Proceedings of the 25th Linear Accelerator Meeting in Japan (July 12-14, 2000, Himeji, Japan)

[12P-30]

Investigation of Spurious Oscillation in Klystron Due to Back-going Electrons from Collector

Z. Fang, *S. Fukuda, *S. Yamaguchi, and *S. Anami

The graduate university for advanced studies
**High energy accelerator research organization (KEK)*
1-1, Oho, Tsukuba-shi, Ibaraki, 305-0801, Japan

Abstract

Back-going electrons from a collector to a drift tube are one of the possibilities causing spurious oscillations in a klystron. This kind of instability occurred in the 324MHz klystrons being developed at KEK. In this paper, the oscillation phenomena and mechanism are described. And simulations of back-going electrons using EGS4 have been performed. The back-going electron coefficients and energy distributions were obtained under different beam voltages and collector shapes. The simulation results are the basis of the oscillation condition study and the collector design.

1. Introduction

In a klystron, electrons are emitted from an electron gun, pass through a drift tube, and finally enter and spread in a collector under space-charge forces. After the electrons bombard the collector surface, back-scattered electrons are produced, and some of them return to the drift tube of the klystron. These back-going electrons are modulated by the gap voltage of the output cavity, and induce a gap voltage in the input cavity. Thus the back-going electrons and the main beam of the klystron form a feedback system and it's possible to cause spurious oscillations in the klystron. This kind of instability occurred in the 324MHz klystrons(3MW output power, 650μs pulse width, and 110kV beam voltage) being developed at KEK. During the high voltage processing of the klystrons, spurious oscillations were observed without any driving input power.

In order to suppress the oscillations, back-going electron simulations using EGS4 have been performed. The back-going electron coefficients and energy distributions have been investigated under different beam voltages and collector shapes.

2. Oscillation phenomena

During the high voltage processing of the tube #1 of 324MHz klystron, unexpected oscillations were observed from both the output and input cavities without any driving input power. The oscillation frequency is near to 324MHz, and the oscillations occurred when the beam voltage is 63~71kV and larger than 90kV.

When a bending magnetic field was applied at the collector region to deflect the electron beam, the oscillations stopped. It showed that the collector region was the source of the oscillations. And there is no resonance in the collector since the operating frequency of 324MHz is very low. So, the oscillations were not caused by collector resonance. Therefore the oscillations were concluded to be caused by the back-going electrons. When the back-going electrons going into the drift tube were deflected by the applied magnetic field, the oscillation stopped.

We could decrease the amount of back-going electrons by enlarging the collector size. In the tube #1A, a collector with a larger radius and length was used. And the experiment results showed that the oscillations disappeared in the low beam voltage region and the oscillations started from 95kV. The collector length was increased further in the tube #2, and the beam voltage threshold of the oscillations became higher again. The collector shapes and the oscillation regions of these 3 tubes are summarized in Table 1.

Table 1. Collector shapes and beam voltage regions of oscillations

Tube	Collector radius(cm)	Collector length(cm)	Beam voltage regions of oscillation (kV)
#1	6.5	62.4	63<V<71,V>90
#1A	11.5	92.4	V>95
#2	11.5	122.4	V>102

3. Oscillation mechanism

After the electrons bombard the collector surface, due to an inelastic process with atomic electrons, back-scattered electrons are produced. And some of the back-scattered electrons in the collector return to the drift tube of the klystron and form a feedback system to cause spurious oscillations when the following condition is satisfied:

$$A\bullet\beta > 1$$

A is the voltage gain induced by the main beam of the klystron. A = Vo / Vi, where Vi and Vo are the input and output cavity gap voltages respectively. β is the voltage gain induced by the back-going electron current. The back-going electrons are modulated by the output cavity gap voltage Vo′, and induce a voltage Vi′ in the input cavity gap. β = Vi′/ Vo′. And β is proportional to the back-going electron current since the beginning of the oscillations is in the small-signal linear region. So, in order to suppress the oscillations, we must decrease the amount of back-going electrons.

4. Simulation of back-going electrons

We applied the EGS4(Electron Gamma Shower) Monte Carlo method[1] to the back-scattered electron simulation in the complicated case of a klystron collector with an external magnetic field. Before this complicated simulation, we had applied EGS4 to some simple cases, such as an electron beam is incident on a copper plate(thicker than 1mm), and compared the simulation results with experiment results. We found that the simulation results of back-scattered electron coefficients and energy distributions agree with experiment results very well.

In order to perform the EGS4 simulation of the back-scattered electron in the klystron collector, the trajectories of the incident electron beam were calculated at first. The cathode radius is 4.5cm with a magnetic field of 130Gauss on it. The beam radius is 3.5cm at the entrance of collector and the focusing magnetic field on axis Z in the collector region is shown in Fig.1. The trajectories of the incident electron beam are shown in Fig.2. Then the calculation results(incident electron positions, velocities and energies when they bombard the collector surface) are used as initial conditions to start the EGS4 Monte Carlo simulation. The trajectories of the back-scattered and back-going electrons are shown in Fig.3.

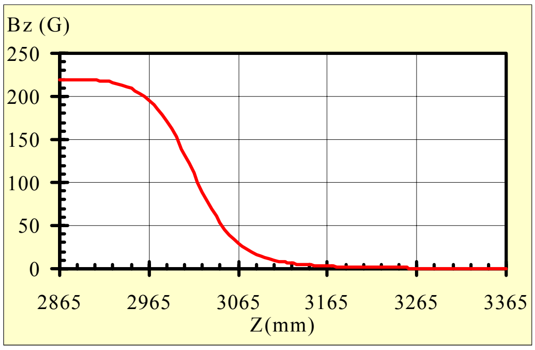

Fig.1. Magnetic field on axis Z in the collector region.

