Homogeneous Mode of Dielectric Barrier Discharges

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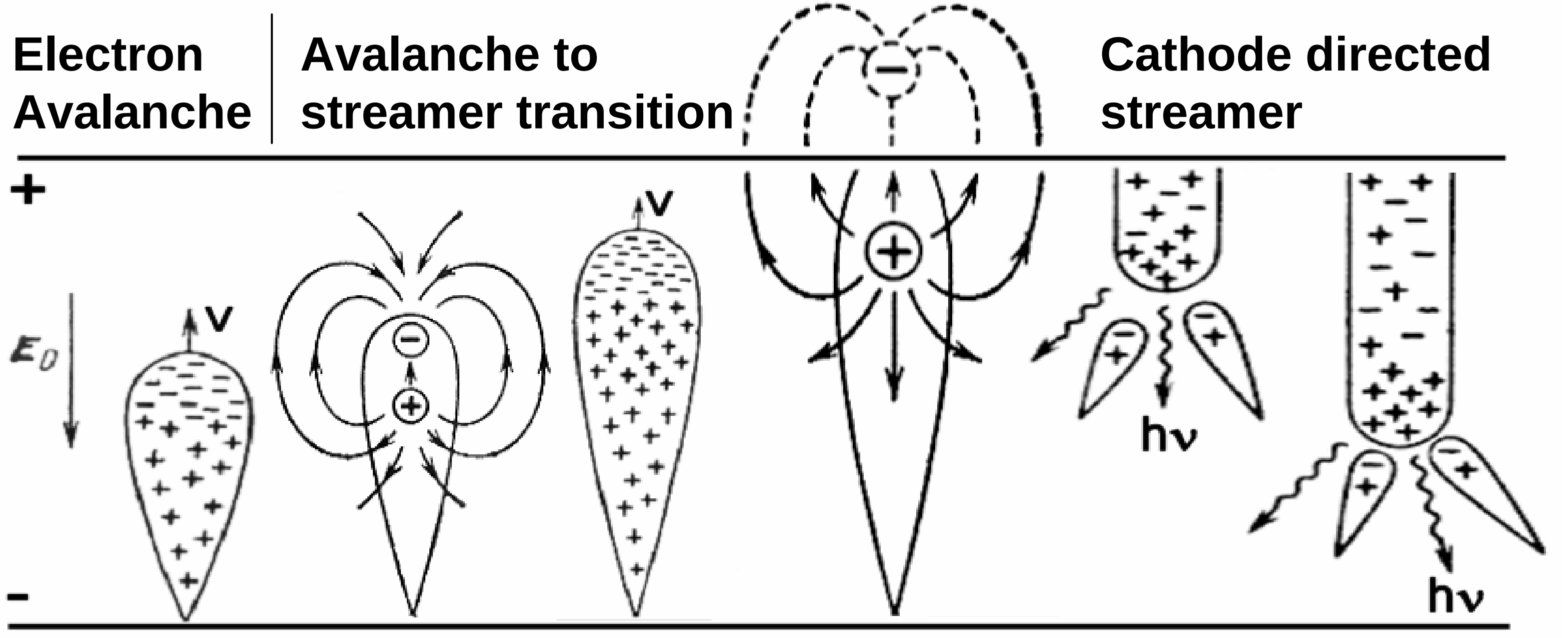
Electron Avalanches and Streamers in Discharge



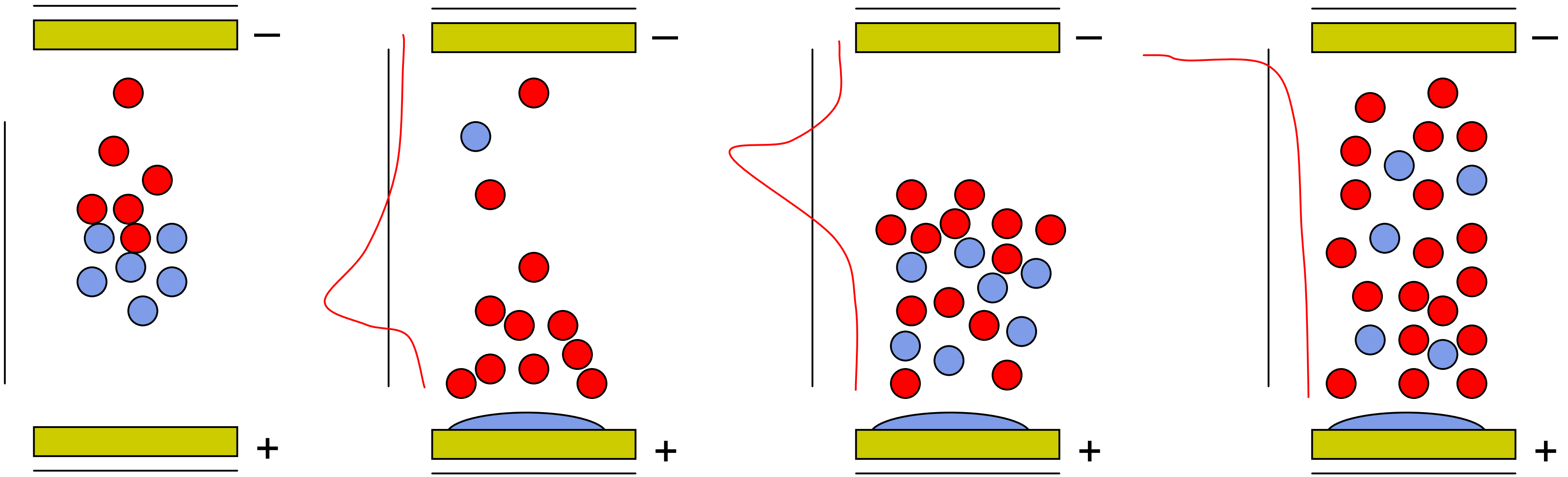
DBD Filament

- Microdischarge (40 ns)
- Microdischarge Remnant (1 ms)

Microdischarge

- Electron Avalanche (10 ns)
- Cathode Directed Streamer (1 ns)
- Plasma Channel (30 ns)

