Plasma Efficiency and Losses for pulsed Xe Excimer DBDs at high Power Densities

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GEC, Saratoga Springs 2009

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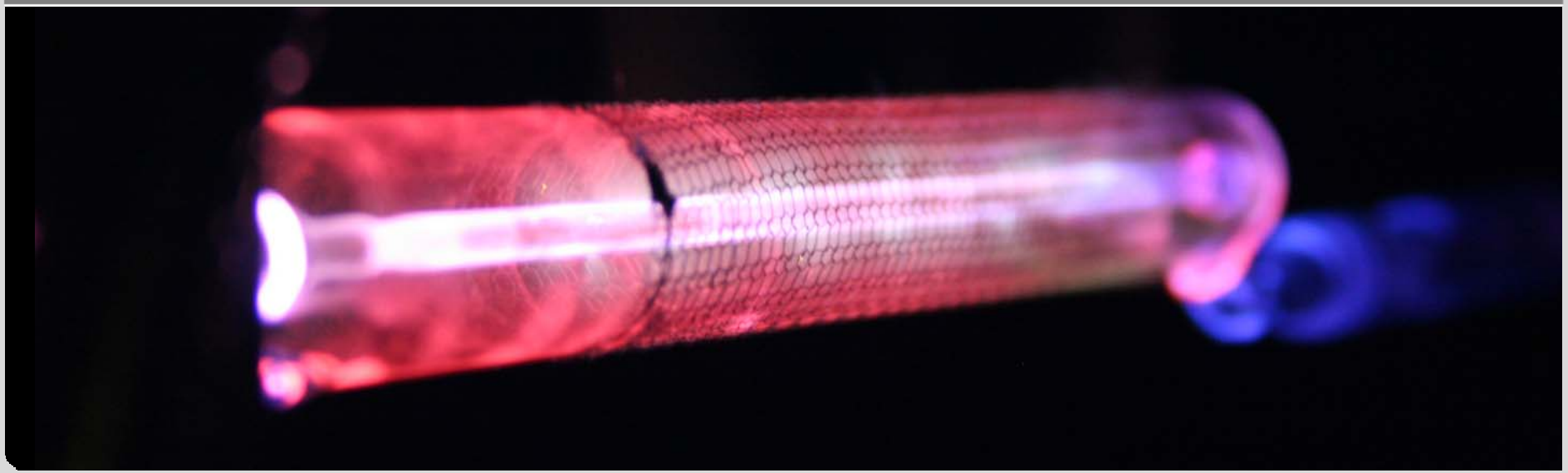


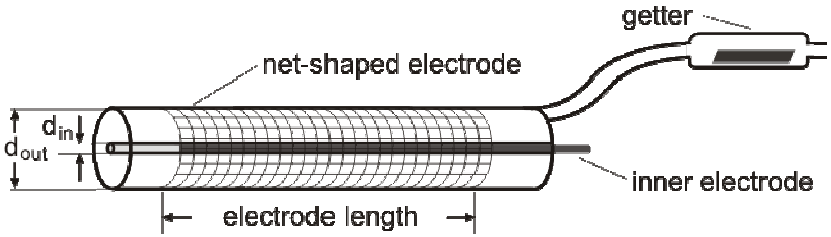
Dielectric Barrier Discharges

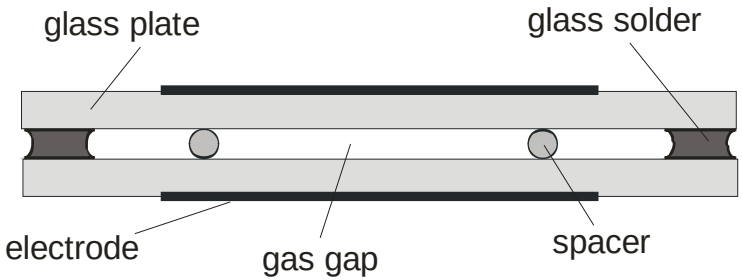
- Non-equilibrium plasma
- Xenon excimer
- Radiation around 172 nm
- Plasma efficiency up to 65 % [1]

