ISR-VA/OG/sm 17th September 1973

ISR PERFORMANCE REPORT

Correlation between background a Electron-Proton Instability

Run 348, 5C26, both rings, 27-28.8.73
Run 354, 5C26, both rings, 06-07.9.73

Purpose : to investigate the occurrence of the e-p instability in the ISR and to correlate the instability with background and decay rate.

Results : Electron-Proton lines could be seen in both rings at current levels below 10 A.

Increasing artificially the neutralisation intensifies the e-p instability and may produce whole families of up to 30 lines.

It appears that contrary to what one would expect, the proton oscillation frequency may lie outside the betatron frequency range of the stack. One could deduce non-integral parts of the Q-value of up to 0.82 for a stack on the 5C line.

On an aperture limited stack one can see a very clear correlation between beam loss and background spikes on one side and the disappearance of a previously stable e-p line. In the presence of a stable e-p line one observes low background and low decay rate.

The observed patterns of e-p lines may vary from a very fast succession of sporadic lines over a wide frequency range to lines with extremely stable frequency and with a repetition rate between seconds and up to minutes. This pattern may change without obvious reason.

An increase in vertical beam height of the order of 3.5×10^{-4} to 1.3×10^{-3} mm per e-p instability has been observed.

Observations in run 348 :

The experiment was done with stacks of 10 A. Beam 2 was lost soon after stacking and could not be restacked due to PS failure. The whole experiment had to be abandonned early since also beam 1 was lost due to a 18 kV transient.

Nevertheless some observations could be made on a single e-p line around 90 MHz. Switching off the clearing voltage in individual octants did not noticeably affect the line. It was therefore not possible to localise the region of increased neutralisation which provoked this line. However, artificial neutralisation in octant 3 gave rise to the appearance of a whole family of lines covering a wide frequency range. This is shown in Figures 1 to 3.

Contrary to the earlier observations one could see two distinct groups of lines when switching off clearing in octant 3, see Figure 4. Could it be that the two groups are associated with two distinct straight sections in this octant?

Figures 5 and 6 show electron lines at frequencies of 100 and 105 MHz respectively. In the middle between the two longitudinal Schottky lines one can make out the transverse Schottky scan of the stack. It can be seen quite clearly that the e-p line does not sit inside the stack. From the location of the line between the Schottky lines one would deduce a non-integral part of the Q-value of 0.82 and 0.7 respectively. This observation has been made before (K. Hübner) and makes it doubtful whether it is possible to say from the observation of an e-p line which part of the stack is contributing to the instability. A possible explanation of the frequency shift could be found in a non-linear theory of the e-p instability which has been investigated by K. Hübner (Perf. Report 19th September 1972).

One may furthermore speculate whether this effect could shift protons into resonances which are even outside of the stack and cause beam blow up and loss. If this were so and since the frequency shift depends on various unknown parameters, it could explain why one observes a variety of beam behaviour and e-p instabilities under apparently unchanged conditions.

Observations in run 354

Most of the observations were done on a single stack of about 12 A in ring 1. Towards the end of the experiment 6.5 A were stacked in ring 2.

Electron-proton lines were observed on a free stack as well as on an aperture limited stack (horizontal and vertical scrapers in the "find beam" position).

The activity of the e-p lines did not seem to depend on whether the stack was aperture limited or not.

Background of I5 and the dI/dt signal were recorded. Again a very clear correlation could be seen between the disappearance of the e-p line and the spike in the background. The correlation with the dI/dt signal is very pronounced but only for the aperture limited case.

Figure 7 shows a typical pattern of the dI/dt and background signal. During quiet periods a stable line of about 80 MHz could be observed (Figure 8). The line disappeared gradually over a few tenths of a second and during this time the spikes shown on figure 7 could be observed.

The pattern of background and of the e-p instability did not remain the same throughout the experiment but changed from one fairly stable line to a rapid succession of lines spread over a wide frequency range. Very regular repetition rates could be observed on single lines ranging from about 1 sec (Figure 9) to 1.5 min. intervals (Figure 7).