Microdischarges in DBD



Electron Avalanche

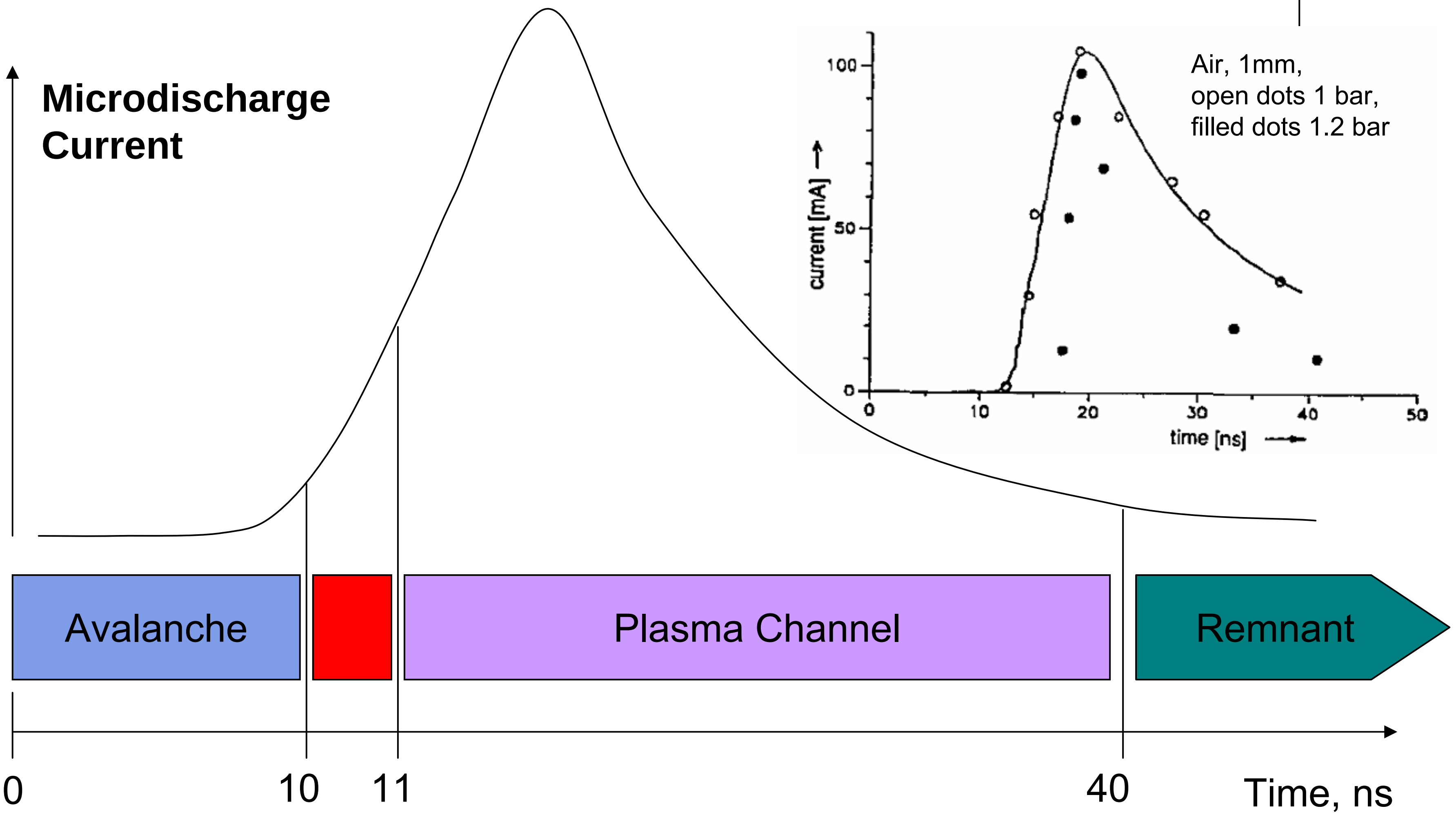
Cathode Streamer Formation

Cathode Streamer

Plasma Channel

- **Most of the charge is transferred during plasma channel phase.**
- **Charge is transferred until local electric field is collapsed.**

Microdischarge timeline



Air, 1mm,
open dots 1 bar,
filled dots 1.2 bar

Microdischarge Current

Avalanche

Plasma Channel

Remnant

0

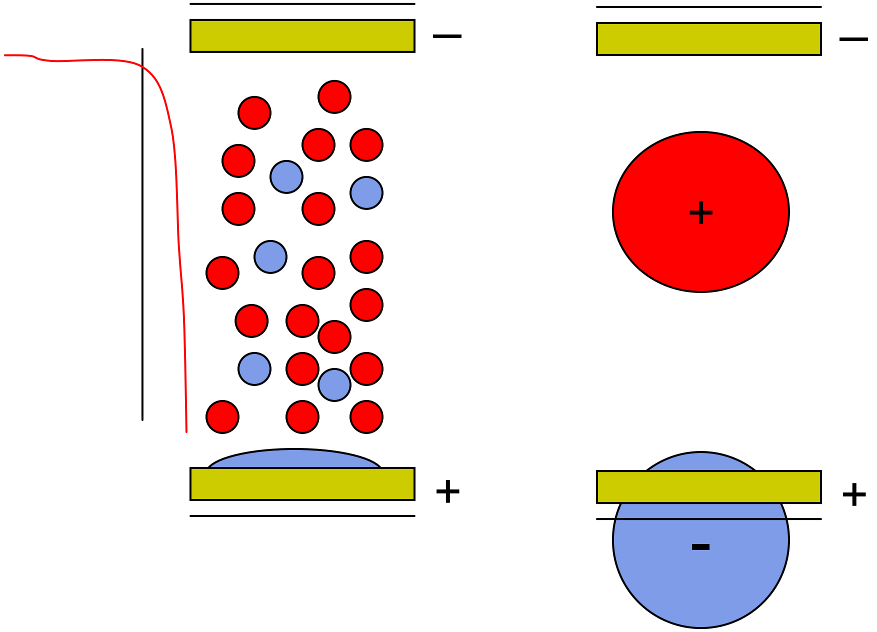
10

11

40

Time, ns

Shielding Radius of Microdischarge Remnant

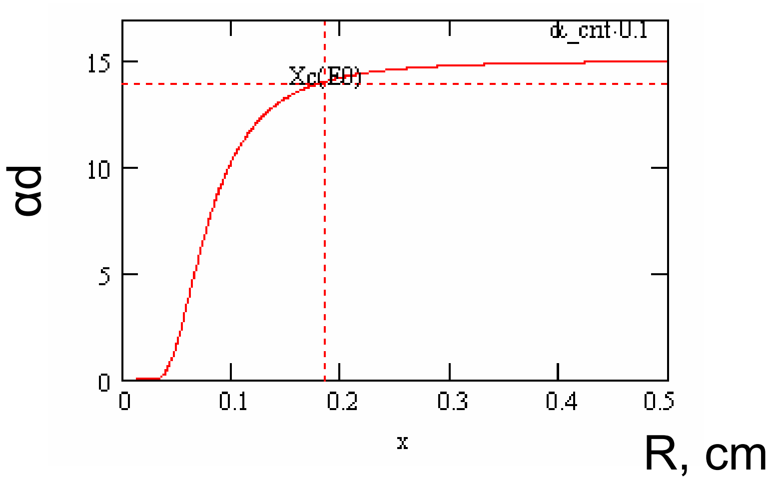


Electric field of equivalent charges

$$\frac{1}{4\cdot\pi\cdot\varepsilon_0}\cdot\frac{2\cdot N_m\cdot q}{(d/2)^2}=E_0 \qquad \alpha(E)=A\cdot\exp(-\frac{B}{E})$$

