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Influence of hydrogen on the characteristics of an excimer XeCl* laser

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The characteristics of an electric-discharge XeCl* laser were improved by the addition of hydrogen to an He–Xe–HCl mixture. The energy of the output radiation pulses increased by 15% and the operation of the laser became stabilized. A study was made of the dependence of the output energy on the hydrogen concentration.

Beginning from the seventies the popularity of excimer lasers as effective sources of visible and ultraviolet radiation has increased. The best characteristics among excimer lasers have been reported for rare-gas halides KrF*, XeCl, etc. Further forced energy deposition in the medium is causing difficulties, so that it would be highly desirable to consider improvement of the excimer laser characteristics by optimization of the composition of the gas mixture.

The present paper reports an increase in the efficiency of an electric-discharge XeCl* laser on addition of hydrogen to an He–Xe–HCl mixture. We shall give the dependence of the output energy of the laser on the hydrogen concentration.

The active medium was excited by a transverse discharge preceded by ultraviolet preionization. The electrical part of the apparatus was in the form of the circuit shown in Fig. 1. A storage capacitor C_0 consisted of three K-15-10 capacitors connected in parallel and 10 nF each. A high-pressure spark gap G was used to switch on the discharge. The dimensions of the main discharge gap were $60\times0.5\times2$ cm (where 2 cm was the distance between the electrodes). The voltage across the electrodes was $U = 18$ kV, the duration of the discharge at midamplitude was $\tau_d \approx 50$ ns, the duration of the laser output pulses was $\tau_l \approx 30$ ns. The output energy was measured with a IKT-1M calorimeter and the duration of the output pulses was determined with an FK-22 photocathode.

Preliminary ionization of the medium was provided by a discharge on the surface of an insulator. The preionization system[2] was located axially along the electrodes. The discharge on the insulator surface was characterized by a high spectral brightness in the short-wavelength range, which ensured effective preionization of the gas mixture.

The influence of the addition of hydrogen on the output characteristics of the laser was investigated as follows: first, the composition of the He–Xe–HCl mixture was optimized in respect of the output energy. It was found that when this composition was He:Xe:HCl = 1000:10:1, the energy reached 21 mJ, which corresponded to an efficiency of $\eta = 1.5\%$ relative to the stored energy. Then, hydrogen was added to this optimized He–Xe–HCl mixture. The dependence of the output energy on the hydrogen concentration was determined (Fig. 2). In the case of a mixture with the He:Xe:HCl:H_2 = 1000:10:1:1 composition the energy of the radiation pulse is increased by 15% reaching 25 mJ; moreover, the stability of operation of the laser improved. Lasing occurred at wavelengths $\lambda_1 = 307.87$ and $\lambda_2 = 308.0$ nm. An improvement in the reproducibility of the energy from one pulse to another was clearly due to recovery of the HCl molecule by the reaction

$$H_2 + Cl_2 \rightarrow 2HCl. \qquad (1)$$

Since an increase in the energy deposited in the mixture resulted in a practically linear increase in the output energy, it was concluded that the HCl donor was not significantly "depleted" during one pulse. Therefore, the increase in the energy of the first pulses in the series could not be explained by the reaction (1). The improvement in the output characteristics of the laser was clearly due to the following factors:

1) cooling of electrons due to excitation of vibrations of the H_2 molecule:

$$H_2 + e \rightarrow H_2(v) + e, \qquad (2)$$

which increased the rate of excitation of vibrations of the HCl molecule[1] in accordance with the reaction

$$HCl + e \rightarrow HCl(v) + e; \qquad (3)$$

2) transfer of the vibrational excitation from the molecules

$$H_2(v) + HCl \rightarrow HCl(v) + H_2.$$

Therefore, when hydrogen was added to the He–Xe–HCl mixture, there was an effective increase in the

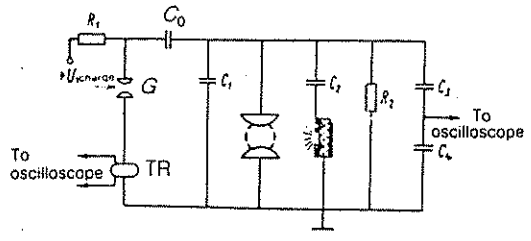

FIG. 1. Electrical part of the apparatus: R_1 and R_2 are resistors in the charging circuit; C_0 is a storage capacitor; G is a discharge gap; C_1 is a peaking capacitor; C_2 is a decoupling capacitor in the preionization circuit; C_3 and C_4 are capacitors in the voltage divider circuit; TR is the current transformer.

