

STUDIES FOR TUNING ALGORITHM OF SUPERCONDUCTING CAVITY AMPLITUDE AND PHASE IN THE RAON ACCELERATOR

Hyunchang Jin and Ji-Ho Jang

Institute for Basic Science, Yuseong-daero 1689-gil, Yuseong-gu, Daejeon, Korea

Abstract

The RAON accelerator utilizes the low energy and high energy superconducting linacs for the acceleration of the stable ion beams and the rare isotope beams. The low energy superconducting linac is composed of the quarter-wave resonator (QWR) and the half-wave resonator (HWR) cavities, and the high energy superconducting linac consists of two kinds of single-spoke resonator (SSR) cavities. In the beam commissioning, the tuning of these superconducting cavities is a significant issue to achieve the targeted beam energy and to avoid the deterioration of the beam quality. In this paper, we will present the tuning program based on the phase scan tuning algorithm for the superconducting cavity amplitude and phase in the RAON accelerator and describe the simulation results.

INTRODUCTION

The Rare Isotope Science Project (RISP) has been organized to build the RAON accelerator [1] which will accelerate the rare isotope and stable ion beams for a wide range of science programs. The beams generated by an electron cyclotron resonance ion source (ECR-IS) or an isotope separation on line (ISOL) system will be accelerated by the low energy superconducting linac (SCL1 or SCL3) after passing through the low energy beam transport (LEBT) [2] section, the radio frequency quadrupole (RFQ) and the medium energy beam transport (MEBT) section. These accelerated beams are used in the low energy experimental halls or re-accelerated by the high energy superconducting linac (SCL2) for the experiments at the in-flight fragmentation (IF) system or the high energy experimental halls. The schematic layout of the RAON accelerator is shown in Fig. 1.

The superconducting linac of the RAON accelerator consists of the cold and warm sections. The cold section includes the cryomodule which surrounds the superconducting cavities and the warm section is comprised of the quadrupoles and the diagnostic equipments. For the acceleration efficiency, two types of cavities, quarter-wave resonator (QWR) and half-wave resonator (HWR), are used at the SCL1 (SCL3) and the two types of single spoke cavities (SSR1 and SSR2) are used at the SCL2. The reference frequencies of the SCL1 and SCL2 sections are 81.25 MHz for QWR cavities, 162.5 MHz for HWR cavities and 325 MHz for SSR cavities, respectively. For the successful beam commissioning at the RAON accelerator, the tuning of the each equipment is a significant issue before the beam operation. Especially, the tuning of the superconducting cavity amplitude and phase is very important for the beam acceleration and the avoidance of the beam loss. In this paper, the tuning

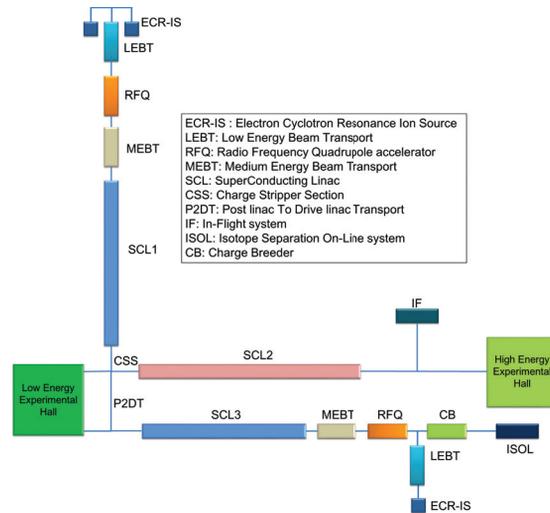


Figure 1: Layout of RAON accelerator.

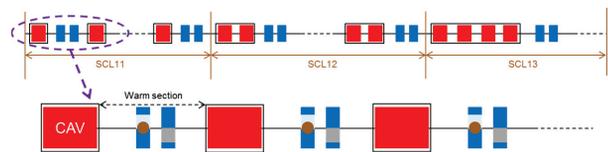


Figure 2: Layout of low energy superconducting linac section, SCL1.

studies at the low energy superconducting linac, SCL1, will be discussed with a multi-particle beam simulation code, DYNAC [3]. The layout of the SCL1 is shown in Fig. 2. In addition, we will present the graphical user interface (GUI) for the cavity amplitude and phase tuning with a computing language program, MATLAB [4].

TUNING ALGORITHM

For the tuning of the radio-frequency (RF) amplitude and phase of the superconducting cavities, the well-known tuning technique, phase scan signature matching [5], is used. For a certain cavity, the beam energy change with the fixed cavity amplitude is measured as varying the cavity phase and this beam energy can be obtained by using the beam position monitors' (BPM) time-of-flight (TOF) method. In the studies, the DYNAC code is used for the beam simulations. Table 1 shows the tuning procedure in detail.