Shielding or Interaction radius

$$R(E)=\left(\frac{d}{2}\right)\cdot\sqrt{\left(\frac{\alpha\cdot d\cdot B}{E}\right)^{\frac{2}{3}}-1}$$



In air for 1 mm gap estimated shielding radius is about 2 mm
(8 microdischarges per 1 cm^2)
Shielding is established almost instantly after streamer strike during plasma channel phase

Townsend Microdischarges

Features of Townsend Microdischarges

1. No streamers, thus plasma channel phase is delayed.
2. Plasma channel is responsible for the shielding thus shielding is delayed.
3. Electric field collapsed to E_0 when $\alpha(E_0)=\ln(1/\gamma+1)/d$, thus plasma channel and shielding is weaker. (total transferred charge is less than in streamer driven microdischarge)
4. Uniform discharge can be obtained if microdischarge time lag is less than plasma channel shielding time.
5. Since total transferred charge is less Townsend microdischarge are harder to sustain (they require stronger memory effect than streamer driven microdischarges). This defines lower frequency limit.

Simulation of Townsend Microdischarges

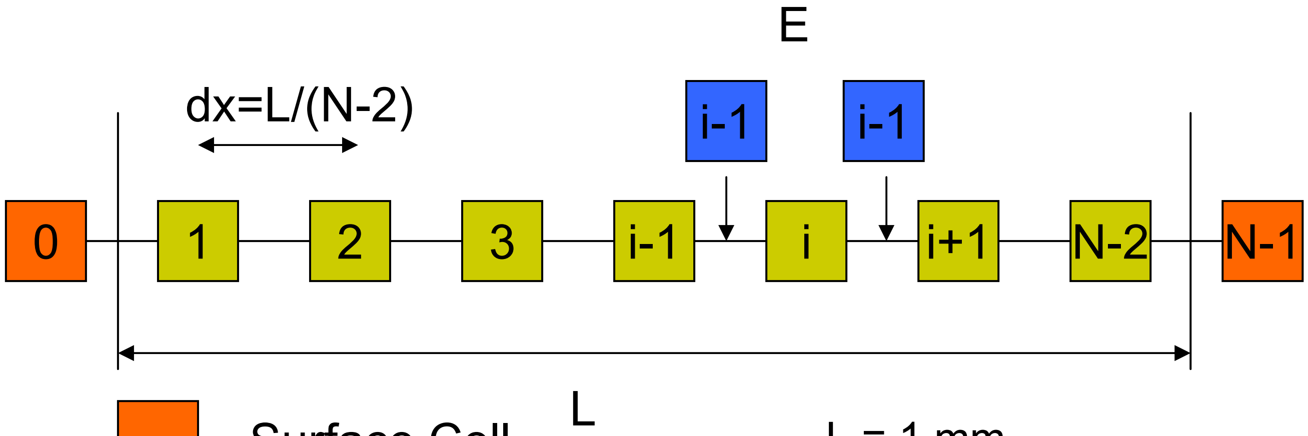
$$\frac{\partial N_e}{\partial t} = N_e \alpha \cdot |W_e| - N_e \eta \cdot |W_e| - N_e N_p \beta + \frac{d}{dx}\left(D \cdot \frac{dN_e}{dx} - N_e W_e\right)$$

$$\frac{\partial N_p}{\partial t} = N_e \alpha \cdot |W_e| - N_e N_p \beta - \frac{d}{dx}\left(N_p W_p\right)$$

$$\frac{d^2\phi}{dx^2} = -\frac{e}{\varepsilon}(N_p - N_e)$$

$$E = -\frac{d}{dx}\phi$$

Space discretization: upwind
Time discretization: BDF method with
adaptive time step



