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Low Level RF Workshop 2022

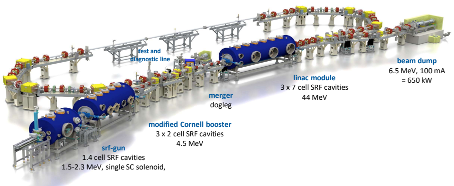
9-13 Oct 2022, Brugg-Windisch, Switzerland

HZB Helmholtz Zentrum Berlin

STATUS OF THE HELMHOLTZ ZENTRUM BERLIN SEALAB LLRF INFRASTRUCTURE

ABSTRACT: **The preparation of the LLRF Control equipment of the SeaLab project for the commissioning is going on. The current hardware configuration comprises gun and booster cavities under server PC control and the standalone transverse deflecting cavity controller. The ongoing infrastructure works, i.e. cabling traces termination/patch panels connection, network installation and power lines distribution, are going to lead to the final equipment relocation to the RF equipment hall till the end of this year. The control EPICS system was preconfigured to monitor the LLRF equipment and its status. The hardware upgrade, i.e. exchange by the newer ADC/VM and Mezzanine boards, is planned for this autumn. Beside that the basis for the future scientific studies in the SeaLab become the Xilinx RFSoC. Number of applications are migrating from mTCA equipment to RFSoC, because of more rapid prototyping, reach peripheral devices, and open architecture supported by Xilinx. Among them are system analyzer, detuning control, RF system observer, and self-excited loop.**

bERLinPro: Energy Recovery Linac



Developments to date [1]:

- Beam dynamics and manipulation: merger, recirculatory, beam brake-up;
- SRF systems: photo-injector, high power booster, HOM-damped Linac
- Injector: high repetition laser system, high QE cathode
- Control of beam loss and radiation protection: dark current suppression, high-power beam dump
- High power RF sources:
  - 3 x 270kW Klystrons: 1 in use for copler conditioning + 2 for Booster
  - 15kW SSAs: Linac + Tcav + Booster
- Completed setup for the vacuum system

Missing components:

- Linac module
- Linac cryo module

Transition to Sealab [2,3]

ERL facility future applications (LLRF) [4]:

Injector measurements:

- Emittance preservation in merger;
- Microbunching investigations.

Accelerator test facility:

- Machine learning
- RF power saving
- Detuning compensation

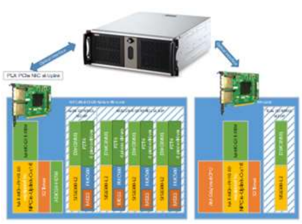
CW SRF cavities/ module test facility

Multicolor UED/ THz/IR source

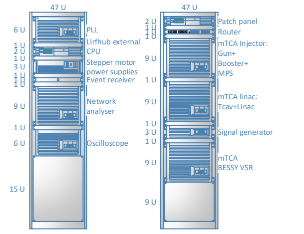
LLRF Setup in Hobicat

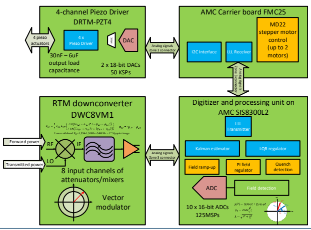
Sealab LLRF includes 2 crates + external CPU

1 cavity LLRF HW/FW setup

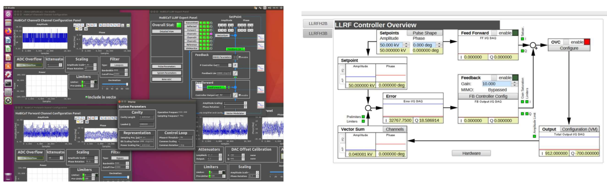


Sealab LLRF climatized racks filling plan

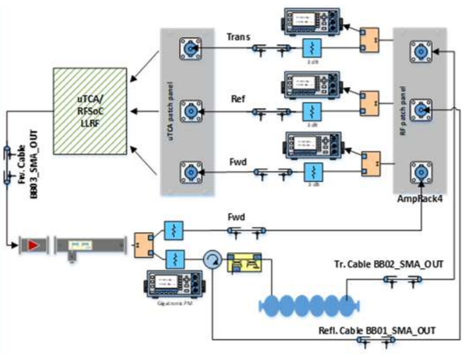




Recent Control System migration and LLRF Control Panels update: S Studio Eclipse to CS Studio Phoebus



Hobicat test facility



Measurement equipment: PLL, 3 Power Meters, Cernox Temperatur (Cooldown reference (Helium vessel endplate), Beam tube (FPC side), Coupler port, Tuner motor, Piezo), OST, Vacuum gauge, PaPu), Dosimeter, Scintillator, Heater for quench, 15 kW/4kW SSA.