SIMULATION RESULTS

The reference uranium beam, $^{238}\text{U}^{33.5+}$, is used at the following simulations. Figure 3 shows the phase scan data for the first cavity of the SCL1. With the DYNAC code, the

Table 1: Procedure of Cavity Amplitude and Phase Tuning

Step	Explanation
1	Collect phase scan data for each cavity calculated by DYNAC code
2	Measure beam energy change as varying phase
3	Compare the measured data with the collected data
4	Calculate the difference and compensate results
5	Repeat step 1–5 for next cavity

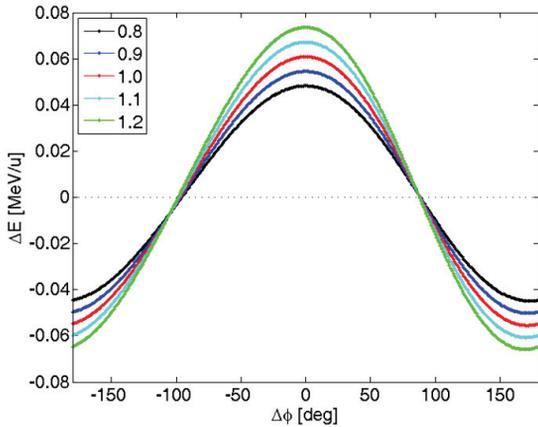


Figure 3: Phase scan data for first cavity of the SCL1. The design cavity amplitude is expressed as 1.0 in the figure.

beam energy change is scanned for the design amplitude as varying the cavity phase and then same procedures are carried out for different cavity amplitudes from -20 % to +20 % with 10 % step. The phase scan step is 1.0 degree of 81.25 MHz. When the beam energy is measured for several cavity phases as shown in Fig. 4, the measured data is compared with the scanned data and then the differences of cavity amplitudes and synchronous phases are calculated. At this simulation, the phase scan step is 10.0 degree of 81.25 MHz. Figure 5 shows the calculated result. The cavity

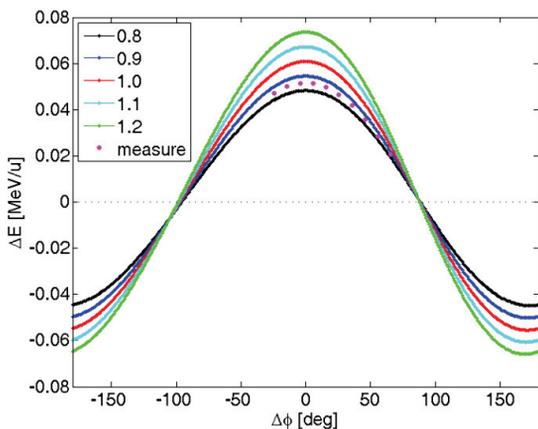


Figure 4: Measurement data for first cavity of the SCL1.

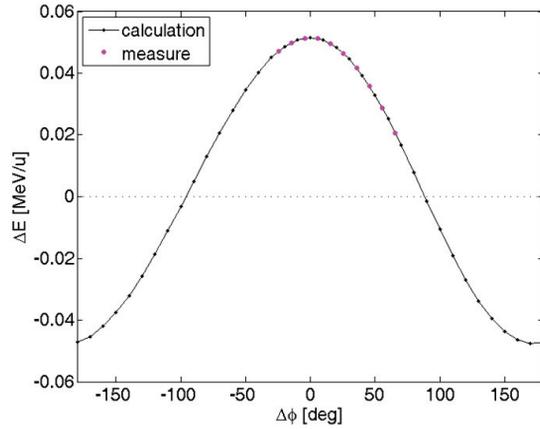


Figure 5: Calculation result for first cavity of the SCL1.

amplitude and phase corresponding to the measured data are calculated and these values are tuned to the design values. As a result, the error of the calculated result comparing to the design values is less than 1.0 % after the tuning.

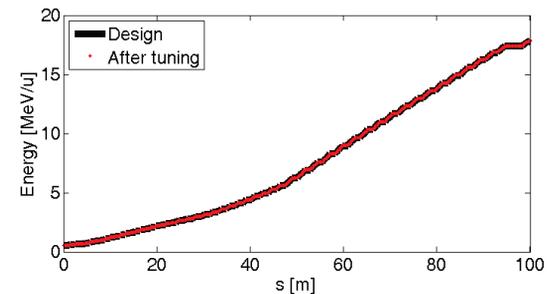
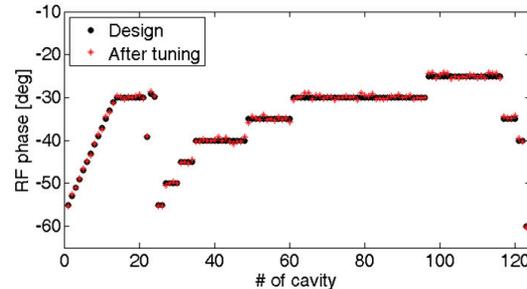
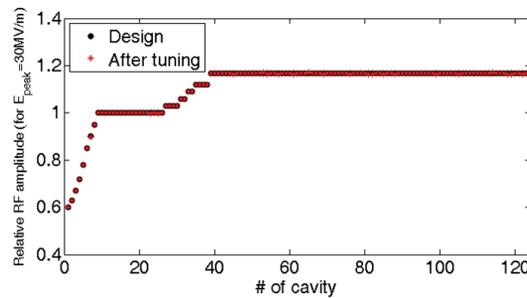


Figure 6: Results of cavity amplitude and phase tuning at the SCL1 (top: cavity amplitude, middle: cavity phase, bottom: beam energy).

