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Electron detachment instability and self-organization of gas discharge plasma in working mixtures of chemical non-chain HF(DF) lasers

BELEVTSEV A A[1], FIRSOV K N[2], KAZANTSEV S Yu[2], KONONOV I G[2], ZHANG Lai-ming[3]

(1. *Joint Institute for High Temperatures, Institute for High Energy Densities, Russian Academy of Sciences, Moscow* 125412, *Russia*;
2. *Prokhorov General Physics Institute, Russian Academy of Sciences, Moscow* 119991, *Russia*;
3. *State Key Laboratory of Laser Interaction with Mater, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun* 130033, *China*)

Abstract: This paper reports on investigating the ionization instability in active media of electric discharge non-chain HF(DF) lasers due to electron impact detachment of electrons from negative ions. This instability has been triggered in large volumes of SF_6-based mixtures, spatially separated from electrodes, through the gas heating by a pulsed CO_2 laser radiation. A self-organization phenomenon in a Self-sustained Volume Discharge (SSVD) on a laser-induced gas heating and resulting in formation of quasi-periodic plasma structures in the bulk of discharge gap is experimentally studied. Special attention is given to the evolution of these structures on changing the gas temperature and specific electric energy depositions. A plausible relation of the found self-organization effect to the electron detachment instability treated is discussed. Also suggested is the mechanism of moving a single plasma channel in working media of HF(DF) lasers owing to destruction of negative ions by electron impact.

Key words: HF(DF) laser; electron detachment instability; self-organization phenomenon; self-sustained volume discharge; plasma structure

非链式化学 HF(DF)激光器工作气体中电子分离的非稳定性和气体放电等离子体的自组织现象

BELEVTSEV A A[1], FIRSOV K N[2], KAZANTSEV S Yu[2], KONONOV I G[2], 张来明[3]

(1. 俄罗斯科学院 高能密度研究所 高温实验室,莫斯科 125412;
2. 俄罗斯科学院 普罗霍罗夫普通物理研究所,莫斯科 119991;
3. 中国科学院 长春光学精密机械与物理研究所,
激光与物质相互作用国家重点实验室,吉林 长春 130033)

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摘要：报道了放电引发的非链式HF(DF)激光器中的激活介质由电子碰撞负离子分离引起的电离非稳定性。这种非稳性出现在电极空间分离、脉冲CO_2激光加热的基于SF_6的混合气体的大体积放电中。实验研究了自引发体放电过程中由激光加热引起的放电等离子体的自组织现象以及由此在放电间隙的大部分区域形成的准周期等离子体结构。重点分析了等离子体结构随气体温度和注入能量的变化，讨论了等离子体自组织对电子碰撞分离不稳定性所产生的影响，解释了混合气体中由于电子碰撞使负离子消失导致的单等离子体通道移动的产生机理。

关　键　词：HF/DF激光器；电离非稳定性；自组织现象；自引发体放电；等离子体结构
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1 Introduction

Ionization instability of Self-sustained Volume Discharge(SSVD) in SF_6 and its mixtures is of great interest in view of development of chemical non-chain HF(DF) lasers[1].

Currently, a number of ionization instability mechanisms in electronegative gases are known. A general theoretical approach to the problem is developed in Ref. [2]. In Ref. [3]-[5], the mechanisms are thoroughly considered of the ionization instability in working media of CO_2 lasers due to electron detachment from negative ions by neutral and electronically excited components. For excimer lasers, the instability mechanism arising from the electron impact dissociation of small electronegative admixtures("burning away" of a halogen additive) has been studied in greater detail in Ref. [6]-[9]. The instability in SF_6, according to Ref. [10], may exclusively be caused by the stepwise ionization of SF_6 molecules.

