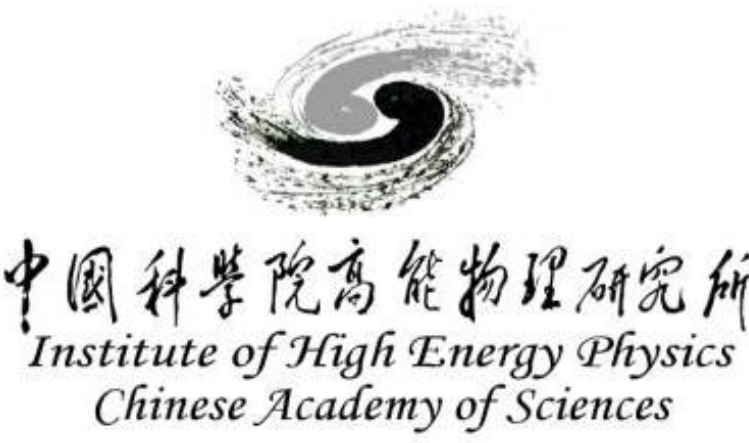# Development of a 166.6MHz digital low-level RF system for HEPS-TF project

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Abstract

A 166.6 MHz superconducting RF system has been proposed for the High Energy Photon Source (HEPS), a 6 GeV kilometer-scale light source. A 166.6MHz digital low-level RF system for HEPS-TF project has been developed firstly. And the digital low-level RF system has been successfully applied to the horizontal high power test of 166.6MHz superconducting cavity. The cavity field stability has been successfully achieved about ±0.03%(peak-peak) in amplitude and ±0.02 degree(peak-peak) in phase while the cavity field voltage is up to 1.2MV. It can meet the field stability requirements towards ±0.1% in amplitude and ±0.1 degree in phase of HEPS project. Further study and optimization of the system is under way.
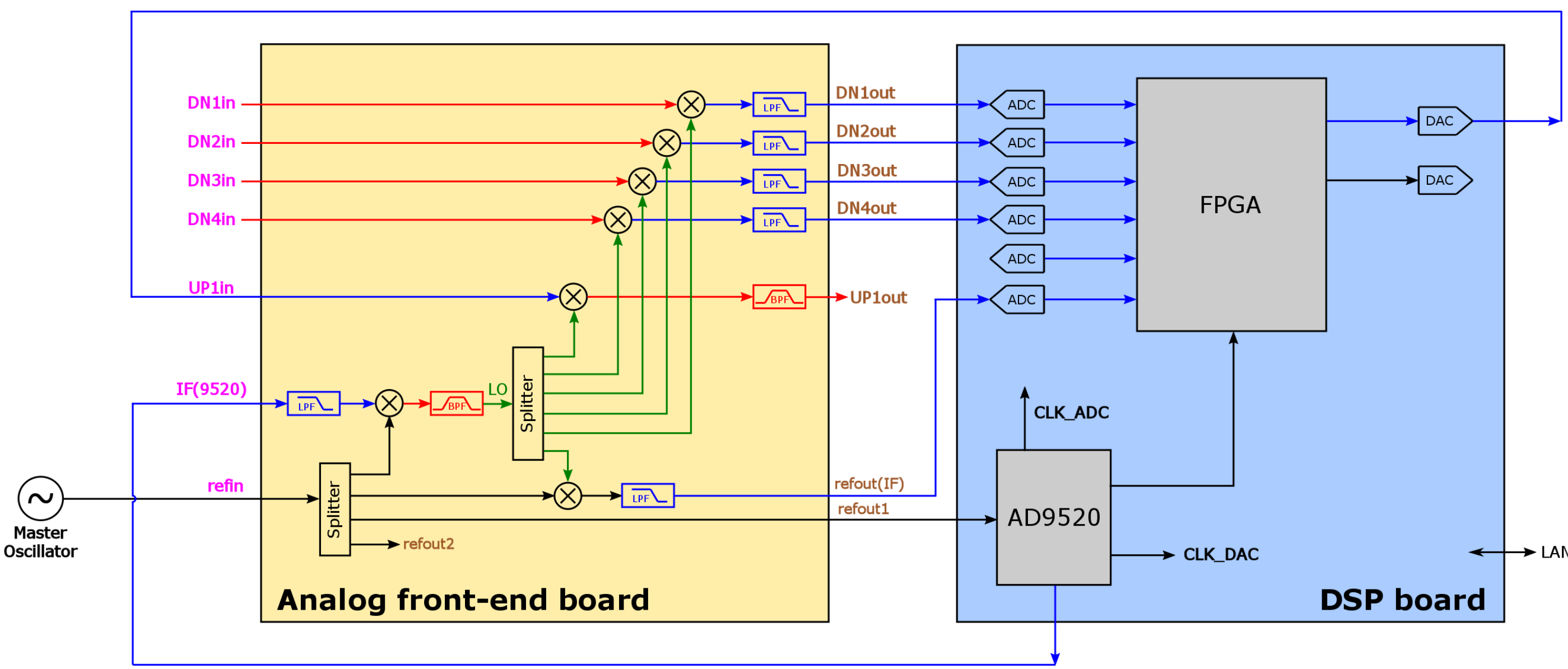
1. High Energy Photon Source

