LLRF Upgrade and Dual-Harmonic Operation at SIS18

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SIS18 RF Systems

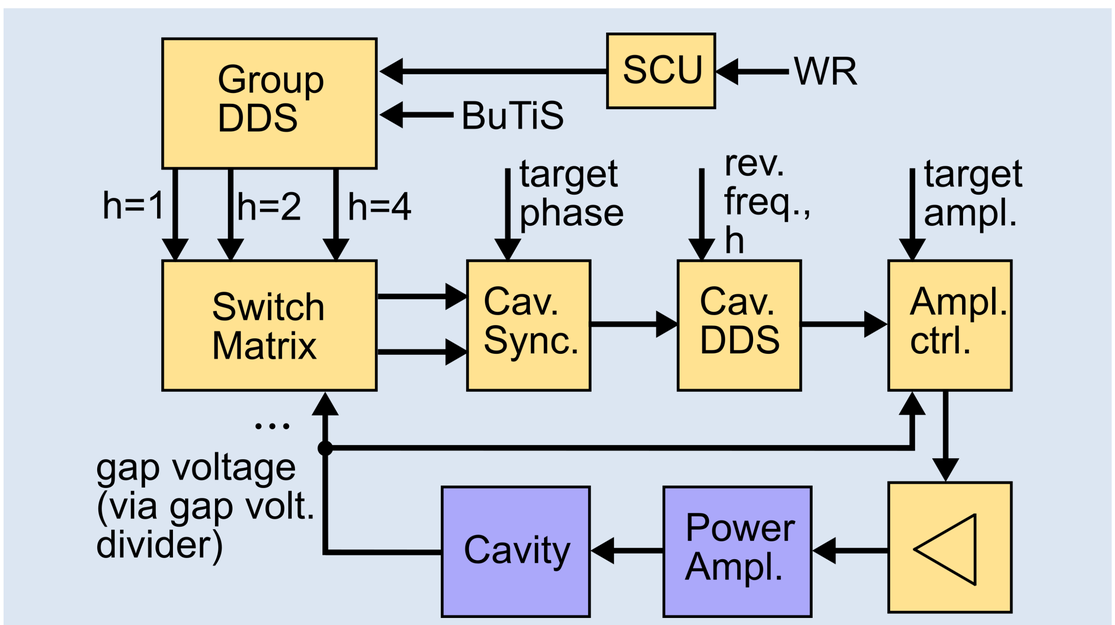
RF systems of heavy-ion synchrotron SIS18 as future pre-accelerator for FAIR SIS100 synchrotron:

- 3 magnetic alloy accelerating cavities
- 2 ferrite cavities
- 1 bunch compressor cavity

Major Changes of LLRF Topology Since 2016

Realization steps towards designed topology [1]:

- Switch matrix for distribution of gap and reference signals for the cavity (phase) synchronization
- BuTiS (Bunch Phase Timing System, [2]) station for local generation of reference signals (Group DDS), dedicated clock signals coupled to WR
- New control system front-end hardware (SCU) and software, using FESA and White Rabbit (WR) timing system



Selected LLRF Strategies

Reaching required amplitude (better than ±6%) and phase accuracy (better than 3°):

- Relevant signal lines carefully measured and adjusted to reach equal electric delays
- Calibration of Group DDS reference signals with respect to BuTiS, stays valid even after changing harmonic numbers of Group DDS [3]
- Calibration of ferrite and magnetic alloy cavity systems in amplitude and phase

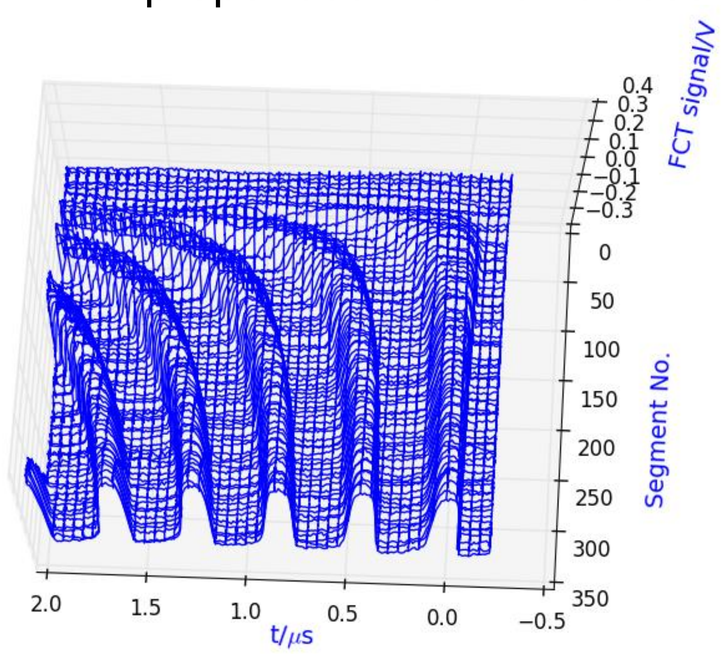
Machine Development Experiment Parameters

Ion species	$^{12}C^{6+}$
Number of particles (typical)	$1.1 \cdot 10^9$
Injection energy	11.378 MeV/u
Revolution frequency (h=1) at injection energy	214.3 kHz
Extraction energy	1300 MeV/u
Revolution frequency (h=1) at extraction energy	1.257 MHz
Beam current at flat-top (typical)	1.1 mA
Harmonic number MA cavities	h=2
Harmonic number ferrite cavities	h=4

