FIRST BEAM TEST OF THE TILT MONITOR IN THE ATF2 BEAM LINE

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Abstract

We have studied the beam orbit tilt monitor for stabilizing the beam orbit in ATF2 as well as future international linear collider. Once we can measure a beam orbit tilt with high precision at one point, we can relate this data with the beam position profile at the focal point. Tilt monitor is a new type of the cavity beam monitor, like cav BPM. According to our simulation, the expected limitation is about 35 nrad. The prototype was completed and installed in the test area on the ATF2 beamline. The first beam test have been done in December 2009.

INTRODUCTION

We have developed the "tilt monitor" to improve the beam stabilization at IP in ATF2 [1] as well as ILC [2]. Generally the orbit tilt is calculated from two position data. We are using the cavity BPMs for detecting the beam position. The angle resolution is dependent on the position resolution and the distance between the two BPMs. For example, when the position resolution at each BPM is 10 nm and distance between the two cavities is 10 cm, angle resolution becomes about 140 nrad. Of course, if the larger the distance is, the better the angle resolution becomes. The tilt monitor is independent of these relative position. This monitor can simply detect the precise beam tilt solely. This independency will become the useful tool around IP, because the large angle jittering restrict the relative position of the BPMs[3].

BASIC PRINCIPLE

Tilt monitor is a new type of the cavity beam monitor. We can use the most basic resonant mode TM110, called 'monopole mode' excited in a sensor cavity for the measurement of the beam orbit tilt.

Monopole Mode Excitation

In the cavity, electro magnetic fields excited by the beam are expanded as the resonant modes according to boundary condition. Among the resonant modes, monopole mode(TM110) is depend on the beam orbit tilt. Fig. 1 shows the electromagnetic field distribution of the monopole mode.

Electric filed of the monopole mode is most strong at the center of the cavity and is perpendicular to the nominal beam axis. In case, beam has the tilt angle along to electric field, the monopole mode energy is excited by beam. The excited energy is proportional to the square of the tilt angle.

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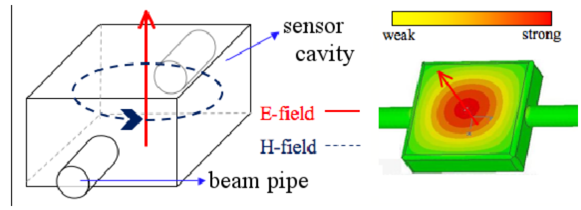

Figure 1: Monopole mode.

Extraction of the Monopole Mode

We extract the magnetic field of the monopole mode from sensor cavity to waveguide through the slit. Figure 2 shows the way to extract the signal. The slit is along to the magnetic field of the monopole mode due to suppressing the another mode mixing. the extracted magnetic field is transmitted in the TE mode. The TE mode signal is extracted from the feed-through to coaxial cable with 50 impedance. The amplitude of the extracted signal is proportional to tilt angle. We can use this relation for measuring beam orbit angle.

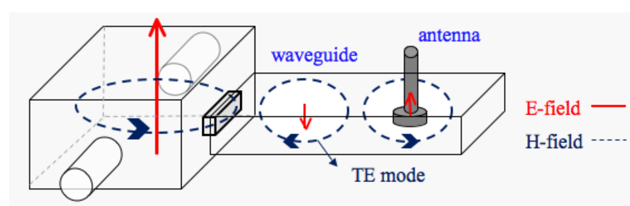

Figure 2: Signal extraction.

PROTOTYPE DESIGN

Tilt monitor is conposed of a sensor cavity and a waveguide to extract the signal. We designed the prototype by using electro-magnetic calculation software, the CST-studio (CST Inc.). Figure 3 shows determined prototype design.

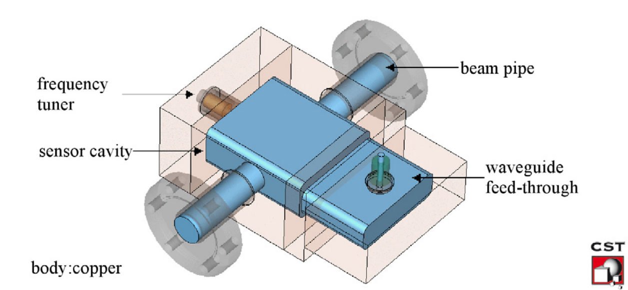

Figure 3: Prototype.

Expected Performance

We evaluated the expected performance. Cavity beam monitor is limited by the thermal noise. Given that it is room temperature and bandwidth is 300 MHz, We compared the output power of the tilt monitor and thermal noise in Fig. 4.