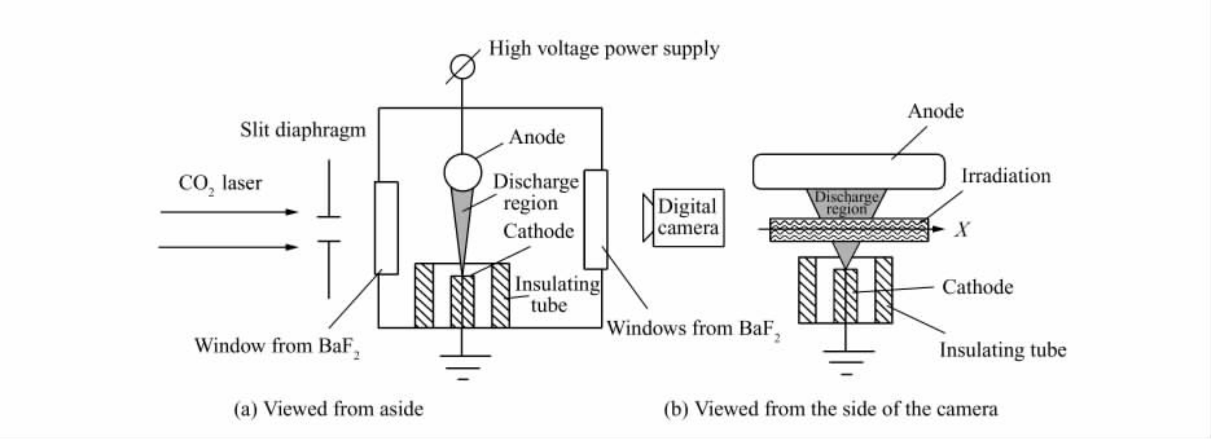
A qualitatively new scenario of the ionization instability owing to electron detachment from negative ions by electron impact can be realized in strongly electronegative gases at intermediate pressures on the time scale of several tens of nanoseconds. For the first time, this problem was touched up in Ref. [11], as applied to SSVD in SF_6 and its mixtures. The key idea is in the following.

In SF_6-based mixtures at intermediate pressures and room temperatures, the best agreement between the calculated time dependences and the recorded SSVD voltage and current oscillograms, including a quasi-stationary phase($E/N \approx (E/N_{cr})$, is attained on taking $\beta_{ei} \approx k_d$(see below). Here E is the electric field strength, N is the gas number density; β_{ei} and k_d are the rate constants for electron-ion dissociative recombination and the electron detachment of electrons from negative ions by electron impact; $(E/N)_{cr}$ is the critical reduced electric field. Under the conditions mentioned, the increase in the electron concentration due to destruction of negative ions by electron impact is practically compensated for their losses in a dissociative electron-ion recombination. The above-stated nonlinear mechanism of electron multiplication comes, therefore, to manifest itself only at significant unbalance between the rates β_{ei} and k_d, which is achieved either at strong gas heating or if $E/N \gg (E/N)_{cr}$. Indeed, the rate constant $\beta_{ei} \sim T_g T_e^{-\chi}$($\chi > 0$, T_g is the gas temperature, $T_e = 2\langle\varepsilon\rangle/3$ is the mean electron energy[12] decreases in both cases, while ε_d value can only increase.

The condition $E/N \gg (E/N)_{cr}$ can actually be realized in the vicinity of the tip of an incomplete channel growing from the cathode side. However, the ionization processes develop here only at the distances approaching the channel radius; hereupon great difficulties arise on relevant experimental studies. However, a noticeable unbalance between the rates k_d and β_{ei} to trigger the electron detachment instability mechanism treated can easily be realized in large gas volumes too. In this respect, a very efficiency is the heating of SF_6-based gas mixtures by a pulsed CO_2 laser radiation. It is this method that we have used in the present paper to study the SSVD instability caused by electron detachment from negative ions by electron impact in SF_6 and SF_6-based mixtures, including working media of HF(DF) lasers.

2 Experimental

The experimental set-up (see Fig. 1) and measuring technique did not differ appreciably from those used by us previously in Ref. [11]. An SSVD was investigated in SF_6 and mixtures of SF_6 with C_2H_6, H_2, and Ne at a partial SF_6 pressure $p_{SF_6} = 2.0$ kPa and the total mixture pressures of up to 6.6 kPa. The discharge was triggered in the needle (cathode)-cylinder (anode) geometry at an interelectrode distance of 43 and 53 mm. The needle was simulated by a copper rod segment dressed with a polyethylene jacket. The cathode was armored in a segment of a 15 mm inner diameter dielectric tube extending by 12 mm above the needle tip. The specific electric energy depositions W_{el} were varied in the range from 0.02 to 0.2 J/cm^3.



