Report on the Observation Run of TAMA300 in the Spring of 2003

Koji Arai,[1] and the TAMA collaboration
(1) National Astronomical Observatory of Japan, Mitaka, Tokyo 181-858, Japan

Abstract

This paper describes operational status of TAMA300, a 300-m interferometric gravitational wave detector in Japan, during the observation run for two months in the Spring of 2003, as well as the enhancement of the systems prepared for this run.

1. Introduction

Several projects to construct interferometric gravitational wave detectors are in progress through the world. A Japanese 300-m interferometric gravitational wave detector, TAMA300, has been constructed at the National Astronomical Observatory of Japan in Mitaka, Tokyo [1, 2]. The TAMA300 detector started its first operation in 1999 preceding the other large-scale detectors. Since then, eight times of data taking runs have been performed.

The latest observation run, called Data Taking 8 (DT8), was held from 14th February to 15th April in 2003 as the first long-term international joint observation with interferometric detectors which are sensitive enough to detect galactic gravitational wave events; three interferometers of the LIGO project [3] and TAMA300 were made on line in the same period. Prior to the DT8 run, power recycling had been implemented to TAMA300.

In this paper, first, we describe the observation system with which the power recycled interferometer successfully works in the long-term operation. Second, the operational status of the detector during the observation is described. More precise report on the interferometer sensitivity will be given in a related paper in this volume.

2. Enhancement of the observation system

In DT8, TAMA300 operated with power recycling. Since the control system and the observation system were previously constructed to be suitable for the non-recycled interferometer, they had to be modified for DT8. For this purpose, an alignment control system for the recycling mirror, optical axis control servos, and a newly-revised automatic lock acquisition system were employed.

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The alignment of the mirrors must be controlled so as to keep the highest performance of the detector. The alignment control system for four test masses using the wave-front-sensing technique [5] could be used for the recycled interferometer without modification. A mechanical modulation scheme [6] was utilized for the alignment control of the recycling mirror. Sinusoidal signals at 60Hz and 70Hz were applied to tilt and rotation of the recycling mirror, respectively. The control signals are obtained from the intensity of the beam in the recycling cavity with lock-in amplifiers; the intensity has sinusoidal component at these frequencies when misalignment of the mirrors is present. The control bandwidth of the servo loops are a few hundred mHz.

In order to maintain the beam axis to the 10-m mode cleaner stationary, the position and direction of the laser beam on the injection table was actively controlled. Two beams are picked off from the main beam. Two mirrors with actuators in the main optics chain are controlled so that the two beams hit the center of two quadrant photodiodes. As a result, translation and tilt of the main beam were controlled, and the mirror misalignment of the mode cleaner with regard to the incident beam is suppressed.

The automatic lock acquisition system was fully revised [7]. In TAMA300 the lock of the recycled interferometer is acquired using auxiliary signals [4]. Therefore, in order to reach the state for low noise operation, numbers of switching of control systems in a certain order are needed according to the optical state of the interferometer. The automatic lock acquisition of TAMA300 was realized by analog-digital interfaces and a PC with Labview as a master controller; the system controls digital switches embedded in the analog servos, watching the state of the interferometer. For the lock acquisition, an operator only needs to adjust the initial alignment of the mirrors in a specified way. When the mirrors are properly adjusted, the lock is automatically established within a few minutes. After that, a logic signal to show the observation status is manually set to the observation mode by the operator. This signal is recorded by the high speed data acquisition system together with the detector output in order to indicate the observation period suitable for data analyses.

3. Operational status during Data Taking 8

The DT8 run has been held from 14th February to 15th April in 2003; TAMA300 operated for 1424 hours (59.3 days). Figure 1 shows the observation status during the run. The boxes in the figure indicate the periods when TAMA300 was in the observation mode that was described above. Stable operation of TAMA300 was realized most of the time, although the operation was frequently disrupted in the daytime of weekdays. The total amount of the data in the observation mode reached 1158 hours. This corresponds to the duty ratio of 81.3%. Duration of the lock stretches was 2.82 hours in average. The longest