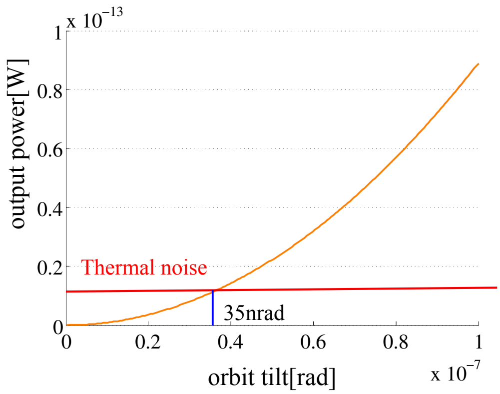

Figure 4: Output power from the tilt monitor.

CAVITY PARAMETER MEASUREMENT

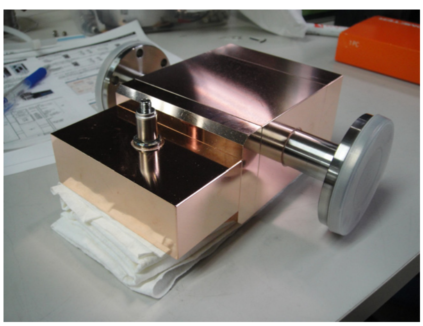

Figure 5: Prototype of the tilt monitor.

Figure 5 shows the completed prototype. We measured the cavity parameters of the completed prototype by using Networkanalyzer. Networkanalyzer can measure the S parameters. We connected the port1 to feed-through and measured the reflection amplitude (S11). S11 shows the resonant curve of the sensor cavity. We can calculate the basic cavity parameters from resonant curve. Table 3 shows designed values and measured values. We confirmed that the prototype would meet the requirement for pratical use.

Table 1: Margin Specifications

parameter	designed value	measured value
Freqency(TM110)	2.856GHz	2.855GHz
loaded Q	2650	2740
$\beta(Q_{ext}/Q_0)$	3.5	3.4
decay time	150nsec	156nsec

BEAM TEST

After confirmation of the cavity parameters. We installed the tilt monitor in the ATF2 beam line. The tilt monitor is set on the base that has the rotating mechanism. We can make the mechanical tilt against the beam artificially from -15 mrad to +15 mrad. The minimum step is 10 μrad.

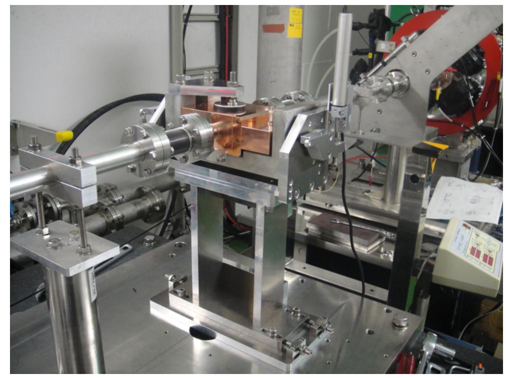

Figure 6: Installation.

Confirmation of the Principle

We confirmed the basic principle by using the rotating mechanism. We measured the signal amplitude against the mechanical tilt. As we can see in the Fig. 7, the signal amplitude is proportional to the tilt angle. In view of the fact that we amplify the minute RF signal, the signal magnitude satisfy the simulation result.

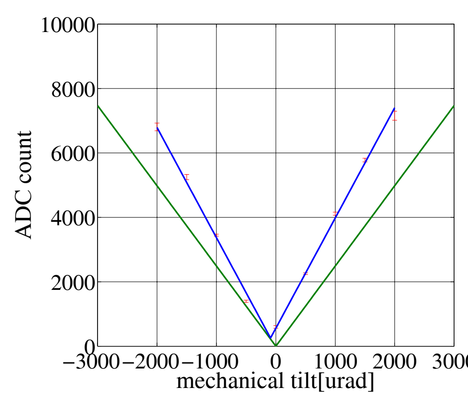

Figure 7: Confirmation of the principle: The blue line shows the beam test result. The green line shows the simulation result.

Influence of the Beam Position

We fixed the mechanical tilt and checked the position dependence. We translate the beam by using the two steering magnet. Figures 8 and 9 show the signal amplitude against the vertical (horizontal) position.

