Formation of electrical prepeak in pulsed glow discharge via gas heating

M. Voronov, V. Hoffmann

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Outlook

- Introduction: electrical properties of μs PGD
- Pressure waves: experimental investigations
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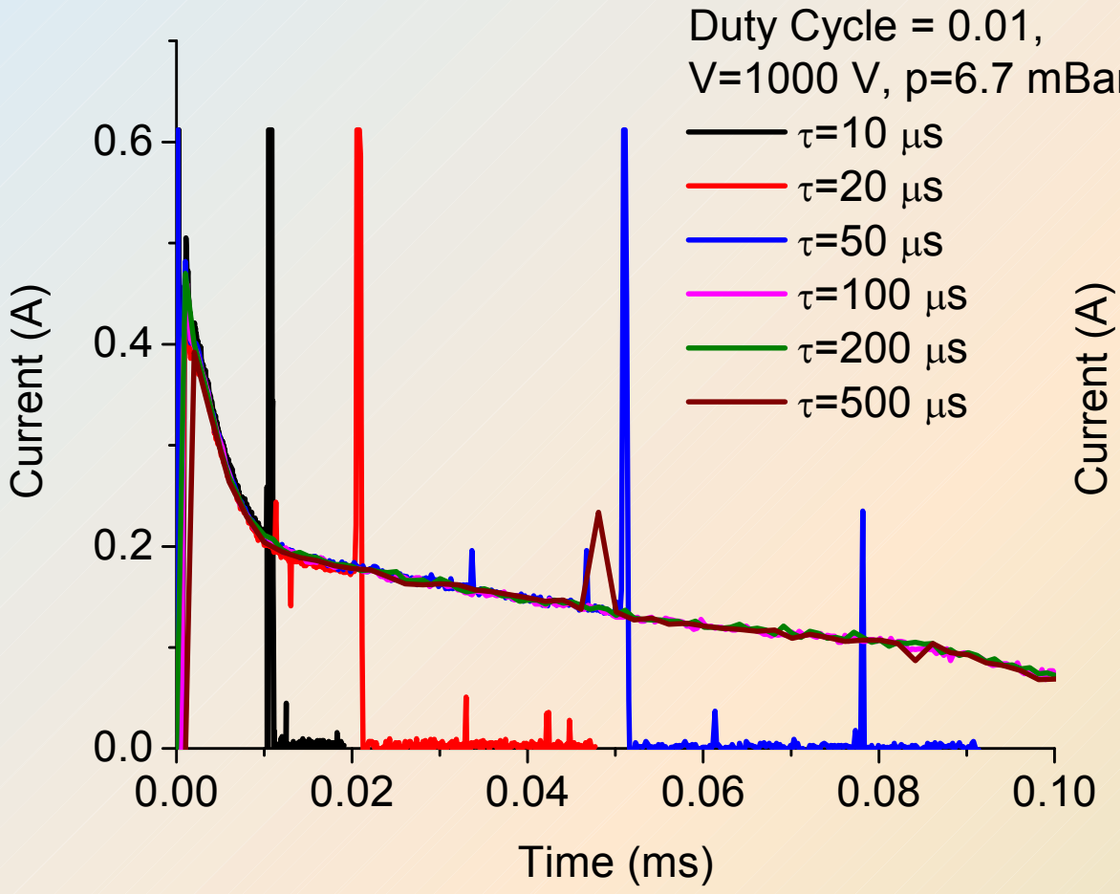
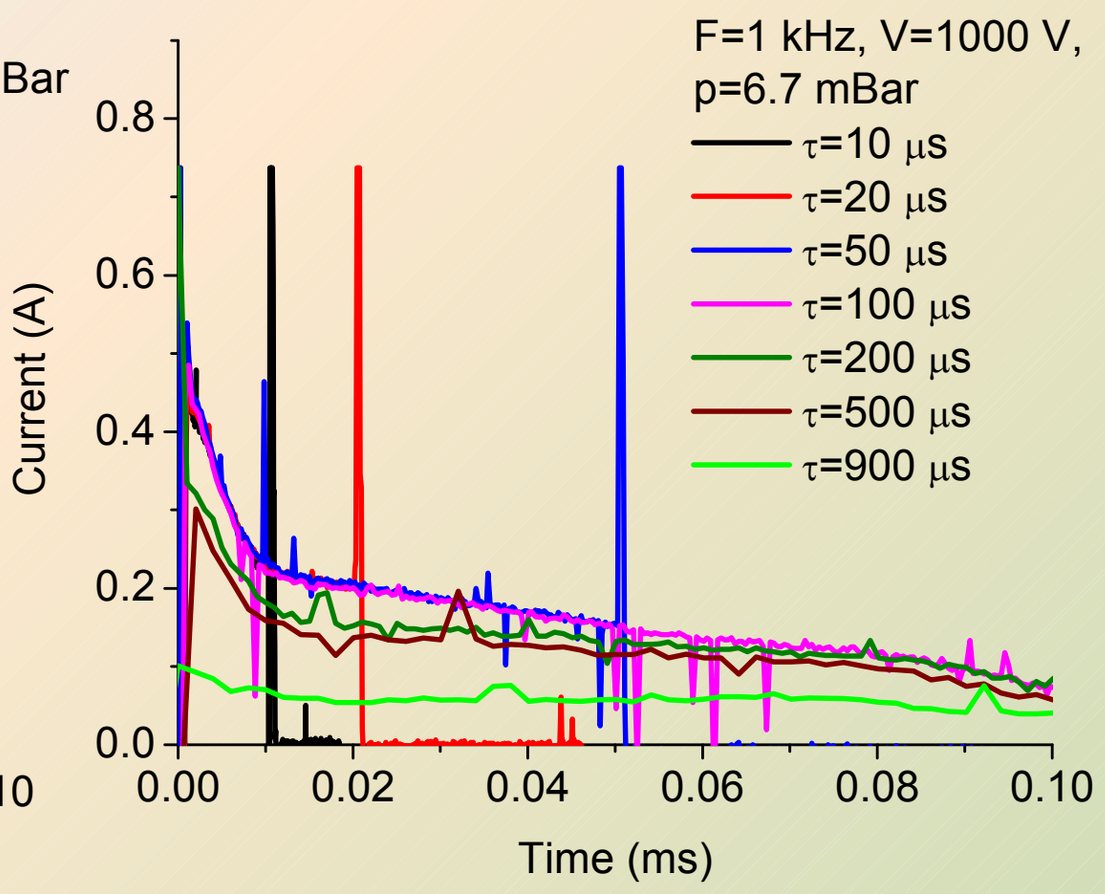
Electrical properties of μs PGD

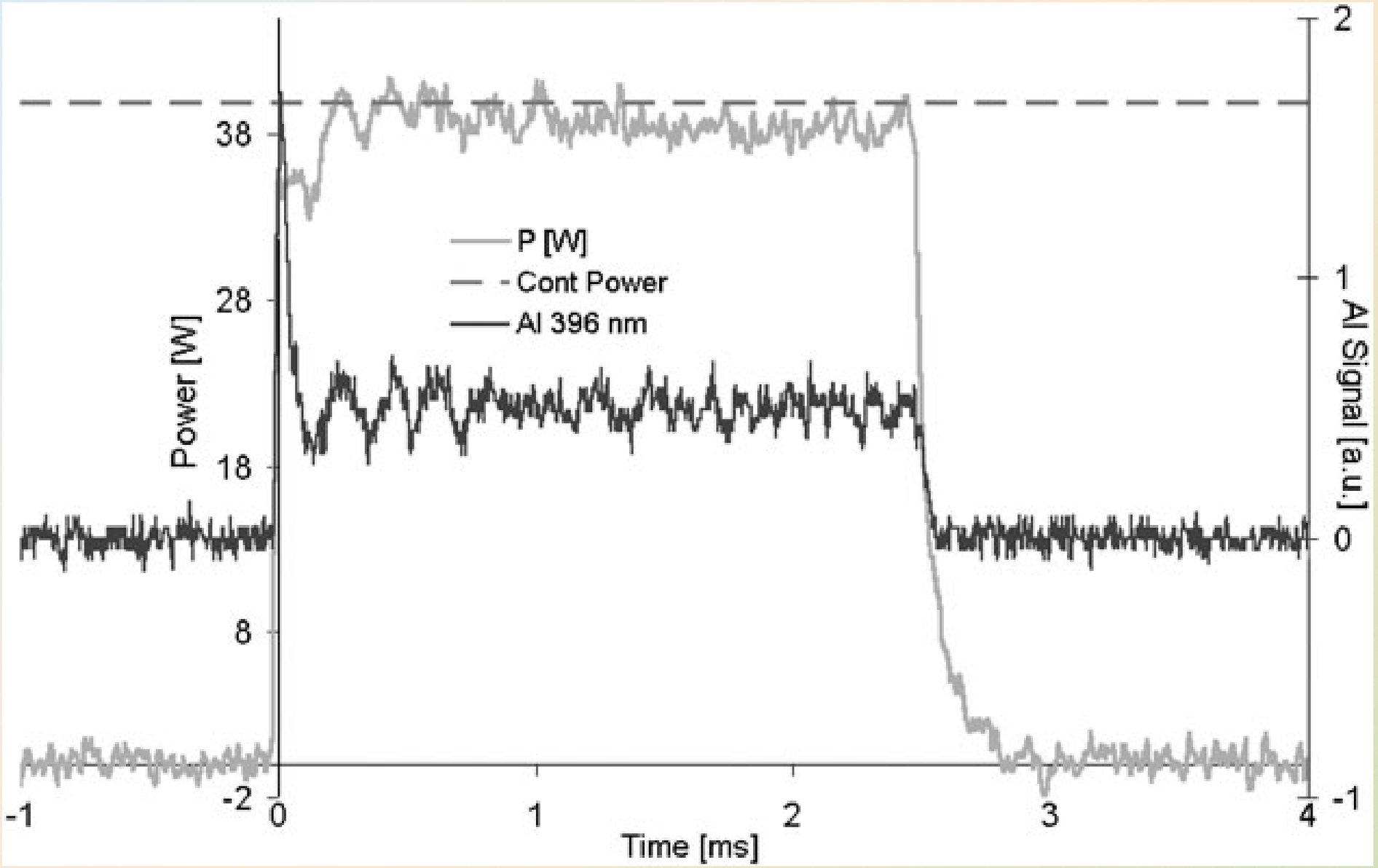
V. Hoffmann, V. Efimova, M. Voronov, P. Šmíd, E.B.M. Steers, J. Eckert, *Journal of Physics: Conference Series* 133 (2008) 012017





