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A1-3 Stimulated Emission in InSb under the Two-Photon Excitation

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The two-photon excited semiconductor laser offers the possibility of providing a high power output, because the non-equilibrium carriers can be generated over a large volume in semiconductor by the two-photon excitation. For InSb, the electron mass is so small that the emission frequency can be easily changed with magnetic field. Therefore the two-photon excited InSb laser has the possibility of powerful and tunable light source in the infrared region.

Recently, the stimulated emission in InSb excited by a CO_2 laser has been observed by Manlief and Palik.[1)] But they could not observe the spontaneous emission due to the noise and the properties and mechanisms of it have been unknown in detail. We observed both the spontaneous and stimulated emissions in InSb and measured their emission properties, especially, the pumping wavelength dependence of the emission properties. This dependence is considered to be important to explain the mechanisms of the two-photon excited InSb laser.

The sample used was n-InSb with a carrier concentration of 4.47×10^{14} cm^{-3} and a mobility of 6.86×10^5 $cm^2/v.sec$ at 77 K. The shape of the sample was a rectangular slice. ($5.0 \times 5.0 \times 1.5$ mm^3) Two surfaces were polished to form an optical cavity with a length of 1.5 mm. The sample was mounted on a cold finger which was cooled at 20 K by a closed cycle refrigerator. The selected single line output from a TE CO_2 laser was focused on the sample by a KRS-5 lense. The TE CO_2 laser was excited by a line-type pulse generator in order to reduce a spark noise. The CO_2 laser beam propagated parallel to the axis of the optical cavity. The emission analyzed by a spectrometer was measured with a Au:Ge or a p-InSb detector which is low noise and sensitive at 5 μm region. The detected signal was displayed on an oscilloscope directly.

In Fig.1 is shown the example of the stimulated emission under the pumping at 9.3 μm. The stimulated output exhibited pulse-to-pulse variation in the peak power. The maximum emission intensity is plotted in Fig.2 as a function of pumping laser intensity. Exciting at 9.3, 9.6 and 10.3 μm, above the threshold for the stimulated emission, the emission intensity increased very rapidly. According as the wavelength of

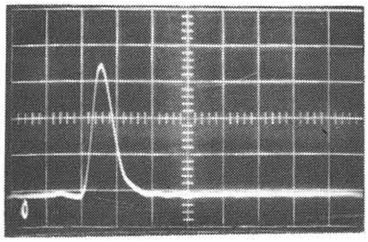

Fig.1 Oscilloscope trace of a stimulated emission detected by a Au:Ge detector.
sweep time : 1 μsec/div.

pumping light became longer, the threshold pumping intensity increased. Pumping at 10.6 μm, no stimulated emission was observed. It seems that this is due to the differences of transition probability in each case. Below the threshold, the spontaneous emission was observed at every pumping wavelength, of which intensity was proportional to square of the pumping laser intensity. This characteristic indicates the direct recombination of the excess carriers. The emission spectra are shown in Fig.3. The narrowing phenomenon was observed. The linewidths of spontaneous and stimulated emissions were measured about 1000 Å and 90 Å respectively. The wavelength of stimulated emission was varied with magnetic field which was applied perpendicular to the pumping beam. (see Fig.4) The shift of wavelength was about 18 Å/kG. This shift is smaller than the earlier reported one,[1] but similar to that of InSb diode laser.[2]

Further experiments are now in progress to clarify the mechanism of this InSb laser and to realize a powerful and tunable light source in the infrared region.

1) S.K.Manlief and E.D.Palik : Appl. Phys. Letters 22 (1973) 443

2) R.J.Phelan,Jr. and R.H.Rediker : Proc. IEEE 52 (1964) 91

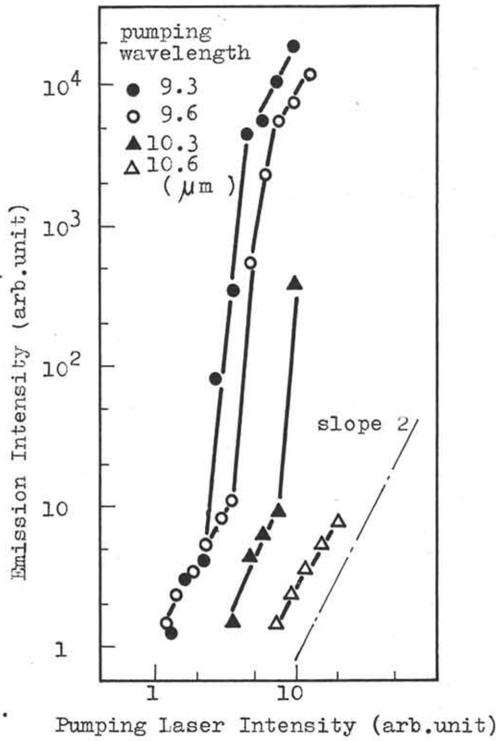

Fig.2 Pumping laser intensity dependence of the emission intensity, pumped at 9.3, 9.6, 10.3 and 10.6 μm.

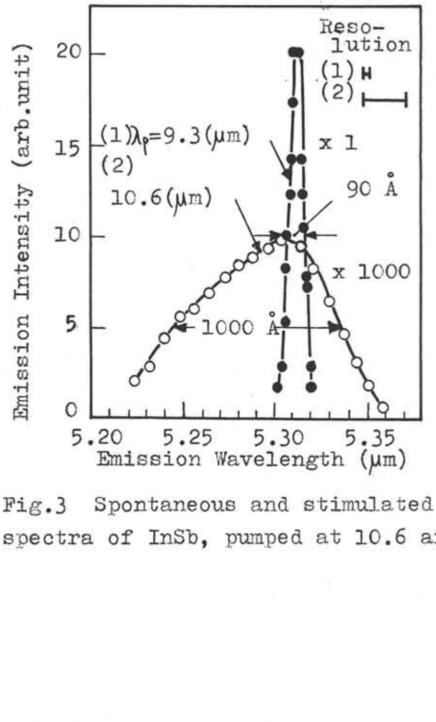

Fig.3 Spontaneous and stimulated emission spectra of InSb, pumped at 10.6 and 9.3 μm.

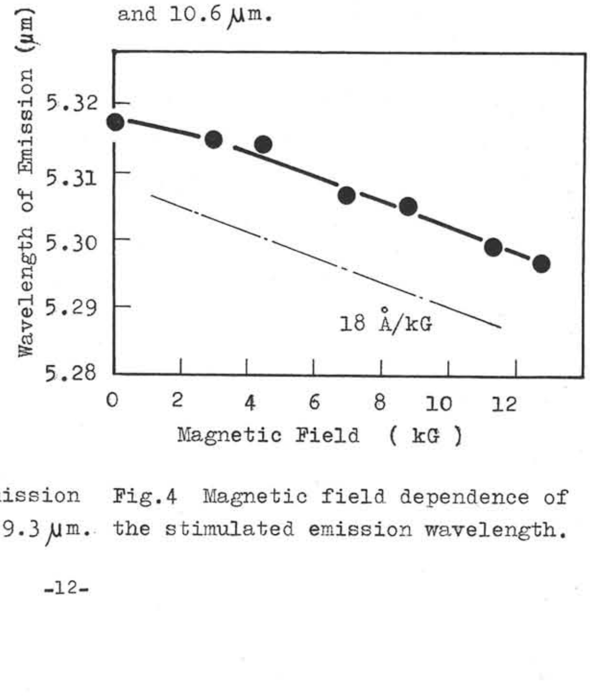

Fig.4 Magnetic field dependence of the stimulated emission wavelength.