THE DISCHARGE IN INI VAPOR AS A LASANT FOR INDIUM 451.1 NM LASER

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Abstract

An indium atom transition 451.1 nm from resonant to metastable state is considering to obtain laser action according to the well known scheme of lasers on selfterminating transitions. The ini salt was taken as a source of indium atoms in discharge. Emission spectra of discharge clearly shows large efficiency of excitation of 451.1 nm indium selfterminating transition.

1. Introduction

The copper vapor laser, that has a number of unique properties is the most well known among the lasers on selfterminating transitions (st). A large progress was made during the 35-years period of development of this direction in laser physics but there are still a number of large problems. Among them - the creation of an effective blue st laser, the solution of which will result the development of color laser projection systems for optical amplification of images brightness. Here we present the results of experimental investigation on the possibility of obtaining laser oscillation on the st of indium atom.

Only the Bi- and Fe- lasers on atomic ST are known in the blue spectral region [1, 2]. Both of them demonstrates the low average power and efficiency of laser action and thus have not any significant applications.

The indium atom, that depends to the third group of the periodical system of elements, is attractive due to its peculiar structure of energy levels (see Fig.1). The ground 5p $^2P_{1/2}$ and metastable 5p $^2P_{3/2}$ ($E_e = 0.274$ eV) levels of In atom belongs to the $4d^{10}5s^{2}5p$ electron configuration. The excitation of $5p \rightarrow 6s$ external electron results the creation of an isolated resonant 6s $^2S_{1/2}$ state ($E_e = 3.02$ eV). The transitions between the levels of these configurations forms a spectral doublet - the resonance line 410.1 nm and ST line 451.1 nm.

The boundary efficiency determined as

$$\eta = \frac{g_m}{g_r - g_m} \frac{E_r - E_m}{E_r},$$

have the value of 60.6 % ($E_r, g_r$ and $E_m, g_m$ - the excitation energies and statistical weights of the resonant and metastable levels). An additional argument for the investigation of the indium vapor
as lasant for a perspective ST laser on blue line was the similarity of its electron structure to the thallium atom, on the green ST line of which laser action has been observed [3] previously.

![Graph showing energy levels and transitions of the indium atom]

**Fig.1. The structure of the indium atom energy levels (energy, ev) and transitions (wavelengths, nm; transition probabilities, 10^7 s^-1).**

It should be mentioned about a number of limitations on the possibility of obtaining lasing oscillation on in st line. First of all it is the very low energy of metastable level laying close to the ground state. The necessary saturated pressure of indium vapor (0.1 mm hg) can be reached at 1042 °C [4] and at this conditions the metastable to ground states population ratio has a value of 0.18. Meanwhile, one of the gould criteria of effective st laser as well as the experience of work with these lasers demands the value of this ration less than 10^-3. This excludes the possibility of using the pure indium metal probe for vaporization in the discharge tube. Another limitation concerns the branching ratio for transition probabilities from resonant level both to ground and metastable states [5] (see fig.1). Thus the excitation of the upper laser level should be realized at very high speed.

2. Experimental setup

In our investigations the discharge zone was confined by ceramic o-rings (10 mm id) placed in the quartz tube. The ini salt pieces were placed between them. The length of the discharge zone was 400 mm. External oven was used for the heating of the discharge tube. According to [6], the saturated vapor pressure of ini 2 mm hg (the smallest pressure at the scale) corresponds to 400 °C. The approximation of the pressure to 0.1 mm hg gives the temperature value 300 °C.

The discharge was excited in the pulse-periodical mode using the discharge circuit with storage capacitor (2200 pf) and a commutational thyratron tgi1-2000/35.

3. The experimental results

The discharge emission spectra (integrated by time) of the ini vapor mixture with neon and
helium were investigated varying the excitation conditions (tube temperature 100 - 400 °C, buffer gas pressure 2 - 30 mm Hg, pulse repetition frequency 3 - 10 kHz and 100 Hz). To record these spectra the grating grid monochromator mdr-6, photomultiplier feu-106, amplifier v7-30 and an x-y recording device were used. An example of the obtained spectra is presented at fig.2. These spectra are almost similar in spite of the different excitation conditions. In the whole range of the apparatus spectral sensitivity the intensities of in atom spectral lines are dominant. The highest intensities are observed for the transitions from the resonant level and for the $5^2d_{3/2,5/2} \rightarrow 5^2p_{3/2}$ transitions (325.6 + 325.8 nm). Other atomic lines we determined as the transitions between the lowest states of in atoms. Two molecular emission bands of the parent molecules ini - a → x (~ 410 nm) and b → x (~ 400 nm) [5] are also observed. A number of low intensity lines were not identified. Such kinds of emission spectra are typical for the copper-halide st laser.

The absorption spectra (Fig. 3) also were obtained using the continuous spectral source (hydrogen and hot filament lamp), the radiation of which passed through the laser tube with the discharge switched off. The absorption molecular bands of InI X - A, X - B and X - C transitions were observed. The last one, C → X band was not registered on the emission spectra. The resonance line 410.2 of In is located within the X - A absorption band.
Fig. 3. The absorption spectrum of the InI vapor

\((p_{Ne} = 2 \text{ mm Hg, } t = 20 (1), 200 (2), 370 (3) \degree C)\).

Nevertheless, no stimulated emission was observed. We have suggested, that the choice of the InI salt was not successful, because of the not satisfactory ratio of the metastable to ground states concentration of indium atoms \(\sim 10^{-2}\) at vapor pressure of 0.1 mm Hg. In future, another chemical compound of In will be used - InBr\(_3\) - for which this ratio is \(\sim 2 \times 10^{-3}\).

References