Letters to the Editor

ON THE DEVELOPMENT OF RADIAL DISTRIBUTION OF EXCITATION DURING THE PUMPING IN THE POWER STAGE OF AN IODINE LASER[1]

ОБ ЭВОЛЮЦИИ РАДИАЛЬНОГО РАСПРЕДЕЛЕНИЯ ВОЗБУЖДЕНИЯ ВО ВРЕМЯ НАКАЧКИ ИОДНОГО ЛАЗЕРА В КАСКАДЕ УСИЛЕНИЯ МОЩНОСТИ

L. PEKÁREK[2], V. KREJČÍ[2], Praha

System of nonlinear partial differential equations describing the absorption of pumping light and photolysis in a cylindrical geometry is solved numerically. It is shown that an optimum duration of the pumping discharge exists in the investigated simplified situation.

In the power stage of the iodine laser constructed at FIAN USSR [1], a high current pulse discharge initiated by wire explosion in the axis of the laser tube has been used as the source of optical pumping. This arrangement makes it possible to utilize high energy ultraviolet photons which, in the alternative arrangement with quartz flash lamps, are absorbed by the lamp walls. On the other hand, by the wire-initiated pumping, the usable volume of the active mixture decreases due to the intensive shock wave propagating rapidly through the gas medium from the tube axis outward.

In order to achieve high output power, it would be ideal to attain full dissociation of the used C_3F_7I (or CF_3I) molecules even near the tube walls at a time when the cylindrical portion of the tube volume hit by the shock wave is still small enough.

The photodissociation increases the transparency of the gaseous medium, so that photons, emitted by the cylindrically expanding source at a later time, penetrate to greater distances and accomplish the pumping even farther away from the source.

The total usable energy stored in the excited iodine atoms in the laser tube depends on the degree of inversion (which, if the pyrolysis and other loss processes are neglected grows during the pumping with growing time) and on the volume of the region not yet hit by the shock wave (this volume decreases with growing time). It is apparent that an optimum duration of the pumping light pulse must exist, during which the total number of excited atoms in the usable volume of the laser tube is maximal.

A detailed analysis of the pumping kinetics, published in [2], takes into account a number of reactions in the gas mixture (including pyrolysis), but restricts itself to the region of the thin sheat in front of the light source. The dependence of the changes in the mixture on the space coordinates is thus ignored, and the problem is reduced to the solution of a system of ordinary differential equations describing the time changes of the different components of the misture.

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[2] Institute of Physics, Czechosl. Acad. Sci., Na Slovance 2, 180 40 PRAHA, Czechoslovakia.

In the presented contribution a very simplified kinetic model is used, but the spatial propagation of the inversion is taken fully into account. The model is described by the following system of nonlinear partial differential equations:

$$\frac{\partial N}{\partial t} = -\beta NI \qquad (1)$$

$$\frac{\partial I}{\partial r} = -\alpha NI - I/r,$$

where N is the density of the parent molecules (C_3F_7I), I is the local intensity of the pumping radiation (both supposed to depend on the time t and on the radius r), α and β are constants depending on the medium.

We have solved system (1) numerically for several values of constants and for different initial and boundary conditions, using the IBM 370 computer. The total power of the pumping source and the energetic spectrum of the emitted photons were taken as constant for the calculation, while the radius of the radiating cylinder of the source r_1 grew from its initial value r_0 with the speed V of the shock wave.

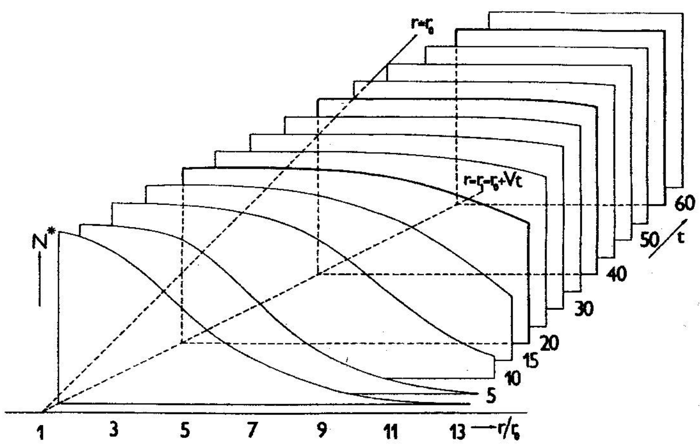

Fig. 1. Radial distribution of excited iodine atoms N^* for different times t. r_0 — initial radius of the pumping discharge, r_1 — radius of the shock wave propagating with a constant velicity V. The intensity I of the pumping radiation is supposed to be constant at $r = r_0$ for any time.

In Fig. 1 there is an example of the computed dependence of the excited atoms density on the space coordinate r for various times. The total number of excited iodine atoms in the volume not hit by the shock wave obtained by numerical integration as a function of time is shown in Fiq. 2. The maximum of the determined curve is rather pronounced and is attained for the chosen parameters at $t \doteq 25$.

The program form solving system (1) has been designed so that, if needed, the discharge intensity as well as the shock wave speed can be chosen as time dependent.

A system similar to (1), but formulated for a plane problem, describes the amplification of a light wave propagating along the tube axis. If used as the end stage amplifier of a nannosecond light pulse, the iodine laser utilizes only one of the two excited levels of the $^2P_{1/2}$ iodine atom state, since these two states act separately due to a long relaxation time of mutual transitions. If, however, an optical pulse

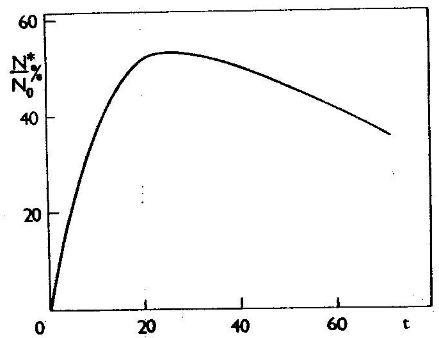

Fig. 2. Time dependence of the total number of excited iodine atoms in the active volume of the laser tube. N_0 — the initial number of parent molecules in the whole tube.

containing both frequencies occurring due to the hyperfine splitting could be used for amplification, as proposed in [3], an increase of the output power by up to 50 % could be expected.

Amplification of the two simultaneous pulses with different frequencies is, however, not independent, as the ground state $^3P_{3/2}$ of the iodine atom is in spite of its hyperfine splitting common to both frequencies due to fast relaxation processes. This causes a coupling between the two amplified waves, which may lead, e.g., to an irregular or oscillatory amplitude modulation and can influence the output power. A simple adaption of the computer program used for solving system (1) should be sufficient for treating the latter problem, too.

REFERENCES

[1] Borovič, B. L., et al.: *Silnotočnyje izlučajuščije razrjady i gazovije lazery s optičeskoj nakačkoj* (Editor N. G. Basov); Radiotechnika *15* (19xx), 133.
[2] *ibid*, p. 133.
[3] *ibid*, p. 189.

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