


POPULATION PROCESSES IN HIGH-PRESSURE INERT-GAS-MIXTURE LASERS

A. R. Sorokin

Working-level-population processes are analyzed on the basis of detailed investigations of the amplitude-time structure of the laser and spontaneous emission following a pulsed electric discharge in the mixtures He + R (R = Ar, Kr, Xe), Ar + Xe. Account is taken in the analysis of excitation by electrons (direct and stepwise) and of population as a result of relaxation processes (collisions of second kind with electrons; radiative cascades, recombination processes; collisions with the atoms of the working and buffer gases; excitation transfer from helium molecules). It is concluded that under optimum efficiency conditions inversion is produced in the lasers considered as a result of direct electron collision with the working atoms (Ar, Kr, Xe), which are in the ground state.

INTRODUCTION

This paper is devoted to an investigation of the mechanisms whereby inverted population is produced in high-pressure lasers (p > 1 atm) on transitions of Ar, Kr, and Xe.

It is known that Ar, Kr, and Xe have at low pressure (p \( < 10^{-3} \) atm) about 140 atomic lines [1]. Most of them belong to the transitions \((n+1)s-np\) and \((n-1)d-np\) \((n = 4, 5,\) and 6 for Ar, Kr, and Xe, respectively). Also known are nine \(np-ns\) laser lines, all of which terminate on metastable \(ns\) levels [2]. The remaining lines correspond at low pressure to \((n+1)p-(n+1)s\) and higher-placed transitions. In most cases, lasing is observed during the time of pump action, but also in the discharge afterglow in isolated transitions [3].

The \(s\) and \(d\) levels are optically linked with the ground state. Their excitation function by electrons reaches a maximum within 2-3 times the threshold energy and falls off gently (for \(4\theta'_{1/2}\), of argon, Fig. 1).

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Fig. 1. Excitation functions for the argon levels \( 4p_{1/2} \), \([5]\) and \( 4s_{1/2}^0 \), \([4]\).

Transitions from p levels to the ground state are forbidden. The effectiveness of excitation of these levels, starting with the threshold, increases rapidly and reaches a maximum within one threshold energy unit. The maxima of the excitation functions are clearly pronounced (for \( 4p_{1/2} \), of argon, Fig. 1). The largest cross sections, comparable with those of the resonant ns levels, are possessed by the very lowest np levels.

Owing to the abrupt fall-off of the effectiveness of the np-level excitation at high electron energies, no inversion is produced on the np-ns transition, e.g. in Ar and Ne, as a result of direct electron impact at low pressure, owing the stepwise population by electrons via the resonant ns levels \([2]\). On the contrary, inverted states of the s-p or d-p transitions are obtained as a result of direct electron excitation \([6]\). Afterglow lasing appears as a result of recombination processes \([7]\).

In the mixtures He + R (R = Ar, Kr, Xe) at high pressures there are only 20 transitions. They are listed in \([8, 9]\), and for R and Xe also in Tables 1,2. Seven lines start out from the np levels, and six of them are observed only at high pressures. It is surprising that laser lines that terminate on 4s resonance levels were observed in an He-Ar laser from the \( 4p_{1/2} \), level of argon \([8]\). The remaining lines, observable also in low pressures, belong to the transitions \((n-1)d-\text{np}\), and in Kr and Xe also to \((n+1)p-(n+1)s\) (three lines).

The high-lying laser transitions have thus vanished at high pressures. The transitions \((n+1)p-(n+1)s\) and \((n-1)d-\text{np}\) have become greatly impoverished. Although the number of np-ns lines changed insignificantly, their spectral composition became completely redistributed.

The energy properties and the mechanism of inversion on the transitions of Xe at atmospheric pressure of the working mixtures were investigated in a number of papers \([12-18]\), but under substantially different excitation conditions.

The emission of an electric-discharge He-Xe laser with less than 0.1% xenon was concentrated in the afterglow of the discharge, and the population of the working levels was due to recombination \([12, 13]\).

Lasing was observed in \([12, 13]\) also during the action of the pump, but at much lower energy. On the contrary, in \([14, 15]\) (Xe content ~1%) and also in \([8, 9]\) the bulk of the emission of an He + R laser took place during the action of the current pulse. The inversion mechanism was attributed in these cases, albeit without detailed corroboration, to direct excitation by electrons. It was shown in \([16]\) that the decisive role in the electron-beam-controlled Ar-Xe laser is played by stepwise excitation and ionization of the xenon via long-lived 6s levels.

Detailed investigations of the laser transition \( 4p_{1/2} \rightarrow 4s_{3/2}^0 \) in the He + Ar mixture were carried out in \([19]\). In the author's opinion, inversion is produced on the transition as a result of direct transfer of excitation from molecular states of helium.