Surface Processes

- Surface recombination
- Thermal desorption
- Secondary emission

🟧 Surface Cell

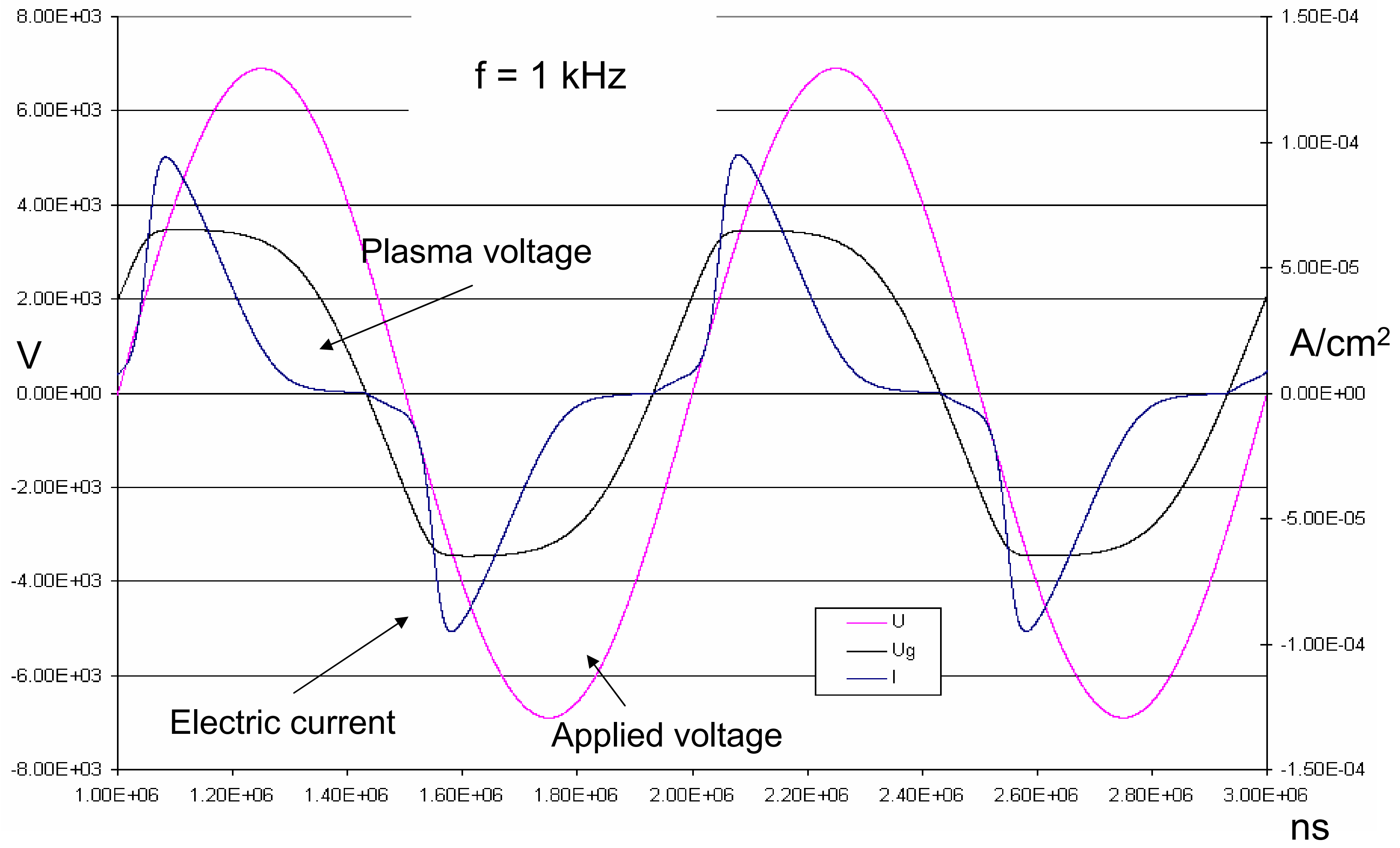
🟨 Volume Cell

L = 1 mm

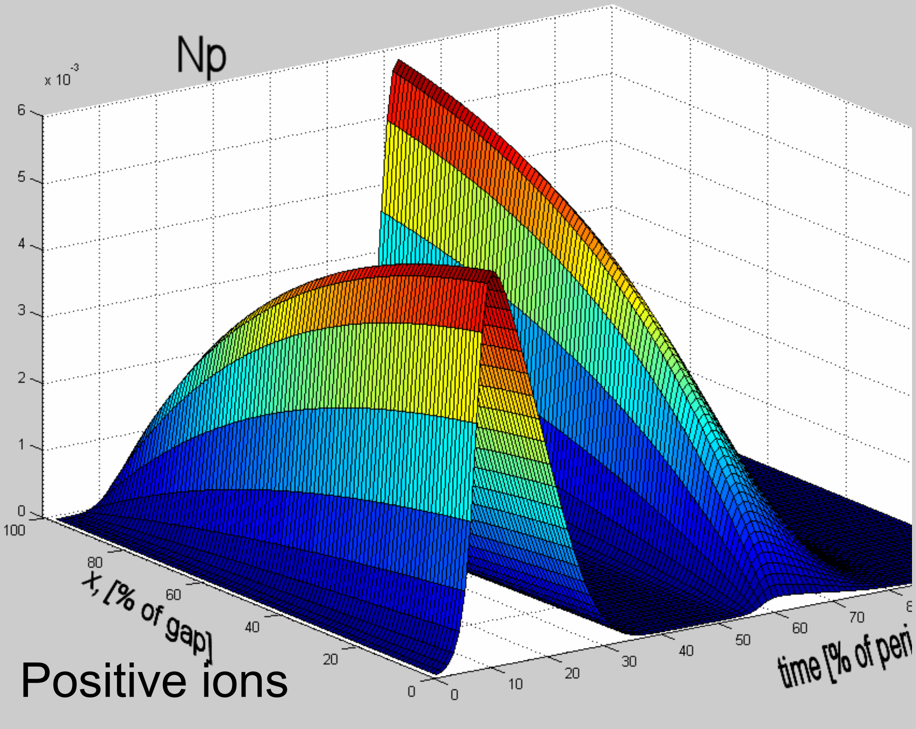
L_D= 1 mm (ε=3)

V_0=6.9 kV

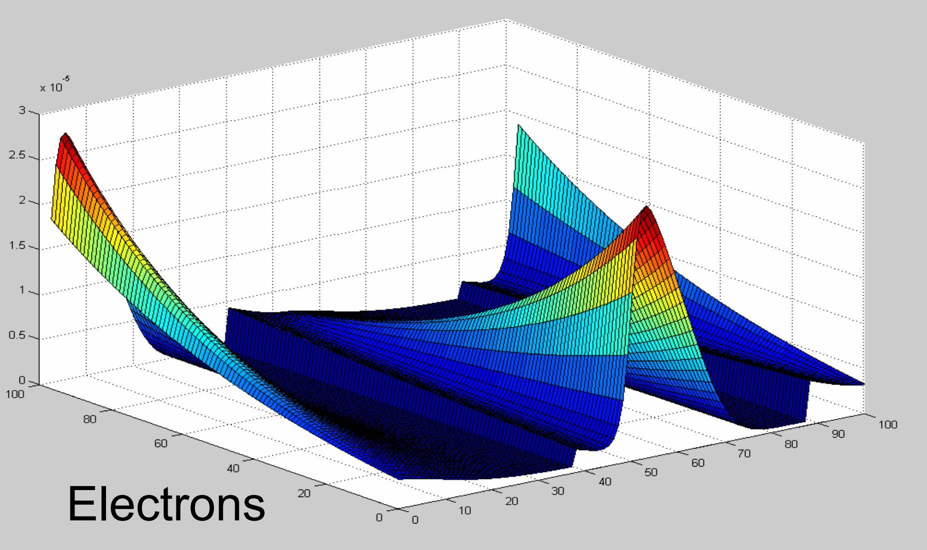
Simulation Results



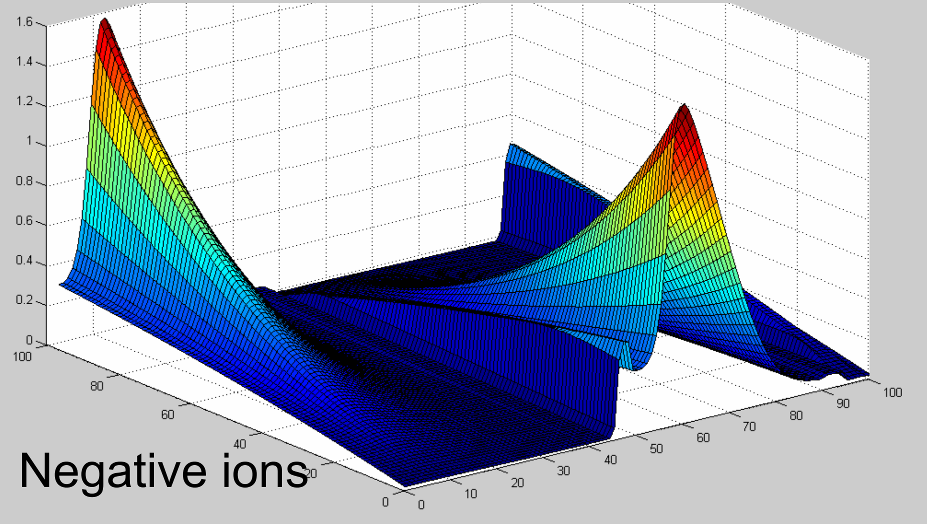
Spatio-Temporal Structure of the Discharge at 1 kHz



