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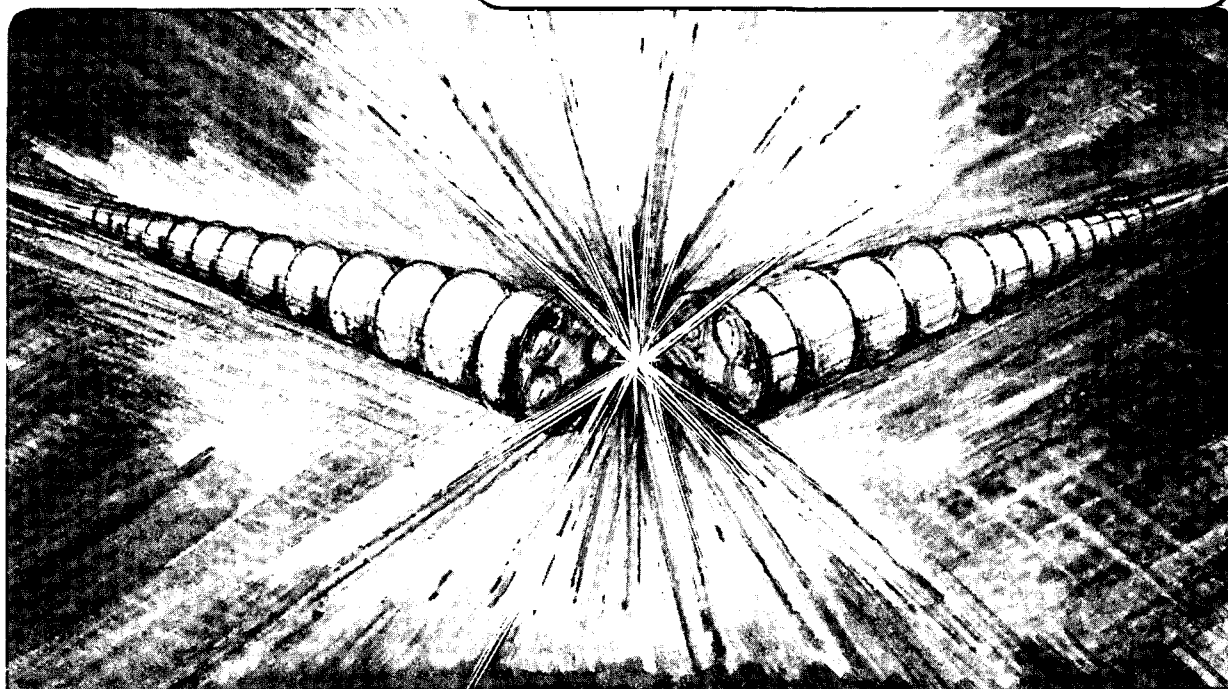
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### Damping Transverse Oscillations of Bunches in RHIC

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June 1988

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Damping Transverse Oscillations of Bunches in RHIC\*

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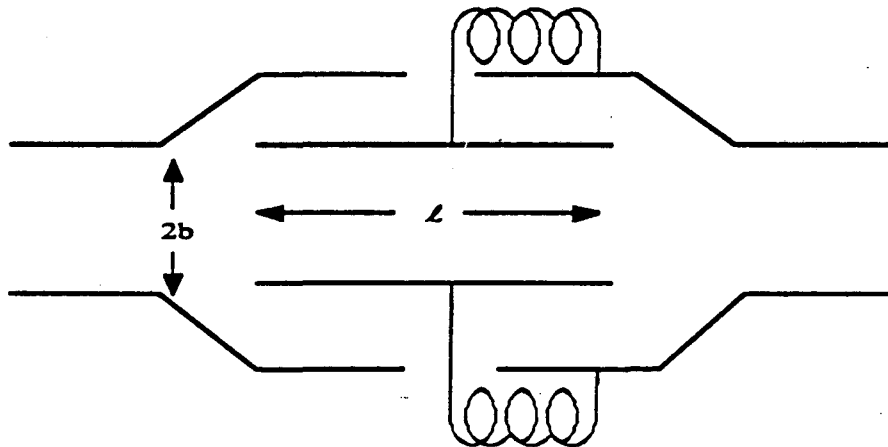
# Damping Transverse Oscillations of Bunches in RHIC

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To examine one aspect of the feasibility of suppressing transverse coupled-bunch motion, an estimate of the kicker power and bandwidth will be made. We expect that large power will not be required, so that the kicker electrode need not provide maximum coupling. This also reduces its contribution to the beam impedance, which is calculated at the end of this paper.

