BEAM LOADING OBSERVED DURING THE DEBUNCHING PROCESS IN THE KEK-PS

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Amplitude and phase modulations on a cavity voltage are observed at the flat-top of the KEK-PS, where the voltage is reduced. An rf frequency is slightly shifted from the accelerating frequency to get a debunched beam for the slow extraction.[1] A simple analysis of this beam loading is described on condition that a cavity impedance takes only a resistive part. The analysis agrees well with the observed results corrected by some effects of the feedback loops in the rf acceleration system.[2]

We summarize the acceleration system composed of the cavity, the rf generator and the beam as shown in Fig.1. The sum of the generator current I_g and the beam current I_b flow through the cavity. The I_g and I_b are

$$I_g = I_{go}\cdot\sin\omega_g t \qquad (1)$$

$$I_b = I_{bo}\cdot\sin(\omega_b t + \theta_b) \qquad (2)$$

where ω_g is an angular frequency of the generator, ω_b an rf component of the beam and θ_b a constant value of phase. The voltage on the cavity, V_c, is

$$V_c = V_{co}\cdot\sin(\omega_g t + \Theta) \qquad (3)$$

where

$$V_{co} = V_{go}\{1 + x^2 + 2x\cdot\cos\varphi(t)\} \qquad (4)$$

and

$$\Theta = \tan^{-1}\frac{x\cdot\sin\varphi(t)}{1 + x\cdot\cos\varphi(t)} \qquad (5)$$

V_{go} is the cavity voltage without the beam, $x = I_{bo}/I_{go}$ and $\varphi(t) = (\omega_b - \omega_g)t + \theta_b$. The eq. (4) shows an amplitude modulation (AM) and the eq. (5) a phase modulation (PM). When $x \ll 1$, eq. (4) is linearized to a usual AM, $V_{co} \doteqdot V_{go}\{1 + x\cdot\cos\varphi(t)\}$. Wave distortions both in AM and PM arise, according as x is increased.

The index of AM, m given by $(V_{comax}-V_{comin}) / (V_{comax}+V_{comin})$ is equal to x from eq. (4) and is dependent on beam intensity. The observed modulation frequency is equal to the difference between the rf frequency and the rf component of the beam. Measurements are done to verify the calculation described above. The m is measured as a function of the rf voltage on the cavity. A mV_{go} value will remain constant against varying V_{go} under a constant beam intensity. The mV_{go} is, however, decreased as increasing V_{go}, which may be due to a nonlinearity of a diode in the AVC loop.[2] A correction due to an amplitude dependence of the loop is added to the value. The corrected values ($\dot{m}V_{go}$) become constant as shown in Fig.2, corresponding to each beam intensity. Since the $\dot{m}V_{go}$ shows an induced voltage by the debunching beam, we can know the rf component of the beam from the measurements of the m value.

An output of a phase detector used for the tuning of the cavity[2] is also modulated by the beam at the same frequency as the AM. An amplitude of the PM is measured as a function of the m. The result is shown in Fig.3 together with a calculated value using eq. (5). The measured value agrees well the calculated one except a offset error of 3 deg., which may due to a noise in the tuning loop.

References

1) K. Endo and C. Steinback, KEK-77-13 (1977)
2) M. Kondoh et al., IEEE Trans. NS-26,No.-3, (1979) 3950
3) H.H. Umstätter, MPS/SR, Note 69-9, (1969)

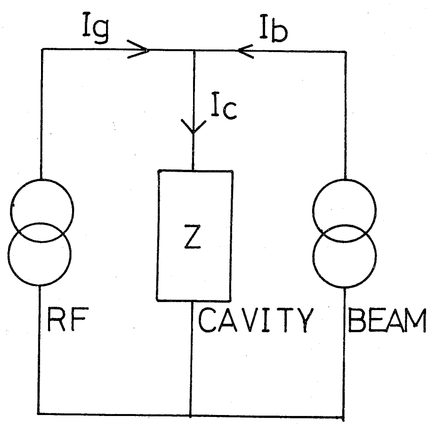

Fig.1 Schmatic diagram of beam loading

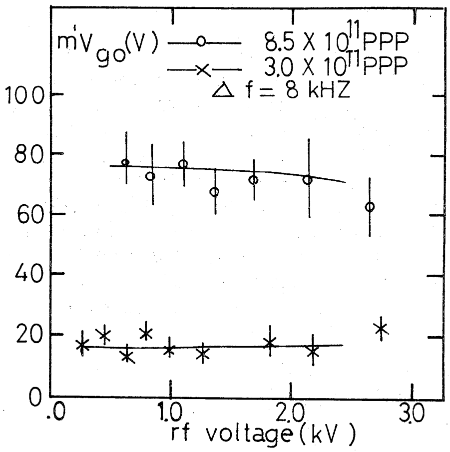

Fig.2 Corrected values of mV_{go}

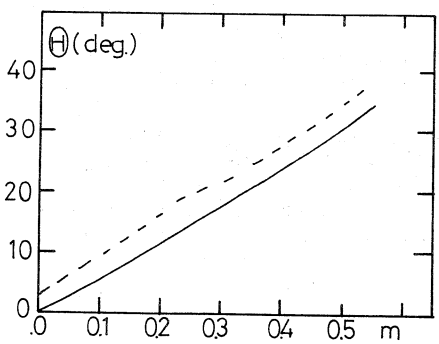

Fig.3 Amplitude of PM
a solid line is calculated.
a dashed line is measured.