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ISR PERFORMANCE REPORT

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R2, 22 GeV/c, 20 bunches

Study of longitudinal instabilities of bunched beams

Summary

Phase oscillations of bunched beams were studied using the "mountain range display". Quadrupole mode oscillations with growth times of $\tau \sim 0.2$ sec were observed with high rf voltage, and sextupole mode oscillations with $\tau \sim 0.5$ sec were dominant for a small rf voltage.

1. Rise of the instability

The matched beam is kept bunched on the injection orbit with a constant rf voltage V_i and $\Gamma = 0$. The onset and growth of phase oscillations for bunch 12 and 13 were observed on a "mountain range display". For $V_i = 16$ kV - bunch length ~ 16 ns - a quadrupole mode oscillation shows up after ~ 0.35 sec and grows with $\tau \sim 0.2$ sec, Fig. 1. Later, a dipole mode becomes dominant. For $V_i = 5.8$ kV - bunch length ~ 22 ns - a sextupole mode oscillation appears after ~ 0.3 sec and grows with $\tau \sim 0.5$ sec. Later, a dipole mode becomes dominant, and some higher modes seem to be present.

2. Phase relation between different bunches

Fig. 3 shows the oscillations of the first 17 bunches 0.5 sec after injection. There is a pattern which repeats itself after $\sim$ six or seven bunches. This indicates a mode number $n = 4$ or $n = 5$.

3. Oscillations of the first bunch

Fig. 3 shows that the first bunch oscillates with a smaller amplitude than most of the latter bunches. This indicates that the fields which drive this phase instability, decay to some extent (but not completely) during the "gap" of $\sim 1\ \mu s$.

4. Oscillations during acceleration

Fig. 4 shows the bunches during acceleration with $V_i = 16$ kV = const. and $\Gamma = 0.4$. The behaviour is very similar to the one with $\Gamma = 0$.

5. Conclusions

For $V_i = 16$ kV - bunch length ~ 16 ns - mostly $m = 2$ mode oscillations are excited; for $V_i = 5.8$ kV - bunch length ~ 22 ns - $m = 3$ mode oscillations are dominant. Based on Sacherer's [1)] theory one estimates a resonator frequency of ~ 75 MHz to be responsible for the instability (if one deals with only one resonator). Using the mode number $n = 4$ or 5 (which describes the phase relation between bunches) a set of possible frequencies around 75 MHz could be given. However, because of the large errors this is presently not of much help.

The rate of rise $\Delta\omega$ of the instability can be obtained approximately by correcting the observed rise with the Landau damping. One gets

$$\Delta\omega_2 \sim 6\ \text{sec}^{-1} \quad \text{for } V = 16\ \text{kV}, \quad m = 2$$

$$\Delta\omega_3 \sim 4\ \text{sec}^{-1} \quad \text{for } V = 5.8\ \text{kV}, \quad m = 3$$

Using Sacherer's theory, the shunt impedance of the resonator can now be estimated to be $Z \sim 5\ k\Omega$, $Z/k \sim 23\ \Omega$, (k = resonator frequency/ circumferential frequency).

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1) F. Sacherer; A Longitudinal Stability Criterion for Bunched Beams, CERN/MPS/Int. BR/73-3.