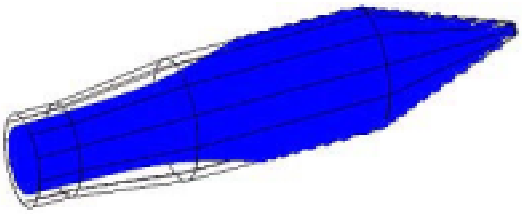

Fig.2. Trajectories of the incident electron beam in the collector.

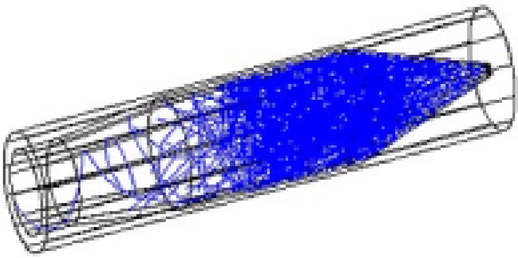

Fig.3. Trajectories of the back-scattered and back-going electrons in the collector.

The back-going electron coefficients and energy distributions have been investigated under different beam voltages(Fig.4). We found that the back-going coefficients are almost same and the peak energy (E/Eo) of the energy distributions always locates at 0.7~0.8.

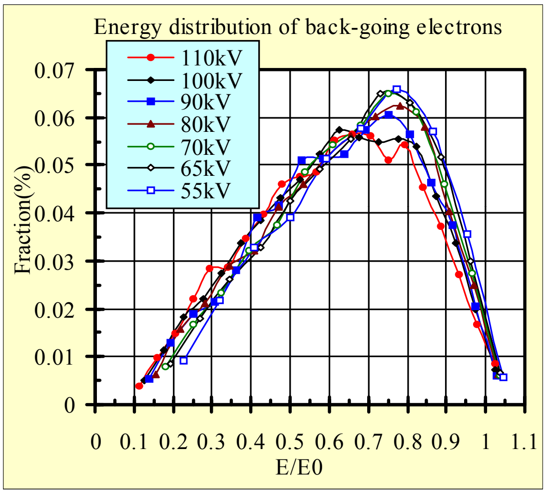

Fig.4. Energy distribution of the back-going electrons under different beam voltages.

5. Collector shape and back-going electrons

Simulations of back-going electrons have been performed for different collector shapes (Fig.5). For a certain collector radius, when the collector length becomes larger, the back-going coefficient decreases rapidly at first, then slowly, and finally tends to a constant. This means that the contribution to the back-going coefficient from the cone surface of the collector becomes smaller and smaller, and finally the contribution to the back-going coefficient mainly comes from the part of the beam-sinking cylinder surface which is nearer to the collector entrance. Also for a certain collector length, when the collector radius becomes larger, the back-going coefficient decreases in the same way. In short, the beam-sinking collector surface which is nearer to the collector entrance will gives the main contribution to the back-going coefficient. So, when we design a collector, we should let all of the parts of the beam-sinking collector surface far away from the collector entrance. Also we could decrease the back-going coefficient by using a small the drift tube radius(Fig.6).

For the collector of the tube #1, #1A, and #2, the back-going coefficients are 0.66%, 0.17%, and 0.14% respectively. From the recent study results of the oscillation conditions[2], we expected that the spurious oscillations would start from 103±1kV in the tube #2. And the latest experiment results showed that the oscillations started from 102kV. They agreed well.

6. Summary

The back-going electrons might cause spurious oscillations. By the simulation using EGS4, the back-going electron coefficients and energy distributions as function of beam voltage and collector shape were obtained. Oscillation conditions are always complex, and we will go on with the study of the oscillation conditions by using the EGS4 simulation results.

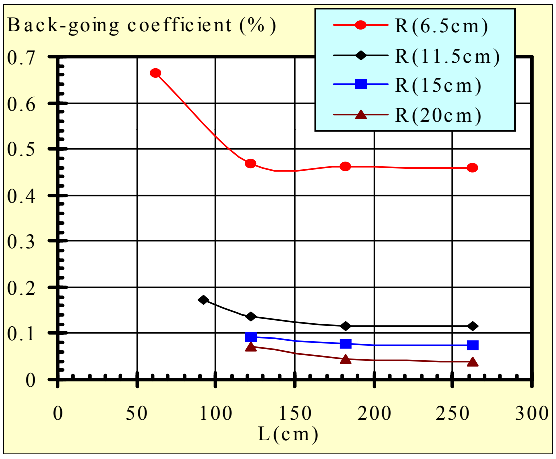

Fig.5. Back-going coefficient as function of collector shape. (drift tube radius : 5.0cm, R: collector radius, L: collector length.)

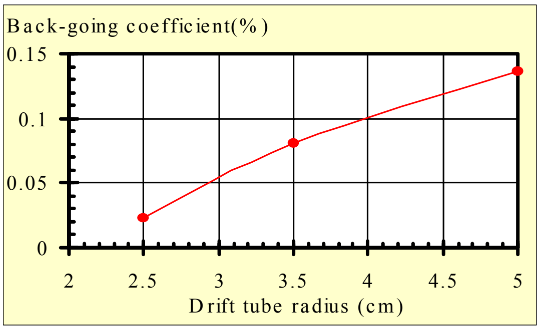

Fig.6. Back-going coefficient as function of drift tube radius.(collector radius: 11.5cm, collector length: 122.4cm)

References

[1]. W. R. Nelson, H. Rirayama and D. W. O. Rogers, SLAC-report-265, 1985.

[2]. Z. Fang, S. Fukuda, S. Yamaguchi, and S. Anami, to be presented in Proc. of the 20th international linac conference, California, USA, August, 2000.