Figure 10 shows the time structure of a 100 MHz line. The picture is taken with multiple sweep and the time scale is 1 msec/div.

Figures 11 and 12 show another line of 85 MHz on a slow sweep of 5 sec/div. and on 2 msec/div. when these two pictures were taken, 15 m of artificial neutralisation had been added to ring 1.

During a period of regular repetition rate of the instability the vertical beam blow-up was measured with the halo-scraper in the final beam mode. From the difference in scraper position one finds a vertical beam blow up of 3.5×10^{-4} mm and 1.3×10^{-3} mm per instability.

In the last hour of the experiment we stacked to 6.5 A in ring 2. In presence of beam 2 the previously spiky background of ring 1 disappeared and we observed a steady rate of 25 K. The beam decay rate improved by a factor of 2 to about 60 ppm/min. After dumping of beam 2 the background became again spiky and the decay rate increased.

The decay rate of beam 2 was below 10 ppm/min. and the background very quiet. Nevertheless we could see stable electron lines, figures 13 and 14.

Comparison between beam blow up due to e-p instability and the beam decay rate of the aperture limited stack.

The decay rate of the aperture limited stack was observed to be 550 ppm/min. The aperture given by the scrapers was 500 mm^2. On this stack one could see a regular repetition of an e-p instability (1.2 seconds) as shown in Figure 7. The beam blow up due to one occurrence of the instability was found to be 0.35 to 1.3×10^{-3} mm.

From the decay rate of the aperture limited stack one finds a diffusion constant of

$$D = 4.6 \times 10^{-4}\ mm^2\ sec^{-1}.$$

Taking the larger value of 1.3×10^{-3} mm for the beam blow up and putting this into the formular for the diffusion constant of the e-p instability by E. Keil one finds $D = 3 \times 10^{-5}\ mm^2\ sec^{-1}$. Even for this oversimplified comparison the agreement is rather bad.

