A DECAY RATE PLOT OF STORED ELECTRON BEAM CURRENT AND ITS APPLICATIONS

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ABSTRACT

The effects of pressure rises due to gas desorption from a chamber wall caused by synchrotron radiation (SR) and a local pressure rise due to gas flow from the side of SR beam lines are discussed with respect to a decay rate of stored electron beam current I. It is shown that the decay rate of I is a good measure to indicate Touschek effect of the stored beam and conditions of gas pressure of a storage ring. The decay rate plot against I by a computer processing is always recorded during the operation of TERAS to indicate decay modes and lifetime of the stored beam current.

ELECTRON BRAM CURRENT MONITOR

The stored electron beam current is measured by monitoring the emitted SR with a silicon photodiode (SPD). The amplified signal from SPD using an operational amplifier is used to indicate the beam current on digital panel meters. The calibration of this monitor has been performed by simultaneous measurement of SR at different viewing port with a photomultiplier (PM).[1] The amplified signal from the PM decreases stepwise in amplitude corresponding to a decrease in the number of stored electrons of the order of several thousands. By measuring the change in output voltage for a number of steps, the PM sensitivity can be determined in the term of output signal per electron. It is possible subsequently to use the linearity of the PM signal to scale the output of the SPD monitor. The monitor enables us to measure the beam current in the range between 1μA to 1.5A within 1% accuracy.

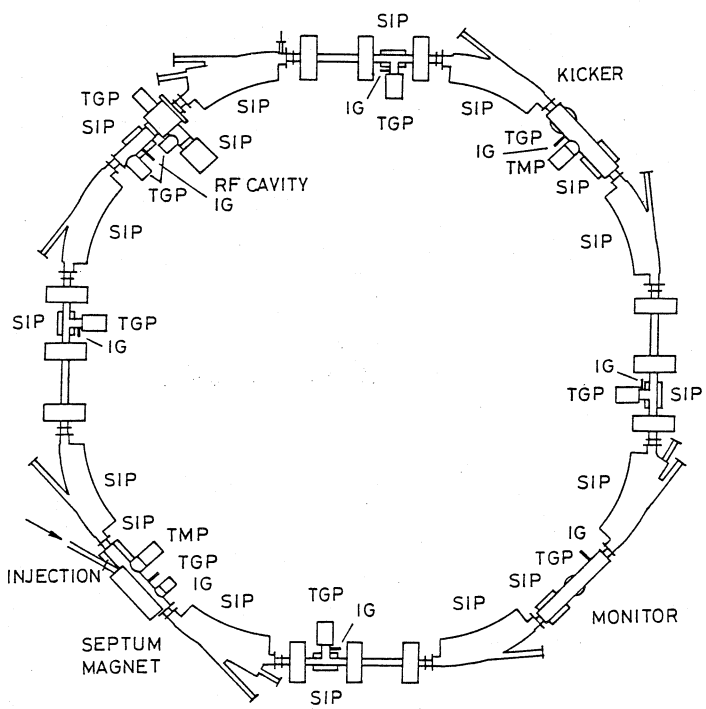

Fig. 1 Vacuum system for TERAS.

VACUUM SYSTEM AND PRESSURE RISE WITH STORED BEAM

Im provement of the vaccum system was done to increase total pumping speed and beam lines for experiment in Jan. 1983 as shown in Fig.1. [2] Total pumping speed of the mounting and built-in pumps has been increased up to 13000 l/sec from 8000 l/sec. An ionization gauge is attached at each straight section of the ring. The typical value of the residual gas pressure is about 0.15 ntorr.

The recent pressure rises with stored beam are 3.0×10^{-3} ntorr/mA at 400 MeV, 4.4×10^{-3} ntorr/mA at 500MeV and 6.4×10^{-3} ntorr/mA at 600MeV. Fig.2 shows a typical variation of the gass pressure P with stored beam current I at 600MeV. The experimental data well fit the solid line expressed by

$$P = b_0 I + c_0, \quad (1)$$

where $b_0 I$ is the pressure rise ΔP due to the stored beam current I, that is,

$$\Delta P = b_0 I \quad (2)$$

and c_0 is the residual gas pressure.

