Stimulated Optical Radiation in Ruby

Schawlow and Townes¹ have proposed a technique for the generation of very monochromatic radiation in the infrared optical region of the spectrum using an alkali vapour as the active medium. Javan² and Sanders³ 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 $^2F_2$ state and then quickly lose some of their excitation energy through non-radiative transitions to the $^2E$ 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 ($^2E$) 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 (≈ 10⁶) reduction in linewidth when mode selection techniques are used¹.

I gratefully acknowledge helpful discussions with G. Birnbaum, R. W. Hellwarth, L. C. Levitt, and R. A. Satten and am indebted to L. J. D'Haenen and C. K. Asawa for technical assistance in obtaining the measurements.

T. H. MAITMAN
Hughes Research Laboratories,
A Division of Hughes Aircraft Co.,
Malibu, California.