Performance of Feed-Forward Circuit for the JAERI FEL Superconducting Linac

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Abstract

The RF system of the JAERI FEL superconducting linac is operated with the pulse length of 3 ms and the repetition rate of 10 Hz. The electron beam can be accelerated with the pulse length of 1 ms or less. The beam load of the long pulse increased the beam energy dispersion, and resulted in some beam loss after the 180-deg bending magnet system. The RF system with a long time constant could not catch up with a fast change of the beam load. A newly introduced feed forward circuit compensated residual parts of the amplitude and phase feedback. This circuit successfully improved the beam transport.

1. Introduction

The JAERI FEL superconducting linac is operated with a pulse mode because of radiation shields and cooling capability of He refrigerators. The pulse length is 3 ms and the repetition rate 10 Hz. As the superconducting cavity has high loaded Q-factor of 1×10^6 [1], the pulse length of 2 ms is used to rise the accelerating field. Therefore, the electron beam can be accelerated with the pulse length of about 1 ms or less. Though the beam transport was adjusted with short pulse length and the pulse length was extended, the energy dispersion got bad for the long pulse. This was due to a long time constant of the RF system including the superconducting cavity. When the perturbation such as a beam load occurred, the long time constant caused the feedback delay and the feedback system could not catch up with the changes of the perturbation. To compensate the delay of the feedback system, a feed-forward circuit was installed to the RF system. With this system the acceleration test was done. In this paper we describe the feed-forward system and the results of the beam test.

2. Feed-Forward Circuit

The RF system with the feed-forward circuit was shown in figure 1. The feed-forward processes were as the following.
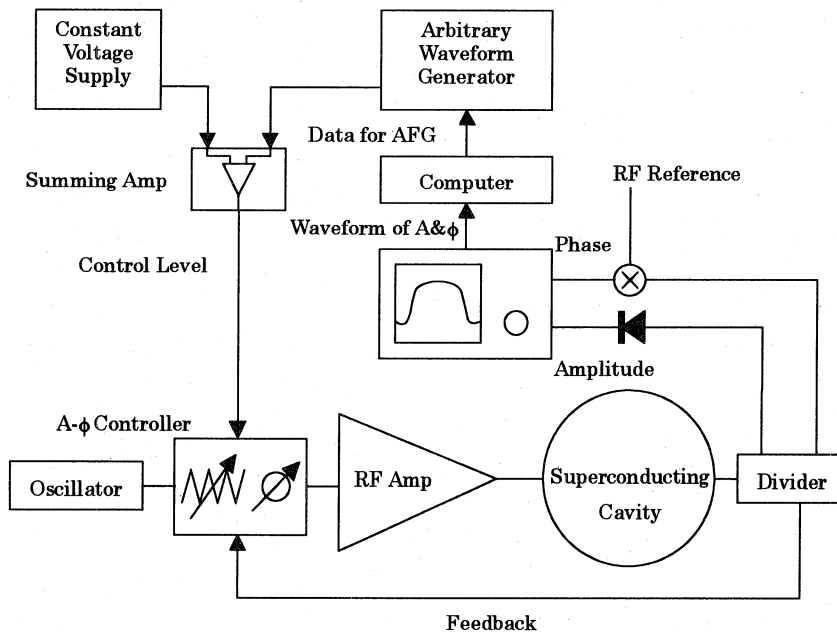(1) The feedback circuit was equipped in the RF

Fig. 1 The Block diagram of feed-forward circuit

system.

(2) The feedback levels of amplitude and phase were controlled by external constant voltage sources.

(3) Waveforms of the amplitude and phase in the cavity were measured with beam acceleration.

(4) The waveforms were transferred to a computer to search and optimize the control signals..

(5) According to the calculated data, an arbitrary waveform generator (AWG) generated the additional control signals.

(6) The both signals of the constant voltage supply and the AWG were summed with the summing amplifier. The summed signal was used as the reference signal of the RF control.

(7) The same processes from (3) to (6) were repeated until the levels of the amplitude and phase in the cavity got flat.

3. Beam Load

The validity of the feed-forward circuit was examined by comparing the beam current with and without the circuit. The beam was accelerated through the superconducting linac and was transported through the three 60-degree bending magnet system and an undulator. As the large energy dispersion resulted in the beam loss at the bending system, the beam current was measured at the exit of the first 60-degree bending magnet. A core monitor was used for measurement. The beam pulse length was 600 μs.

First, the measured beam current without the feed-forward circuit is shown in figure 2. The beam current decreased after 50 μs. This means that the energy dispersion increased after 50 μs.

Second, the second cavity of the four superconducting ones was controlled with the feed-forward circuit. The beam current was shown in figure 3. The beam current was almost constant all over the pulse length except for the beginning of the pulse.

The change of the amplitude in the cavity was shown in figure 4. The amplitude decreased about 6 % at maximum during the acceleration without the feed-forward circuit. While the change of the amplitude with the feed-forward circuit was within ±2 %.