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P. Strubin

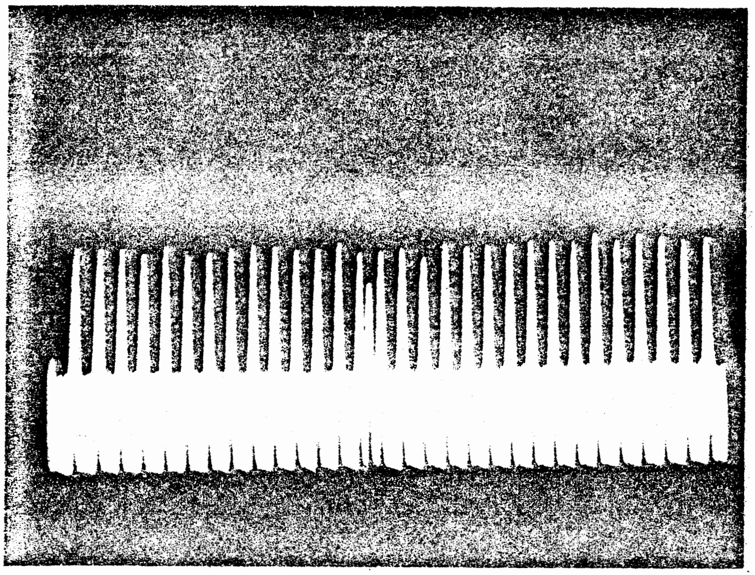


Figure 1

90 MHz center frequ.
1 MHz / div
I_1 = 9.4A

all clearing On

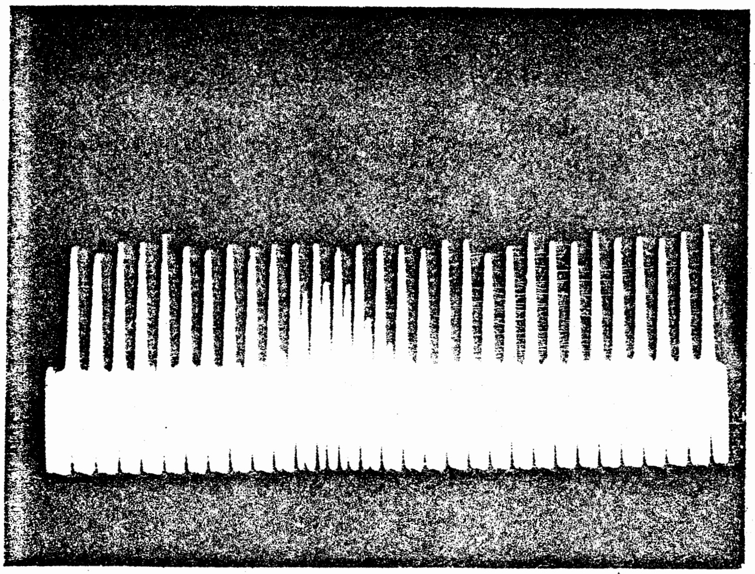
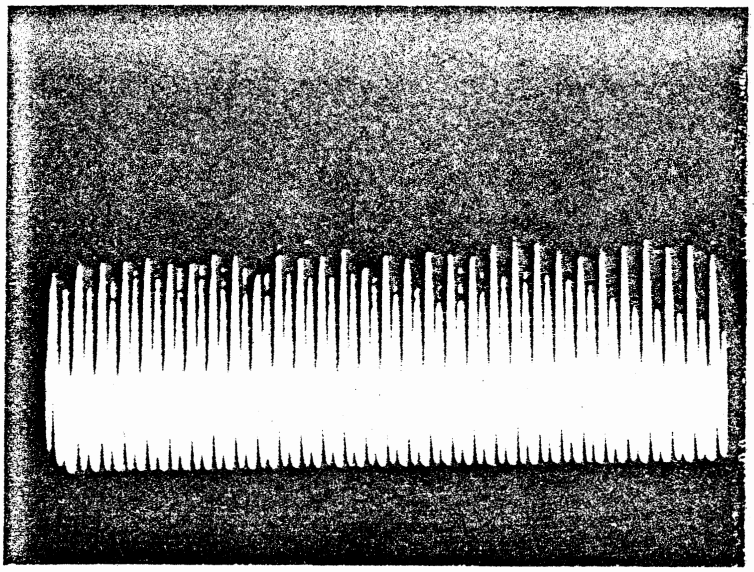


Figure 2

90 MHz cf.
1 MHz / division
I_1 = 9.4A
15 m neutralised

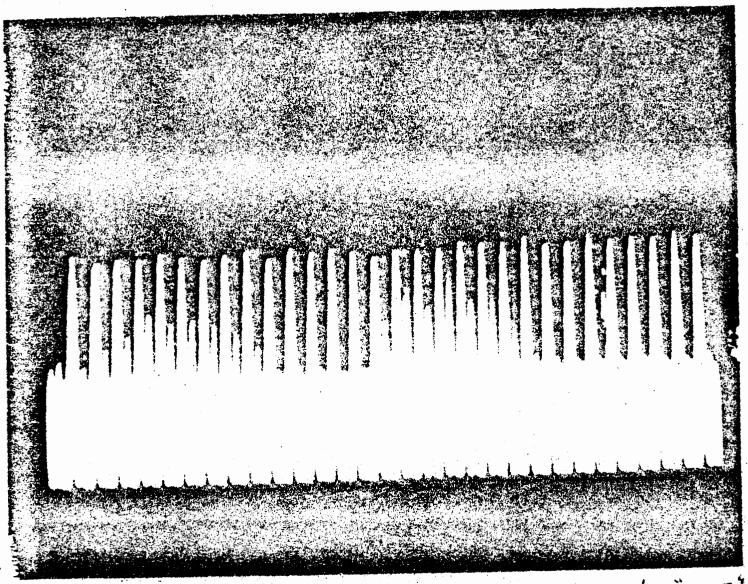


I_1 9.4 A cf ~ 80 MHz BW = 30 kHz 1MHz/div (centr = 50 m)

