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Development of RF Set-point Program for PEFP Linac Commissioning

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1. Introduction

The proton engineering frontier project (PEFP) is developing a 100-MeV proton linear accelerator [1]. The installation of the linac cavities has been finished in the accelerator tunnel at Gyeongju site. The alignment and beam commissioning is scheduled at the end of this year and the early 2013, respectively. In the beam commissioning process, we will use a well-known phase scan method [2] which determines the operating points of the RF amplitude and phase for each DTL tank. We are now developing an RF set-point program for the phase scan method. This work summarized the present status of the program development.

2. Phase Scan Method and RF Set-point Program

2.1 Phase Scan Method

The phase scan method is a well-developed technique to determine the RF amplitude and phase of an accelerating cavity [2]. It uses the measurement results of beam phases at the end of the cavity depending on the input values of the RF amplitude and phase. The results are compared with the simulation results to determine the operation values of the RF amplitude and phase. This method was used for beam commissioning of the linear accelerators in SNS [3,4] and J-PARC [5,6].

We will use a beam phase measurement result depending on the RF phase with a fixed RF amplitude. It will be compared with simulation results as a function of the RF phase with several RF amplitudes. From the minimization condition of χ, we can determine the amplitude and phase. The χ value is defined as

$$\chi^2 = \frac{1}{N}\sum_{i=1}^{N}\left[f_{\mathrm{ex}}(\phi_i) - (b + f(\phi_i - a))\right]^2,$$

where N is the number of the experimental data and ϕ_i is the RF phase of each datum. The $f_{ex}(\phi_i)$ is the experimental beam phase at the RF phase of ϕ_i. The function $f(\phi)$ is the simulation result of the beam phase as a function of the RF phase ϕ. In order to get a best fitting result by comparing the experimental result with a theoretical result, RF and beam phases are shifted by a and b as shown in Fig. 1. The experimental results are not real but artificial data for illustration.

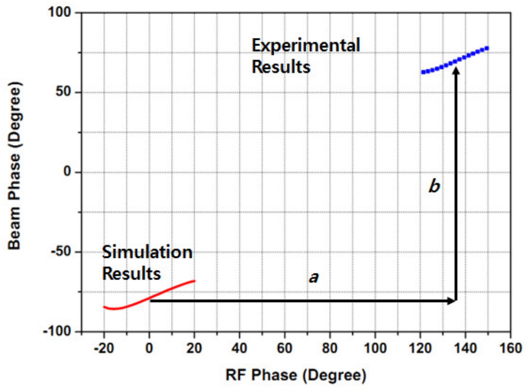

Fig. 1. Experimental results compared with the simulation by shifting RF phase *a* and the beam phase *b*.

2.2 RF Set-point Program

We have developed an RF set-point program based on MATLAB with a nonlinear optimization routine, LEVMAR. In this work, we assumed that an experimental result is compared with 3 theoretical calculations. The screen of the RF set-point program is shown in Fig. 2. It consists of 4 parts. The first is one for input parameters including DTL tank indentification, 3 RF amplitudes of simulation results, the input LLRF (low level RF) value of the RF amplitude, and initial values for movement *a* and *b*. Each parameter has a default value and it should to be changed to get correct results. The second shows the overlap between the experimental and simulation results after moving simulation data by the parameters, *a* and *b*. It also calculates the χ value in each case. The third part is the summary of the result. It shows the determined values for RF amplitude and phase. The forth part is the

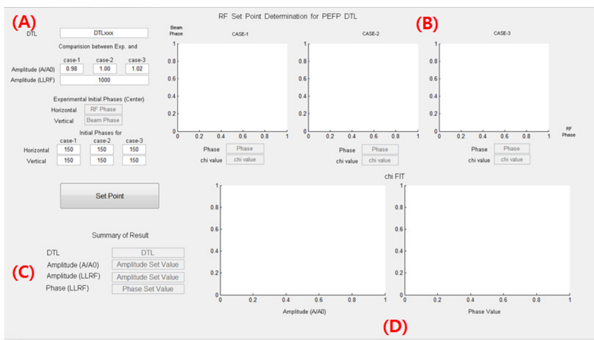

Fig. 2. Screen for beam commissioning program: (a) input parameters (b) χ^2 calculation by comparing an experimental result with 3 simulations (c) determined RF amplitude and phase by quadratic fittings in (d).

quadratic fitting of the χ data obtained in the second part. In order to calculate RF set point, the “Set Point” button is pushed after filling the input parameters.