(a) Viewed from aside　(b) Viewed from the side of the camera

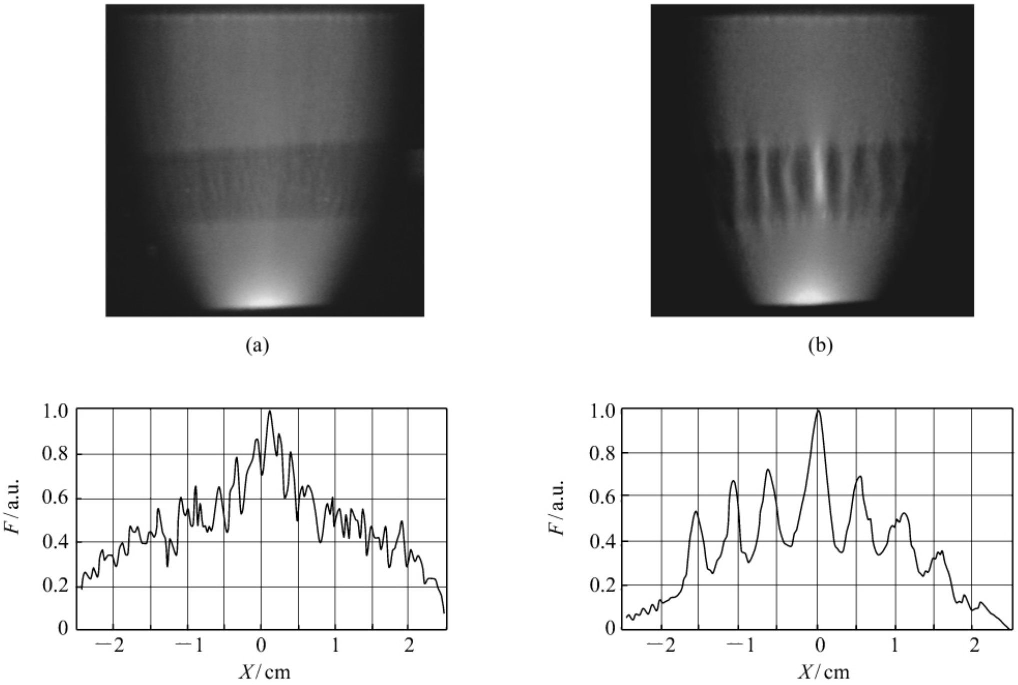
Fig. 1　Experimental setup.

A preliminary gas heating was performed only within a narrow zone of the discharge gap on illumination, the gap by a pulsed CO_2 laser through a 10 mm slit diaphragm arranged normal to the electric field direction (see Fig. 1). As will be inferred from the following, this irradiation scheme allows observing the SSVD constriction immediately in the bulk of the heated gas (like that in a glow discharge [12,14]) rather than in the form of a single channel growing from the cathode spot and bridging finally the discharge gap [15]. The gas temperature T_g established in the SSVD burning region was determined both by the laser radiation energy absorbed by SF_6 molecules [13] and by the propagation velocity of the shock waves formed at the boundaries between the heated and cold gas [16]. The temperature T_g changed from 800 to 2 100 K (the specific energy W_a of the laser radiation absorbed by SF_6 in the SSVD burning region was 0.05 – 0.23 J/cm^3). The voltage pulse was applied with a delay of 4 μs relative to a 3 μs laser pulse at level of 0.1 (the delay was kept from the leading edges of the pulses [17]), which ensured the establishment of the thermal equilibrium between the translation and internal degrees of freedom of the irradiated gas components by the instant of triggering the discharge in the pressure range studied [18].