Figure 3

center frequency 80 MHz
1 MHz / div
I_1 = 9.4A

50 m neutralised



R1 9.4 A cf = 90 MHz BW = 30 kHz 1 MHz/div (CE oct. 3 "OFF")

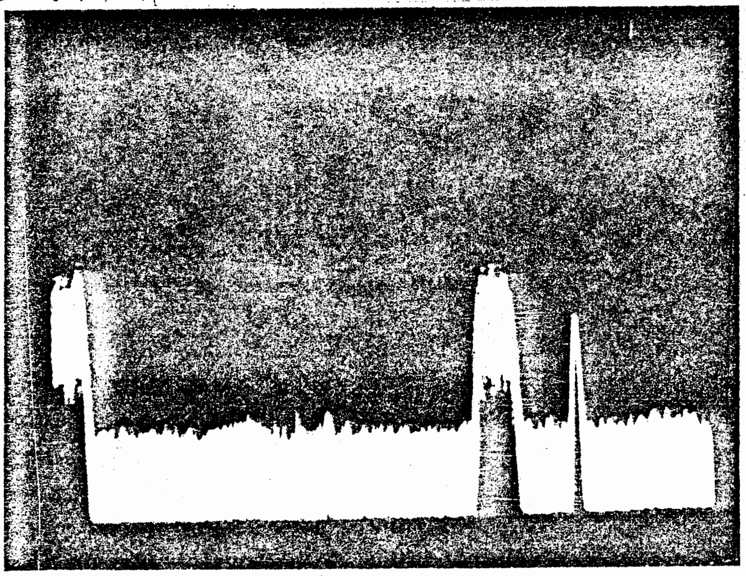
Figure 4

center frequency 90 MHz

1 MHz/div

I_1 = 9.4 A

