THz Quantum Cascade Lasers For High Resolution Spectroscopy

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Abstract— We report on application of the radiation source based on quantum cascade lasers for THz gas spectrometer based on nonstationary effects (free dumping polarization). The phase lock loop system and frequency stabilization system by gas absorption line for quantum cascade lasers of THz frequency range were developed.

Keywords—Quantum cascade laser, radiation source, phase lock loop system, frequency stabilization system

I. Introduction

We report on application of the quantum cascade lasers (QCL) radiation source for terahertz (THz) spectrometer based on nonstationary effects. The essence of a nonstationary spectroscopy is as following: interaction of electromagnetic radiation with ensemble of absorbing molecules results in induction of macroscopic dipole. After a radiation impact is over, absorbed energy is reradiated coherently at the molecular transition frequency. The nonstationary spectrometers can be realized in a phase switching [1] or fast passage modes [2].

The main problem of high precise spectroscopy is development of high-stable tunable coherent radiation sources. The modern spectroscopic requirements to THz radiation sources are frequency stabilization with accuracy $\sim 10^{-8} - 10^{-10}$, Doppler resolution ($10^4$), high spectral purity and smooth tuning of frequency in wide frequency range. The perspective THz radiation sources are QCL. They have a high output power and can generate radiation in pulse and continuous modes together with fast tuning of frequency. But use of QCL for spectroscopy requires development the phase lock loop systems (PLL) or frequency stabilization system of QCL.

II. THz radiation source on QCL

A. Phase lock loop systems of QCL

The PLL system for DFB QCL is designed using a room temperature superlattice (SL) harmonic mixer [3]. The harmonic mixer is pumped with a local oscillator (LO) at 190.744 GHz provided by an amplifier-multiplier-chain (AMC) source from VDI14. This AMC chain is a quadrupler (x16) system that is driven by an 11.2 GHz R&S microwave synthesizer. The 18th harmonic of the LO source is combined with the QCL frequency by the SL mixer. The PLL bandwidth is shown to be 7 MHz with 96% of QCL power phase locked to the reference.

B. Frequency stabilization system of QCL

The other way is the stabilization of THz QCL frequency by gas absorption line. The line of molecular transition can be used as high stable source of reference frequency. The frequency stabilization of QCL with use of H2O absorption line at 3.5 THz was developed. The advantage of this method is absence of reference signal frequency transfer in working range which demands the multiplying of reference frequency.

III. Conclusion

After the QCL based radiation source was shown to be operational a laboratory model of the spectrometer has been set up and tested. The test measurements of various gases have demonstrated that the spectrometer can be employed in different applications.

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References