We generated an artificial experimental data set for a DTL tank by using PARMILA code in order test the program. The amplitude is assumed to be the design values. The RF phase is changed from -26° to 16° with the interval of 2°. We added some values to RF phase and beam phases in order to reflect real situation. The RF phase is shifted by 135.4°.

Fig. 3 shows the input domain of the program. It shows that the name of cavity is DTL101, the relative amplitudes A/A_0 are 0.99, 1.00, and 1.01 for simulation results, the LLRF amplitude is 1000, and the initial values of the movement are 150°. In the middle of the screen, the center values are shown of the experimental results for RF and beam phases. Fig. 4 represents the comparison result of the artificial experiment with 3 simulations. It also shows the χ value in each case: 0.675 for A/A_0 = 0.99, 0.404 for A/A_0 = 1.00, and 0.757 for A/A_0 = 1.01. Fig. 4 shows the quadratic fitting of the χ values in Fig. 2 for determining the relative amplitude A/A_0 (left) and the RF phase (right). The result is summarized in Fig. 6. It shows the amplitude set point is 0.999 which implies the LLRF amplitude should be 1000.66. The phase set point is 135.05° which is very close the input shift vale of the RF phase, 135.4°.

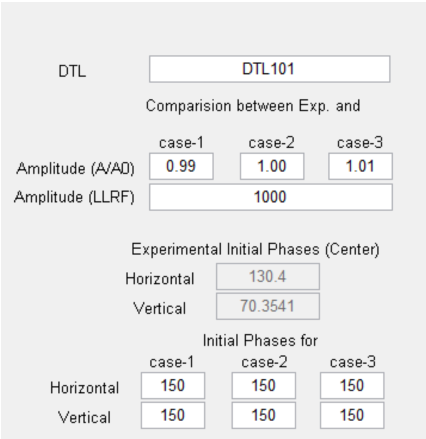

Fig. 3. Input parameters.

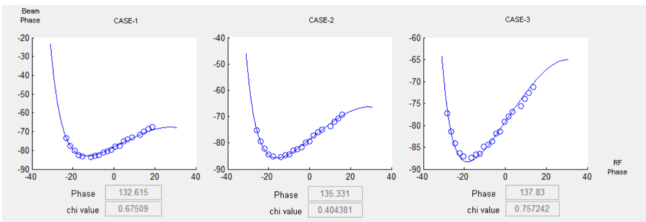

Fig. 4. The χ values obtained by comparing the experimental result with 3 simulations.

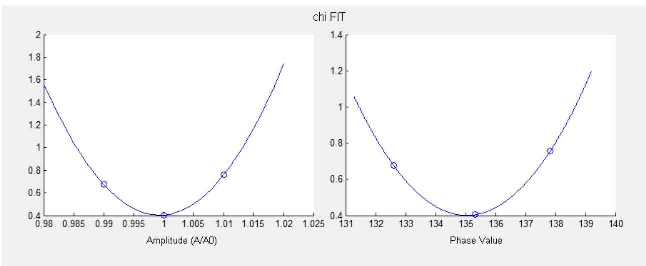

Fig. 5. Quadratic fitting of χ values for 3 different cases of the relative amplitudes and phases.

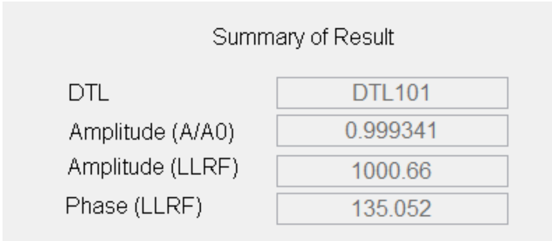

Fig. 6. Determination of the RF set point, amplitude and phase.

3. Conclusions

We developed an RF set-point program with a phase scan method in order to determine the RF amplitude and phase of DTL tanks. We also tested the program by using an artificial experimental result. It shows that the program is working well to determine the amplitude and phase values.

ACKNOWLEDGEMENT

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