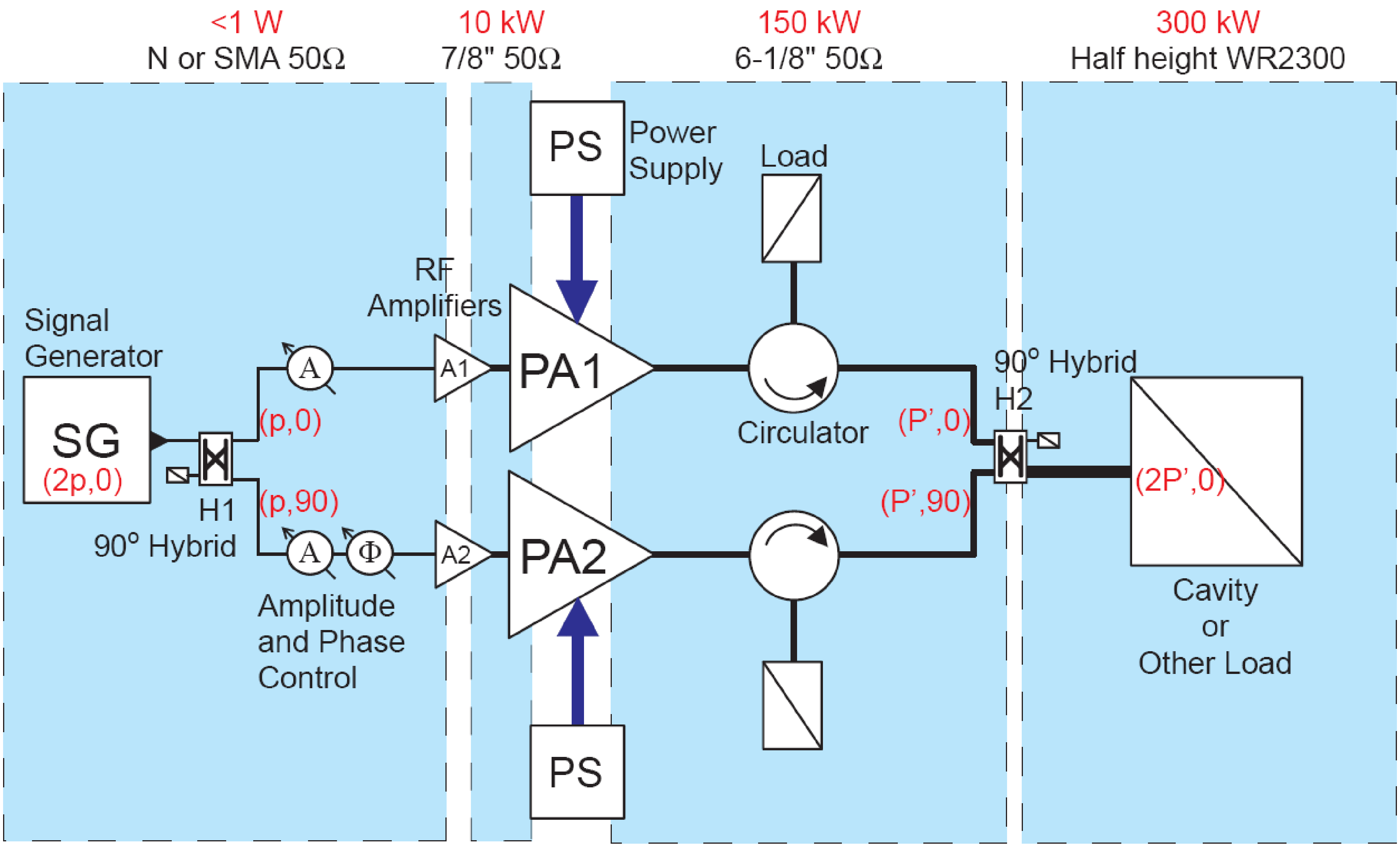


Figure 8: CCII average forward power during "Flat Top" at EAcc=26MV/m.

