DEVELOPMENT OF ELECTRONICS FOR THE ATF2 INTERACTION POINT REGION BEAM POSITION MONITOR

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Abstract

Nanometer resolution beam position monitors have been developed to measure and control beam position stability at the interaction point region of ATF2. The position of the beam has to be measured to within a few nanometers at the interaction point. In order to achieve this performance, electronics for the low-Q IP-BPM was developed. Every component of the electronics have been simulated and checked on the bench and using the ATF2 beam.

We will explain each component and define their working range. Then, we will show the performance of the electronics measured with beam signal.

INTRODUCTION

ATF2 is a final focus test beam line for ILC in the framework of the ATF international collaboration. The new beam line was constructed to extend the extraction line at ATF, KEK, Japan. The first goal of ATF2 is the acheiving of a 37 nm vertical beam size at focal point (IP). The second goal is to stabilize the beam at the focal point at a few nanometer level [1] for a long period in order to ensure the high luminosity. To achieve these goals a high resolution IP-BPM is essential. In addition for feedback applications a low-Q system is desirable.

CONCEPT OF LOW-Q IP-BPM

We have developed a low-Q cavity bpm in order to achieve shorter timing resolution with a high position resolution. The developed low-Q IP-BPM consists of a one-cell sensor cavity and a one-cell reference cavity. The design for low-Q IP-BPM has been described elsewhere [2]. Table 1 shows the design parameters for low-Q IP-BPM.

Table 1: Design parameters for low-Q IP-BPM

	X	Y	Reference
f (GHz)	5.712	6.426	6.426
β	8	9	0.0117
Q_0	5900	6020	1170
Q_{ext}	730	670	100250
τ (ns)	20.35	16.60	2484.19

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MEASUREMENT OF LOW-Q IP-BPM ELECTRONICS

The design and detailed description for the low-Q IP-BPM electronics has been described [2]. The electronics used to process the raw signals from the cavity BPM were developed. Figure 1 shows the developed low-Q IP-BPM electronics diagram and Fig.2 shows the raw waveform from the low-Q IP-BPM electronics.

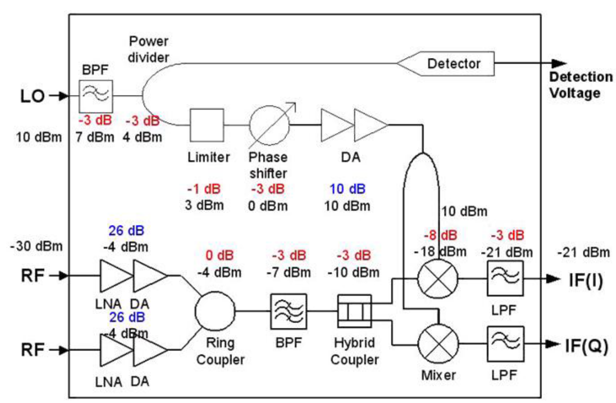

Figure 1: Developed low-Q IP-BPM electronics block diagram

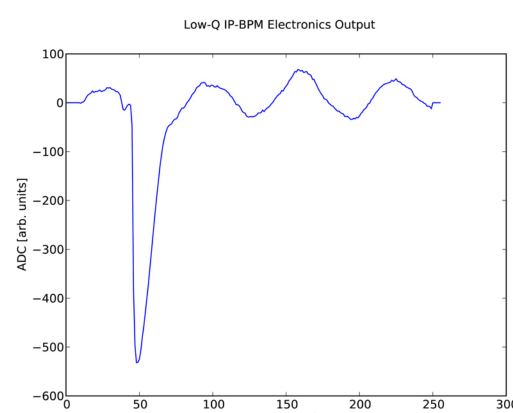

Figure 2: The raw waveform from the low-Q IP-BPM electronics.

Latency

We measured the latency of the low-Q IP-BPM electronics. The low-Q IP-BPM will use for FONT (Feedback On Nanosecond Timescales) [3] so fast response time is required. Latency here is the time delay between input RF and the output IF signal from the low-Q electronics.

