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STUDY OF THE AVALANCHE TO STREAMER TRANSITION IN GLASS RPC EXCITED BY UV LIGHT

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Abstract

Ammosov V., Gapienko V., Kulemzin A. et al. Study of the Avalanche to Streamer Transition in Glass RPC Excited by UV Light.: IHEP Preprint 2002-11. – Protvino, 2002. – p. 8, figs. 11, refs.: 2.

Small glass RPC filled with Ar/Isob./Freon mixture has been exposed to light from UV laser. Dependence of avalanche-to-streamer transition process on the laser beam intensity and on high voltage applied to RPC were studied. Two types of streamer signal has been observed. Using CCD TV camera, pictures on multi-streamer propagation over RPC were obtained.

Аннотация

Аммосов В., Гапиенко В., Кулемзин А. и др. Изучение лавина-стример перехода в стеклянной РПК, облучаемой ультафиолетом.: Препринт ИФВЭ 2002-11. – Протвино, 2002. – 8 с., 11 рис., библиогр.: 2.

Небольшая стеклянная РПК, наполненная смесью аргон/изобутан/фреон, была облучена излучением ультрафиолетового лазера. Изучалась зависимость лавина-стример перехода от интенсивности света и от приложенного напряжения. Наблюдалось два типа стримерного сигнала. С помощью CCD камеры были получены изображения стримерного разряда в РПК.

Introduction

Working voltages for RPC operated in avalanche mode is close to values at which avalanche transforms into streamer. If one wants to use RPC in saturated avalanche regim he should be ready to see from time to time strong streamer signal. At low threshold of electronics any big pulse is not desirable because it produces a multichanel firing.

An attempt to get better understanding on how streamer grows from avalanche was done in present work. Glass RPC with 2 mm gas gap was exposed to UV laser beam. By variation of UV light intensity we tried to understand how appearance of streamer and its characteristics depends on charge in avalanche and on working voltage, HV. Both: induced signal from pick-up electrode and light emitted by discharge in RPC were registrated.

Early good correspondence between electrically induced signals and light emmition from glass RPC was found in [1]. The correspondence was observed in the following aspects: signal shapes, pulse heights and timing. In [2] one can see pictures of streamer discharge in glass RPC taken using image intensifier and CCD camera.

1. Experimental setup

Fig. 1 shows experimental setup. LGI-21 pulse laser was a source of light with 337 nm wave length. Duration of laser pulse was 8 ns, maximal energy in pulse was about 40 μJ. Frequency of light pulses can be variated. Taking into account $\sim$1 s recovery time of our RPC when it was operated in streamer mode, we chose the laser pulse frequency so, that time between two discharges in RPC was bigger than 10 s. Being a source of high level noise, laser was installed outside test room, 7 m far from RPC. UV light was focused in 0.3 mm diameter spot on entry glass plate of RPC by long-focuse spherical mirror (SM).

At first stage of present work two photomultipliers (PM1, PM2) were used for monitoring of laser beam intensity and for to measure spectrum of light from discharges in RPC. One of photomultipliers, PM1, was faced to spherical mirror. Added with UV filter it measured part of light scattered off SM because of mirror unperfection and thus a monitoring of laser intensity, was carried out. Second photomultiplier, PM2, faced to RPC was used to registrate light from discarges occuring in gas. By changing of optical filters between PM2 and RPC it was possible to measure light in different ranges of spectrum. Signals from both photomultipliers were fed to a QDC.