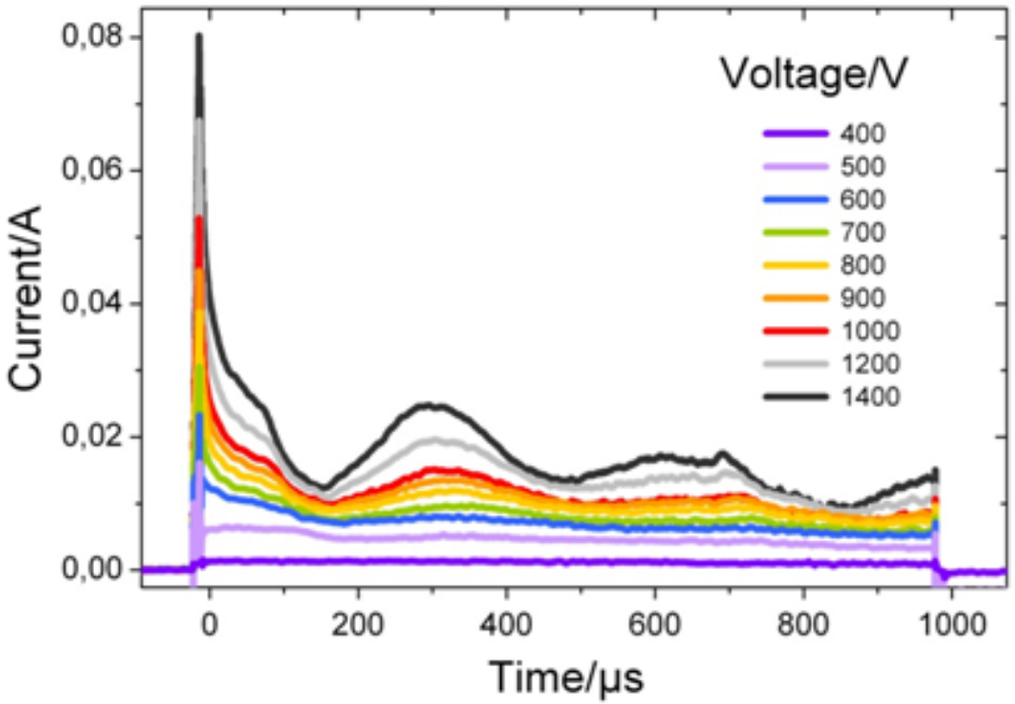
Electrical properties of μs PGD

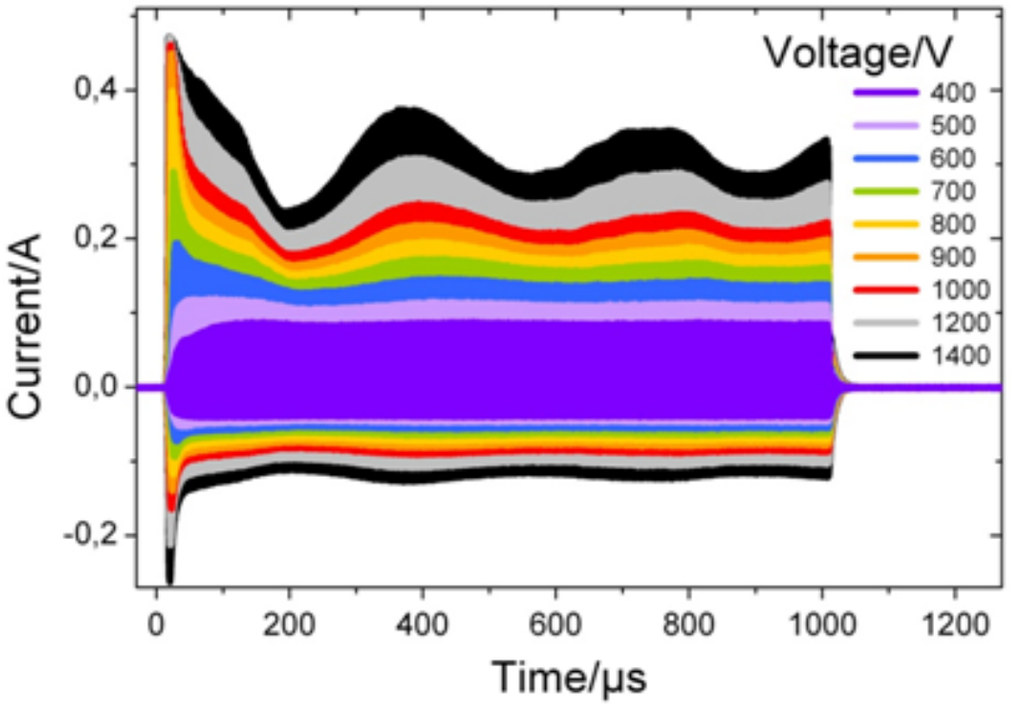
Th. Nelis, M. Aeberhard, M. Hohl, L. Rohr, J. Michler, *JAAS*, 2006, 21, 112–125



Electrical properties of μs PGD

V. Efimova, V. Hoffmann, J. Eckert, *JAAS*, 2011, 26, 784–791





DC discharge
p=6 hPa
τ=1 ms
F=200 Hz

RF discharge
p=6 hPa
τ=1 ms
F=200 Hz

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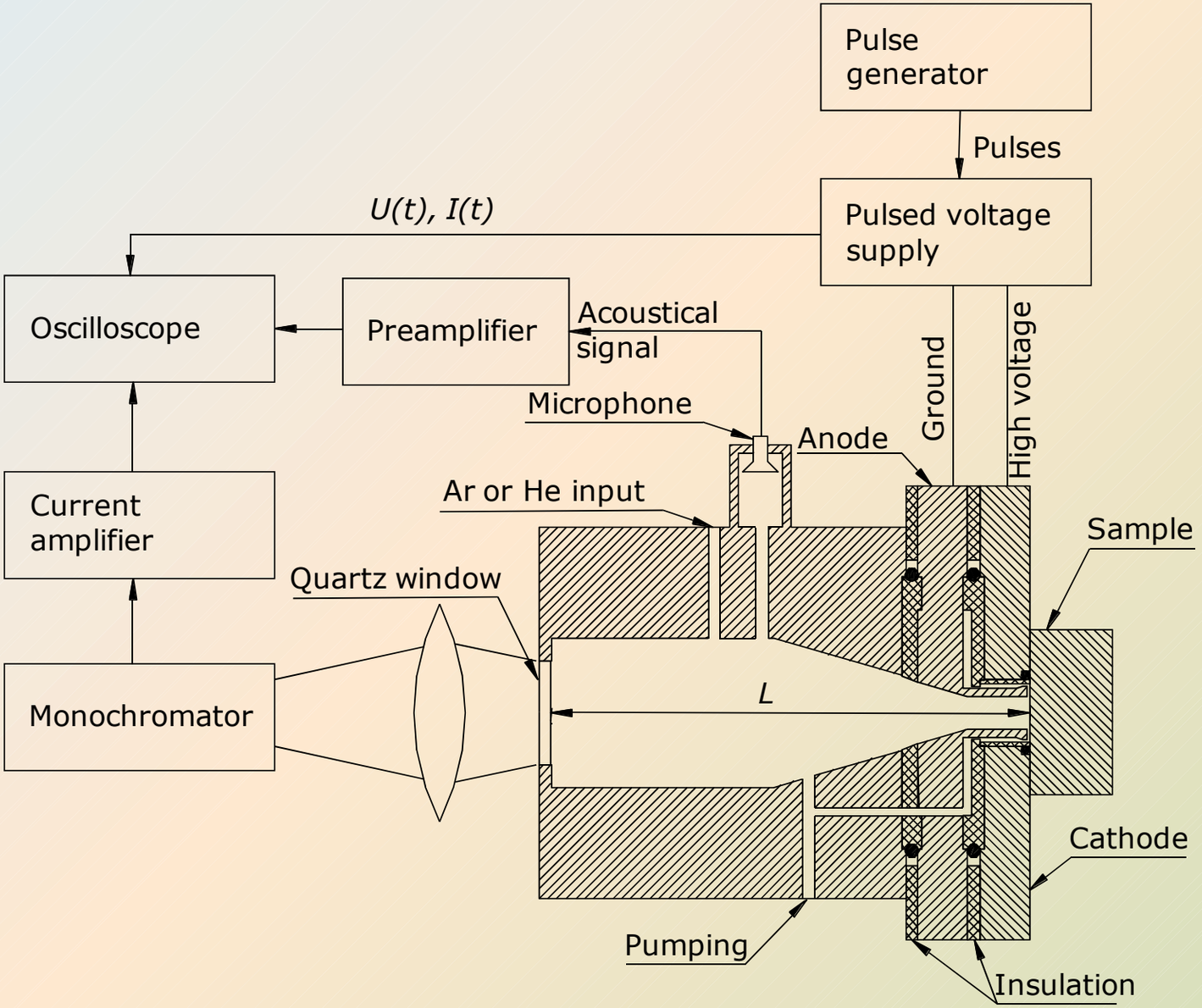
Pressure waves

M. Voronov, V. Hoffmann, W. Buscher, C. Engelhard, S.J. Ray, G.M. Hieftje,
JAAS, 2011, 26, 811–815



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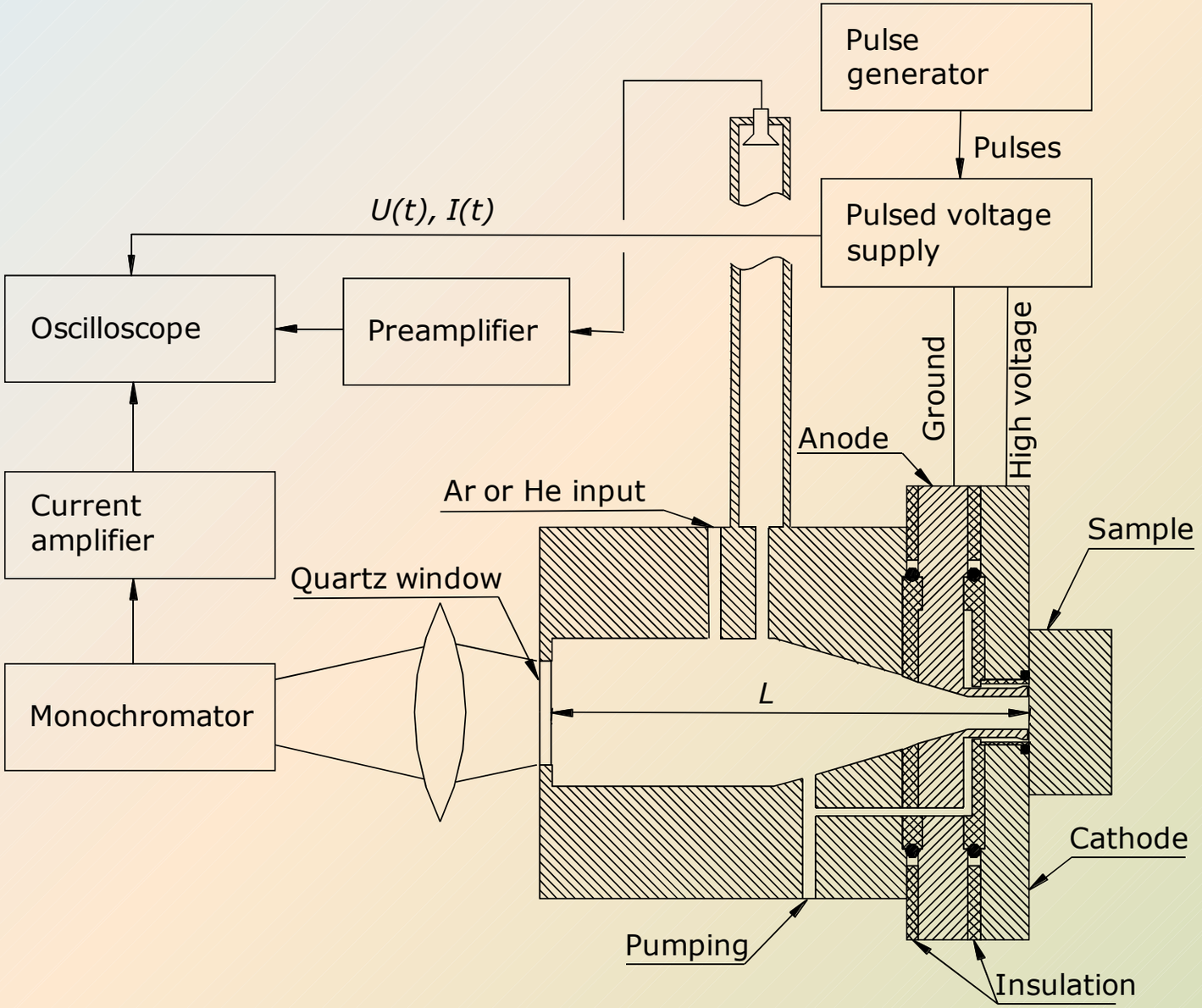

