Modeling of a Dielectric Barrier Discharge Lamp for UV Production

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Outline

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  - What is an Excilamp?
  - Dielectric Barrier Discharges (DBD)
  - Applications of Excilamps
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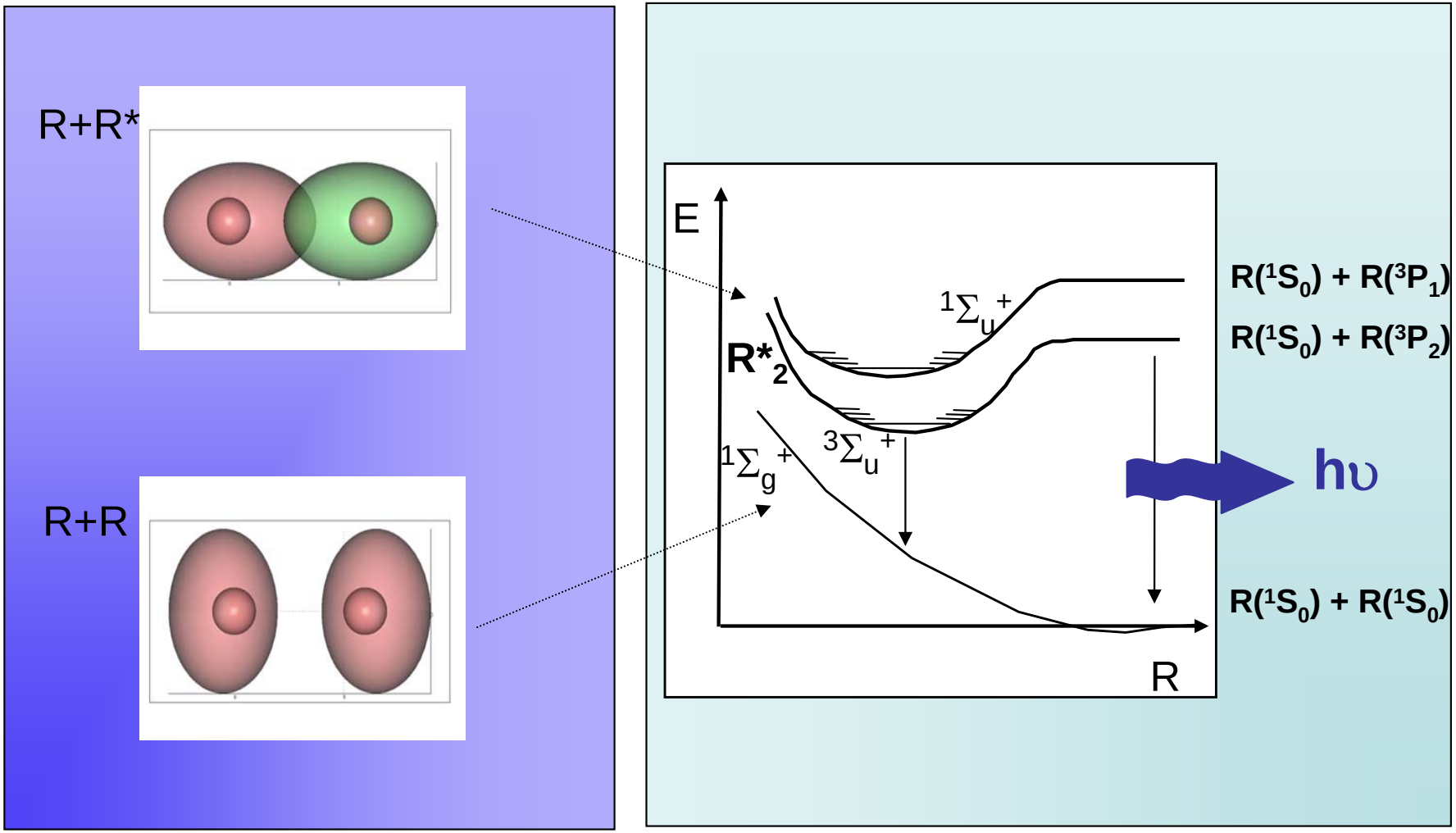
  - Boundary Conditions
- ✓Obtained results
  - Influence of the Power Supply Mode
  - Influence of External Elements
  - Tool for Efficient Power Converter Design
- ✓Conclusion

What is an Excilamp?

Excimer: contraction of "Excited Dimer"



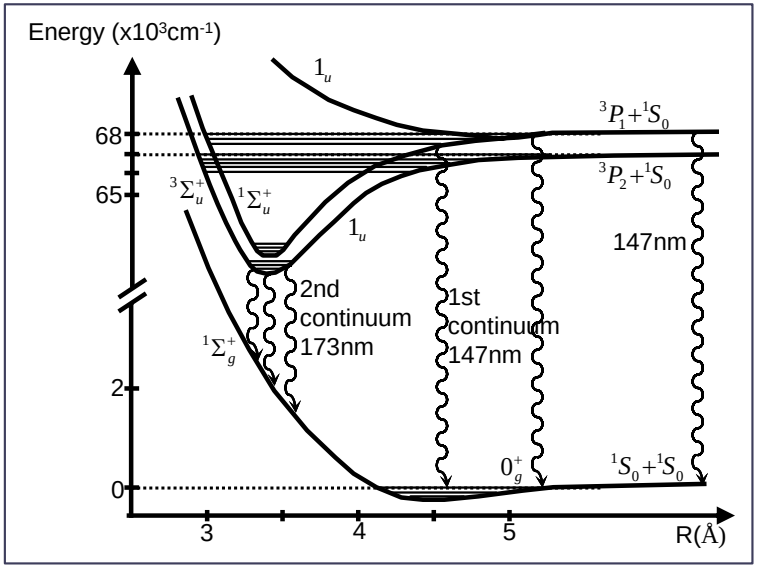
What is an Excilamp?

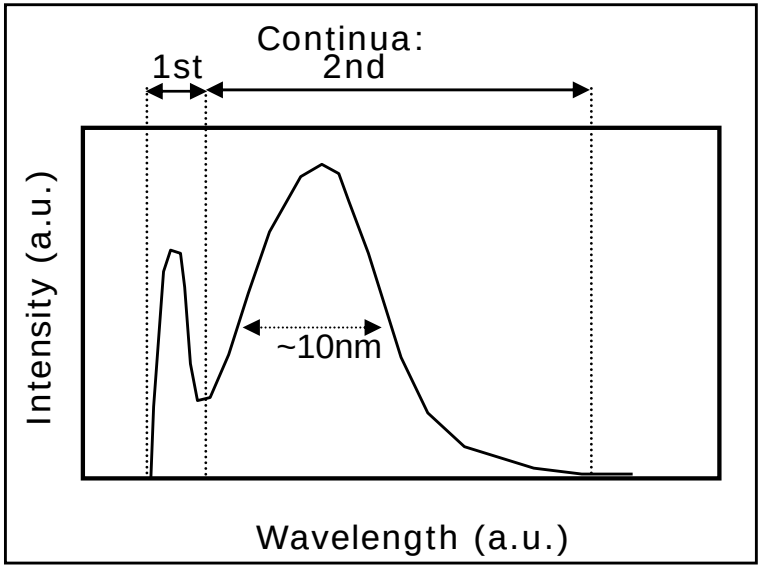
Excilamp:

