DIGITAL LOW LEVEL RF SYSTEMS FOR SESAME Synchrotron

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Abstract

SESAME the Synchrotron Radiation Light Source in Allan (Jordan) consists of a 22 MeV Microtron and an 800 MeV Booster Synchrotron (original from BESSY I, Berlin, Germany) and a newly designed 2.5 GeV Storage Ring. The RF system consists of four 500 MHz ELETTRA cavities powered by four 80 kW Solid State Amplifiers with the first amplifier produced by SOLEIL and the other three produced by SIGMA-PHI. The RF plant is controlled by the digital Low Level Electronics from Dimtel. Inc. The system has been installed at the end of 2016. This report describes the setup of the facility and the results of the commissioning.

SESAME SR MAIN PARAMETERS

Energy	GeV	2.5
Current	mA	200
Circumference	M	133.2
Harmonic No.		222
Energy Losses per turn	keV	603
Momentum compaction		0.008
Natural Emittance	nm.rad	26
Energy Spread	%	0.1

500 MHZ ELETTRA CAVITIES

No. of Cavities		4
Frequency	MHz	499.65
Coupling Factor		2
Maximum Voltage	kV	650
Maximum Cavity Power	kW	66

80 KW SOLEIL SOLID STATE AMPLIFIER

P_{out}	kW	80
Total Gain	dB	78
Max.Pref @ Pulsed 10us	kW	80
Max.Pref @ CW	kW	30
Efficiency at full Power	53	%

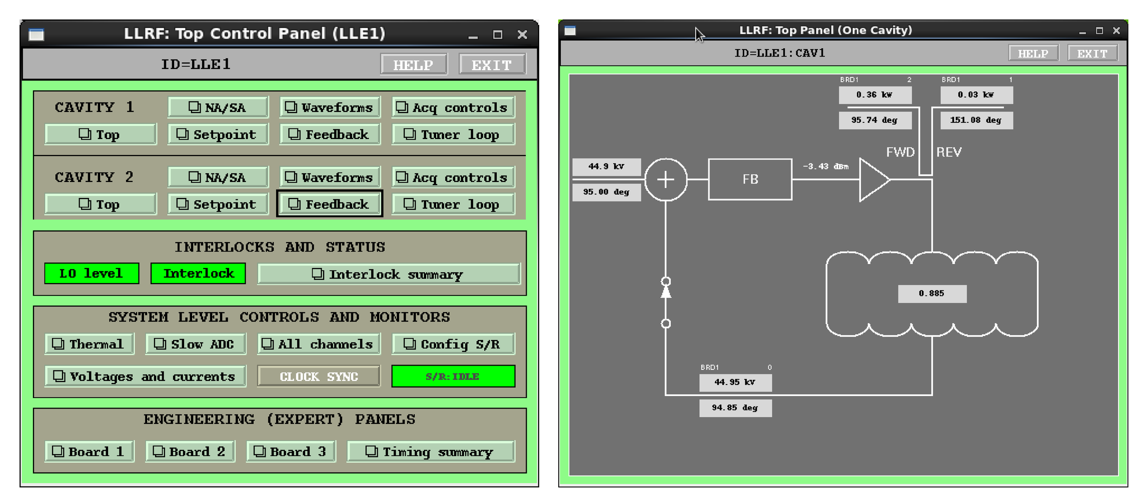
Figure 1: SESAME RF plants, solid state amplifiers, WR-1800 waveguides and LLRF9/500 controllers in the center racks.

LOW-LEVEL RF LLRF9/500

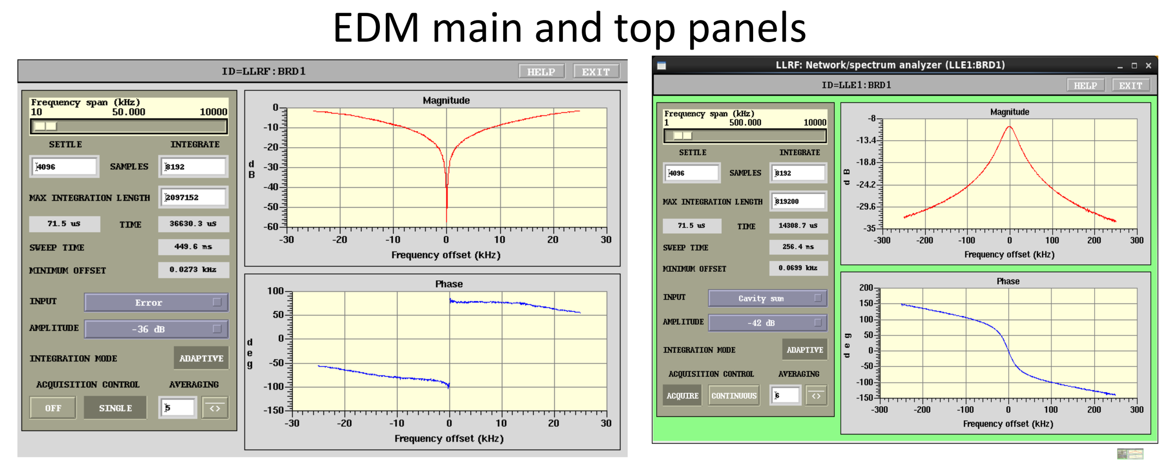
LLRF architecture is based on three Dimtel, Inc. LLRF9/500 processors. Each unit has 9 RF inputs and 2 filtered and interlocked RF outputs and is capable of controlling two RF cavities. For SESAME RF SR and Booster systems, three LLRF9/500 units provide 27 RF inputs, with 15 of these inputs used to measure individual cavities in the booster and the storage ring (three signals per cavity: probe, forward, and reflected).