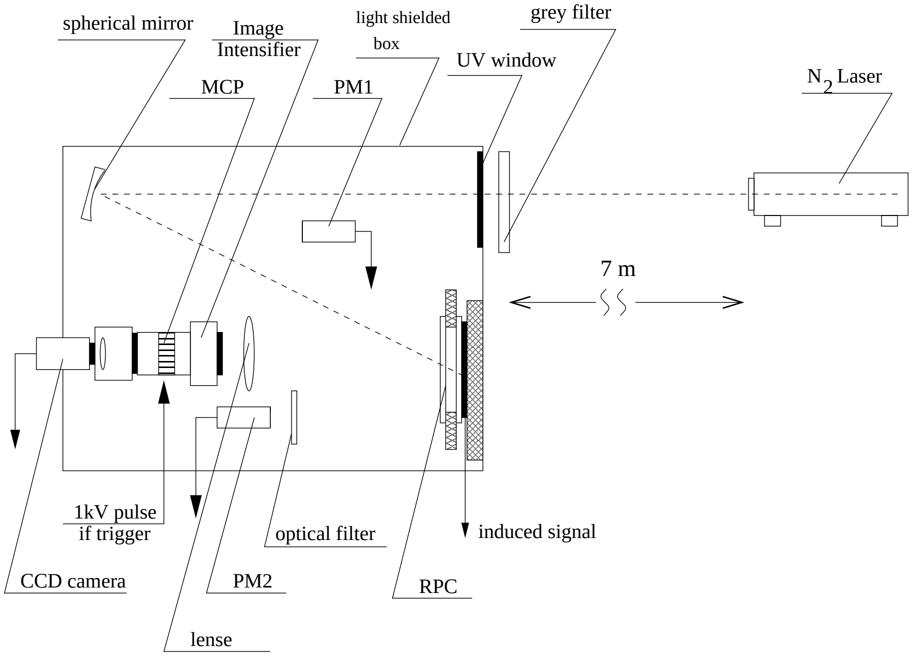

Fig. 1. Experimental Setup.

RPC, PMs were haused in light shielded box as it is shown in Fig. 1. Light from laser entered this box through window made of glass transparent for UV only. Intensity of light, I, was changed with grey optical filters installed between laser and UV entry window.

At final stage of the work, second photomultiplier, PM2, was replaced with image intensifier and TV CCD camera to get picture on how streamer spreads over RPC.

Small 10×10 cm^2 RPC with 2 mm gas gap was made of 2 mm glass plates. Bulk resistivity of glass was found to be $\sim 5 \times 10^{12} \Omega$cm. A high voltage cathode was performed by metalization of the glass plate surface. Transparency for visible light of thin metallic layer was about 70%. 2 mm in diameter area in centrum of cathode was free of metallization. UV light entered RPC through this area.

Anode electrode was done as a layer of carbon paint on glass surface. Again, 2×2 mm area free of paint was in center of anode for UV light can leave RPC without producing scintillation.

Induced signal from anode was amplified by U33 amplifier having gain=20 and 400 MHz bandwidth. RPC signal and signals from photomultipliers were digitized with 11-bits P267 module (“SUMMA” standart). The input sensitivity of P267 is $\sim$0.3 pC/count. When it was necessary to estimate the RPC efficiency, discriminator with 6 mV threshold was used after U33 amplifier.

In our study we felt RPC with $Ar/iso - C_4H_{10}/CF_3Br$: 54/36/10 mixture.

2. Experimental results

First part of this section presents results on avalanche to streamer transition. Second subsection shows data on spectrum of light coming from streamers. Examples of optical images are in the third part.

2.1. Avalanche to streamer transition.

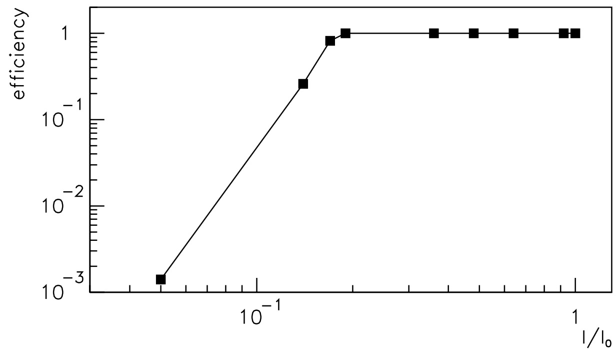

Fig. 2. Probability to get the RPC reply at different intensity of laser pulse. $HV = 7.8$ kV.

First of all, we looked how efficiency (ϵ) of the RPC excitement depends on the laser pulse intensity(I). Fig. 2 shows ϵ versus I/I_0, where I_0 is the maximal intensity what we could get with LGI-21. This result was obtained with voltage, $HV = 7.8$ kV, at which no streamer signal was observed when tested our glass RPC with cosmics. As Fig. 2 demonstrates a reply from RPC is always seen at $I/I_0 > 0.2$, below this intensity not every light pulse produces discharge in RPC. Only one of $\sim 10^3$ pulses evokes discharge at $I/I_0 \leq 0.05$. We think that at this low intensity, $\sim 5\%$ of I_0, UV light knocks out only one electron from cathode. Tests with low intensity are called here as a work in "one electron" mode.