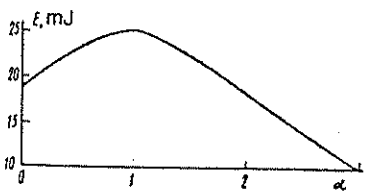

FIG. 2. Dependence of the output energy on $\alpha = [H_2]/[HCl]$ for a mixture of the He:Xe:HCl = 1000:10:1 composition with $[He] = 8\times10^{19}$ cm^{-3}.

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mber of vibrationally excited $HCl(v)$ molecules and of ctive $XeCl^*$ molecules as a result of the multistage process $HCl(v) \rightarrow Cl^- \rightarrow XeCl^*$.

When the hydrogen concentration was $[H_2] > 1.5[HCl]$, there was a strong reduction in the output energy of the laser. This was due to quenching of the $XeCl^*$ molecules by hydrogen and due to absorption of laser radiation by the H_2 molecules.

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Lasing due to impurity color centers in yttrium aluminum garnet crystals at wavelengths in the range 1.35–1.45 μm

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Low-threshold wide-band lasing was achieved for a YAG crystal with optically and thermally stable color centers. The absorption and luminescence spectra were determined, and the gain was measured in the range of wavelengths corresponding to the color-center luminescence. The cross section of the lasing transition was estimated (8×10^{-19} cm^2) and the efficiency of conversion of the pump radiation from a neodymium laser into the output radiation was determined (10%).

Solid-state tunable lasers operating in the near infrared have some important applications. Much of the work on these lasers has been concerned with the spectral and lasing characteristics of crystalline materials doped with transition-metal ions V^{2+}, Ni^{2+}, and Co^{2+} and with lasers made using these materials and emitting in the range 1.2–1.8 μm (Ref. 1). However, lasers of this type are not used widely because the active medium has to be cooled to cryogenic temperatures. Considerable progress has recently been made on the construction of color-center lasers using alkali halide crystals, which can operate efficiently at room temperature.[2,3] Unfortunately, the instability of the parameters of active elements of lasers of this type under the influence of elevated temperatures or of ultraviolet and visible optical radiation limits seriously the potential applications of these lasers.

We shall report lasing observed in the range 1.35–1.45 μm for optically and thermally stable impurity color centers in yttrium aluminum garnet (YAG) crystals. Impurity color centers in crystals with the garnet structure can be formed by doping with chromium and oxidation of this impurity to the quadrivalent state. These color centers have strong absorption bands in the visible and near-infrared parts of the spectrum. Figure 1 shows the absorption spectrum recorded at 300 K for a YAG crystal containing color centers. Excitation of such a crystal in the absorption band of the color centers produced luminescence in the wavelength range 1.25–1.7 μm, the spectrum of which is shown in Fig. 2. The luminescence decay kinetics observed on pulsed excitation of the color centers with a Q-switched and neodymium laser was exponential with a time constant 4.6 μs at 300 K. Bleaching of the crystals with color centers was observed in a band at 9000–12 000 cm^{-1} when they were subjected to the same neodymium laser radiation and the density of the absorbed energy was ~40 mJ/cm^3, which indicated that a population inversion was attained for the main transition in the color centers. Bleaching of YAG crystals with color centers in the absorption band at moderate densities of the absorbed energy and the wide spectrum of the color-center lumines-

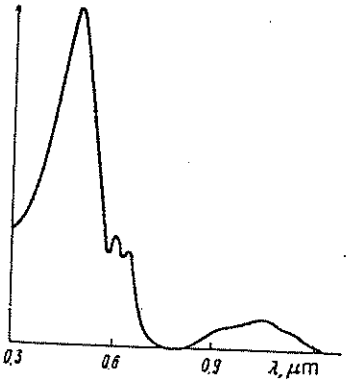

FIG. 1. Absorption spectrum of a YAG crystal with color centers.

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RGG R590

Lots made up

look up in PPL manual

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conc Osc g/liter

1/2 liter

~~in draw~~

RGG in frig

glass jar Methanol if possible