광펌핑 세슘원자 주파수 표준기에서 제 2차 Zeeman 주파수 이동 측정 및 개선

Measurement and Improvement of the Second-order Zeeman Frequency Shift in an Optically Pumped Cesium Beam Frequency Standard

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Since a hyperfine transition in the cesium-133 atom was adopted as the uniform frequency reference, several laboratories have developed novel cesium beam frequency standards in order to get better performance. The cesium beam frequency standards categorize two types in accordance with the atom selection method - by magnets or by laser. It is expected that the optical method will improve the frequency stability and the accuracy of cesium beam frequency standards in comparison with the conventional method with magnets. Recently it comes true by the optically pumped frequency standard NIST-7 and NRLM-4, which show the accuracy of 7×10^{15} and 2.9×10^{14}, respectively.

We have constructed an optically pumped cesium-beam frequency standard (named KRISS-1) which is intended to use as a primary frequency standard. The accuracy evaluation of the frequency standard is being performed before working as a primary frequency standard. By the way, the accuracy of frequency standards implies the total uncertainty of all kinds of frequency shift, and therefore we must reduce each uncertainty to get a higher accuracy. There are several factors to produce the frequency shift and uncertainty in the cesium beam frequency standard, for example, the second-order Doppler effect by the distribution of the atomic velocity, the second-order Zeeman effect by the magnetic field, and factors related to the microwave cavity and the servo systems.

This paper describes the evaluation of the frequency shift and uncertainty caused by the second-order Zeeman effect in the KRISS-1. In particular, we adopt a dual servo system which consists of two independent feedback loops to stabilize the magnetic field as well as the clock signal.

We have measured the frequency shift and uncertainty of the optically pumped atomic clock, KRISS-1, due to the second-order Zeeman effect. We composed an additional feedback loop to stabilize the first-order Zeeman frequency for the stabilization of the magnetic field, and as the result, the uncertainty was reduced by about ten times compared to that without the feedback loop.

We found that the feedback loop was very useful to make the magnetic field become constant irrespective of the temperature variation in the environment where the KRISS-1 was placed. The final frequency shift and uncertainty were 3.2×10^{-10} and 3.2×10^{15}, respectively.

References

[1] Jacques Vanier and Claude Audoin, *The Quantum Physics of Atomic Frequency Standards*. Bristol: U.K. IOP Publishing Ltd., 1989

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Table I. Frequency shifts and uncertainties due to the second order Zeeman effect.

	Frequency shifts	Uncertainty without feedback loop	Uncertainty with feedback loop
Static magnetic field	3.2×10^{10}	3.0×10^{14}	1.4×10^{15}
Magnetic field inhomogeneity between the two interaction regions	-	2.9×10^{15}	2.9×10^{15}
Unequal magnetic induction in the interaction regions	-1.9×10^{13}	-	-
Combined uncertainties	-	3.0×10^{14}	3.2×10^{15}

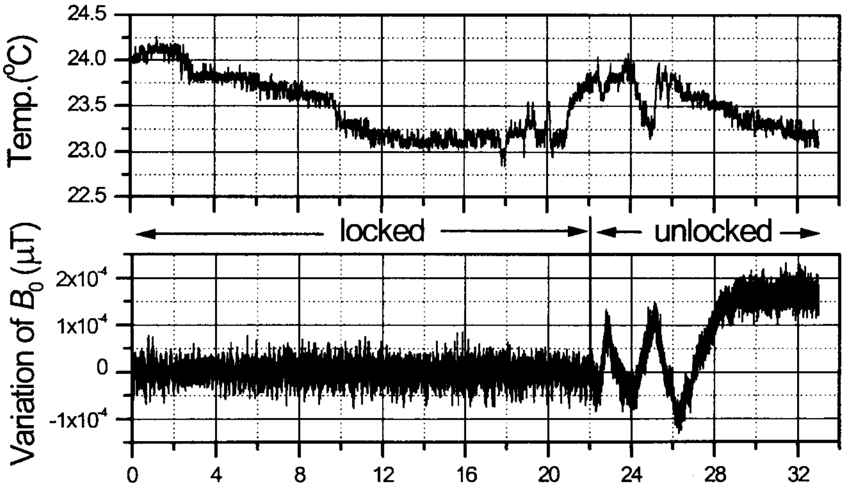

Figure I. Stabilization of magnetic field.