Mean value of induced charge, $< Q >$, measured in "one electron" mode is shown in Fig. 3a as a function of high voltage. Behavior of $< Q >$ in Fig. 3a looks like what we saw with this gas mixture in case when RPC was crossed with cosmics: avalanche signal rising from 0.05 pC to ~ 1 pC with HV growth from 7.5 kV to ~ 8.2 kV becomes to be accompanied by strong streamer signal, ~ 100 pC, at $HV > 8.1 - 8.2$ kV. Fraction of streamer at different HV is given in Fig. 3b. Avalanche signal caused by laser beam has less variation in amplitude than charged particle does because no variation in distance along which avalanche grows: avalanche always starts by electron knocked out from cathode. That is why avalanche signal can be separated from noise (pedestal) without problem even at $< Q > \approx 0.05$ pC. A behavior of streamer induced signal in "one electron" mode looks like a set of sparks following in time one by one. A delay between avalanche signal and first streamer pulse can be up to 100 ns. Below we call this type of streamer as "streamer-A".

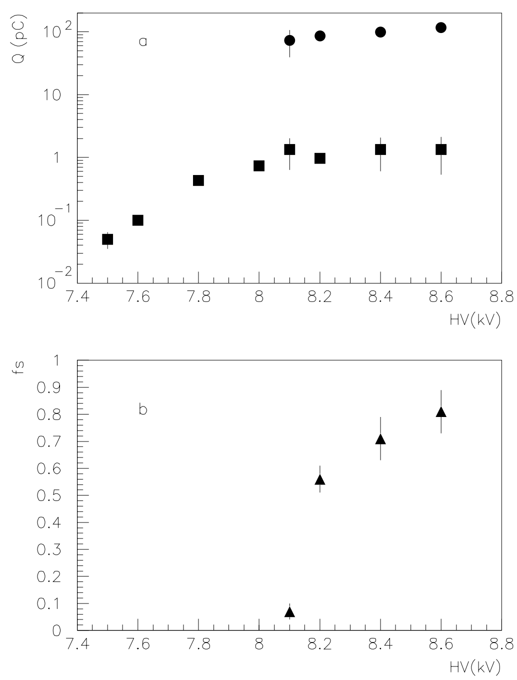

Fig. 3. Measured at different high voltages: **a** — mean charge of avalanche (boxes) and of streamer (circles), **b** — fraction of streamer-A signal. Data were obtained in "one electron" mode.

It was interesting for us to see how induced signal changes if to increase number of primary electrons knocked out by UV light. Fig. 4a shows $< Q >$ as a function of I/I_0. Measurement was carried out at $HV = 7.8$ kV. Charge of avalanche, $< Q_a >$, (boxes) rises with growth of light intensity. When $< Q_a >$ reaches about 1 pC, streamer signal (triangles) appears. However, this streamer signal differs from streamer-A observed at more high HV in "one electron" mode: it consists of only one pulse with charge of 30 pC. Its amplitude spectrum is rather narrow – width of distribution is few pC only. This streamer follows avalanche with few ns delay and its duration is $7-10$ ns (FWHM). We call this streamer as "streamer-B". In range $I/I_0 = 0.2-1$ no considerable variation in charge of streamer-B was found. Fraction of "streamer-B" at different HV is presented in Fig. 4b.

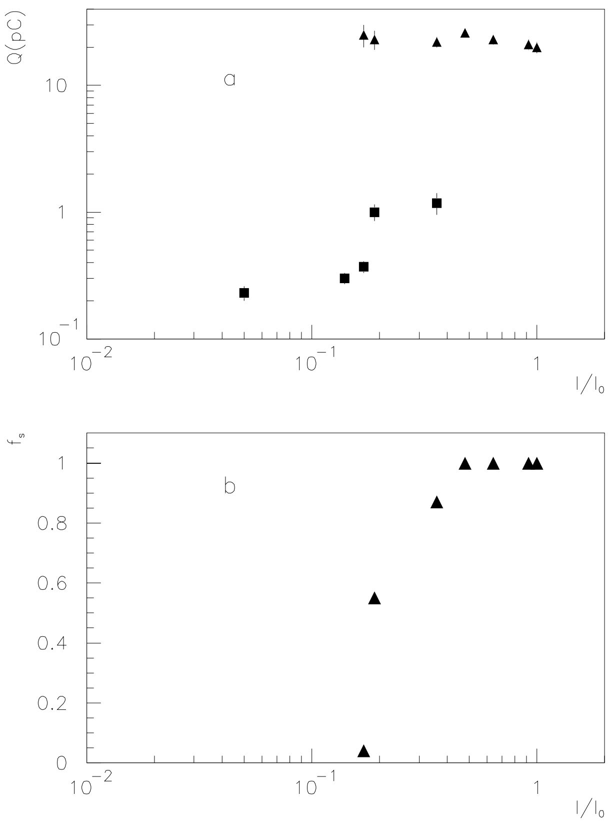

Fig. 4. Upper picture shows charges of avalanche (boxes) and streamer-B (triangles) as functions of light intensity. Fraction of streamer-B at different I/I_0 is given in fig.4b. Data were obtained at HV=7.8 kV.

