LTi
Light Technology Institute

METHOD TO MEASURE THE INNER ELECTRICAL VALUES OF A DBD INCLUDING SPACE CHARGE FIELD

Klaus Trampert, Mark Paravia, Wolfgang Heering

DBD

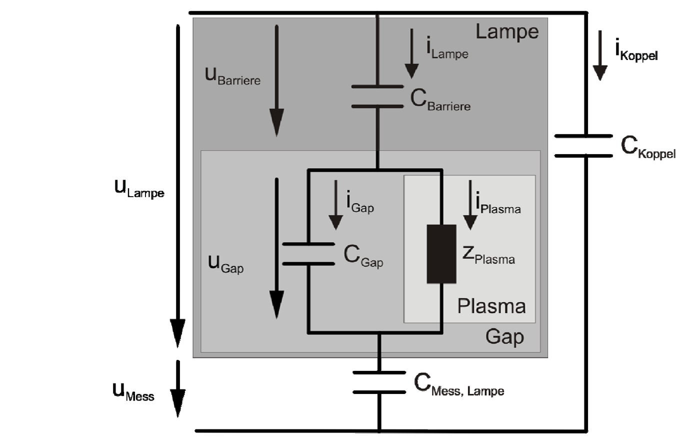
Xe- DBD characteristics

- simple construction
- mercury-free discharge
- every shape possible
- long lifetime
- flat discharge

electric characteristics

- dielectric isolation of plasma
- transient self restricted discharge
- direct measurement of internal values not possible
- high frequency signal in high voltage regions
- capacitive coupling

measurement set up



$$u_{Barriere} = \frac{C_{Mess}}{C_{Barriere}} \cdot u_{Mess}$$

$$u_{gap} = u_{lamp} - u_{barriere} = u_{lampe} - \frac{C_{meas}}{C_{barriere}} \cdot u_{meas}$$

$$i_{plasma} = \left(1 + \frac{C_{gap}}{C_{barrier}}\right) \cdot \left(i_{lamp} - i_{couple}\right) = \left(1 + \frac{C_{gap}}{C_{barrier}}\right) \cdot i_{difference}$$

$$i_{gap} = i_{lamp} - i_{plasma}$$

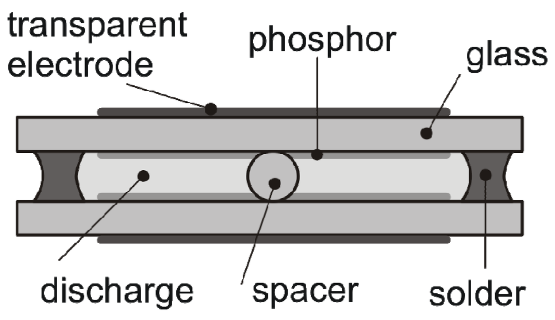
method

- determination of inner values with the help of two additional capacitances
- Law of capacitance divider for C_{meas} and $C_{barrier}$ ➔ $v_{barrier} \sim v_{meas} \sim C_{meas}$
- If $C_{couple} = C_{lamp}$ the displacement current of C_{lamp} and C_{couple} is equal ➔ $i_{plasma} \sim i_{lamp} - i_{couple}$

problems

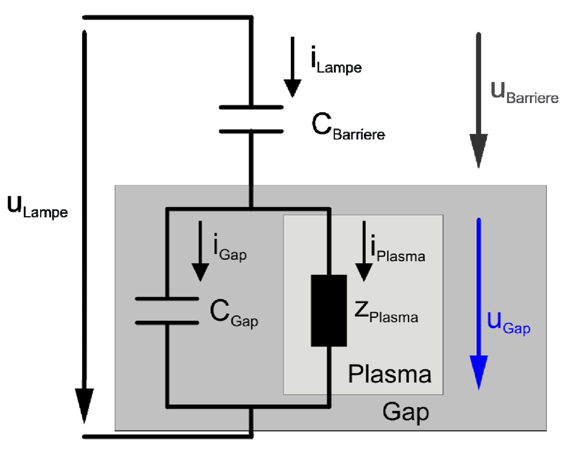
- resonances between C_{lamp} and stray inductance of cable to lamp
- precise matching of $C_{lamp} = C_{couple}$ necessary
- precise knowledge of $C_{barrier}$ necessary

electrical DBD model



equivalent electrical circuit

- dielectric barrier
  - dielectric capacitance $C_{barrier}$
- discharge gap
  - vacuum capacity C_{gap}
  - plasma impedance z_{plasma}



