7. TEA

FB242 Gas discharges: physical mechanisms and applications

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To generate the non-equllibrium plasma at near-atmospheric-pressures (important for many applications) it is necessary to avoid of „ (e) The filamentary glow to arc transition"

It can be done in the following types ot the non-stationary high-pressure discharges (or their cobinations)

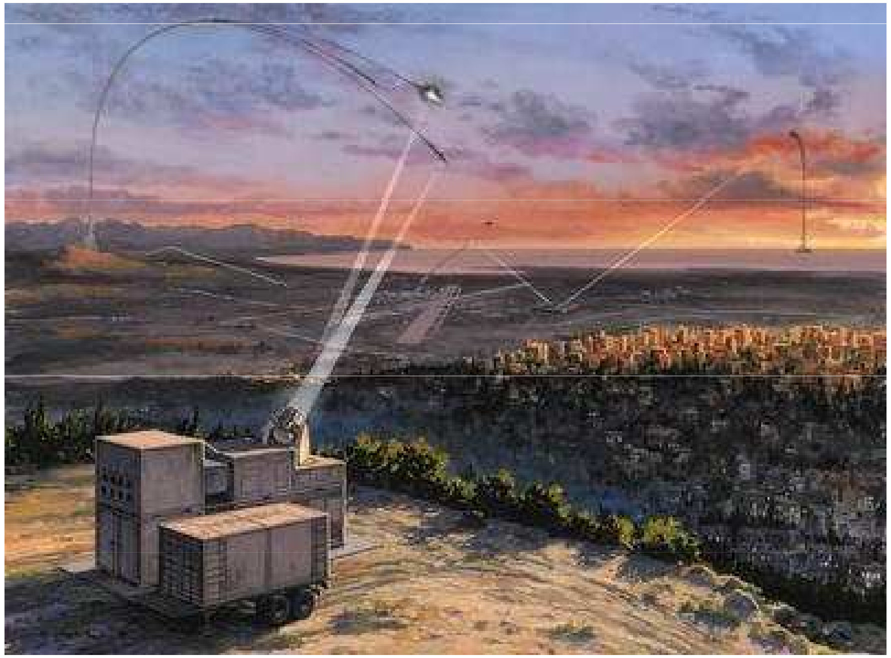
1. ***Impulse discharges** - the case of TEA lasers excitation – extremely multiavalanche initiated streamer breakdown*

1. ***Corona discharges (DC or AC)***

3. ***Dielectric barrier discharges (one or several dielectric „barriers" are situated on the lectrode surfaces, or in the gap)***

Why is the military laser-crazy?

Lasers are the dream weapon for the military. You can fire them from incredible distances with pinpoint accuracy and have the potential to be a game-changer in any battle. Advanced lasers could be used to detonate RPGs or missiles before they get to the target, they can punch through walls, and could potentially blow up ICBMs before they get too far off the ground (Reagan's infamous Star Wars plan). There's no ammunition concerns, just power, and despite being totally un-serviceable in the field, the lack of moving parts makes the possibility of breaking very slim



Laser weapons: Is this the dawn of the death ray?

By David Szondy

March 21, 2018

In the 1980s and '90s, excimer TEA lasers looked like the most promising candidate for the first high-power laser weapon, but the reaction is very difficult to control and maintain and the chemicals required are extremely dangerous to handle, so it isn't surprising that enthusiasm for them has waned as alternatives have appeared.

Carbon dioxide TEA lasers are of particular interest to the military because they produce high-power infrared beams that can cut metal.

The carbon-dioxide laser (CO_2 laser) was one of the earliest gas lasers to be developed. It was invented by Kumar Patel of Bell Labs in 1964[1] and is still one of the most useful types of laser. Carbon-dioxide lasers are the highest-power continuous-wave lasers that are currently available. They are also quite efficient: the ratio of output power to pump power can be as large as 20%. The CO_2 laser produces a beam of infrared light with the principal wavelength bands centering on 9.6 and 10.6 micrometers (μm).

https://en.wikipedia.org/wiki/Carbon-dioxide_laser

https://www.iqsdirectory.com/articles/laser/co2-lasers.html

The Canadian Association of Physicists (CAP) is pleased to announce that the 2008 CAP Medal-INO of Outstanding Achievement in Applied Photonics is being awarded to **Dr. Jacques Beaulieu**, for **the invention of the transversely-excited atmospheric carbon dioxide laser as well as his work in system performance modeling.**

A leading physicist and researcher, Dr. Jacques Beaulieu has had a decisive influence on Canadian laser history with the development of a brand new type of high power gas laser called the CO2-TEA laser which stands for Transverse Excitation at Atmospheric pressure laser**. In the late 1960s, there was intense competition with teams in Europe and the US striving to increase the operating pressure of pulsed CO2 lasers to produce a compact, efficient high power laser source for applications such as ranging and material processing. Dr. Beaulieu developed a solution that was both elegant in its simplicity and far reaching in its impact. Nine patents were eventually filed on various aspects of the new laser. Dr Beaulieu came up with a new concept of using a double discharge, the first discharge leading to pre-ionization of the gas and the second discharge leading to pumping the population inversion. The main benefits from that laser were its operation at atmospheric pressure leading to broadening of absorption lines and large energy density storage allowing faster amplification of the signal. This in turn led to its gain-switch operation on a submicrosecond time scale.** This low cost table-top mega-watt peak power pulsed laser was recognized around the globe as a technological revolution for laser processing as well as for plasma generation and studies.

