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Continuously tunable single-frequency 1.52-μm diode laser for gas analysis

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***Abstract*. A single-frequency continuously tunable diode laser with a hybrid fibre Bragg grating resonator (hybrid laser) is built for recording the absorption line of ammonia. The continuous tuning within 40 GHz (1.33 cm^{-1}) was achieved for the first time for a hybrid laser emitting 5 mW in the line of width $\delta\nu \leqslant 15$ MHz (0.0005 cm^{-1}) with the side-mode suppression exceeding 20 dB.**

Keywords: *diode laser, fibre grating, continuous tuning, gas analysis.*

The extensive recent studies of injection lasers with a fibre Bragg grating (FBG) in the external resonator (hybrid lasers) have solved the problem of fabrication of compact pigtailed lasers [1, 2]. The main goal of these studies is to obtain the dynamic single-frequency lasing at a stable frequency [3, 4]. To achieve this goal, FBGs with a narrow (1 – 3 Å) reflection spectrum are used and the Q factor of the laser-diode (LD) resonator is reduced by applying the AR coating on its front face to obtain the reflectivity $R = 10^{-3} - 10^{-4}$. In this case, the continuous tuning range of hybrid lasers is only 100 – 200 MHz [5].

In paper [6], we have proposed a new approach to the development of hybrid lasers, which makes it possible to obtain single-frequency lasing continuously tunable in the region exceeding 30 GHz by varying the pump current. This allows the application of hybrid lasers in molecular spectroscopy, in sensors for detecting various gases, in systems for environment monitoring and in various interferometric fibre sensors. The method uses a FBG with a broad (3 – 10 Å) reflection spectrum and semiconductor laser chips with a plane Fabry – Perot resonator whose front face is AR-coated to have the reflectivity $R = 0.01 - 0.02$. In this paper, we used this approach to build a single-frequency broadly tunable laser for detecting ammonia. Analysis of the threshold conditions of the dynamic single-frequency oscillation in the laser of our design showed that the optimal values of the reflectivity R lie in the range 0.01 – 0.02, which provides the injection-current laser tuning within the FBG line upon shifting the low-Q resonances of the Fabry – Perot modes of the LD resonator.

We studied the tuning parameters of the lasers by using the setup shown schematically in Fig. 1. An InGaAsP/InP laser diode emitting at 1.52 μm with the resonator length of 350 μm was mounted on a Peltier refrigerator. The reflectivities of the rear (R_1) and front (R_2) diode faces were 0.4 and 0.02, respectively. The efficiency of radiation coupling into a FBG fibre was ~ 30 % and the optical length of the hybrid resonator was ~ 3 mm. The lasing threshold of the laser module with the resonator containing a FBG achieved 50 mA.

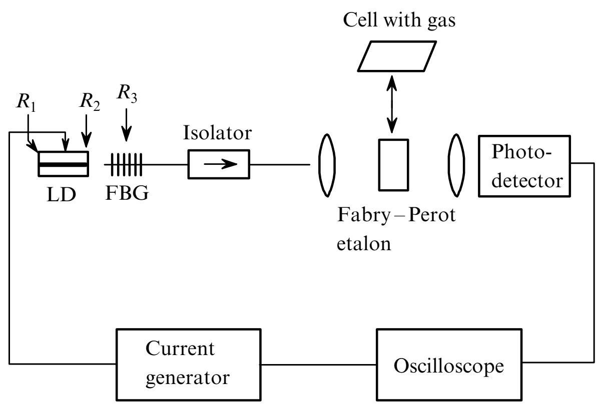

Figure 1. Scheme of the experimental setup for studying the continuous tuning of hybrid lasers.

The output radiation of the hybrid fibre laser propagated through an optical isolator, was collimated with a micro-objective, and transmitted through a Fabry – Perot etalon with a free spectral range of 5 GHz. Then, the radiation was directed to a photodetector whose signal was observed with an oscilloscope. The laser frequency was scanned by applying saw-tooth pulses with the rate of rise 20 mA ms^{-1} to the LD. An absorption line was observed by replacing the Fabry – Perot etalon by a cell with pure ammonia at a pressure of ~ 150 Torr at room temperature. The cell length was 50 cm. The emission spectrum of the laser was recorded by directing radiation from the laser fibre pigtail to an MS96A spectrum analyser (Anritsu) with the resolution $\delta\lambda = 1$ Å.

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We used in experiments several FBGs with different reflectivities ($R = 0.1 - 0.5$). The FWHM of the reflection spectrum of FBGs was 3.5 Å and the Bragg wavelength was 1520.5 nm, coinciding with one of the intense absorption lines of ammonia within 0.1 Å (the difference between this wavelength and the wavelength 1520.925 nm in Fig. 2 is related to the calibration of the instruments used for measuring these wavelengths). The laser chip coupled with the FBG produced $1 - 5$ mW of single-frequency radiation with the $20 - 35$-dB suppression of side modes (depending on the FBG reflectivity). The laser linewidth measured with the help of a confocal resonator was $\delta\nu_g \leqslant 15$ MHz.

