Capillary Discharges of Different Kinds: Theory an Simulation

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- *Bobrova, Bulanov, Razinkova, Sasorov* Plasma Phys. Reports, **22**, 349 (1996)
- *Bobrova, Bulanov, Farina, Pozzoli, Razinkova, Sasorov*
  Plasma Phys. Reports, **24**, 1 (1998)
- *Bobrova, Bulanov, Farina, Pozzoli, Razinkova, Sakai, Sasorov, Sokolov*
  Laser and Particles Beams, **18**, 623 (2000)
- *Kaganovich, Sasorov, Cohen, Zigler* Appl. Phys. Lett., **75**, 772 (1999)
- *Esaulov, Sasorov, Soto, Zambra, Sakai*
  Plasma Phys. & Contr. Fusion, **43**, 571 (2001)
- *Bobrova, Esaulov, Sakai, Sasorov, Spence, Butler, Hooker, Bulanov*
  Physical Review E, **65**, 016407 (2002)
- *Janulevich, Rocca, Bobrova, Sasorov, Lucianetti, Bortolotto, Sander, Nickles*
  SPIE, **4505**, 7 (2001)

  Vrba, Vrbova, Bobrova, Sasorov, Cachoncinlle, Pouvelse, Robert, Sarroukh, Gontiez, Viladrosa, Fleurier
  X-Ray Lasers 2002, eds. J.J. Rocca et al.. AIP, 2002, p. 133
- *Vrba, Vrbova, Jancarek, Bobrova, Sasorov, Limpouch, Pina, Nadvornikova, Fojtik*
  ibid., p. 139

- 1d two-temperature MHD simulation
- takes into account all dissipative electron terms in this geometry.
- plasma, neutral gas, and condensed material of the capillary wall treats simultaneously in the same manner.
- equation of states and degree of ionization are obtained assuming LTE.

Physical effects taken in to account:

- magnetic compression and shock waves
- Joule heating
- thermal conduction to relatively cold walls
- heating, evaporation and ionization of wall material (formation of a new plasma)

The ranges of the parameters of the capillary discharges are very wide.

There are a lot of types of capillary discharges. They differ strongly from each other by relative roles of different physical processes governing plasma dynamics in the discharges. *For some discharge some physical process may be much more important than a second one. However for other ranges of the parameters we may have the opposite situation.*

Thus there are several domains in the parameters space with quit different dynamics of the capillary discharge plasma.

Unfortunately, we have now no complete picture of dividing of the parameters space in such domains.

Nevertheless I will try to give some outlook of possible kinds of plasma dynamics in the capillary discharges and of main relevant physical processes.

ablation ⟷ no ablation

- plastics (polyacetal, polyethylene, ...)

strong ablation in almost a whole possible range of parameters

I = 200 A - 30 kA; diam = 200 μm - 4 mm

a “bottle neck” is not vaporization of the wall material

but heat transport from plasma to ionize the vapors

- ceramics

no ablation at all at *I* ~ 200-300 A

I > 3-10 kA ⟹ ???

- glass

It is like plastics case for thinner capillaries (< 1 mm) at ~ 1kA.

Ablation takes place even for 1-2 cm tubes (40 kA), but the “bottle neck is this case is determined by vaporization rate

“magnetized” ⟷ “unmagnetized” discharges

- “unmagnetized”

skin layer depth > *capillary radius* ⟹ magnetic and electric field penetrate plasma well ⟹

⟹ strong Joule heating of plasma ⟹ plasma pressure > magnetic field pressure ⟹

⟹ magnetic forces plays only minor role ⟹ no magnetic compression, no MHD instabilities