The energy dispersions caused by these amplitude changes were calculated with the PARMELA code. The calculations were done by fixing the all phases and by changing the amplitude
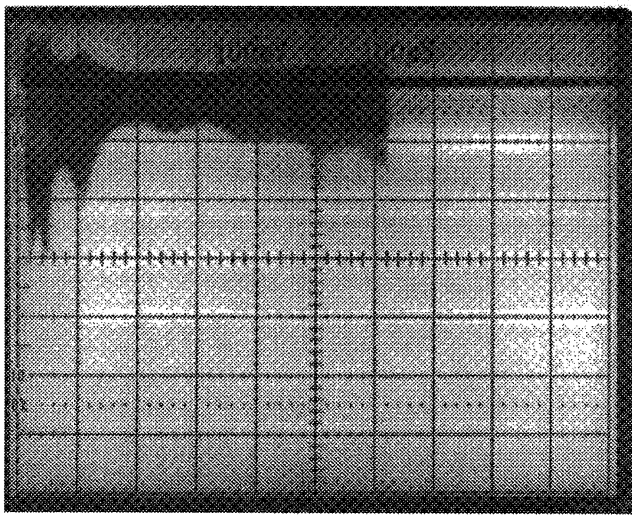

Fig.2 The beam current at the exit of the first 60-degree bending magnet without the feed-forward circuit
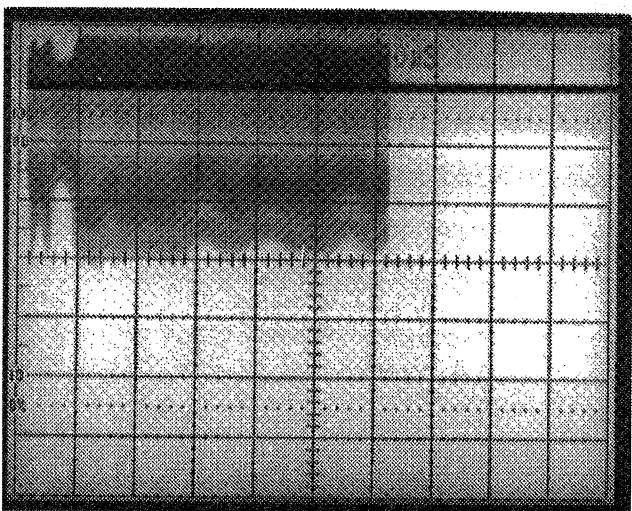

Fig.3 The beam current at the exit of the first 60-degree bending magnet with the feed-forward circuit
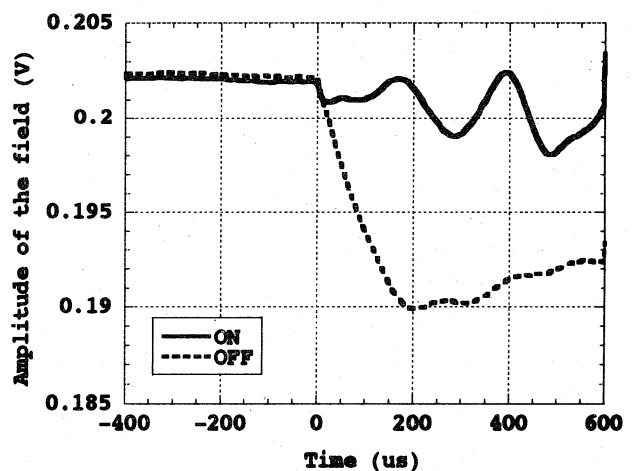

Fig.4 The amplitude in the second cavity with and without the feed-forward circuit.
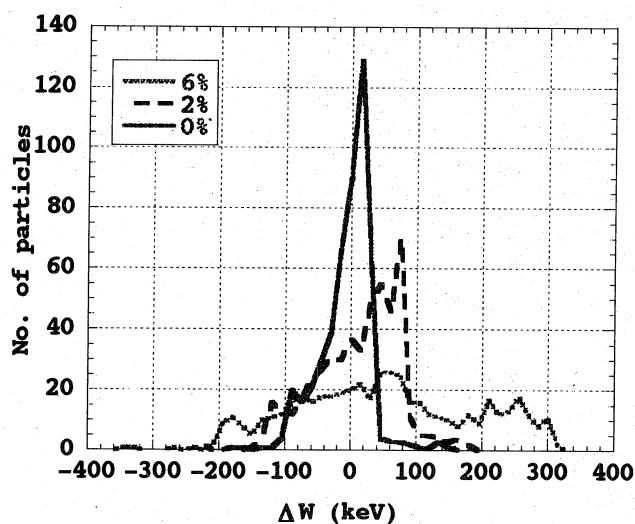
Fig.5   Energy distributions calculated with the PARMELA code.   The field decreased 0%, 2% and 6%.

of the second cell and fixing the others.   The calculated energy dispersions are shown in figure 5. Two-percent drop of the amplitude indicates 1.4 times increase of the energy dispersion.   However, six-percent drop indicates 3.6 times increase, which would be too large to accept the transport through the bending magnet.

The control signal from the AWG was generated by a simple line patterns of the pulse shape. Therefore, the fine optimization of the control signal will decrease the change of the amplitude in the cavity..

4.   Conclusion

The feed-forward circuit made the beam transport through the bending magnet good even when the pulse length was long.   This means that the energy dispersion got small in the long pulse mode operation.   We have been developing the program for optimizing the signal of the feed-forward circuit.   This will improve the energy dispersion further.

Reference

[1] M.Sawamura et al., *Nucl. Instr. Methodes in Phys. Res.*, A341, 391 (1994)