Remaining 9 inputs can be utilized to monitor additional channels, if needed. LLRF9/500 performs cavity field stabilization in amplitude and phase. Phases of probe and forward signals are used to control cavity resonant frequency in a tuner loop, which communicates to motion control hardware via Ethernet.

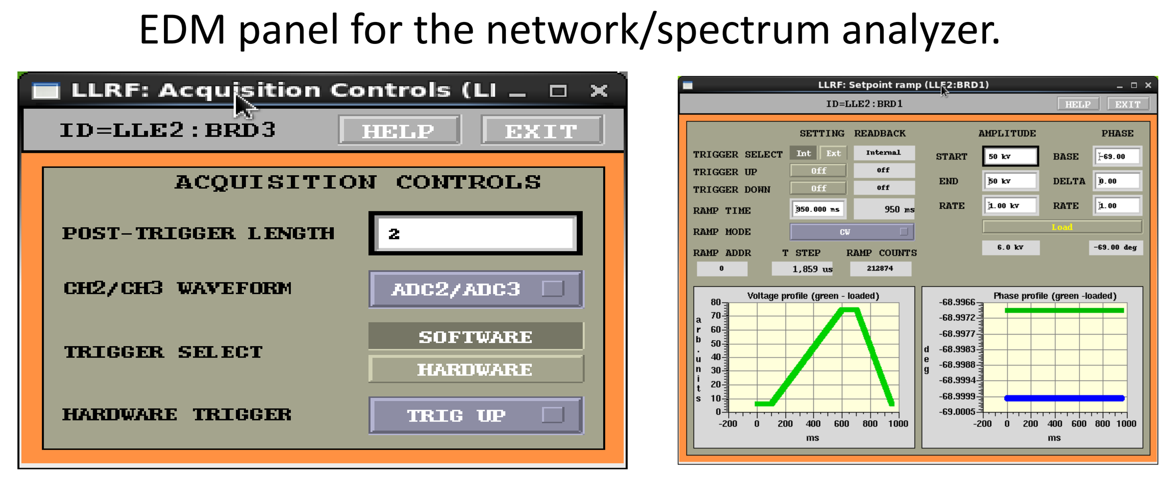
LLE CONFIGURATION



EDM main and top panels



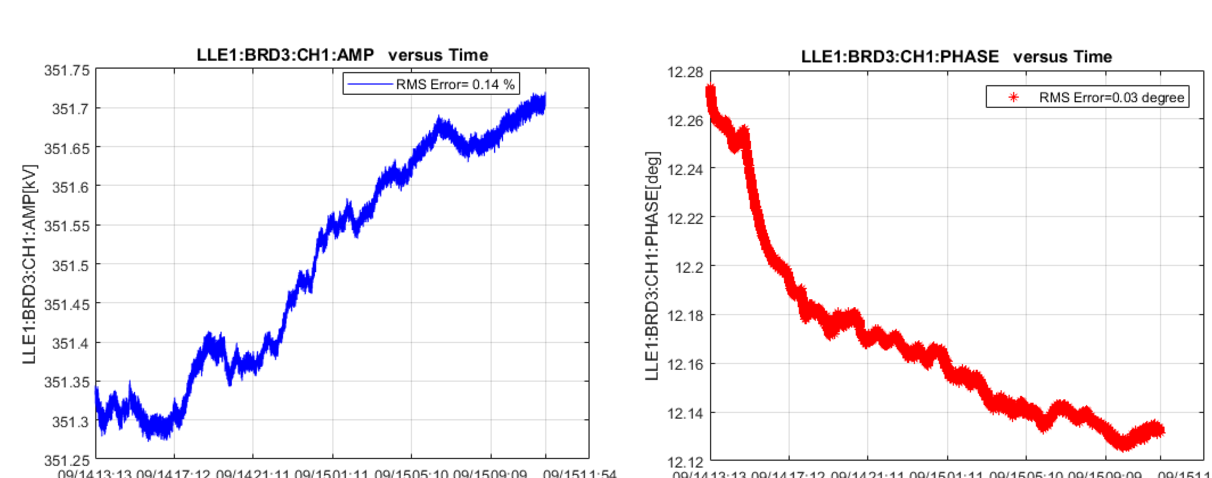
EDM panel for the network/spectrum analyzer.