“magnetized” ⟷ “unmagnetized” discharges

- “magnetized”

skin layer depth < capillary radius ⟹ . . . ⟹

⟹ magnetic compression,
low Joule heating

$$t_c \sim \frac{c_A}{R_c}$$

$t \sim t_c$:

stable 1st compression,

very compact, dense and
hot plasma column
at the axis

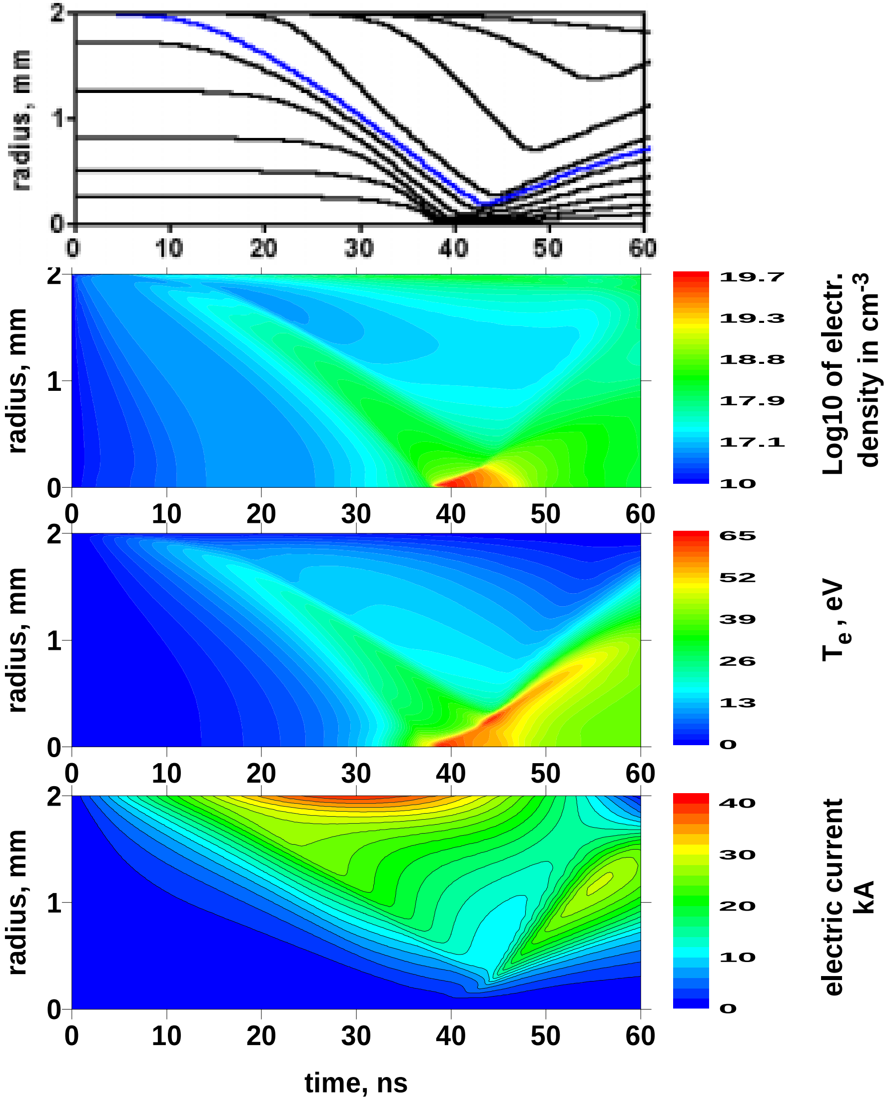
$t >> t_c$:

mhd instabilities,

turbulent mixing,

enhanced heat
transport and
resistance

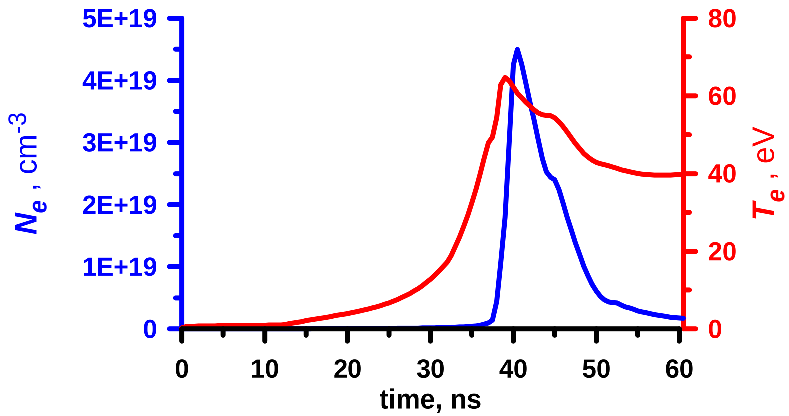
Simulation of the Rocca capillary discharge



