Floor Tilt and Vibration Measurements for the ATF2

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The construction of the ATF2 project will begin in 2007 by extending the existing ATF damping ring. The ATF damping ring was built on a reinforced floor with pile foundation while the floor outside of the damping ring does not have any specially reinforced structure. The tilt and vibration of the floor were measured in the ATF area and outside where the ATF2 beam line is scheduled to be built. The results suggest that the floor of the new ATF2 beam area should also be reinforced as the vibration and diurnal tilt motion of the floor were found to be larger than those in the ATF damping ring area. The results of the measurements are reported in this paper.

1. INTRODUCTION

The Accelerator Test Facility (ATF) at KEK was built for R&D work for a future electron-positron linear collider [1]. The main goals of the ATF project are to produce, measure and control a very low emittance beam. The ATF is composed of an electron gun, a 1.5 GeV electron linac, a 1.5 GeV damping ring of 138 m circumference and an extraction line for beam diagnostics. Construction of the ATF started in 1993 by adding the damping ring to the pre-existing injection linac in the assembly building. Reinforcement of the assembly building floor was needed as it was not strong enough to support the concrete shield blocks required for shielding the radiation from the damping ring. A special foundation with more than 200 piles, 1 m in diameter and 14 m in length, was used. The piles support thick concrete slabs, concrete shields, accelerator components and structure. A length of 14 m was chosen because the test-boring core samples indicated the existence of a hard soil layer at 11.5 m below the ground level. Many expansion joints were introduced to prevent the floor from cracking due to thermal expansion and contraction. The expansion joints also play an important role in damping the floor motion and vibration.

The ATF2 project will extend the existing ATF extraction line with an ILC-type final focus system [2]. Although the ATF2 beam energy is two orders of magnitude smaller than the ILC beam energy, many features of the ATF2 are common to the ILC final focus system. The ATF2 optics design is identical to that for the ILC, and the natural chromaticity and the relative beam energy spread are similar. The beam will be focused down to about 40 nm in the vertical direction at the IP, which is only a factor of 5 larger than at the ILC. Most of the tolerances, such as the tolerances on magnetic field, jitter vibration and power supply stability, are common between the ATF2 and the ILC. The tolerance on the magnet position jitter is somewhat looser than that for the ILC, though the beam center has to be controlled to within a few nanometers at the IP. With all the similarities between the ATF2 and the ILC listed above, ATF2 will be a very good model for the ILC final focus system and a successful commissioning of the ATF2 project will assist in the design of the ILC.

1.1. ATF2 beam line

The new ATF2 beam line will be built in a building which was originally used as an assembly hall. The assembly building is shown in Fig.1. The ATF damping ring is located at the ground level. The ATF2 new beam line will be installed outside of the present ATF damping ring as is indicated in Fig.2. The floor of the ATF2 area does not have any specially reinforced structure like the floor of the ATF damping ring area, as stated in the previous section. In order to see if floor reinforcement is really needed for the new ATF2 beam line, floor tilt and vibration in the ATF2 area were measured and compared with those of the ATF.

Figure 1: Outside look of the “assembly” building where the ATF resides.