- Phosphor coated lamps for
  - UV water disinfection
  - Advanced oxidation processes

[1] Vollkommer, Hitzschke, US000005604410A (1994)

Experimental setup
Lamp overview





barrier:	fused silica
gas gap:	4,5 - 5,5 mm
xenon:	210 - 400 mbar
frequency:	20 - 200 kHz

barrier:	glass
gas gap:	2 mm
xenon:	50 - 350 mbar
frequency:	20 - 200 kHz

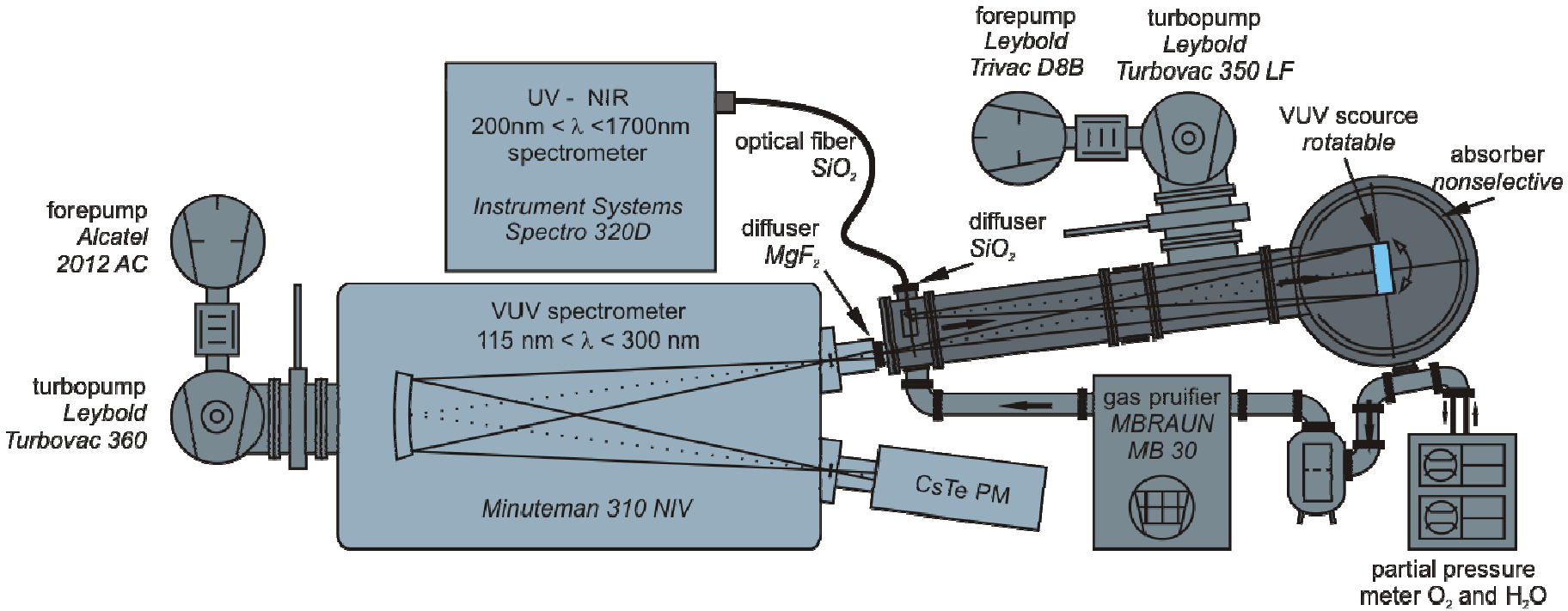
Investigation:

- radiation flux
- optical losses
- plasma efficiency estimation

Investigation :

