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The Inversed Populations in the Active Medium of an Electronic Energy Explosion (EEE) in the Air

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Abstract

Electrical discharge at the voltage 440 V near the surface of the ferrite piece is used for initiating of electronic energy explosion (EEE) in the air. In the active zone of EEE proceeds the nitrogen oxidation branched chain reaction. The mirrors of an optical resonator are positioned at both sides of the active zone of EEE. Blue super-luminescence is observed at these conditions. Addition of moistened sodium nitrate powder in the active zone of EEE results in appearance of laser generation in red and green regions of spectra. The obtained results are interpreted in terms of branched chain reaction producing electronically excited atoms O(1S) and molecules NO(B 2Π) and NO_2*.

Keywords:* Branched chain reaction; Electrical discharge; Electronic energy; Electronically excited molecules and atoms; Explosion; Laser generation; O(1S); NO(B 2Π); NO_2*; Nitrogen oxidation; Populations inversion; Sodium nitrate; Stimulated emission of radiation

Introduction

A chemical-kinetic model of nitrogen oxidation branched chain reaction has been recently published [1]. According to this model, three kinds of electronically excited particles are involved in the chain mechanism: NO (B2Π), N_2-O(1S), NO_2*. All three of them are able to produce laser generation of visible radiation.

According to the review [2] of experimental data concerning EEE in Air that has been published recently, the key in understanding the nature of the EEE lies in the fact that the electrical discharge near the surface of a ferrite piece is formed at the voltage of about 400 V/cm, which is by two orders of magnitude lower than what is needed for the production of electronic avalanches by the ionization of molecules in collisions with electrons. For this reason, the role of chemical ionization processes (like O(1S) + N => NO(+) + e(-)) increases. Formation of O(1S) atoms in the chemical chain reaction results in EEE. Thus, EEE in the air enables us to perform the branched chain reaction mentioned above in the experiment.

Electro-explosion of sodium nitrate [3] produces a radiating gas-dust cloud. The light emitted by this cloud is produced by the mechanism of stimulated emission of radiation [3].

The design of the discharge unit, used in our last experiments with EEE (FIG. 1) allows us to cover one of the electrodes with sodium nitrate powder. This could result in an intensification of O(1S) atoms production by sodium nitrate decomposition in the discharge zone. O(1S) atoms play an important part in the mechanism of nitrogen oxidation chain reaction [1]. One can assume that an increase in the chain reaction velocity would increase the laser generation intensity in the reaction zone. The aim of this work was to investigate such a possibility.

Methods

The experimental installation used is outlined in FIG. 1. The AC-rectifier charges the capacitors (C = 1000 μF) to the voltage of 220 V (on each of them). Putting electrodes A and B into electrical contact results in 440 V voltage applied to the discharge gap 2. Both electrodes of the discharge gap are in contact with the surface of a ferrite core 1. Such ferrite cores are used in TV fly back transformers. At the voltage of 440 V between the electrodes, a bright flash of EEE is formed in the discharge gap 2 and around it.

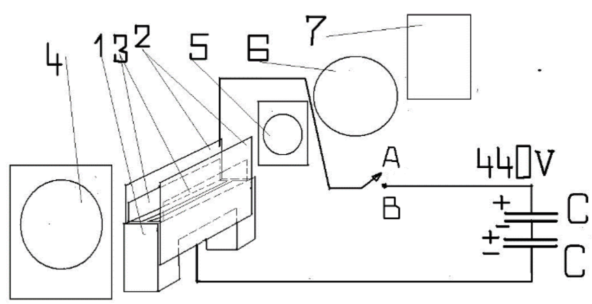

FIG. 1. **The optical resonator contains two mirrors: 4 and 5. One of them (marked as 4) is characterized by the reflection coefficient close to 1. It is 50 mm in diameter. Another mirror (marked as 5) reflects about 50% at the wave length of 600 nm and is transparent to blue and violet light. Its diameter is 20 mm. There is a lens 6 (120 mm in diameter with focus distance 850 mm) installed behind the mirror 5. A white screen 7 is placed close to the focus of the lens. Video recording of the light spots on the screen which can be seen at the moment of EEE in the discharge gap 2 is made by the digital camera Sony DSC-650. In order to insert sodium nitrate in the active zone of EEE, the sodium nitrate powder moistened by one drop of water was placed at the surface of one of the electrodes of the discharge gap 2.**

