Development of a practical absolute-wavelength-stabilized laser source for field use of accurate geophysical-measurement devices

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We have developed a practical absolute-wavelength-stabilized laser source for field use of accurate geophysical-measurement devices.

As one kind of the ultimately high-sensitivity observation devices, there is a type of devices adopting a laser interferometer: a laser tiltmeter, a laser strainmeter, an absolute gravimeter and so on. These devices can acquire more accurate values and smaller changes of each physical quantities (tilt, strain, or gravity) in comparison with conventional types of geophysical-measurement devices. Moreover, the principle of acquiring signals (laser interferometer) enables their size to be more compact than that of conventional types.

However, in order to obtain these benefits simultaneously and perfectly, it is decisively important to stabilize a wavelength of the laser source. Especially in our application (long-term observations), the laser source must have the characteristics of long lifetime and low power consumption, and the **absolute** wavelength of the laser needs to be stable because it is directly connected with the long-term sensitivities of observation devices.

These requirements have been realized by using narrow-linewidth Laser Diodes (a DBR-LD and a DFB-LD that oscillate at 852 nm in wavelength) as the laser source and a wavelength-stabilization feedback system with Ceasium (Cs) gas cell as the absolute wavelength reference (it has the universal electronic transitions at 852 nm in wavelength). In addition, to obtain higher stability of wavelength, we adopted a modulation transfer (MT) spectroscopic method (which is a kind of saturated absorption spectroscopic technique) as a technique of acquiring a reference signal to lock the wavelength of the lasers. At the laboratory-phase of this development, we confirmed and showed that the wavelength stability of a DBR-LD locked to one of the 852 nm hyperfine transitions by the MT method reached to $1{*}10^{-10}$ in a Gatetime region longer than 100 s which corresponds to for example the sensitivity of the order of $1{*}10^{-13}$ rad with a laser tiltmeter (in measuring time scale of more than 100 s), that is three orders better than that by non-stabilized laser sources.

After this confirmation, we transferred this wavelength-stabilization system from laboratory-phase to practical-phase, in other words we have built up the hand-carriable compact and low power consumption wavelength-stabilized laser source for our actual field uses. The stabilization system is constructed on a breadboard in a carriable rackbox (40 cm square) generally used in various fields. However, to obtain an advanced relative-wavelength-stability by removing the effect of modulation current applied to the DBR-LD, we also constructed a offset lock stabilization system with an additional laser source (DFB-LD) in this rackbox. This enabled us to draw out the non-modulated (relative wavelength is stable) and simultaneously absolute-wavelength-stabilized laser beam, in addition we can take out the beam in **fiber output** because the slave laser (DFB-LD) is the type of fiber-pigtailed butterfly case.

In constructing these systems, we devised mainly two original techniques in optical part of the system. One is the Doppler-trend subtraction method which suppresses the enhanced intensity noise of the laser beam by passing through a gas cell. This technique contributes the absolute stability of wavelength approximately one order better than that without the technique. The other is the way of holding a gas cell (which is made of glass) rigidly to the breadboard but softly enough not to be broken by unexpected mechanical shocks. To realize it, we devised the way where two conventional piping parts (made of vinyl chloride) that have loose edges are holding both sides of the gas cell.

We will show the details of this self-build practical laser source for accurate geophysical measurements.