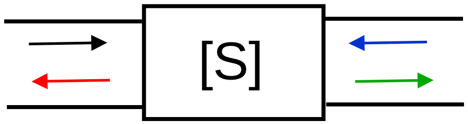
R. Carcagno et al. Proceedings of SRF2007, Peking Univ., Beijing, China

FREIA high-power source

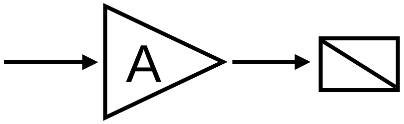


Testing of the FREIA high-power source

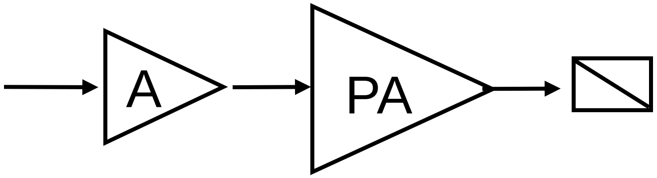
- Low-power characterization of all components using VNA;



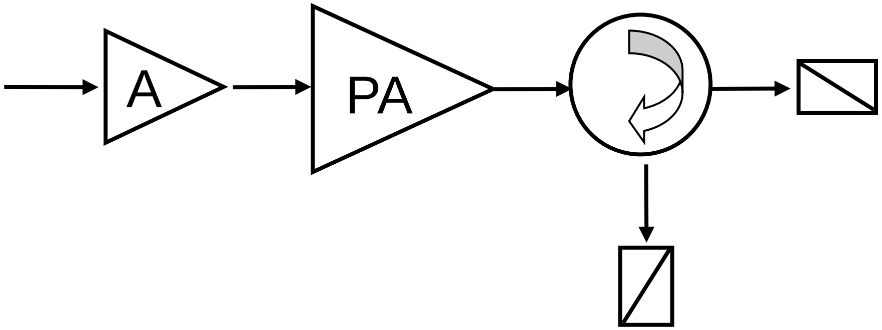
- Testing of the preamplifiers on a dummy load;



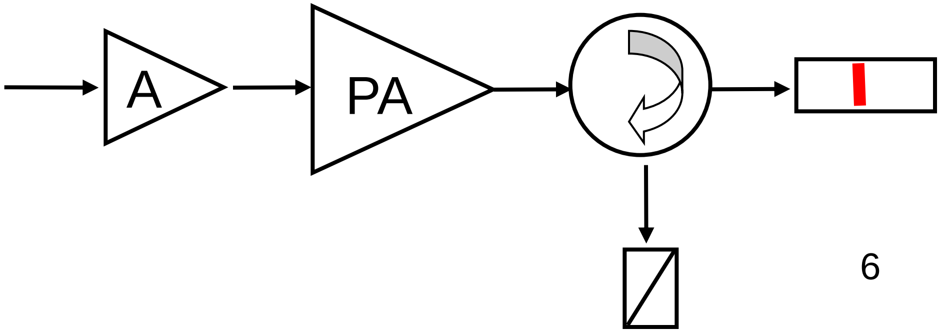
- Testing of the high-power amplifiers on a dummy load;



