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SUPPRESSION OF TRANSVERSE INSTABILITIES BY OCTUPOLE LENSES

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The Landau damping of transverse bunched beam instabilities can only be achieved with octupoles. [Sextupoles, which act on transverse coherences through the chromaticity, can provide no Landau damping because of the periodic synchrotron motion.[1]] As a rule of thumb the betatron frequency spread produced by such a field should exceed the total frequency shift (real + imaginary parts added in quadrature) due to the impedance driving the instability.

To estimate the required frequency spread we calculate

$$\Delta Q_i = \frac{U}{\Omega_o} = \frac{NRr_p}{\pi\gamma^3 Q_o \beta^2 B}\left[\frac{\xi_1}{h^2} - \frac{\epsilon_1}{h^2} - \frac{1}{2a^2}\right]$$

which is the real part of the frequency shift due to the beam itself and its interaction with a perfectly conductive vacuum chamber. For a beam .85cm height with $h = 4$cm at $\gamma = 12$ ($\beta = 1$) and a bunching factor of .1 we obtain a $\Delta Q_i \approx .0014$ at 5×10^{12} protons. The corresponding value of U is 3.2×10^3/sec. A single bunch e folding time of 2.5×10^{-3} sec has been observed. This gives a growth rate of 400 sec^{-1} which corresponds to the V term in the stability analysis and indicates that U>>V.

Since the beam is larger in the horizontal plane we shall only calculate the frequency spread in the vertical plane due to the horizontal motion, i.e.

$$\Delta Q_o = \frac{1}{16\pi} \epsilon_H \beta_H \beta_V \frac{b}{p}$$

where $\epsilon_H = 13.5 \times 10^{-6}$ Meter radians is the normalized horizontal emittance, p the momentum and $b = \int B''' \, ds$ is the integrated octupole strength. For $\gamma = 12$ and $b = 5.5 \times 10^4$ K gauss/meter^2 we obtain a $\Delta Q_o = 9.2 \times 10^{-3}$ for the octupoles located at horizontal $\beta_{min} = 10.8$ meters. Thus at 10^{13} ppp if the beam emittances do not change there is a factor > 3 available in the strength over the simple criterion.

Octupoles have been used to stabilize the vertical instability in the CERN P.S. for several years(2) and recent measurements(3) indicate that in fact less octupole strength is requied than given by the above estimate. It is thus probable that the octupole strength given should be sufficient to provide effective Landau damping at the projected AGS intensity level of 10^{13} ppp.

References

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