Parameter	Value
Energy	6 GeV
Circumference	1360.4 m
Current	200 mA
Energy loss/turn	4.4 MeV
Beam power	900 kW

2. RF System
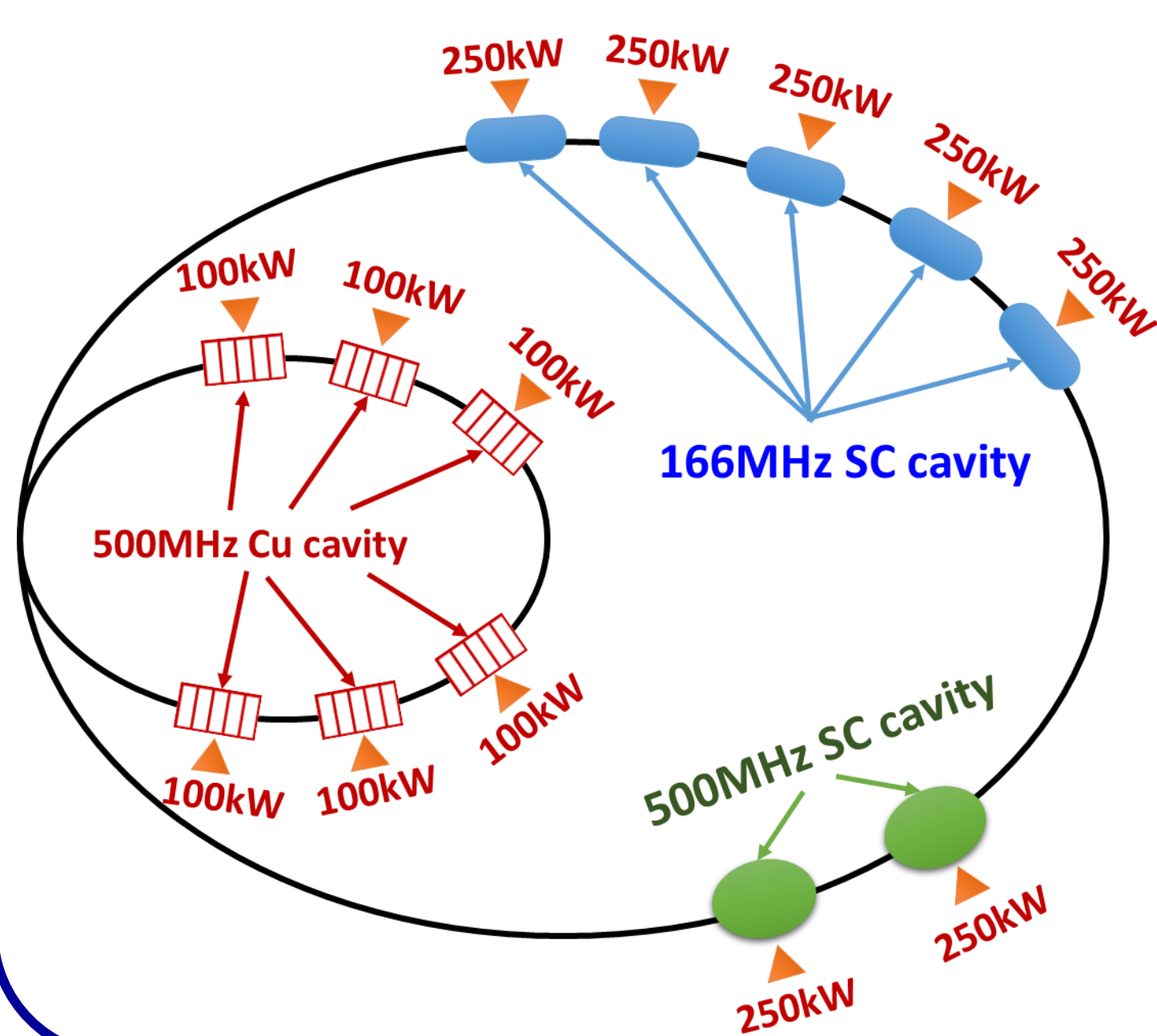
Beam parameter	Value
Beam energy [GeV]	6
Beam current [mA]	200
Energy loss/turn [MeV]	4.4
Beam power [kW]	900
RF parameter	**Value**
RF frequency [MHz]	166.6, 499.8
Total RF voltage [MV]	5.4, 3.2
RF field stability (A, Φ) (peak-peak)	±0.1% ±0.1°