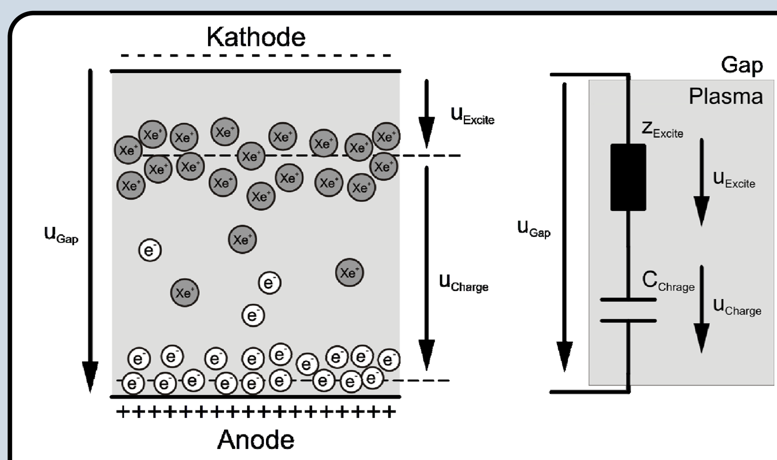
electrical values

- outer values
  - lamp voltage v_{lamp}
  - lamp current i_{lamp}
- inner values
  - barrier voltage $v_{barrier}$
  - gap voltage v_{gap}
  - displacement current i_{gap}
  - plasma current i_{plasma}

impedance z_{plasma}

- nonlinear
- time dependent
- voltage dependent
- **unknown memory effect due to the space charge!**

space charge model



ansatz

$$C_{Lampe} \cdot u_{Lampe} = C_{Gap} \cdot u_{Gap} + C_{Charge} \cdot u_{Charge}$$

conditional equation

$$u_{Charge} = u_{Barriere} - u_{Lampe} \cdot \left(\frac{C_{Gap}}{C_{Gap} + C_{Barriere}}\right)$$

$$u_{Excite} = u_{Gap} - u_{Charge}$$

working hypothesis

- DBD = conservation of charges inside the gap
- centre of charge clouds near by the barrier at the beginning of ignition
- field between ions and electrons weakest the applied voltage V_{gap}

conclusions

- homogenous charge distribution ➔ $A_{electrode} = A_{charge}$
- distance between ions Electrons ➔ $d_{gap} = d_{charge}$
- negligible polarisation ➔ $\varepsilon_{r;\ charge} = 1$