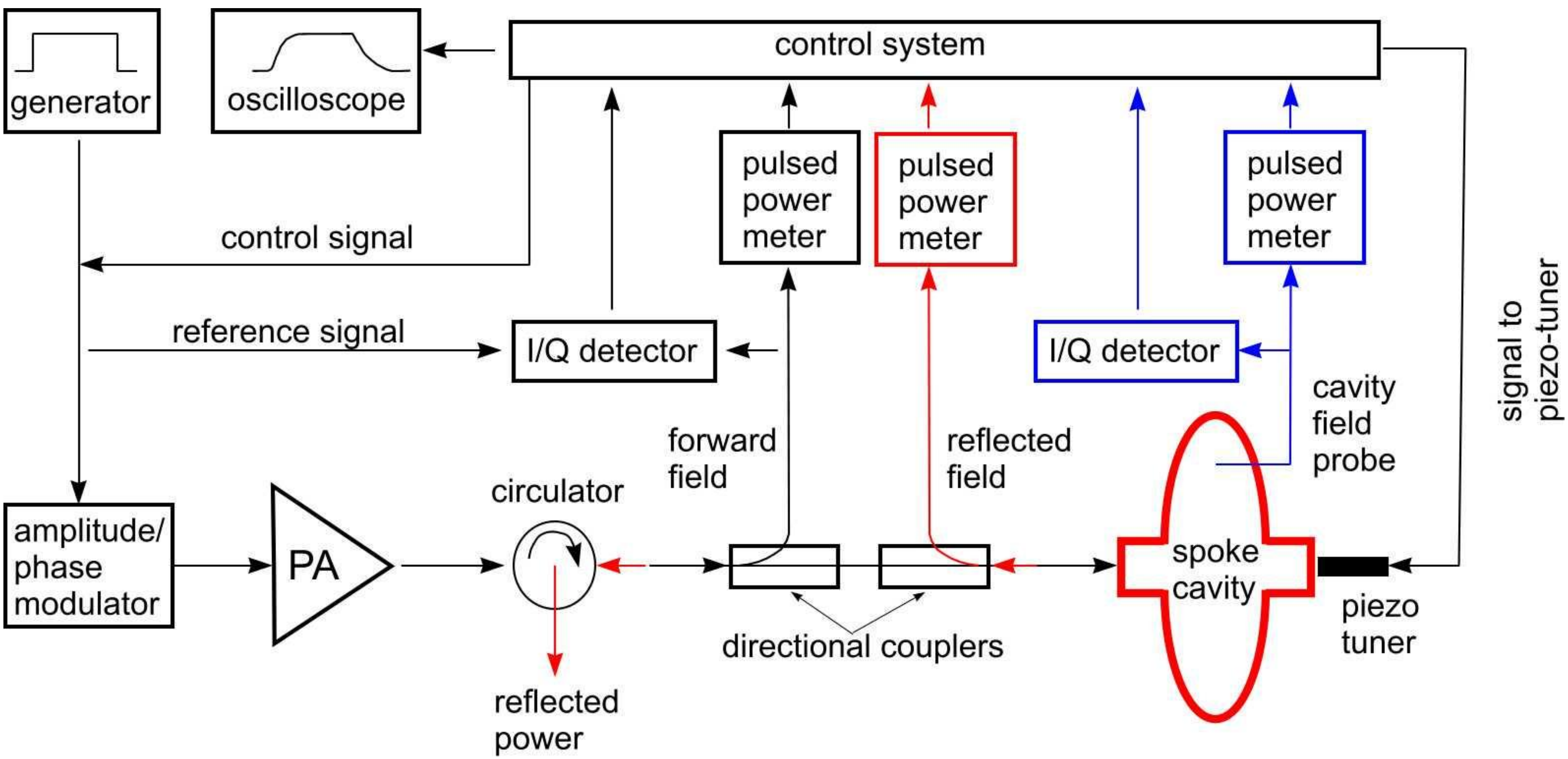
- High-power testing of all components, especially the circulators and measurement of their insertion loss;



- Testing of the high-power amplifiers on a sliding short for different phases of reflection.



FREIA test stand



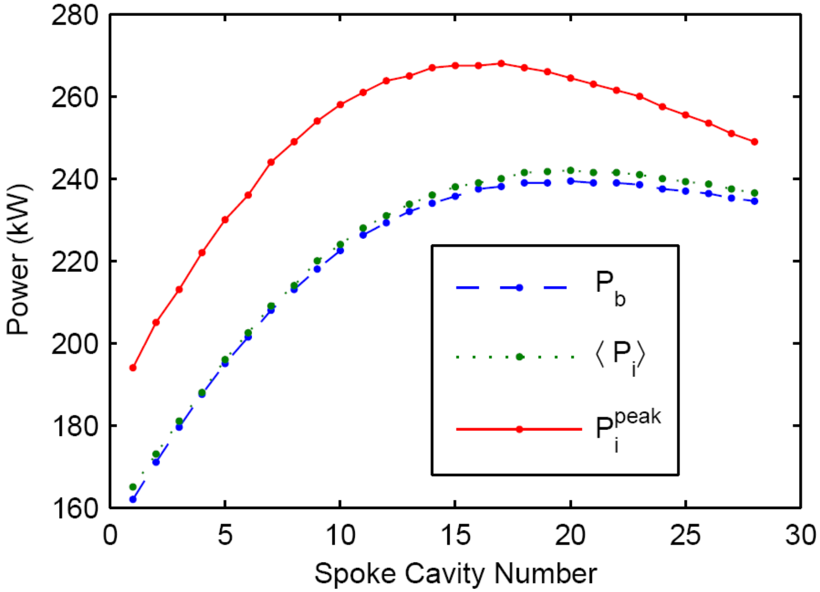
Proposed experimental studies on the spoke cavity