Same procedures are carried out for all cavities of the SCL1. Figure 6 shows the simulation results before and after

the tuning along the SCL1. After the tuning of the cavity amplitude and phase, the calculated amplitudes and phases of all cavities become close to the design values. Also, the beam energies before and after the tuning agree within 1.0 % error. These results are kept for the measurement errors, ± 1.0 % amplitude error and ± 1.0 degree phase error.

DEVELOPMENT OF GRAPHICAL USER INTERFACE

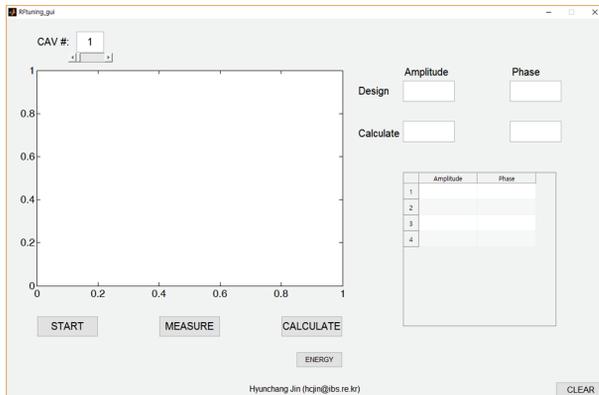


Figure 7: GUI for the cavity amplitude and phase tuning.

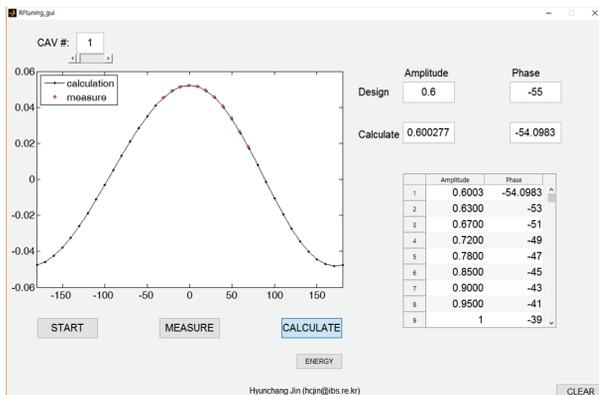


Figure 8: GUI with CALCULATE button.

For the efficient commissioning, the GUI based on the MATLAB program has been developed for the cavity amplitude and phase tuning. Figure 7 shows the initial screen of the GUI. With the START button, the phase scan data is

shown for a certain cavity and the measured data is plotted at the screen with the MEASURE button. Also, the calculation result is appeared with the CALCULATE button as shown in Fig. 8. This procedure can be carried out for each cavity one by one. After the calculation, the new beam energy compared with the design value will be shown with the ENERGY button. This development of the GUI for the cavity tuning will be continued to be used for all cavities of the RAON accelerator.

SUMMARY

We presented the studies for the cavity amplitude and phase tuning at the low energy superconducting linac (SCL1) of the RAON accelerator. With the phase scan signature matching technique, the tuning was carried out for each superconducting cavity of the SCL1. As a result, the measured cavity amplitude and phase values were tuned to the design values within 1.0 %. Also, the beam energy became close to the design value after the tuning of all cavities of the SCL1. In addition, the graphical user interface for the tuning has been developed for the efficient commissioning. This research will be helpful for the beam commissioning of the RAON accelerator.

ACKNOWLEDGMENTS

This work was supported by the Rare Isotope Science Project of Institute for Basic Science funded by Ministry of Science, ICT and Future Planning and National Research Foundation of Korea (2013M7A1A1075764).

REFERENCES

- [1] D. Jeon, et al., "Design of the RAON accelerator systems", Journal of the Korean Physical Society 65.7 (2014).
- [2] H. Jin and J. Jang, "Beam dynamics at the main LEPT of RAON accelerator", Journal of the Korean Physical Society 67.8 (2015).
- [3] E. Tanke, "DYNAC: A multi-particle beam dynamics code for leptons and hadrons", LINAC02, Gyeongju, TH429 (2002).
- [4] P. Marchand, "Graphics and GUIs with MATLAB", CRC Press, Inc., 1995.
- [5] T.L. Owens, et al., "Phase scan signature matching for linac tuning", Fermilab Report, LU-186 (1992).