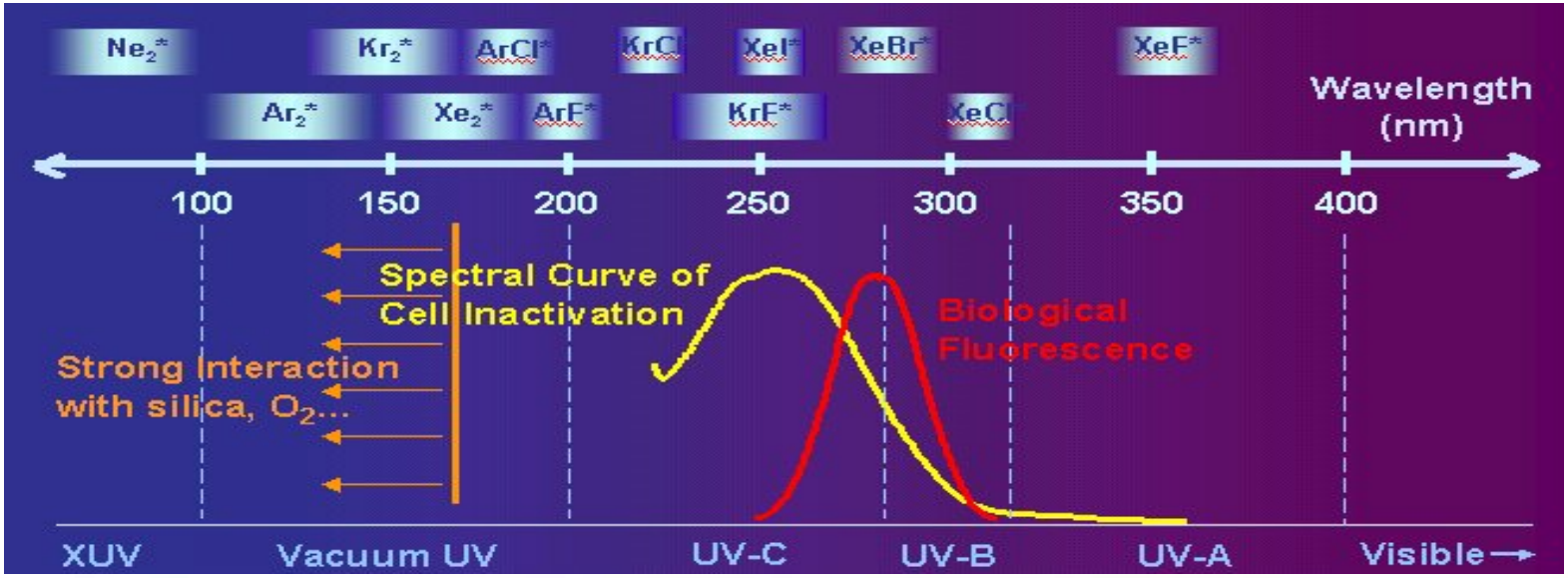
-Excimer Lamp

Or

-Exciplex Lamp



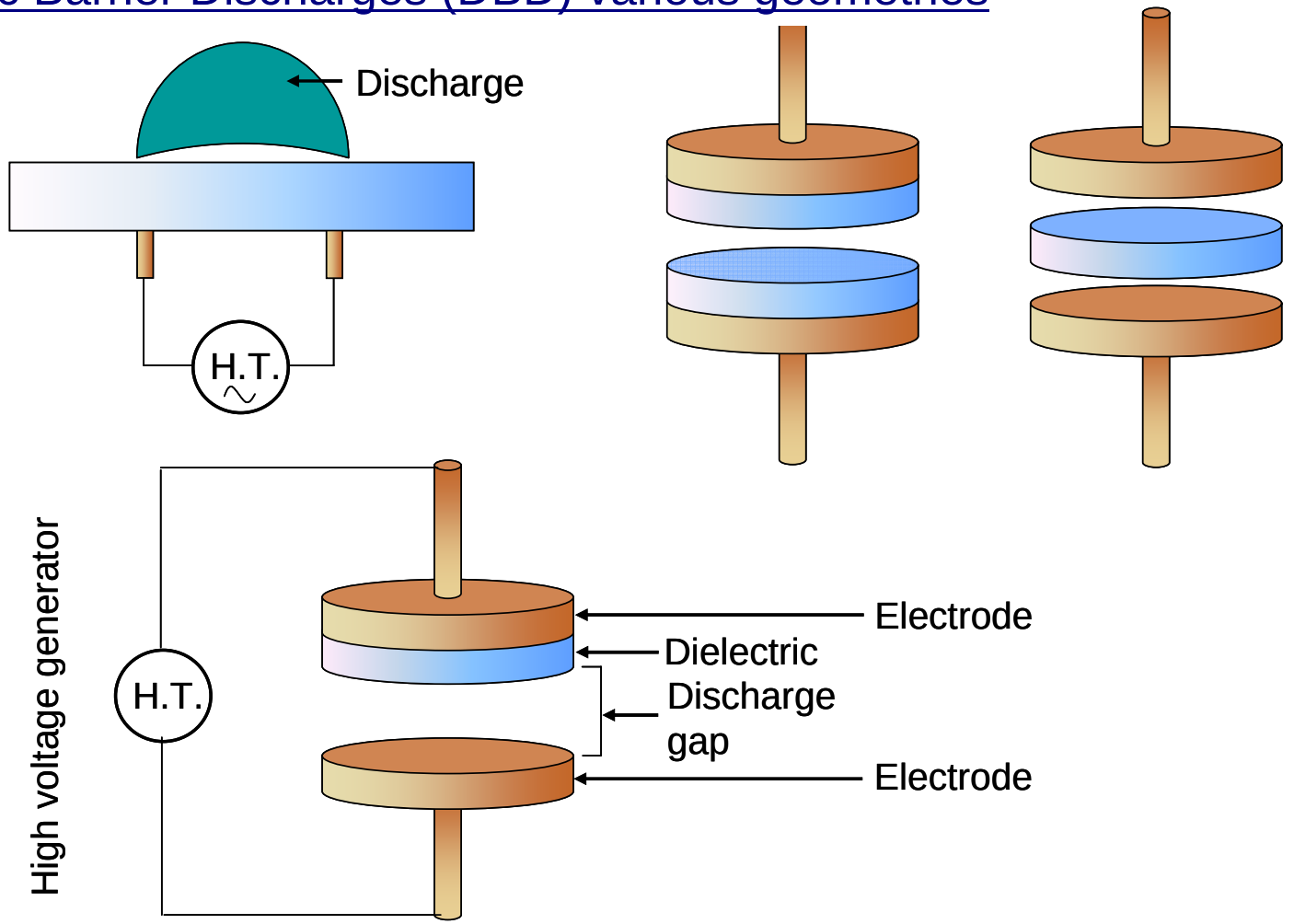




(http://www.physics.mq.edu.au/~rmildren/DBDs.html)

