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# TAMA-300 PROJECT FOR GRAVITATIONAL WAVE DETECTOR

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## ABSTRACT

This paper reports on the outline and the status of the TAMA-300 project, the 300 meter laser interferometer gravitational wave detector developed by a team of scientists of several research institutes and universities in Japan. In fact the project has been funded and its construction started at the National Astronomical Observatory, Mitaka, in spring 1995. And the constructions of the tunnels for the east-west and north-south arms and of the central building are completed and a half of pipes for laser beams were brought in. Very stable laser oscillator has been almost completed and mew techniques such as vibration isolations, recycling of laser power, and suspension of mirrors by double pendulums have been developed. In fact the purposes of the project are to establish techniques necessary for future km-class detectors and to operate the detector to catch possible gravitational wave events in nearby galaxies such as Andromeda, the target sensitivity being $3 \times 10^{-21}$ at 300Hz.

*Key Words :* gravitational wave, interferometer

## I. OUTLINE OF THE PROJECT

The gravitational field exists anywhere caused by masses in the universe and as the masses are always accelerated the field, namely, the curvature of space, also changes with time. According to Einstein's general theory of relativity by the accelerations of the masses gravitational wave is emitted. And it is known that neutron star binaries highly accelerated in non-spherically symmetric way emit the wave, particularly, in their final stage. As it is expected that such gravitational wave can be detected if properly designed detectors are developed, there are now several groups in the world which are developing such instruments.

In Japan also in the past decade or so a group of scientists concerned at various institutes has been working to find out an idea how to detect gravitational wave and to develop techniques to realize such detectors. In fact scientists at Physics Department of University of Tokyo succeeded in developing and operating a 4 meter laser interferometer of Fabry-Perot type and at the National Astronomical Observatory by applying this technique a 20 meter laser interferometer was constructed. At the Institute of Space and Astronautical Sciences the construction of a 100 meter interferometer of delay-time type has been completed and under operation.

In the meantime several techniques for the detectors such as stabilizing laser oscillators, vibration isolation, suspension of mirrors by double pendulums, recycling of laser power and others have been studied and developed by the group and some of them have been introduced in the 20 meter interferometer.

Besides the instrumentation works a group of theoreticians have been engaged in studying to understand how gravitational waves are emitted from possible sources like binary neutron stars in their final coalescence stages by solving the equations numerically and what physical parameters could be obtained by catching gravitational waves from such sources.

Then the basic idea of the TAMA-300 project was fixed. In fact it is a 300 meter laser interferometer of Fabry-Perot type to be constructed in the Mitaka campus of the National Astronomical Observatory, 20km from the center of Tokyo. In fact the proposal was submitted to a screening committee of the Ministry of Education, Science, Culture and Sports at the end of 1993, to obtain the funds. In fact the idea is in principle not different from those of LIGO and VIRGO projects of USA and Europe in spite of the difference in size. In the spring 1995, funds were secured to develop the TAMA-300 project.

The TAMA-300 project is a joint one among the National Astronomical Observatory, the Institute for Cosmic Ray Research of University of Tokyo, the National Laboratory for High Energy Physics and the Institute of Space and Astronautical Sciences as well as two institutes of University of Tokyo, University of Electro-Communication and Kyoto University.

The author is the project leader and Drs. K.Tsubono (Department of Physics, University of Tokyo), M.Fujimoto (National Astronomical Observatory), and K. Kuroda (Cosmic Ray Research Instiute) are senior members of the team. About 20 staff members of the participating institutes as well as about 10 post-doctorial fellows including foreign scientists and 15 graduate students make the project team.

## II. INSTRUMENT

The TAMA-300 interferometer consists of two arms of L-type, in both north-south and east-west directions, of 300 meters long, and the laser beams will be transmitted through vacuum pipes of 40cm diameter and of $10^{-6}$Pa. They are in underground tunnels of 2 x 1.5 meter size and consist of 11 meter units with electro-chemical buffing inside. And two sets of vacuum pumps are operated for each arm. In fact the underground tunnels for the arms and the central building which accommodates the laser oscillator, the beam splitter, the recycling mirror and the photo-detector as well as the vacuum chambers have been completed, and about a half of vacuum pipes have been brought in.

The laser oscillator which is one of the most important elements of the detector and should be very stable in frequency and output power is almost completed. It is an injection locked LD pumped Nd:YAG with output power of 10W and wavelength of 1,064nm. And it is expected that by introducing a recycling technique factor of 10 will be gained in power so that the effective power of the laser will be 30W. The laser beam is modulated with 15.25MHz by an electro-optical modulator and goes through a mode cleaner of 10m long to screen out any modes other than the fundamental one($TEM_{00}$).

And after the recycling mirror of radius of curvature of 9km it is split into the two cavities of different directions. However, there is a difference of 50cm in length between the two cavities so that the 15.25MHz modulation will be remained after any interference. The beams go back and forth along the same path in each of Fabry-Perot cavity between the two mirrors and the beams in different directions interfer with each other and the further interference is taken between the two beams from the two cavities. The cavity fineness of the interferometer will be 520. And any phase difference and its time variation is tried to detect by a device.

All the mirrors are designed very carefully in their material, polishment and coating and it is decided that their diameters are 10cm with 6cm thickness. For coating the method of ion beam scattering has been adopted so that any loss by scattering is limited within ppm level.

The mirrors are suspended by double pendulums to reduce noises from every source like seismic activities of the ground. In fact it is known that seismic activities are quite strong at low frequency, lower than a few tens of Hz. Every optical elements should be placed at proper positions with proper directions very accurately and the suspension points of the pendulums are adjusted by using picomotors and PZT. The oscillation of the pendulums is controlled by eddy current produced by permanent magnets attached there. Alignments of the optical systems are continuously checked by using portions of the laser beams picked up near their ends with a method of wave front senseing.

This suspension unit is held by a vibration isolation system consisting of a stack set made of layers of gum and metal and X-pendulum of 10m long effective to damp out low frequency vibrations as well as an active control system with a servo-accelerometer operated at 500Hz, the latter being for z-component. By such a combination the noise is expected to be reduced, particularly, at 300Hz. Even though any noise oscillation is damped earth tides and thermal expansion in the optical system still deform the interferometer and such deformations are adujsted by actuators attached to every mirror.

## III. TARGET SENSITIVITY

The target sensitivity of the detector is expected to be $3 \times 10^{-20}$ in 1998 when it is scheduled to start its operation and will be improved by factor 10 in 1999 around the frequency of 300Hz. The target sensitivity cannot be improved further unless thermal noise of mirrors can be reduced by any method. Then the system will be operated by the team of scientists at least for several years. In fact a data reduction and analysis system is also worked out.

With this sensitivity it is hoped that the system can catch gravitational wave events like neutron star binary coalescence in nearby galaxies such as Andromea. In fact theoreticians in the team predict that gravitational wave of enough energy is emitted at a few hundred Hz by such an event.

And the team of the TAMA-300 project desires that after successful completion and operation of the detector a new system of km-class will be funded. In fact while the TAMA-300 project is going on, it is planned that much higher technology will be developed for the future.