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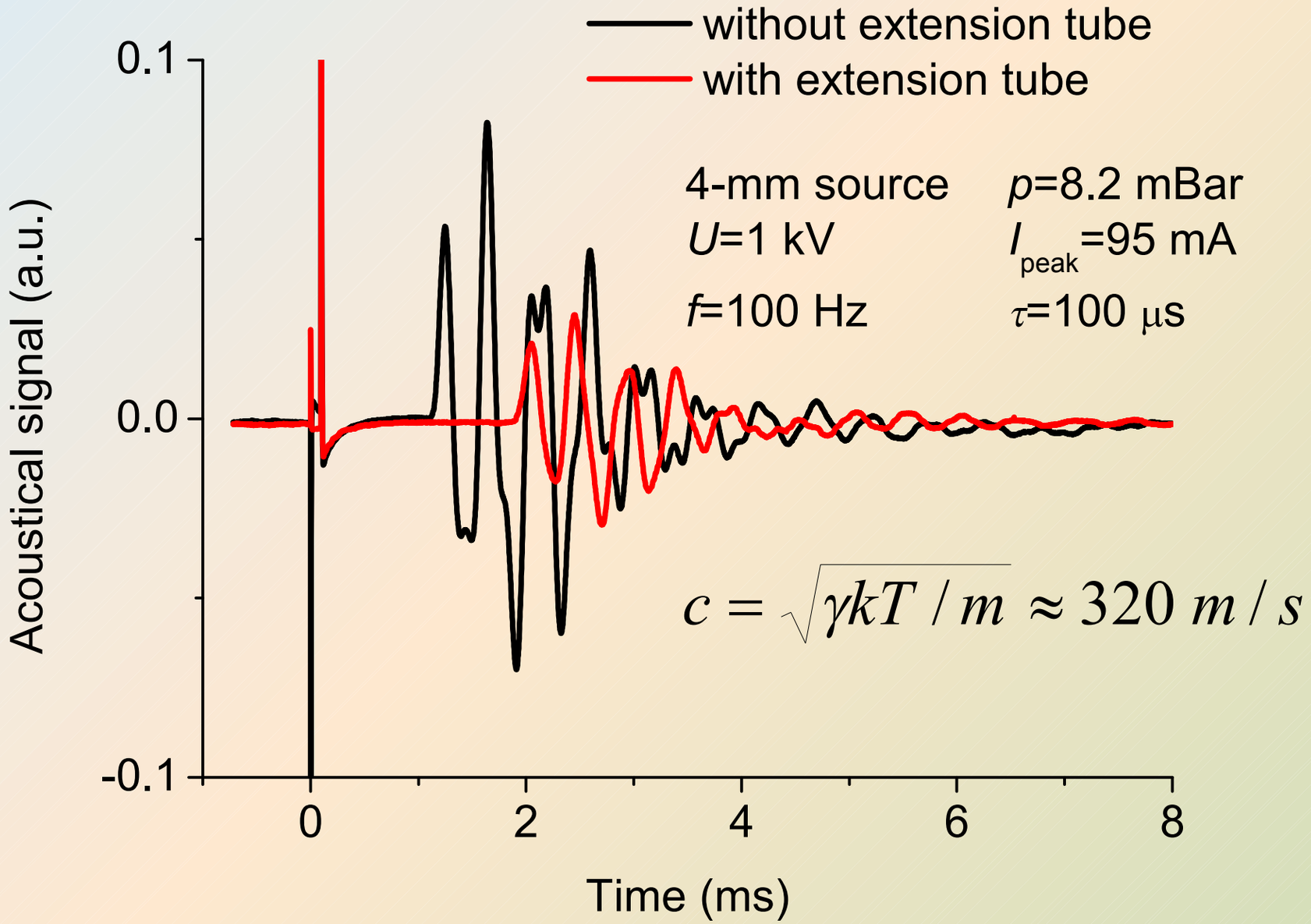

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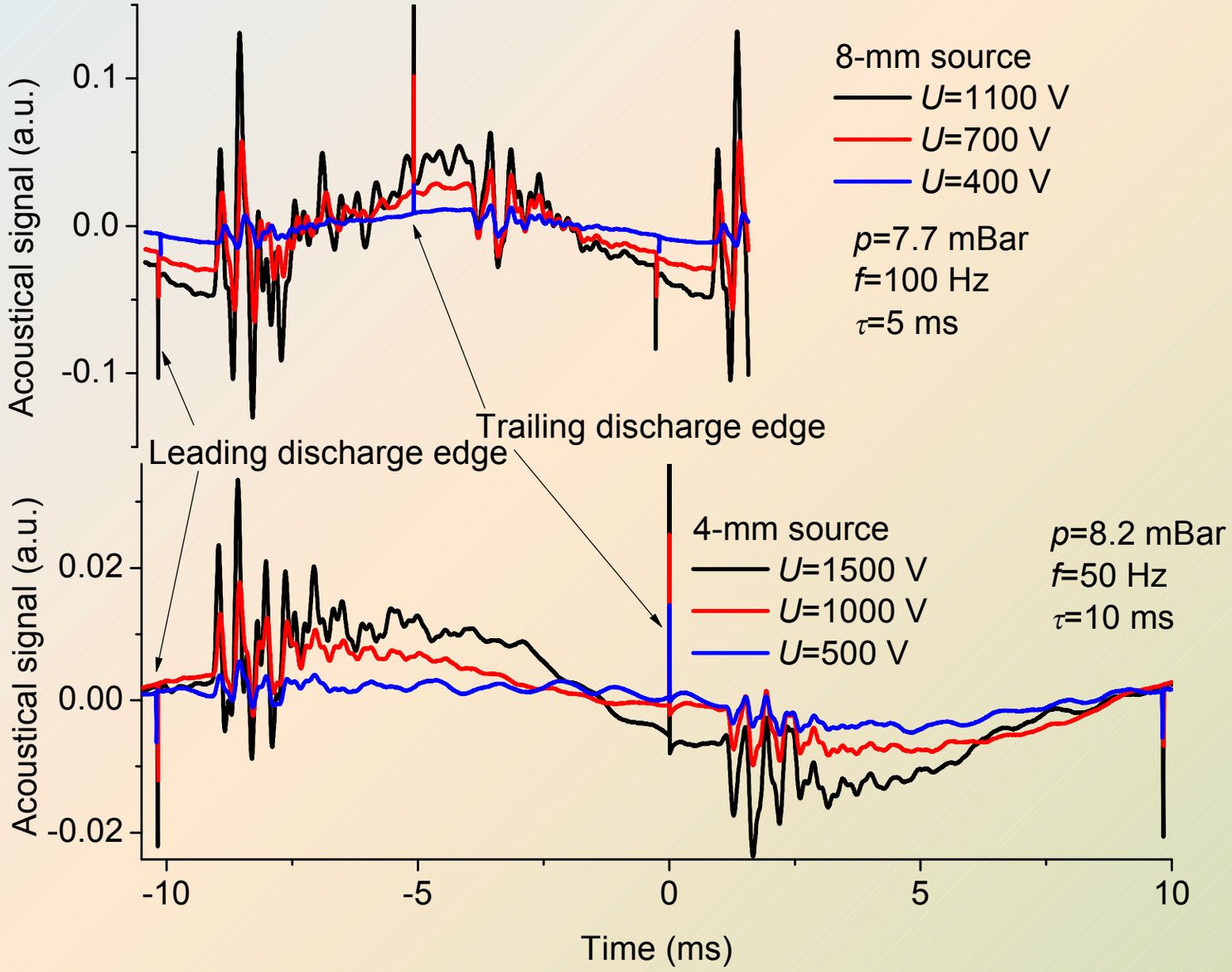

