Saturated Dispersion Resonances in a Cr^{2+}:ZnSe/CH_4 Laser with a "Dry cooled" Methane Cell

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Two main concepts for realization highly stable optical/microwave interrogative oscillators are adopted at present: microwave cryo cooled sapphire generators and lasers, stabilized to ULE/Silicon supercavities. In spite of great achievements for these devices (short-term stability 10^{-15}-$4\cdot10^{-17}$) the necessity of more compact, less complex interrogative oscillators with minimized frequency drifts is still one of the important tasks in the area of frequency metrology.

In present work we continue the development of an interrogative oscillator, based on mid-IR quantum reference, namely, saturated dispersion resonances (SDR) of methane ($\lambda \sim 2.4$ μm) recorded with a low noise two-mode Cr^{2+}:ZnSe laser with an intracavity CH_4 cell. As it was shown in our previous work[1] possibility to reach stability at the order of $(3\text{-}5)\cdot10^{-16}$ (at 1 s) in this system looks realistic. Attractive features of the Cr^{2+}:ZnSe/CH_4 system are lower sensitivity to environmental conditions and lower frequency drifts at the middle-term averaging times (10 s -10^3 s) as compared to above mentioned interrogative oscillators, based on passive resonators as frequency reference.

As it was shown[1], for detecting the SDR with required parameters (linewidth, S/N ratio) the low pressure methane gas (~1 mTorr) should be cooled down to 80K or less. In the previous experiment[1] the CH_4 cell was cooled by liquid nitrogen (LN) that may be not convenient in practical applications.

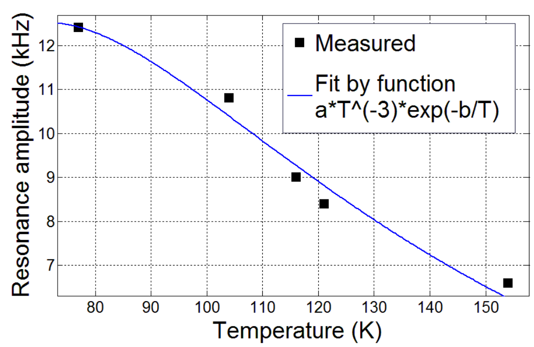

Fig 1: SD Resonances amplitude vs. temperature in the "dry cooled" CH_4 cell.

Now we have developed the two-mode Cr:ZnSe/CH_4 laser with an internal methane cell cooled down to LN temperatures by means of a compressor cryo system. One of the essential questions important for estimation of the feasibility of such concept is the level of the laser frequency noise induced by mechanical vibrations of the cryo system. The parameters of the laser were estimated experimentally by recording SDR amplitude vs temperature (Fig.1, the temperature was measured at the cryo panel inside the cell) and the laser beat frequency noise spectral density with the cryo system turned "on" and "off".

Main results:

1) the lowest temperature reached in the experiment is the same as in case of the "LN" methane cell;

2) mechanical noise produced by the cryo system doesn't affect the SDR registration sensitivity level (~ 0.03 $Hz/Hz^{1/2}$, determined by the F/V converter used)[1].

[1]M. Gubin, M. Frolov, A. Kireev, et al, "Cr:ZnSe Laser with 0.03 $Hz/Hz^{1/2}$ Frequency Noise for Compact Methane Based OFS", in Proceedings of EFTF -2012, April 23-27,2012, Gothenburg, Sweden, p. 459.