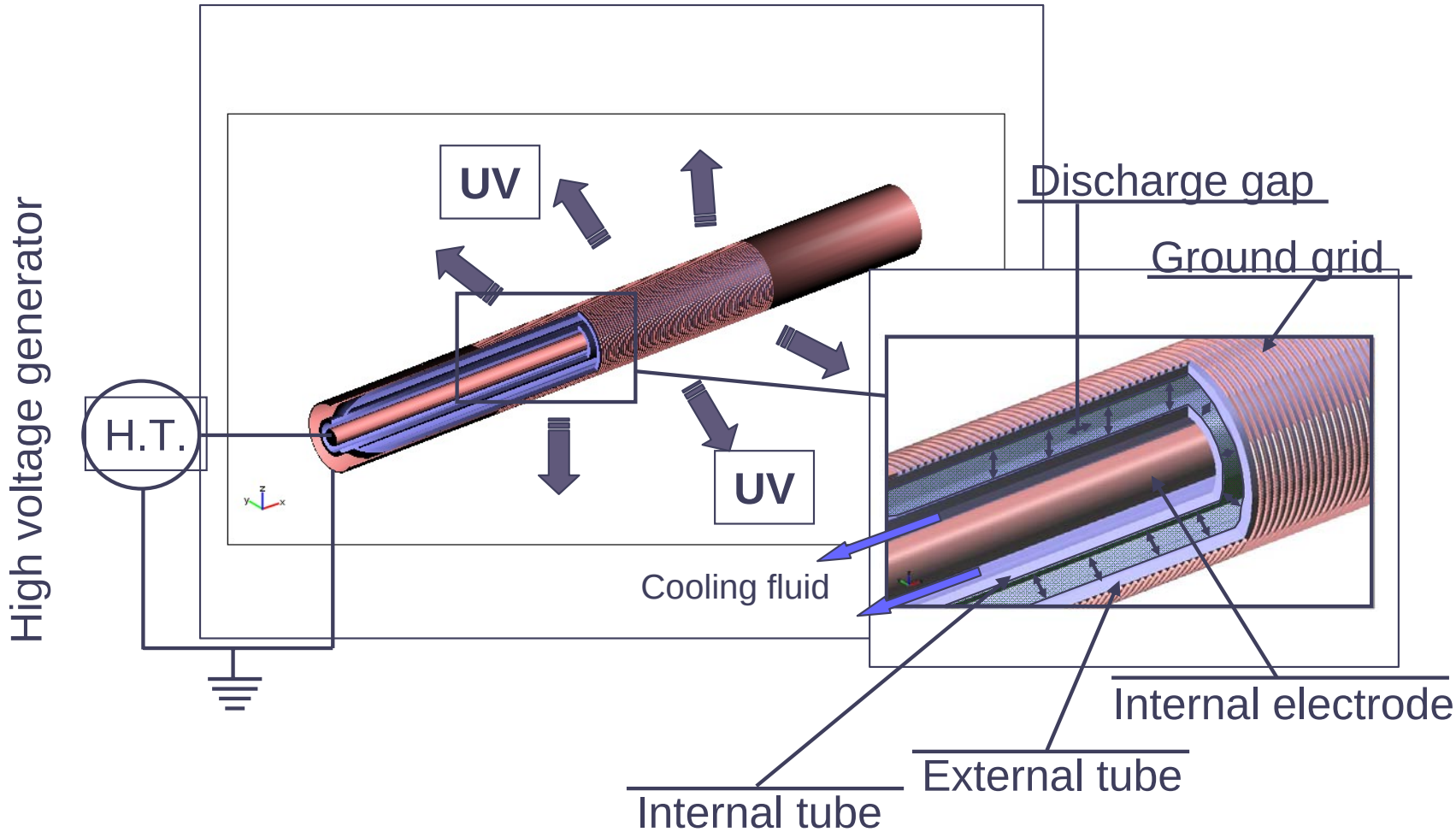
What is an Excilamp?

Dielectric Barrier Discharges (DBD) various geometries



What is an Excilamp?

DBD: the axisymetric geometry (coaxial)



What is an Excilamp?

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Applications of excilamps

Industrial:

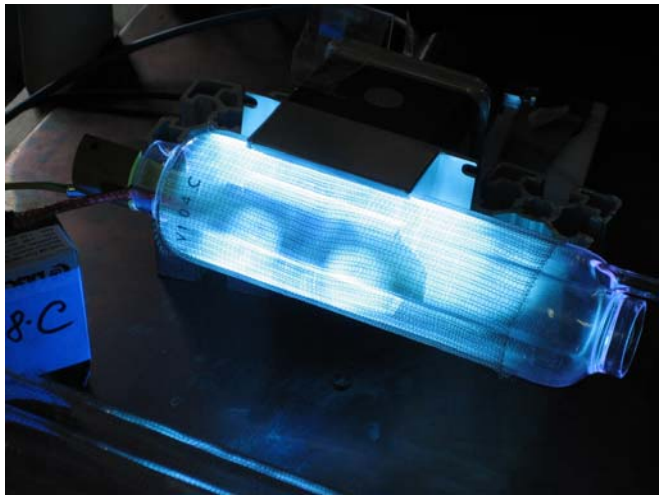
- Photochemistry

Environment:

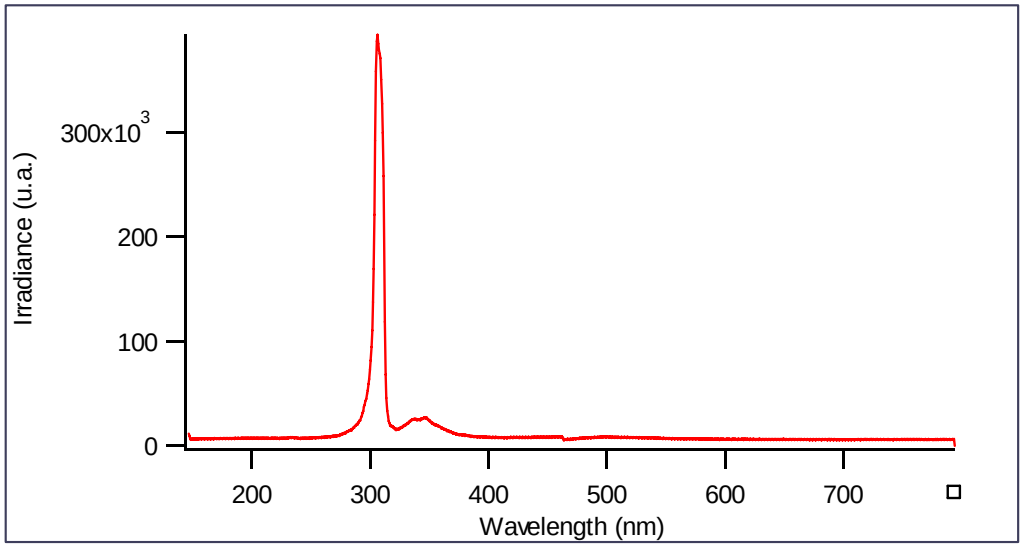
- Water Treatment
- Sterilization

Health:

- skin disease treatment



Xenon/Chlorine excilamp



Xenon/Chlorine excilamp spectrum

UVB radiation especially suited for treatment of psoriasis and vitiligo.