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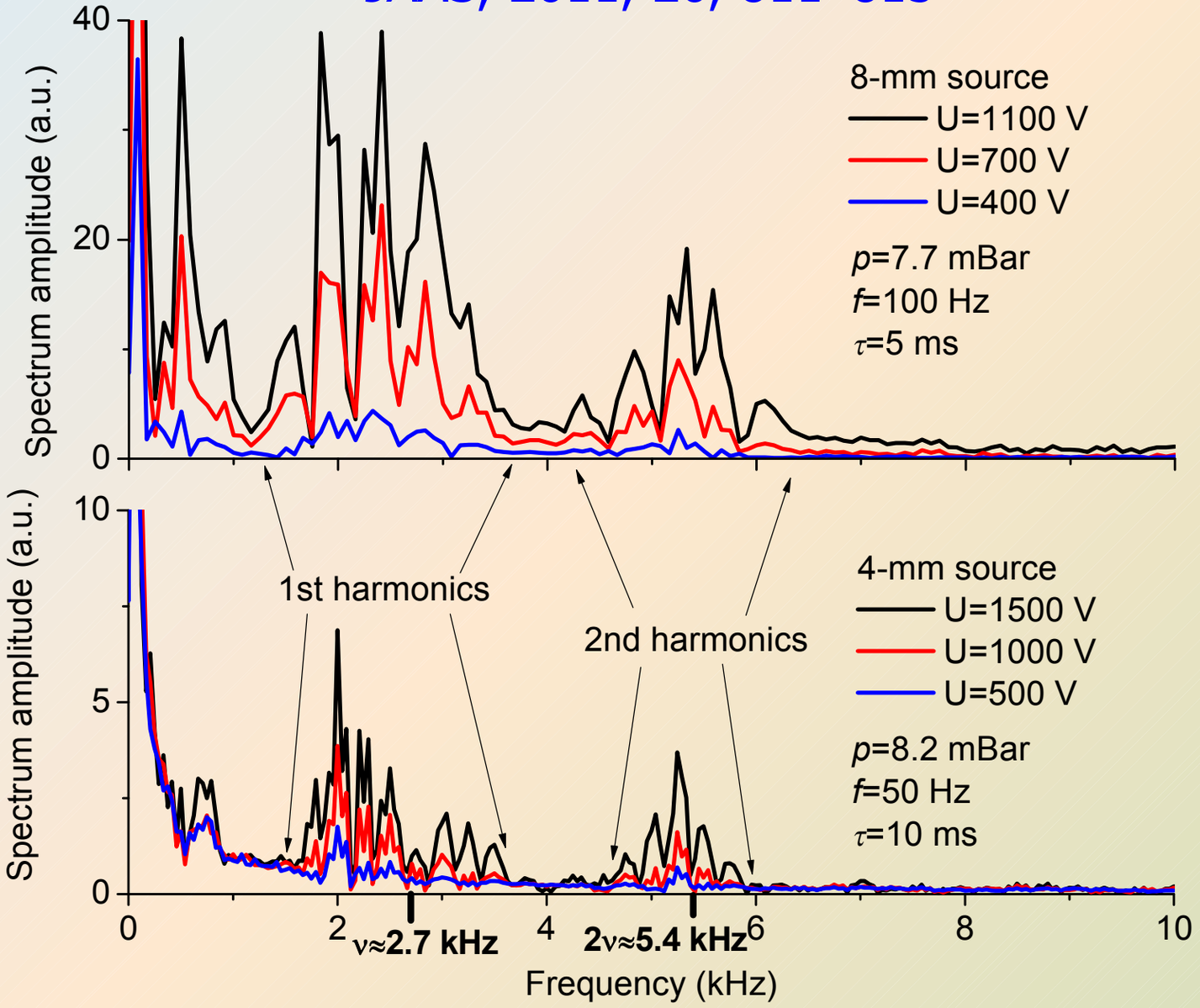

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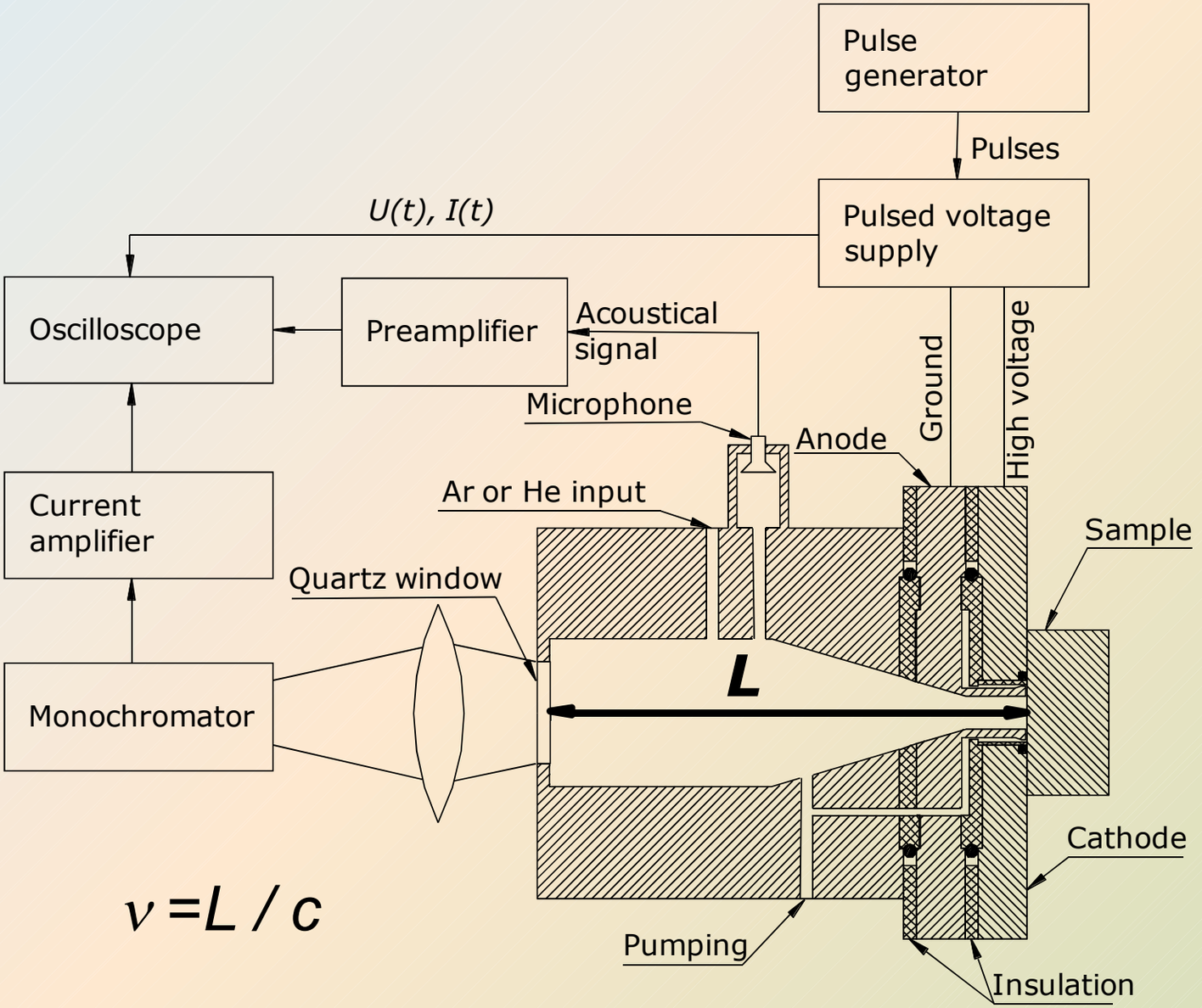
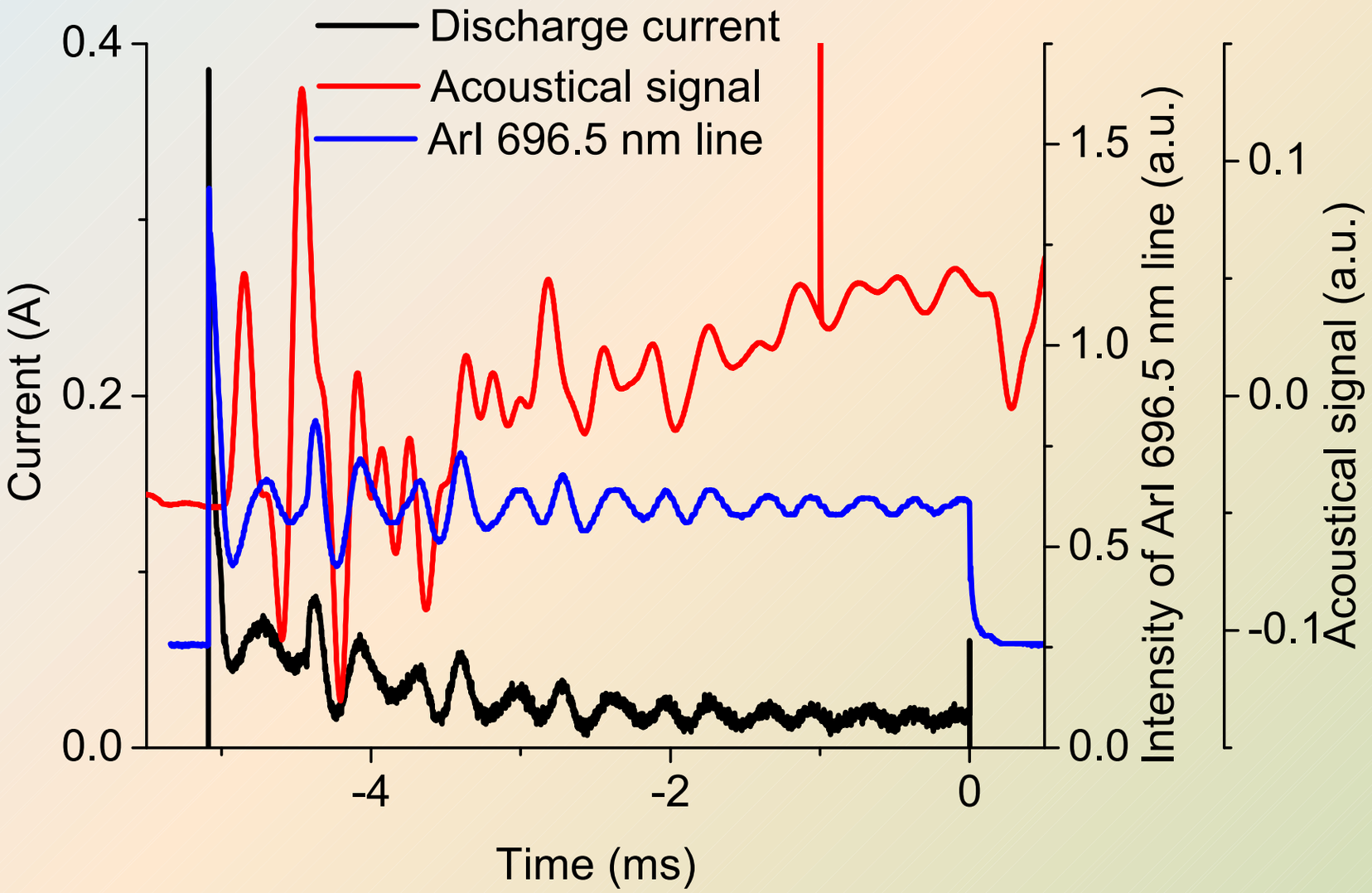