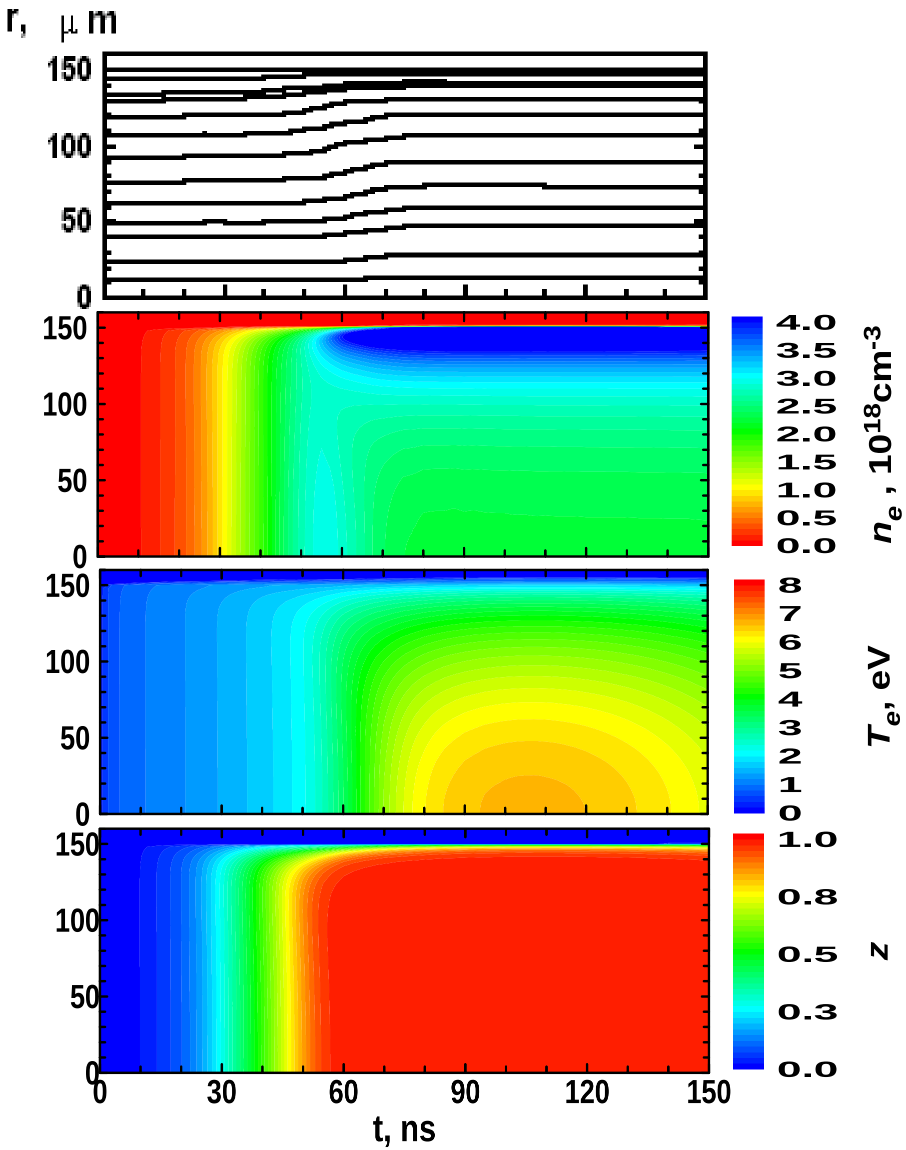
polyacetal capillary of 4 mm diameter

prefilled with Ar, ρ_0 = 1.37 μg/cm^3

I_{max} = 40 kA, half period = 60 ns



Ceramic capillary filled with hydrogen



ceramic capillary of 300 mm diameter

filled with hydrogen; p_0 = 67 mbar

I_{max} = 250 A, half period = 200 ns

Oxford experiment:
Spense, et al. PRE, **63**, 015401 (2001)
Bobrova, et al. PRE, **65**, 016407 (2001)