Positive ions



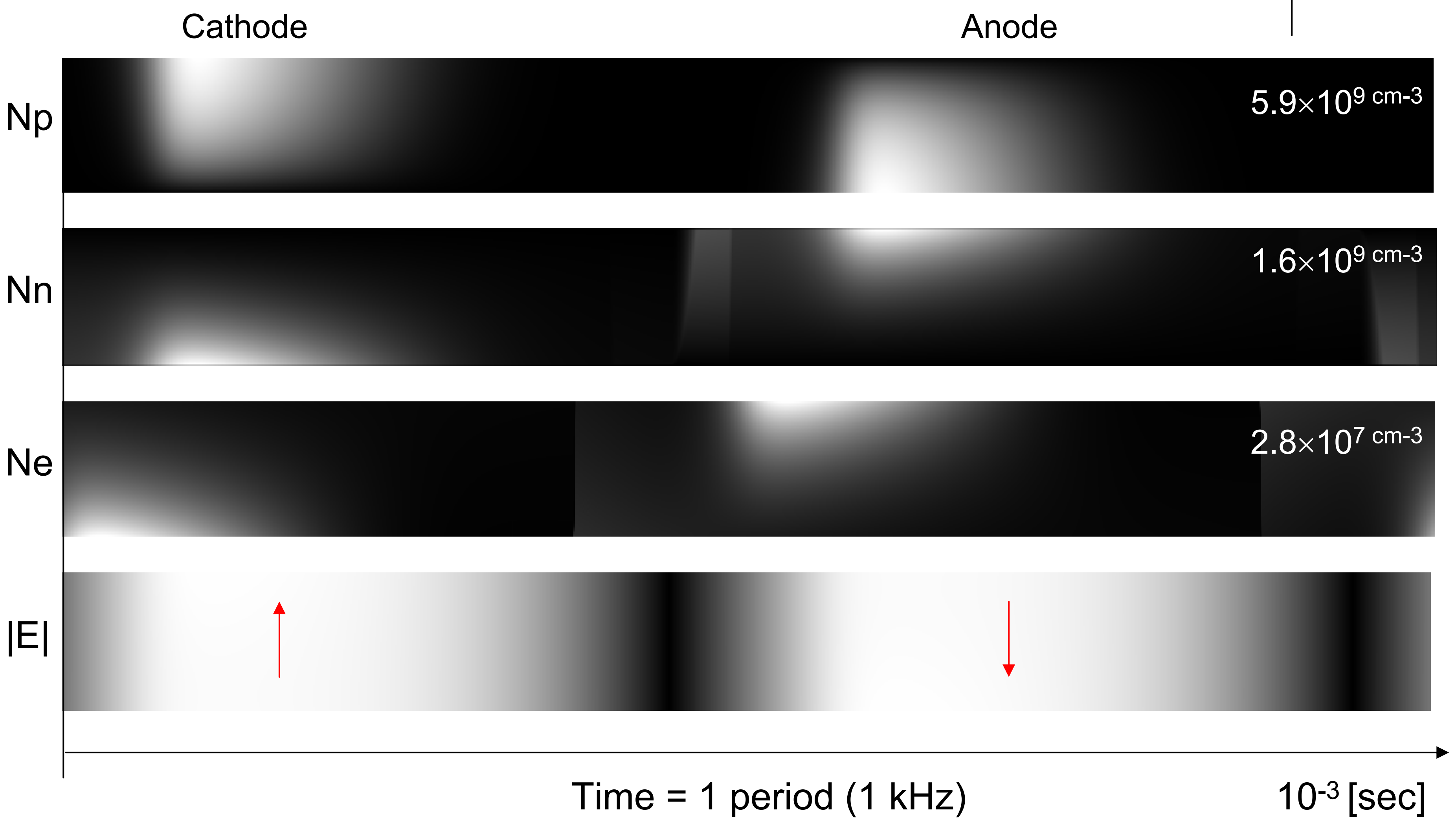
Electrons



Negative ions

Results with attachment,
f=1kHz, 6.9 kV,
L=1 mm, L_D=1 mm (ε =3)

Spatio-Temporal Structure of the Discharge at 1 kHz



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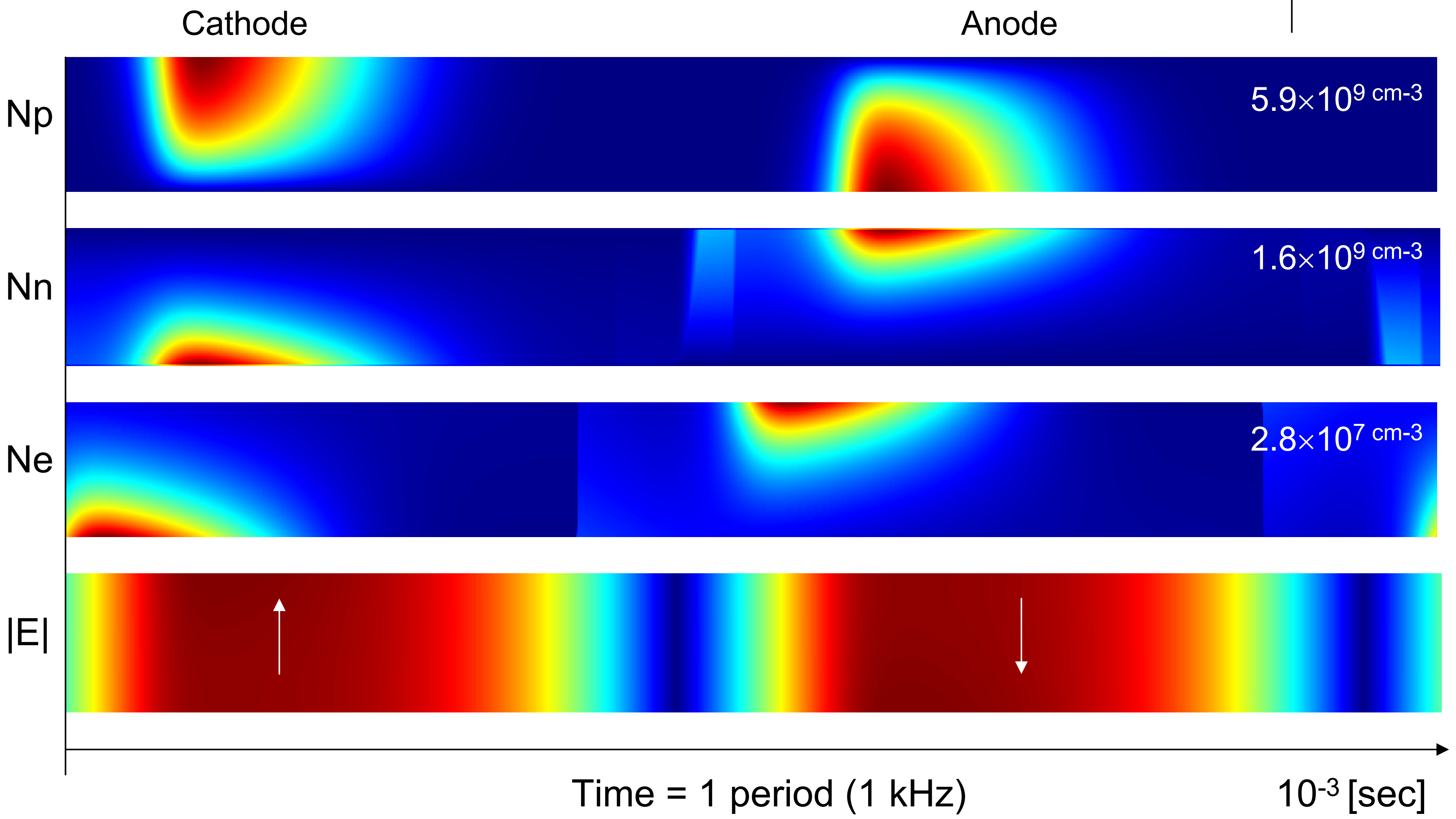