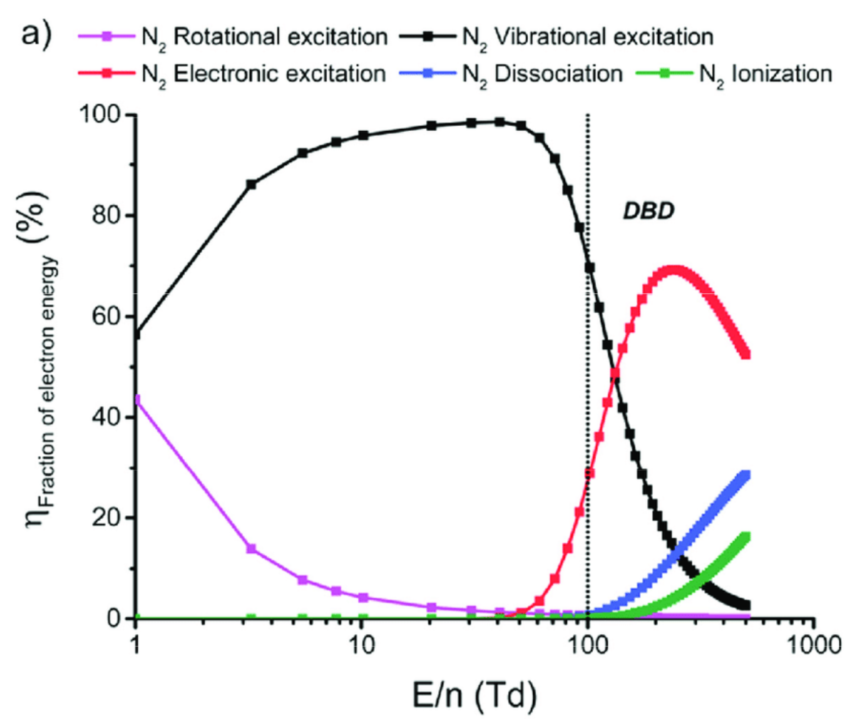
At low gas pressures, the CO2 laser is basically a continuous wave system that depends for its excitation on resonant energy transfer in collisions of N2 molecules in the 1st vibrationally excited level (v = 1) with ground state CO2 molecules:

$$\begin{aligned}&N_2(v=1) + CO_2\ (\text{ground state}) \rightarrow \\ &N_2(v=0) + CO_2\ (\text{upper laser level}) + \Delta E\ (\text{small}).\end{aligned}$$

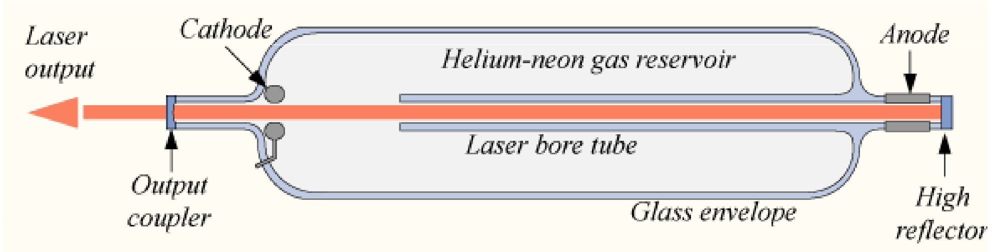
The N2 molecules are excited by collisions of electrons in the discharge run in a gas mixture containing He, N2 and CO2. In 1969, R. Dumanchin and J. Rocca-Serra in France and A.J. Beaulieu in Canada recognized that, by increasing the gas pressure of the discharge from 5-20 Torr (the range characteristic of the CW systems) to pressures on the order of one atmosphere (760 Torr), the population inversion density could be increased enormously. This is because the number of target N2 molecules that electrons could hit, and the number of target CO2 molecules that excited N2 molecules could hit, would increase correspondingly. However, there is a problem in running longitudinal discharges at such high pressures. The voltages required to cause breakdown and to sustain a discharge are unacceptably high, and so Beaulieu turned to the solution of running the discharge transversely across the width of the discharge volume rather than along its length.

Colin Webb, "History of Gas Lasers, Part 2: Pulsed Gas Lasers," Optics & Photonics News 21(2), 20-27 (2010)
https://opg.optica.org/opn/abstract.cfm?URI=opn-21-2-20

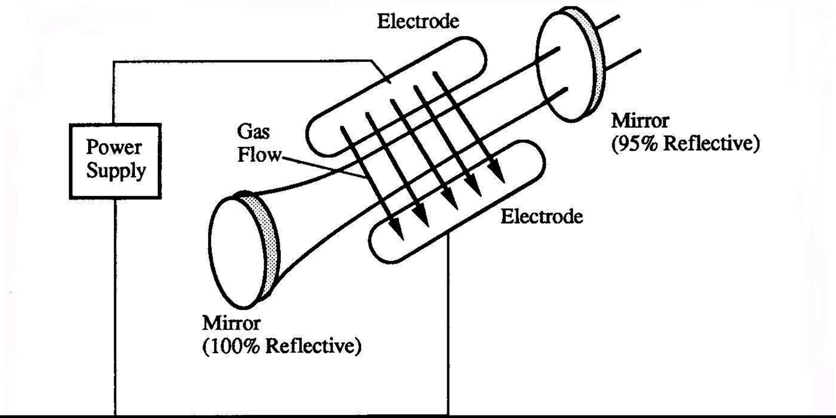
•Catalysts 10(11):1358 DOI:10.3390/catal10111358



Low pressure – „logitudial" Townsend mechanism



High pressure – „transversal" streamer mechanism



Aplikovaná laserová technika
Applied laser technology

CO2 lasery na míru – řešení pro toho, kdo má jasno.