Results of the experiments

In FIG. 2 one can see a frame from the video recording of the above-described light spots on the white screen. The general appearance of these light spots enables one to argue that their origin is connected with stimulated (not spontaneous) emission of radiation. The first argument for this statement is the absence of penumbras around the spots: only sharp borders between light and shadow can be seen. So the light spots in FIG. 2 are formed by parallel light beams. Two light spots of different color in FIG. 2 also differ in their location on the screen: photon avalanches of different color propagated at different angles to the optical axes of the lens. The directions of these avalanches did not correlate with each other. FIG. 2 does not allow us to describe the full color composition of the EEE radiation, but the presence of red-orange and blue colors in the radiated light can be established.

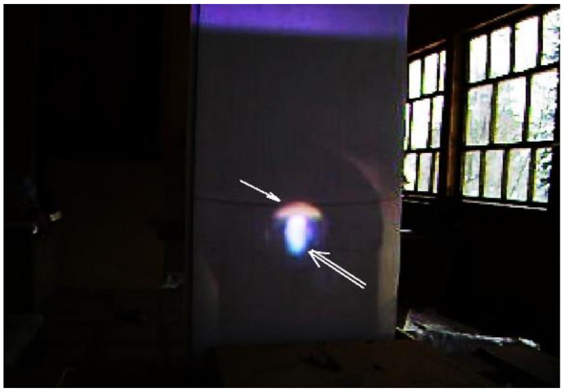

FIG. 2. **A frame from the video recording, containing an image of a light spot when sodium nitrate was not added to the discharge gap. The single arrow points to the red-orange spot, the double arrow points to the blue spot.**

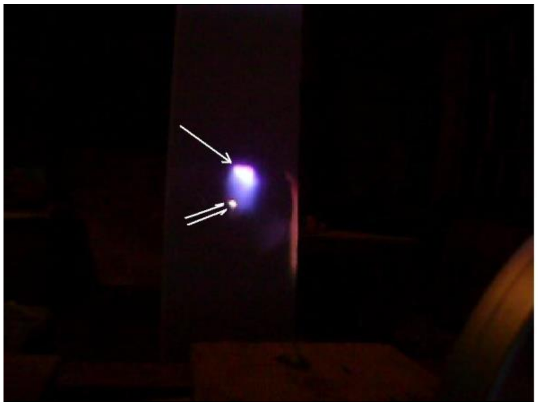

FIG. 3**. The light spots on the screen after addition of moistened sodium nitrate to the discharge gap. The single arrow points to the blue light spot, produced by NO(B $^2\Pi$) molecules. The double arrow points to the spot produced by the laser generation.**

Application of moistened sodium nitrate powder to the surface of one of the electrodes of the discharge gap results in the change of the light spots' general appearance. A very bright and very compact spot appeared in the lower part of the image in FIG. 3. It can be assumed that this spot is connected with laser generation. Placing a red glass before the objective lens of the video camera resulted in the image in FIG. 4, indicating the presence of red color laser generation. In accordance with the mechanism of branched chain reaction suggested in Chemical kinetic model [1], red laser generation can be attributed to the NO_2* molecules. The radiation spectrum of these molecules is characterized by a maximum at wavelength 600 nm [4].