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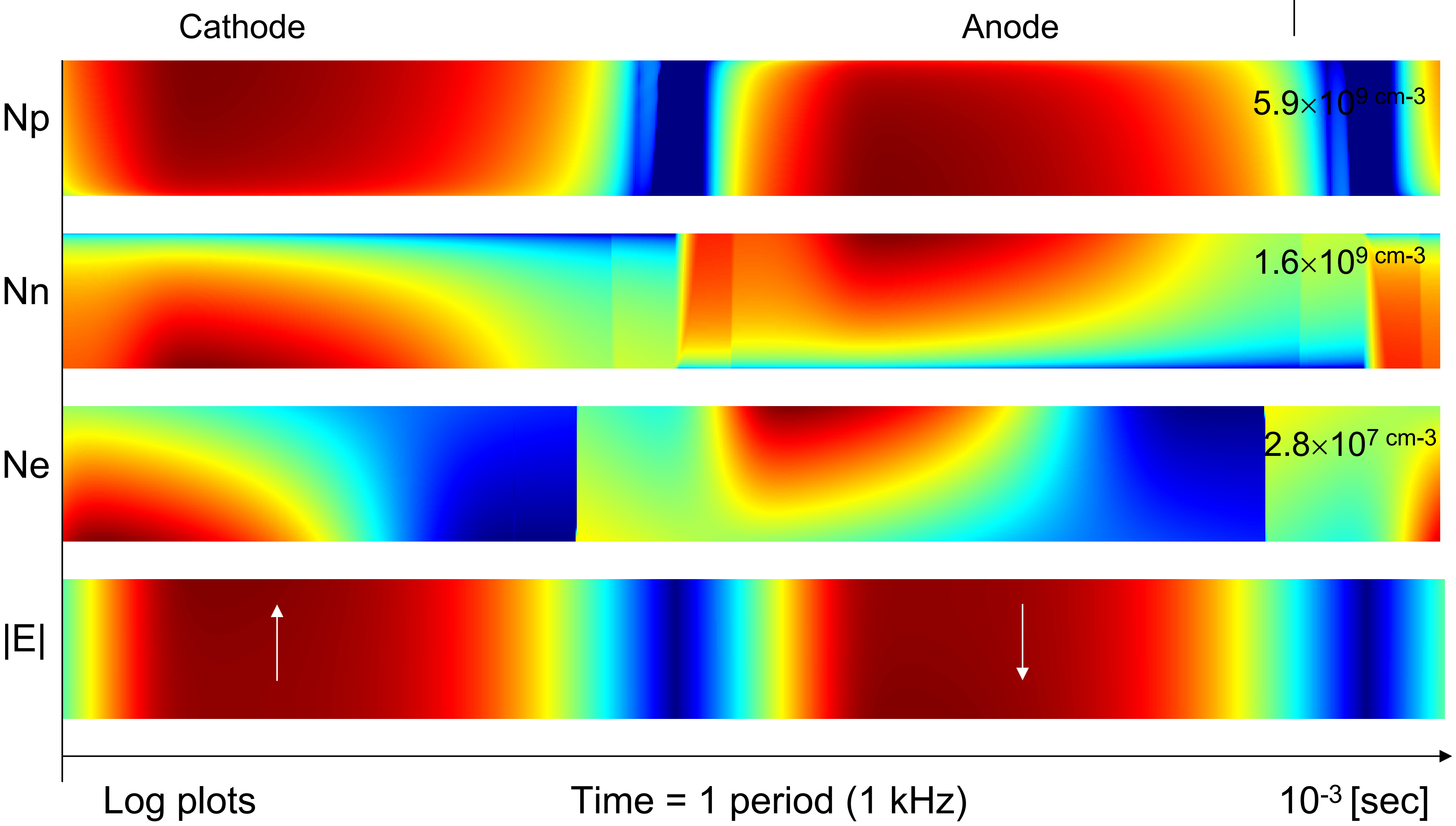