$\nu = L / c$

Pressure waves

M. Voronov, V. Hoffmann, W. Buscher, C. Engelhard, S.J. Ray, G.M. Hieftje,
JAAS, 2011, 26, 811–815

8-mm source p=7.7 mBar U=1100 V f=100 Hz τ=5 ms



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M. Voronov, V. Hoffmann, W. Buscher, C. Engelhard, S.J. Ray, G.M. Hieftje,
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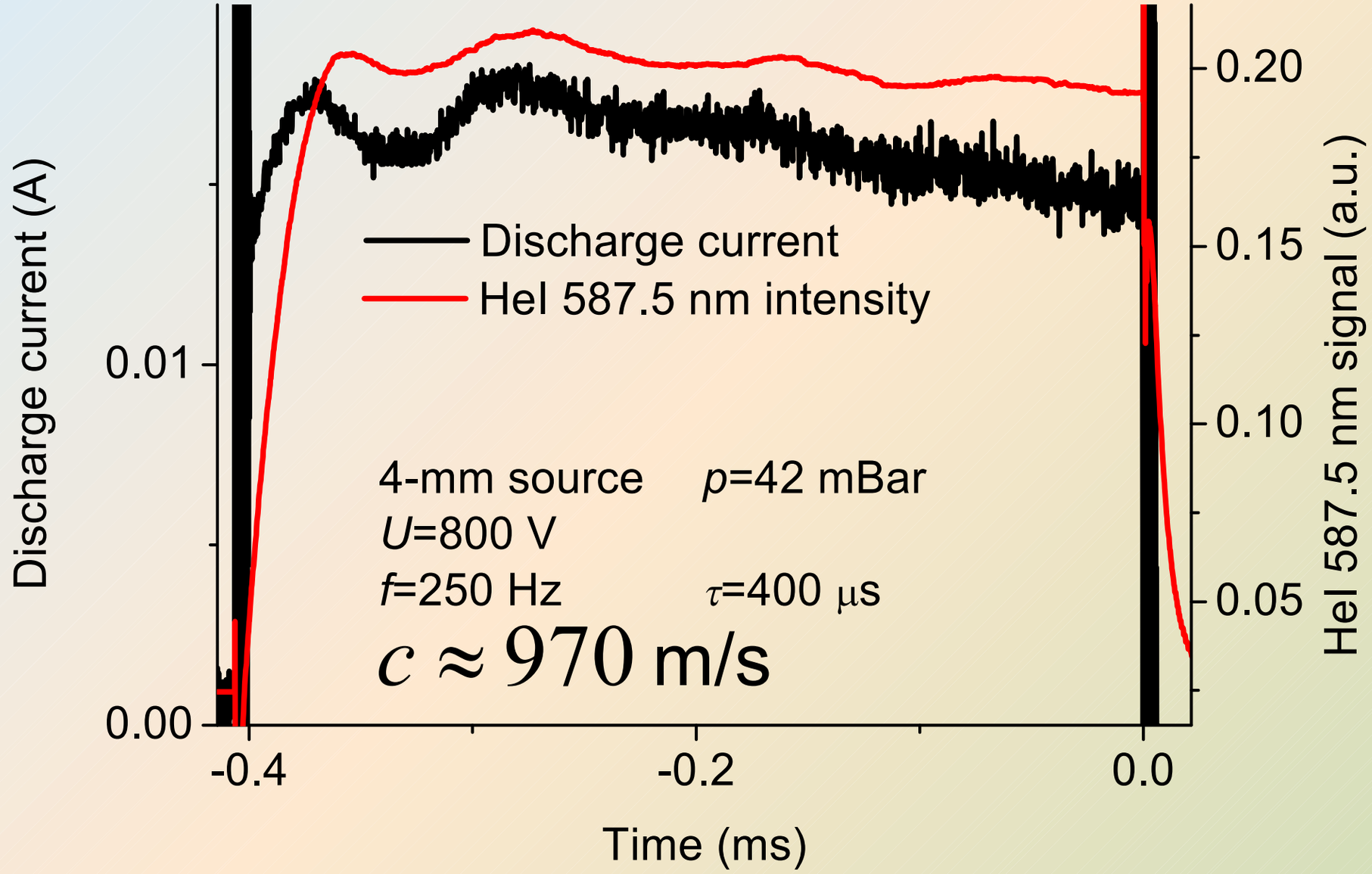
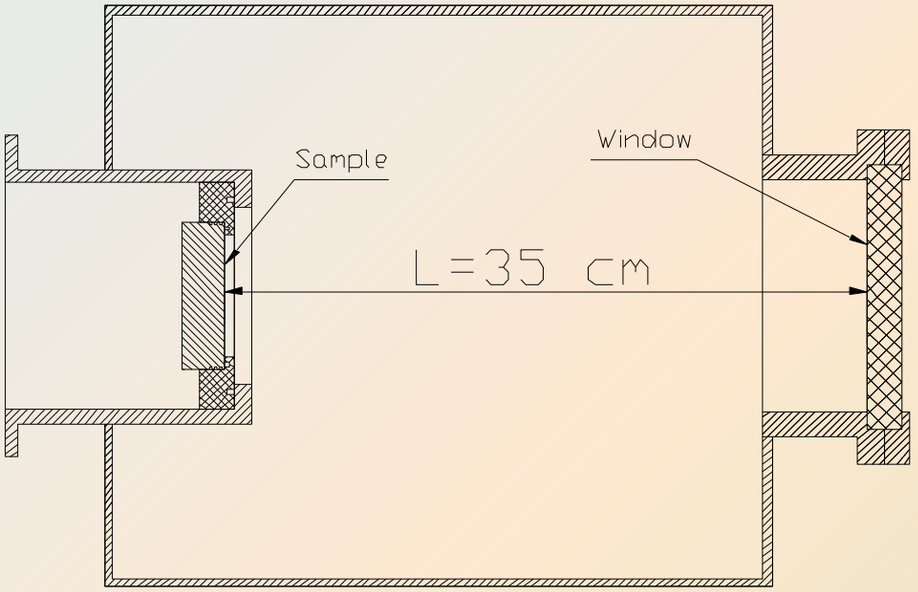
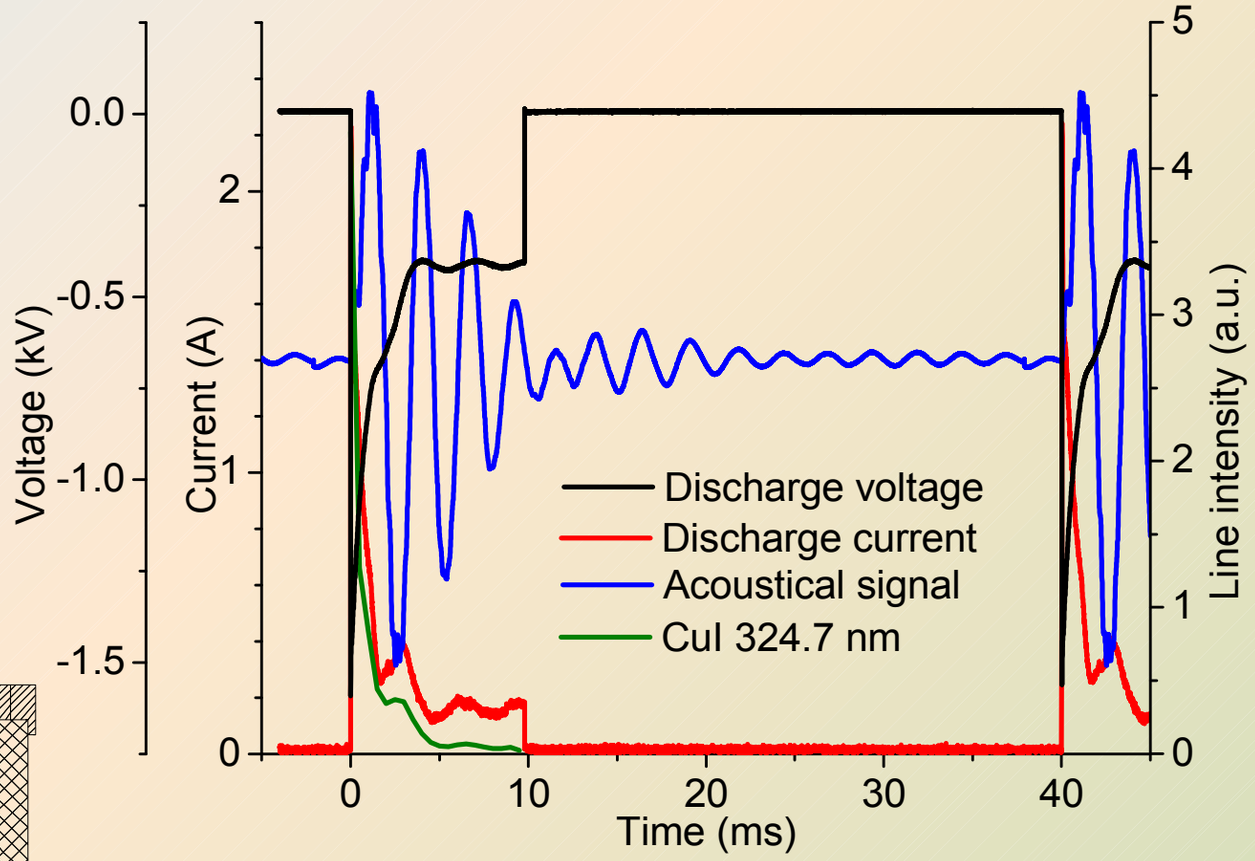


Pressure waves

A big Discharge cell with 8-cm cathode





τ =10 ms, f = 25 Hz,
U_{peak} = 1.2 kV, p=1 hPa.
The voltage falls until about 400 V in approximately 5 ms

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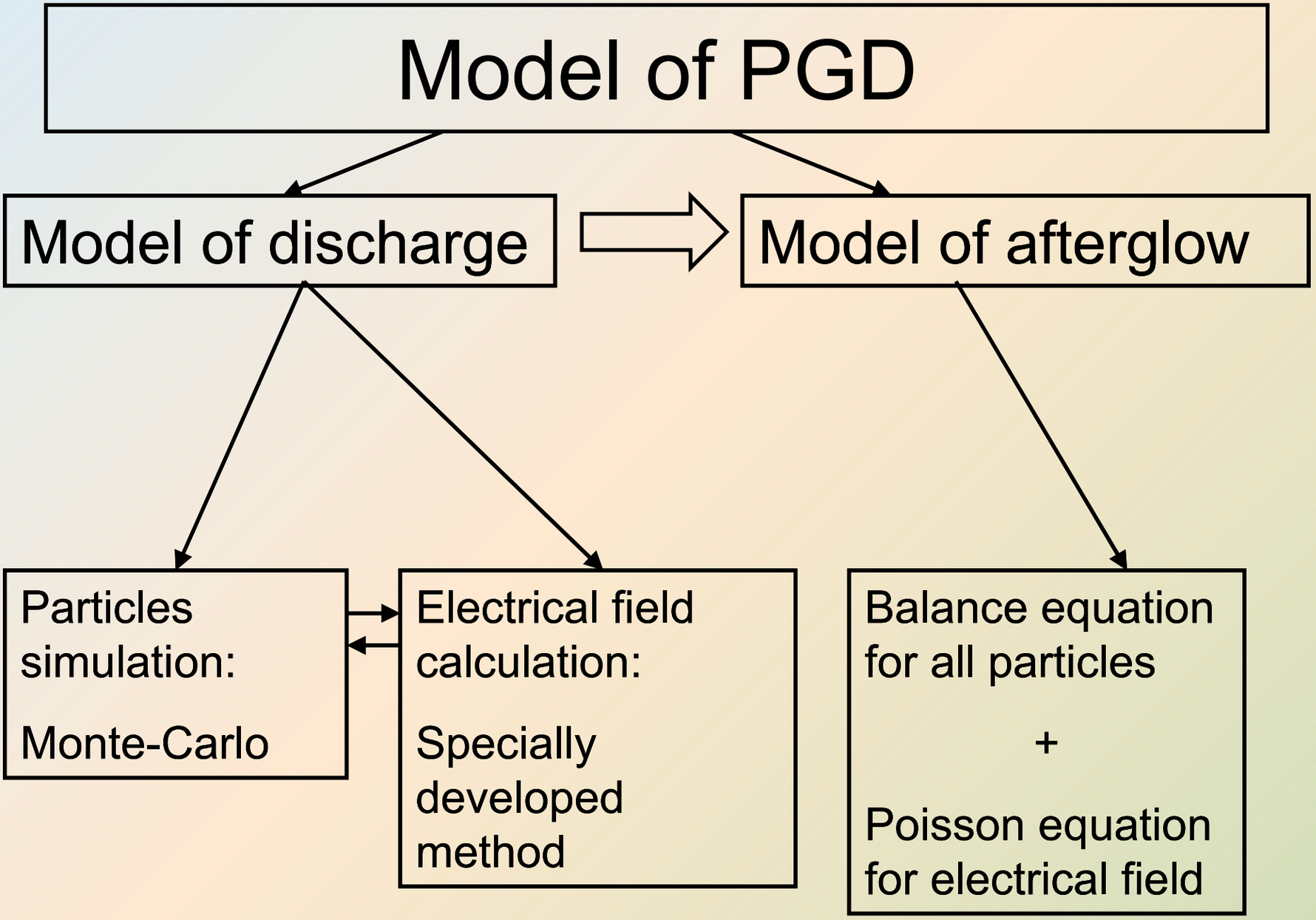
Simulation of prepeak