Acquisition system and configurable set point profile

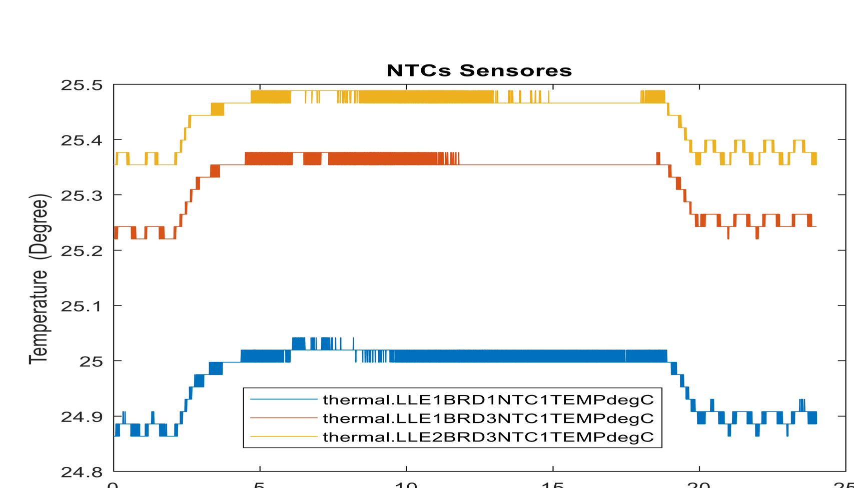
FIELD STABILITY WITHOUT BEAM

The amplitude and phase stability measurement was performed over 24 hours and without beam. Pick up voltage signal from cavity probe 2 has been connected to spare fast ADC in LLRF9/500. Figure below shows amplitude and phase stability over 25 hours with 0.1 second sampling interval.



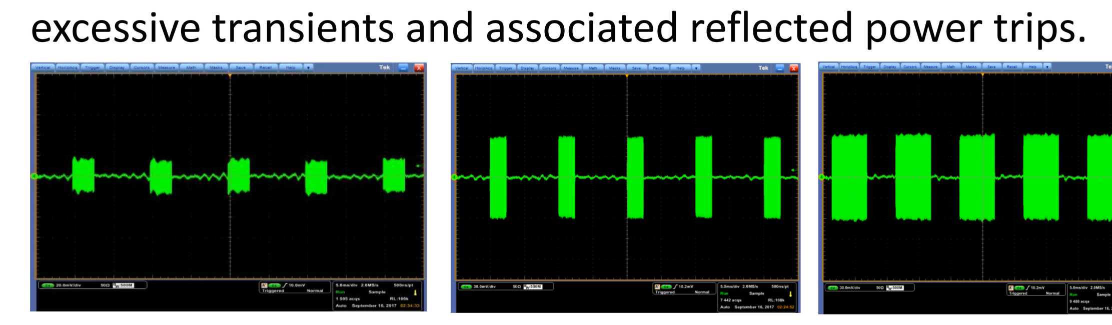
INTERNAL TEMPERATURE STABILIZATION

LLRF9/500 uses active thermal stabilization of the sensitive RF electronics and is capable of rejecting a wide range of ambient temperature variations. A total of 10 internal temperature sensors are monitored via EPICS. FPGA code is designed to shutdown signal processing paths and on-board devices for hardware thermal protection.

