ADJUSTMENT OF RADIATION SPECTRUM OF INJECTION LASERS BY DOPPLER-SIGNAL OPTICAL HETERODYNING

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A procedure for changing the spectral characteristics of injection lasers by Doppler-signal optical heterodyning by changing the injection current is discussed. Results of current tuning of the radiation frequency, coherence, and other characteristics of AlGaAs-heterolasers by using the above procedure under conditions of c.w. lasing are reported.

Key words: radiation spectrum tuning, optical heterodyning, coherence injection laser, Doppler signal.

Introduction. Injection lasers (IL) find ever increasing applications in data-acquisition systems (DAS). ILs show much promise in such systems owing to their numerous advantageous properties, in particular, the possibility of adjustment of the spectral characteristics of their radiation. Many works (see, e.g. [1-5]) are devoted to investigation of the tuning characteristics (TC) of ILs. However, as an analysis of [3-5] shows, the spectral line width of the radiation in the majority of modern coherent DAS based on tunable ILs must not exceed 0.01-1.00 MHz. To measure the TC of such narrow spectral lines, only the method of optical heterodyning can be, in fact, used.

Traditional prism-type grating monochromators possess insufficiently high resolution and a large time of spectrum recording, which is a bottleneck in measurements of small variations of IL lasing frequency. Heterodyne systems are more sensitive for detection of changes in lasing frequency, but their implementation based on a Michelson interferometer requires many optical elements and careful alignment of the systems. Recently, a fiber-optic autoheterodyne system was developed for TC investigation of such ILs [3]. However, fiber-optic-interferometer based systems with sufficiently high resolution require technologically complicated couplers, radiation input-output assembles, microoptics, and so on. Taking into consideration the importance of allowance for several radiation characteristics for many simultaneous spectrometric measurements [6], it is an urgent problem to seek methods of high-speed analysis of the complex of tuning characteristics ILs which can be easily implemented in practice.

To investigate IL TC, use can be made of Doppler-signal autoheterodyning. In this case, the only optical element used is a movable semitransparent plate mounted in front of the IL. In this optical circuit, we are concerned with heterodyning of two waves. The first wave is the reference wave, which passes directly from the laser to the photoreceiver, whereas the second wave is the signal wave, which arrives at the photoreceiver after reflection from the semitransparent plate and the front face of the IL cavity. The electric vectors $E_1$ and $E_2$ of the reference and signal waves can be written in the form

$$E_1 = E_{01} \cos \omega t,$$

$$E_2 = E_{02} \cos \left[ \omega t + \varphi_D (t) \right],$$
where $E_{01}$, $E_{02}$ are the amplitudes of the reference and signal light waves; $\omega = 2\pi \nu$ is the circular frequency of IL radiation; $\varphi_D = (2\omega/c)S(t)$; $S(t)$ is the oscillation law of the semitransparent plate; $c$ is the velocity of light; $t$ is time.

In this case, the time-averaged intensity of the electric field received by the photodetector is described by the expression

$$\langle E^2 \rangle = E_0^2 \{1 + \cos \varphi_D(t)\}, \quad (1)$$

where for simplification it is assumed that $E_0 = E_1 = E_2$. From (1) it is seen that the intensity of the output signal consists of constant $E_0^2$ and frequency-modulated $A = E_0 \cos \varphi_D(t)$ components. For the case when the oscillation amplitude of the semitransparent plate is less than $\lambda/2$ ($\lambda$ is the wavelength of IL radiation), the function $S(t)$ is close to harmonic oscillations. With continuous changing of the injection current of the IL, the frequency of its radiation undergoes tuning and the heterodyne signal periodically attains a maximum value at the frequencies at which the phases of the reference and signal waves coincide. Thus, the picture of the maxima allows judgement of the slope of tuning of the laser radiation frequency $d\nu/d\nu$.

**Experiment.** The block diagram of an experimental setup intended for IL TC is shown in Fig. 1. Radiation from the investigated laser L positioned on a movable stand MS falls onto a glass plate GP fixed on piezoceramics PS of tubular form. An alternating voltage from generator G with frequency $\nu < 1$ kHz is applied to the piezoceramics. The amplitude $U_\alpha$ of the voltage from generator G is chosen to ensure the necessary displacement of the reflector (plate GP) in space. The IL radiation that has passed through the plate and been subsequently reflected from it and the front side of the laser and has the Doppler frequency shift falls onto photoreceiver PR and is detected by detector D. The output signal of the detector is sent to the Y-input of recorder R, to the X-input of which a signal of a mechanical-electrical transducer MET is brought. Oscillograph O serves for visual monitoring of the amplitude of the Doppler signal. Movable stand MS is displaced with the aid of an electric motor with a reducing gear and a micrometer screw. As a mechanical-electrical transducer, use was made of a PPLM-M-20 multiturn wire-type potentiometer. Prior to measurements the setup was aligned by an He-Ne laser.

In a full period of piezoceramic oscillation, the reflecting plate GP was stopped twice. This determines the periodicity of changing of the beat frequency. Choosing the amplitude of GP vibration in space as $S_{\text{max}} = (3-5)\lambda/2$ and displacing the IL along the optical axis of the experimental setup, it can be seen that at distances that are multiples of the optical length of the resonator $L_{\text{opt}} = L_g n_{\text{gr}}$ ($L_g$ is the geometric length of the resonator; $n_{\text{gr}}$ is the group index of refraction allowing for dispersion of the active region) the correlation peaks of the heterodyne signal are recorded (Fig. 2). Here, the change in the width of the first correlation peak is strictly proportional to the change in the width of the radiation spectrum of the IL. This fact is checked by direct measurement of the spectrum with the aid of a KSVU-23 industrial spectral unit. Besides, knowing $L_{\text{opt}}$ and $L_g$ it is easy to calculate the group index of refraction of the active region of the IL ($n_{\text{gr}} = L_{\text{opt}}/L_g$) and the intermode interval in the spectrum of lasing.