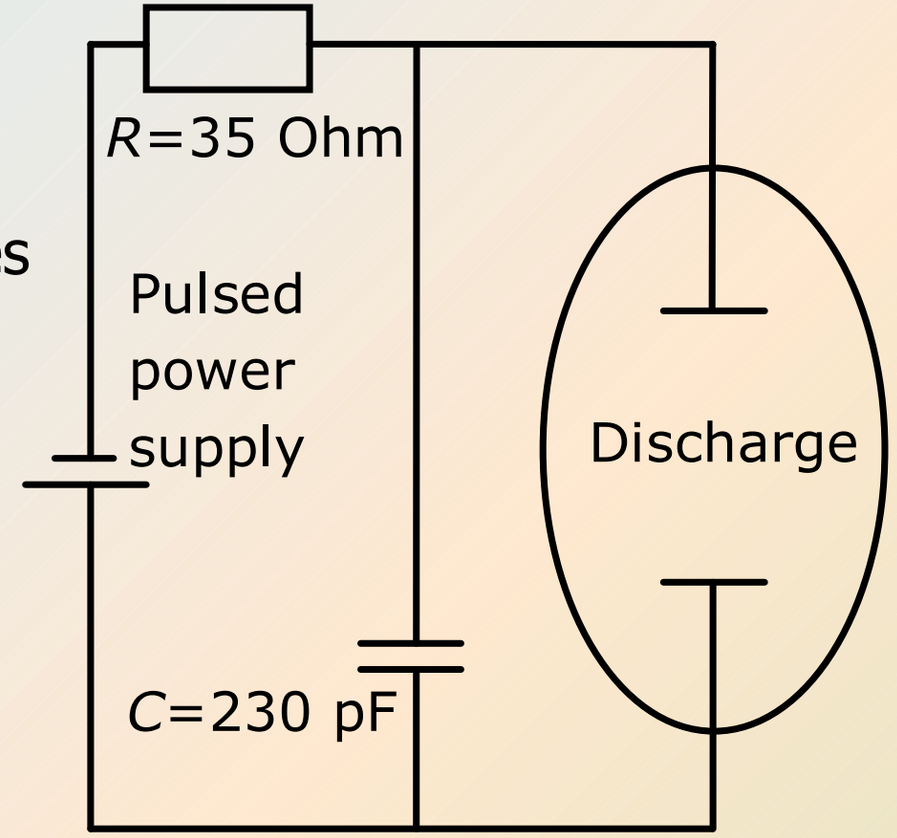
M. Voronov, A. Ganeev, *Spectrochimica Acta B*, 2009, 416–426