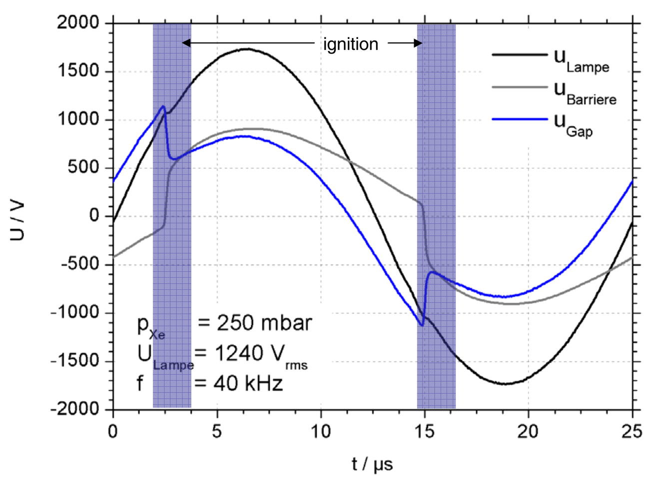
equivalent electrical circuit

$$C_{charge} = C_{gap}$$

$$z_{plasma} = C_{charge} + Z_{excite}$$

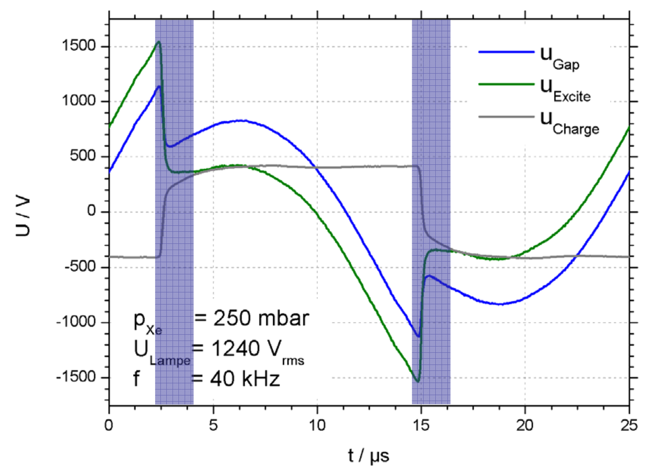
sinus

measured internal voltage

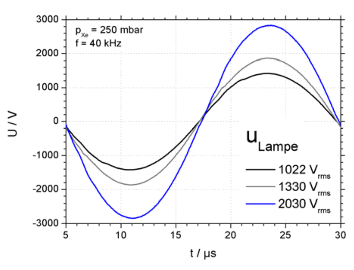


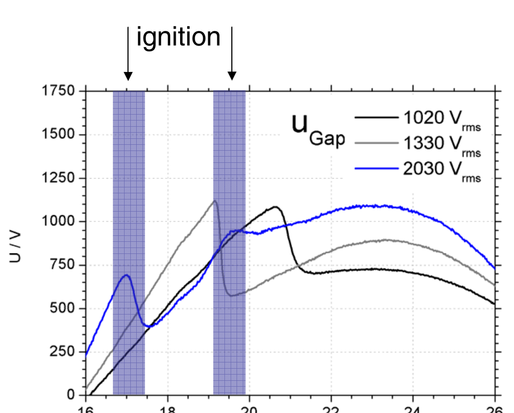
- symmetrical bipolar excitation
- gap voltage ≠ lamp voltage
- influence of space charge
- ignition at $v_{gap,\ max}$
- at low lamp voltage two ignitions per period
- ignition voltage not dependent from lamp voltage

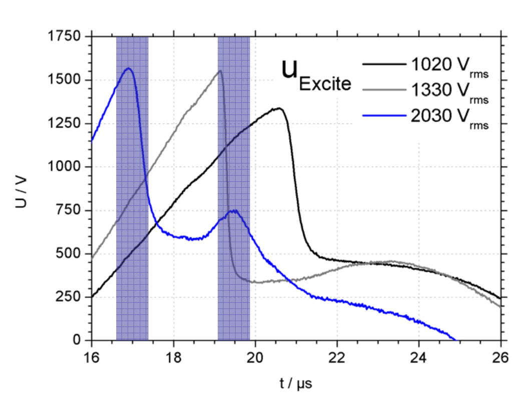
calculated space charge



- v_{charge} show the influence of space charges
- bipolar excitation causes accumulation of charges on the walls
- v_{excite} at ignition is supported by v_{charge} of last ignition bipolar ignition
- v_{excite} greater than v_{gap} at ignition







problem of common ignition voltage definition

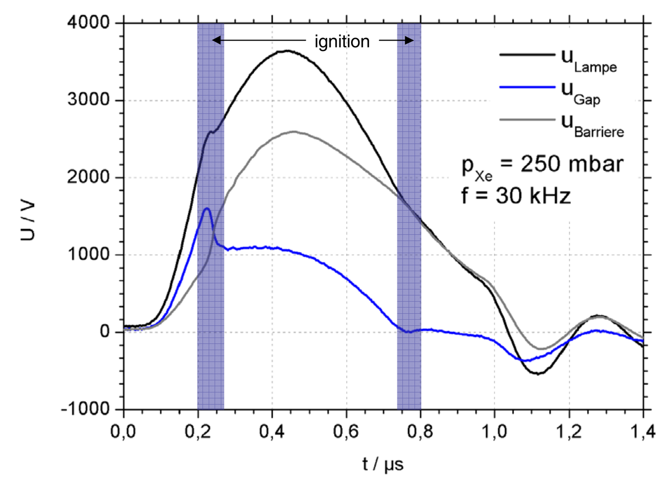
- $V_{ignition} = V_{gap,\ max}$
- $V_{ignition}$ depends on outer lamp voltage
- at higher v_{lamp} two or more ignitions per half period with increasing ignition voltage despite perionization effect
- ignition voltage of sinusoidal excitation up to a factor 2 smaller than at pulsed excitation