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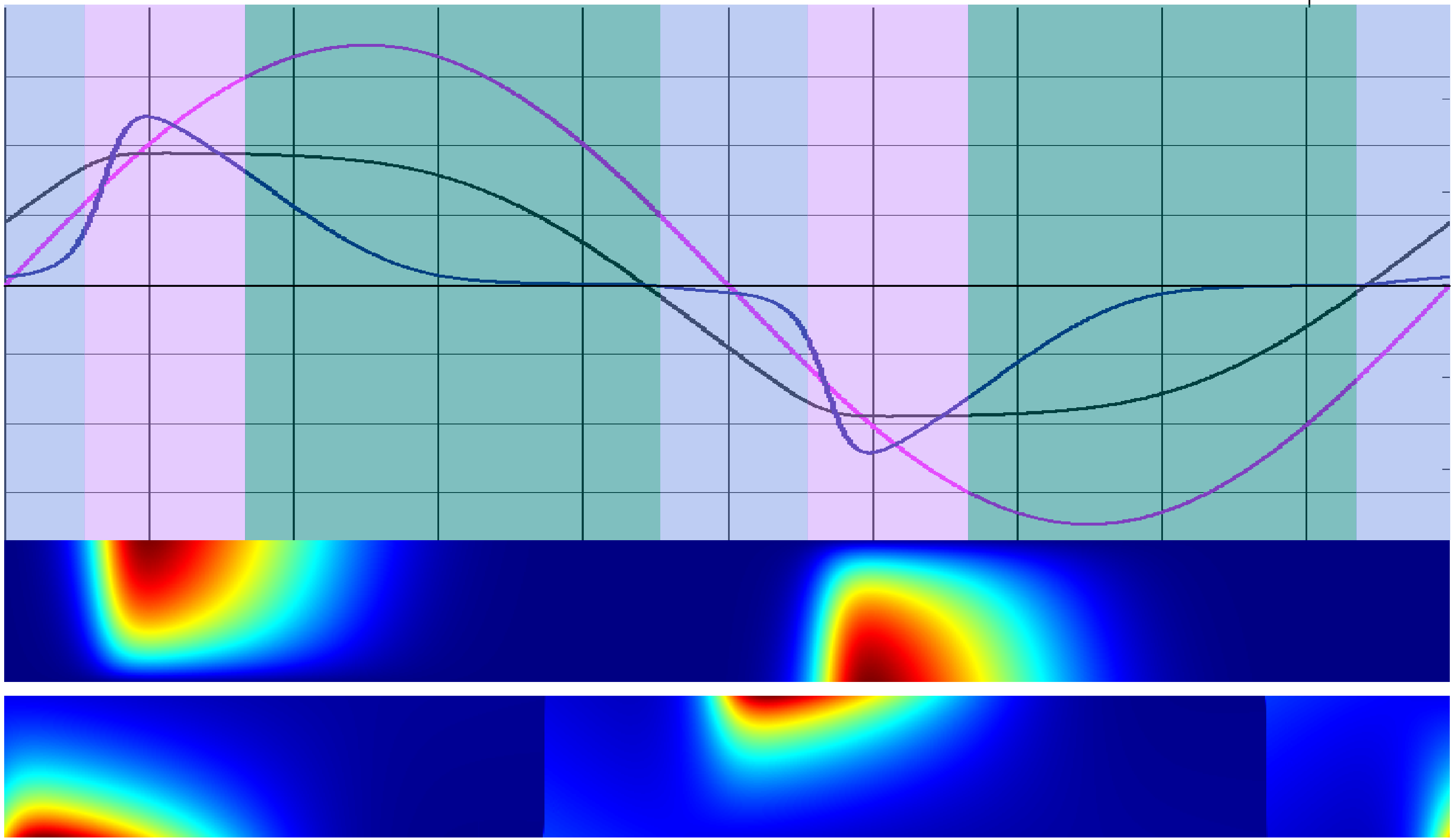
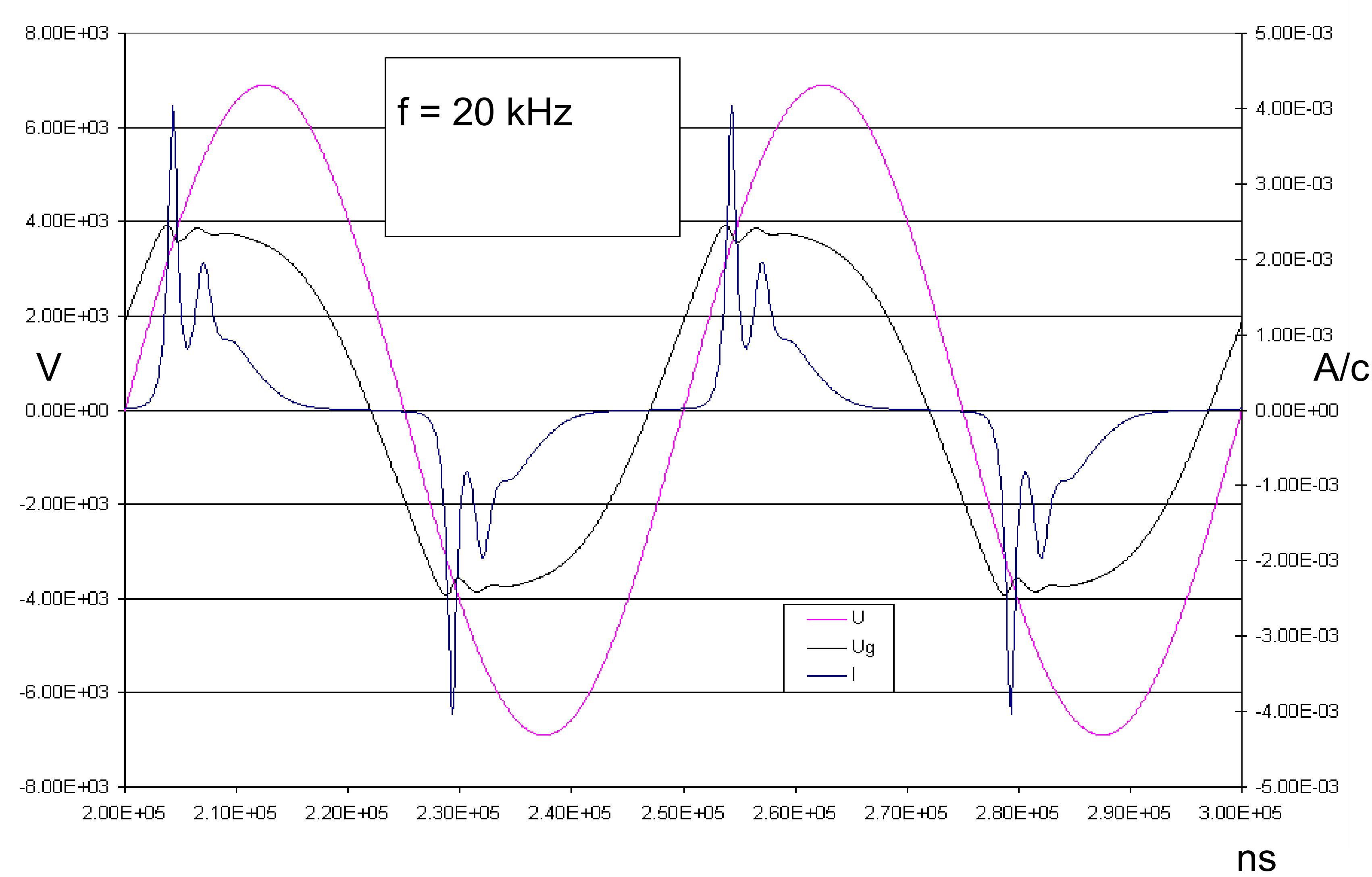
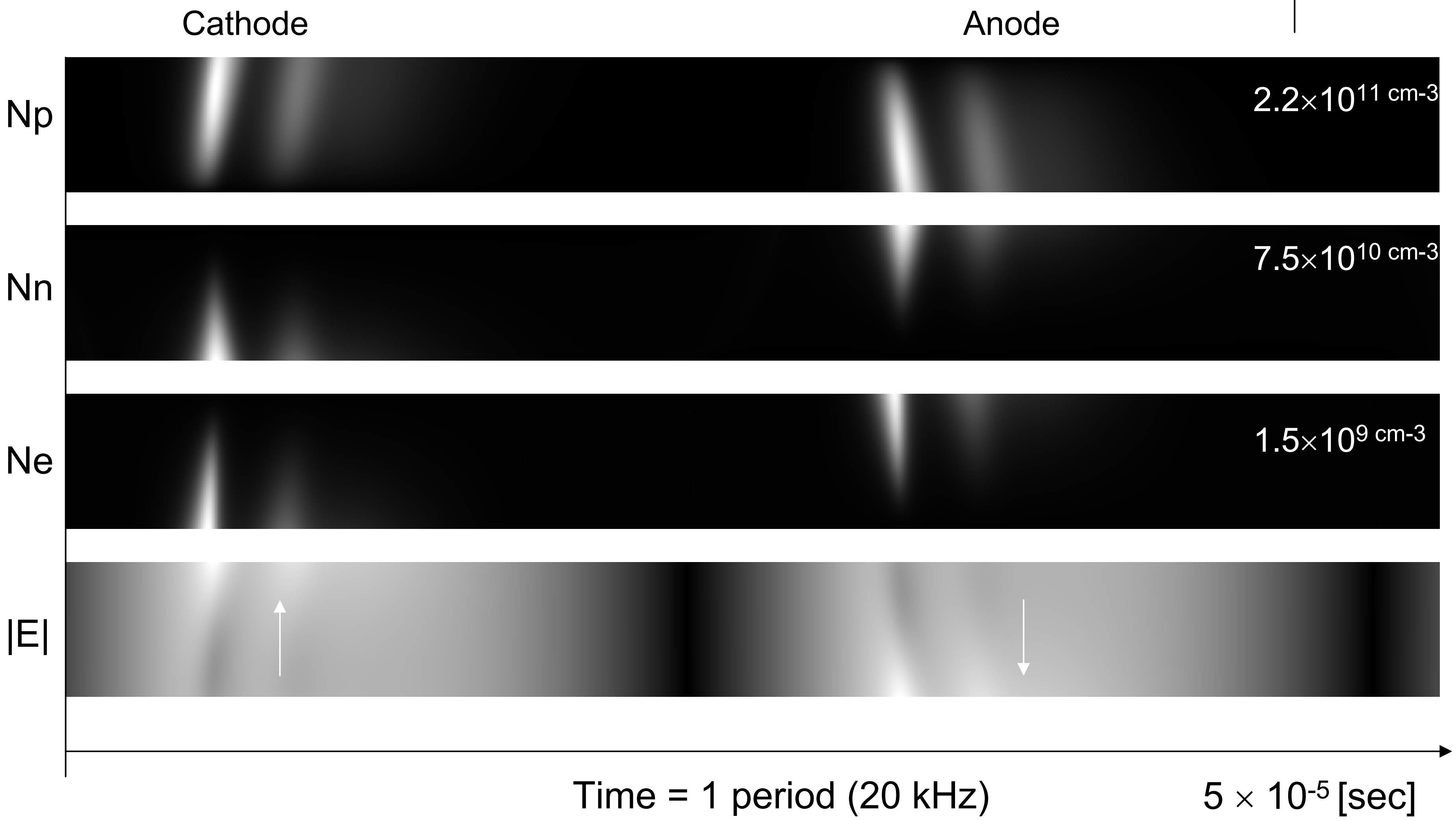


