Testing of Cr:ZnSe Laser with Intracavity Methane Cell in 77-300 K Temperature Range

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***Abstract*— The mid-IR cw tunable solid state two-mode Cr^{2+}:ZnSe laser with intracavity methane cryocell was developed. The laser was applied for sub-Doppler spectroscopy of ($\nu_1+\nu_4$) vibrational-rotational band of methane and observation of narrow resonances of saturated dispersion at λ = 2.36 μm. The new technique of low pressure methane gas cooling was used instead of liquid nitrogen "jacket" design applied in our previous work. Parameters of saturated dispersion resonances were estimated in 77-300 K temperature range. The experiments confirmed that laser with the new "dry cooled" methane cell has prospectives for reaching a short-term frequency stability at the level of 10^{-15} – 10^{-16} and can be used as a compact device.**

***Keywords* – Cr^{2+}:ZnSe; solid state lasers; tunable lasers; IR lasers; optical frequency standards; methane absorption lines; two-mode regime**

We continue the development of a two-mode tunable solid state optically pumped Cr^{2+}:ZnSe laser for registration of narrow saturated dispersion (SD) resonances at ($\nu_1+\nu_4$) vibrational-rotational band of methane at 2.3-2.5 μm.

In our previous work we carried out two experiments:

- measurement of intrinsic frequency noise of the Cr^{2+}:ZnSe solid state laser [1];

- observation of SD resonances at R(2) CH_4 line at 2.36 μm at room and liquid nitrogen (LN) temperatures [2].

Now the new experiment of observation of SD resonances at different temperatures using «dry-cooled» gas cryocell was conducted. One of the goals was to estimate the applicability of more practicable cooler based on a gas compressor for future Cr^{2+}:ZnSe /CH_4 optical frequency standard (OFS).

For the implementation of the Cr^{2+}:ZnSe /CH_4 OFS we use two-mode method of saturation spectroscopy which was successively applied in our He-Ne/CH_4 systems [3]. A low pressure CH_4 absorption «dry-cooled» cryocell was placed inside the laser cavity. The laser operates at two adjacent longitudinal modes with frequency difference ω_{12} ~ 125 MHz. A cw Tm fiber laser at 1.94 μm with maximum output power 2.8 W is used for optical pumping. Typical output power of the Cr^{2+}:ZnSe laser is in the range of 60-80 mW through the 2.3-2.5 μm tuning spectral range.

The SD resonances at E - component of the R (2) line (λ = 2.36 μm) for various temperatures were analyzed. Two advantages make this line attractive as a frequency reference: firstly, it has no hyperfine structure and secondly, it belongs to a transition with low rotational number J = 2. The latter means that the absorption coefficient can be significantly increased by methane cooling.

The SD resonances at different temperatures (77, 125 and 154 K) are shown in Figure 1.

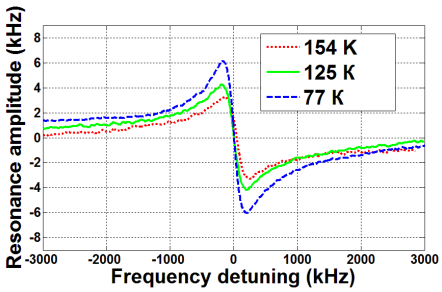

Fig. 1. SD resonances at E-component of the R(2) line ($\nu_1+\nu_4$) band at different temperatures

Results of measurement the SD methane resonance peak-to-peak amplitude in 77-300 K temperature range are shown in Table 1.

Table 1. Results of measurement the SD methane resonance peak-to-peak amplitudes in 77-300 K temperature range

T, K	77	104	116	125	154	300
Peak-to-peak amplitude, kHz	12.4	10.8	9.0	8.4	6.6	1.5

The experiment confirmed that our «dry-cooled» gas cryocell can work as effectively as LN cryocell did and the level of mechanical vibrations caused by compressor system is still negligible at present level of sensitivity.

These results are important for future development of optical frequency standards based on a tunable solid state optically pumped Cr^{2+}:ZnSe/CH_4 laser system.

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