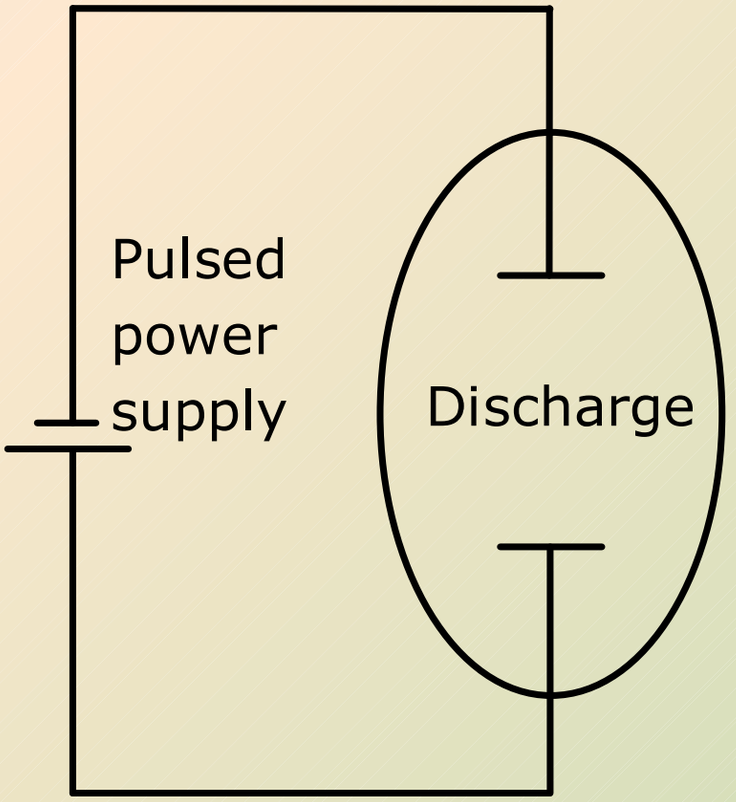
Simulation of prepeak

M. Voronov, V. Hoffmann, W. Buscher, C. Engelhard, S.J. Ray, G.M. Hieftje, *JAAS*, 2012, 27, 1225–1233

Effect of capacity charging takes place in nanosecond range



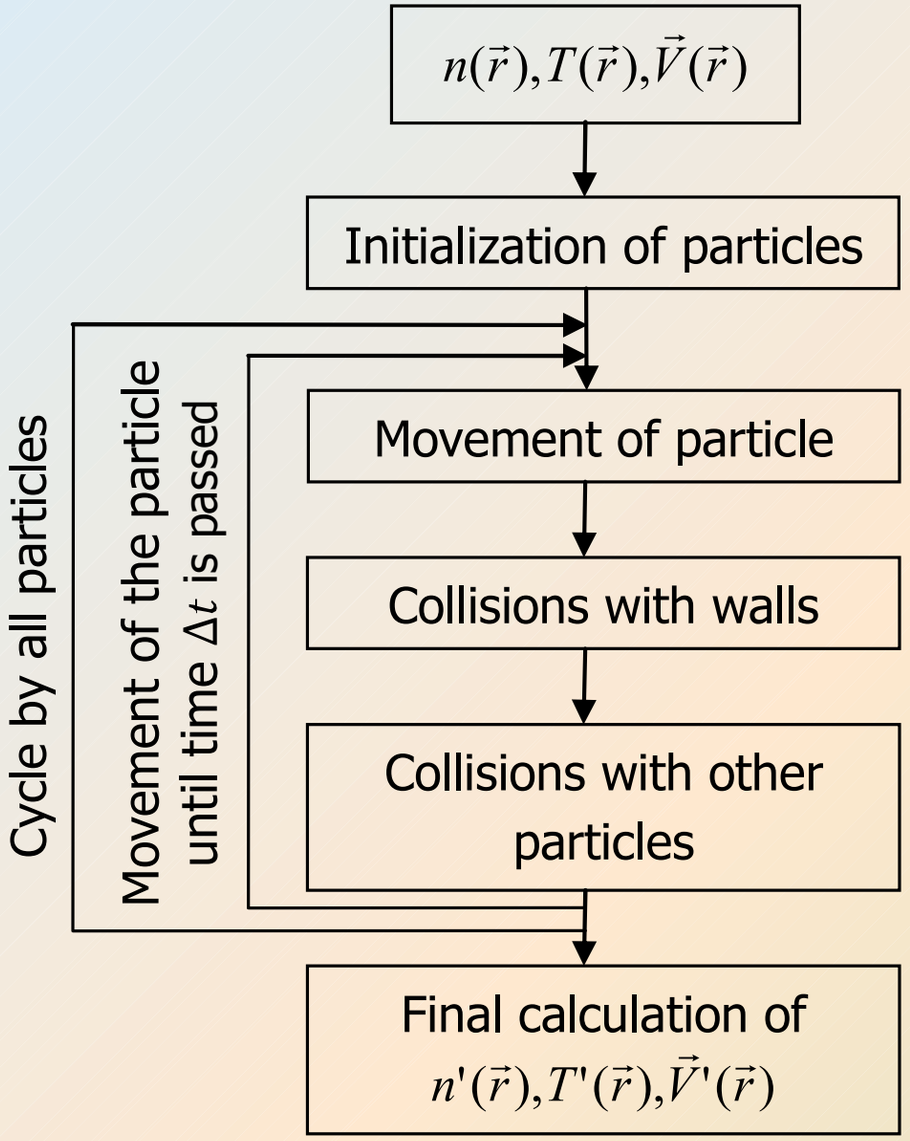
Electrical circuit



Simulated electrical circuit

Simulation of prepeak

M. Voronov, V. Hoffmann, W. Buscher, C. Engelhard, S.J. Ray, G.M. Hieftje, *JAAS*, 2012, 27, 1225–1233

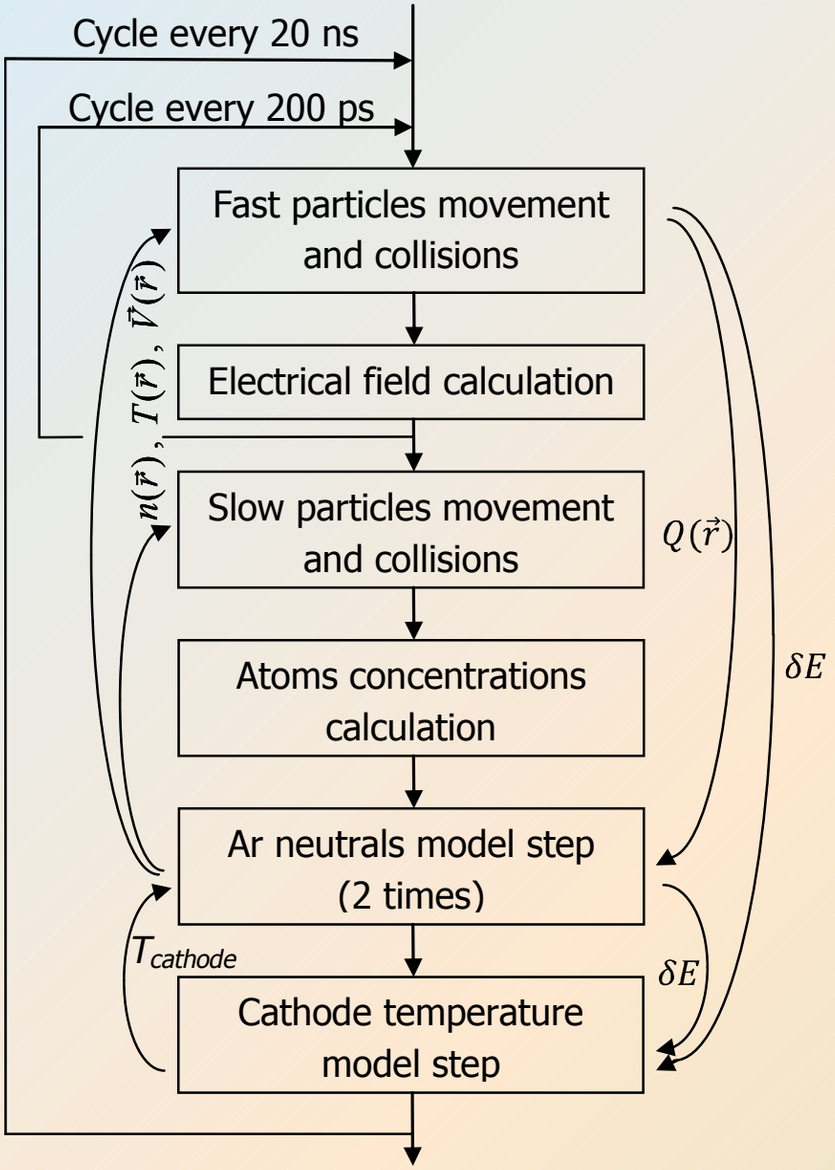


A separate Monte-Carlo based submodel of Ar evolution in time and space can be used for different tasks

Ar concentration, temperature and flow are simulated simultaneously

Simulation of prepeak

M. Voronov, V. Hoffmann, W. Buscher, C. Engelhard, S.J. Ray, G.M. Hieftje, *JAAS*, 2012, 27, 1225–1233



$$\Delta T(\vec{r}) = \frac{Q(\vec{r})N_A}{n(\vec{r})Vol(\vec{r})c_V}$$

$Q(\vec{r})$ is a heat transferred to Ar by plasma
n is Ar concentration
Vol is a volume of elementary grid cell
N_A is Avogadro's number
$c_V = 3R/2$ is the molar heat capacity
R is the gas constant

Simulation of prepeak

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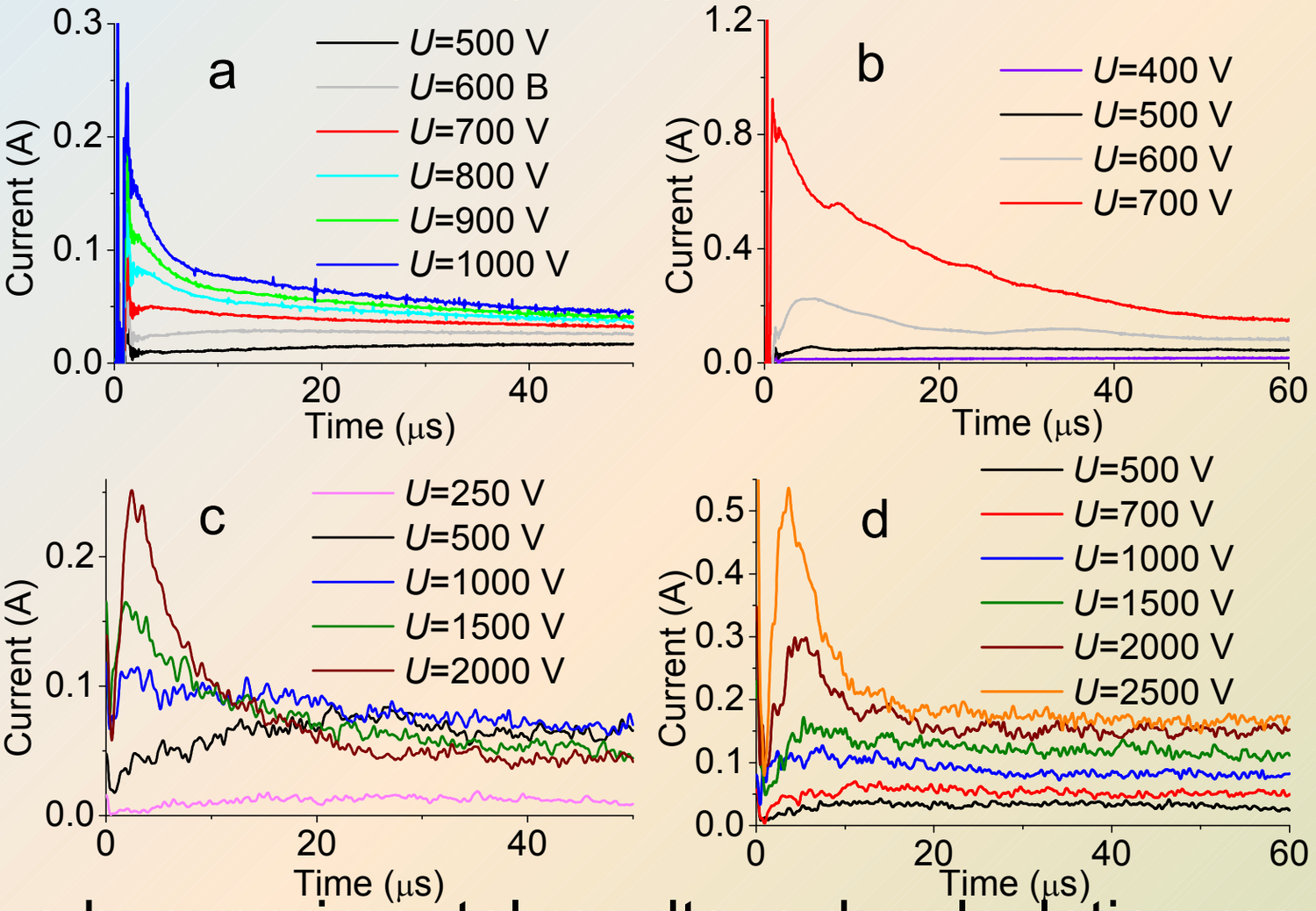

a,b: experimental results, c,d: calculation results.

a,c: p=8 hPa, b,d: p=12 hPa.

Simulation of prepeak

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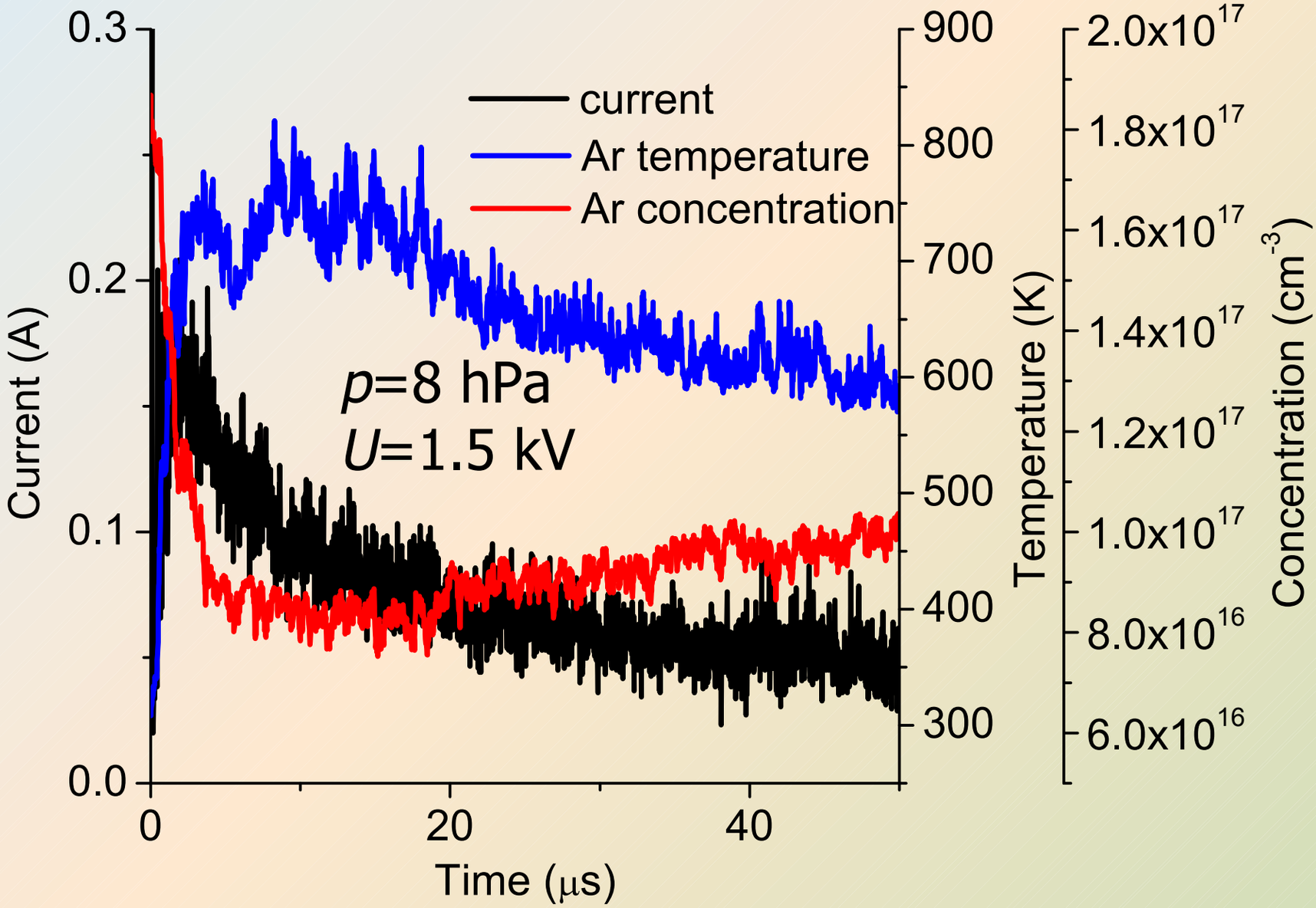
JAAS, 2012, 27, 1225–1233



