Analysis of Signals from Beam Position Monitor Pickups on the SPring-8 Storage Ring

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The SPring-8 storage ring has 288 beam position monitors (BPM's) to measure positions of electron beams with respect to sextupole magnets. During the commissioning of the ring or in the injection tuning, the BPM's are operated in the single pass mode wherein the beam trajectories are measured turn by turn with resolutions of 100 - 1000 μm. When a stable beam is stored, the COD mode is used wherein the beam orbit averaged for hundreds of turns are measured with a resolution better than 10 μm. The specified resolutions require the BPM electronics to have signal to noise ratio of 10-100 and 1000 for the single pass mode and the COD mode, respectively. To give a basis for the design considerations of BPM electronics, we have calculated signals of BPM pickups on the SPring-8 storage ring.

The BPM's on the storage ring consist of button type pickups. The equivalent circuit of a button pickup is shown in Fig. 1, where C is the capacitance of the button and R is the characteristic impedance of the feedthrough. An electron beam is represented by an equivalent current source i(t). The time dependence of the current is the time derivative of the charge Q(t) on the button induced by the beam. Given the current i(t), the output voltage signal V(t) from the pickup is the solution of the ordinary differential equation,

$$\frac{dV(t)}{dt} + \frac{V(t)}{CR} = \frac{i(t)}{C} \quad .$$

A simplified model of the storage ring BPM is assumed. The cross section of the beam chamber is approximated by a cylinder of diameter 40 mm. The diameter of the button is 10 mm. The beam is at the center of the chamber. The capacitance of the button and the characteristic impedance of the feedthrough are 3.0 pF and 50 Ω, respectively.

The signal for an electron bunch in the first turn of the storage ring is shown in Fig. 2. The upper panel shows the equivalent current source and the lower panel the output voltage signal. The bunch length is 63 ps (r.m.s.) which is equal to the natural bunch length in the synchrotron. The beam current is 5.5 μA/bunch or 1.6×10^{8} electrons per bunch. Without beam loss in injection it corresponds to 10 mA in 500 consecutive bunches in the booster synchrotron.

The signal for an electron bunch stored in the storage ring is shown in Fig. 3. The upper panel shows the equivalent current source and the lower panel the output voltage signal. The natural bunch length in the storage ring is 10 ps (r.m.s.). The beam current is 5 mA/bunch or 1.5×10^{11} electrons per bunch.

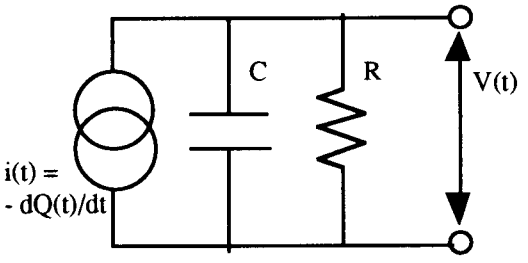

Fig. 1. The equivalent circuit of a button pickup.

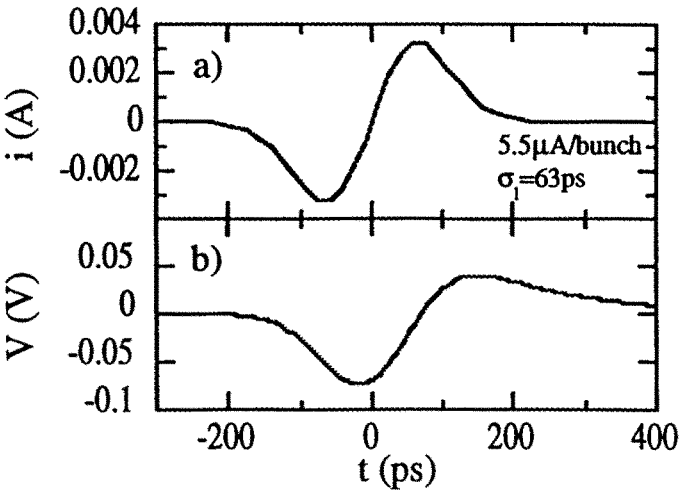

Fig. 2. The signal for an electron bunch in the first turn of the storage ring. (a) The equivalent current source. (b) The output voltage signal.

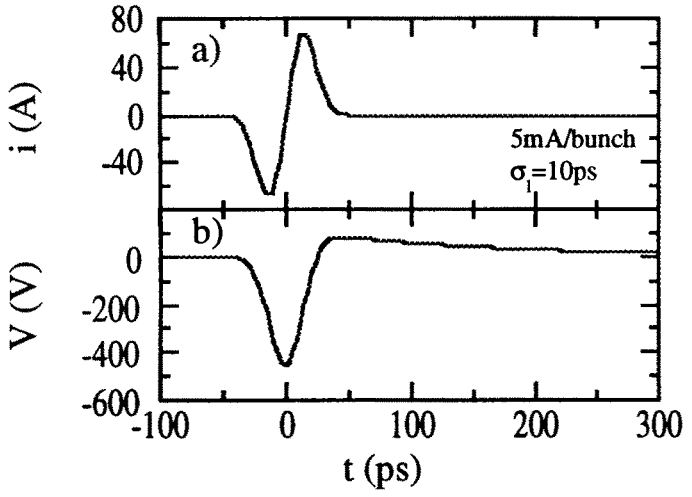

Fig. 3. The signal for an electron beam stored in the storage ring. (a) The equivalent current source. (b) The output voltage signal.