UPGRADE OF THE BPM READOUT ELECTRONICS FOR THE ATF DAMPING RING

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Abstract

The ATF (Accelerator Test Facility) damping ring has been operated since January in 1997 at KEK, and several beam studies are in progress. For the beam orbit measurement, button-type beam position monitors (BPMs) are prepared in the damping ring. Clipping modules and charge-sensitive ADCs are used in the readout system so as to measure the beam position in a single revolution of beam. The position resolution was about 50 μm at a beam intensity of 0.5×10^{10} electrons. However, higher resolution became increasingly necessary for our beam studies. In this paper, we considered the noise figure of a preamplifier in the clipping module. In addition, we are developing a fast clipping circuit to respond to a high frequency component in a BPM signal.

1 INTRODUCTION

The ATF was constructed to research and to develop necessary technology for future linear colliders [1]. It consists of a 1.54-GeV injector linac, a damping ring, a beam transport line from the linac to the ring, and an extraction line for the beam diagnostics and several beam studies.

To achieve a low emittance is one of critical issues to obtain a high luminosity in future linear colliders, as well as to achieve a high acceleration efficiency and a strong final focus. Future linear colliders require a very low vertical emittance, typically $\gamma\varepsilon_Y$ = 30 nm in term of normalized emittance. A damping ring is the most feasible method for obtaining such a low emittance.

We must correct the dispersion of beam orbit, which is small (η < 2 mm) in the wiggler sections, to achieve an extremely low emittance in the ATF damping ring. We usually measure the dispersion by comparing two closed-orbit distortions between different RF frequencies ($\Delta f \approx 10$ kHz). This dispersion measurement requires a position resolution better than 5 μm.

2 BPM READOUT SYSTEM

There are 96 button-type BPMs in the ATF damping ring. Most of BPMs have a cylindrical shape with an inner diameter of 24 mm, and have four button-type pickup electrodes of 12 mm in diameter. BPM signals induced by a beam are sent to clipping modules through long cables (RG223/U), typically 40 m in length. Each cable length is determined by taking account of time of flight so as to detect BPM signals in the same turn by a common trigger signal synchronized with the beam revolution. Bipolar BPM signals are clipped by 8-ch clipping modules. Then unipolar output signals are integrated and digitized in a 16-ch 14-bit charge-sensitive ADC. A gate signal for each ADC is generated from the common trigger signal. This BPM readout system allows us to measure the beam orbit in any revolution of beam by changing delay time of the common trigger signal [2]. In this chapter, we describe the clipping module and show its performance.

2.1 Clipping Module

The clipping module consists of two stages of amplifier, two filters, and a clipping mini-card as shown in Figure 1. The gain of two amplifiers is variable, but we usually use them at the minimum gain because of enough beam intensity. A low-pass filter of 100 MHz is necessary for stable operation of CLC401, a band-pass filter of 30 MHz is for Schottky diodes (MATSUSHITA MA700A) in a clipping mini-card as shown in Figure 2. Because the Schottky diodes behave like a capacitance at higher frequencies than 30 MHz

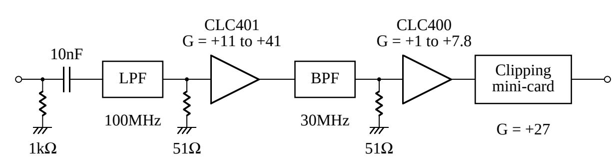

Figure 1. Block diagram of clipping module.

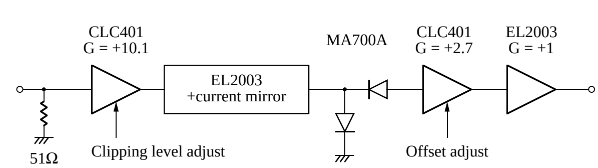

Figure 2. Clipping mini-card in clipping module.

2.2 Performanceof Clipping Module

The linearity of a clipping module was measured by using test signals and stored beams. It has a non-linearity due to a property of Schottky diodes as shown in Figure

3. We assume that a stored beam in the damping ring repeatedly runs in a same orbit. Pulses with a pulse width of 1 ns were generated by a 500-MHz pulse generator HP 8131A, and differentiated by a capacitor of 5 pF to make bipolar test signals. Pulse height of test signal was converted into an equivalent beam intensity by comparing two average ADC counts. We correct such a non-linearity by a calibration database.