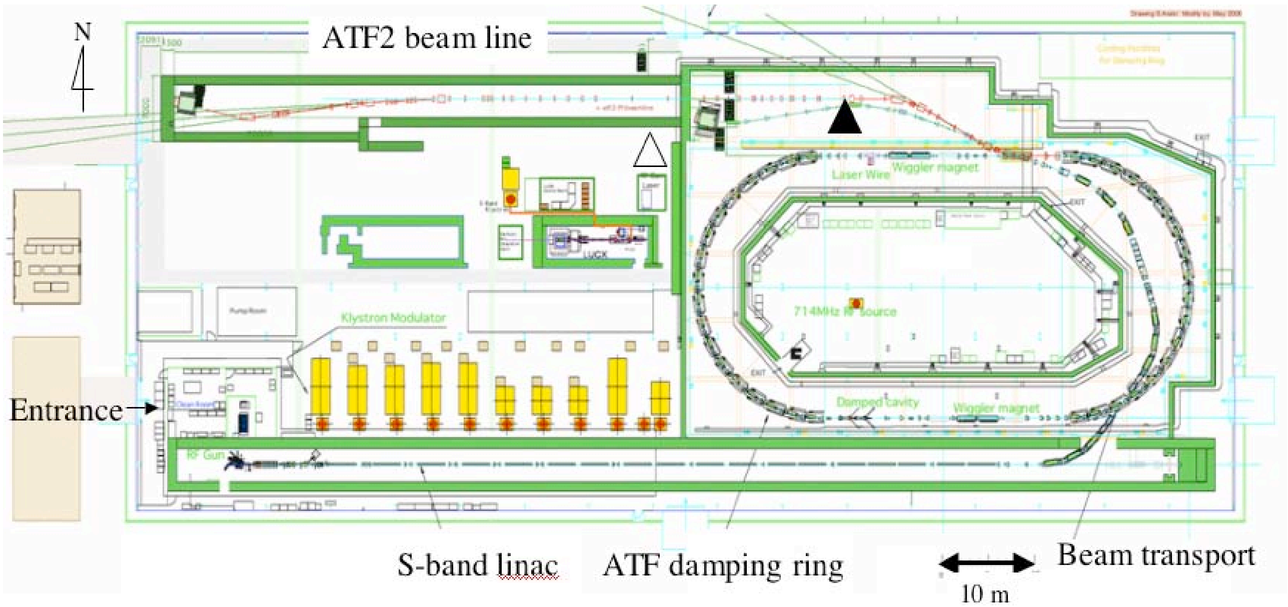

Figure 2: The ATF2 layout

2. FLOOR TILT COMPARISON BETWEEN ATF AND ATF2

The floor tilt was measured using 2-axis Leica Nivel 20 digital tilt meters. The ATF floor data were taken for a 7 day period, starting from Oct.25th 2004 to Nov.1st, 2004 in the area indicated by a solid triangle in Fig.2. The ATF2 data were taken for about 5 days starting from Nov.5th to Nov.10th, 2004 in the area indicated by an open triangle in the same figure. The sensors were placed so that the x-direction corresponds to North-South, which is perpendicular to the new ATF2 beam line, and the y-direction to East-West, which is parallel to the beam line. The measurement results from one sensor are plotted in Fig. 3 for both x- and y- directions along with the outside air temperature for the ATF area. An earthquake occurred on Oct. 27th while the tilt measurement was taking place. It appears as sharp lines in the plot even though the tilt data sampling rate was once every five minutes. It is seen that the floor tilt recovered smoothly after the earthquake. The earthquake turned out to be one of the large aftershocks of the 2004 Mid-Niigata earthquake. The aftershock was reported as being magnitude 6.1, and an intensity level 6^{-} on the 7-grade Japanese intensity scale at its origin in Niigata prefecture, while the intensity level at the KEK area was 2.

The temperature variation inside the building was less than two degrees during this period. There is a clear day and night effect in the outside temperature, as large as 15 degrees, while there is no clear such effect in the floor tilt in the ATF area.

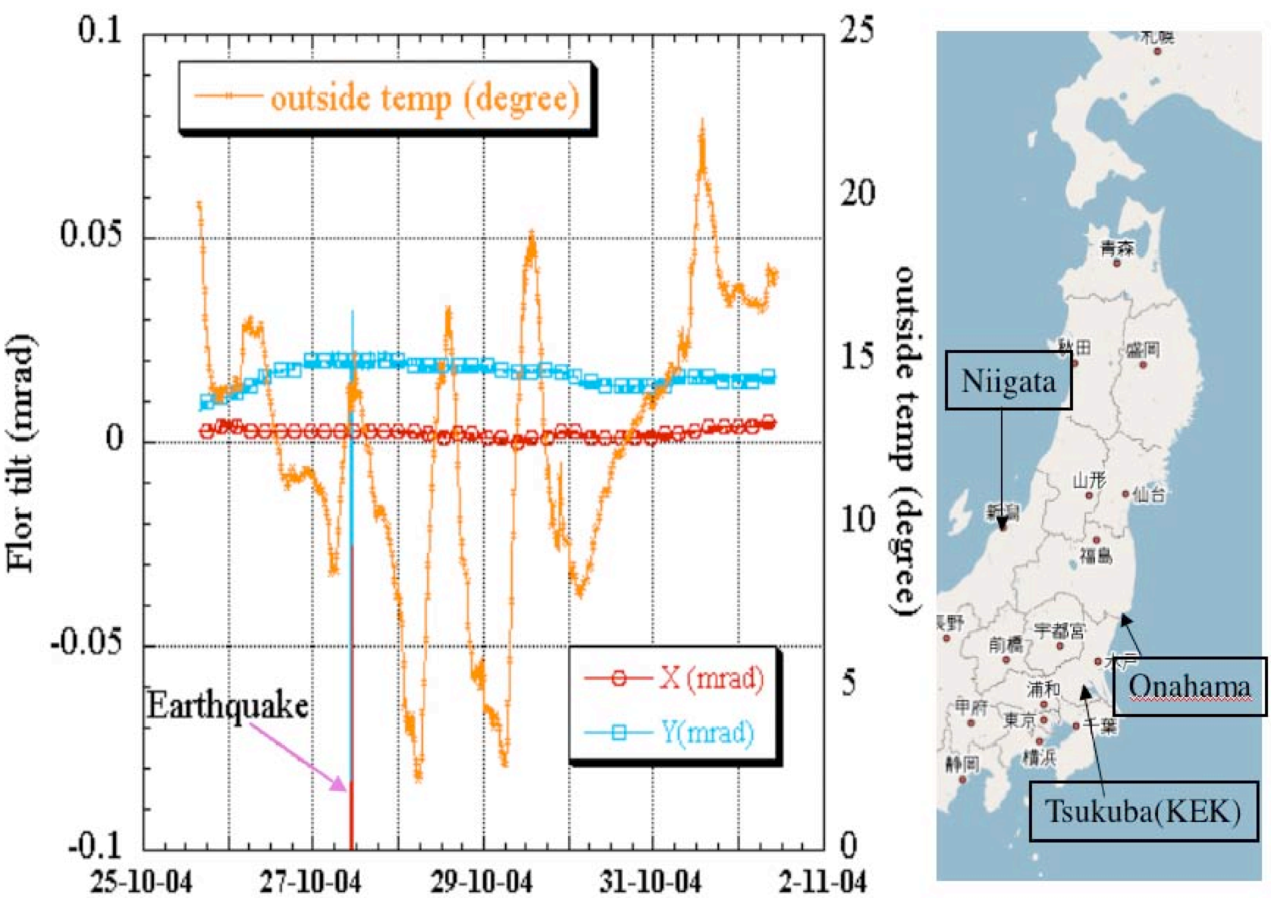

Figure 3: Floor tilt for a 7 day period measured in the ATF area. An earthquake aftershock of magnitude 6.1 occurred at Niigata on Oct. 27th , which can be seen as sharp spikes in both x- and y- directions.