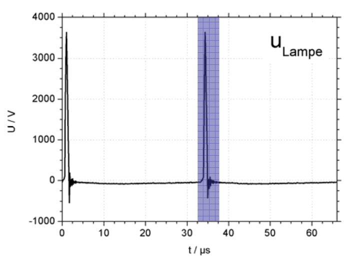
new definition of ignition voltage

- $V_{ignition} = V_{excite,\ max}$
- ignition voltage of first pulse independent of excitation
- right description of preionization effect
- ignition voltage in the same range as with pulsed excitation

pulse

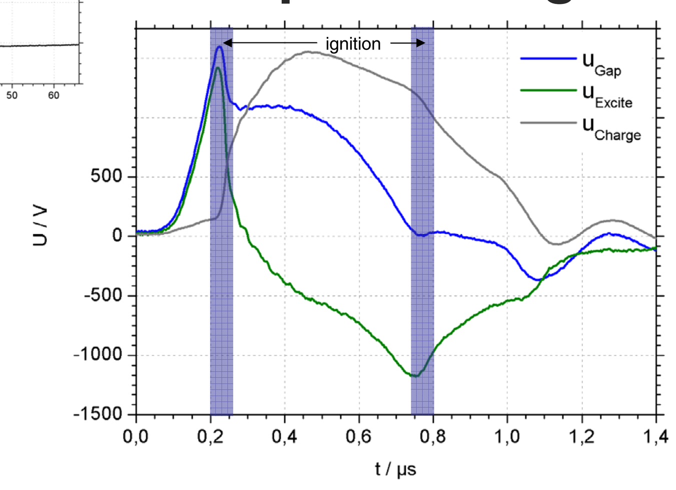
measured internal voltage



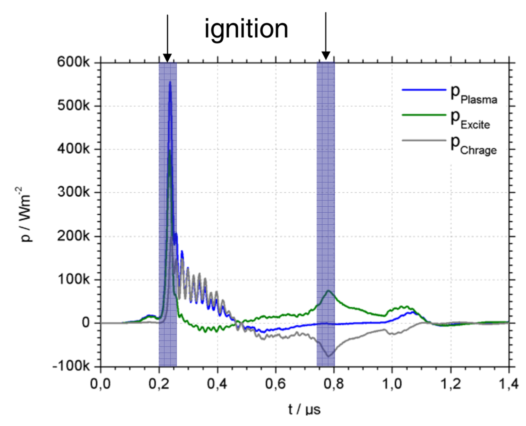


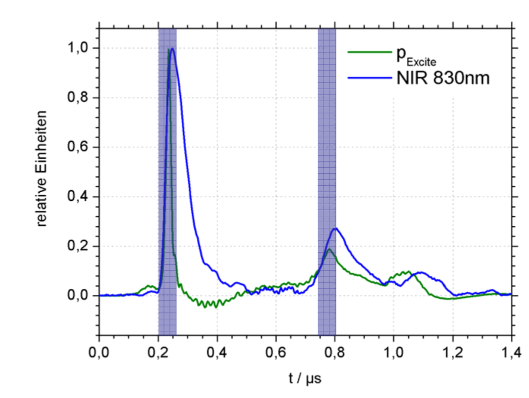
- unsymmetrical bipolar excitation
- gap voltage ≠ lamp voltage
- influence of space charge
- ignition at $v_{gap,\ max}$ and $v_{gap} = 0$
- higher lamp voltage needed for ignition
- second ignition (reignition) on falling edge
- reignition influence first ignition despite long pause between

calculated space charge



- $v_{charge} = 0$ at first ignition
- $v_{excite} \approx v_{gap}$ at ignition
- second ignition (reignition) at $v_{gap} = 0$ V
- second ignition supported by space charge
- ignition at $v_{excite,max}$





problem of common ignition voltage definition

- $V_{ignition} = V_{gap,\ max}$
- $V_{ignition}$ depends on memory effect of last ignition
- second ignition at $v_{gap} = 0$ V in conflict with physical expectance
- no correlation between ignition an v_{gap} at reignition
- no correlation between p_{gap} and ignition

new definition of ignition voltage

- $V_{ignition} = V_{excite,\ max}$
- time of $v_{excite,max}$ correlate with ignition in NIR (823 nm, 828 nm)
- v_{excite} in the same range as at sinusoidal excitation
- explanation of reignition with field of space charges
- p_{excite} has nearly no displacement component
- good correlation between p_{excite} and NIR emission