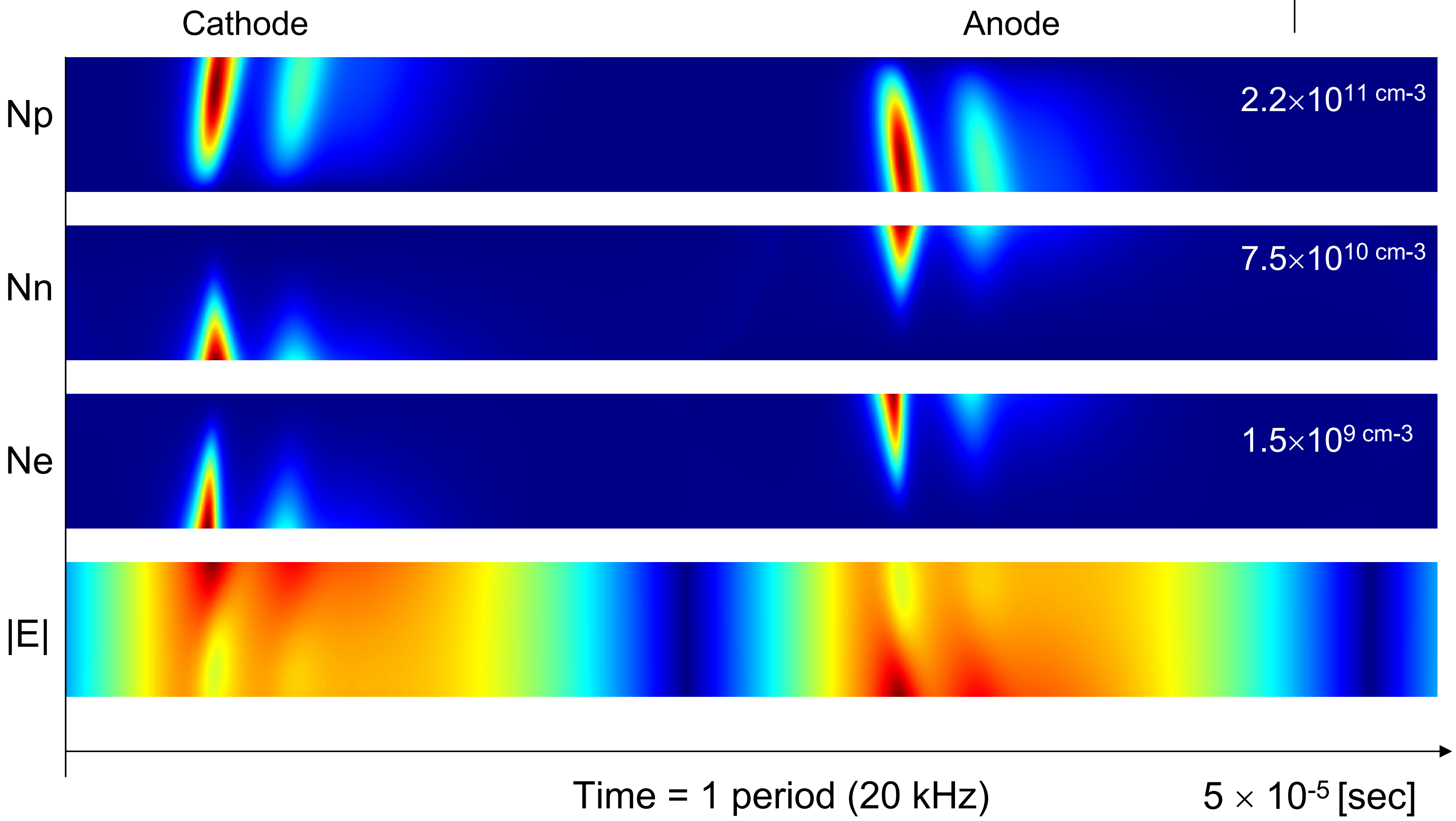
Simulation Results



Spatio-Temporal Structure of the Discharge at 20 kHz



Spatio-Temporal Structure of the Discharge at 20 kHz



Simulation Results