# Development of a Ground Simulator of a Satellite-to-Satellite Interferometry for the Earth's Gravity Field Determination

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Recently, several satellite gravity missions are started to determine the Earth's gravity field with unprecedented accuracy. They are expected to allow the measurement of the temporal variations in the gravity field. Their principle is to observe the free-fall motion of the satellites in the gravity field. They are continuously tracked by global positioning system, and the non-gravitational force acting on them is separated from the gravitational signal by accelerometer. The satellite-to-satellite tracking between twin satellite or the satellite gravity gradiometry is also employed to amplify the signal.

In Japan, feasibility studies for a future satellite gravity mission are undertaken during a three years project started in 2002. The mission goal is to monitor the changes in the geoid with millimeter-level accuracy. Twin satellite will be launched in the same orbit of 450km altitude not to attenuate the gravitational signal, and fly 50km apart to resolve the gravity field with the spatial resolution of 100km. Moreover, the satellite-to-satellite laser interferometry (SSI) between the satellites must be employed to achieve the required range-rate sensitivity of 10nm/s in the measurement band of 0.01- 1Hz. The laser frequency will be shifted approximately 200kHz by Doppler effect, since the maximum range-rate is predicted to be 0.1m/s.

We are developing a ground simulator of the SSI. There are three key studies for the development: study of the velocity and alignment sensing/control technique available for the SSI, retrieval of gravity field from the Doppler shift and development of the frequency stabilized laser with space-qualified design. The simulator is comprised of a doppler measurement system, signal generation and data acquisition (DAQ) system and frequency stabilized laser system. The doppler measurement system is a Mach-Zehnder interferometer with one acousto-optic deflector (AOD) for each arm. The pseudo-Doppler shift corresponding to the relative velocity between twin satellite is produced by one AOD. The interferometer is locked on the half-bright fringe by the other AOD to read out the range-rate signal at a low sampling frequency. The beam jitter will be artificially produced to demonstrate the mirror alignment control. The control signal will be extracted using quadrant photodiodes and fed back to fast steering mirrors to compensate the beam jitter. An optical fiber with the length of 1¥,km will be introduced to evaluate the influence of the frequency and scattered light noise, which appear as spurious signal coupling with the asymmetry of the SSI.

The retrieval of gravity field from the pseudo-Doppler shift is executed on the signal generation and DAQ system. According to a predicted signal obtained by a computer simulation, the sampling frequency and dynamic range required for the system are 10kHz and 24bit to completely retrieve the Earth's gravity field.We decided to simulate the partial gravity field because of the rather wide dynamic range.

The laser frequency noise is required to be below 100Hz/rtHz at 0.1Hz to attain the desired sensitivity. The operation of the light source under the space environment must be also considered. It became clear that an LD-pumped monolithic Nd:YAG laser and a semiconductor laser meet the requirements. The monolithic Nd:YAG laser was employed for the simulator due to its low intrinsic noise and suitability to tune the frequency. The laser frequency is stabilized to a high finesse Fabry-Peort cavity with a rigid spacer, which is covered by five-fold thermal shields in a vacuum chamber for decreasing cavity-length change induced by temperature fluctuation.

The preliminary demonstration of the simulator was performed without the optical fiber and frequency stabilization system. The achieved range-rate sensitivity is 60nm/s/rtHz around 0.1Hz at present. The performance of the SSI under various conditions will be experimentally investigated using the simulator.