In the experiment, monitoring of the SSVD voltage and current was performed with a resistive voltage divider and low-resistivity shunt, respectively. The SSVD was also filming using a digital camera synchronized with a laser pulse. To identify basic processes determining the SSVD voltage-current characteristics, we also recorded the voltage and current oscillograms of a confined discharge, which allowed us to eliminate the influence on the discharge voltage and current of the factors coming from extending the discharge volume on increase in the energy input into the plasma[19]. To this end, the SSVD was triggered in a quartz tube of 8.5 mm in diameter at the interelectrode distance of 43 mm (the needle-plane geometry). Experimental oscillograms were compared with the calculated ones (the design procedure is described in Ref. [20]).

3 Experimental results

In Fig. 2(a) and 2(b) are given the SSVD photographs in mixture $SF_6:Ne:C_2H_6$ taken at $W_{el}=0.15$ J/cm^3, discharge current duration $\tau_{dis}=270$ ns and different T_g values.



(a) (b)

(c) (d)

Fig. 2 Photographs SSVD at $T_g=1250$ K(a) $T_g=900$ K(b); distributions of SSVD radiation intensity F along the coordinate X in $T_g=1\,250$ K(c) and $T_g=900$ K(d). Mixture $SF_6:Ne:C_2H_6=5:5:1$, $p=4.4$ kPa, $W_{el}=0.15$ J/cm^3, $\tau_{dis}=270$ ns.

Fig. 2(c) and (d) show the corresponding discharge plasma glow intensity distributions along the X-axis passing through the middle of the heating zone in parallel to its boundaries (see Fig. 1). In the heating region, the SSVD is seen to show a filamentary-like spatial plasma (current) structure close to a quasi-periodical structure. A spatial period of the formed structure decreases on increasing T_g values. Despite a filamentary-like SSVD structure, plasma channels in the heating zone possess a diffuse character at moderate values of W_{el} and τ_{dis}. Increase in W_{el} or τ_{dis} results in the dominance of a single channel (as a rule, in line with the central electric field tube) and its constriction. It is significant that similarly to cold gas[19] the SSVD constriction threshold in pure SF_6 is lower than in SF_6-C_2H_6 mixtures with respect to parameters W_{el} and τ_{dis}. By way of example, Fig. 3(a) and (b) shows the SSVD photographs in mixture $SF_6:Ne:C_2H_6$ (Fig. 3(a)) and pure SF_6 (Fig. 3(b)) taken at (a) $\tau=270$ ns and $W_{el}=0.2$ J/cm^3; (b) $\tau=150$ ns and $W_{el}=0.11$ J/cm^3. It is seen that the instability develops immediately in the irradiated region of the discharge gap. Some analogy appears to be appropriate here with the low-pressure glow discharge constriction[12,14]. On further increase in W_{el} or τ_{dis}, a spark channel bridges the whole gap. At constant values of W_{el} and τ_{dis} the SSVD constriction probability may also increase with increasing T_g in the irradiated zone of the gap.

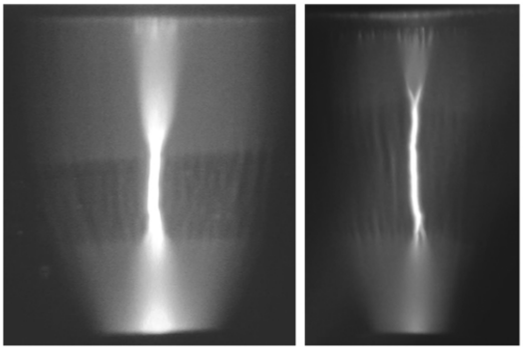

(a) (b)

Fig. 3 Photograph of SSVD in mixture $C_2H_6:SF_6:Ne = 1:5:5$, $W_{el} = 0.2$ J/cm^3, $T_g = 1\,250$ K, $\tau_{dis} = 270$ ns and $p = 4.4$ kPa (a); pure SF_6, $T_g = 1\,100$, $\tau_{dis} = 150$ ns, $W_{el} = 0.11$ J/cm^3 and $p = 2.0$ kPa (b).