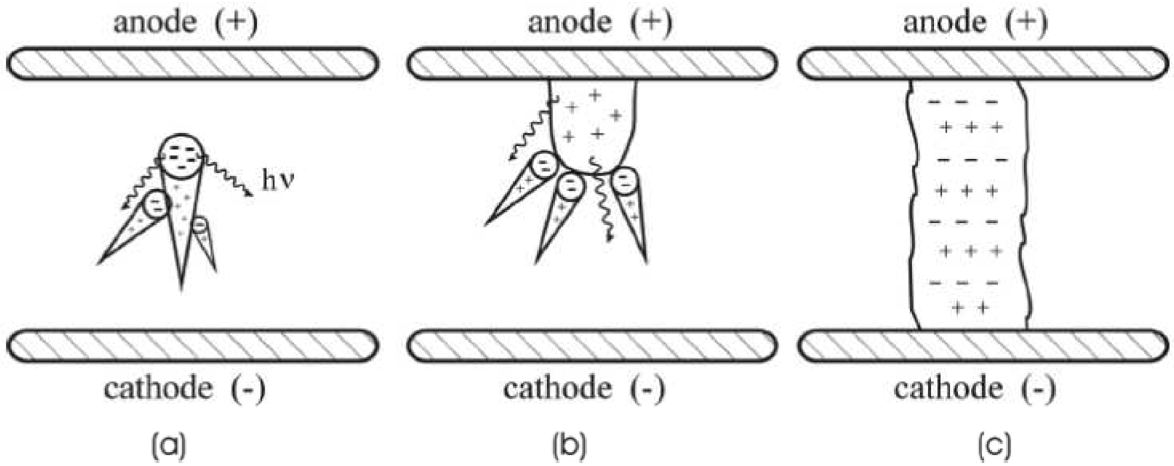
Od roku 1992 vyrábíme CO2 lasery pro vaše aplikace.

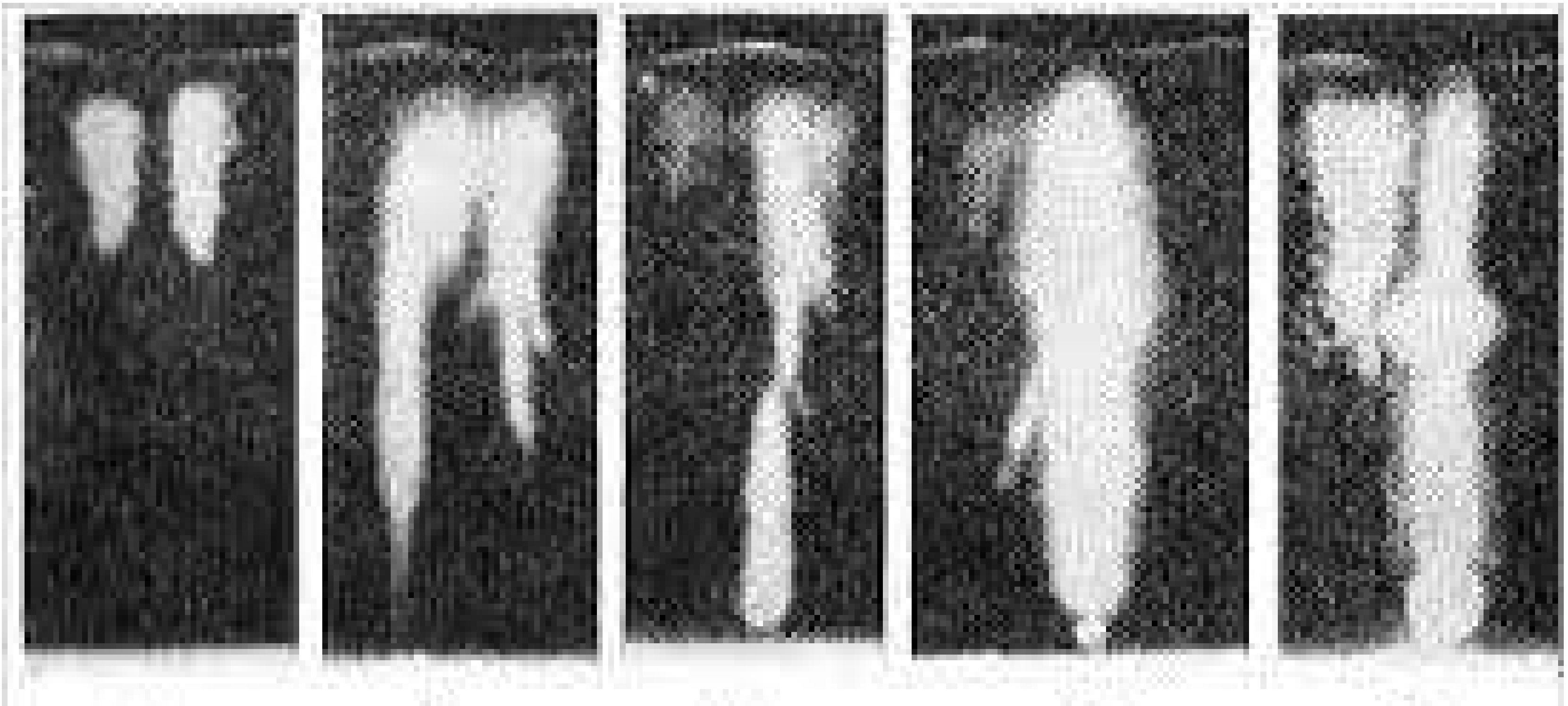
DŘEVO | PAPÍR | PLASTY | TEXTIL | ARAMID | KARBON | IZOLACE
PLEXISKLO | MDF | KOBERCE | KŮŽE | KOREK | POLYSTYREN | ***a další***