Model Description

Fluid model:

Plasma out of equilibrium ⟹ Boltzmann equation

⟹

Drift-diffusion equations:

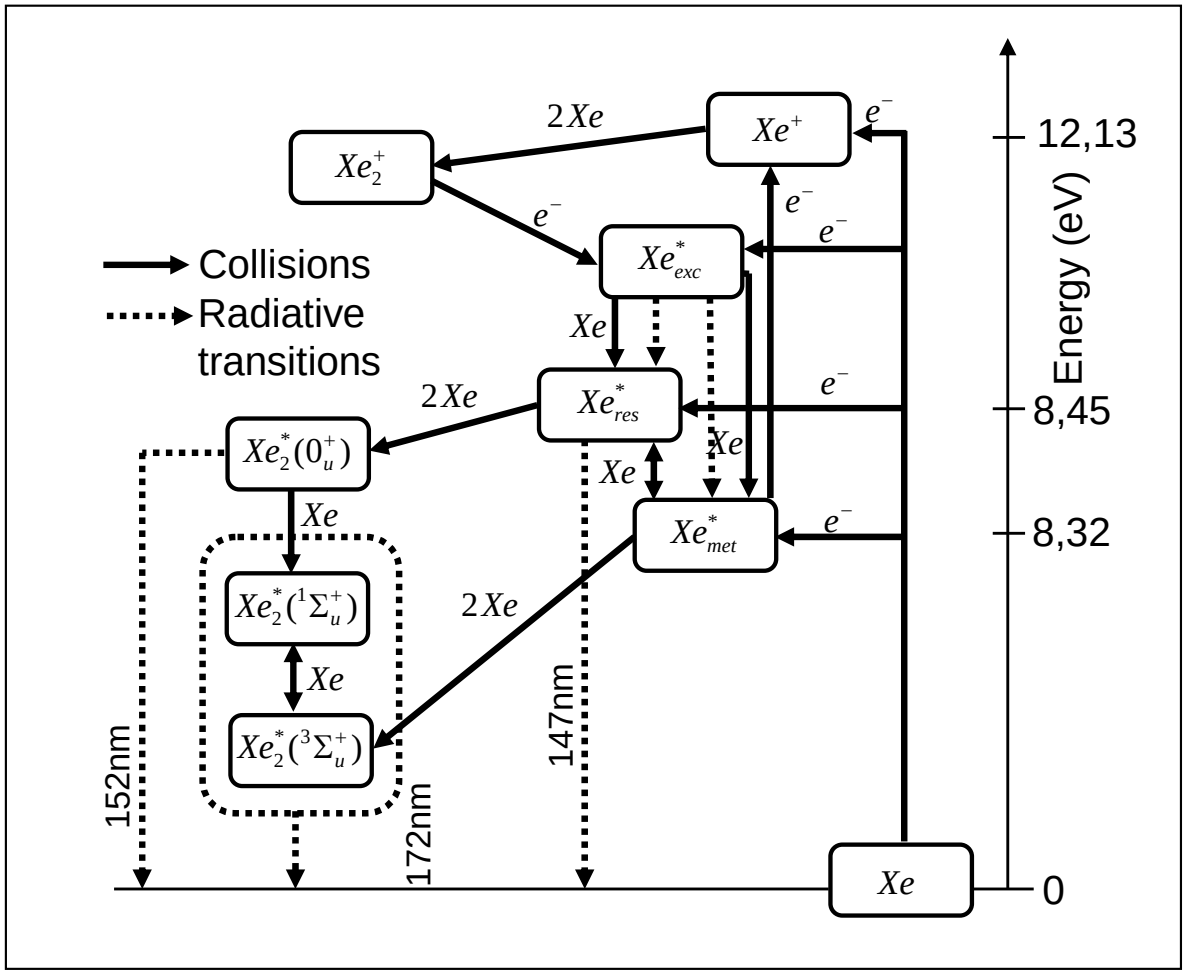
$$\begin{cases} \dfrac{\partial n}{\partial t} + \vec{\nabla}.\vec{\Gamma} = S \\ \vec{\Gamma} = -D\vec{\nabla}n \pm \mu n\vec{E} \end{cases}$$

⟸

PDE system to solve:

$$\begin{cases} \vec{\nabla}.(-\varepsilon\vec{\nabla}V) = e(n_i - n_e) \\ \dfrac{\partial n_e}{\partial t} + \vec{\nabla}.(-D_e\vec{\nabla}n_e + \mu_e n_e\vec{\nabla}V) = S_e \\ \dfrac{\partial n_i}{\partial t} + \vec{\nabla}.(-D_i\vec{\nabla}n_i - \mu_i n_i\vec{\nabla}V) = S_i \\ ..... \\ ..... \end{cases}$$

Chosen kinetics scheme:



Boundary conditions:

1 - Coupling of volume densities and surface densities through the Weak Boundary Application mode

For electrons

$$\begin{cases} \dfrac{dn_{se}}{dt} = K_{sadse} n_e - K_{sdes} n_{se} - K_{srec} n_{se} n_i \\ \vec{\Gamma}_e . \vec{u}_n = K_{sadse} n_e - K_{sdes} n_{se} + K_{srec} n_e n_{si} \end{cases}$$

1 – Boundary Conditions for the Electrostatic Potential

$$\begin{cases} V(electrode\ 1) = 0; V(electrode\ 2) = 5000 \sin(2\pi 50 \times 10^3 t) \\ V(electrode\ 1) = 0; \varepsilon \vec{\nabla} V(electrode\ 2) = \int_0^t \dfrac{I(t)}{A} dt \end{cases}$$