At next step we looked for signals from RPC at maximal intensity of light. Fig. 5 gives mean induced charge as a function of HV when I/I_0 was ≈ 1. Below 7.4 kV only avalanche signals were observed. Mean avalanche charge is shown in the figure with circles. At 7.4 kV, as Fig. 5 shows, streamer signal (boxes) with $< Q_s >= 15$ pC appears. This streamer signal is "streamer-B": it consists of only one narrow (FWHM$\approx$ 10 ns) pulse. Variation in its amplitude is about $10-15\%$. Time between "streamer-B" and avalanche signal is few ns. Amplitude of "streamer-B" rises slowly with HV from 15 pC to about $\sim$30 pC. Probability to observe "streamer-B" at different HV is shown in Fig. 6 (boxes). At voltages of $7.8-8.3$ kV "streamer-B" is only signal what we could see. Starting from HV $\sim$8.3 kV both "streamer-B" and "streamer-A" (triangles) can be observed. Fraction of "streamer-A" rises with HV as it is shown in Fig. 6 (triangles). Presence of "streamer-A" can be noticed by eye through the RPC glass wall: it looks like a set of sparks near the point where light enters RPC. Some of sparks are few *cm* far from this point.

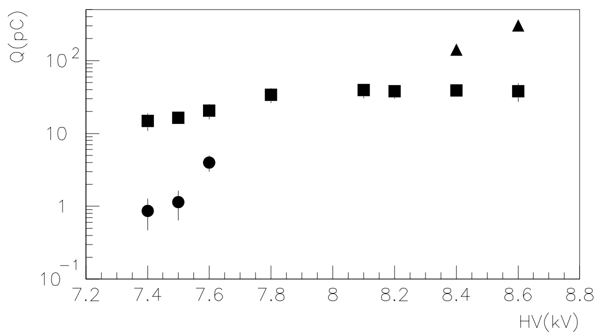

Fig. 5. Three types of signal observed at different HV. Intensity of light $I/I_0 \approx 1$. Charge of avalanche signal is given with circles, streamer-A is shown with triangles, black boxes describe streamer-B.

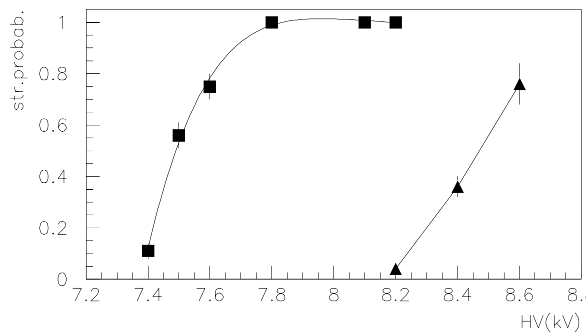

Fig. 6. Probability of streamer-A (triangles) and streamer-B (boxes) at different HV. Intensity of UV light is maximal.

2.2. Light coming from discharges

Light coming from discharges through glass plate was measured with photomultiplier "FEU-87". To estimate spectrum of light from discharges a set of measurements was carried out with five different optical filters (BS8, JS4, JS12, JS18 and OS13), installed between RPC and photocathode. Transparency of these filters at different wave length is given in Fig. 7.

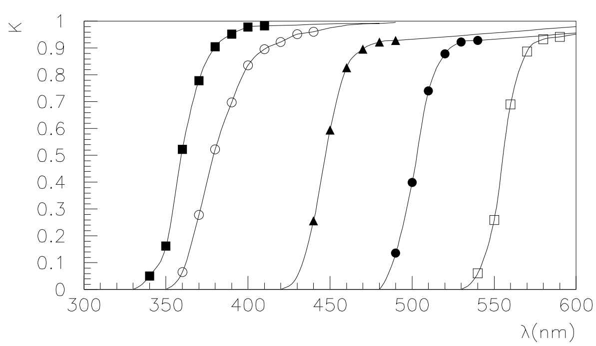

Fig. 7. Transparancy as a function of wave length for five optical filters: BS8(black boxes), JS4(sweet circles), JS12(triangles), JS18(black circles), OS13(sweet boxes). Curves are taken from specifications given by manufacturer of filters.