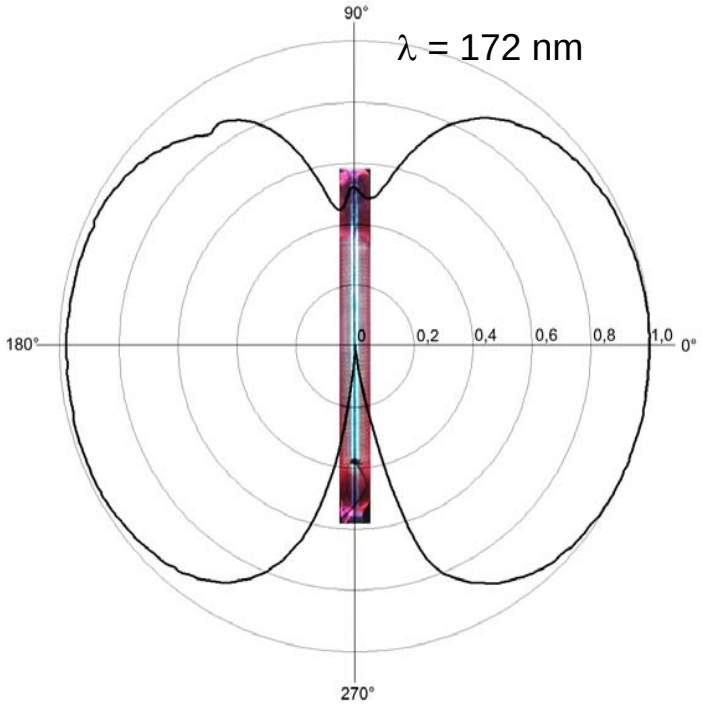
- luminance
- inner electrical values
- NIR (823 nm, 828 nm)

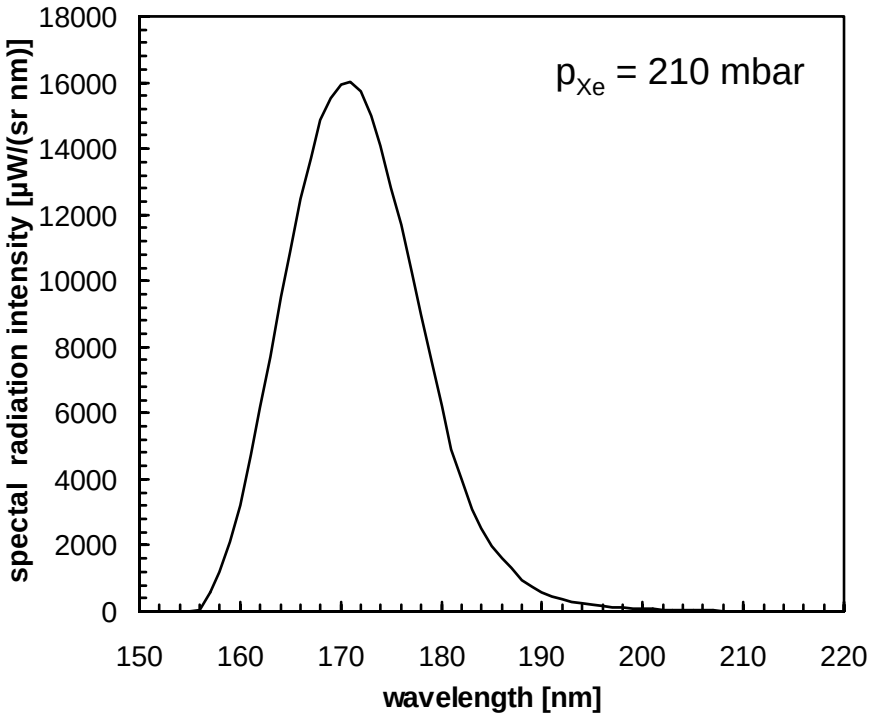
Experimental setup
VUV goniometer



- wavelength range from 115 nm < λ< 1700 nm
- absolute calibration from VUV to NIR
- photometric distance = 120 cm (max lamp size = 12cm)
- ability to measure angular distribution of radiant intensity