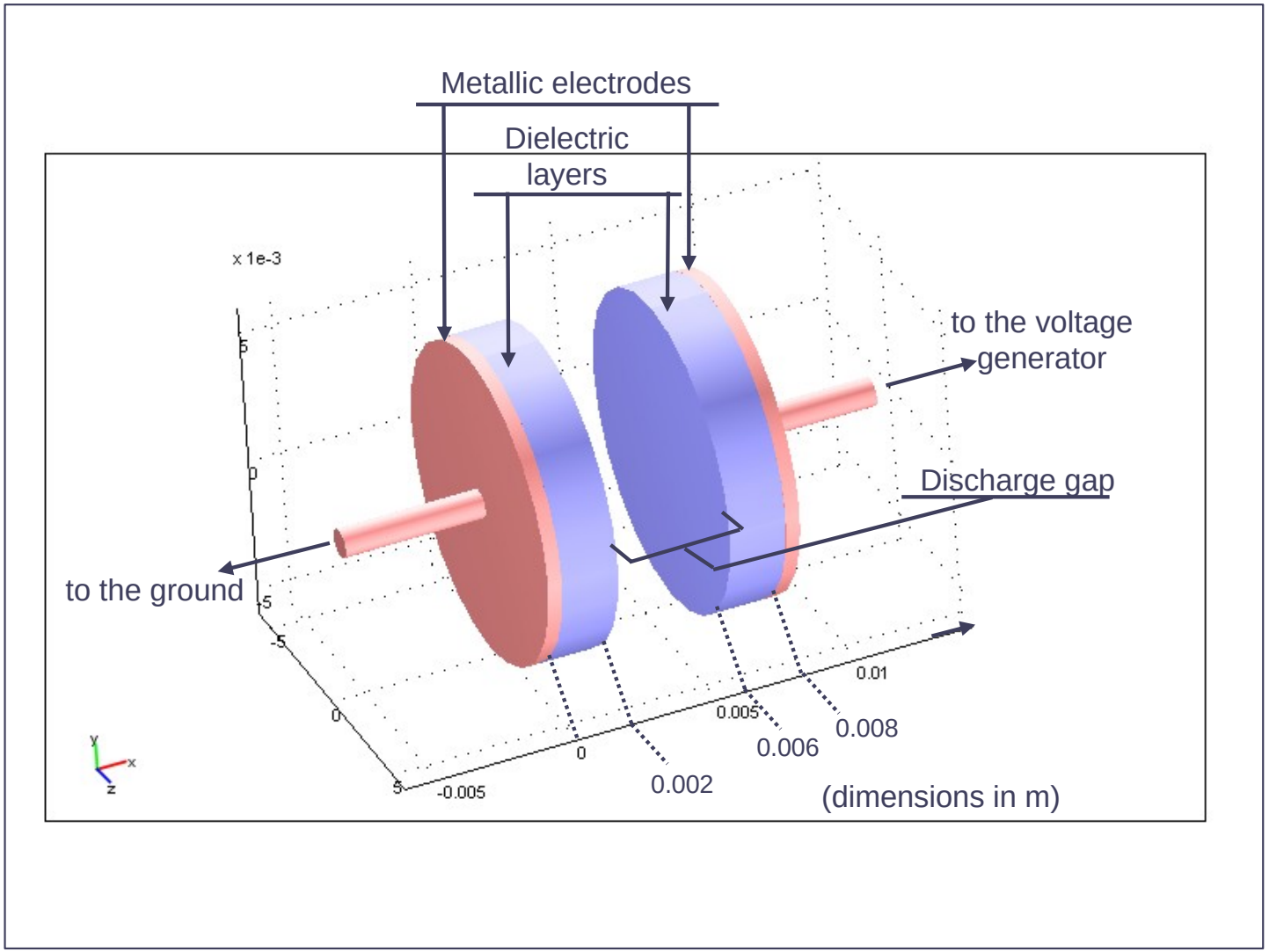
⟸ **Voltage Source**

⟸ **Current Source**

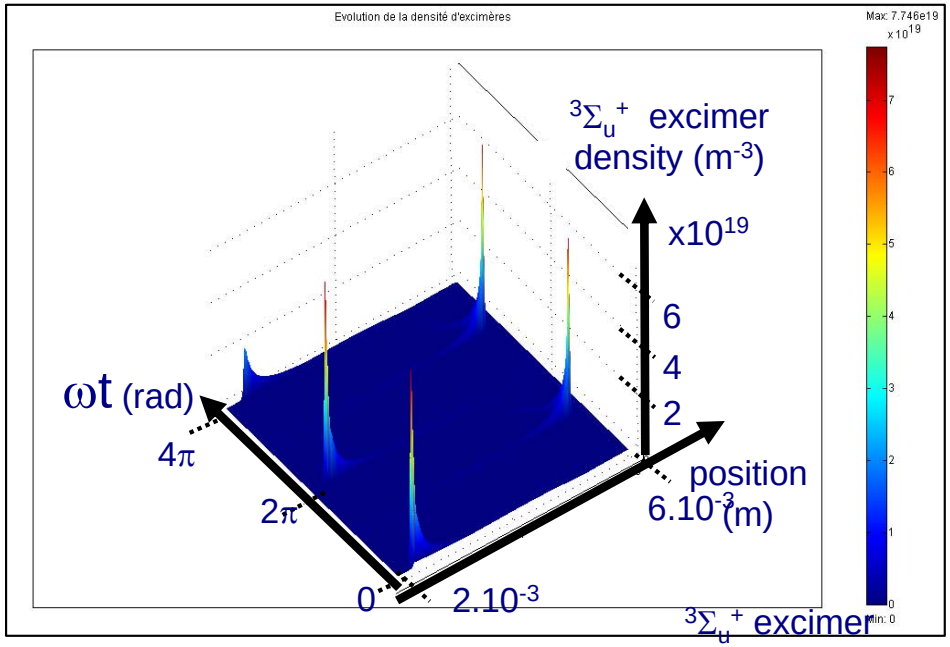
Electric field discontinuity is taken into account at the charged dielectic boundaries