ŠKODA | BENTLEY | BOEING | SEAT | SIKORSKY | MAYBACH
VW | Mercedes-Benz | PORSCHE | AIRBUS | Ford | TATRA
Carrier | Webasto | TEG | přihoda | ECE Group | SKY

PREIONIZATION

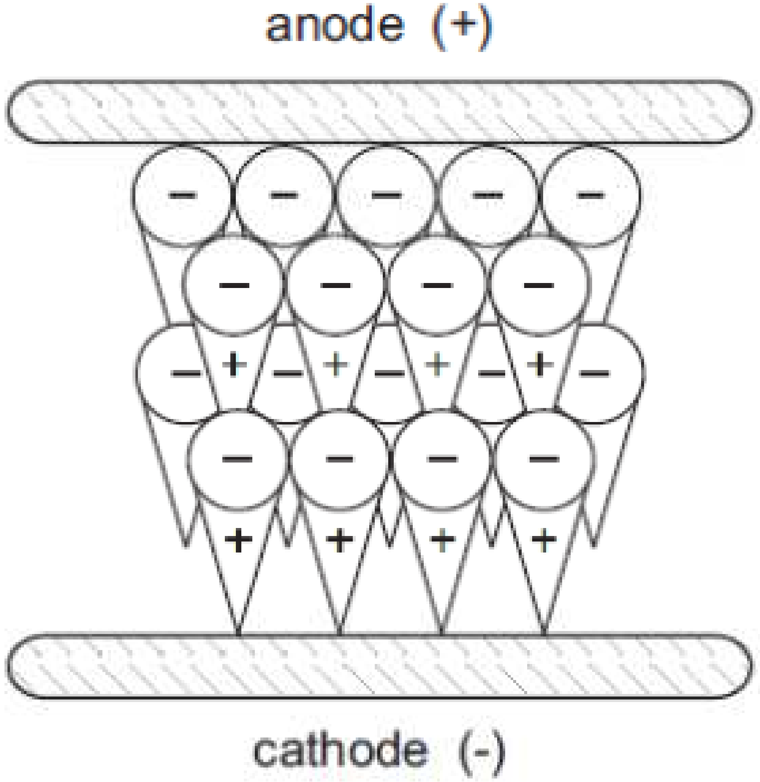
Streamer formation from a single or several separated avalanches :





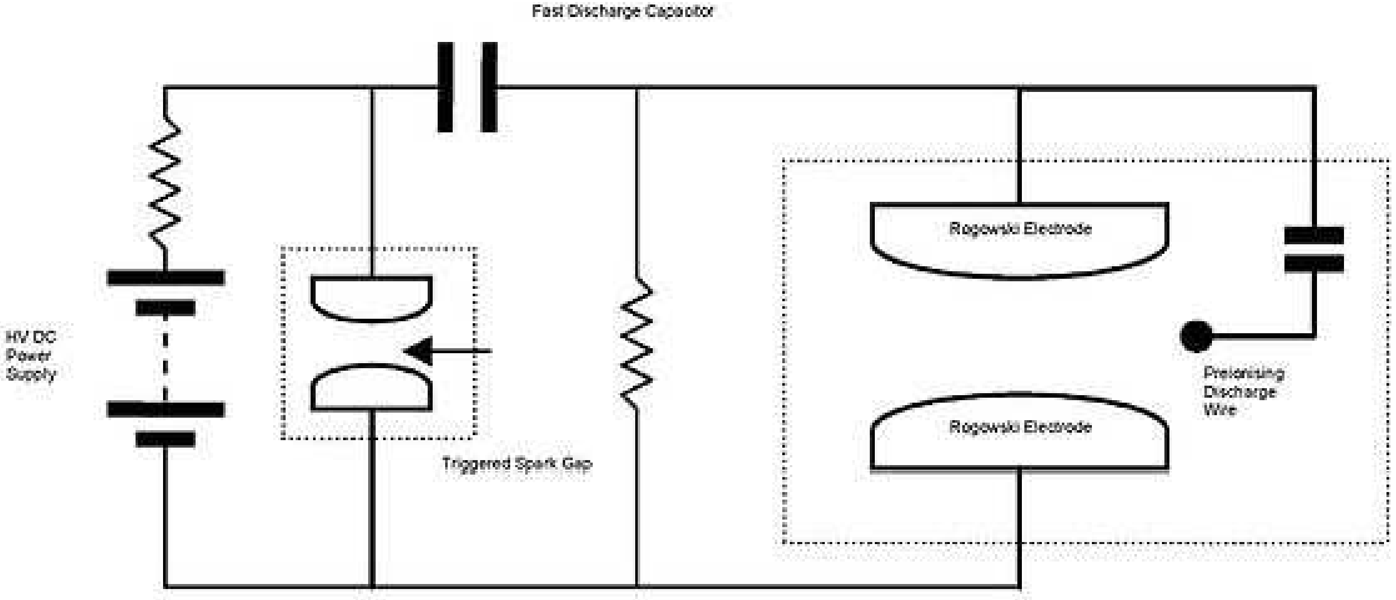
The homogeneous formation of pulsed multi-avalanche uniform discharges due to the preionization