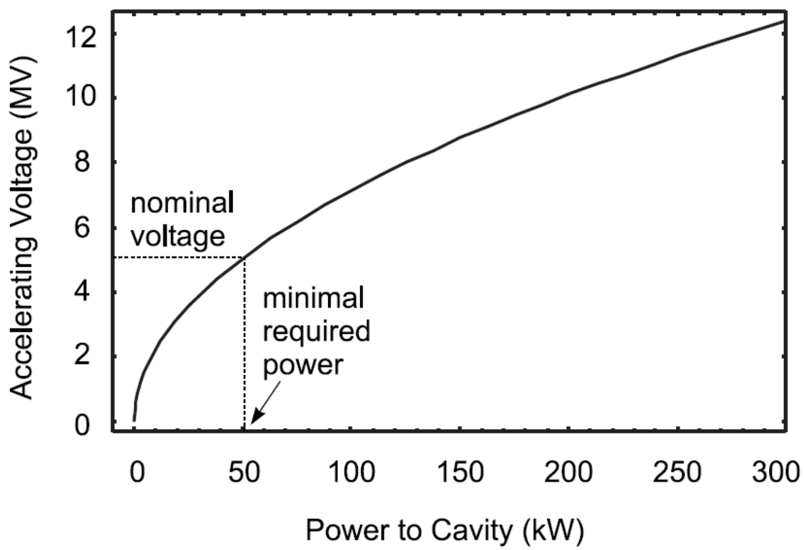
- Perform testing of the cavity coupler;
- Reach nominal accelerating gradient;
- Measure Lorentz force detuning of the cavity;
- Study microphonics;
- Test the cavity tuner;
- Implement automatized feed-forward compensation system.

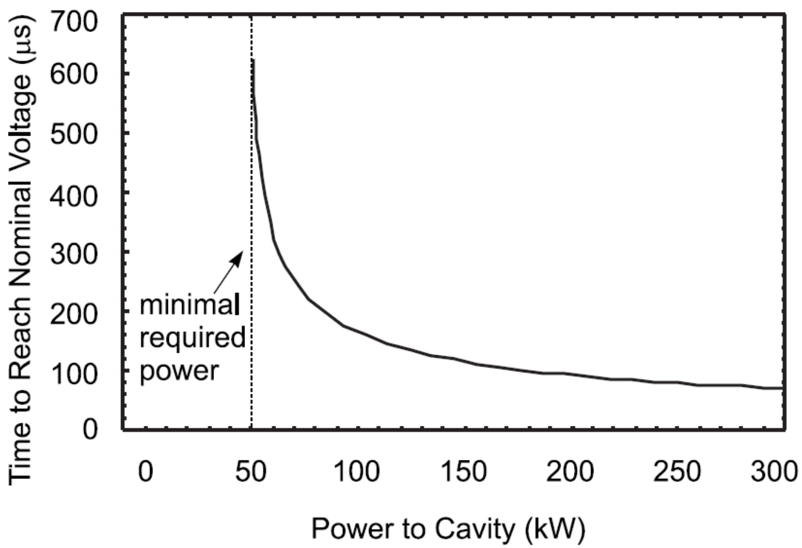
Charging the cavity

Table I. Beam and spoke cavity parameters.

