Development of a stabilized semiconductor laser for a light source in a satellite-to-satellite laser interferometer

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There is a plan to measure the time varying gravity field for the global observation of the environmental changes by using the laser interferometric technique for satellite-to-satellite tracking instead of using the radio technique as used in the current inter-satellite system, GRACE. This is because the laser interferometric technique will improve the sensitivity of the system as far as 10 nm/s. The laser light source of this interferometer must have several characteristics, such as lightweight, smallness, high efficiency, low power consumption, long lifetime, and high frequency stability, however we have no laser which has all of these characteristics by now. Because a diode laser has almost all of these characteristics except for the frequency stability, we are trying to stabilize its oscillation frequency and investigating the possibility of a diode laser as a light source in a satellite-to-satellite laser interferometer.

In our laboratory, we have employed the Rb-D2 absorption line as the external reference frequency, to stabilize the oscillation frequency of a diode laser at 780nm (384THz). Any discrepancies between the external reference signal and laser oscillation is detected as an error signal by applying the direct modulation to the laser injection current, and negatively fed back to the laser bias current in a popular method. This method has certain drawbacks, however, in that its use further destabilizes the frequency, resulting in a broadening of the laser oscillation spectrum. To avoid this, we applied a Faraday effect-based method of magnetic field modulation, which modulates the external frequency reference signal, instead of the laser oscillation frequency, without broadening the spectral width of the laser oscillation. In addition, the stabilization frequency can be swept and controlled. So, in this study, we applied the Faraday effect, in conjunction with the PEAK method we proposed in our previous work, to improve a control signal, as well as the tractability of the laser frequency to the reference. However, because the acquisition of the PEAK method's stabilization point depends on the accurate combination of two signals, it is imperative that Rb-cell temperature fluctuations be held to a minimum.

In recent years, a femto second mode lock pulse laser optical comb generator has been developed as a new reference frequency source for the frequency measurement. Because the optical comb can provide the precise frequency references in a wide range of light frequency, we have measured the frequency stability of our system using the optical comb and obtained the results of about 10**-10 in the square root of the Allan variance or the frequency stability df/f0 from 1 s to 100 s in the averaging time. The symbols df means the frequency variation and f0 means the center frequency of the laser oscillation.

The value, which is requested to measure the relative velocity variation of the twin satellites system is about 10 nm/s, requires the df/f0 better than 10**-12 from 1 s to 10 s in the averaging time for its laser light source. So, we introduced the double optical feedback method to narrower the oscillation line width of our stabilized diode laser and to improve its frequency stability. The double optical feedback method is reported recently as a new type of optical feedback method without any active control of mirrors in order to obtain the stable laser output with narrowed oscillation spectrum. We succeeded to stabilize the oscillation frequency of the diode laser using the Faraday effect based method in the double optical feedback condition and obtained the improved stability, because we could control the stabilization point by our Faraday effect-based method.

By using these methods, we will improve and evaluate the stability of the laser to meet the requirement.