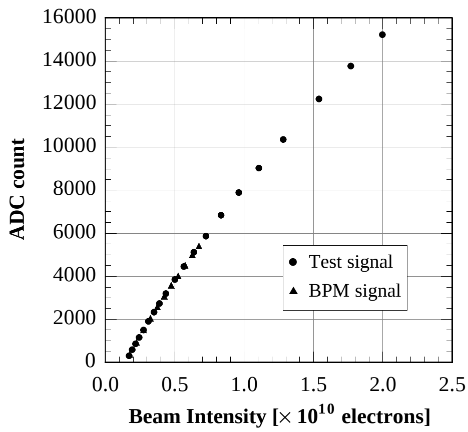

Figure 3. Linearity of clipping module.

Position resolution was estimated by using test signals. A test signal was divided into two by a splitter. Two identical test signals were fed to two inputs of a clipping module. Simulated beam position X is defined as

$$X = S \cdot \frac{\frac{A_1}{M_1} - \frac{A_2}{M_2}}{\frac{A_1}{M_1} + \frac{A_2}{M_2}},$$

where A_1 and A_2 are ADC counts, M_1 and M_2 are the mean ADC counts, and S is the position sensitivity (6388 μm). The simulated position resolution is defined as an RMS of X. The difference in gain between two channels is canceled out by using ADC counts normalized by the mean values.

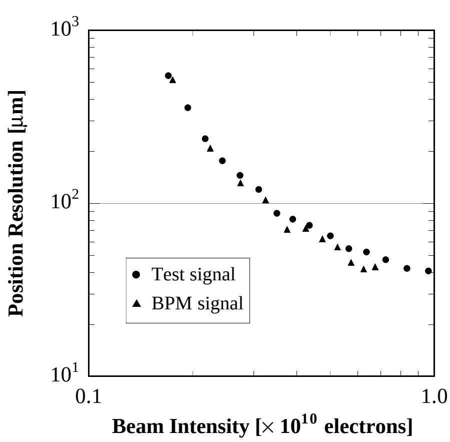

Figure 4. Position resolution of clipping module.

We also measured the beam position resolution with stored beams. To cancel out the difference in gain, polynomial P was fitted to ADC data of two channels in a range of the beam intensity. ADC counts of channel 1 are converted into ADC counts equivalent to those of channel 2 with this polynomial. Beam position X is defined as

$$X = S \cdot \frac{P(A_1) - A_2}{P(A_1) + A_2}.$$

The position resolution is defined as an RMS of X. The result is shown in Figure 4. The position resolution is about 50 μm at a beam intensity of 0.5×10^{10} electrons.

3 MODIFICATION OF CLIPPING MODULE

We reduced input noise of the preamplifier of the clipping module to improve the beam position resolution. The first-stage OP amplifier CLC401 was changed to a low-noise OP amplifier CLC425, and gain-setting and feedback resistors were decreased as shown in Figure 5. A transformer was also applied in front of the first stage. Parameters are compared between before and after this modification in Table 1 [3].

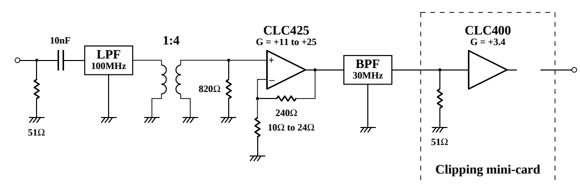

Figure 5. Modified clipping module.

Table 1. Intrinsic input voltage noise density e_n, intrinsic input current noise densities i_{n+} and i_{n-}, gain-setting and feedback resistors R_G and R_F, transformer, total equivalent input voltage noise density e_{ni}, noise figure, and predicted resolution σ are compared between before and after modification of the preamplifier.

	before	after
OP amplifier	CLC401	CLC425
e_n [nV/√Hz]	2.4	1.05
i_{n+} [pA/√Hz]	2.6	1.6
i_{n-} [pA/√Hz]	17	1.6
R_G [Ω]	200	12
R_F [Ω]	2000	240
Transformer	n/a	1:4
e_{ni} [nV/√Hz]	4.35	0.73
NF [dB]	20	6
σ [μm]	17	3

The position resolution was investigated by using test signals and stored beams. We obtained about 20 μm at a beam intensity of 0.5×10^{10} electrons.