clearing in OC3 off



R2, 9.9 A, c.f. 100 MHz, BW: 3 kHz, 50 kHz/div

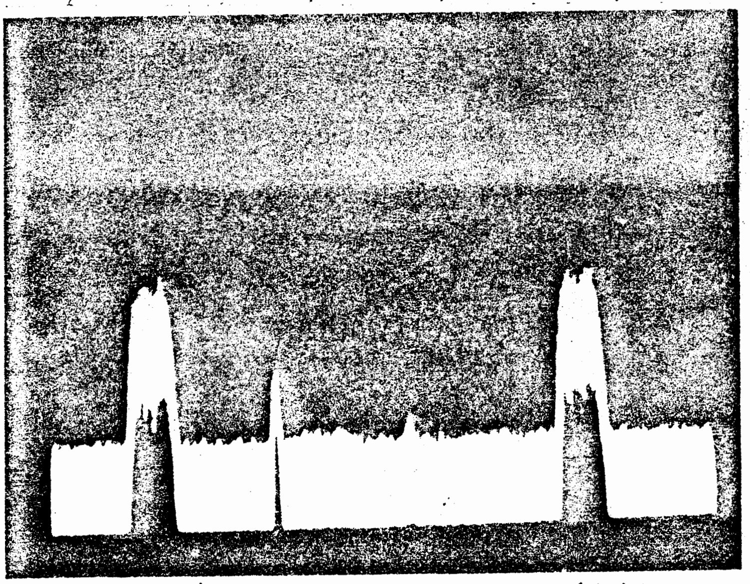
Figure 5

center frequency 100 MHz

BW 3 kHz

50 kHz/div

I_2 = 9.9 A



R2, 9.9 A, c.f. 105 MHz, BW 3 kHz, 50 kHz/div