Jeffrey I. Levatter *and* Shao-Chi Lin: Journal of Applied Physics 51, 210 (1980)

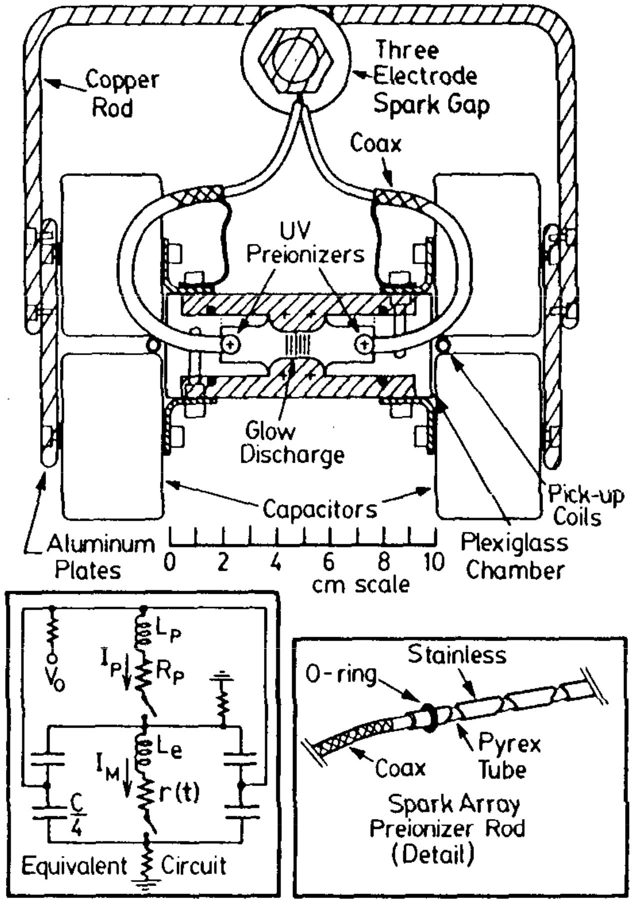


Technical solution:

Preionization using an auxiliary discharge:



CO2 TEA Laser Discharge Circuit



Preionization by gamma-rays:

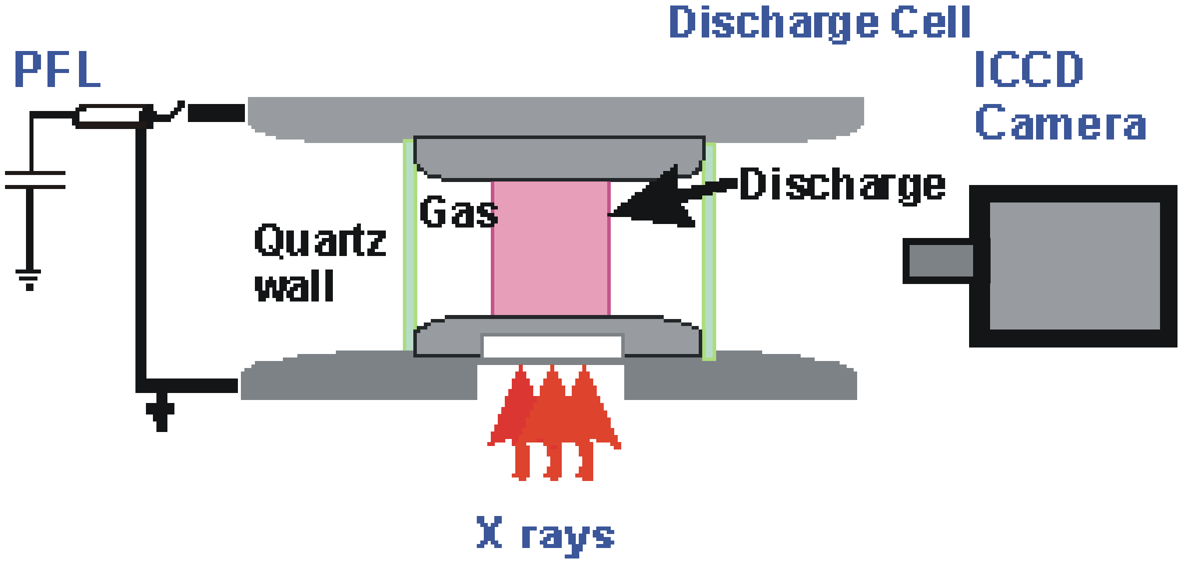


Fig: (4). Schematic of the experimental set up

Instability of the multiavalanche discharge plasma – generation of the cathode spots

