OBSERVATION OF SCHOTTKY SIGNAL AT TARN AND ON-LINE Q MEASUREMENT

A. Noda, M. Takanaka, M. Yoshizawa and S. Kadota

Institute for Nuclear Study, University of Tokyo

Abstract

Schottky signal of the injected beam is observed at TARN. For beam intensity of 10^8, the observed signal level is about 0.6 μV for the 72-nd and 73-rd harmonics of the revolution frequency, which is in good agreement with calculation. Transverse side bands are also observed which can be used for on-line Q measurement. The horizontal Q-value obtained by this method is 2.245, while the one measured by an RF knock-out method is 2.241.

1. Introduction

So as to take basic data for the system design of stochastic cooling, Schottky signal is observed at TARN with use of already installed electrostatic pick-up.[1] In order to reduce thermal noise level, previously used FET amplifier with input impedance of 100 kΩ is replaced by a low noise pre-amplifier (noise figure is 2.5 dB) with input impedance of 50 Ω. By connecting a spectrum analyser with mini-computers, analysed spectra can be storaged and Schottky signal can be succesfully observed by averaging.[2] As the pick-up is a position sensitive one, simultanuous observation of longitudinal and transverse modes are also performed using this high sensitivity system, which gives the fractional part of Q-value without beam perturbation.

2. Observation of Schottky Signal

Schottky current (root mean square current), i_{sc}, is given as

$$i_{sc} = 2ef_0\sqrt{\frac{N}{2}}\,, \qquad (1)$$

where N, e and f_0 are number, charge and revolution frequency of the circulating beams, respectively.[3] This is estimated at 3 nA for beam intensity of 10^8, which is smaller more than 3 orders compared with the bunched beam current, i_B, given by the following Eq.

$$i_B = ef_0N. \qquad (2)$$

So it is important to study the noise level. The noise level can be estimated by the relation,

$$i_n = \sqrt{10^{\frac{\nu}{10}}\, kTB/R}, \qquad (3)$$

where ν, k T, B and R are noise figure (dB) of the pre-amplifier, Boltzmann constant (1.38×10^{-16} erg·K^{-1}), temperature given in Kelvin, band width of the observation system and input impedance of the pre-amplifier, respectively. Numerical values for the present case are ν = 2.5dB, T = 300°K, B = 3Hz, R = 50Ω and i_n is estimated at 0.7 nA. In the real observation made by the system illustrated in Fig. 1, the beam current induces voltage signal at the pick-up with certain coupling impedance, C, as follows

$$V = C\cdot i_{sc}. \qquad (4)$$

Then the voltage level at the input of the spectrum analyser is given as

$$V = 10^{\frac{G}{20}}\cdot C\cdot i_{sc}\,, \qquad (5)$$

where G is the gain of the amplifier system. According to the calibration with a pulse generator, C is estimated at 0.6Ω for the corresponding frequency region. Taking this factor into acount, the signal level is estimated to be the order of 0.1 μV, which is much lower compared with the thermal noise level (about 10 μV). So as to observe this low level signal, 2500 times averaging is made. The observation is made 10 seconds after injection, when the beam is already perfectly debunched, and is continued about 200 seconds. Typical example of the obtained spectra are shown in Fig. 2. The signal level is about 0.6 μV for the 72-nd and

73-rd harmonics of the revolution frequency, which agrees well with the estimation.

3. On-line Q Measurement

The pick-up is position sensitive one as illustrated in Fig. 3 and its induced signal contains both longitudinal and transverse modes which can be expressed

$$S_L = kIx_0 = kx_0 I_0 \sum_{n=-\infty}^{\infty} e^{j(2\pi n f_0 t + \phi_1)}$$

$$S_T = kIx_\beta = k\sqrt{\beta\varepsilon}\, I_0 \left[\sum_{n=0}^{\infty} e^{j[2\pi(n+Q)f_0 t + \psi_1]} + \sum_{n=1}^{\infty} e^{j[2\pi(n-Q)f_0 t + \psi_2]}\right], \qquad (6)$$

where x_β and I represent betatron oscillation and beam current, respectively. This signal gives spectral lines as illustrated in Fig. 4 and from the spacing between longitudinal and transverse modes, Δf, the fractional part of Q-value, q, is given as

$$q = \frac{\Delta f}{f_0}\,. \qquad (7)$$

Typical example of simultaneous observation of these modes is shown in Fig. 5. From the data, horizontal Q-value is measured to be 2.245, which is in good agreement with the value 2.241 obtained by an RF knock-out method.[4)]

References

1) N. Tokuda and S. Watanabe, INS-NUMA-21 (1980).
2) M. Takanaka et al., INS-NUMA-33 (1982).
3) F. Sacherer, CERN-ISR-TH/78-11 (1978).
4) A. Noda et al., INS-NUMA-27 (1980).

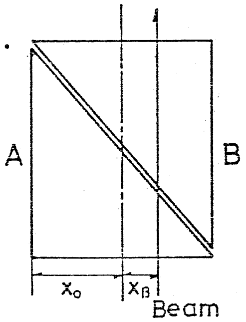

Fig. 3. Illustration of the position sensitive pick-up.

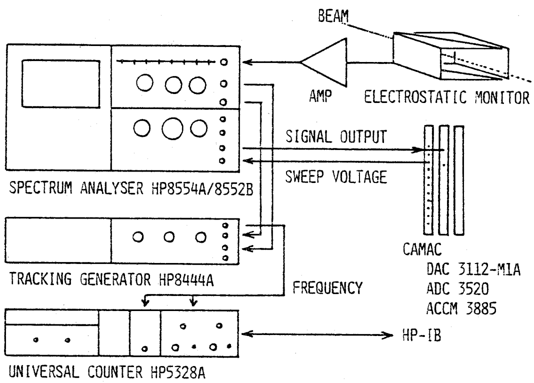

Fig. 1. Illustration of the measurement system.

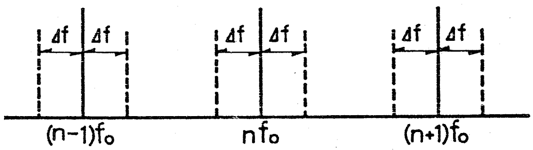

Fig. 4. Spectral lines of longitudinal and transverse modes.

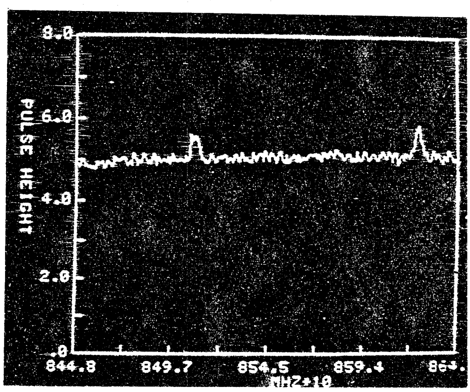

Fig. 2. Observed Schottky signal.

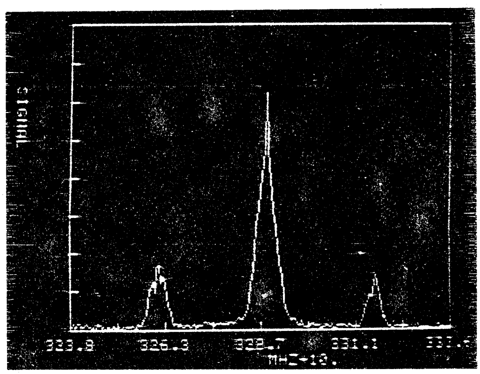

Fig. 5. Simultaneously observed longitudinal and transverse modes.