HIGHER-ORDER MODES OF KEK-PF CAVITY

AND BEAM INSTABILITIES

Y. Yamazaki, K. Takata and S. Tokumoto

National Laboratory for High Energy Physics

It is well known that the bunched beam instabilities can be driven by cavity-like objects. The possible beam instabilities for the KEK-PF electron storage ring were discussed in detail by Takata.[1] It was expected that the slowly varying parts of the cavity and ring impedances are small enough to store the designed beam current 500 mA for the multi-bunch operation. However, serious instabilities of the coupled bunch oscillations may arise from the rapidly varying part of the cavity impedance associated with the higher-order mode resonances. Here, the number of bunches is 312 and the accelerating frequency is 499.99 MHz. Thus the higher-order modes in the accelerating cavity were studied by using the model cavity. (see Ref. 2).

Resonant modes possible in an axially symmetric cavity are designated by TM0, TE0 and HEMν ($\nu \gtrsim 1$). The TM0 modes can cause the longitudinal beam instabilities,[3,4] which are studied in terms of the shunt impedances. The HEM1 modes are associated with the transverse beam instabilities.[5,6] The transverse coupling impedance defined by[5]

$$Z_{\perp} = \lim_{\Delta\to 0} j \frac{\int_{-d/2}^{+d/2} [\vec{E}+\vec{V}\times\vec{B}]_{\perp} e^{jkz} dz}{I\Delta}$$

has been widely used in studies of the transverse bunched beam instabilities. The deflecting mode is excited by the beam current I displaced from the equilibrium orbit by an infinitesimal amount Δ. Then $eZ_{\perp}\cdot I\Delta$ is a transverse momentum impulse received by a relativistic electron traversing the cavity of the length d.

The resonant frequencies and shunt impedances of the TM0 modes can be calculated by the computer program SUPERFISH. However, no computer program is available to calculate the parameters of the HEM1 modes. Thus the experiment is crucial for the transverse beam instabilities.

Fifteen resonances were observed up to 1,300 MHz, and mode assignments were made for all of the resonances. Field distributions were measured for the TM0 and HEM1 modes with a technique developed by Maier and Slater.[7] The measured data were used to determine the shunt impedances for the TM0 modes and the transverse coupling impedances $R_{\perp}/Q$ for the HEM1 modes. The procedure is detailed in Ref. 8. The results are listed in Table I. The present experimental results for the TM0 modes were in excellent agreement with the SUPERFISH calculation.

The growth-rates of the longitudinal and transverse coupled bunch oscillations were estimated from the present experimental results and the formulas developed in Refs. 3-6. The estimated growth-rates for almost all observed resonances were faster than the radiation damping rates (sometimes 1,500 times faster). Thus it is necessary to develop a device to avoid the instabilities.

Two openings are prepared in the cavity to damp the higher-order mode resonances (see the figure in Ref. 2). Coupling loops and antennas were tested in the model cavity. A half-wavelength shorting plunger was attached to the coupling loop to stop the fundamental (accelerating) mode. The external Q-values of the damping couplers are listed in Table I. The damping couplers had practically no effect on the fundamental mode.

The growth-rates of the beam instabilities with the damping couplers are compared with the radiation damping rates in the last column of Table I. It is expected that the Landau damping will be factor two or three faster than the radiation damping. Thus the higher-order modes were well damped to stabilize the beam except for the 1,300 MHz resonance. Another opening will be necessary at the position where the electric or magnetic field of the 1,300 MHz resonance is very strong.

1) K. Takata, Nucl. Instr. Meth. (to be published), KEK Preprint 80-1 (1980).
2) Y. Yamazaki and K. Takata, present Proceedings.
3) C. Pellegrini and M. Sands, PEP Report PEP-258 (1977).
4) K. Takata, KEK Report KEK-79-6 (1979).
5) F.J. Sacherer, Proc. 9th Int. Conf. on High Energy Accelerators, Stanford, 1974, p.347.
6) R.D. Kohaupt, DESY Report H1-74/2.
7) L.C. Maier, Jr. and J.C. Slater, J. Appl. Phys. 23 (1952) 68.
8) Y. Yamazaki, K. Takata and S. Tokumoto, KEK Report (to be published).

Table I Properties of observed TM0- and HEM1-mode resonances in the KEK-PF cavity.

Mode and Parity	Frequency (MHz)	R_{sh}/Q (Ω) or $R_{\perp}/Q$ (Ω/m)	Unloaded Q	External Q of Damping Couplers	Growth-Rates of Instabilities Divided by Radiation Damping Rates
TM0+	499.5	222	44,000	2×10^7	-
TM0-	758.4	81	37,000	60	2
TM0+	1052.2	0.19	38,000	570	0.1
TM0+	1299.9	12.0	97,000	2,600	30
HEM1-	689.0	< 22	45,000	50	< 0.1
HEM1+	829.3	207(35)	56,000	190	2
HEM1-	1070.8	666(31)	40,000	80	3
HEM1+	1137.9	6(3)	45,000	290	0.1
HEM1-	1245.0	< 34	95,000	890	< 2