Fig. 1

$V_i = 16$ kV

$\Gamma = 0$

$I \sim 77$ mA

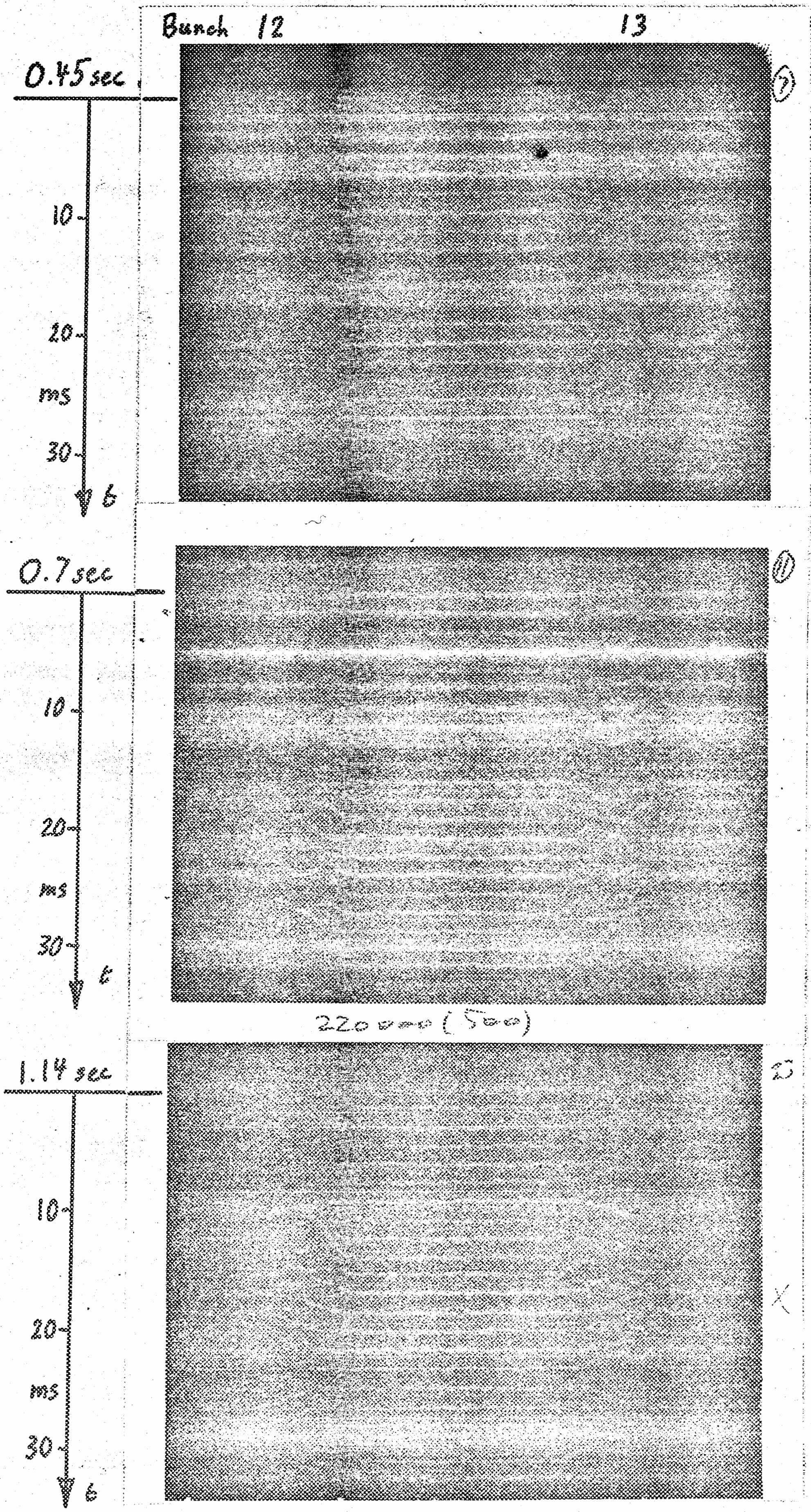


Fig. 2

$V_i = 5.8\,kV$

$\Gamma = 0$

$I \sim 77\,mA$

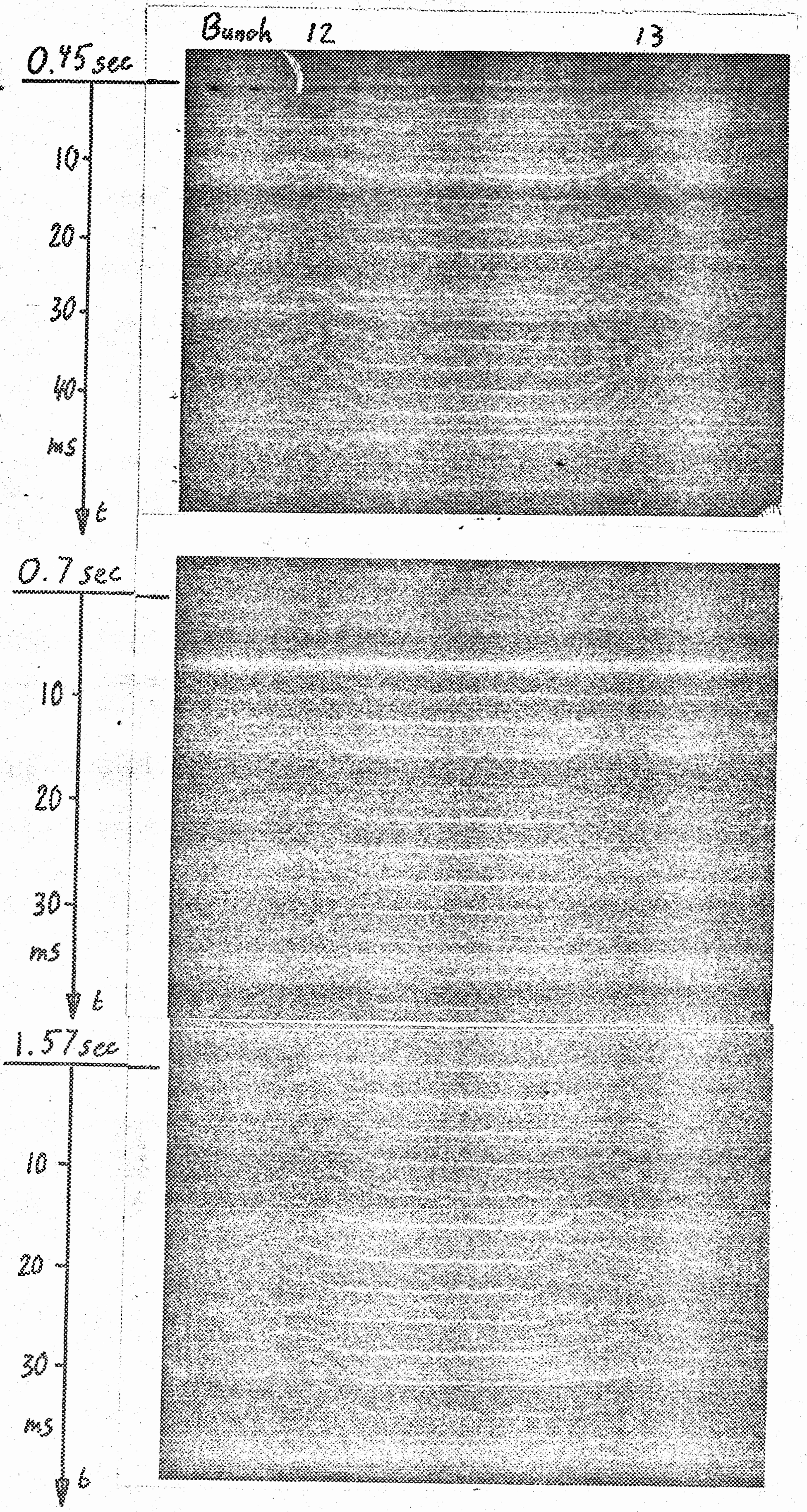
