Stimulated Optical Radiation in Ruby

Schawlow and Townes\(^1\) have proposed a technique for the generation of very monochromatic radiation in the infrared optical region of the spectrum using an alkali vapoour as the active medium. Javan\(^2\) and Sanders\(^3\) have discussed proposals involving electron-excited gaseous systems. In this laboratory an optical pumping technique has been successfully applied to a fluorescent solid resulting in the attainment of negative temperatures and stimulated optical emission at a wave-length of 6943 Å; the active material used was ruby (chromium in corundum).

A simplified energy-level diagram for triply ionized chromium in this crystal is shown in Fig. 1. When this material is irradiated with energy at a wave-length of about 5500 Å, chromium ions are excited to the \(^4F_2\) state and then quickly lose some of their excitation energy through non-radiative transitions to the \(^4E\) state. This state then slowly decays by spontaneously emitting a sharp doublet, the components of which at 300° K. are at 6943 Å and 6929 Å (Fig. 2a). Under very intense excitation the population of this metastable state \(^4E\) can become greater than that of the ground-state: this is the condition for negative temperatures and consequently amplification via stimulated emission.

To demonstrate the above effect a ruby crystal of 1-cm. dimensions coated on two parallel faces with silver was irradiated by a high-power flash lamp; the emission spectrum obtained under these conditions is shown in Fig. 2b. These results can be explained on the basis that negative temperatures were produced and regenerative amplification ensued. I expect, in principle, a considerably greater (\(\sim 10^6\)) reduction in line width when mode selection techniques are used\(^4\).

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