Next, the floor tilt in the ATF2 area was measured from Nov.5th to Nov. 9th. Fig.4 shows the floor tilt in the ATF2 area for the x- and y- directions. A clear day and night effect, about 10 μrad peak-to-peak, is seen in both x- and y- directions. There seems to be a drift in the x-direction, which shows a weak correlation with the atmospheric pressure as is shown in Fig. 5. In comparison, the floor tilt measured in the KEK B-factory experimental hall, which lies 12 meters below ground level and is built on a pile foundation, was less than 5 μrad peak-to-peak when the outside air temperature variation was 15 degrees [3]. Hence, stabilization of the floor motion is hoped for by reinforcing the ATF2 floor. We recommended that the floor in the ATF2 area should be reinforced in the same way as the ATF floor.

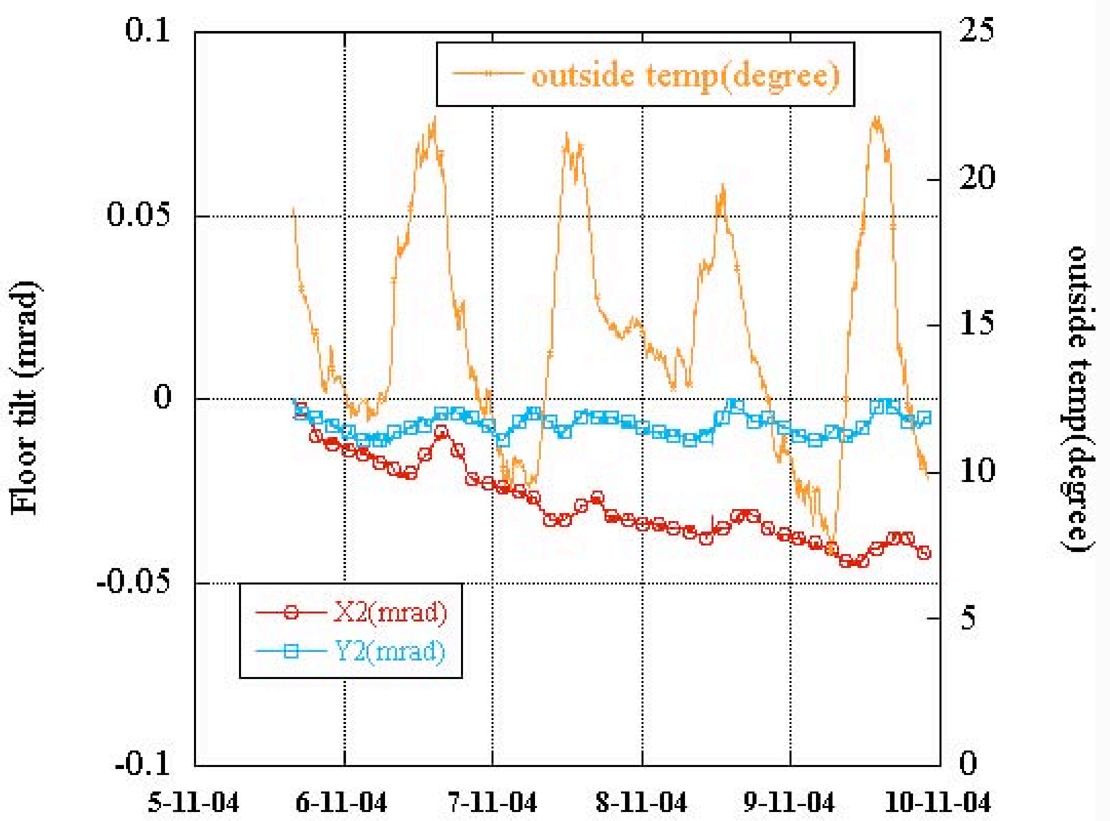

Figure 4: Floor tilt for a 5 day period in the ATF2 area. A day and night effect is seen in both x- and y- directions.