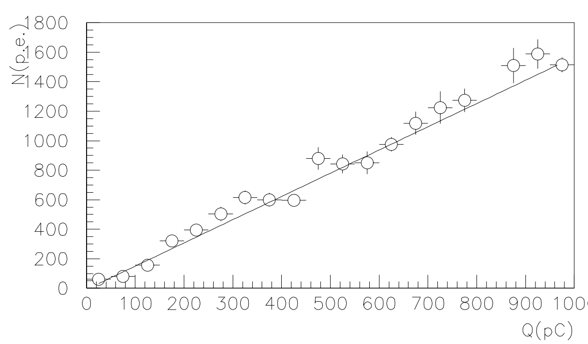

Fig. 8. Light from streamer (number of photoelectrons) as a function of induced charge. No filter between PM and RPC. Line shows the result of fit by linear law.

From the beginning we should say that attempts to measure light from avalanche were failed. Light from avalanche is rather week. It is at level of background light. Background light is due to reemittion by glass (and by dust on glass surface) during few ten ns after UV puls. For the streamer signal good proportionality between induced charge and number of photoelectrons ($N_{p.e.}$) was observed. Value of $N_{p.e.}$ as a function of $< Q >$ is given in Fig. 8. Data in this figure were obtained without any optical filter between RPC and PM. The figure demonstrates good proportionality between induced charge and light output. Linear approximation of the data brings a scale value of $\sim 1.59 \pm 0.02$ p.e./pC. By the same way, $N_{p.e.}$ versus $< Q >$ was gotten for cases when PM was added with five filters mentioned above. Scales found after approximation with linear law are presented in the following table for each filter.

filter	BS8	JS4	JS12	JS18	OS13
$N_{p.e.}/pC$	1.56 ± 0.04	1.46 ± 0.02	0.94 ± 0.02	0.55 ± 0.01	0.12 ± 0.002

The table gives a possibility to reconstruct spectrum of the streamer light coming through glass cathode in $\lambda \approx 300 - 600$ nm range. Corrected for the FEU-87 sensitivity characteristic this spectrum is shown in Fig. 9.

2.3. Images of streamer discharge

As was said above, streamer looks by eye through the glass window as one or several bright spots.

To get images of discharges we used the same glass RPC as it was in measurements of light spectrum. The RPC was viewed with Image Intensifier (II) “KANAL” having bialkali photocathode. High voltage pulse sent to microchannel plate inside “KANAL” opens the Image Intensifier. Output screen of II was viewed with CCD camera. Self-made card inside IBM PC was used to digitize signals from CCD camera. Images were recordered into files. Furthermore, images could be observed during data-taking on a TV screen.

It was found that streamer looks through the glass window like one or several bright spots. Diameter of each spot is about 2 mm. Fig. 10 supports idea that correlation between “optical” and “electrical” information exists. The figure shows number of bright spots, N_s, observed through the glass window as a function of induced charge. Good enough proportionality between N_s and charge can be seen in the figure.

As examples showing how streamer develops in space, Fig. 11 presents two pictures obtained with image intensifier and CCD camera. Real size of each image is 3.5×5.5 cm. Position of a spot which is the most close to center of a picture corresponds to place where UV beam crosses RPC. Pictures were obtained for streamer-A process.

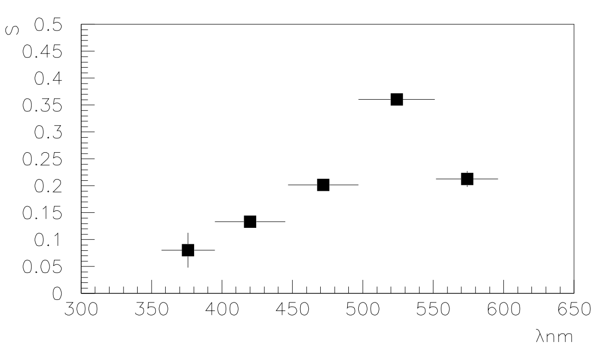

Fig. 9. Reconstructed spectrum of light from streamer.

