

I. INTRODUCTION

This review concerns chemical lasers; what are they, and how do they compare with other high-power laser devices (Fig. 1)? First of all, what do we wish to include as a chemical laser? Not every device which consumes chemicals and produces laser output is necessarily a chemical laser (Fig. 2). However, a device in which chemicals are burned, with the reaction exothermicity immediately appearing as population inversion, will normally be referred to as a chemical laser (Fig. 3). In addition, however, we have recently seen a new definition of chemical lasers arise - "lasers involving chemical processes" (Fig. 4). Some of these are in reality electrically excited lasers and will not be treated in this review. However, the photodissociation lasers, such as the iodine lasers studied by Professor Karl Kompa, involve a non-exothermic chemical process, and will be included here.

II. PHYSICAL PRINCIPLES AND CHEMICAL REACTION SYSTEMS

Most chemical lasers operate on vibrational-rotational transitions in a diatomic molecule. The energy levels of such a molecule are approximately represented by the allowed energy states of a rotating vibrator as given by quantum mechanics. The strongest laser transitions involve a vibrational change $\Delta V = -1$, and a rotational change of $\Delta J = +1$, as indicated in Fig. 5.

Given these possible energy levels in the lasing molecule, we must ask: How does a chemical reaction lead to vibrational inversion? Figure 6 shows a crude "billiard ball" picture of the reaction between a fluorine atom and a hydrogen molecule, as seen in the center of mass system. The fluorine atom approaches the hydrogen molecule, and sometime during the collision the electronic orbits change in such a way that the chemical bond is shifted. After the collision, the fluorine is bonded to one of the hydrogen atoms, and the other hydrogen atom departs alone. We know from the chemical bond energies that this total process leads to a release of energy. The question is, in what form is the energy released?

From a physical standpoint, we may use the following intuitive picture. The electrons move in their orbits so much more rapidly than the heavy atoms that the chemical bond shift is accomplished in a very short time during the collision. This occurs too rapidly for the heavier atoms to accelerate, so that the energy release tends not to appear in the form of

heavy atom velocities (kinetic energy). Instead, the electron jump occurs when the hydrogen and fluorine atoms are further apart than they would be in equilibrium in an HF molecule. Thus, the HF molecule is formed with a "stretched" molecular bond, containing potential energy. Then, as the HF and H separate, this stretch is converted into vibration in the newly formed bond. Thus, according to this simplified picture, an exothermic reaction may lead to products with strongly excited vibrational modes.

Figure 7 gives an example of this vibrational excitation in a special case - in which a covalent molecule reacts and yields an ionic molecule as a final product. The figure shows the potential energy of the system as a function of the separation between A and BC, for the reaction $A + BC$. The difference in potential curves for the two configurations at large separations is equal to the ionization potential of A, minus the electron affinity of BC. However, the potential curves cross at shorter distances because of the strong coulomb attraction in the ionized configuration $A^+ + (BC)^-$. Thus, if the system begins in the configuration $A + BC$ with the separation between A and BC decreasing, there comes a time during the collision when the system can change to the ionized configuration $A^+ + (BC)^-$ while still conserving its internal (potential) energy. Then as the atoms separate, the A^+ atom uses coulomb attraction to pull a B^- atom out of the $(BC)^-$ molecule. This particular process, which specifically