DECAY MODES OF STORED ELECTRON BEAM CURRENT

(1) DECAY MODES DUE TO GAS PRESSURE [3]

The decay rate of the beam current I due to gas pressure is proportional to PI.

$$dI/dt = -\beta PI, \quad (3)$$

and thus

$$dI/dt = -\beta(b_0 I + c_0)\, I. \quad (4)$$

The eq.(4) can be written as

$$dI/dt = -bI^2 - cI. \quad (5)$$

The eq.(5) shows that the decay rate due to gas pressure includes two kinds of decay mode. When $bI^2 \gg cI$, the eq.(5) can be written as

$$dI/dt = -bI^2. \quad (6)$$

The lifetime of the beam current can be estimated by

$$\tau_I = 1.718\, I/|dI/dt|, \quad (7)$$

and we call this condition decay mode I.

When $cI \gg bI^2$, the eq.(5) can be written as

$$dI/dt = -cI. \quad (8)$$

The lifetime of the beam current can be estimated by

$$\tau_{II} = I/|dI/dt| \quad (9)$$

and we call this condition decay mode II.

It should be noted that the estimate of lifetime is quite different according to the decay mode as shown by the eqs.(7) and (9).

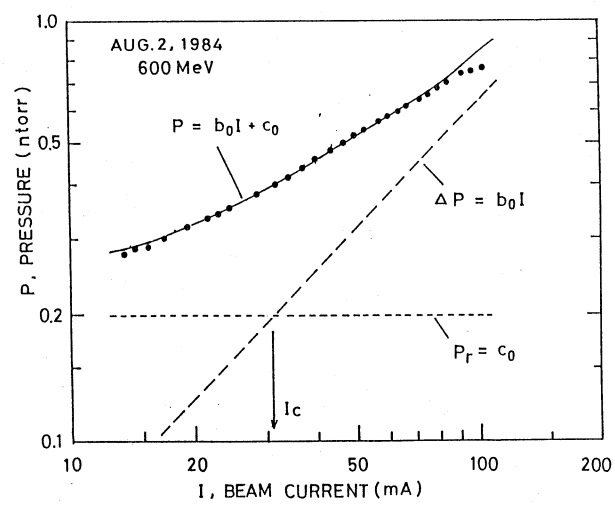

Fig. 2 Variation of gas pressure with beam current.

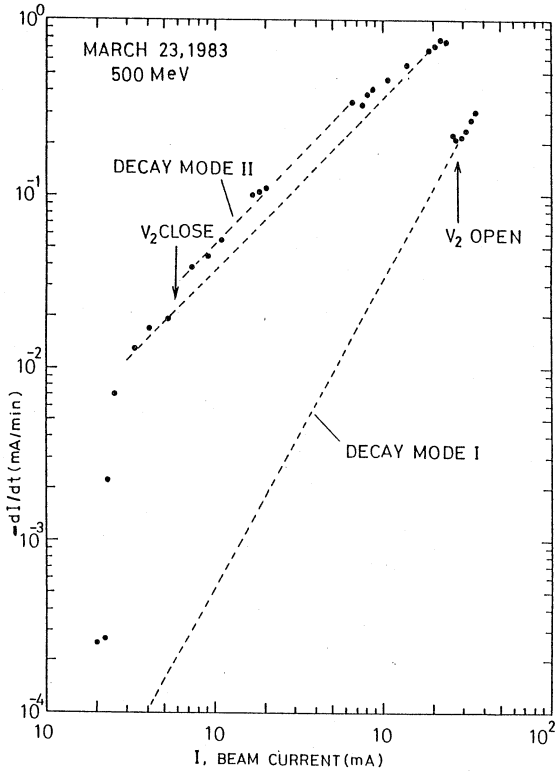

Fig. 3 Decay modes of stored beam current. Case 1. Effect of gas flow from the beam line 2 is large compared with pressure rise in TERAS.