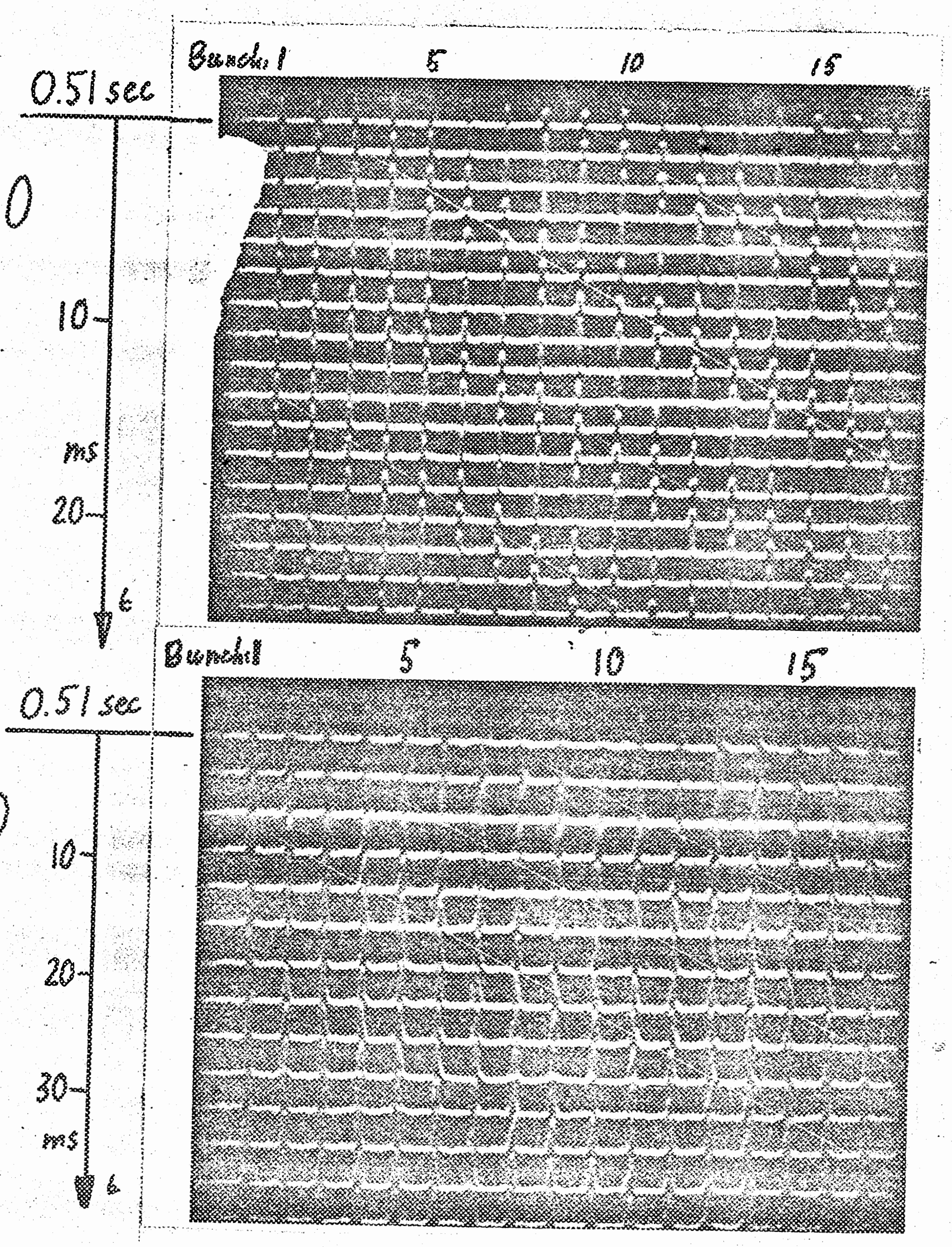


Fig. 3.

$V = 16\,kV,\ \Gamma = 0$



$V = 5.8\,kV,\ \Gamma = 0$

$I \sim 77\,mA$

Fig. 4

V = 16 kV

Γ = 0.4

I ~ 77 mA