3. LLRF Block Diagram and Hardware

DSP Board

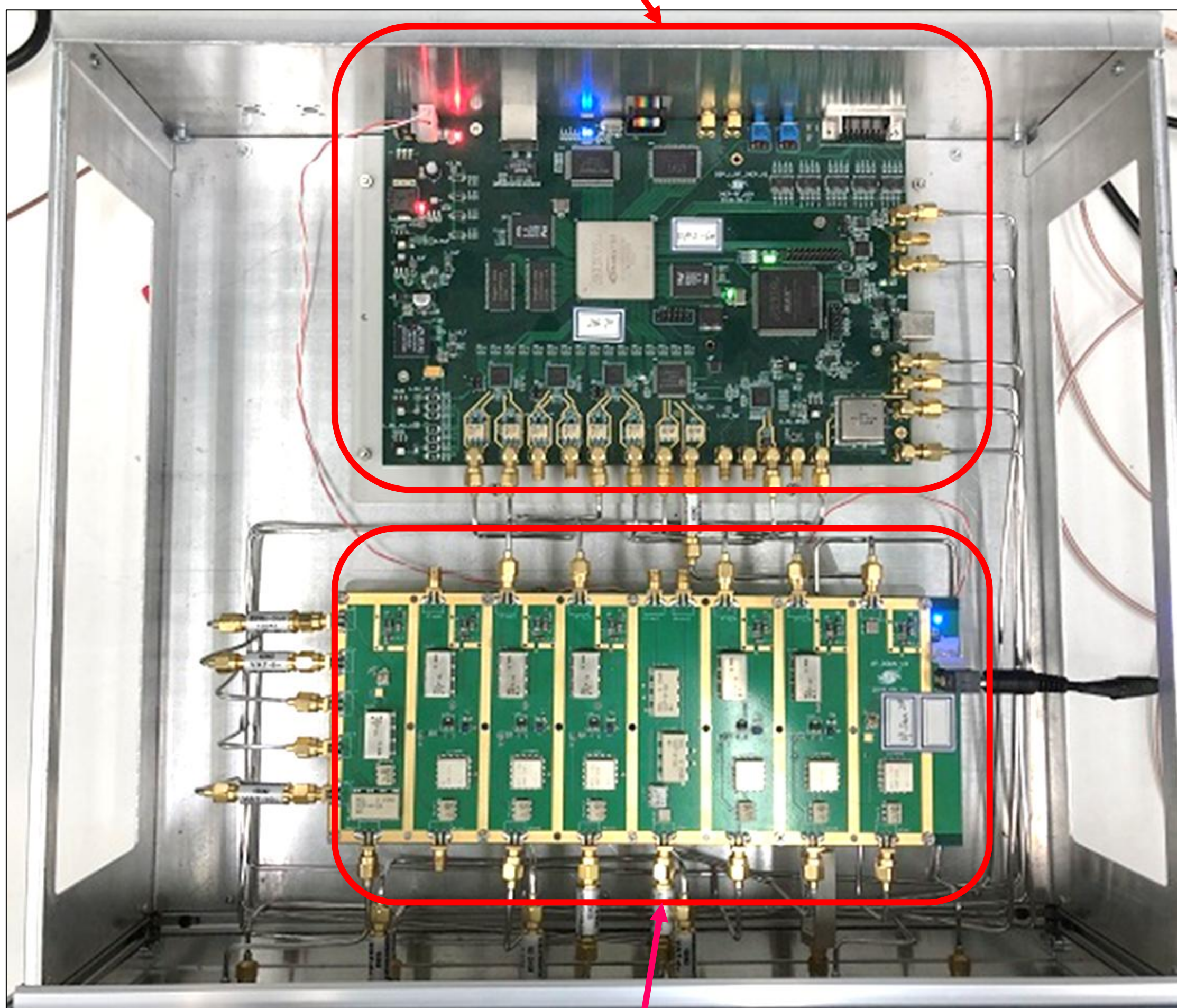**Analog Front-end**

Mockup Cavity

DSP board

- FPAG: ALTERA Stratix III
- ADC: 3 dual-channel 16-bit 125MSPS AD9268-125
- DAC: 1 dual-channel 16-bit 800MSPS AD9788
- CLK Distribution: AD9520

Analog Front-end

- RF: 166.6MHz
- IF: 9.8MHz
- LO: 176.4MHz
- Up conversion: 1 channel
- Down conversion: 5 channels
- RF out: 2 channels (1 backup)