Figure 6

center frequency 105 MHz

BW 3 kHz

50 kHz/div

I_2 = 9.9 A

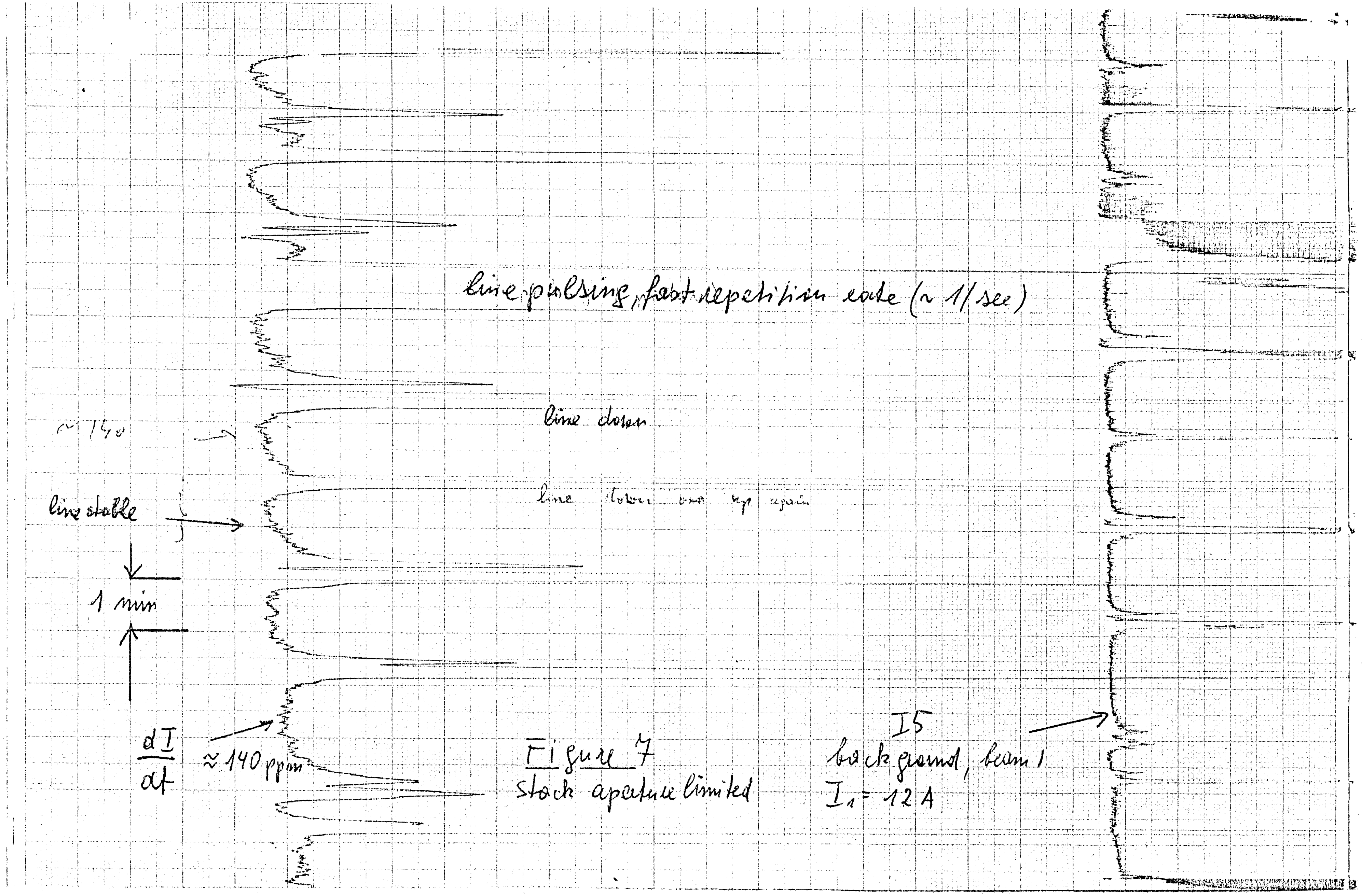


Figure 7
stack aperture limited

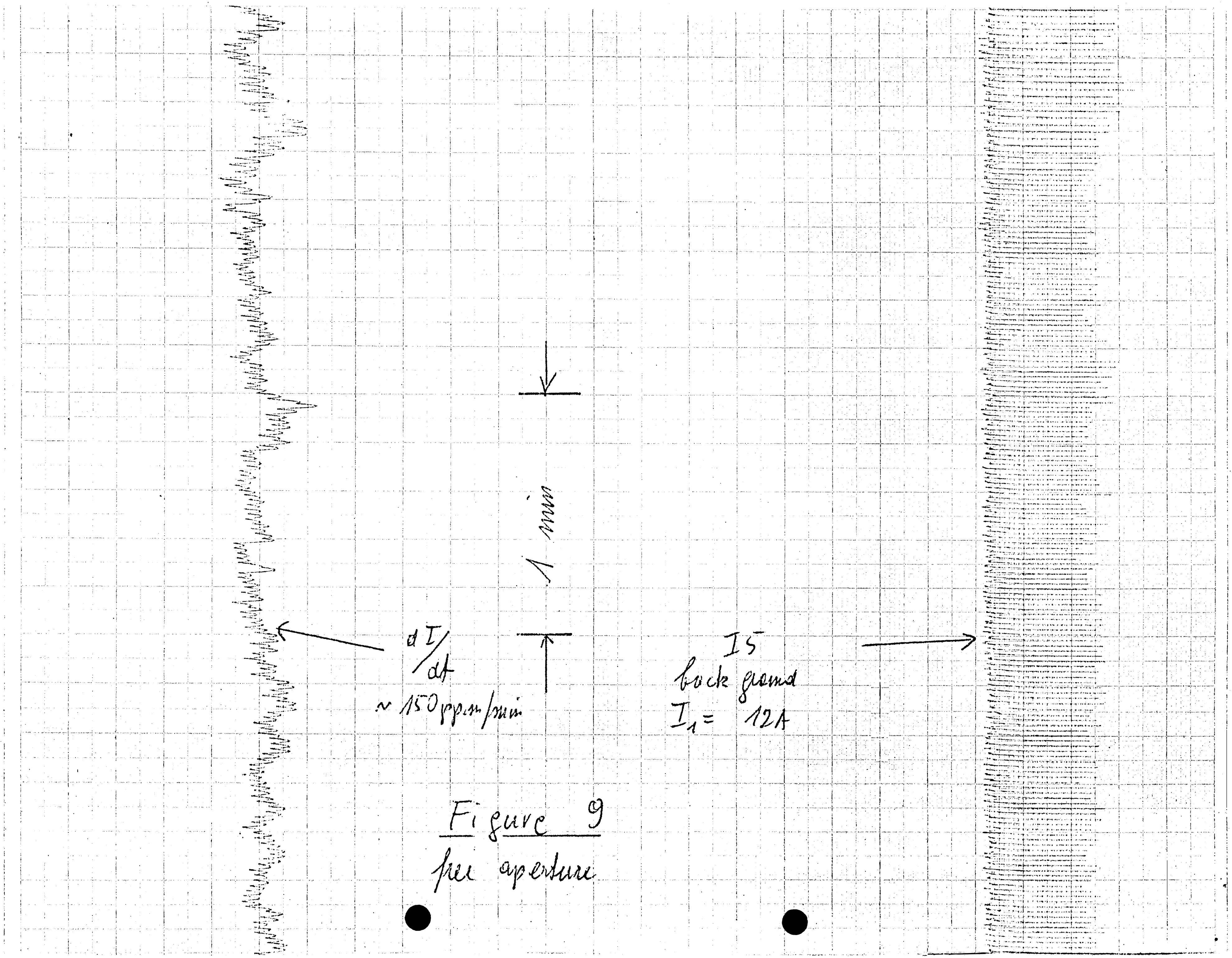
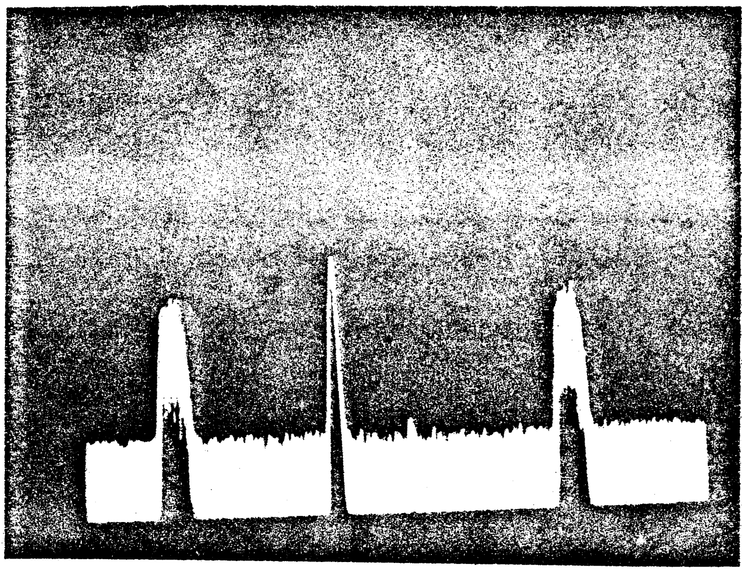