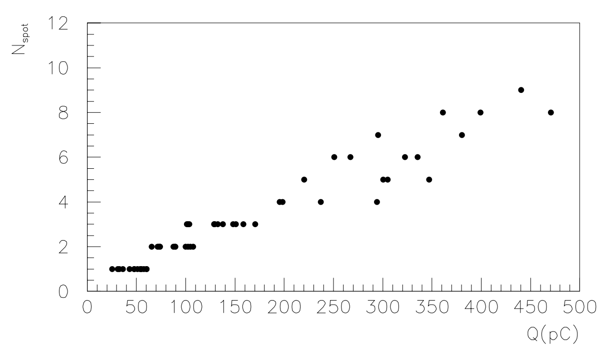

Fig. 10. Number of light spots as a function of induced charge.

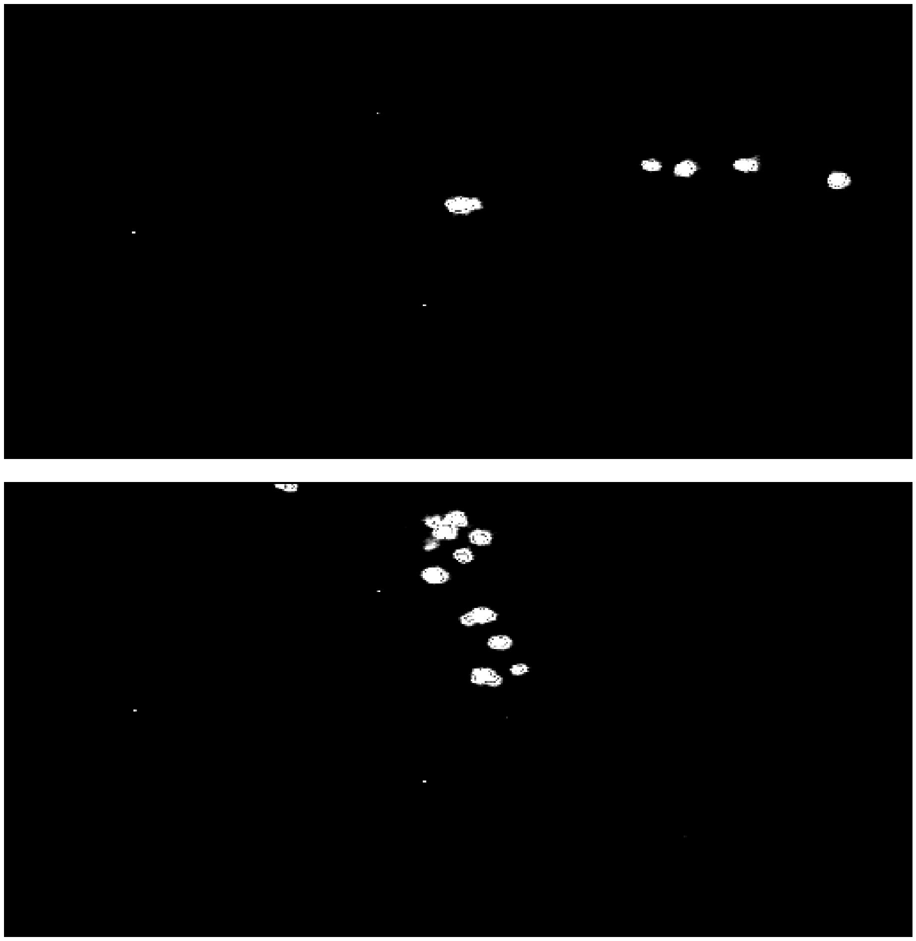

Fig. 11. Two examples of picture obtained with CCD camera for streamer discharge.

3. Conclusions

Excitement of glass RPC by the UV pulse laser provided with interesting information on how avalanche transforms into streamer. Two types of streamer have been observed. One of them, "streamer-B", is produced by field of primary avalanche – it appears when charge of avalanche (exactly say, induced charge) reaches $\sim$1 pC and it weakly dependes on initial electric field in wide range of HV. "Streamer-B" follows avalanche discharge with few ns delay only.

Second type of streamer, "streamer-A" appears when HV exceeds some value, for our gas mixture it was at $HV > 8.2$ kV. Appearance of "streamer-A" does not depends on number of primary electrons in avalanche. By eye, through the glass plate, this streamer looks like several sparks round point where laser light enters RPC. Some of sparks are few cm far from primary point. It seems this kind of process in RPC is connected with secondary photone emission from primary discharge.

Estimations on spectrum and intensity of light from discharges in the RPC have been done. We hope, these date can be useful in future for everybody who will try to reconstruct a space-time picture of processes in RPC by use of optical information.

References

[1] Y.Inoue et.al., NIM A394 (1997) 65-73.

[2] I.Kitayama et.al., NIM A424 (1999) 474-482.

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