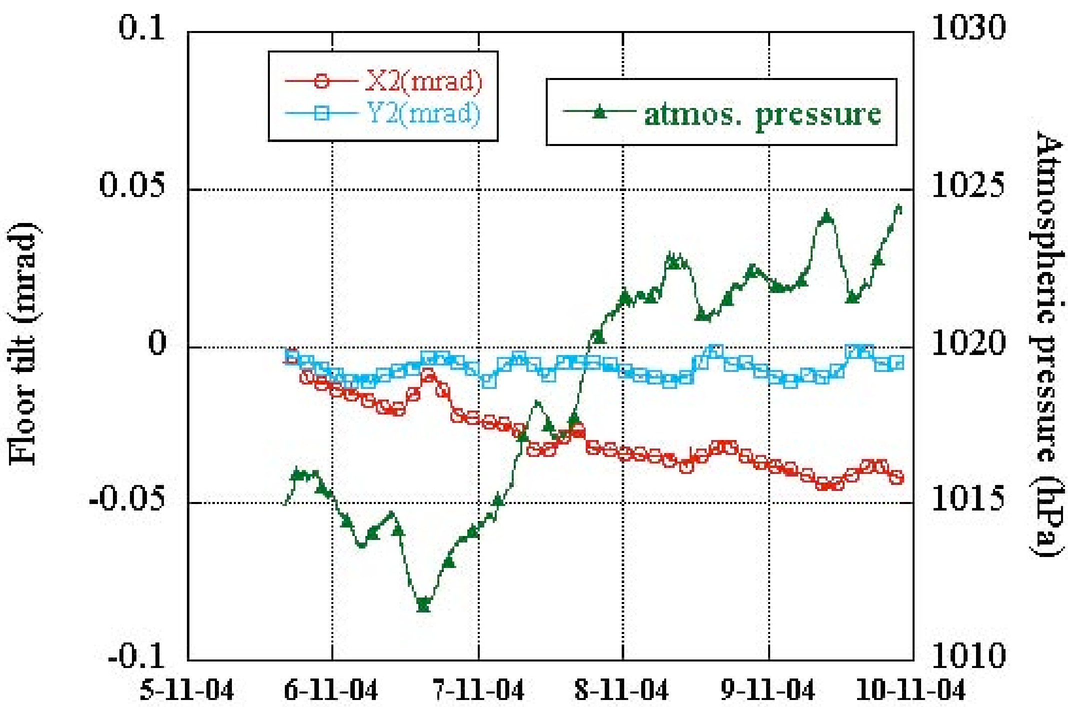

Figure 5: Floor tilt for a 5 day period in the ATF2 area plotted along with atmospheric pressure.

3. FLOOR VIBRATION

Floor vibration was measured on different days using different sensors in the ATF and ATF2 areas. The locations of the vibration measurements were the same as for the floor tilt measurement locations, as indicated by solid and open triangles in Fig.2. The sensors used for the measurements are the following:

- Servo type velocity sensor VSE355G2 (Tokyo Sokushin Co. ,Ltd.)
- Servo acceleration sensor MG-102S (Tokkyo-kiki Co., Ltd.).

Sensor resolution and huddle tests were performed for each type of sensor [4] [5]. The velocity sensors were used to measure the ATF floor vibration and the acceleration sensors were used for the ATF2 floor vibration measurements. The reason for using different sensors at different locations was due to the availability of the sensors at that point. A consistency check was performed between the velocity sensors and the acceleration sensors prior to this experiment and they were consistent for the frequency range above a few tenths of one Hertz.

3.1. Comparison Between ATF and ATF2

Figs. 6, 7 and 8 show the integrated amplitude of the floor vibration for x (perpendicular to the ATF2 beam line), y (parallel to the ATF2 beam line) and vertical directions, respectively. The data were taken around midnight in both cases. It is seen that the floor vibration is larger for the frequencies above 1 Hz in all three directions in the ATF2 area. There are more complicated structures in the ATF2 floor vibration, such as the peaks at around 10 Hz, 13 Hz and 25 Hz. The vibration is largest in the vertical direction. The vertical amplitude exceeds 40 nm, which is the design vertical beam size of the ATF2 project, at 10 Hz. Though the vibration sources have not been identified, it is an indication that reinforcing the floor structure might help in damping the vibration, to the level of the ATF floor at least.