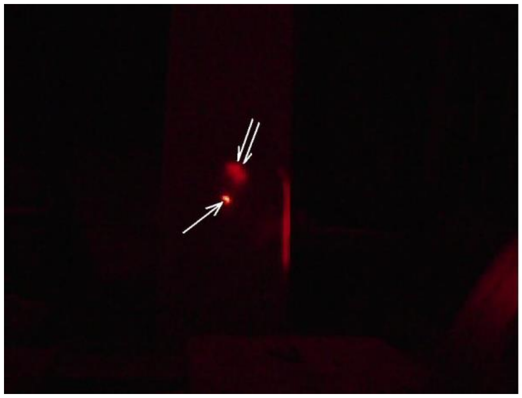

FIG. 4. **Red glass is positioned before the objective lens of the video camera. The single arrow points to the red light spot produced by the laser generation of NO2 molecules. The double arrow points to the red light spot produced by super luminescence of NO2 molecules.**

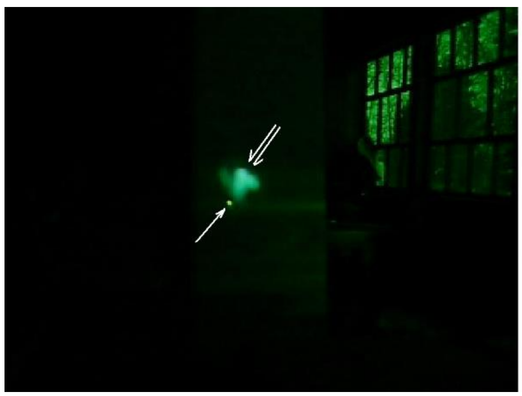

FIG. 5. **Green glass is positioned before the objective lens of the video camera. The single arrow points to the green light spot produced by the laser generation of N2O(1S) molecules. The double arrow points to the blue light spot produced by super luminescence of NO(B 2Π) molecules.**

Discussion

It is impossible to explain the observed images of light spots on the screen in terms of geometric optics as images of the light source formed by the lens. The distance between the lens and the discharge gap was less than the focus distance of the lens. Under such conditions the lens does not form any sharp image of the light source emitting spontaneous radiation. Thus it can be stated, that EEE in air forms an active medium, which is characterized by the formation of inverted populations of several kinds of electronically excited molecules. This statement is in agreement with the conclusions of the mechanism of nitrogen oxidation branched chain reaction suggested in Chemical kinetic model [1]:

$O(^3P) + NO(B\ ^2\Pi) \Rightarrow O(^1S) + NO$ (1)

$O(^1S) + N_2 + M \Rightarrow N_2\text{-}O(^1S)^* + M$ (2)

N_2-O(^{1}S) + O => NO + NO(B $^2\Pi$)* (3)

NO + O + M => NO_2* + M (4)

NO(B $^2\Pi$) molecules have strong emitting transitions in the blue region of spectrum [5]. These molecules produce blue spot of super-luminescence (FIG. 2, 3, 5). Super-luminescence is possible in one-mirror-resonator [7] (one of the mirrors used was transparent for blue and violet light, as mentioned above). Exciplexes (excited complexes) N_2-O(^{1}S) radiate in green (557 nm.). NO_2 radiates in red and orange [4]. These molecules produce green and red laser generation, respectively (FIG. 4, 5).

Another possibility exists for explaining of red laser generation: in the medium containing N_2O_3 the recombination reaction N_2O_3 + O <=> N_2O_4* results in red radiation of N_2O_4 molecules [8]. These molecules can produce laser generation in the same spectral region, as reaction (4) [9].

The oscillogram of EEE in Air [2] shows that the onset of the explosion is delayed at several milliseconds with respect to the discharge initiation. Process of accumulation of NO molecules and O atoms until critical concentrations in the active zone of reaction takes some time (several milliseconds). The loss of NO molecules and O atoms to surrounding atmosphere by means of thermal expansion process is characterized by approximately the same time. For this reason, the appearance of laser generation crucially depends on the rate of chemical reaction in the active zone.

Thus the observation of NO_2* laser generation resulting from the introduction of sodium nitrate in the EEE in air active zone is in agreement with conclusions [1] and [3]: extraction of O(^{1}S) atoms in decomposition of sodium nitrate enhances the rate of NO and NO_2* formation in the nitrogen oxidation reaction.

Conclusion

The presented experiments constitute the first instance of observing the laser generation of electronically excited molecules produced by a branched chain reaction.

Such reactions are believed to have a high potential for designing effective chemical lasers [10]. The obtained results confirm the mechanism of nitrogen oxidation branched chain reaction suggested in Chemical kinetic model [1].

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