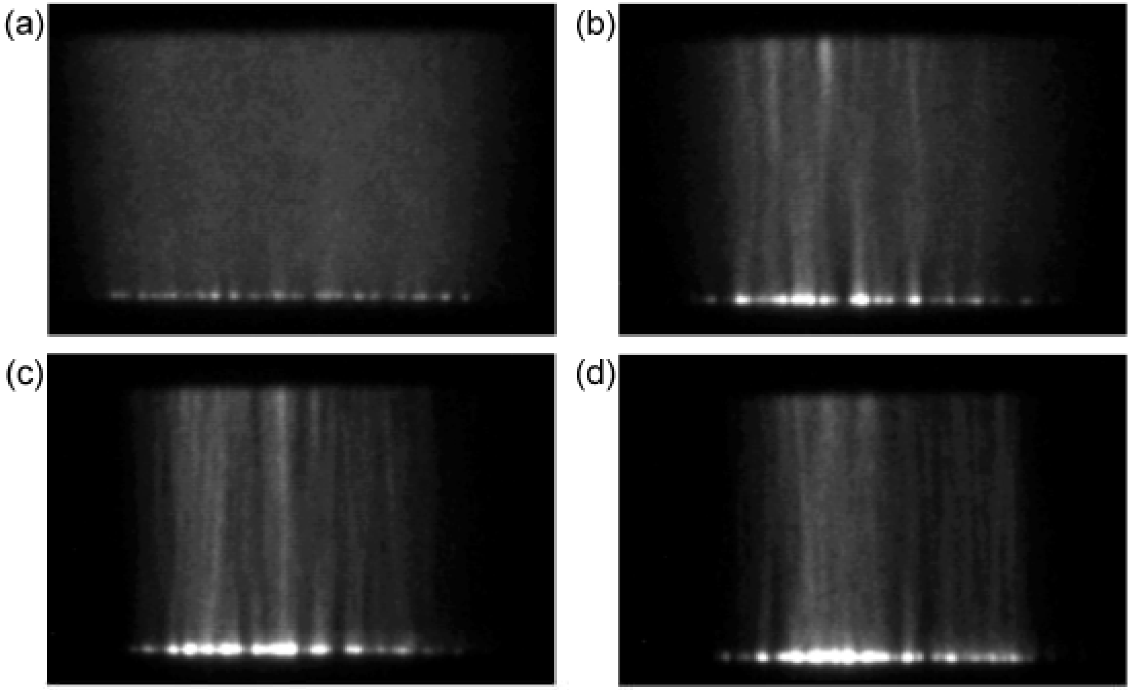
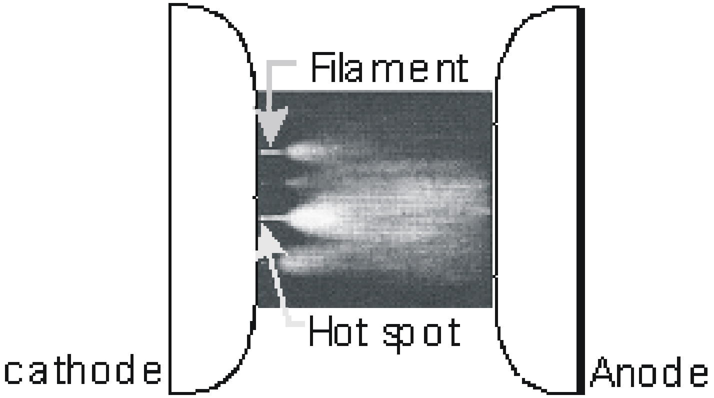


Figure 4.14: Temporal development of a discharge in volume 2 in HCl/Kr/Ne with partial pressures of (1/100/4899) mbar and a power deposition of 540 kW cm^{-3}*.(a) 100 ns, (b) 200 ns, (c) 300 ns, (d) 400 ns after breakdown.*



STREAMER BREAKDOWN ALWAYS OCCURS IN THE FOLLOWING SEQUENCE OF EVENTS

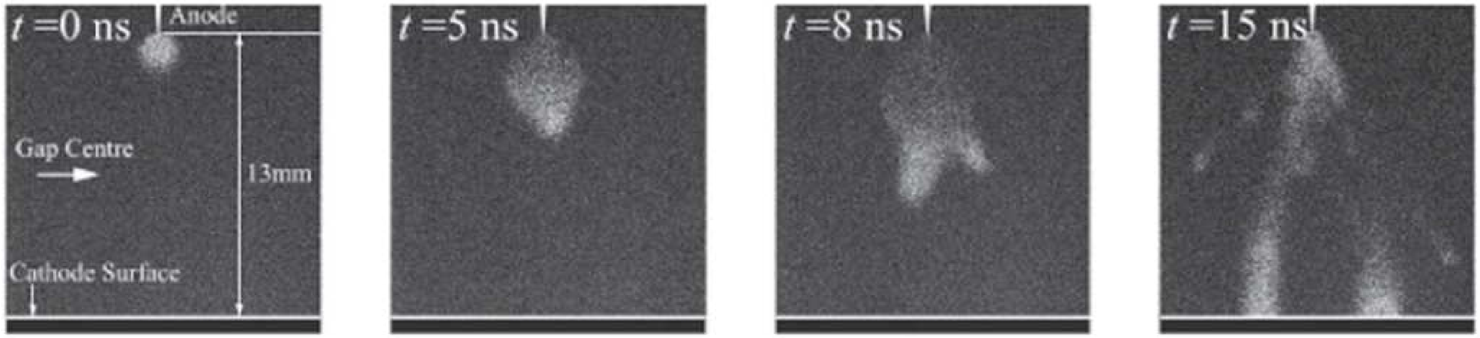
(a) The avalanche stage, wherein the streamer initiating charge in a localized region is formed by charges generated in a single avalanche or more often accumulated in a sequence of avalanches

(b) The positive primary streamer initiation: after an initial delay, when the streamer initiating charge partially shields itself from the external field forming a 'critical' region of relatively dense plasma (10^{13}–10^{15} cm−3) resulting in the primary positive streamer starts to propagate.