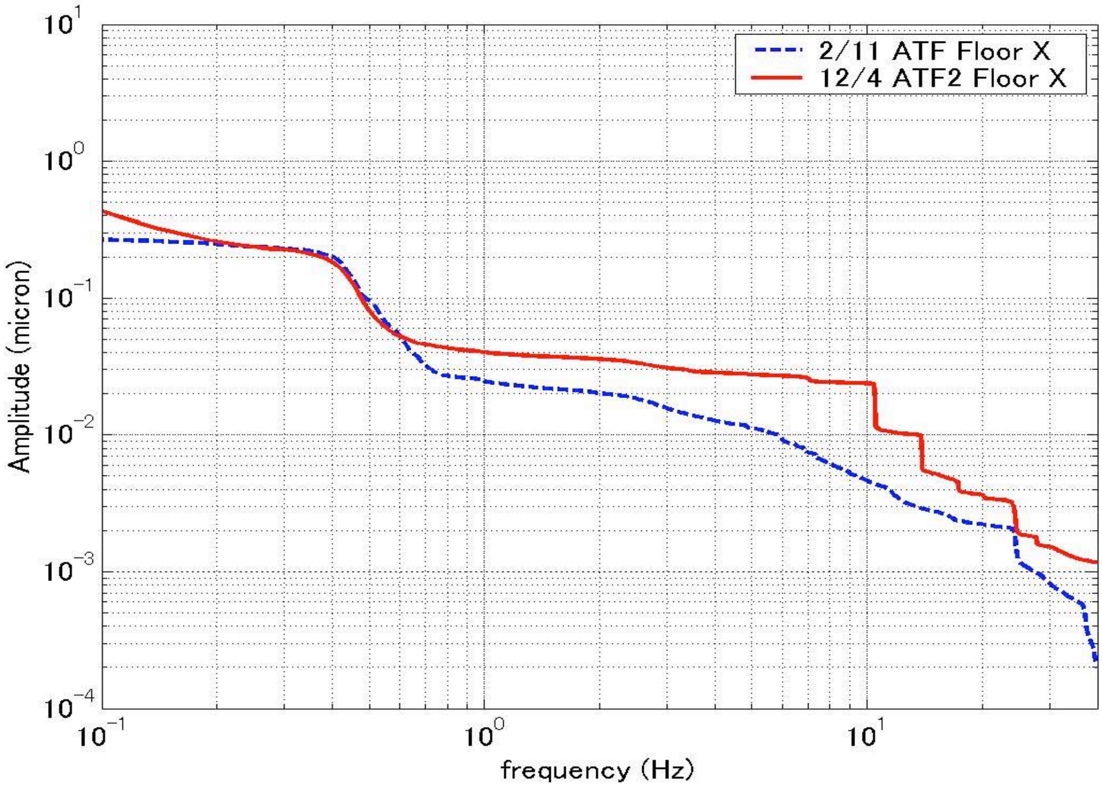

Figure 6: Integrated amplitude in the x-direction.

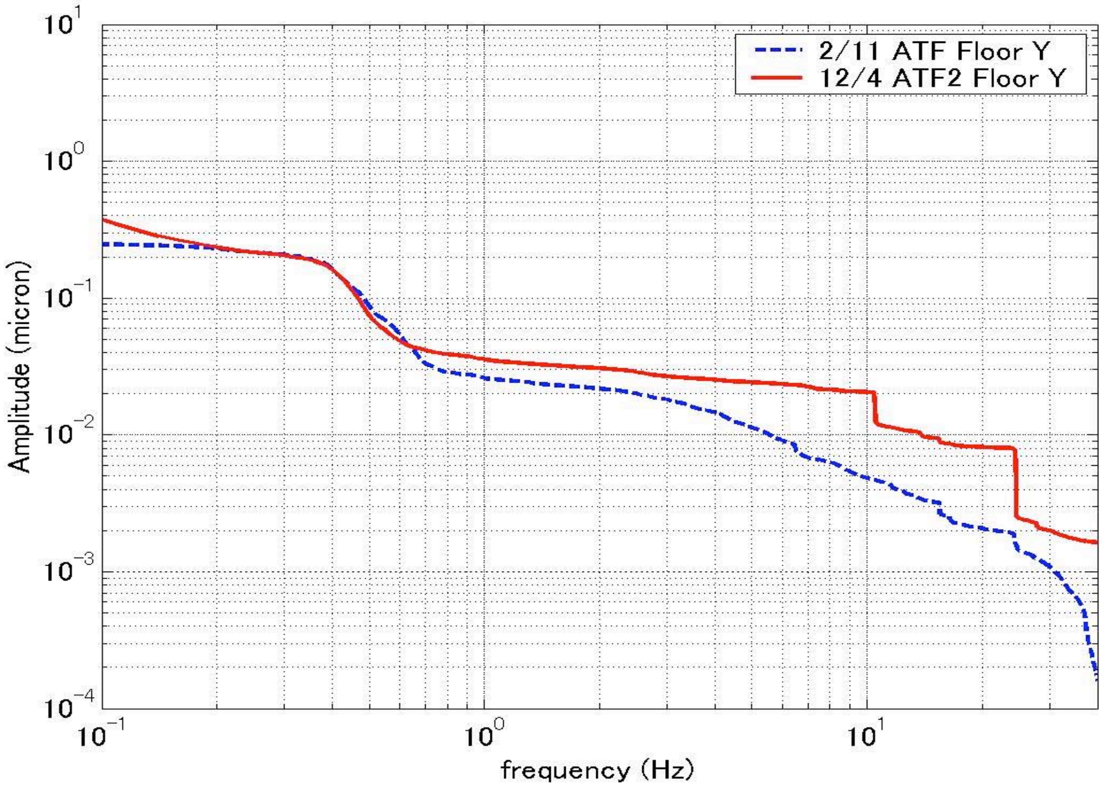

Figure 7: Integrated amplitude in the y-direction.