Results for silica lamps: angular distribution and spectra





- angular distribution of radiant intensity (ARI) shows optical thin plasma
- Xe_2^* spectra is overlapped with transmission edge of fused silica (~155 nm)

Results for silica lamps: Calculation of plasma efficiency

- light flux:

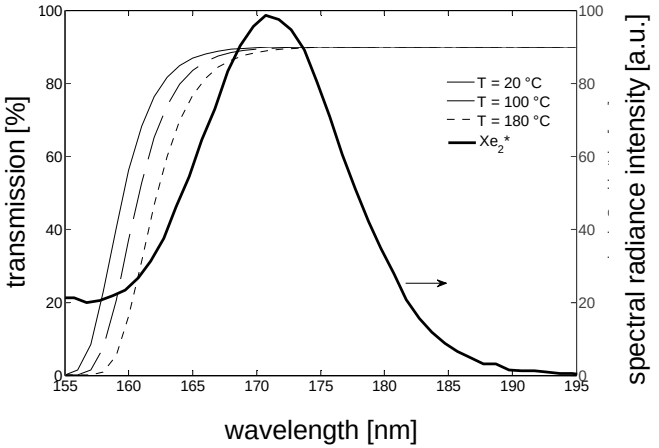
$$\Phi = \int_{\lambda_1}^{\lambda_2} \int_0^{2\pi} \int_0^{\pi} I(\lambda, \varphi, \gamma) \sin(\gamma) d\lambda d\gamma d\varphi$$

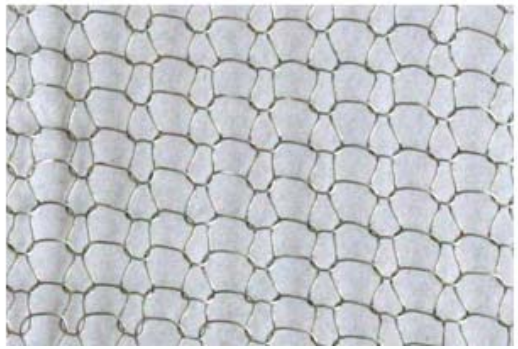
$$\Phi = 4\pi \cdot \overline{ARI} \cdot \Delta\lambda \cdot \sum_{i=1}^{n_\lambda} I(\lambda_i, \varphi_{j=\varphi_{Mess}})$$

- extraction efficiency T_{eff}:
  - transmission of silica
  - net-shaped electrode
  - absorption of inner barrier

- plasma efficiency:
  - isotropic emission of Xe_2^* (4π)

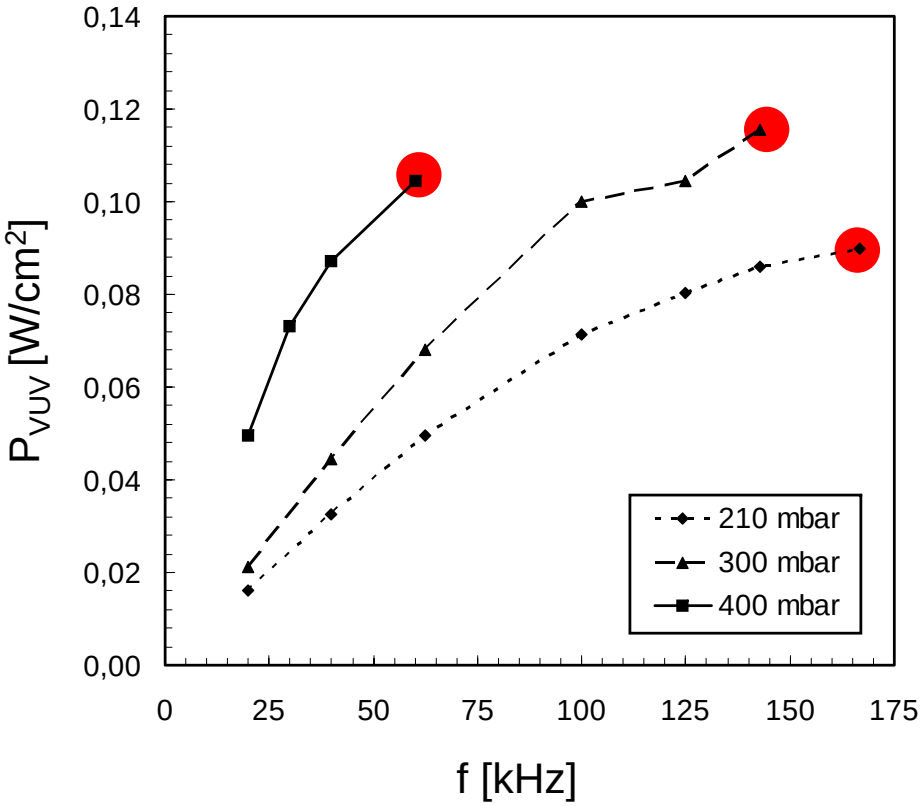
$$\eta_{Plasma} = \frac{\Phi}{\overline{ARI} \cdot T_{eff} \cdot P}$$