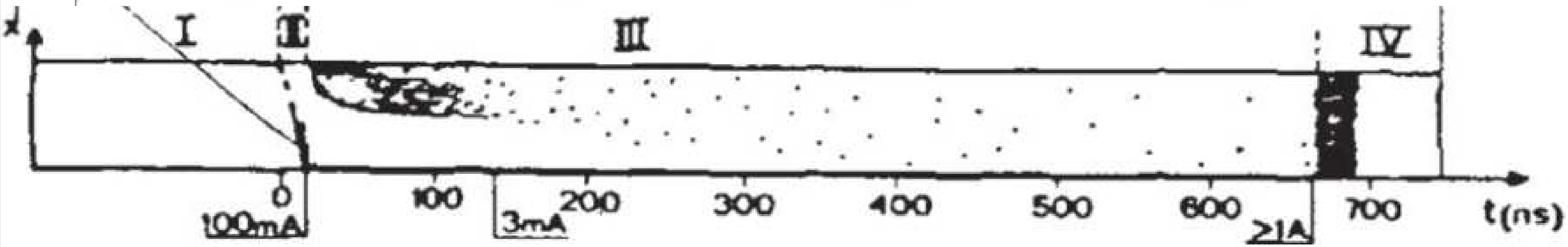
(c)The positive streamer propagation, where the primary streamer head propagates as a luminous spot of the diameter typically less than 1 mm with the velocity usually in the range 10^{7} –10^{8} cm s^{-1} followed by a less luminous streamer trail.

(d) The streamer arrival to the cathode, forming an active glow-discharge type cathode spot, which is effectively producing the electrons by direct impact ionization in the cathode fall

(e) The filamentary glow to arc transition is often initiated by the growth of secondary streamers