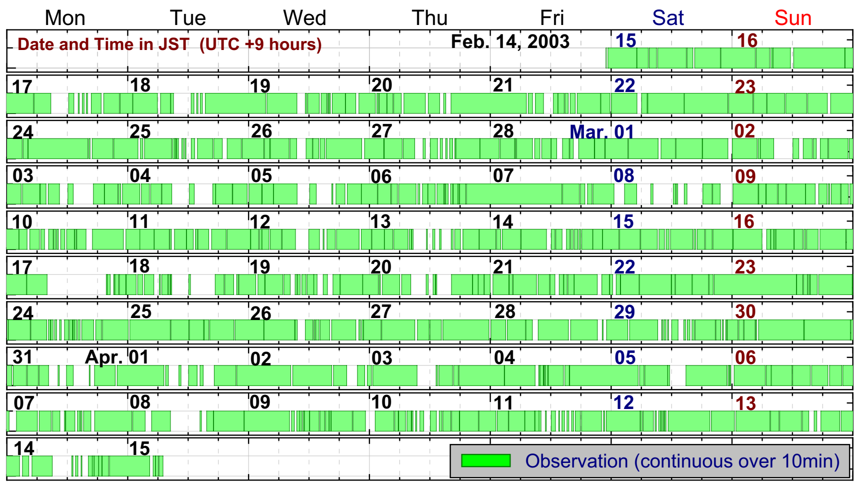

Fig. 1. Observation status during Data Taking 8. Each box shows the period when TAMA300 was fully functional and the valid data was accumulated.

lock stretch was 20.5 hours.

As soon as the run has started, degradation of the duty cycle in the daytime was found. The lower plot in Fig. 2 shows the duty cycle at each time of the day; 24 hours were split into 240 segments, and the probability to be in the observation mode was calculated for each segment of 6 minutes. The time is expressed in JST (UTC+9). The figure shows that the duty cycle before 8:00, around noon, and after 17:30 was about 90% while the duty cycle was lower in the other period. This degradation was caused by seismic disturbances in the daytime. The stability of the interferometer operation depends on the level of seismic vibration between 0.1 Hz and 10 Hz because the vibration isolation is not efficient in this low frequency region. In addition, the site is in a city area where the ground motion in the low frequency region is largely excited in the daytime by human activities, such as heavy traffic. Particularly, the most significant reason for the loss of the duty cycle was construction works nearby the observatory.

As well as the duty cycle, the sensitivity also showed the daily trend. In order to see this, "observable distance" is used as one of the indices to evaluate the sensitivity. It is defined by the distance at which inspiraling compact binaries can be detected with SNR of 10 with matched filtering analysis [2], assuming the binary has specific equal masses and present in the optimum direction for the detector. The observable distance through DT8 was calculated from a power spectrum of the strain sensitivity for every 50 seconds. The upper plot in Fig. 2 shows the observable distance of TAMA300 for $1.4\,M_{\odot}$-$1.4\,M_{\odot}$ binary inspirals. The average observable distance of about 35 kpc was obtained in the nighttime. On the other hand, the distance in the daytime shows the reduction of about 20%.

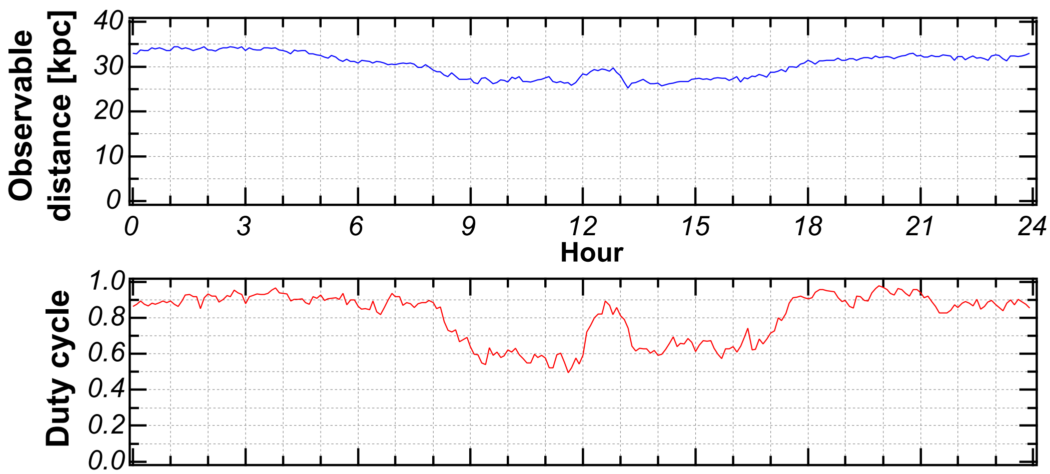

Fig. 2. Daily trend of the detector performance in DT8. The observable distance (upper) and duty ratio (lower) were shown. Each value was calculated for a segment of 6 minutes.

Our interest is dependence of the duty cycle and the sensitivity on the seismic disturbance level. This issue is under investigation. In particular, separating the effect of the construction works is being attempted.

4. Summary

The observation run of TAMA300, called Data Taking 8 (DT8), was held in the Spring of 2003 for two months. For this observation, the control system and the observation system were enhanced to be suitable for the power-recycled interferometer. In DT8, TAMA300 operated for 1424 hours and accumulated observation data of 1158 hours, which corresponds to the duty cycle of 81.3%. The daily trend of the duty cycle and the sensitivity was found; the duty cycle was about 90% and 60% in the daytime and in the nighttime, respectively. The sensitivity degradation of about 20% has been observed in the daytime.

5. References

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