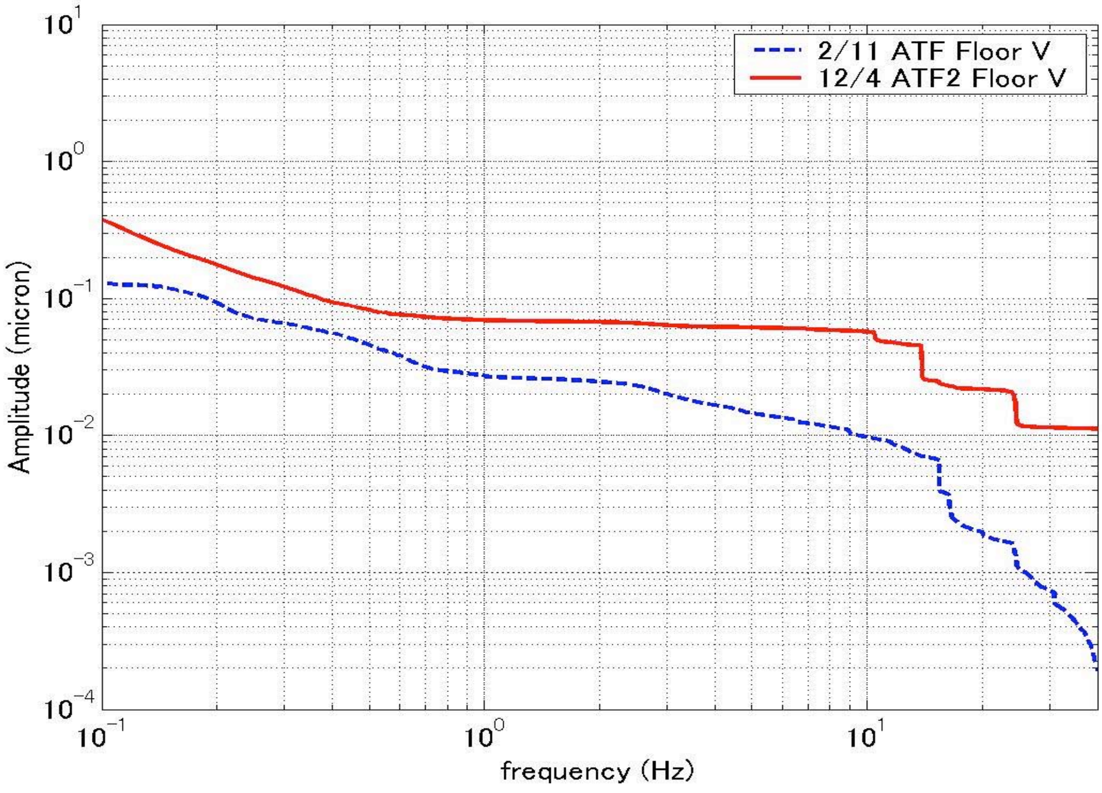

Figure 8: Integrated amplitude in the vertical direction.

3.2. Day to Day Fluctuations in the ATF2 area

In order to see the vibration amplitude dependence on time and dates, the data were recorded every hour for 5 days in December 2004 in the ATF2 area. Fig.9 shows the integrated amplitude for the frequency range above 50 Hz obtained from two acceleration sensors placed several meters away from each other, one closer to the concrete shield of the ATF damping ring placed on the floor painted yellow (marked "yellow" in the following plots) and the other placed on the floor painted green (marked "green" in the following plots). There is an expansion joint between the yellow floor and the green floor. The vibration amplitude seems to be smaller on the yellow floor, especially in the x-direction. The expansion joint might be causing the damping on the yellow floor. The vibration appears to become smaller, especially in the vertical direction, over the weekend. It may be concluded that the vibration above 50 Hz comes from some kind of human activity in this area. A weekend effect is observed clearly.

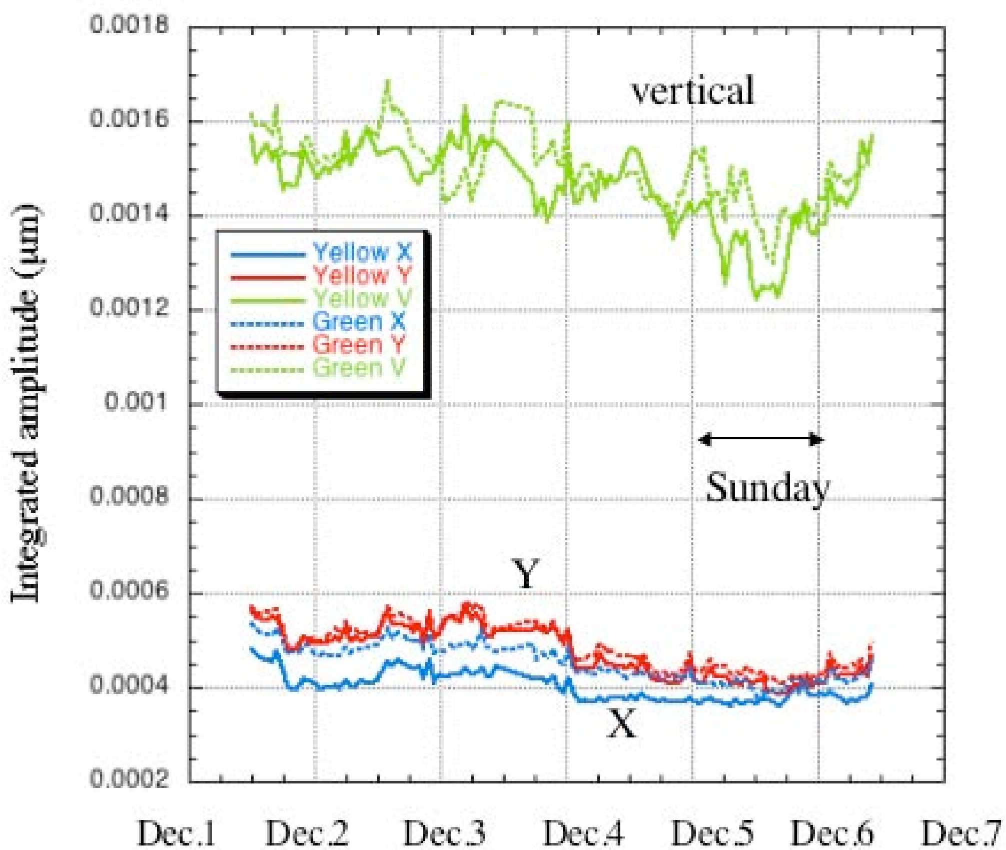

Figure 9: Integrated amplitude for f > 50 Hz in the ATF2 area.

