STUDY OF STABILITY OF RF LINAC WITH AR MODEL

S. Isaka†, R. Kato, T. Konishi and G. Isoyama
Institute of Scientific and Industrial Research, Osaka University
8-1 Mihogaoka, Ibaraki, Osaka 567-0047, Japan
H. Sakaki, Japan Atomic Energy Research Institute
Shirakata-Shirane, Tokai, Naka, Ibaraki 319-1195, Japan

Abstract

We are studying operational stability of the L-band linac at ISIR, Osaka University. The RF phase and the power for the prebuncher have been measured, together with environmental parameters including temperatures at various locations and the AC line voltage. The measured data have been analyzed with the auto regressive (AR) model and noise contribution rates have been calculated. The feedback structure of the system has been derived for the long-term drift of the RF phase. It was found that the AC line voltage and the temperatures of the klystron room affected the RF phase or stability of the linac. After renewal of the air conditioners for the linac building, the temperature of the klystron room has become more stable and as a result fluctuations of the RF phase has been reduced.

1 INTRODUCTION

We are conducting experimental studies on free electron laser (FEL) and Self-Amplified Spontaneous Emission (SASE) in the infrared region using the L-band linac at the Institute of Scientific and Industrial Research (ISIR), Osaka University. Although stability of the electron beam is essential for these studies, we observe fluctuations of the electron trajectory and the electron energy, so that the experiments are sometimes interrupted. We conceive that the electron beam instability originates in fluctuations of the RF field for acceleration. In order to identify sources of the instability, we have measured environmental conditions for a long time, which may affect the accelerating RF field, including the AC line voltage and frequency, temperatures at various points.

The auto regressive process (AR) model is a method to analyze series of data in chronological order. It may be applicable to analyze the feedback structure of a complicated system consisting of mutually interacting elements. The AR model has been successfully applied to study on stability of RF linacs of SPring-8 and JAERI.

We have analyzed the measured data using the AR model in order to find sources of instability. In this paper, we will report results of the measurements and the analysis using the AR model.

† sato25@sanken.osaka-u.ac.jp

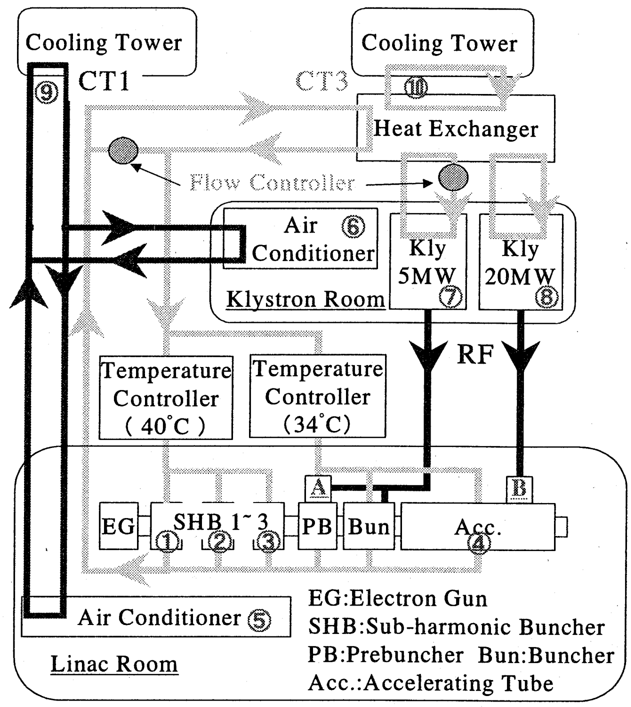

Fig. 1: Schematic diagram of the temperature control system and the measurement system. The letters A and B denote measurement points for the RF power and thephase. The numbers ① through ⑩ are those for temperatures. The AC line voltage was also measured.

2 MEASUREMENT SYSTEM

The measurement system for the accelerator and the utilities are shown schematically in Fig. 1. The RF power of the 5 MW klystron is provided to the prebuncher (PB) and the buncher, while the power of the 20 MW klystron is provided to the accelerating tube. In this study, we observed the RF power and the phase supplied to PB. We used two cooling systems in the building for the ISIR linac; CT1 for air conditioners and CT3 for the linac. Each cooling system had a cooling tower on the roof for discharging heat from the cooling system into the air. The air conditioners were renewed in the Spring 2000, and CT1 has not been used since then. Temperatures of various locations shown in Fig. 1 were measured with thermistors.