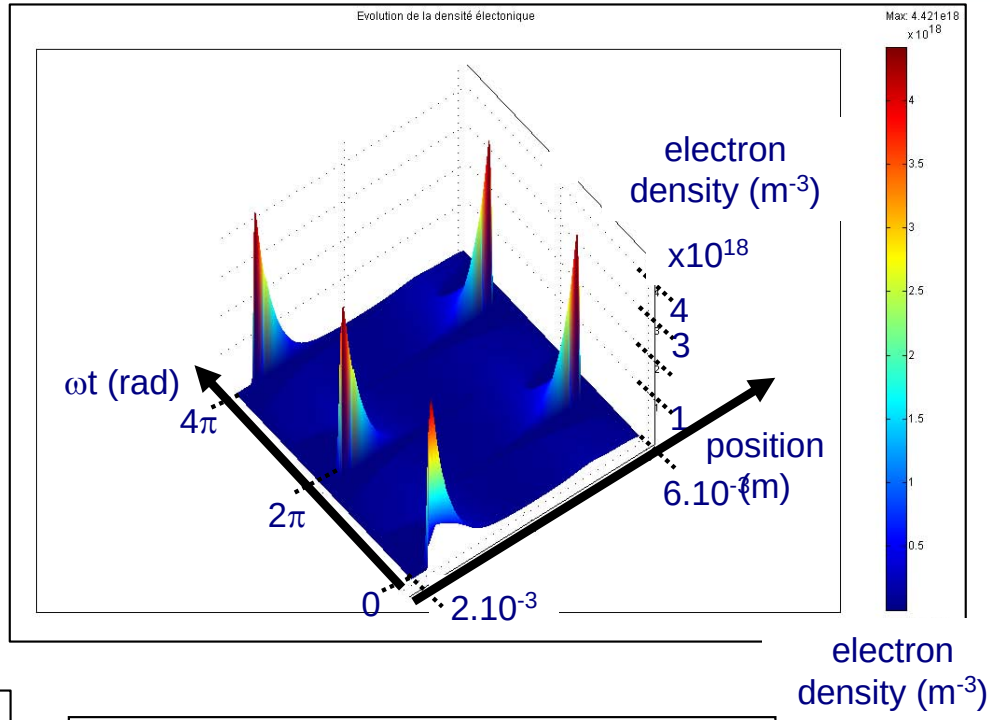
Model Description

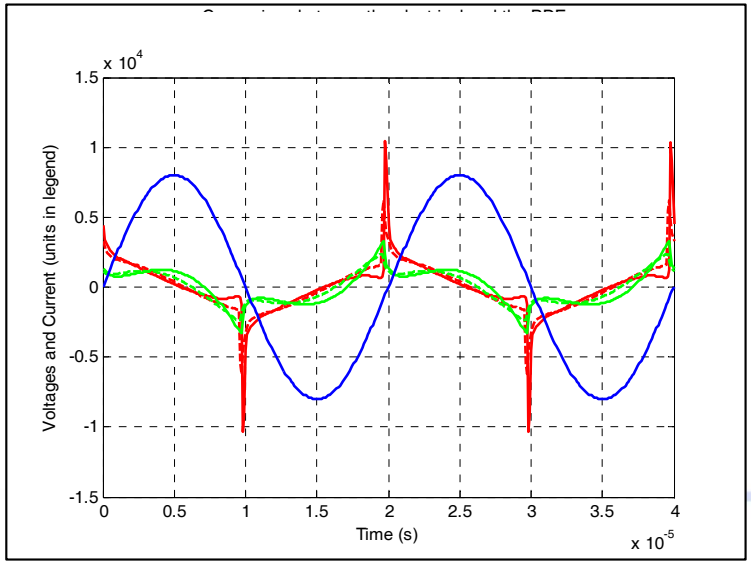
Considered geometry:



Results obtained





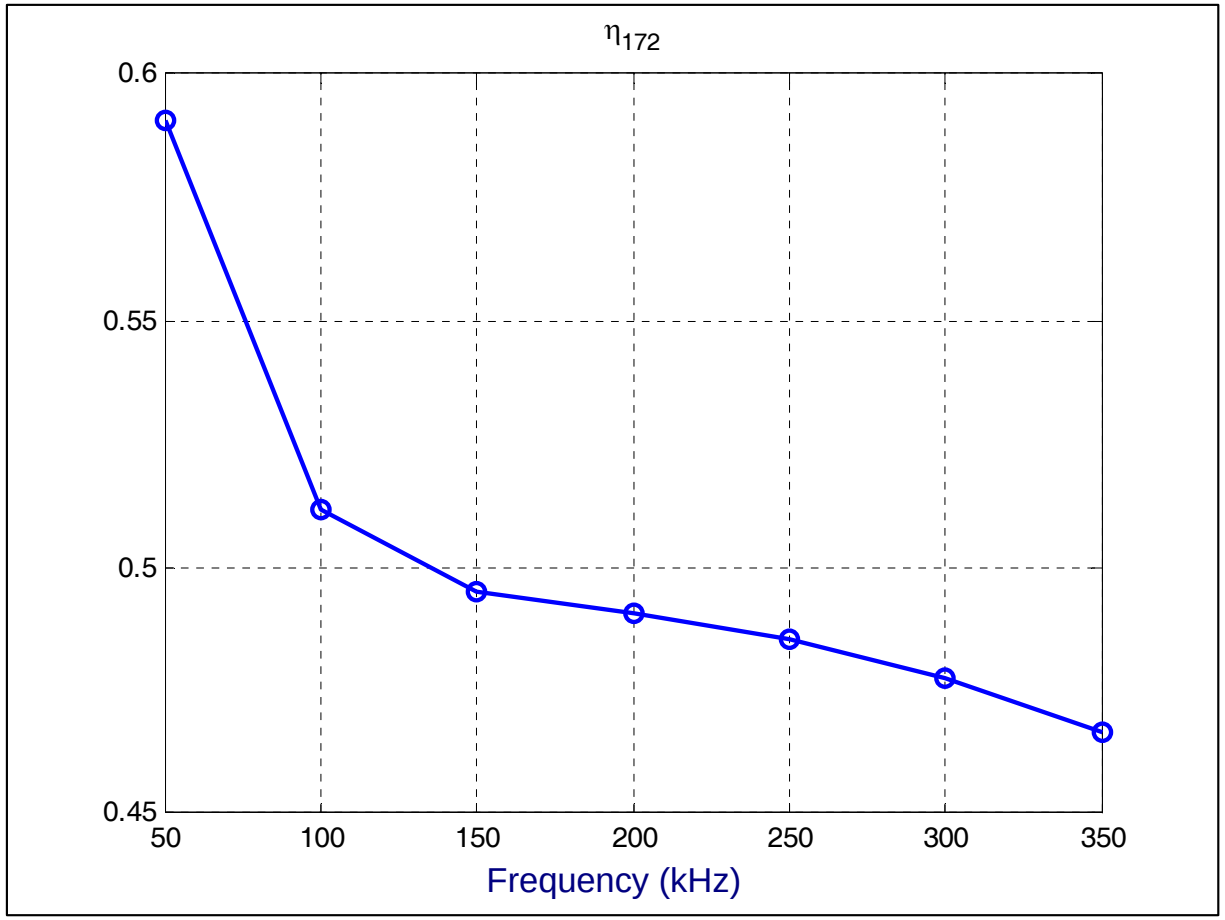


Legend:

- Applied voltage (V)
- Voltage drop in the whole gas gap according to the PDE model (V)
- Total current according to the PDE model (x10^{6}A)