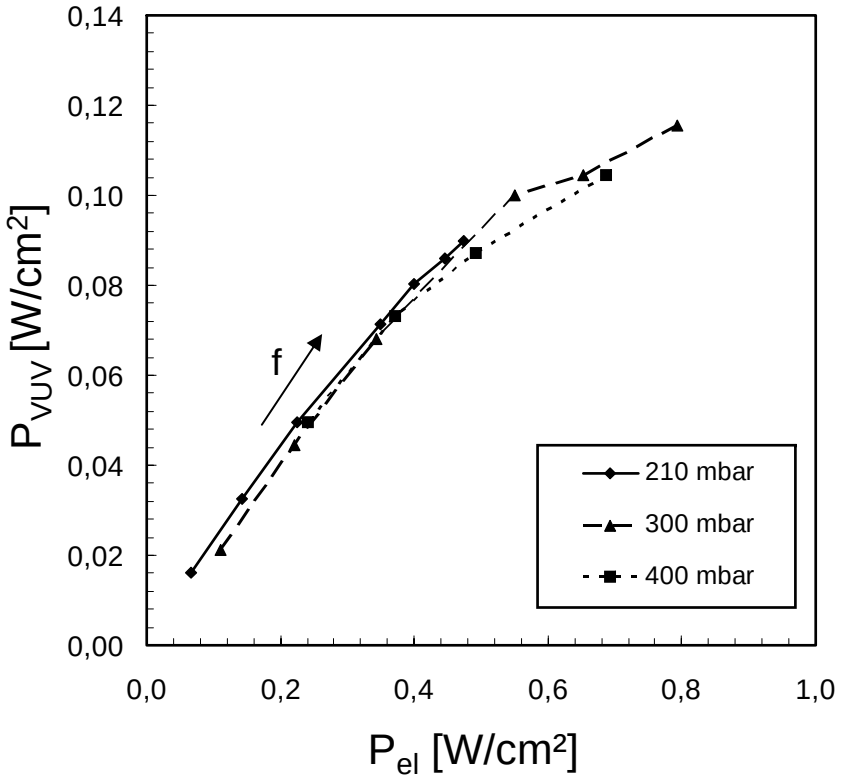
Results for silica lamps: efficiency

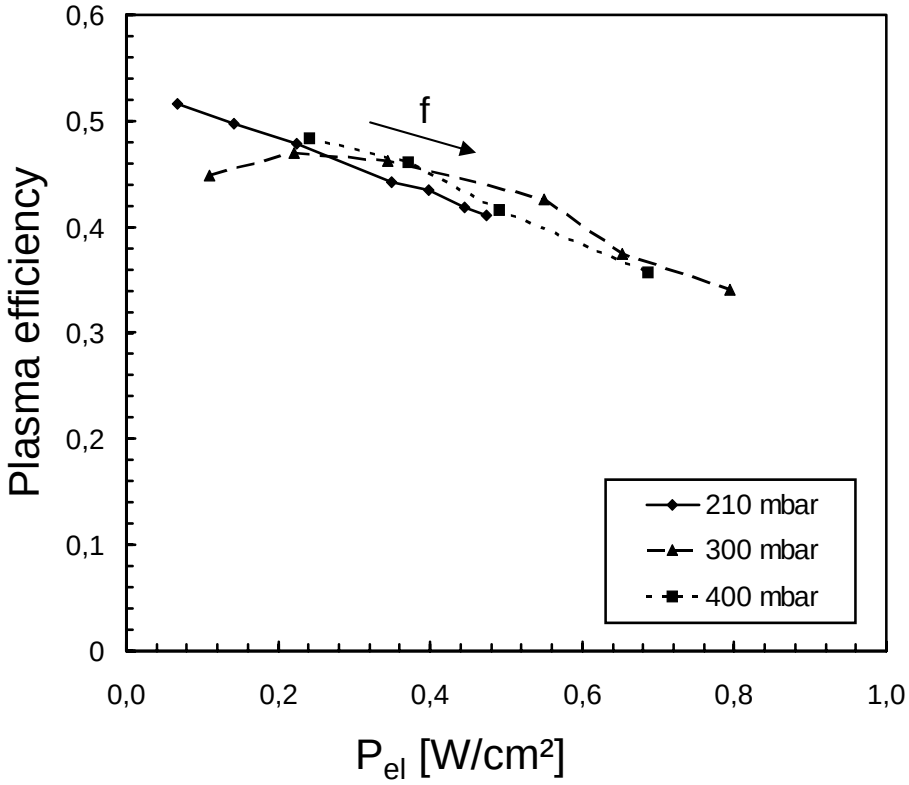
- Variation of repetition rate:



- maximum optical power density:
  P_{VUV} = 0,12 W/cm² at