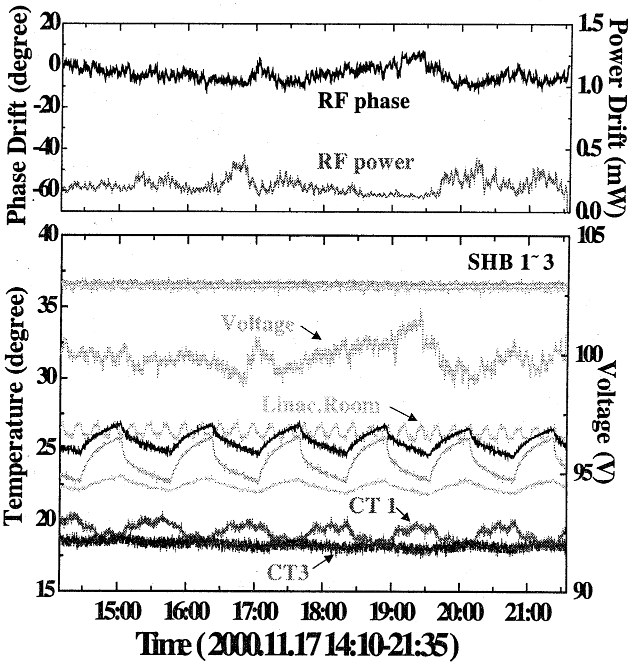

Fig. 2: RF phase and the power for PB measured together with the various temperatures and the AC voltage on 17 November 2000.

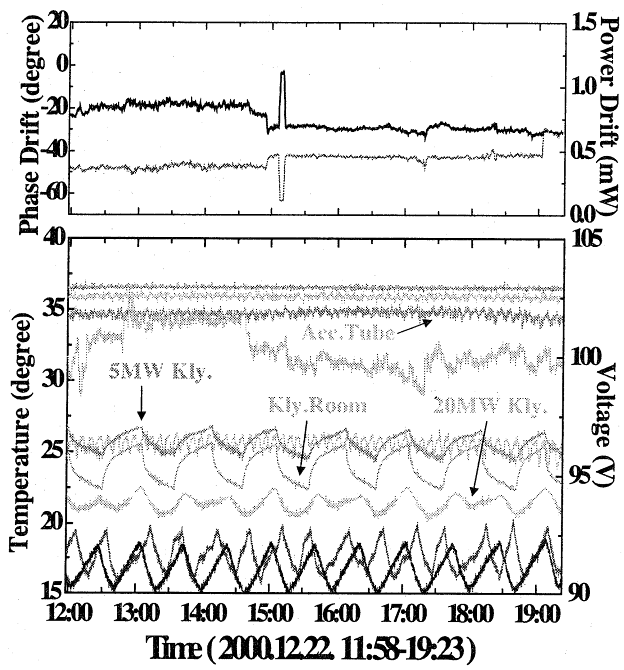

Fig. 3: RF phase and the power for PB measured together with the various temperatures and the AC voltage on 22 December 2000.

3 RESULTS OF MEASUREMENTS

We observed the RF phase and the power for PB and the AC line voltage together with temperatures at various locations on 17 November 2000, 22 December 2000 and 18 July 2001. Results of the measurement on 17 November 2000 are shown in Fig. 2. The RF phase and the power are shown in the upper panel, and the AC