4. Lab Tests
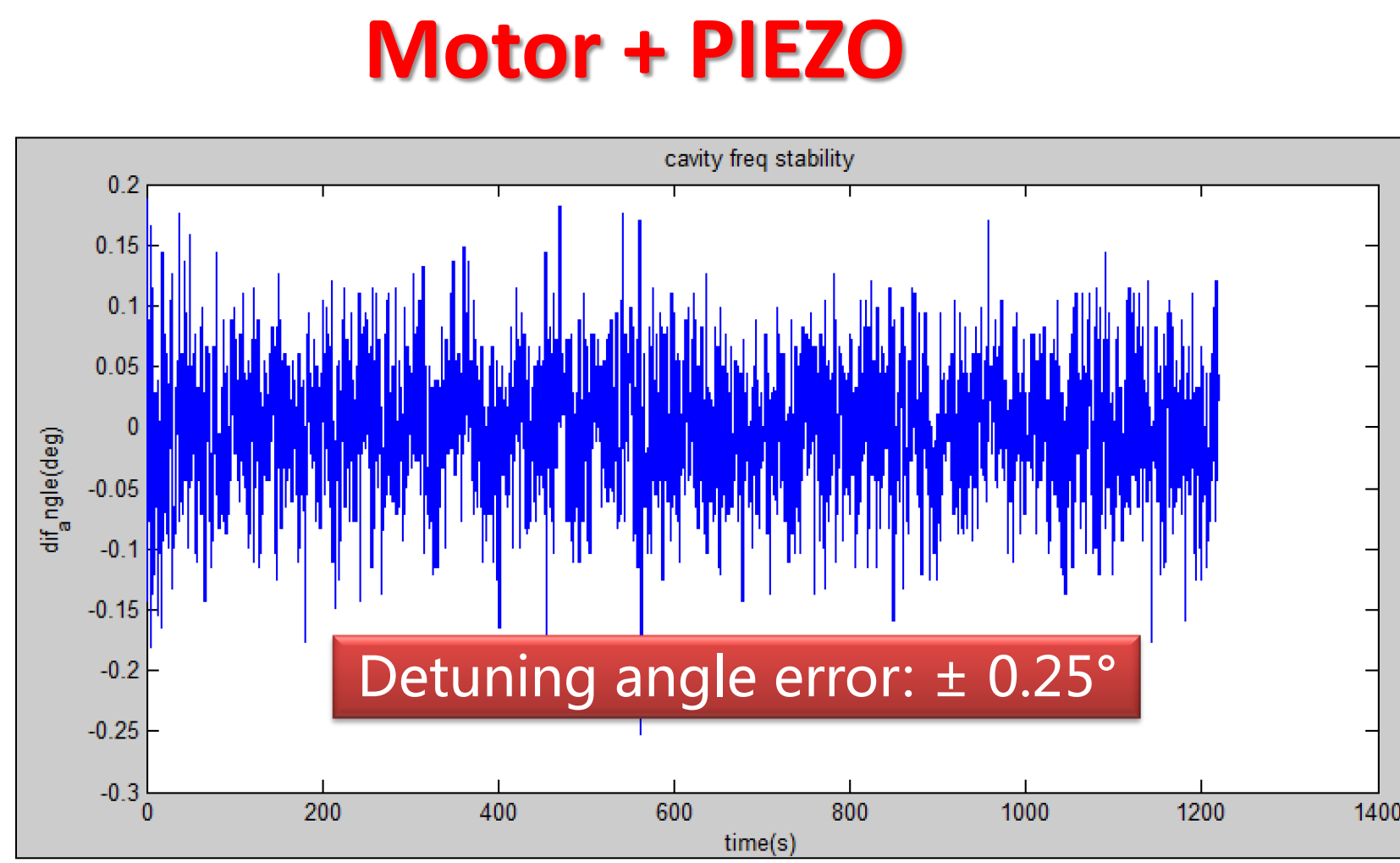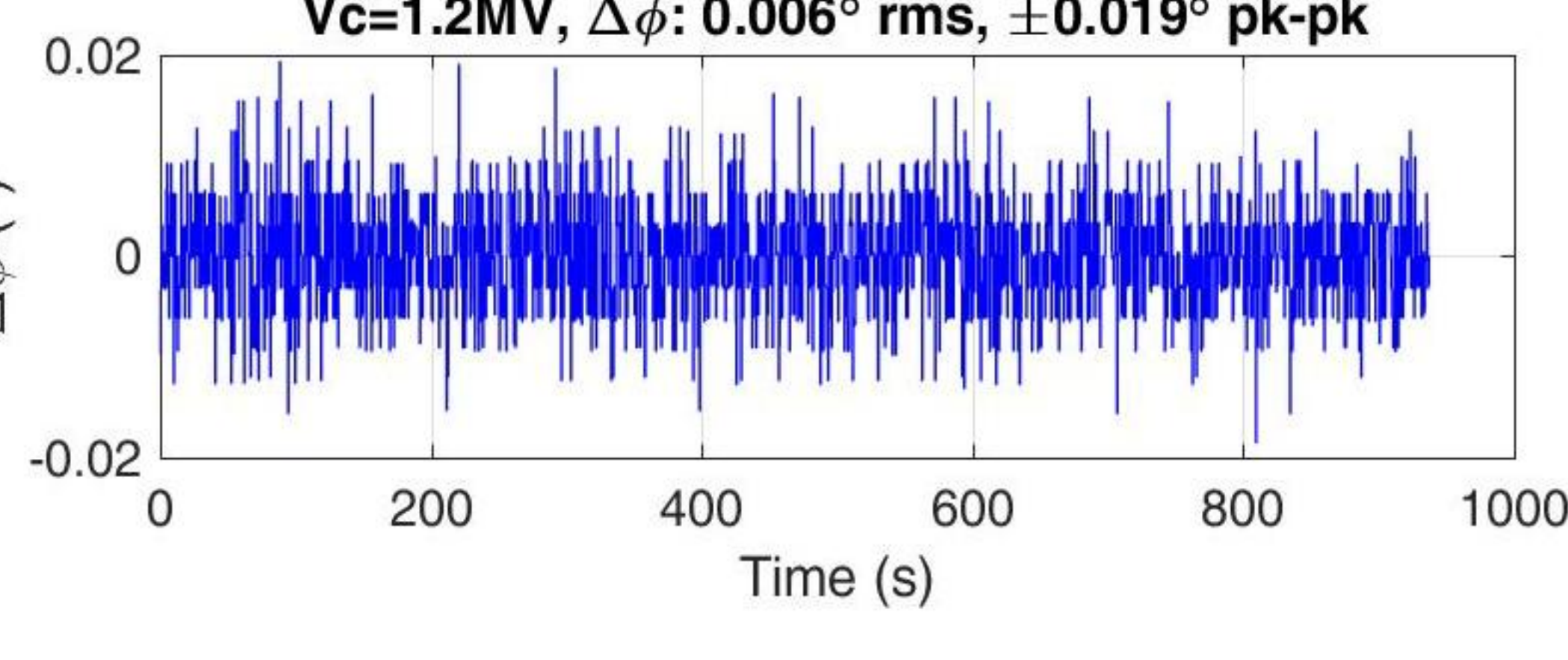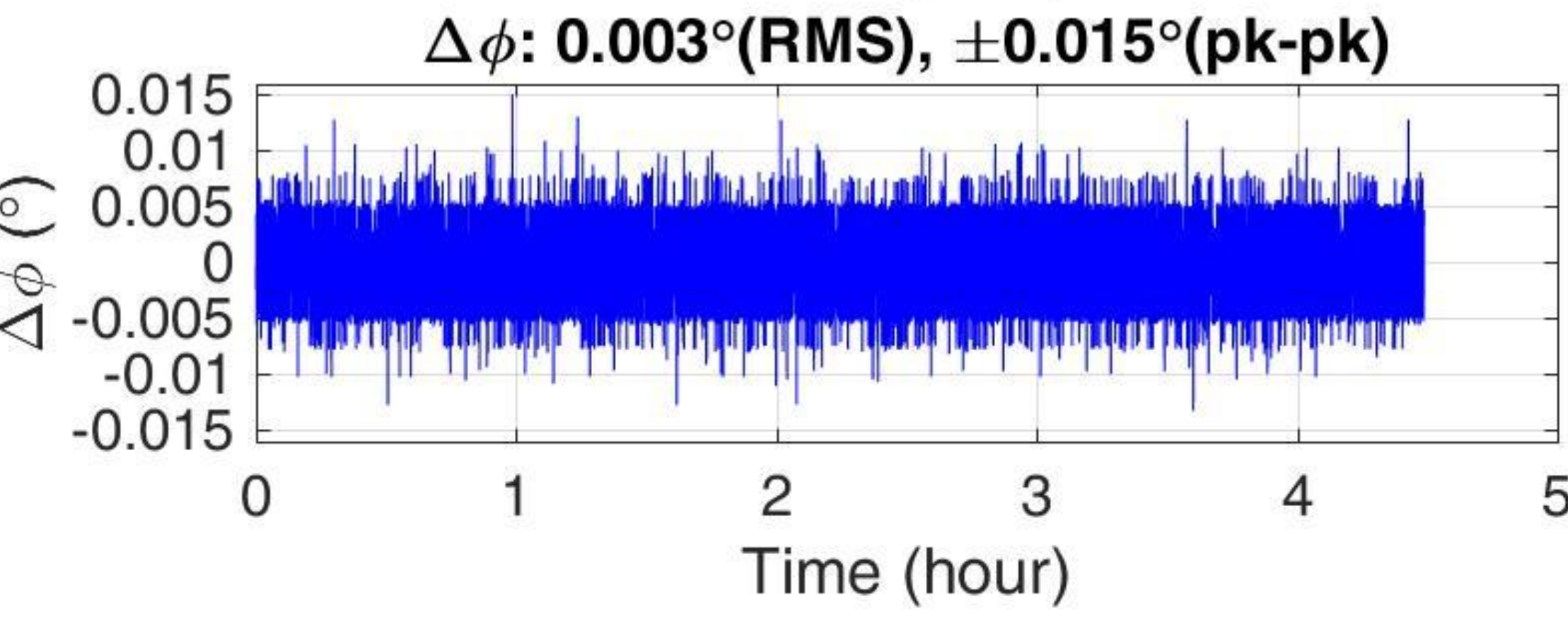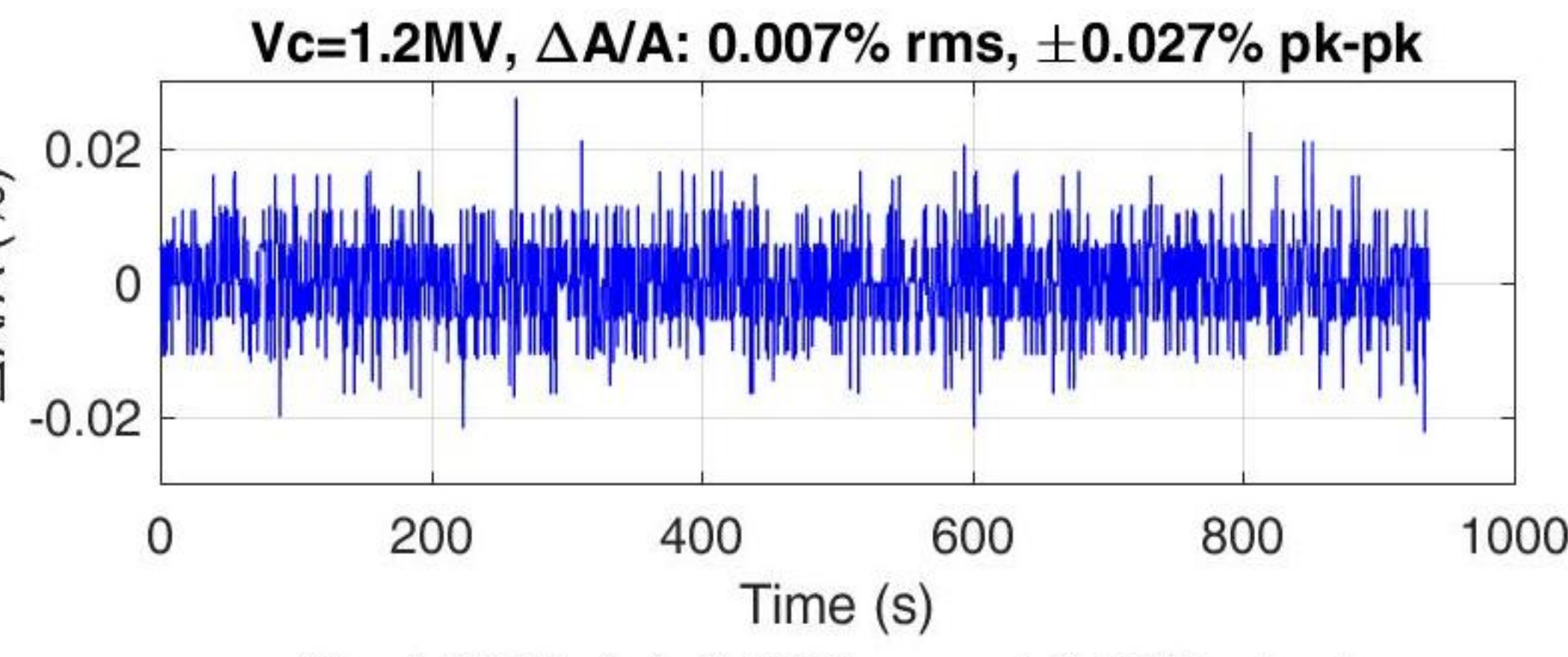

ΔA/A: 0.005%(RMS), ±0.026%(pk-pk)

Δϕ: 0.003°(RMS), ±0.015°(pk-pk)

Vc=1.2MV, ΔA/A: 0.007% rms, ±0.027% pk-pk

Vc=1.2MV, Δϕ: 0.006° rms, ±0.019° pk-pk

Motor + PIEZO

Detuning angle error: ± 0.25°

	ΔA/A	ΔΦ
HEPS SR specification	**±0.1%(pk-pk)**	**±0.1°(pk-pk)**
Self-closed loop (in lab)	0.006%(rms) ±0.032%(pk-pk)	0.003°(rms) ±0.016°(pk-pk)
On mockup cavity (in lab)	0.005%(rms) ±0.026%(pk-pk)	0.003°(rms) ±0.015°(pk-pk)
On SC cavity at 4K (on horizontal test bench)	0.007%(rms) ±0.027%(pk-pk)	0.006°(rms) ±0.019°(pk-pk)

LLRF + Mockup Cavity

LLRF + Superconducting Cavity

Tests In Summary