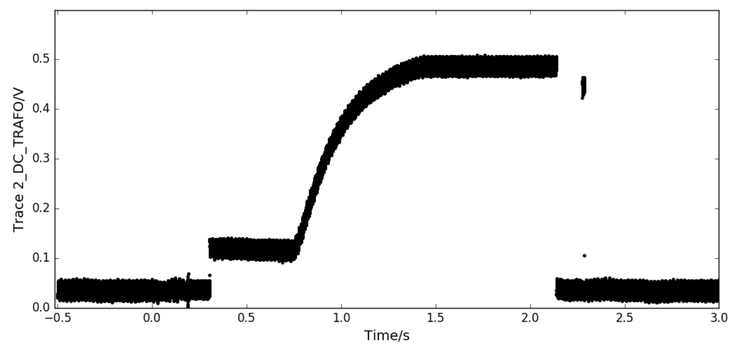
Dual-Harmonic Operation

Machine development experiment:

- Dual harmonic scenario with h=2 (MA cavities) and h=4 (ferrite cavities)
- Longitudinal bunch shapes (2 bunches) show proper dual-harmonic acceleration

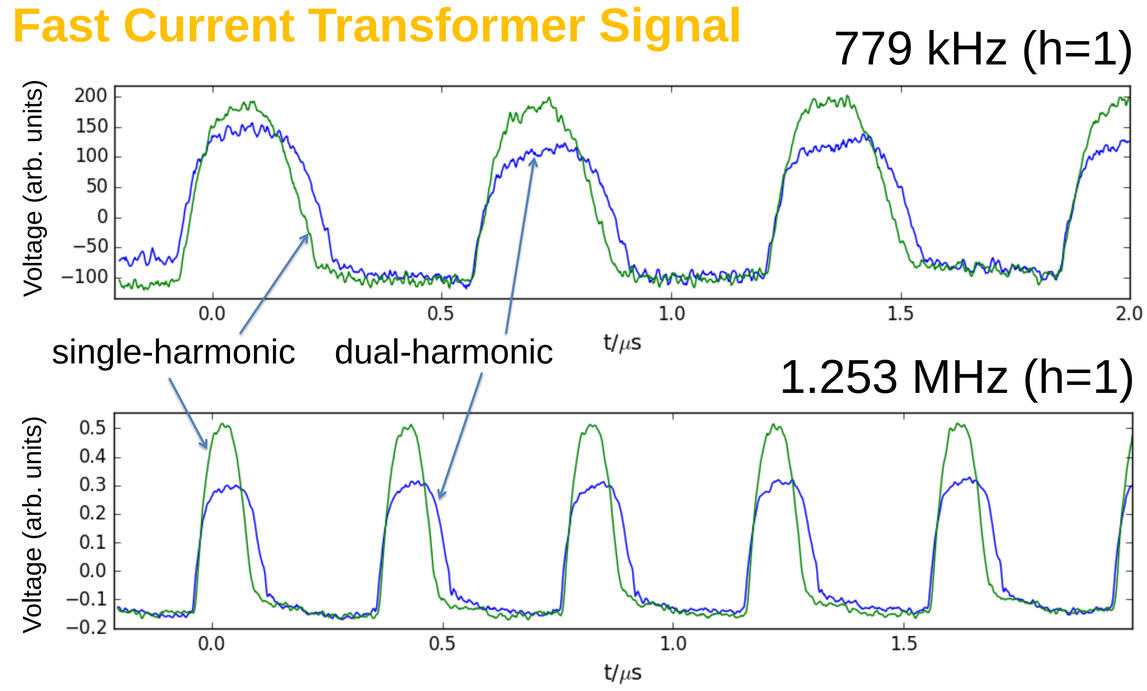


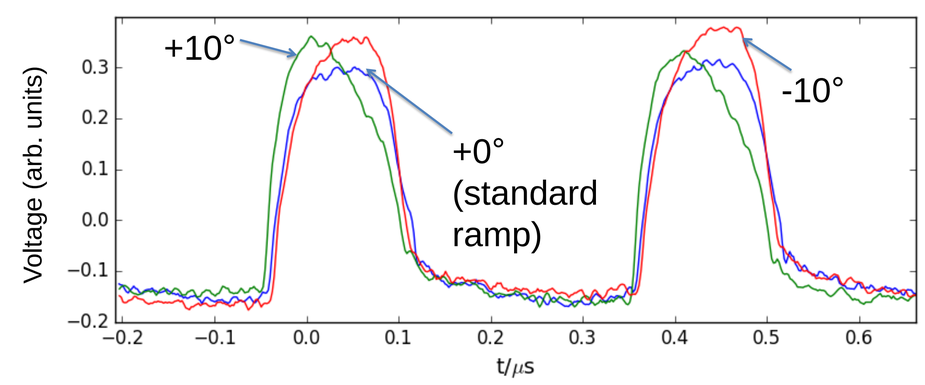
Waterfall plot of beam current signal after post-processing (removing DC component of each segment)



DC beam current signal, no significant beam losses

Fast Current Transformer Signal





Target phase ramp variation

Conclusion

- Major LLRF upgrade prepares SIS18 for FAIR
- Previously achieved phase accuracy [4,5] has been re-established

References

[1] H. Klingbeil et al., Phys. Rev. STAB 14, 102802, 2011
[2] B. Zipfel and P. Moritz, IPAC2011, MOPC145, 2011
[3] A. Andreev et al., IPAC2017, THPAB097, 2017
[4] K.-P. Ningel et al., IPAC'10, TUPEA037, 2010
[5] B. Zipfel et al., IPAC2014, THPRO102, 2014