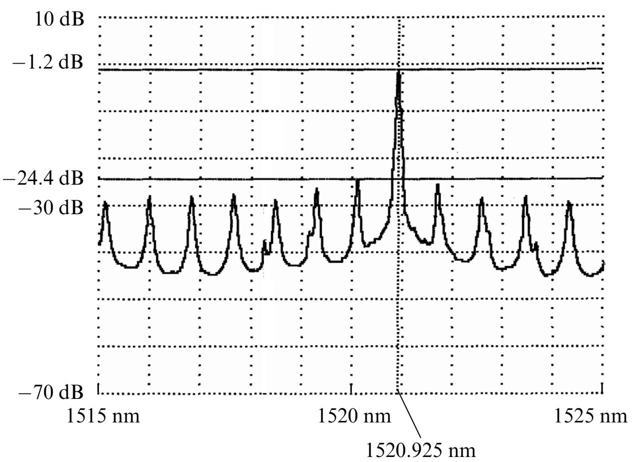

Figure 2. Typical emission spectrum of a hybrid laser for $R_1 = 0.4$, $R_2 = 0.02$, $R_3 = 0.13$, $\Delta\lambda_{FBG} = 3.5$ Å (oscilloscope photograph).

Figure 3 shows the absorption line of ammonia recorded with a hybrid laser containing a FBG with the reflectivity $R = 0.13$ and the FWHM of the reflection spectrum $\Delta\lambda_{FBG} = 3.5$ Å. The transmission peaks of the Fabry–Perot etalon presented in the figure demonstrate the range of continuous tuning equal to 40 GHz (1.3 cm^{-1}). The injection current was continuously tuned within ~ 70 mA, and the tuning rate was $d\nu/dJ_p \approx$ 0.5 GHz mA^{-1}. The tuning range and tuning rate of the laser are comparable with those for DFB lasers.

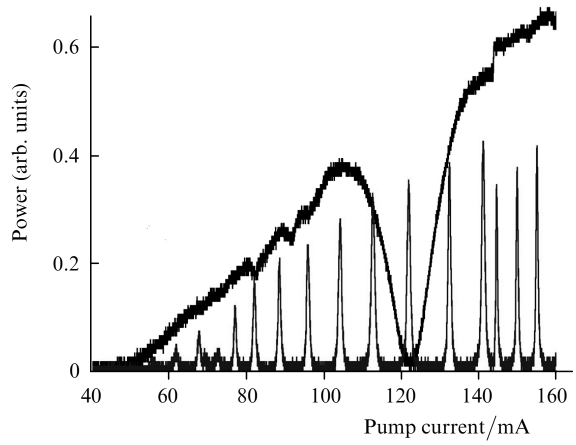

Figure 3. Absorption line of ammonia recorded at $P = 150$ Torr at 300 K and transmission peaks of a Fabry–Perot etalon (free spectral range is 5 GHz).

Thus, we have built continuously tunable narrowband hybrid lasers for recording the absorption lines in gases. The central emission line of hybrid lasers can be set very accurately. This opens up the prospects for broad applications of these lasers for recording the absorption lines of gases in the transparency region of optical fibres ($0.7 - 1.7$ μm). They represent a simple and low-cost alternative to DFB lasers used for such studies at present.

References

1. Duraev V.P., Nedelin E.T., Nedobyvailo T.P., Sumarokov M.A., Shishkov V.V. *Kvantovaya Elektron.*, **25**, 301 (1998) [*Quantum Electron.*, **28**, 290 (1998)].
2. Duraev V.P., Nedelin E.T., Nedobyvailo T.P., Sumarokov M.A., Klimov K.I. *Kvantovaya Elektron.*, **31**, 529 (2001) [*Quantum Electron.*, **31**, 529 (2001)].
3. Campbell R.J., Armitage J.R., Sherlock G., Williams D.L., Payne R., Robertson M., Wyatt R. *Electron. Lett.*, **32**, 119 (1996).
4. Sykes V. *J. Lightwave*, March, 130 (2001).
5. Belovolov M.I., Gladyshev A.V., Duraev V.P., Nedelin E.T., Zykov-Mizin K.A. *Proc. SPIE Int. Soc. Opt. Eng.*, **5381**, 20 (2004).
6. Gladyshev A.V., Belovolov M.I., Vasiliev S.A., Dianov E.M., Medvedkov O.I., Nadezhdinskii A.I., Ershov O.V., Beresin A.G., Duraev V.P., Nedelin E.T. *Spectrochim. Acta A*, **60** (14), 3337 (2004).