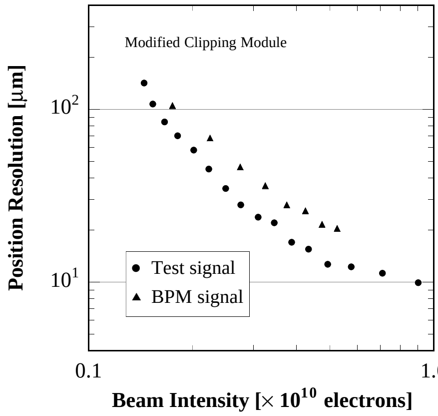

Figure 6. Position resolution of modified clipping module.

4 DEVELOPMENT OF FET CLIPPING CIRCUIT

The clipping module needs a band-pass filter of 30 MHz. But a frequency component of 30 MHz in a BPM signal is very minor. If a clipping circuit can operate at a higher frequency, the position resolution will be improved. We tried to make use of an MOS FET under the class B operation to clip bipolar signals. Figure 7 shows the transfer characteristic of an MOS FET (HITACHI 2SK439) together with a theoretical curve which is fitted to the data in a range of the gate voltage less than 0 V.

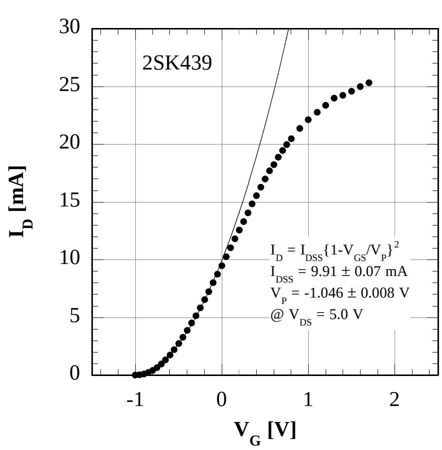

Figure 7. Transfer characteristic of an MOS FET.

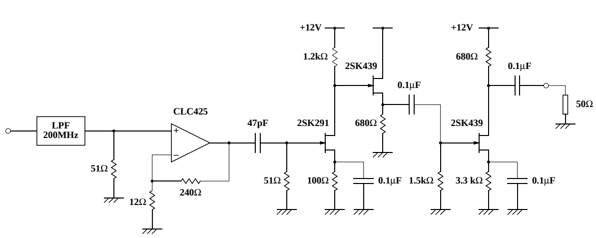

Figure 8. Prototype FET clipper.

The prototype FET clipper is shown in Figure 8. It consists of a low-pass filter of 200 MHz, a low-noise preamplifier (CLC425) following by an FET amplifier, and an FET clipping circuit. A decoupling capacitor of 47 pF behaves as a high-pass filter to reducethe band width.

We prepared two channels of FET clipper, and measured the position resolution. The resolution was about 10 µm at a beam intensity of 0.5×10^{10} electrons as shown in Figure 9. But this plot has a distortion around a beam intensity of 0.5×10^{10} electrons. It seems to come from the band width of CLC425. We used a low-pass filter of 200 MHz, but the band width of CLC425 in this configuration was about 100 MHz according to the data sheet.

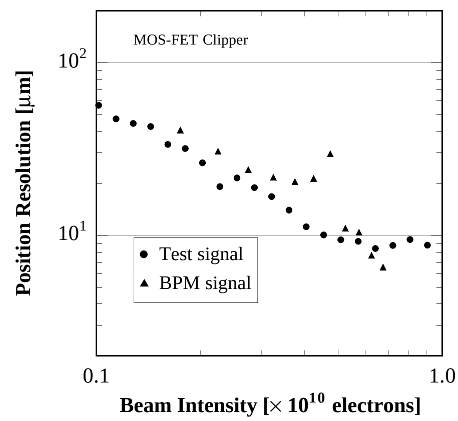

Figure 9. Position resolution of prototype FET clipper.

5 SUMMARY

The position resolution of the clipping module is improved to 20 µm at a beam intensity of 0.5×10^{10} electrons by changing the preamplifier to a low-noise one. In addition, we tried to use an MOS FET instead of Schottky diodes to clip bipolar signals. If the band width of preamplifier is improved, the resolution seems to be better than 10 µm.

ACKNOWLEDGMENT

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REFERENCES

[1] F. Hinode et al., “ATF Design and Study Report”, KEK Internal 95-4 (1995).
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[3] S. Smith (SLAC), private communication (1998).