Spectrum of Low-Voltage THz Emission of Strained p-Ge Resonant-State Laser

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The spectrum of stimulated THz emission of a uniaxially stressed p-Ge resonant-state laser (RSL) is measured at low electric fields at which the continuous-wave operation of RSL is possible. The lines observed show that the mechanism of lasing in diffusive regime of electric field heating carriers is the same as at high voltages when the carriers accomplish the streaming motion. It is due to an inverted population of resonant states of acceptors induced by strain. A new line caused by optical transitions between continuum and resonant states is found.

Gallium-doped Ge crystals with Ga concentration of $2*10^{14}$ cm^{-3} were used in the experiment at liquid helium temperature. The samples of a square cross section of $0.7*0.9$ mm^2 and 10 mm long were cut in the [111] crystallographic direction. Uniaxial pressure *P* and electric field *E* were applied along the samples. Voltage pulses of 1 msec duration were applied to contacts positioned on the long (lateral) plane of the sample on a distance 7 mm one from another. The resonator formed in our case by well-parallel lateral sample planes (plane parallelism was better than 5 arcsec) was necessary to obtain the low-voltage stimulated THz emission. The spectrum of THz radiation was registered by a cooled InSb detector tuned by a magnetic field.

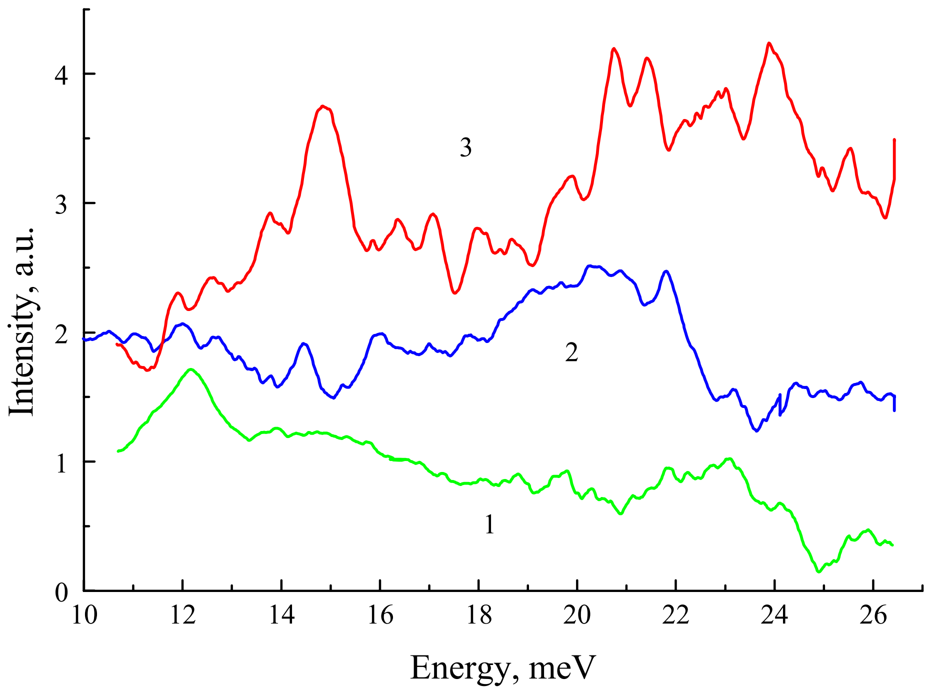

Fig. 1: Radiation spectrum at different electric fields.

The spectrum of THz radiation from compressed p-Ge at different voltages just above the voltage of impurity breakdown is shown in Fig.1. The upper curve shows that the low-voltage stimulated emission spectrum contains several peaks corresponding to direct optical transitions between different resonant and localized acceptor states. At the pressure of 7.15 kbar, the peak energies are 20.5, 21.5, 23, 24 and 25.5 meV (Fig. 2). The peak positions are shifted approximately by 1 meV to higher energies as compared with those observed at the pressure of 6.85 kbar under excitation with short (0.5 μsec) pulses of high voltage (up to 3 kV/cm); the high-voltage spectrum is shown, for comparison, in Fig. 2, too. This shift corresponds to the difference in pressure.

There are different regimes of heating carriers by high and low electric field applied. If the electric field is high enough for carriers to reach the optical phonon energy, the distribution function is stretched along the field direction. It is so called *streaming motion* regime. It begins at electric fields above approximately 20 V/cm for p-Ge. At low fields, the distribution function is due to *diffusive* heating regime and is nearly of Boltzmann type with electron temperature. Nevertheless, as it clearly seen from the existence of peaks in the emission spectrum (Figs. 1 and 2), the mechanism of low-voltage lasing in case of diffusive heating carriers is the same as for high electric fields when carriers accomplish the streaming motion. The lasing is due to stimulated optical transitions between strain-split acceptor states caused by an inversion of population of resonant acceptor states relative to that of localized states.

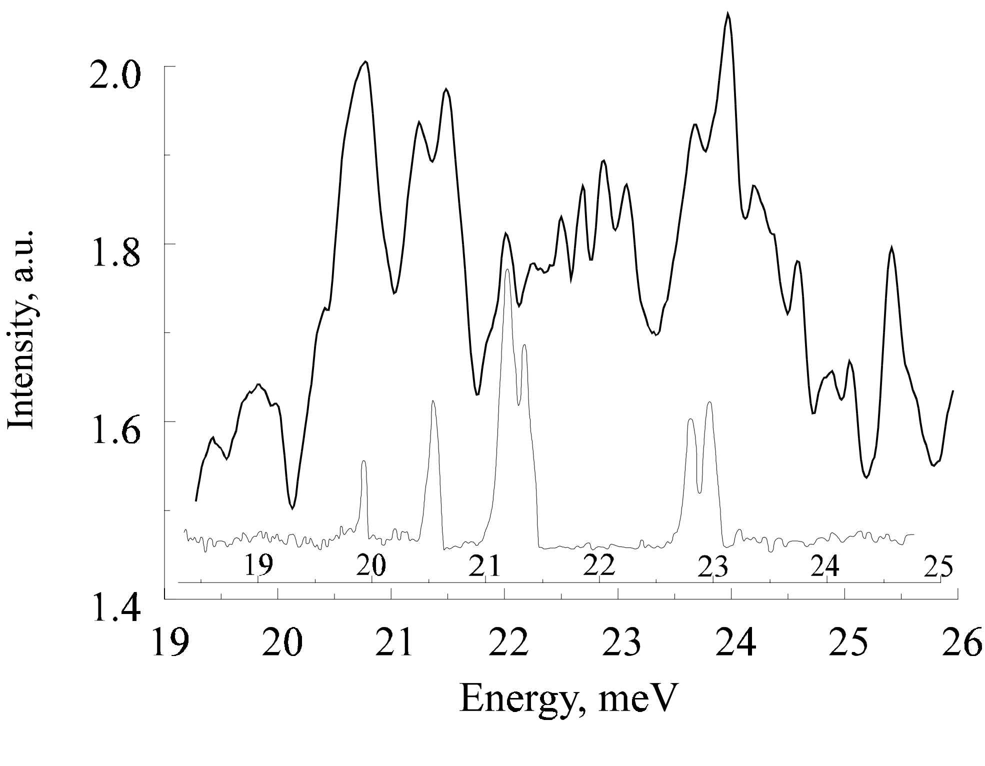

Fig. 2: Stimulated emission spectra at 14 V/cm (upper curve) and 3 kV/cm pulsed (0.5 μsec) electric field.