The voltage oscillogram of a confined SSVD in SF_6 taken at $p = 2.0$ kPa and $W_{el} = 0.12$ J/cm^3 has been compared with the relevant voltage time dependences calculated accounting for the following processes: electron impact ionization and attachment; ion-ion recombination with the rate constant $\beta_{ei} = 2\times10^{-8}$ cm^{-3} [21]; dissociative electron-ion recombination (the corresponding rate constant was varied within the range $0.5 - 3\times10^{-7}$ cm^{-3}); electron detachment of electrons from negative ions by electron impact, $k_d = 3\times10^{-7}$ cm^{-3} [22]; SF_6 dissociation by electron impact, the energy for F-atom formation was ~4 - 6 eV, according to different data (see Ref. [23], [24] and references cited therein). The best agreement between the calculated time dependences and the experimental oscillogram, as mentioned, has been attained at $\beta_{ei} \approx k_d$.

Given all the above, the following three key features should be kept in mind on analyzing the SSVD instability mechanisms in SF_6-based mixtures, including working media of HF lasers:

First, an SSVD in the heating zone shows a filamentary quasi-periodic structure, with the spatial period depending on T_g value;

Secondly, the instability development of an SSVD starts from its constriction immediately in the irradiated zone of the discharge gap;

Thirdly, at room temperatures, electron multiplication due to electron detachment from negative ions by electron impact is compensated for electron losses in the process of electron-ion recombination ($\beta_{ei} \approx k_d$).

4 Discussion

4.1 Nonlinear mechanism of ionization multiplication in working media of HF(DF) lasers

The negative ions, primarily SF_6^- and SF_5^-, are known to form in SF_6 and SF_6-based mixtures by electron impact[25]. At gas pressures of 4.4 kPa and discharge durations of 100 - 300 ns typical of the present study, no ion-molecule reactions involving both SF_6^- and SF_5^- have time to occur. For instance one of most effective reactions $SF_6^- + SF_6 (F^- + SF_5 + SF_6$ exhibits a characteristic time of ~6 μs under the conditions stated and the (E/N)-values approaching (E/V_{cr}) (the corresponding rate constant is taken from Ref. [26]). According to data of the Ref. [25], the characteristic times for the reactions of electron detachment from negative ions by neutral molecules should be much larger. The only effective field-independent process involving heavy particles might be the associative detachment with electron liberation in collisions of negative ions SF_6^- and SF_5^- with SF_6 molecules and formation of complex molecular aggregates. Unfortunately, no reliable information on the relevant rate constants in SF_6 can there be found in the literature. As for other molecules, the corresponding constants are known to differ by up to 5 – 6 orders of magnitude. Such being the case, any reasonable quantitative estimates of the associative detachment rate constants in SF_6, relying on the data available, are now highly improbable. More importantly, the associative detachment process is linear with respect to electron density and does not therefore affect the nonlinear instability mechanism, which will be further dealt with in this study. Keeping the aforesaid in mind, we can confidently state that only ionizing collisions of ions SF_6^- and SF_5^- with electrons are of real interest under the conditions considered.

In SF_6 at room temperature T_0 and $(E/N_{cr}^{T_0})$, the rate constant for the electron impact formation of SF_5^- is approximately twice as large as that for SF_5^- production[26]. In a laser-heated gas, the situation may be different. Indeed, the reduced electric field becomes appreciably higher compared to $(E/N_{cr}^{T_0})$, because of electron attachment to vibrationally excited molecules of SF_6[16,27]. Considering the electron impact rate at higher gas temperatures to be not less than that at room temperature, we can assume that the total electron attachment rate increases too. However, whether vibrational excitement affects the relative yield of negative ions SF_6^- and SF_5^- and in which way is not clear at present. Therefore both the negative components mentioned are to be dealt with.

