HOLOGRAPHIC DFB LASER WITH FAN-SHAPED
GRATING FOR A SPECTROFLUORIMETER

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A method for recording fan-shaped transmitting phase holographic gratings that ensure tuning of the
wavelength of emission for a DFB (distributed-feedback) dye laser is presented. Traditional optical ele-
ments are used in the scheme of grating recording. A change in the degree of grating fanning is
reached here without replacement of gratings. The possibility of obtaining frequency-tuned emission by
means of the fan-shaped gratings created is demonstrated experimentally.

Keywords: DFB dye laser, fan-shaped holographic grating, laser spectrofluorimeter.

Tunable laser sources with pulses of subnanosecond duration are indispensable for a number of practi-
cal applications. Lasers of this type are especially convenient for investigations of dynamic processes in solu-
tions of organic compounds and in biological objects (cells, membranes, and so on) [1].

Our earlier investigations have shown the potential for applying a laser system consisting of a TEA
N2 laser + a DFB laser based on dye solutions for obtaining tuned subnanosecond pulses. This arrangement can
be used both as an autonomous source of tuned radiation and in laser spectrometers and spectrofluorimeters
with high time-resolution capabilities [2, 3]. Using an automated laser subnanosecond spectrofluorimeter [3], in
which an "Ametist" DFB laser is employed [4], the spectral and spatial heterogeneity of probes has been stud-
ied in bilayer phospholipid membranes and erythrocyte ghosts [5].

The holographic DFB dye laser [6], consisting of a cuvette with a dye solution, whose input facet
serves as a phase transmitting holographic grating, is a very convenient source of lasing (from the point of
view of its use in spectrofluorimeters). The emission wavelength in this device does not depend on the spectral
composition of pumping and is determined only by the period of the holographic grating d and by the index
of refraction of the solution n:

\[ \lambda_e = nd. \] (1)

The optical system, which is usually used for the formation of two pumping beams that interfere in an
active medium, is replaced by a phase holographic grating. This makes it possible to simplify radically the
system and, what is more important, to remove restrictions as to time and spatial coherence of pumping laser
radiation. The use of gratings with different periods allows one to obtain emission at discrete frequencies.
However, the impossibility of smooth tuning of the emission wavelength is a definite shortcoming of the holo-
graphic DFB laser with a fixed period of holographic grating. Here smooth tuning can be fulfilled only by
changing the index of refraction of the dye solution. The latter can be done by mixing two solvents with dif-
f erent indices of refraction or by changing the temperatures of the solution. Both methods are very inconven-
ient for practical purposes.

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Another way to achieve smooth tuning of wavelength in a holographic DFB laser is the use of a fan-shaped holographic grating (HFG) on the input facet of the cuvette, i.e., of a grating with a smooth change in its period when scanning is performed along its generatrix (Fig. 1). The change in the period with displacement by unit length is called the step of fanning $h = (d_1 - d_2)/l$. But, although the solution is attractive in principle, the complexity is associated with the technique of fabrication of HFG.

To form an HFG, it was suggested in [7] that the scheme of optical recording should contain two mirrors with specially curved ("twisted") surfaces which would bring together the pumping beams and lead them out to the surface of a polyurethane film in which the recording of the grating was made. The preparation of a pair of such mirrors, whose surfaces must have exactly the same curvatures, is a very complicated technological problem. Moreover, to change the degree of fanning, it is necessary to fabricate a new pair of mirrors with a different surface curvature.

In the present article we describe a method of obtaining an HFG for a DFB laser with smooth frequency tuning, which allows one to dispense with the above-mentioned "twisted" mirrors and use traditional optical elements. Moreover, the method makes it possible to change the degree of fanning without replacing optical elements in the scheme of grating recording.

The optical scheme of recording an HFG is shown in Fig. 2. A vertically polarized lasing beam is expanded by a telescope 1 and divided into two beams by a beam splitter 2. These beams are directed to a recording medium 7 by a beam-convergence system 3. Each arm of the system 3 contains a mirror 4 and two equifocal cylindrical lenses 5 and 6 with the distance between them equal to the sum of their focal distances $2F$. The generatrix of the lens 5 is vertical and the generatrix of the lens 6 forms a certain angle $\alpha$ with the latter. The angle $\alpha$ can be varied, and this allows one to form gratings with a different step of fanning in the recording medium.

The principle of the formation of an HFG in the given scheme is shown in Figs. 3 and 4. The parallel beams with a flat front formed after the telescope 1 and the beam splitter 2 are transformed by the lenses 5 into beams with a cylindrical wave front. If the generatrices of the cylindrical lenses 5 and 6 ($O_5-O_5'$ and $O_6-O_6'$) are parallel, i.e., $\alpha = 0$, then beams I and II (Fig. 2) are incident on the recording medium 7 at a certain angle $\phi_0$ forming an HFG with a constant period which is the same along its entire height. However, if $\alpha \neq 0$, then the beam which passed through the lens 5 arrives at the cylindrical lens 6 but as a beam shifted from its optical axis, with the magnitude of shifting changing along the lens height. In this case the beam that passed through the lens 6 contains rays incident on the recording medium 7 at different angles. Let us select rays $R_1-R_2$ in the beam passed through the lens 5. Since the lens 6 is turned through the angle $\alpha \neq 0$, the ray that passed through the optical axis of the lens 5 will be displaced from the optical axis of the lens 6 by the distance $\alpha$. There is a surface of the lens 6 in the direction of the ray $R_1$ and this surface is tangent to the cylindrical surface of the lens 5. The surface between the rays $R_1$ and $R_2$ is a plane one with the normal coinciding with the direction $\alpha$. A similar analysis of the other beam also leads to the conclusion that the beam to be transformed into an HFG is a fan-shaped beam.