Figure 9

free aperture



vsl
CE

Figure 8
stable e-p line
with low decay rate
and quiet background

multiple sweeps   not ap. limits

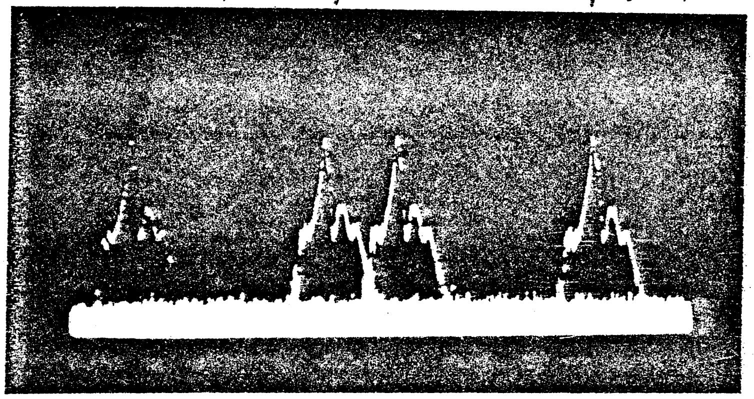


Figure 10
electron line at
100 MHz fixed frequency
1 msec / div
(multiple sweep)

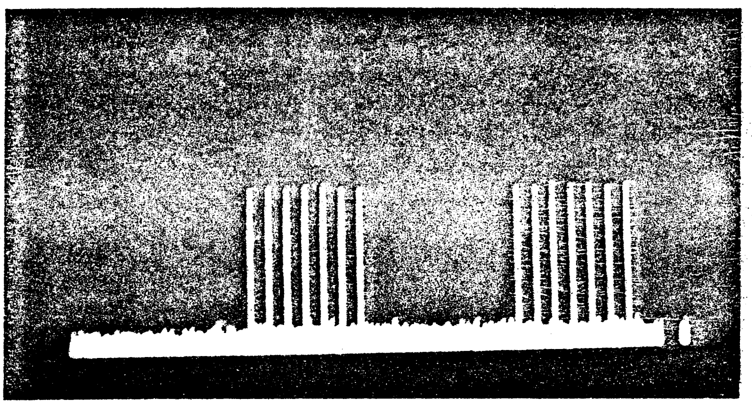


Figure 11.
electron line at
85 MHz
single sweep
5 sec / div