The electron detachment from negative ions SF_6^- by electron impact was first considered in Ref. [22]. There have been some quantitative assessments in Ref. [22], which give convincing evidence of this process to be very efficient. The corresponding rate constant was estimated to equal $k_d(SF_6^-) = 3\times10^{-7}\ cm^3/s$. This assessment proceeded from the assumption that the cross-section for the electron detachment by electron impact is not less than that of the electron elastic scattering, which is in excess of $10^{-15}\ cm^2$[25]. Account was also taken of the electron affinity to SF_6 molecules(0.65 – 1 eV[25]) to be much less than the mean electron energy $\langle\varepsilon\rangle \sim 8-10$ eV at the reduced electric fields approaching the critical one[25]. Therefore the electron detachment from SF_6^- by electron impact may be thought of as a non-threshold process. As for SF_5^- having the electron affinity $E_{aff} \sim 2.8$ eV[25], the corresponding electron detachment rate should be reduced compared to that of the elastic scattering by approximately 40% accounting for the Boltzmann factor $\exp(-E_{aff}/T^*)$, $T^* < 2\langle\varepsilon\rangle/3$. Therefore, the difference between SF_6^- and SF_5^- can actually be neglected and, correspondingly, some averaged detachment constant k_d be taken.

Keeping the aforesaid in mind and aiming mainly at a qualitative insight into the nature of the instability induced by electron impact detachment, we may give the relevant system of equations in the form

$$\frac{dn_e}{dt} - (\alpha - \eta)u_e n_e + (K_d - \beta_{ei})n_e N_n, \quad (1)$$

$$\frac{dN_n}{dt} = \eta u_e n_e - k_d n_e N_n. \quad (2)$$

Here n_e and N_n are the electron and negative ion densities, respectively; α and η are the electron impact ionization and electron attachment coefficients, u_e is the electron drift velocity. It should specially be stressed that in strongly electronegative gases, like those treated in this study, the ion densities may be much larger than the electron ones. Therefore the electron losses due to electron-ion recombination in these gases take on much greater importance as compared to that in electropositive ones. This particular feature permits us also to ignore term $\beta_{ei}n_e^e$ in equation (1). In addition, no account is taken of the ion-ion recombination process in equations (1) and (2). Because of a fairly low recombination rate constant β_{ii} at the reduced electric fields approaching $(E/N)_{cr}$[21], this process comes into play only at a final stage of SSVD and does not appear to affect radically a general pattern of the instability growth described by equations (1) and (2).

Equations (1) and (2) may be reduced to a single nonlinear integro-differential equation describing the electron multiplication in active media of HF(DF) lasers[11]. In Ref. [11], exact analytical solutions for $n_e(t)$ have been obtained. They radically depend on parameter ξ[11]:

$$\xi = \frac{a^2/\lambda - 2}{\lambda},$$

$$a = \left(\frac{\alpha}{\eta} - 1\right),$$

$$\lambda = \frac{n_e(0)}{\eta u_e}(k_d - \beta_{ei}). \qquad (3)$$

where $n_e(0)$ is the electron density at the initial stage of the quasi-stationary phase.

Let there be $\xi > 0$. Then

$$n_e(t) = n_e(0)\,\frac{2b^2\lambda A}{(1-A)^2},$$

$$A = \left(\frac{a/\lambda - b}{a/\lambda + b}\right)\exp(b\lambda\eta u_e t),$$

$$b = \sqrt{\xi}. \qquad (4)$$

At sufficiently low $n_e(0)$ values and/or closely spaced rate constants k_d and β_{ei}, the electron density does not increase noticeably by the instant the discharge current reaches its maximum. The first is realized at small enough specific electric energy depositions W_{el} whatever should be k_d and β_{ei}. In this case $\lambda \to 0$ and the solution (4) goes into an ordinary electron multiplication law

$$n_e(t) \approx n_e(0)\exp((\alpha - \eta)u_e t). \qquad (5)$$

as if the electron detachment from negative ions by electron impact were absent. That is typical of an SSVD in SF_6-based mixtures at W_{el} values being less 50 J/L even in the laser-heated regions. The second possibility ($k_d \approx \beta_{ei}$) is characteristic of the shock-compressed gas regions sandwiched between the shock wave fronts and the contact discontinuity surfaces wherein the gas temperature is nearly that of the undisturbed regions.