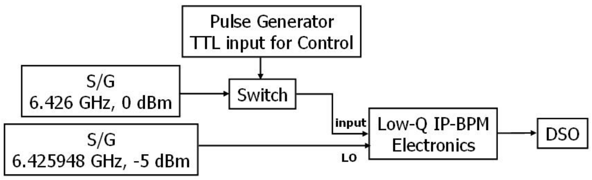

Figure 3: Block diagram of latency measurement

Figure 3 shows a block diagram of the electronics latency measurement, and Fig. 4 shows waveforms on a digital oscilloscope. The yellow trace is the switch control TTL signal. The RF is switched off at a certain time, indicated by the start of the yellow trace. When the TTL input is high, the switch becomes isolating. The blue trace is the output of the low-Q IP-BPM electronics. With the oscilloscopes' markers at the start of the RF off point and the beginning of the electronics' response, the time delay is measured as 30 ns. However, this includes the 10 ns for the switch to respond and a measured cable delay of 3 ns. Using these corrections, the latency of the low-Q IP-BPM electronics is 17 ns, consistent with the bandwidth of the electronics.

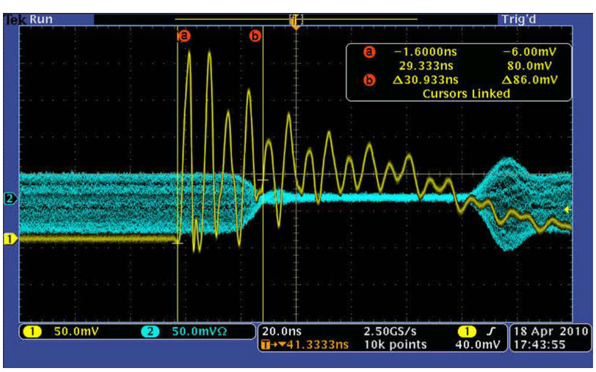

Figure 4: Low-Q IP-BPM electronics latency

Linearity

We compared the low-Q IP-BPM electronics and the C-band heterodyne electronics [4, 5] linearity. Figure 5 shows the block diagram of the linearity measurement. Two signal generators were used for this measurement: one for local oscillator (LO) and one for signal input. The output was measured by a spectrum analyzer. Figure 6 shows the low-Q IP-BPM and C-band heterodyne results.

The conversion gain of the C-band heterodyne electronics and low-Q IP-BPM electronics is 30 dB and 10 dB, respectively. The low-Q IP-BPM electronics sensitivity is around -80 dBm whis is consistent with the estimated result. We get the expected resolution of the low-Q IP-BPM with low-Q IP-BPM electronics. As the expected resolution for IP-BPM electronics is 10 nm. The desired resolution is 2 nm [1], so more development is required.

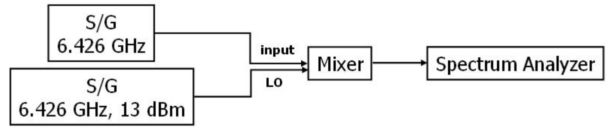

Figure 5: Block diagram of linearity measurement

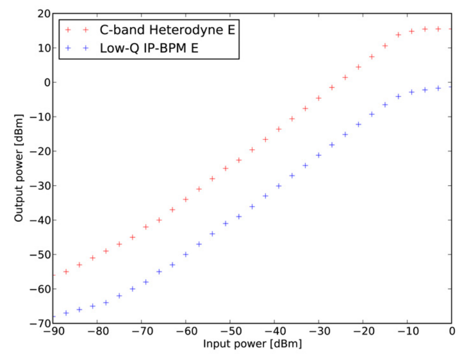

Figure 6: Results of low-Q IP-BPM and C-band heterodyne linearity measurement

LOW-Q IP-BPM BEAM TEST

The low-Q IP-BPM was installed in the extraction beam line (Fig.7).

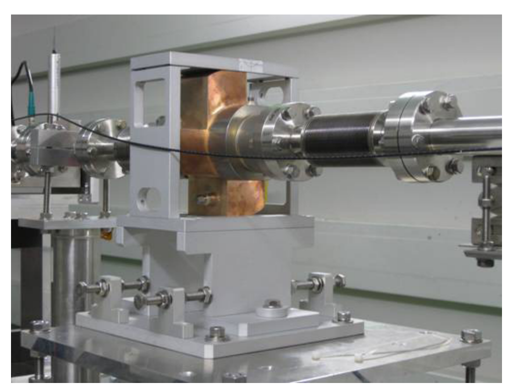

Figure 7: The low-Q IP-BPM installation at ATF2

As we only want to measure the low-Q IP-BPM intrinsic resolution, we used the C-band heterodyne electronics as it has higher sensitivity, and higher gain. Even though the low-Q IP-BPM and C-band BPM decay times are different, the y signal frequency is the same. This allowed us to use the higher sensitivity, and higher gain C-band heterodyne electronics for this test to measure the low-Q IP-BPM intrinsic resolution.

