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S6 - Discharges with runaway electrons
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The Dynamics of Low Pressure Apokampic Discharge Formation in Argon

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Aim

The work proposes to determine the features of the propagation of an apokampic discharge in argon with air impurities.

Materials and Methods

The apokamp discharge discharges was captured in frame-by-frame mode with a Canon PowerShot SX 60 HS camera and was recorded with an HSFC PRO four-channel ICCD camera at a minimum frame duration of 3 ns.
The time dependence of voltage was traced with a high-voltage probe and Tektronix TDS 3034 oscilloscope. The discharge current measured by a high-resistance shunt (R = 1 kOhm) was recorded with a resolution of no worse than 5 ns.
The spectra were recorded using an assembly including a collimating lens with a focal length of 30 mm, an optical fiber with a known transmission spectrum, and an HR2000+ES (Ocean Optics, Inc.) spectrometer based on a multichannel Sony ILX511B CCD array (the operation range is 200–1100 nm and the spectral half-width of the instrumental function is ~1.33 nm) with a known spectral sensitivity. The lens was positioned at different heights h, and the radiation was collected from a 5-mm diameter region.

Results (1)

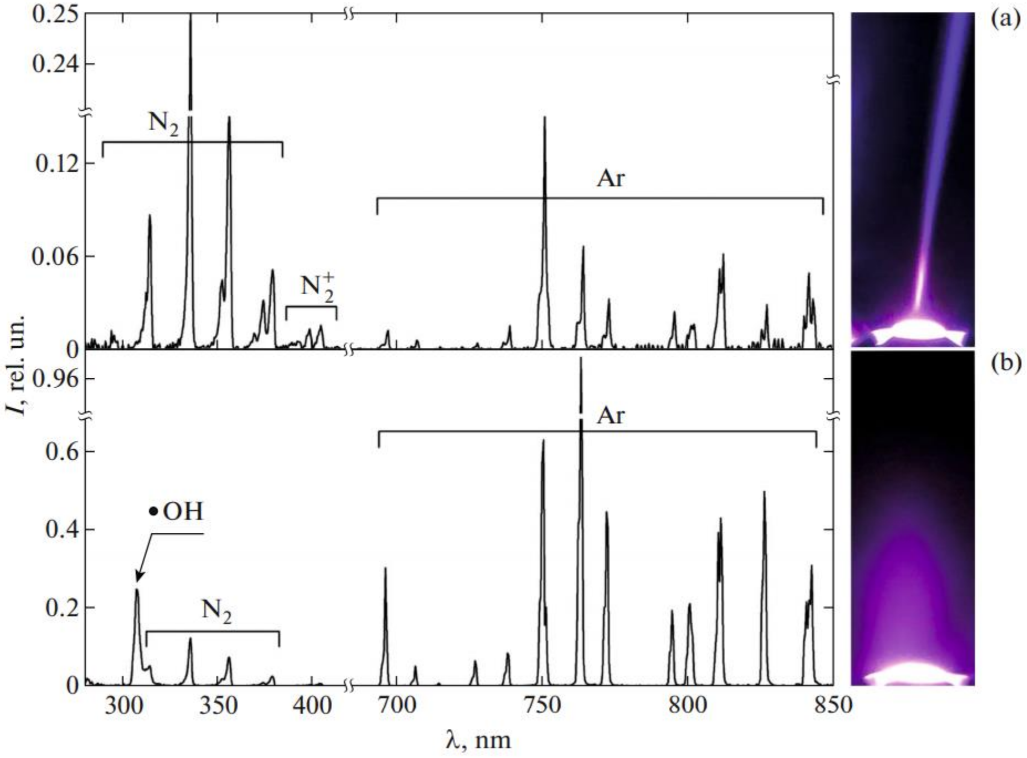

Fig 1. Emission spectra of an apokampic discharge (left) at a height of h = 3 cm from the channel of the main discharge and their typical shape (right) after (a) 4 and (b) 16 cycles of argon pumping.

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In the experiment, we vacuumed the discharge chamber several times and then filled it with argon. This helped to remove the remaining air in the chamber. Fig. 1 presents the discharge emission spectra and corresponding discharge shapes for 4 and 16 cycles of argon pumping into the chamber. In both cases, the spectra were obtained under conditions of moderate pressure up to p = 120 Torr, voltage Up = 3.74 kV, and frequency f = 56 kHz.

It is seen that both $N_2(C^3\Pi_u - B^3\Pi_g)$ and $N_2^+(B^2\Sigma^+{}_u - X^2\Sigma^+{}_g)$ bands and atomic transitions of argon (4*p*–4*s*) are similarly expressed in the emission spectrum after four cycles of argon pumping and puffing (Fig. 1a). After 16 cycles of pumping and puffing, the discharge becomes spatial; this is shown in Fig. 1b. The emission spectrum demonstrates that energy losses for filling of levels of the second positive system of nitrogen significantly decreased and bands of the first negative system of N_2^+ disappeared.

Therefore, under conditions of our experiments, formation of an apokampic discharge – a pulse highvoltage discharge with a streamer ramifying from its outshoot (the so-called “plasma jet”) – requires the presence of molecular nitrogen in the gas mixture. We believe that its concentration is sufficient for the effective energy transfer to it from argon metastables. The residual concentration of water in the discharge chamber with argon was not sufficient for the formation of an apokampic discharge.

