Verification of the RF System Calibration by Means of a Debunching Experiment in SIS18

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Summary

For the FAIR synchrotrons and the upgrade of the GSI synchrotron SIS18, a completely new Low-Level RF system architecture has been realized [1]. Closed-loop control systems stabilize the amplitude and the phase of the RF gap voltages. Due to the non-ideal frequency response of several components, this stabilization is not perfect. The deviations are -10% to $+30\%$ for the amplitudes of the two SIS18 cavities, $-3°$ to $+10°$ for the phase of cavity BE1, and $-8°$ to $+1°$ for the phase of cavity BE2. The required accuracy is $\pm 6\,\%$ for the amplitude and $\pm 3\,°$ for the phase, which has been shown by previous machine experiments and theoretical investigations. In order to fulfil the requirements a dedicated programmable calibration electronics module was developed. Calibration curves can be measured and programmed offline without the beam, but nevertheless, the desired beam behaviour has to be verified by experiments. For this purpose a debunching scenario was realized as a SIS18 beam experiment [2] that proved to be very sensitive to inaccuracies. The results of the experiment show for the first time at GSI, by a beam observation, that the predefined calibration curves meet the accuracy requirements.

Debunching Experiment

A $^{238}U^{73+}$ beam of about $1 \cdot 10^9$ particles with the kinetic energy $11.2\,\mathrm{MeV/u}$ was injected and accelerated up to $120\,\mathrm{MeV/u}$ or $600\,\mathrm{MeV/u}$. The central control system (CCS) provided the standard ramps for the cavities BE1 and BE2, which both operated at $h = 4$. At a fixed energy, a constant control voltage for the amplitudes for both cavities, which corresponds to about $4\,\mathrm{kV}$ amplitude per cavity, was generated by a combination of CCS ramps and manual setups. By synchronizing the cavities with opposite phase, i.e. $+90\,°$ for the cavity BE1 and $-90\,°$ for the cavity BE2, no residual gap voltage should be present. These phases were realized by a control voltage of about $4.5\,\mathrm{V}$ and $-4.5\,\mathrm{V}$ respectively. Thus, the experiment scenario allowed to check the debunching quality at injection energy or at extraction energy. In a two-step optimization process the bunching was minimized by adapting the control voltage of the BE1 target phase first and by adjusting the control voltage for the BE1 target amplitude afterwards.

Results

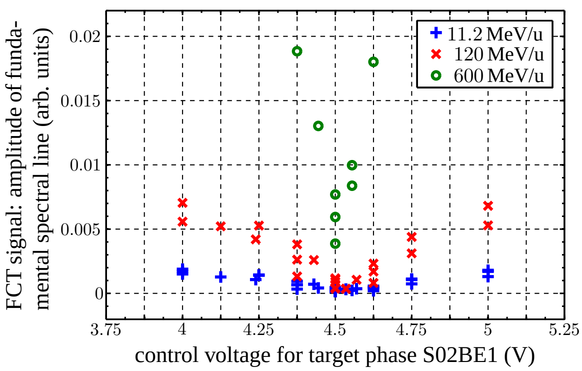

Figure 1: Phase optimization for the cavity BE1

Figure 1 shows the results for the first optimization step of the phase. The beam signal, measured by an FCT (Fast Current Transformer), is evaluated by a discrete Fourier transformation with respect to the control voltage at different energies. An optimum is achieved for a control voltage between $4.375\,\mathrm{V}$ and $4.625\,\mathrm{V}$, which corresponds to a target phase between $87.5\,°$ and $92.5\,°$. Therefore, optimum results for the beam with deviations of less than $\pm 2.5\,°$ from the theoretical value are reached by means of the calibration. In addition, the results of the amplitude optimization clearly show that the best results are obtained within deviations of less than $\pm 5\,\%$ from the theoretical value. The experiment successfully proved that the calibration fulfils the requirements and that the target values lead to the desired beam behavior.

References

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[2] H. Klingbeil, U. Hartel, B. Zipfel: "Beam experiment: Verification of phase and amplitude calibration by means of a debunching experiment in SIS18", GSI internal note 29112012, November 2012.

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