Measurement routine: cables calibration in warm/cold; Q0(Eacc) (helium mass flow); fieldemission (Spectrum); Lorentz force detuning; Pressure sensitivity; Piezo transfer function; LF transfer function; Piezo Range+hysteresis; Motor range; measure Qext(Pfor); TM010 passband; vector modulator calibration;

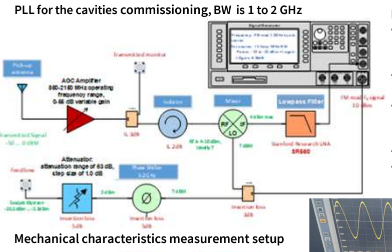
LLRF tests current/next year:

- RF P + piezo PI closed loop, gain stability scan, learn MIMO control as PI controller;
- Kalman, quench detection, ramping field with GDR.

The best reached stability:

- P RF loop: Amplitudy=0,0013, Phase= 0,06°;
- P RF + PI Piezo : Amplitude= 0,001, Phase= 0,028°.

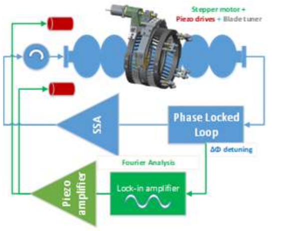
PLL for the cavities commissioning, BW is 1 to 2 GHz

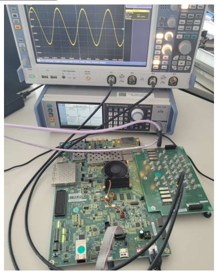


RFSoC projects :

- Detuning calculation
- Phase stability calculation;
- Kalman filter observer
- Feedforward microphonics compensation
- Self Excited Loop
- Portable Cavity Signal Analyzer

Mechanical characteristics measurement setup





CONCLUSION

- Testing Halle 1, Testing Halle 2 with the adjacent clean rooms; SRF Test Stand; Hobicat Test Facility; Sealab with installed RF power, cryo, laser/injector and other ERL infrastructure
- Completion of the injector and linac/dump lines allows Injector Commissioning with beam (up to 5-10 mA, up to few 100 pC, up to 6.5 MeV)
- HW architecture is fixed and updated to the last generation of the mTCA standard boards. It represents 2 crates under control of the host powerful external CPU over optical links.
- FW development milestone projects located at gitlab.msktools.desy.de. The standard FW was updated by the ramp-up and piezo-control
- Control System is updated according to the last control panels architecture
- The testing procedure was worked out on the example of Tesla resonator. The necessary set of test equipment is defined and is improving all the time
- Further software development is aimed at mitigating microphonics and controlling detuning. This goal remains unchanged for berlinPro and Sealab.
- Part of the development is transferred to the RFSoC, which allows to transfer numerous scientific experiments to the open platform. At the same time the development consists mainly in the development of SW once the HW is defined
- The next significant step for LLRF team will be automation of optimal control parameters selection instead of sequential control algorithm tuning procedure. Also several experimental works on optimization of simultaneous operation of several resonators should be carried out.

REFERENCES

[1] M. Abo-Bakr *et al.*, *Status Report of the Berlin Energy Recovery Linac Project BERLinPro*, in *Proc. 9th Int. Particle Accelerator Conf. (IPAC'18)*, Vancouver, BC, Canada, Apr. 4, pp. 4127-4130, doi:10.18429/JACoW-IPAC2018-THPMF034

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[3] J.-G. Hwang, et al., Journal – Korean Physical Society 77 (5): 337-343, 2020

[4] A. Neumann, et al., *Status and Perspective of the Energy Recovery Linac at HZB*, in *Proc. 66th ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs. (ERL'22)*, Ithaka, NY, USA, Oct. 3, https://indico.classe.cornell.edu/event/2018/contributions/1818/

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