Fig. 10 shows the integrated amplitude for the frequency range above 0.3 Hz. The vibration becomes significantly larger, by a factor of 5, in x- and y- directions on Sunday, in contrast to the vibration above 50 Hz. A power spectrum density from Dec. 6 at 1:30 am is shown in Fig.11. Most of the integrated amplitude comes from the wide peak at around 0.3 Hz as seen in Fig.11. In order to see the source of this low frequency vibration, which is believed to come from ocean swell, oceanic wave data were checked. The wave height data at the port of Onahama (see the map in Fig. 3) are plotted in Fig. 12. The wind speed data are also added to the same plot along with the integrated amplitude above

0.3 Hz and 0.1 Hz. The wave height data come from the NOWPHAS (Nationwide Ocean Wave information network for Ports And HarborS, the TOHOKU Regional Bureau, Ministry of Land, Infrastructure and Transport) web page. The wind data are from the Japan Meteorological Agency web page. There is a clear correlation between the low frequency floor vibration and wave height and wind speed. It appears that the floor vibration above 0.3 Hz follows the wind speed more closely than the wave height, though it is not possible to distinguish the contributions from the wave height and the wind speed clearly with the limited amount of metrological data accessed.

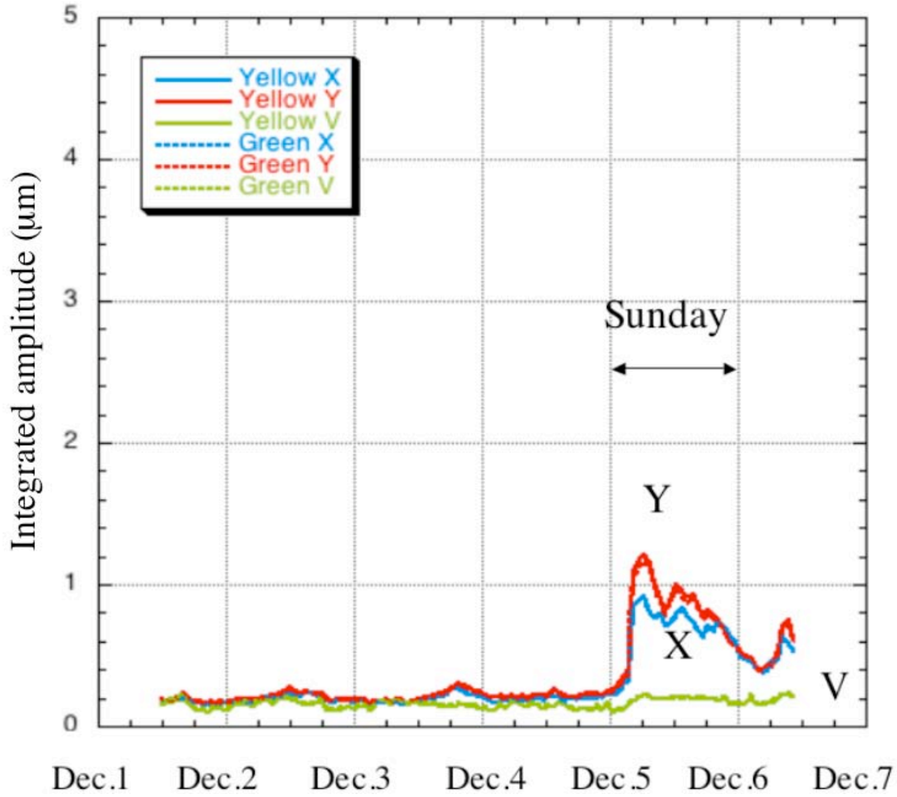

Figure 10: Integrated amplitude for f > 0.3 Hz in the ATF2 area.

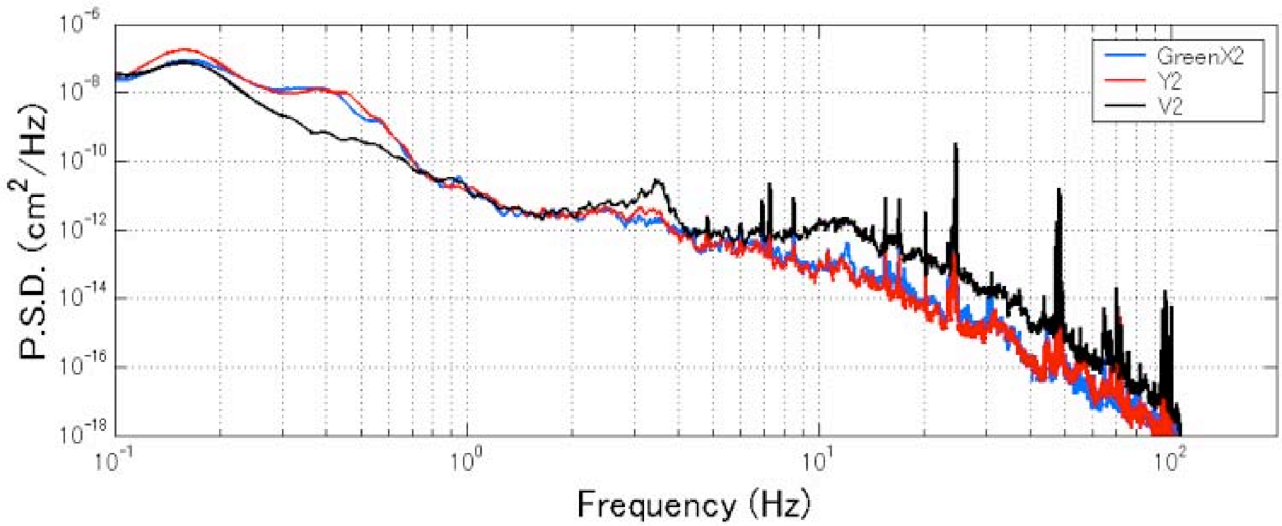

Figure 11: P.S.D. of the floor motion.