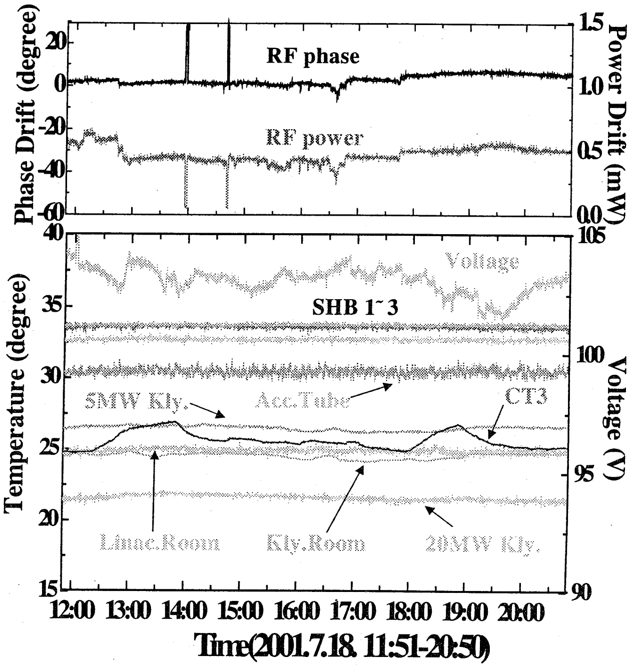

Fig. 4: RF phase and the power for PB measured together with the various temperatures and the AC voltage on 18 July 2001.

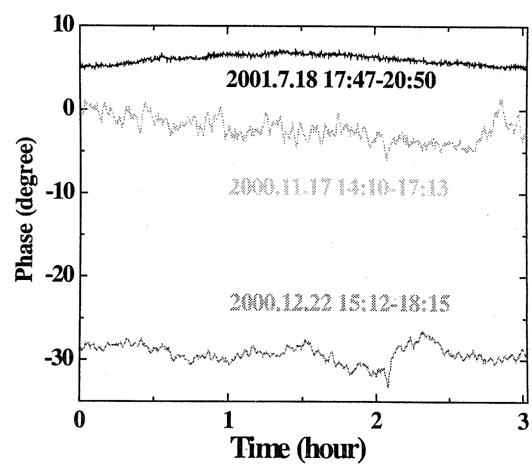

Fig. 5: RF phases for PB.

voltage and temperatures are shown in the lower panel of Fig. 2. Similarly, results of the measurement on 22 December 2000 are shown in Fig. 3 and those on 18 July 2001 are in Fig. 4 The RF phase and the power shown in Figs. 2 and 3 contain high frequency noise components, but long-term variations are similar to that of the AC voltage, so that the AC voltage and the RF power seem to be correlated. The temperatures shown in Figs. 2 and 3 show large periodical variations, which were measured before renewal of the air conditioners. The temperatures shown in Fig. 4 are almost constant expect for high frequency noises, which were measured after the renewal of the air conditioners. Three RF phases measured on these days are compared with each other in Fig. 5. It is apparent that the RF phase has become much more stable after the renewal of the air conditioners.

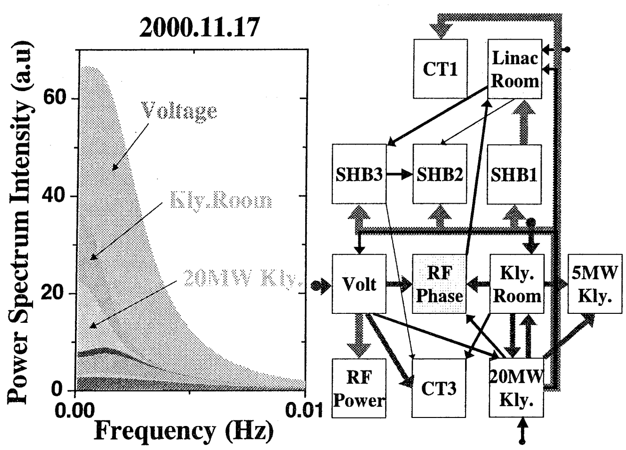

Fig. 6: Power spectrum for the RF phase and a feedback structure of the system at 3.7×10^{-4} Hz on 17 November 2000.

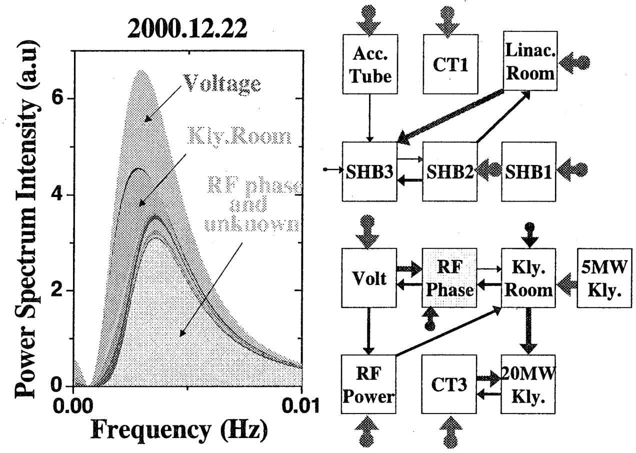

Fig. 7: Power spectrum for the RF phase and a feedback structure of the system at 2.9×10^{-3} Hz on 22 December 2000.

