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DBR LASER DIODES FOR OPTICALLY PUMPED Cs FREQUENCY STANDARDS

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ABSTRACT

This note describes the use of Distributed Bragg Reflection (DBR) type laser diodes for use in optically pumped Cs beam frequency standards. We have used a DBR laser at 852 nm as the optical source for the florescence detection of the Cs clock transition in NIST-7 and find it to be equivalent to the extended cavity diode laser.

INTRODUCTION

The NIST-7 Cs frequency standard has been operational for three years [1]. It is an optically pumped Cs beam frequency standard which uses an extended cavity diode laser as the optical pumping source. This work describes the use of a much simpler source, the DBR diode laser, as a replacement for the extended cavity diode laser in the Cs frequency standard. The DBR laser diode used has (1) an output power > 5mW, (2) a linewidth < 1 MHz, and (3) an operating wavelength 852 nm.

Preliminary measurements showed that the (1) am noise was < 10^{-4} dBv/$\sqrt{\text{Hz}}$ for frequencies < 100 kHz and that (2) fm noise was 5-10 MHz in the modulation frequency < 100 kHz [2]. Other workers in the field have shown that fm noise of < 2 MHz does not affect the signal-to-noise ratio of the detected floresence in a Cs beam system [3]. Since the lasing wavelength of a diode laser is dependent on both laser current and laser temperature a method is needed to servo the system to the correct wavelength. If the servo response is fast enough we can decrease the fm noise with the same system.

WAVELENGTH CONTROL SYSTEM

The reference wavelength we used was the D_2, F=4 → F= 5 cycling transition of the saturated absorption line in a Cs vapor cell at room temperature. This technique gives a reference linewidth of about 8 MHz, very similar to that observed in the Cs beam system. The lock of the laser wavelength to that of the Cs transition was achieved with fm sideband locking [4]. A block diagram of the locking system is shown in Figure 1.

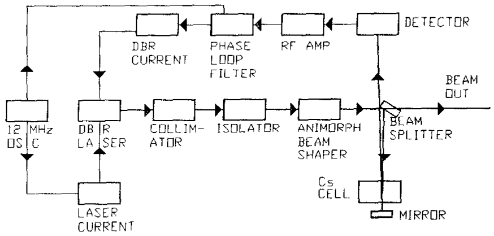

Figure 1. Block schematic of the DBR diode laser stabilized to the Cs saturated absorption.

In a nutshell the system works as follows. A 12 MHz current is injected directly into the gain section of the laser diode giving rise to fm sidebands which are 20 dB down from the single frequency carrier. As shown in Figure 1 a small part of the laser beam is passed through and returned nearly on itself giving rise to the saturated absorption signals from the Cs D_2 transition at 852 nm. This beam is then detected by a fast photodiode. The 12 MHz signal (the beat between the fm sidebands and the carrier) is amplified and quadurature phase detected in the phase-loop-filter section. The quadurature detection has two effects: (1) it discriminates against the doppler broadened background signal and (2) the saturated signals appear as a type of dispersion, and it is this signal that is used as a discriminant to lock the emission wavelength of the diode laser to any of the D_2 hyperfine transitions. The gain of the control loop is rolled off at 100 kHz since the response time of the DBR control section of the laser is > 10^{-5} s and begins to introduce a π phase shift into the loop response at frequencies higher than this.

With the wavelength of the DBR laser diode locked to a Cs saturated absorption line the output beam has the following measured characteristics. The output power is > 2 mW. The am noise is the same as above. The fm noise is now < 1 MHz in amplitude for frequencies < 100 kHz. The overall linewidth as measured by beating the DBR laser beam with that of an extended cavity laser beam was < 1.5 MHz FWHM. The true test of the lock system is to use the DBR laser beam as the optical source to pump the NIST-7 Cs beam frequency standard.

DBR SOURCE AND NIST-7

The DBR laser, with its frequency locked to the D_2 $F=4 \rightarrow F=5$ cycling transition, was used as the optical source for the flouresence detection in NIST-7 frequency standard. An extended cavity diode laser was used for the Cs atom state preparation. The floresence detection of the Cs atoms is very sensitive to both am and fm noise on the laser pumping source; hence this was a critical test for the DBR diode laser and its stabilization scheme.

One measure of the performance of a frequency standard is the Allan variance $\sigma_y(\tau)$. Using the DBR laser we obtain:

$$\sigma_y(\tau) = 9 \cdot 10^{-13}/\sqrt{\tau}.$$

This result is typical of that obtained when the extended cavity diode laser was used as the floresence detection source. This equation implies that for $\tau = 10^4$ s, $\sigma_y(\tau) = 9 \cdot 10^{-15}$, and this was borne out by experiments. It also implies that the noise in NIST-7 is white noise, which would give a $\sqrt{\tau}$ dependence. Other tests show that the limiting noise in NIST-7 is the shot noise of the Cs atoms in the beam.

SUMMARY

We can see no difference in the performance of NIST-7 when a DBR laser doide is used in place of the extended cavity type of laser diode system for the floresence detection. The DBR system has no gratings, PZT transducers, or laser cavities to keep aligned. Furthermore this work now points the way to have all "solid state" devices all the way from the laser source to the Cs beam resonator.

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