At $\xi < 0$, the electron detachment from negative ions plays the predominant role and the expression obtained for the electron concentration

$$n_e(t) = \frac{n_e(0)}{\cos^2(b_2\lambda\eta u_e t)\,[1 - (a/b_1\lambda)\tan(b_1\lambda\eta u_e t/2)]},$$

$$b_1 = \sqrt{-\xi}. \qquad (6)$$

does not go into (3) whatever be $n_e(0)$ and $k_d - \beta_{ei}$.

It follows from expressions (3), (4) and (6) that at unbalance between the detachment and recombination rates ($k_d - \beta_{ei} < 0$) at the stage of increasing the discharge current ($\alpha > \eta$) both solutions (4) and (6) manifest a pronounced "explosive" character, i. e. some finite time after the ionization process starts the electron concentration becomes arbitrary large. Expressions (4) and (6) allow the characteristic "explosion" times τ^{i}_{exp} to be easily determined.

If $\xi > 0$, then

$$\tau^{i}_{exp} = \frac{1}{b\lambda\eta u_e}\ln\left(\frac{a/\lambda + b}{a/\lambda - b}\right), \qquad (7)$$

At $\xi < 0$

$$\tau^{i}_{exp} = \frac{2}{\lambda b_1 \eta u_e}\arctan\left(\frac{\lambda b_1}{a}\right). \qquad (8)$$

In reality, of course, the result obtained means that in a lapse of a certain time $\tau^{i}_{d} \sim \tau^{i}_{exp}$ the electron attachment is partly compensated for by their detachment from negative ions by electron impact. By analogy with the terminology used in the theory of excimer lasers, this process may be called the "burning away" of electronegativity, because in this case we deal with not destruction of electronegative molecules but with losing the ability to capture free electrons because of the electron detachment process.

At the stage of decreasing, the discharge current in the SSVD quasi-stationary phase $\alpha < \eta$, and, correspondingly, $a < 0$. It follows from relationships (4) and (6) that in this case the electron concentration always tends to zero with time. In other words, the volume electron multiplication due to electron detachment from negative ions by electron impact is not capable of being competitive with the attachment-induced electron losses if the electron capture by molecules is more efficient than impact ionization. As a result, in the SSVD quasi-stationary phase ionization instability arising from the "explosive" character of electron multiplication can develop only at the stage of current increase.

4.2 Self-organization of the SSVD plasma on laser heating of SF_6-based mixtures

The nature of self-organization of the SSVD plasma in heated SF_6-based mixtures is not quite clear. In our opinion, this phenomenon can substantially be connected with the development in the SSVD plasma of the ionization instability caused by the electron detachment from negative ions(see above). We now advance some relevant qualitative arguments.

At high gas temperatures $k_{\text{d}} - \beta_{\text{ei}} > 0$, which results in an "explosive" growth of $n_{\text{e}}(t)$ on increasing the discharge current($\alpha > \eta$). The current passage through the discharge gap in the SSVD quasi-stationary phase is controlled by LC-circuit with a characteristic time $\tau_{\text{c}} \sim \sqrt{\text{LC}}$, which is several hundreds of nanoseconds under the conditions of interest, whereas $\tau_{\text{d}}^{\text{i}} \sim 20-30$ ns. Since $\tau_{\text{c}} \gg \tau_{\text{d}}^{i}$, it must necessarily result in the SSVD quasi-stationary phase($E/N \approx (E/N)_{\text{cr}}$) in the current redistribution over the discharge gap to form separate longitudinal current layers(thin filaments at high T_{g}-values) with an enhanced electron concentration. Indeed, a standard linear analysis shows that it is normal to the current direction spatial perturbations that possess the largest increments of growth. In the nonlinear stage of the perturbation development, there can be formed the quasi-periodic structures observed in the experiment.

Following the Ref. [28], it is easy to show that the structures in the form of separate filaments are stabile. On rising the gas temperature, the difference $k_{\text{d}} - \beta_{\text{ei}}$ also increases, which results in a more rapid growth of $n_{\text{e}}(t)$. One can therefore assume that it is for this reason that the number of conducting channels increases with growing T_{g} and, hence, the spatial period of the current structure decreases. An additional argument in favor of the above considerations is also the fact that at extremely low T_{g} values realized in the experiment the quasi-periodic structures did not appear at all. Indeed, in this case $\tau_{\text{d}}^{i} \gg \tau_{\text{c}}$.