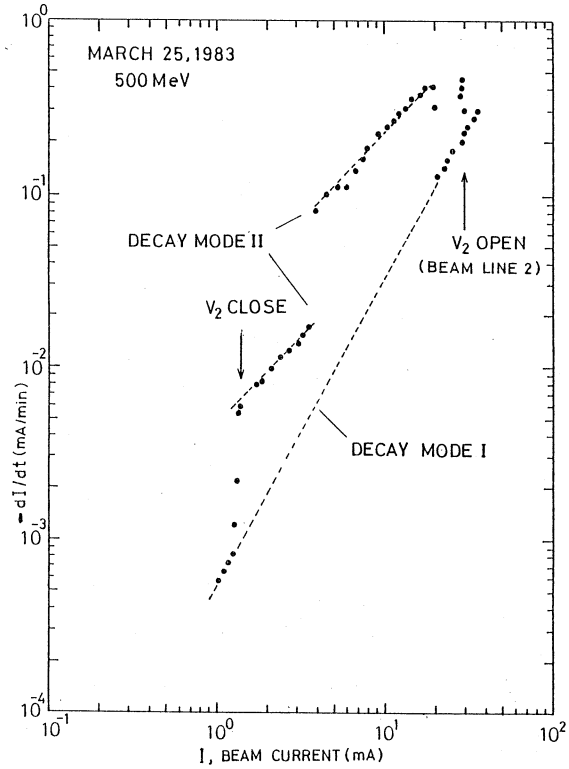

Fig. 4 Decay modes of stored beam current. Case 2. Effect of gas flow decreased compares with case 1.

(2) DECAY MODE DUE TO TOUSCHEK EFFECT

The decay rate of the beam current I due to electron-electron scattering in the stored beam bunches is proportional to I^2.

$$dI/dt = -aI^2. \quad (10)$$

This is decay mode I, and the lifetime of the beam current is given by the eq.(7). Thus, from the eqs.(5) and (10), the total decay rate of the beam current I can be written as

$$dI/dt = -(a+b)I^2 - cI. \quad (11)$$

DECAY RATE PLOT OF STORED ELECTRON BEAM CURRENT I

Fig.3 shows a typical example of the case that a local pressure rise due to gas flow from the side of the beam line 2 is extremely large compared with the pressure rise in the storage ring.

Fig.4 shows s decay rate plot taken after two days. It is easily understood that gas flow from the beam line 2 considerably decreased and the lifetime was improved. At the early stage of the ring operation, the pressure rise due to gas desorption from the chamber wall caused by SR reached up to 17 ntorr. The decrease of decay rate as seen in Fig.5 is due to the decrease of gas desorption caused by SR. The amount of the decrease is proportional to I^2. Thus, the lifetime at the early stage of the ring operation is not mainly due to Touschek effect but the pressure rise. To evaluate the decay rate due Touschek effect given by the eq.(10), the components of bI^2 and cI have been determined using the pressure components of b_0I and c_0. It should be noted that the lines of bI^2 and cI in Fig.6 intersect at the beam current I_c at which the lines of b_0I and c_0 in Fig.2 also intersect. The experimental data well fit the solid line expressed by

$$-dI/dt = aI^2 + bI^2 + cI. \quad (12)$$

The lifetime estimated from the decay rate aI^2 due to Touschek effect shown in Fig.6 is about 24 hours, which is about 5 times of the present lifetime.

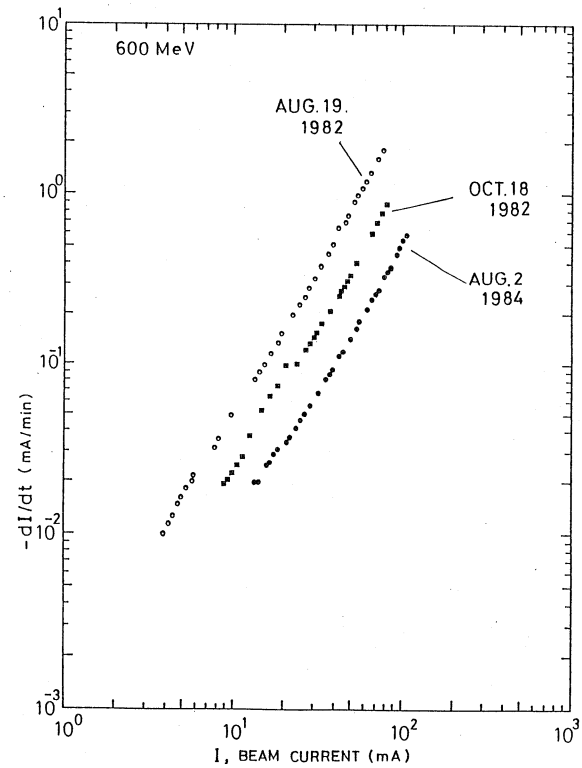

Fig. 5 Decrease of decay rate. The amount of decrease is proportional to I^2. The lifetime at the early stage of operation is not mainly due to Touschek effect but gas pressure rise.