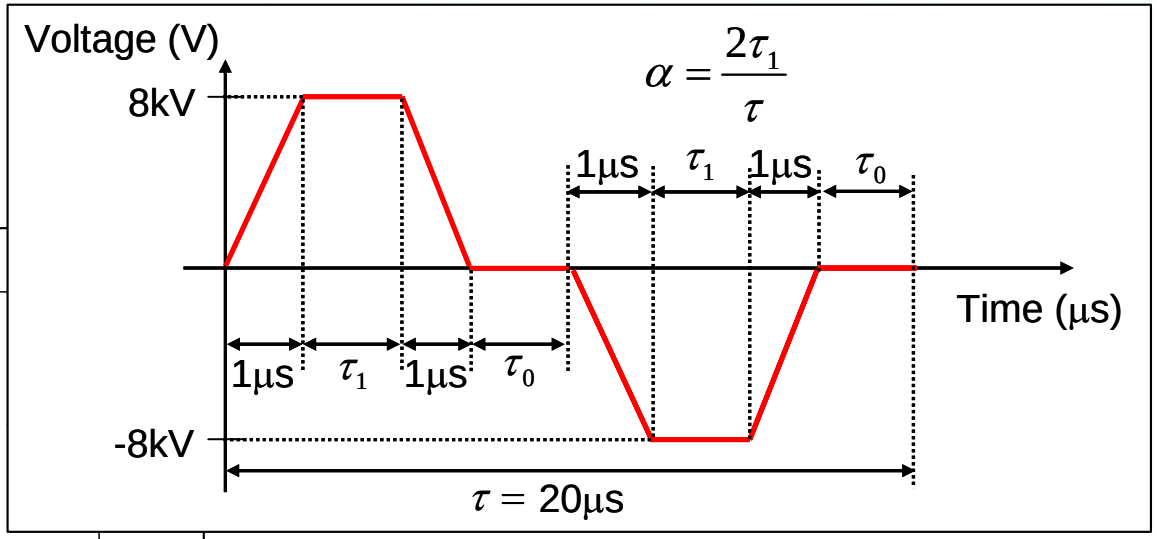
Results obtained

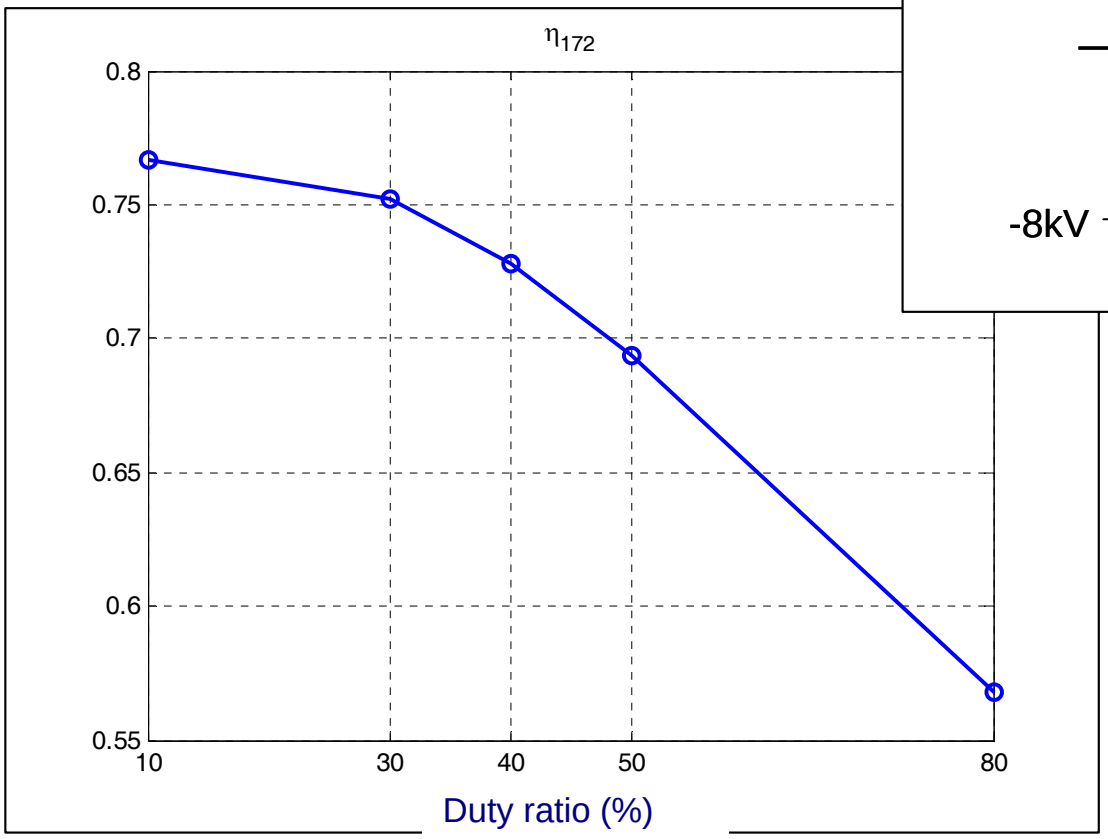
Efficiency of the excilamp supplied with a sine waveform voltage source.



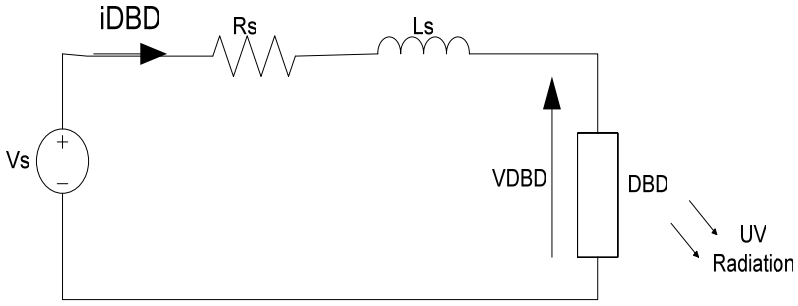
Results obtained

Efficiency of the excilamp supplied with a pulsed waveform voltage source.