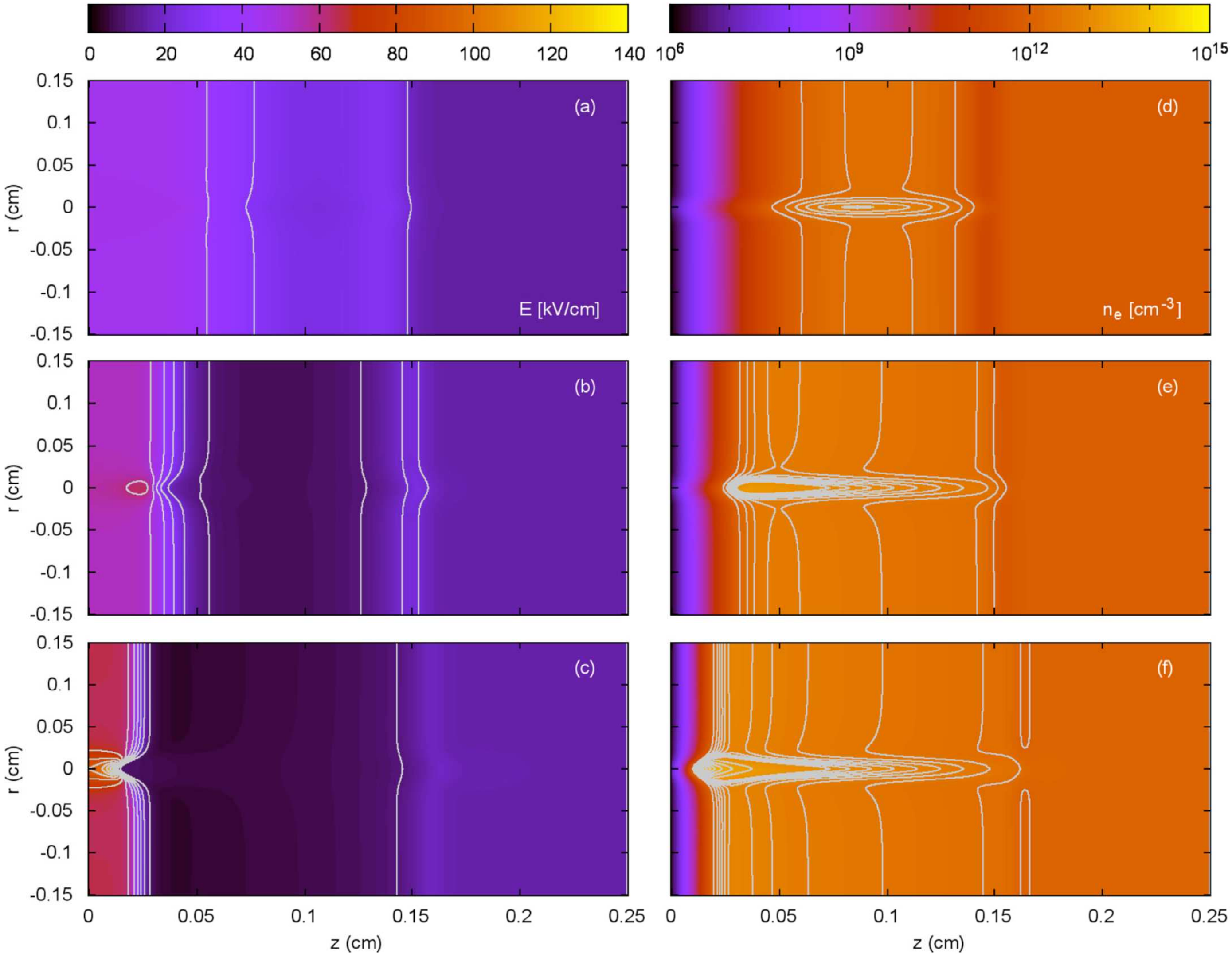


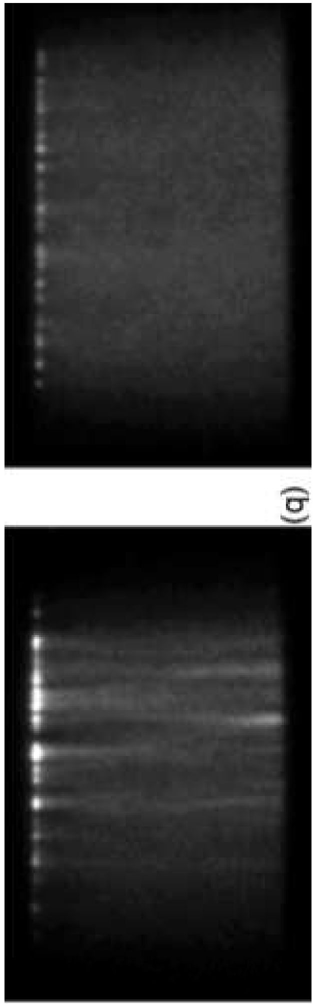
(a) (b) (c) (d)



2D- computer simulations :

M.Cernak, D. Bessieres,and J. Paillol: J. Appl. Physi. **110** (2011)1063

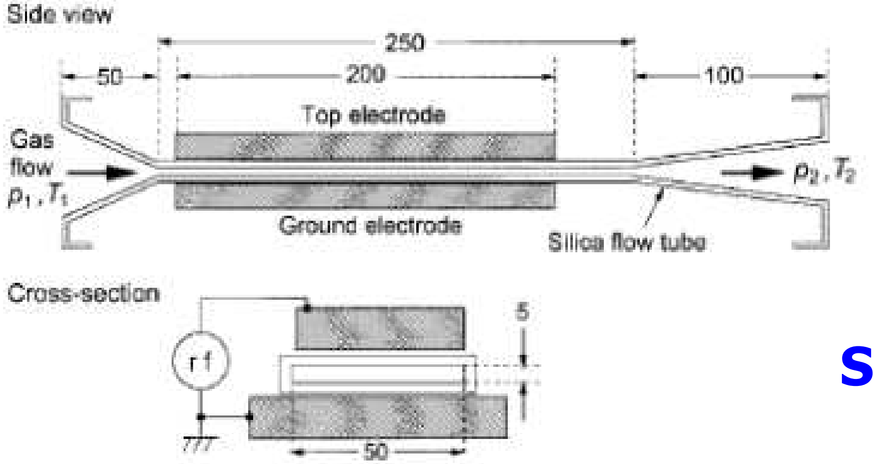




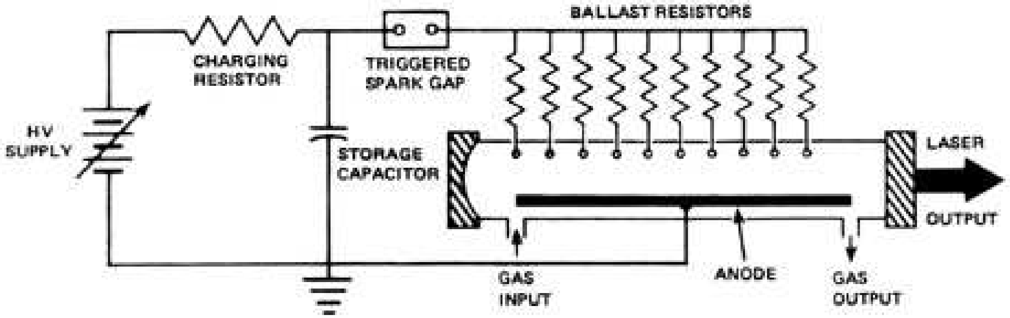
(a)-(c) Electric field and (d)-(e) el. density at 27, 28, and 29 ns

Surprisingy many similarities with the positive streamer !

Stabilization by fast flowing gas



Stabilization by balast resistors:



https://www.youtube.com/watch?v=v9sKqGC3t-0

https://hackaday.com/2015/07/08/legit-hack-creates-tea-laser-power-by-mr-wimshurst/

https://www.hellenicaworld.com/Science/Physics/en/Excimerlaser.html

„The most widespread industrial application of excimer lasers has been in deep-ultraviolet photolithography,[18][20] a critical technology used in the manufacturing of microelectronic devices (i.e., semiconductor integrated circuits or "chips"). Historically, from the early 1960s through the mid-1980s, mercury-xenon lamps had been used in lithography for their spectral lines at 436, 405 and 365 nm wavelengths. However, with the semiconductor industry's need for both higher resolution (to produce denser and faster chips) and higher throughput (for lower costs), the lamp-based lithography tools were no longer able to meet the industry's requirements. This challenge was overcome when in a pioneering development in 1982, deep-UV excimer laser lithography was proposed and demonstrated at IBM by Kanti Jain.[18][19][20][23] With phenomenal advances made in equipment technology in the last two decades, and today microelectronic devices fabricated using excimer laser lithography totaling $400 billion in annual production, it is the semiconductor industry view[22] that excimer laser lithography has been a crucial factor in the continued advance of Moore's law, enabling minimum features sizes in chip manufacturing to shrink from 800 nanometers in 1990 to 7 nanometers in 2018.[24][25] From an even broader scientific and technological perspective, since the invention of the laser in 1960, the development of excimer laser lithography has been highlighted as one of the major milestones in the 50-year history of the laser.[26][27][28]“