We confirmed that the signal is proportional to the vertical position. Horizontal position has no influence. This

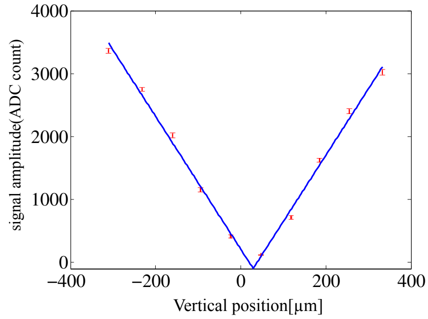

Figure 8: Dependence of the vertical position.

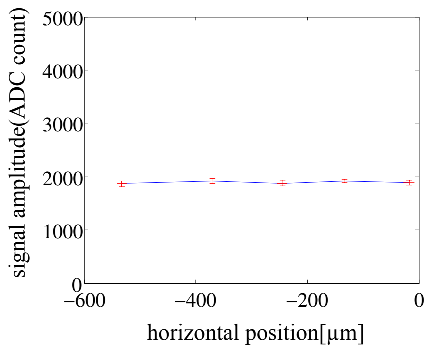

Figure 9: Dependence of the horizontal position.

vertical position dependence will come from the declination of the monopole mode distribution. Around the connection with the beam pipe, the boundary condition of the sensor cavity is slightly breaking. Therefor the electric field of the monopole mode look towards to the beam axis around beam pipe. This breaking electric field grow from the center to the beam pipe circumference. As the result, the monopole mode has the position dependence.

Accuracy Estimation

We fixed the machanical tilt and measured the beam orbit jittering for the Accuracy estimation. We reconstructed the beam orbit from the position data measured by forward and backward cavity BPM. Figure 10 shows the signal amplitude of the tilt monitor against the reconstructed orbit tilt. We can see the good correlation in the micro radian region. Figure 11 shows the residual. The measurement error was estimated as $\sigma = 0.36$ μrad.

Consideration

In this beam test, our primary goal was confirmation of the basic principle. Therefor we used the low gain amplifier for large mechanical tilt. Considering the signal magnitude in Fig. 7, we can improve the accuracy until about 35 nrad that is thermal noise limitation, by using higher gain amplifier.

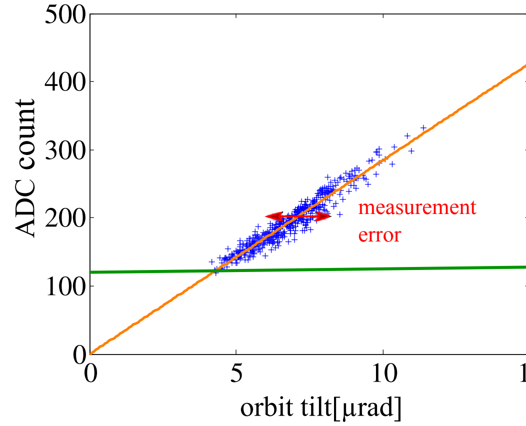

Figure 10: Tilt monitor against the orbit tilt reconstructed by the BPM.

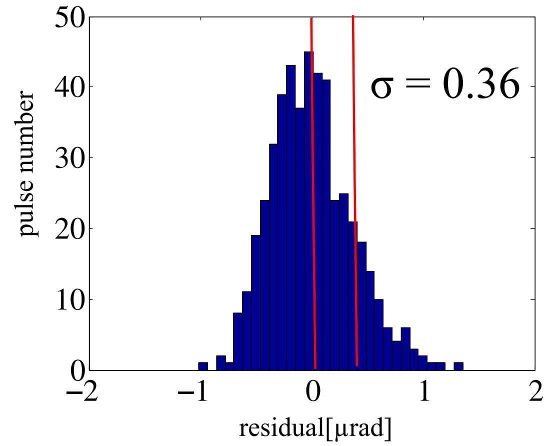

Figure 11: Resolution estimation.

SUMMARY

We have studied about beam orbit tilt monitor. This monitor will measure the beam orbit tilt very precisely solely. The prototype model was completed and installed in the ATF2 beam line for the beam test. We confirmed the basic principle well. We found the vertical position dependence of the tilt monitor. This position dependence comes from the deformation of the sensor cavity by the beam pipe. We are studying cancellation of this position dependence by improving the sensor cavity. The measurement accuracy was estimated to be 0.36 μrad. This accuracy will be improved by the higher gain electronics. We are preparing some new detecting electronics for resolution measurement.

REFERENCES

[1] B.I. Grishanov *et al.*, ATF2 Collaboration, ATF2 proposal (2005).

[2] ILC Global Design Effort and World Wide Study, International Linear Collider Reference Design Report (2007).

[3] T. Nakamura, Master Thesis at The University of Tokyo (2008).