At the stage of decreasing the discharge current the above-considered "explosive" mechanism is not possible because $E/N < (E/N)_{\text{cr}}$ and $\alpha < \eta$(see section 4.1). In this case the instability development can develop at a falling section of the quasi-static U-I characteristic(the relaxation U-I characteristic time $\tau^{\text{UI}} \ll \tau_{\text{c}}$) controlled by the effective ionization coefficient $\alpha_{\text{eff}}(n_{\text{e}}) = \alpha - \eta + (k_{\text{d}} - \beta_{\text{ei}}) n_{\text{n}}(n_{\text{e}}) / u_{\text{e}}$. In doing so, the excess of the attachment rate over that of impact ionization is compensated for electron detachment of electrons from negative ions by electron impact. The SSVD on this portion of the U-I characteristic is unstable with respect to spatially homogeneous fluctuations of the plasma parameters. However, spatially inhomogeneous fluctuations can develop in the SSVD plasma followed by formation of spatial structures comprised of separate current filaments with an enhanced electron density. The relevant scenarios of such a self-organization and the problem of the formed plasma structures stability have been considered in greater detail in the literature(see Ref. [28,29]). Besides, there are certain grounds to believe that the SSVD constriction at long duration discharge pulses does occur at the falling section of the U-I characteristic, too.

4.3 On the mechanism of propagation of conducting channels in SF_6 and its mixtures

A nonlinear electron multiplication mechanism due to unbalance between the rates of electron detachment by electron impact and electron-ion recombination can also affect the propagation of conducting channels in SF_6-based mixtures through the discharge gap at room temperatures if, as already mentioned, $E/N(E/N)_{\text{cr}}$. Such is the case in the vicinity of a single conducting channel growing from the cathode side.

The reduced electric field at the tip of this channel exceeds appreciably $(E/N)_{cr}$[15]. It leads to a significant increase in T_e value and, consequently, to noticeably decreasing β_{ei} (see Introduction). A situation arises, when again, as at high gas temperatures, the difference $k_0 - \beta_{ei} > 0$. It triggers the above considered mechanism of an "explosive" electron multiplication, thereby forms a new plasma-filled segment of the channel ensuring the channel advancement into the interior of the discharge gap. Therefore there are no grounds to invoke a stepwise mechanism of ionizing SF_6 molecules, suggested in the Ref. [10], in order to explain the propagation of conduction channels in SF_6 and its mixtures.

5 Conclusions

In the present paper, a fundamentally novel mechanism of the detachment instability developed in active media of HF(DF) lasers due to electron detachment from negative ions SF_6^- and SF_6^- by electron impact is investigated. Based on principal mechanisms of formation and destruction of negative ions in SF_6 and its mixtures, it is shown that the instability arises from the unbalance of the rate constants for electron detachment from negative ions by electron impact and dissociative electron-ion recombination. Analytical expressions for increasing the electron concentration in time are obtained. It is shown that on increasing the discharge current, the instability development displays an "explosive" character; the characteristic "explosion" time is assessed. On laser heating SF_6-based gas mixtures by a pulsed CO_2 laser radiation, the development of the instability studied has been initiated in large gas volumes with the aim of its experimental study. A plausible connection of this process with a spatial self-organization (formation of current filaments) in the SSVD plasmas of the pre-irradiated SF_6 and SF_6-based mixtures is discussed. The mechanism of propagation of an incomplete channel owing to electron detachment from negative ions by electron impact has been considered.

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Author's biography: Sergey Kazantsev(1971—), Moscow, Russia, graduated from Moscow Engineering Physics Institute(State University) in 1998, His research interests are concerned with experimental investigation of volume self-sustained gas discharge phenomena, development of chemical and high-power electric discharge lasers, and investigation of high power laser beam interaction with matter, laser induced gas breakdown, laser lightning protection. E-mail: kazan@kapella.gpi.ru