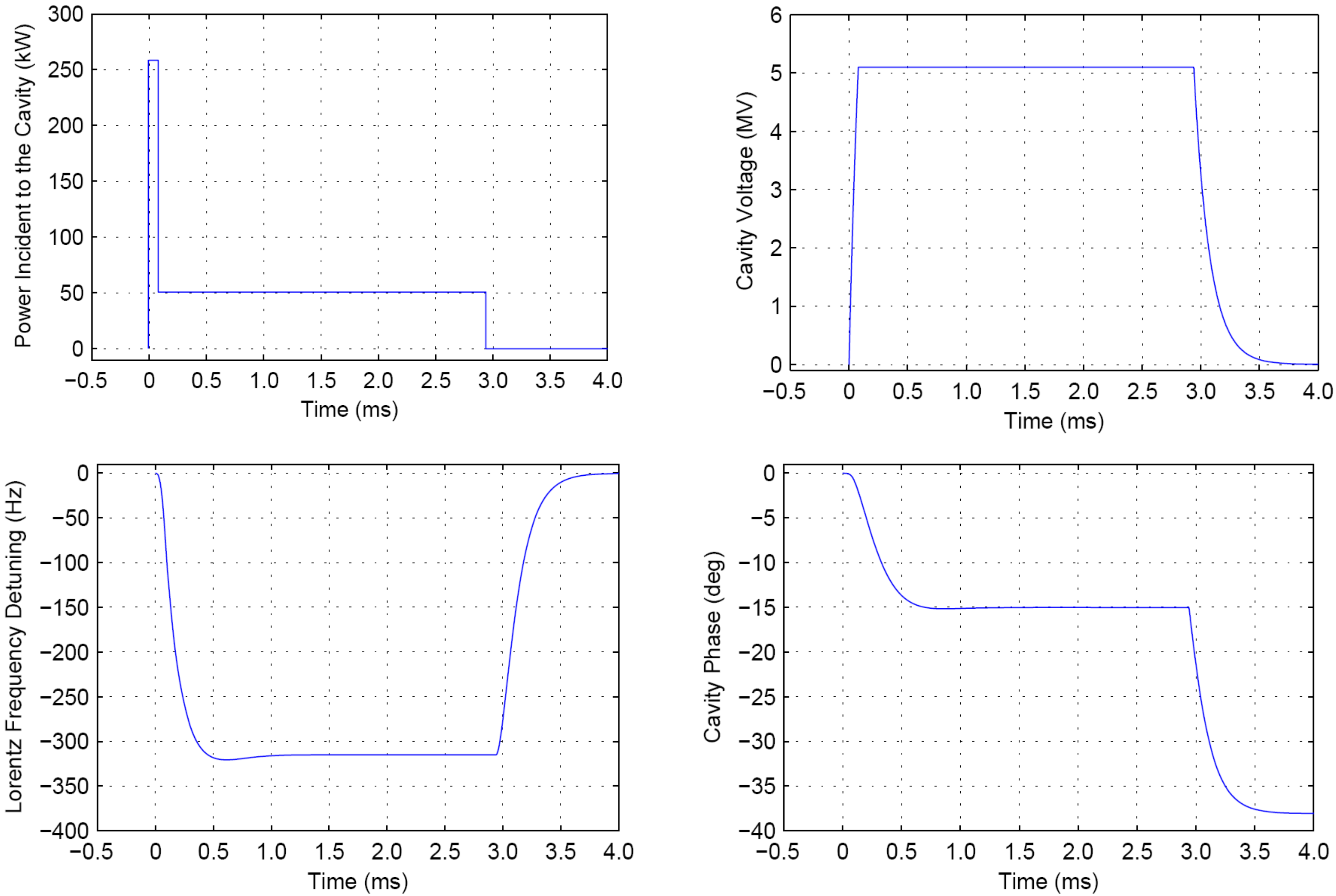
Parameter	Symbol	Value
DC beam current	I_b^{DC}	50 mA
Beam velocity	β	0.386
Accelerating gradient	E_{acc}	8.5 MV
Accelerating length	L_{acc}	0.639 m
Cavity voltage	V_c	5.1 MV
Beam form-factor	F_b	1
Accelerating phase (LINAC convention)	ϕ_e	−30 deg
Bare cavity Q-factor	Q_0	$1.2 \cdot 10^{10}$
Ratio of shunt resistance to total Q-factor	R/Q	426 Ω
Frequency	f	352.21 MHz
Optimal cavity pre-detuning	Δf^{opt}	805.4 Hz
Optimal external Q-factor	Q_{ext}^{opt}	$1.2 \cdot 10^5$
External Q-factor	Q_{ext}	$1.5 \cdot 10^5$
Transit-time factor time	T	0.73
Lorentz detuning coefficient	K_L	-2.8 Hz/(MV/m)^2







Cavity charging without beam



Summary

- The spoke cavity has never been used in a real operating accelerator;
- The electroacoustic stability and tuning system of the cavity can be studied only in a high-power test stand;
- The FREIA group at Uppsala University is building a high-power test stand for studying performance of the ESS spoke cavity;
- The RF test stand will be able to drive the cavity not only in the self-excitation mode but also with closed RF loop and fixed frequency;
- The cavity tuning compensation system will be tested under realistic conditions.