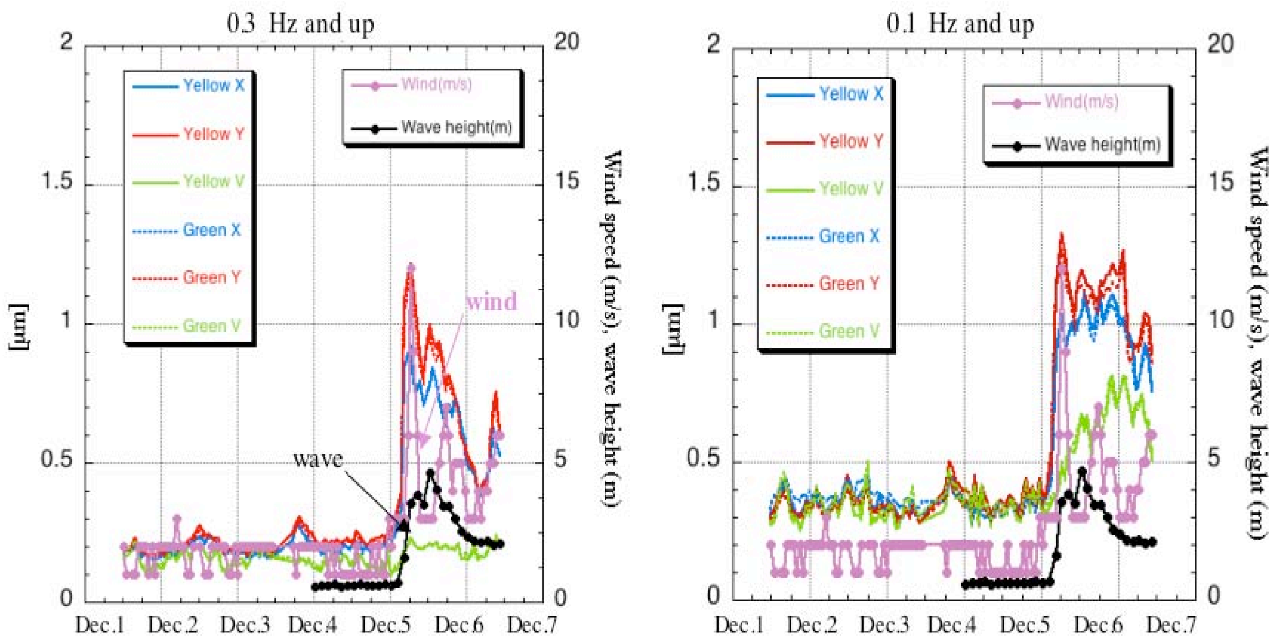

Figure 12: Integrated amplitude as a function of time. Wave speed measured in the Tsukuba area and the wave height measured at the port of Onahama are plotted. Integrated amplitudes of x-, y- and vertical directions above 0.3 Hz and 0.1 Hz are shown in left and right plots, respectively.

4. SUMMARY

Floor tilt was measured in the ATF2 area and the ATF damping ring area using Leica Nivel 20 tilt meters. The diurnal effect in the floor tilt is a few times larger in the ATF2 beam extraction area than in the ATF beam line area. The peak-to-peak daily tilt was measured to be 10 μrad in the ATF2 area in November when the outside air temperature varied by ~15 degrees. There was no such daily tilt in the ATF area. An earthquake occurred during the measurement at the ATF area, but the floor tilt recovered smoothly.

Floor vibration was also measured in both the ATF and ATF2 areas. It was found that the floor vibration is larger in the ATF2 area as well, especially in the vertical direction. The vibration amplitude at 10 Hz is ~50 μm in vertical, which is larger than the vertical beam spot size expected by the ATF2. Floor reinforcement was recommended by these measurements and will be done as a part of the ATF2 construction. The ATF2 floor motion is significantly affected by strong wind and/or waves. This could be a result of the beam line being on the surface of the ground in the assembly building standing on the ground as seen in Fig.1. Unfortunately the data were not taken on windy days in the ATF area due to limited access time to the damping ring during beam operation. Floor reinforcement may also reduce the effects from strong wind and waves.

References

[1] The ATF Group, "ATF Design and Study Report", KEK Internal 95-4, June 1995.

[2] The ATF2 Group, "ATF2 Proposal Vol.1",CERN-AB-2005-035, CLIC note 636, DESY 05-148, ILC-Asia-2005-22, JAI-2005-002,KEK Report 2005-2, SLAC-R-771,UT-ICEPP 0502.

[3] M.Masuzawa et.al., “Vibration measurements in the KEKB tunnel,” KEK Preprint 2004-68, IWAA2004, CERN, October 2004.

[4] http://acfahep.kek.jp/subg/ir/nanoBPM/

[5] R.Sugahara et.al., “Performance of an active vibration system for GLC”, KEK Preprint 2004-64, IWAA2004, CERN, October 2004.

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