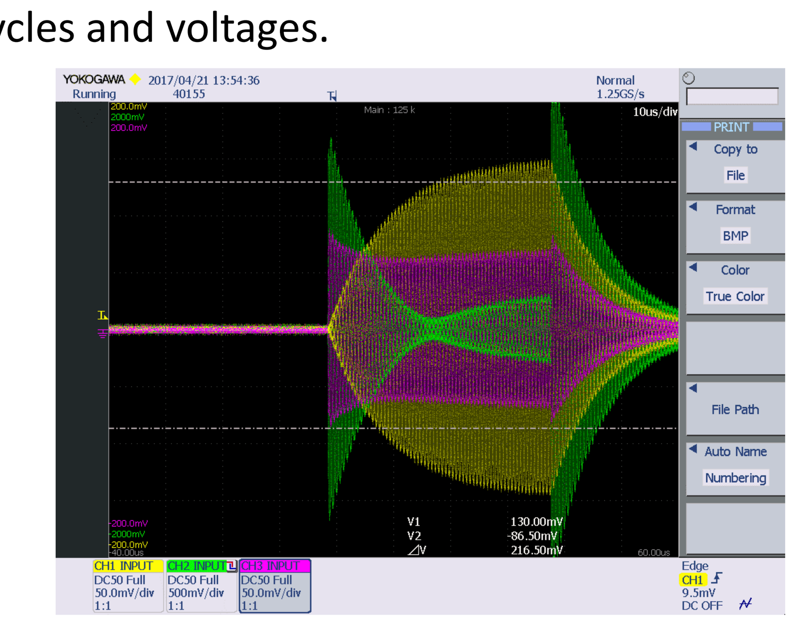


CAVITY CONDITIONING

A Matlab tool has been developed for pulse mode cavity conditioning. At each voltage setting, the duty cycle of 100 Hz pulse train is increased from 1% to 100% in 1% steps while monitoring the interlock signal. In case of an interlock trip the duty cycle is reset to 1% and the process restarts. The tool supports adjustable rise/fall times to avoid excessive transients and associated reflected power trips.



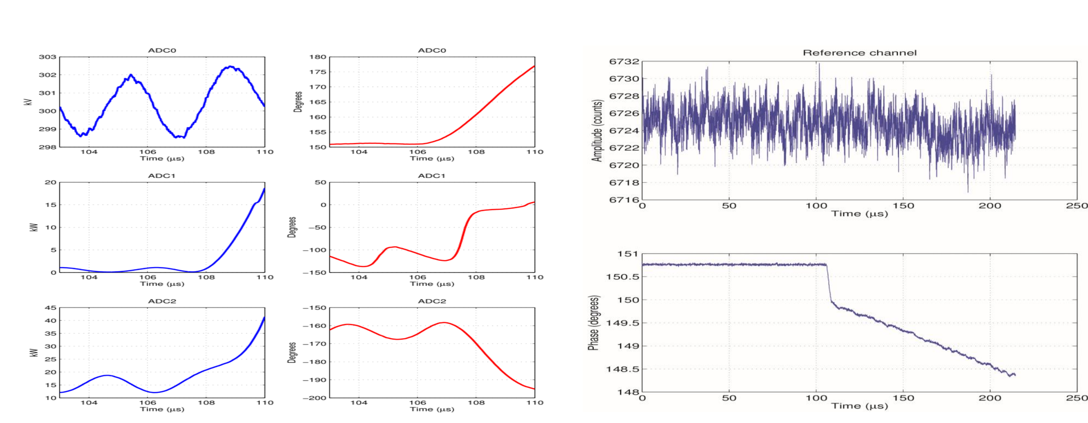
RF high power conditioning using LLRF9/500, upper images are an oscilloscope traces of the SSA drive signal at different duty cycles and voltages.

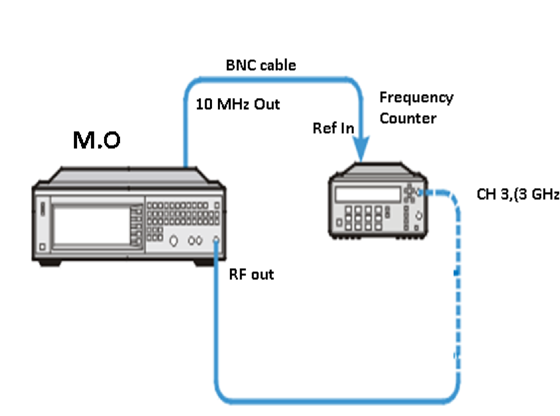


Scope trace showing incident (pink), reverse (green), and probe (yellow) signals during conditioning. Cavity charge/discharge are clearly seen in the probe signal. With coupling β>1, reverse power is higher at the falling edge.

MASTER OSCILLATOR CONTROL

Small changes of the master oscillator (SSX-WORK Microwave) frequency at certain transitions lead to large transient frequency jumps. Resulting phase discontinuities cause RF trips during machine operation. In order to avoid this phenomena we implemented RF frequency adjustment via DC-coupled FM modulation input of the MO. Figures below illustrate the transient jump captured by LLRF9/500 trip acquisition subsystem.





Analog DC-coupled FM modulation preserves phase continuity. In this configuration master oscillator output must be monitored by a frequency counter to measure the actual ring RF frequency.

REFERENCES

[1] Dimtel Inc., San Jose, USA, http://www.dimtel.com