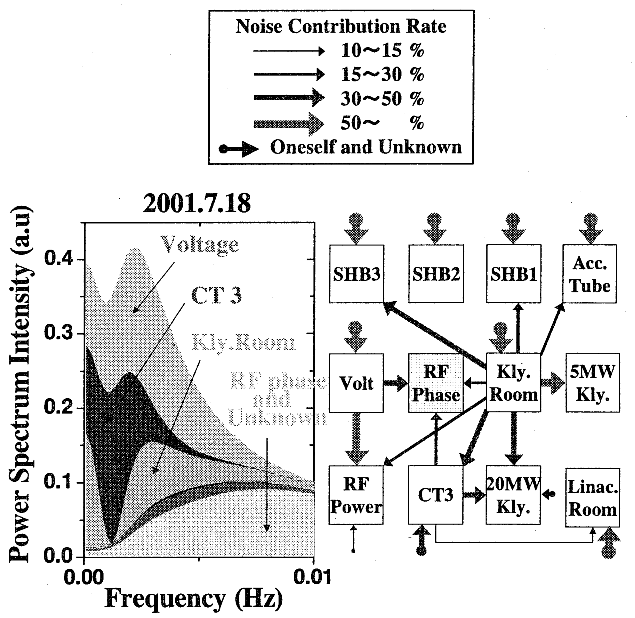

Fig. 8: Power spectrum for the RF phase and a feedback structure of the system at 2.2×10^{-3} Hz on 18 July 2001.

4 ANALYSIS WITH THE AR MODEL

We have analyzed the measured data shown in Figs. 2, 3 and 4, using the AR model. We used data measured for approximately 3 hours for analysis, during which operation of the linac was not intentionally changed. In the AR model, variations and correlations of various parameters are analyzed in the frequency domain. The variation of the RF phase is expressed in terms of the power spectrum and noise contribution rates. The power spectrum for the RF phase obtained from the data on 17 November 2000 is shown on the left side of Fig. 6, in which noise contribution rates from the AC voltage, temperatures of the klystron room and the 20 MW klystron can also be seen. The feedback structure of the system is shown on the right side of Fig. 6, which is derived from major noise contribution rates of the system at a frequency of the peak intensity, 3.7×10^{-4} Hz. An arrow shows the direction of the noise contribution and its width expresses the noise contribution rate. An arrow with a solid circle shows contribution by itself, or in other words an unknown parameter. Similar analysis of the data on 22 December 2001 and 18 July 2001 are shown in Figs. 7 and 8, respectively. The peak frequency of the power spectrum is 2.9×10^{-3} Hz in Fig. 7 and it is 2.2×10^{-3} Hz for Fig. 8.

We see in Figs. 6, 7 and 8 that the main contribution to the fluctuation of the RF phase is the AC voltage and the next one is the temperature of the klystron room. It may be seen in Fig. 6 that the 20 MW klystron temperature affects the fluctuation of the RF phase provided by the 5 MW klystron. It may also be seen in Fig. 7 that the contribution by itself, denoted by RF phase or unknown, is large on 22 December 2000. On 18 July 2001 shown in Fig. 8, CT3 contributes considerably to the RF phase. This contribution is, however, spurious because the temperature of CT3 was measured in the klystron room and the temperature of the klystron room affects the RF phase.

5 SUMMARY AND CONCLUSION

In order to find sources of instability of the L-band linac at ISIR, Osaka University, we measured various parameters affecting the RF phase and analysed the measured data with the AR model. Fluctuations of the RF phase were found to be due to the AC voltage and the klystron room temperature. After the renewal of the air conditioners, temperature variations were reduced and consequently the RF phase became more stable.

6 REFERENCES

[1] H. Sakaki et al., T.SICE Vol.35, No.10 (1999) 1283-1291.

[2] T. Konishi, Master's Thesis, 2001, Osaka University.