L. I. Gudzenko, I. S. Lakoba, Yu. I. Syts'ko, and S. I. Yakovlenko. *Analysis of the possibility of amplifying* VUV *radiation in a helium plasma.* The possibility of basing a plasma laser[1] on the photodissociative $A^1\sum_u^+ \rightarrow X^1\sum_q^+ (\rightarrow 2\mathrm{He}1^1S_0)$ transition of helium dimers ($\lambda \approx 815$ Å) is discussed. The analysis is carried through on the basis of numerical calculations made with a multi-level self-consistent model of the relaxation of a dense helium plasma. Cases of pumping with a pulse of a relativistic electron beam and the afterglow of a gas breakdown by a laser discharge are investigated.

The physical principles of population-inversion formation in such a medium and the principal relaxation mechanisms have been discussed in Refs. 1, 2. A scheme of the relaxation transitions taken into account by the model is given by Fig. 1. The atomic and dimeric excited-state populations, the charged-particle concentrations, and the electron (T_e) and gas temperatures are described as functions of time by a complex

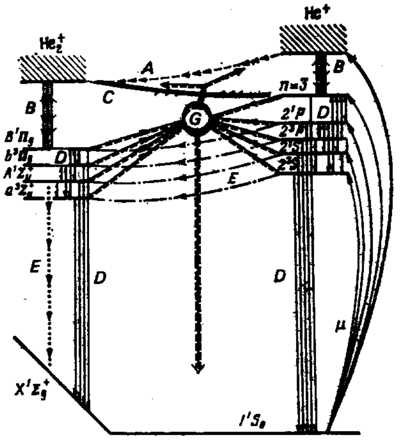

FIG. 1. Diagram of relaxation transitions in helium plasma. A) conversion of atomic ion; B) three-particle recombination and stepwise ionization; C) dissociative recombination and associative ionization; D) transitions between states of discrete spectrum on collisions with plasma electrons; E) spontaneous photodissociative transition; F) collisional association of excited atoms with unexcited atoms; G) Penning processes; H) pumping.

system of essentially nonlinear ordinary differential equations (a total of 14 equations). It has been found practically impossible to solve it by traditional computational methods because of the need to use an unrealistically small step (to insure the necessary accuracy) owing to the distribution over several orders of magnitude of the characteristic times of the processes taking place in the plasma. These difficulties were overcome by using Gaer's algorithm.[3] The gas density N and the "pump frequency" ν were specified as the basic parameters. In electron-beam pumping, $\nu(\mathrm{sec}^{-1}) \approx 6.25 \cdot 10^{18} j(\mathrm{A/cm}^2)\sigma(\mathrm{cm}^2)$, where j is the current density and $\sigma(V)$ is the cross section for inelastic interactions of the beam electrons (V is their energy) with atoms of the gas.

Data on the photoionization cross sections σ_{phi} of the excited dimers at the frequency of the working laser transition, which are needed to take absorption into account, are not yet available. We used values of σ_{phi} obtained for the He$_2^*$ molecule by extrapolating the corresponding experimental values for the He* atom. The results of extrapolation agree with the quasiclassical estimate of σ_{phi} according to Kramers.

In the case of beam pumping, the calculations permitted detailed analysis of the dynamics of the plasma parameters and the amplification coefficient $\varkappa$, as well as qualitative investigation of the relation between them. The results confirm the basic conclusions of the earlier[1,2] qualitative theory of lasing using excimers. In the ranges $N = 3 \cdot 10^{19}$ to $3 \cdot 10^{21}$ cm^{-3} and $\nu = 10^3 - 10^5$ sec^{-1}, the plasma becomes supercooled as soon as T_e reaches a quasistationary value. The maximum $\varkappa^{\max}$ of the amplification factor for the He$_2 A^1\Sigma_u^+ \to$ He$_2 X^1\Sigma_g^+$ transition is always reached under nonequilibrium recombination conditions. Figure 2 shows plots of $\varkappa^{\max}$ against N and ν (gas without impurities, current-pulse duration 12 nsec). Calculations indicate that values 10^{-2} cm^{-1}, which are sufficient for self-excitation, can be obtained at the technically feasible pump parameters $N \sim 3 \cdot 10^{21}$ cm^{-3} and $j \sim 10^5$ A/cm^2 ($V \sim 1$ MeV); the impurity content in the helium must not exceed φ 10^{-6}.

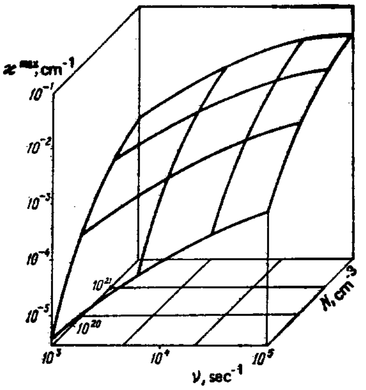

FIG. 2. Maximum value of amplification factor vs. pump parameters (electron-beam source).

TABLE I

N, cm^{-3}	ν_{eq}, sec^{-1}	N_e (0), cm^{-3}	W, W/cm^3	$\varkappa_{\max}$, cm^{-1}
10^{21}	10^8	10^{18}	$8 \cdot 10^{11}$	0.1
10^{21}	10^9	10^{19}	$8 \cdot 10^{12}$	0.6
$3 \cdot 10^{21}$	10^8	$3 \cdot 10^{18}$	$2.4 \cdot 10^{12}$	0.35
$3 \cdot 10^{21}$	$3 \cdot 10^8$	10^{19}	$8 \cdot 10^{13}$	0.9
$3 \cdot 10^{21}$	10^9	$3 \cdot 10^{19}$	$2.4 \cdot 10^{13}$	2.5

In contrast to the electron beam, the energy of laser radiation can be concentrated in a very small volume and be introduced into the medium much more rapidly. The table gives results of model estimates and calculations of $\varkappa^{\max}$ for the case of breakdown of a gas by an ultrashort ($\sim 10^{-11}$ sec) flash of light focused in a cylindrical region ~ 10 cm long and $\sim 10^{-2}$ cm in diameter. Here $N_e(0)$ is the initial electron concentration and W is the specific power input. The resulting requirements for the laser pumping source do not appear too difficult.

The material of the paper has been published.[4]

---

[1] L. I. Gudzenko, L. A. Shelepin, and S. I. Yakovlenko, Usp. Fiz. Nauk **114**, 457 (1974) [Sov. Phys. Usp. **17**, 848 (1975)]; L. I. Gudzenko and S. I. Yakovlenko, Plazmennye lazery [Plasma Lasers], Atomizdat, Moscow, 1972.

[2] L. I. Gudzenko, I. S. Lakoba, and S. I. Yakovlenko, in: Trudy Fiz. Inst. Akad. Nauk SSSR Vol. **90**, Nauka, Moscow, 1976, p. 61.

[3] C. W. Gaer, Comm. ICM 14, 176 (1971).

[4] L. I. Gudzenko, I. S. Lakoba, Yu. I. Syts'ko, and S. I. Yakovlenko, Preprint IAÉ-2912, Moscow, 1977.

Translated by R. W. Bowers