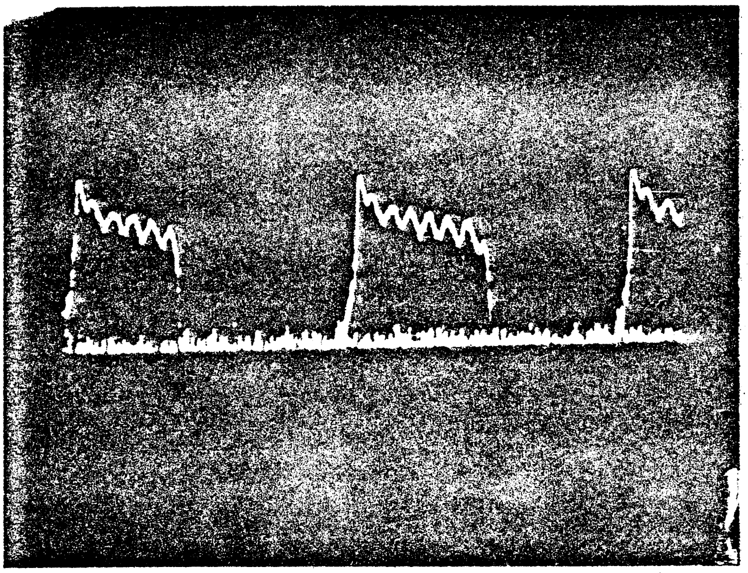
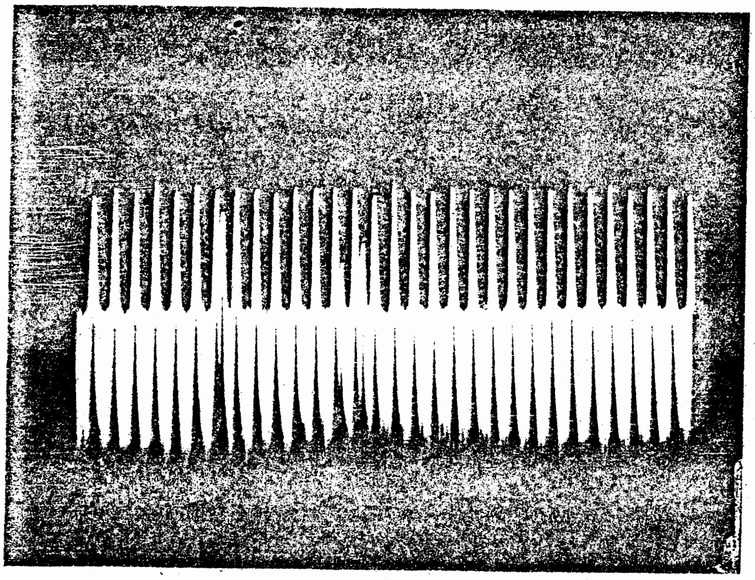


Figure 12
same line as
figure 11
multiple sweep
2 msec / div

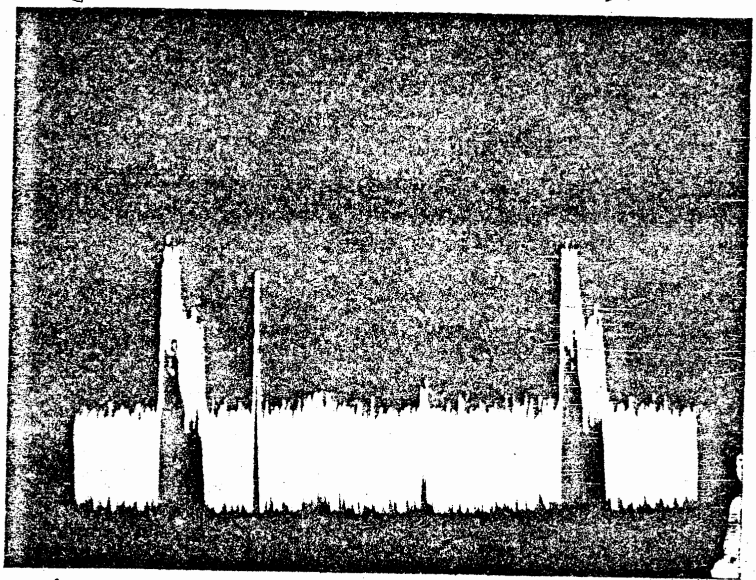
Ro17



Ring 2 $I_1 = 11.6$ $I_2 = 6.5A$

Figure 13

center frequency
105 MHz
1 MHz/div
$I_2 = 6.5 A$



cf 100 kHz 1 kHz BW. 50 kHz/div

Figure 14

center frequency
100 MHz
BW 1 kHz
sweep 50 kHz/div
$I_2 = 6.5 A$