As an example kicker structure, select a pair of "capacitive" strips resonated external to the beam tube to provide the bandwidth needed to accommodate real-time bunch-by-bunch feedback (see Fig. 1).



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Fig. 1

With 57 bunches, the minimum bandwidth needed is  $57 f_0/2$ , where  $f_0$  is the bunch rotation frequency, 78 kHz. But extra bandwidth eases the design, so we could provide

$$\Delta f = 57 f_0.$$

We can choose to operate at a convenient frequency,  $f$ , away from the accelerating rf frequency. If we take 50 MHz, we would have

$$f = 50 \text{ MHz}$$

$$\Delta f = 4.45 \text{ MHz}$$

and the kicker must be tuned to have a loaded  $Q$  of

$$Q_L = f/\Delta f = 11.25.$$

Let the electrodes be strips of length  $\ell = 0.5$  meter, each with characteristic line impedance  $Z_L = 50 \Omega$  and surrounding the beam with a combined coverage factor  $g = 0.5$ .

-We shall calculate the power from the equation<sup>1</sup>

$$P = \frac{1}{2} \left( \frac{\Delta p_{\perp} \beta c}{q} \right)^2 (R_{\perp} T^2)^{-1}$$

in which

$$R_{\perp} T^2 = 4 \frac{Z_L Q_L g^2}{(k_0 b)^2} \tan(k_0 \ell / 2)$$

where  $\Delta p_{\perp}$  is the transverse momentum kick per turn imparted to a particle of charge  $q$  and

$$k_0 = 2\pi f/c = 1.047 \text{ m}^{-1}$$

$$b = \text{half-aperture between plates} = 0.04 \text{ m.}$$

These values give the transverse shunt impedance

$$R_{\perp} T^2 = 8.6 \times 10^4 \Omega.$$

To damp (or overcome growth) at a rate  $1/\tau$  with initial amplitude  $x_0$ , we need on average a corrective kick per turn of

$$\Delta x = -x_0/f_0 \tau.$$

If the betatron function at the kicker is  $\beta_{\perp}$ , this requires a peak transverse momentum kick per turn of

$$\Delta p_{\perp} = \sqrt{2} p \Delta x / \beta_{\perp} = -\sqrt{2} \frac{p x_0}{\beta_{\perp} f_0 \tau}$$

and the kicker power is

$$P = \left( \frac{p \beta c}{q} \frac{x_0}{\beta_{\perp} f_0 \tau} \right)^2 (R_{\perp} T^2)^{-1}.$$

For gold ions at injection, assume

$$\frac{p \beta c}{q} = 29 \text{ GV}$$

$$\beta_{\perp} = 100 \text{ m}$$

$$x_0 = 1 \text{ mm}$$

to obtain  $P = 1.6 \times 10^{-4} / \tau^2$  watt. Using example damping times we have

$\tau$ (ms)	P (W)
1	160
10	1.6
20	0.4

At full energy, the required power is expected to be comparable to this, or less, because a smaller initial amplitude and slower growth rates should offset the larger momentum. The initial amplitude at low energy may be greater than 1 mm if the feedback is asked to correct injection errors.

The transverse beam impedance of this kicker would be

$$Z_{\perp} = R_{\perp} T^2 k_0 / 2 = 0.045 \text{ M}\Omega/\text{m}$$

at 50 MHz with  $\Delta f = 4.5$  MHz. This value could be reduced by using a less efficient kicker, at the expense of power.

## Reference

1. G.R. Lambertson, "Dynamic Devices - Pickups and Kickers," Physics of Particle Accelerators, Eds. M. Month and M. Dienes, AIP 153, Vol. 1, p.1413 (1987).



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