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Abstract

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Stimulated Emission in Gallium Arsenide under Optical Excitation

The production of states with negative temperature in semiconductors was proposed and theoretically investigated in (1-4). In (5) the recombination luminescence of a GaAs crystal was observed and experimentally studied upon excitation by the light of an optical quantum generator (OQG) on ruby. The present work sets forth the results of preliminary studies of stimulated emission and generation in a GaAs semiconductor crystal upon excitation by the light of a ruby OQG with modulated quality factor.

The specimen (Fig. 1), measuring 2×1 mm and 0.5 mm thick, was made from single-crystal GaAs. The polished flat surface of the specimen S, irradiated by the pump light, coincided with the crystallographic plane (111). Two planes perpendicular to it, S_1, S_2, corresponding to the crystallographic plane (110), formed a plane-parallel resonator. The specimen was attached to a cold conductor cooled with liquid nitrogen. For ease of adjustment, an

Fig. 1 and Fig. 2: experimental setup and spectral lines

Fig. 1. 1—ruby OQG with modulated quality factor; 2—specimen (single-crystal GaAs); S_1, S_2—reflecting planes of the specimen forming the resonator; 3—cold conductor; 4—Φ—filter that does not transmit the pump light; 5—ISP-51 spectrograph. ⇒ direction of the pump light; → emission of the specimen

Fig. 2. Spectral generation lines of the specimen (carrier concentration $2 \cdot 10^{17}$ cm^{-3}, mobility 3500 cm^2/V·s) and of an injection laser on a p–n junction

injection OQG made of gallium arsenide was placed next to the specimen. The radiation from the single-crystal GaAs specimen (and from the OQG on the p–n junction) was directed into an ISP-51 spectrograph. In front of the spectrograph a filter Φ was installed, which did not transmit the pump light ($\lambda = 6943$ Å). The emission of the specimen was recorded either on photographic film or visually—with the aid of an electron-optical converter. The energy of the radiation pulse of the pumping OQG was monitored with a photomultiplier.

When the GaAs specimen was irradiated by an unfocused light pulse from the ruby OQG with an energy of about 0.1 J (power 2 MW), a narrowed spectral line was observed at the output of the ISP-51 spectrograph.

recombination luminescence in the spectral interval from 8340 to 8400 Å. When the pump-light pulse energy was increased to 0.15 J, a sharp narrowing of the spectral line (generation) occurred at the wavelength $\lambda = 8365$ Å. The narrowing of the spectral line was accompanied by a narrowing of the radiation directivity diagram of the sample, as well as by a sharp increase in the spectral intensity of the line. The results of processing the spectrogram of generation of the sample and of the OQG at the p–n junction are presented in Fig. 2. The comparatively large width of the generation line, $\Delta\lambda = 32$ Å, is apparently connected with the large number of types of oscillations whose natural frequencies fall within the spectral interval occupied by the line of spontaneous recombination luminescence, and for which the condition of self-excitation is simultaneously fulfilled. Indeed, the interval (in wavelengths) even between axial modes in the resonator was 1 Å and was smaller than the resolving power of the spectrograph, equal to 4 Å. This did not make it possible to resolve the individual generated modes.

Fig. 3. Spectral line of generation of the sample (at liquid-nitrogen temperature) (carrier concentration $1.55 \cdot 10^{17}$ cm^{-3}, mobility 4450 cm^2/V $\cdot$ sec) under the action of the Stokes component of the combinational scattering radiation of an OQG on ruby in liquid nitrogen. An analogous GaAs generation line was also observed at room temperature, with a maximum at $\lambda \approx 9000$ Å.

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As noted in ([6,7]), to create a negative temperature in a semiconductor of the GaAs type (most probably for radiative band-to-band transitions), it is best to use monochromatic radiation whose photon energy only slightly exceeds the energy width of the forbidden band. Such radiation can be obtained in the combinational scattering of OQG light on ruby in liquids and gases. To excite the GaAs sample we used the Stokes component of the combinational scattering of the radiation of an OQG on ruby in liquid nitrogen ([8]). For this purpose, a Dewar with liquid nitrogen was placed between the OQG and the sample. A lens was mounted in front of the entrance window of the Dewar, and a second lens, confocal with the first, was mounted at the exit window. An infrared light filter was placed in front of the sample, transmitting only the Stokes component of the combinational scattering ($\lambda = 8281$ Å). Measurements showed that, for an OQG radiation pulse energy of about 0.3 J, up to 15% of the total energy is converted into the Stokes component. With slight focusing of the radiation of the Stokes component to values of 0.2 J/cm^2, generation arose both at liquid-nitrogen temperature and at room temperature (Fig. 3). The quantum yield was about 4%, and the beam divergence was 4°.

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Note: Figure translations are in progress. See original paper for figures.