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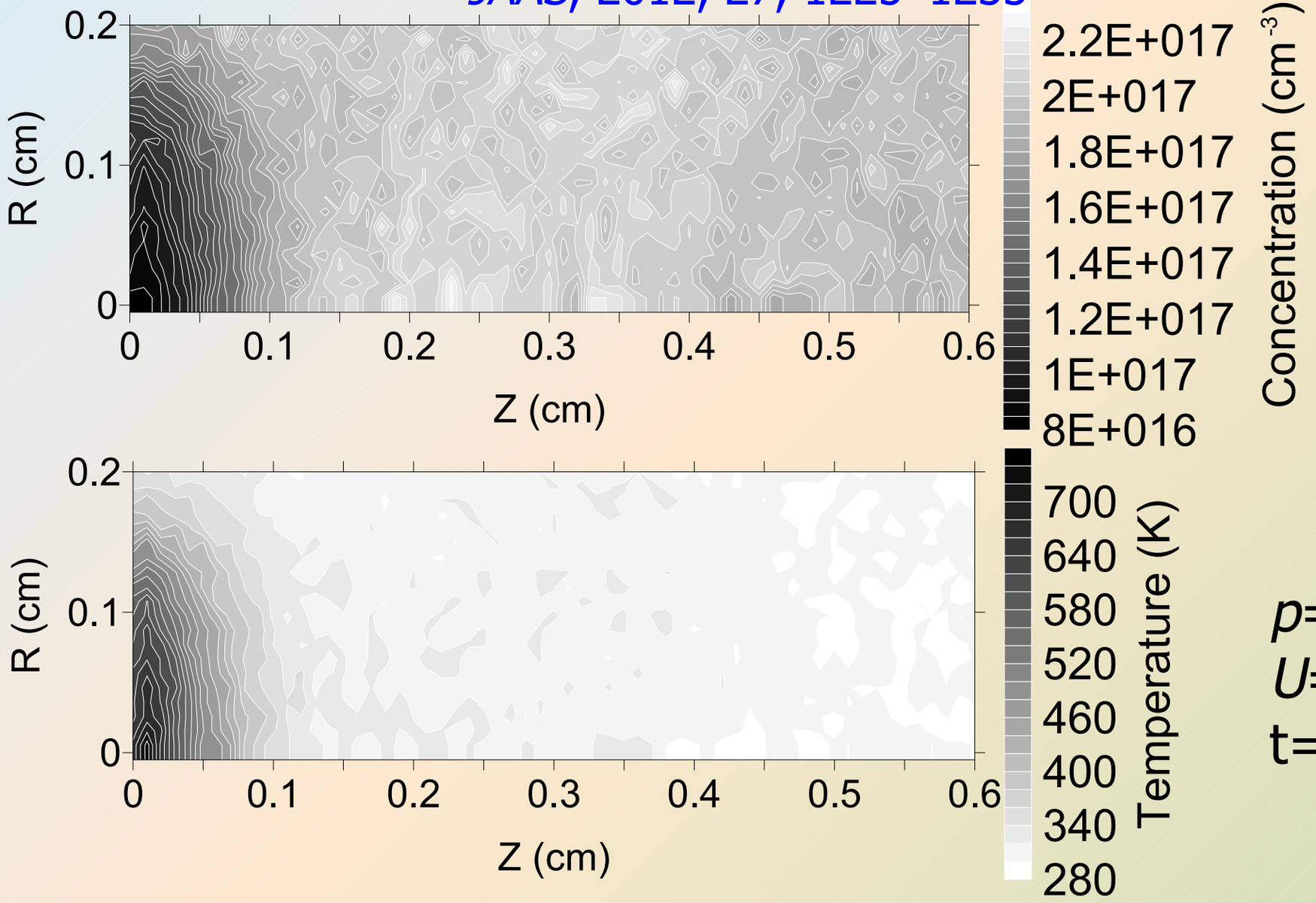

p=8 hPa
U=1.5 kV
t=12 μs

Simulation of prepeak

M. Voronov, V. Hoffmann, W. Buscher, C. Engelhard, S.J. Ray, G.M. Hieftje,
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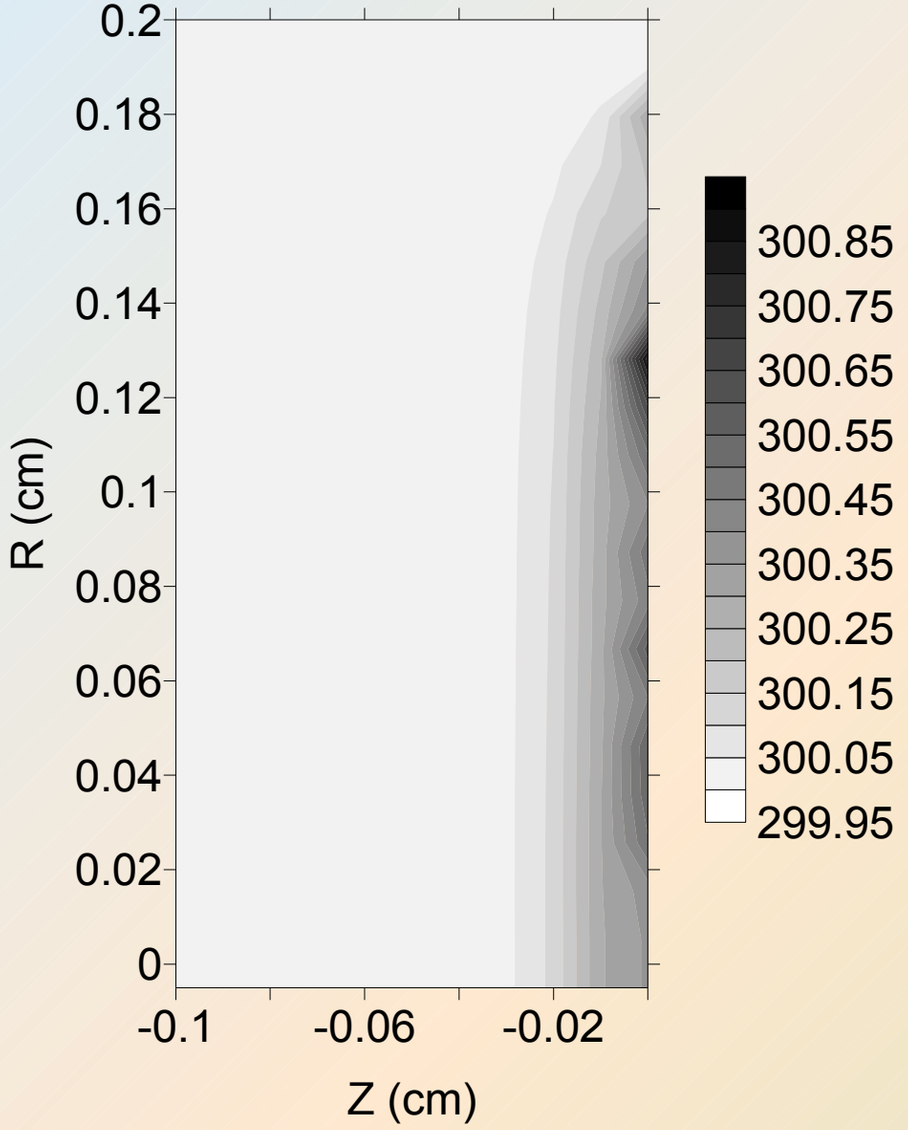

Cathode temperature evolution
p=8 hPa
U=1.5 kV

Simulation of prepeak

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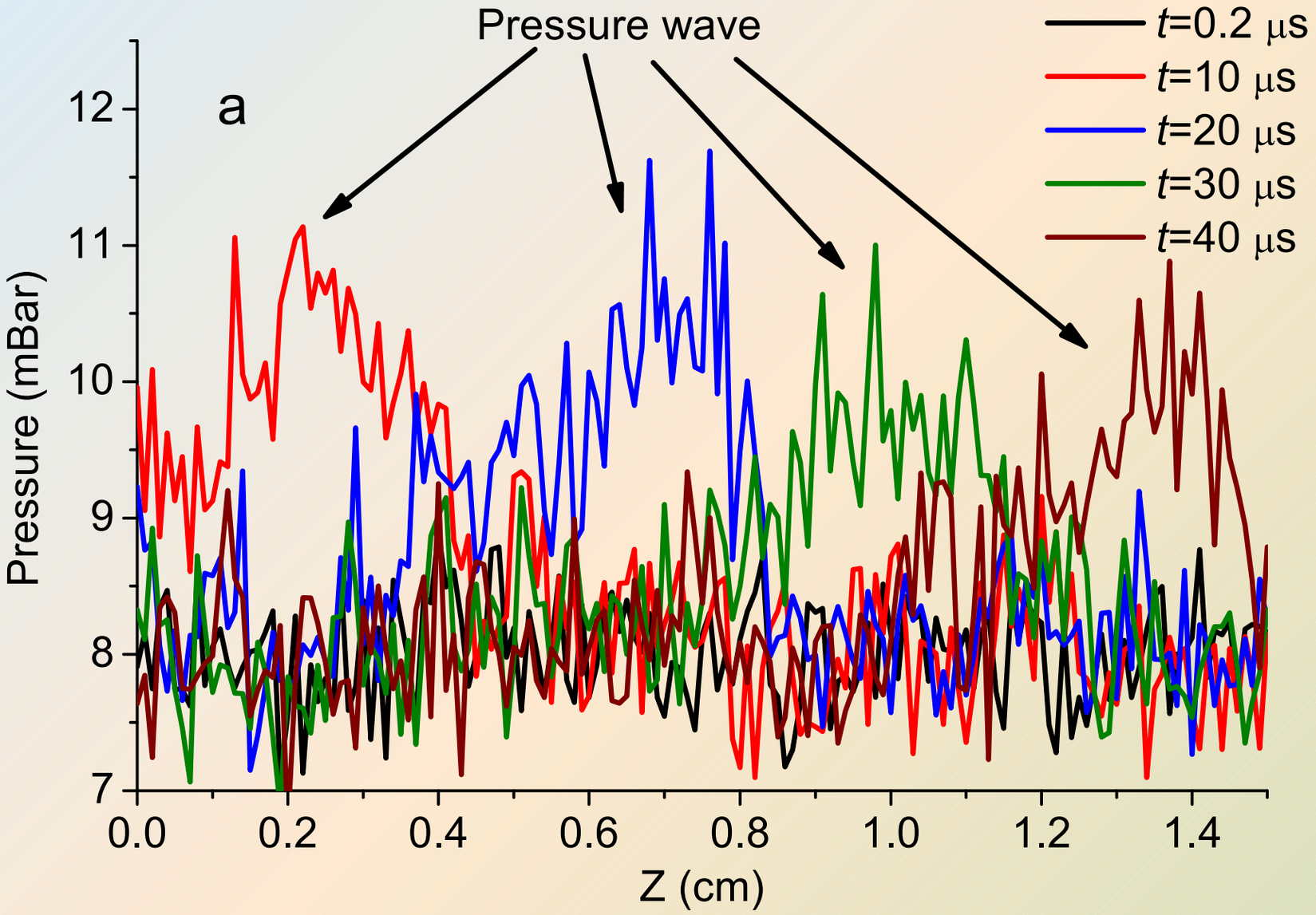

p=8 hPa
U=3 kV

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Conclusion

- A standing pressure wave is formed at the leading edge of the μs PGD and correlated with electrical properties and emission of the plasma
- Electrical prepeak is formed as result of Ar heating and expansion in the leading edge of the μs PGD

Conclusion

- A standing pressure wave is formed at the leading edge of the μs PGD and correlated with electrical properties and emission of the plasma
- Electrical breakdown is formed as result of Ar heating and expansion in the leading edge of the μs PGD

Thank you for your attention!