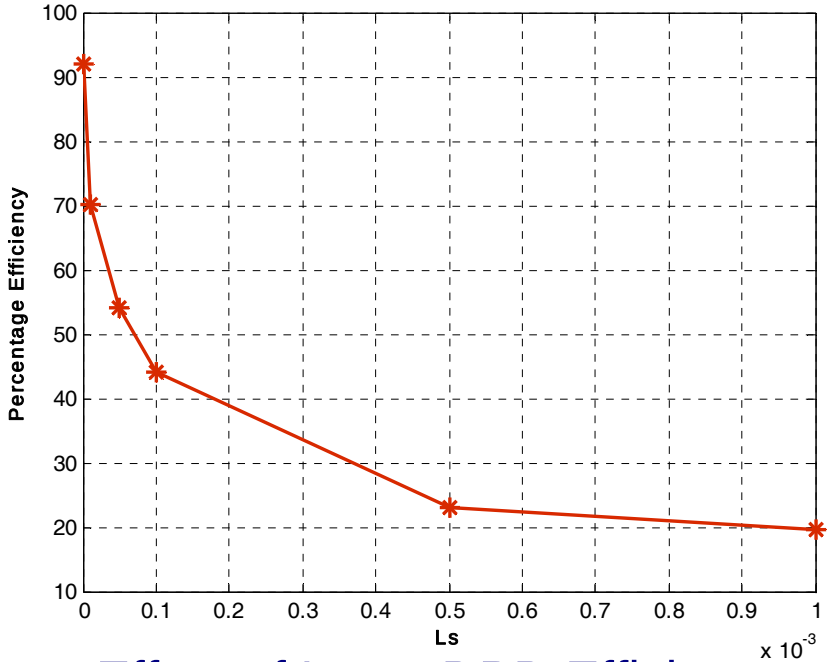




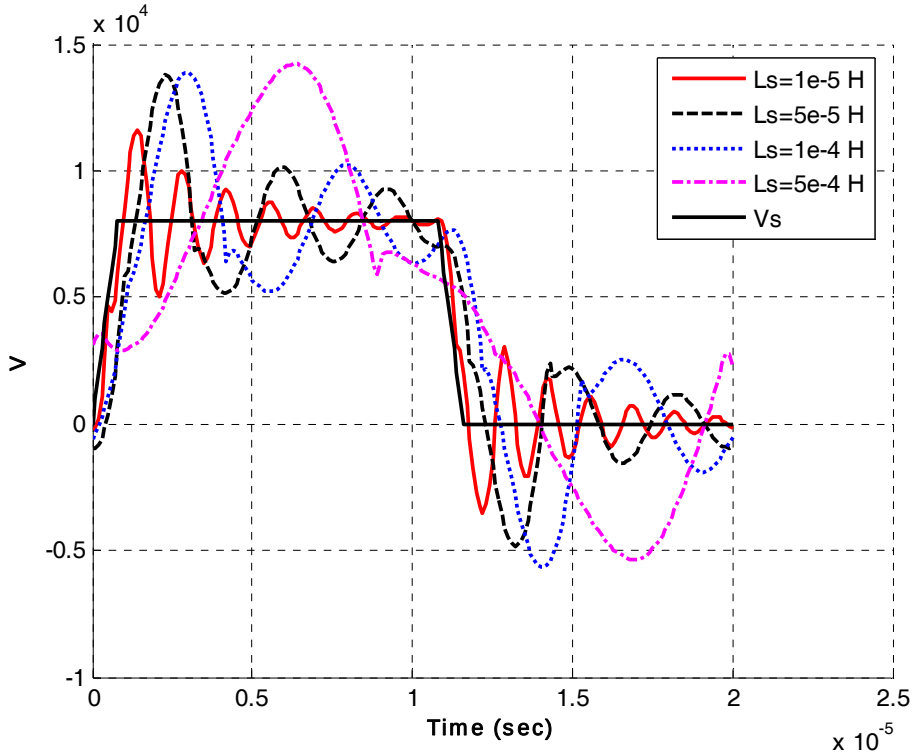
Results obtained



Electrical scheme



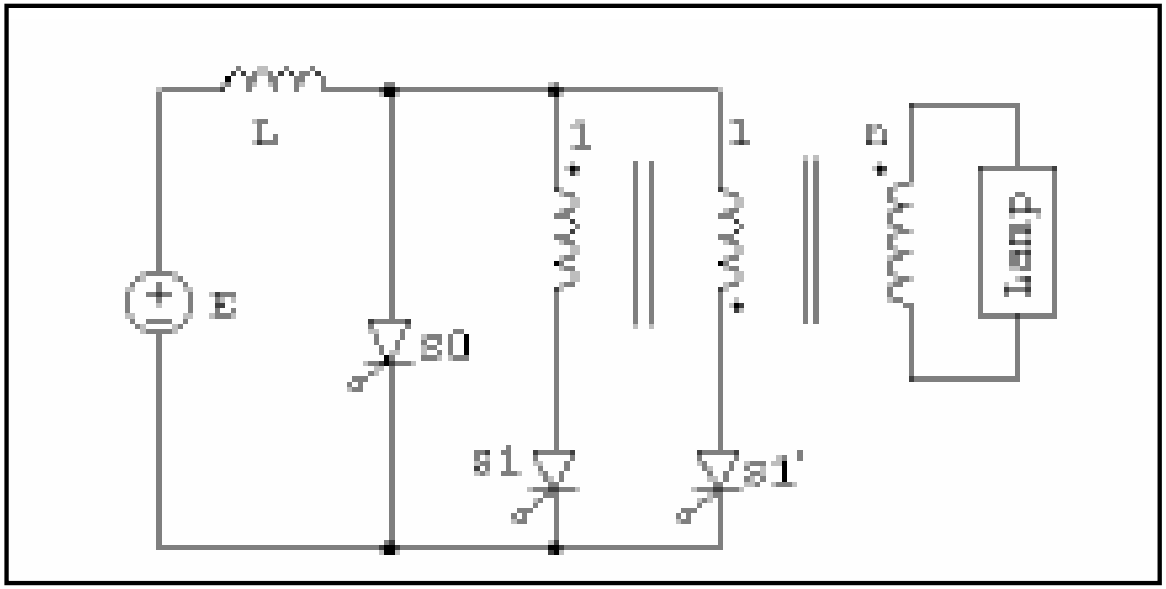
Effect of Ls on DBD Efficiency



DBD Voltage under different parasitic inductances

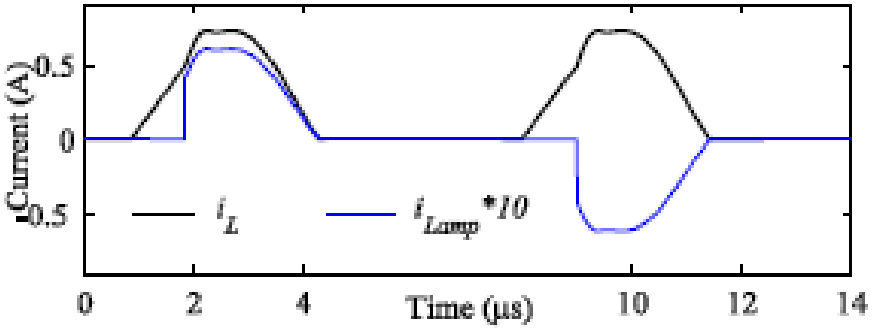
"Simulation of Dielectric Barrier Discharge Lamp Coupled to the External Electrical Circuit" - A. El-Deib, F.P. Dawson, S. Bhosle, D. Buso and G. Zissis – COMSOL Conference 2008 - Boston

Results obtained



Design of a dedicated power converter

"Design of a Current Converter for the Study of the UV Emission in DBD Excilamps" - R. Díez, H.Piquet, S. Bhosle, J.M. Blaquière, N. Roux - ISIE 2008 IEEE International Symposium on Industrial Electronics, 30 june-2 july 2008 - Cambridge (England)



Conclusion

- A PDE model was used to compute the parameters of an operating excilamp

- This model was implemented in COMSOL Multiphysics and could be successfully solved in 1D - time dependant
- Thanks to COMSOL platform, the model can easily be shared with researchers from abroad of from different backgrounds
- The obtained results help in the understanding of the mechanisms involved in the development of the discharge
- They led to the design of new power converter topologies, specially dedicated to excilamps