Results (2)

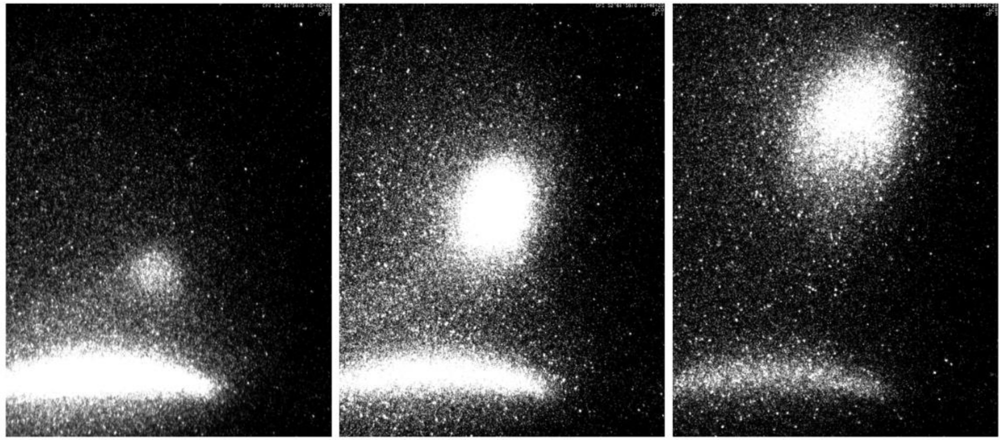

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Fig. 2 The dynamics of apokamp in Ar at 8.5 kHz and 3.75 kV. exposure 20 ns, frame interval 40 ns.

Figure 1 shown the dynamics of apokamp discharge plume in the nanosecond time scale. It gives both values the starting velocity of the streamer head and the average for the time of flight in the field of view. The average velocity depends on many conditions (air pressure, amplitude and frequency of voltage pulses).

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Results (3)

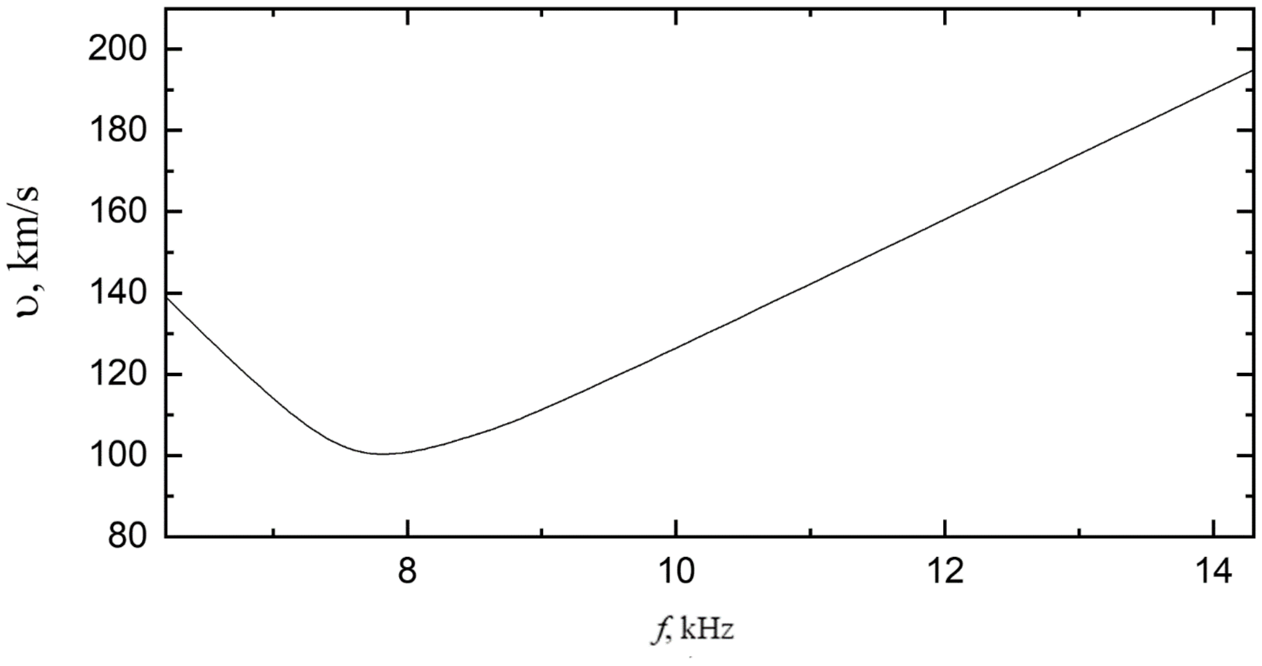

Fig. 2 The dependence of the average velocity of propagation of plasma bullets versus the frequency.

The influence of frequency on apokamp propagation is depicted on Fig. 4. All other things being equal a decrease of the discharge frequency initially leads to an increase of average speed of streamer head, and then to its decrease. The measured average velocity values for 120 Torr range between 97 and 195 km/s.

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Conclusion

Based on optical measurements, the hypothesis was confirmed that the addition of an electronegative gas stabilizes the plasma jet in the apokamp mode. In argon with air impurities, a stable apokampic discharge is formed with a propagation velocity of 195 km/s.

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