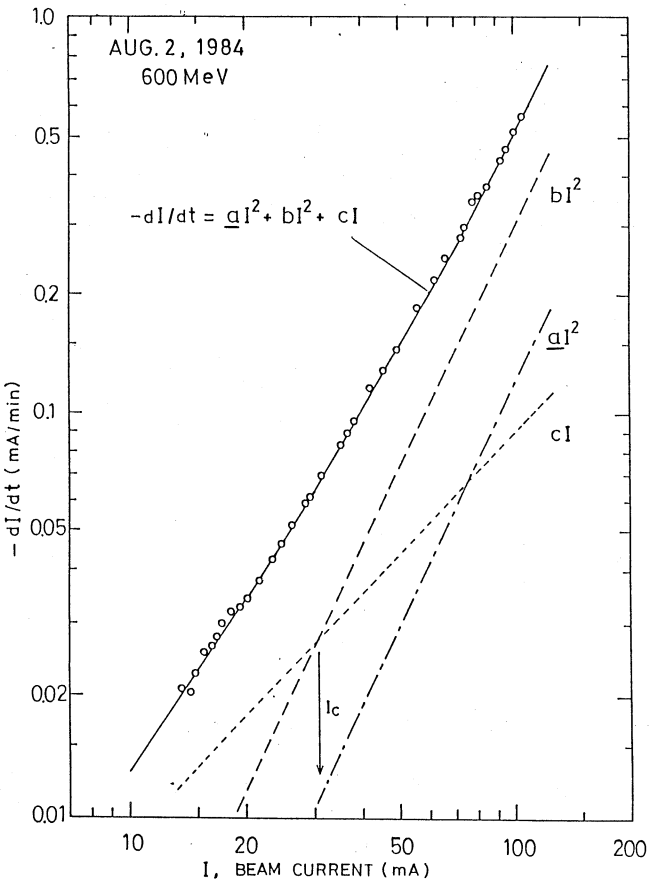

Fig. 6 Decay rate plot and component of Touschek effect ($\underline{a}I^2$).

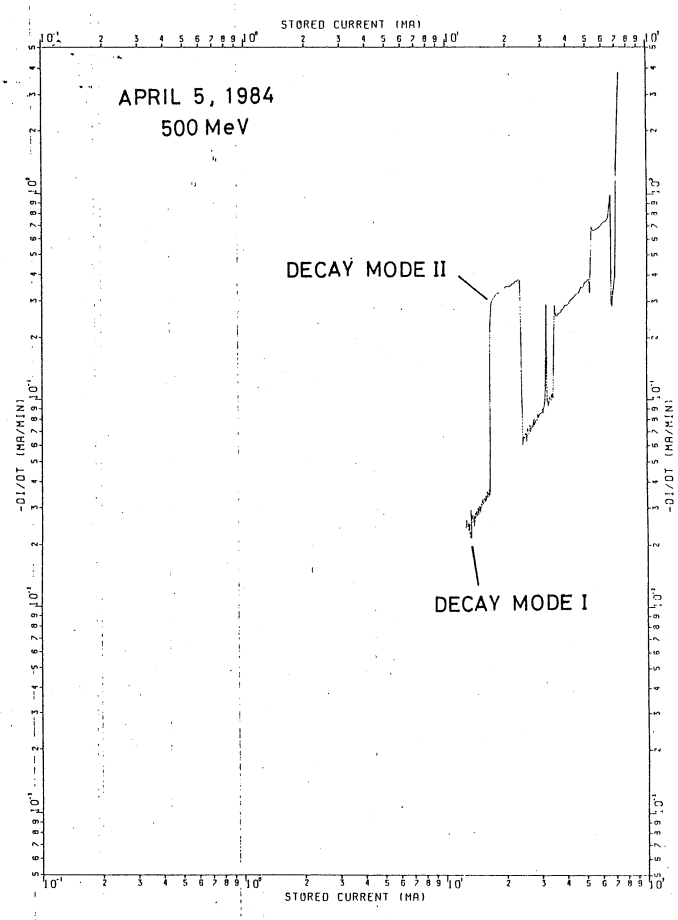

Fig. 7 Decay rate plot recorded by computer processing.

The parameter $\underline{a}$ is a very good measure to indicate the characteristics of the storage ring.

The decay rate plot against I by a computer processing is always recorded during the operation of TERAS to indicate decay modes. Fig.7 shows a typical example.

RFFERENCES

1) T. Noguchi et al., Proc. 4th symposium on Accelerator Science and Technology, RIKEN, 35, 1982
2) T. Tomimasu et al., IEEE Trans., NS-30, No.4, 3133 1983
3) T. Tomimasu, Newer Metal Industry, No.315, 1, 1984 (in Japanese)