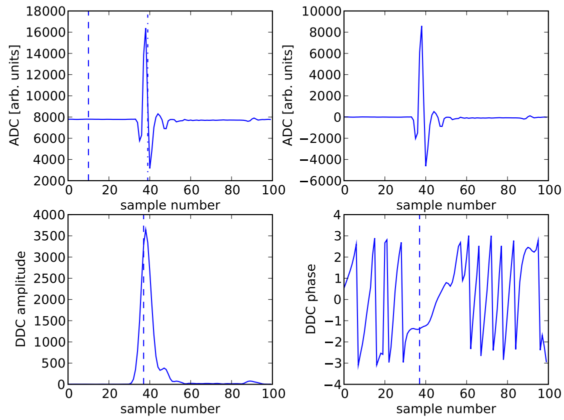

Figure 8: Low-Q IP-BPM raw signal processing steps. The first plot shows the raw signal. The second plot shows the signal without background detection. The third and fourth plot show the DDC amplitude and phase.

The digital down-conversion algorithm [5, 6] was used for the low-Q IP-BPM raw signal processing. The raw waveform from the low-Q IP-BPM was digitized and then multiplied by a complex local oscillator of the same frequency. The signal was filtered using a Gaussian time domail filter with a 10 MHz bandwidth. Figure 8 shows low-Q IP-BPM signal processing steps.

We changed the beam orbit vertically and horizontally using two upstream steering magnets and the output of x and y were detected by diode and C-band heterodyne electronics, respectively.

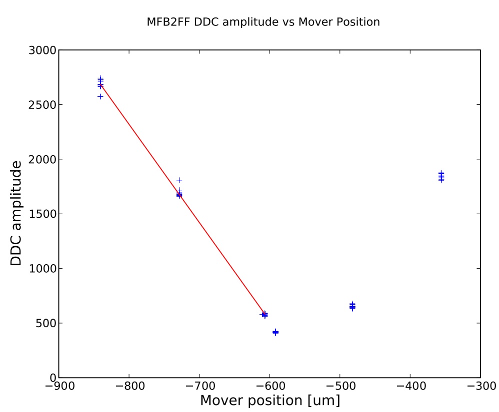

Figure 9: DDC amplitude as function of mover position

Using three cavity BPMs, position resolution of the low-Q IP-BPM can be determined. In this study, we were used two C-band BPMs with no attenuators for high resolution study and these C-band BPMs' resolution below $50\ \mathrm{nm}$. DDC amplitude get from the signal processing and calculated predicted y position of low-Q IP-BPM. The predicted

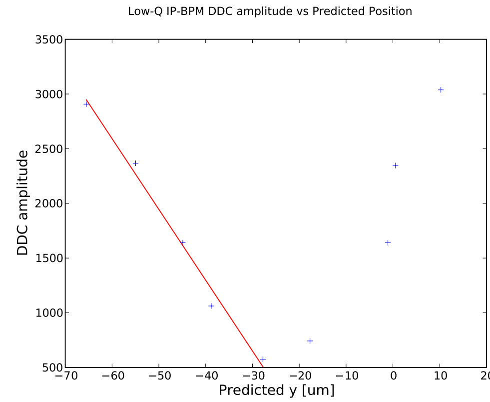

Figure 10: DDC amplitude as function of predicted y position

position of the low-Q IP-BPM was interpolated between two C-band BPMs.

Figure 9 shows the position sensitivity of MFB2FF. Figure 10 shows the position sensitivity of low-Q IP-BPM and the gradient around $64.7\mathrm{DDC}/\mu\mathrm{m}$. It is over 6 times larger between the two than MFB2FF.

CONCLUSION

ATF2 is a final focus test beam line for ILC in the framework of the ATF international collaboration. To achieve 37 nanometer vertical beam size and stability at the focal point (IP), the low-Q IP-BPM and its electronics were developed. The low-Q IP-BPM will use for FONT application so fast response time is required. We measured the latency of the low-Q IP-BPM electronics and the latency is $17\ \mathrm{ns}$. The low-Q IP-BPM electronics sensitivity is around - 80 dBm and the expected resolution for IP-BPM electronics is $10\ \mathrm{nm}$. The desired resolution is $2\ \mathrm{nm}$ [1], more development is required.

The low-Q IP-BPM was installed in the extraction beam line at ATF2. We changed the beam orbit vertically and horizontally using two upstream steering magnets. The electronics' raw output signal was processed using digital down-conversion algorithm. DDC amplitude get from the signal processing and calculated predicted y position of low-Q IP-BPM. The position sensivity is around $64.7\ \mathrm{DDC}/\mu\mathrm{m}$ and this is over 6 times larger than MFB2FF.

REFERENCES

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