  p_{Xe} = 300 mbar
- power density rises with pressure, but …
- transition of homogeneous into filamented discharge (pressure depended)

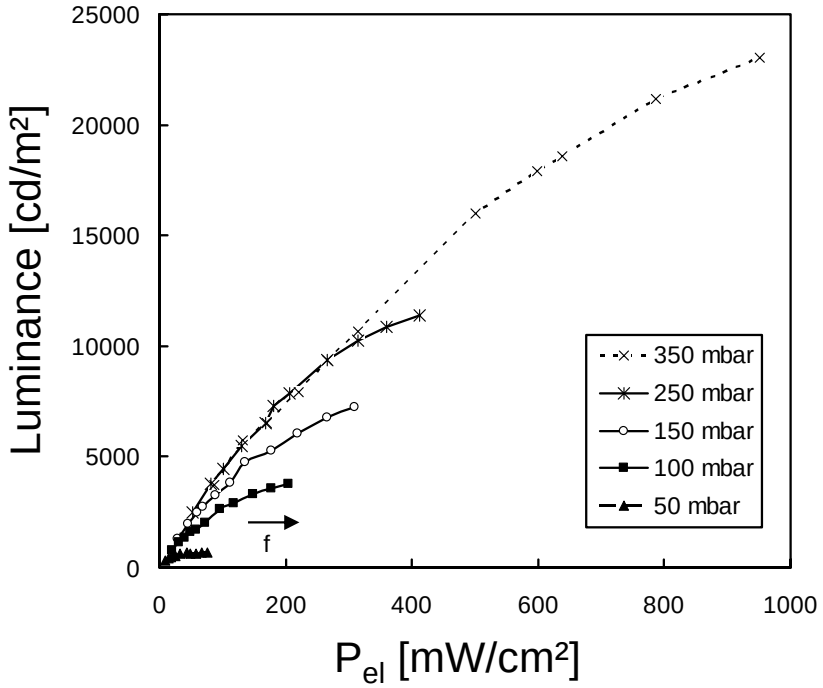
Results for silica lamps: efficiency

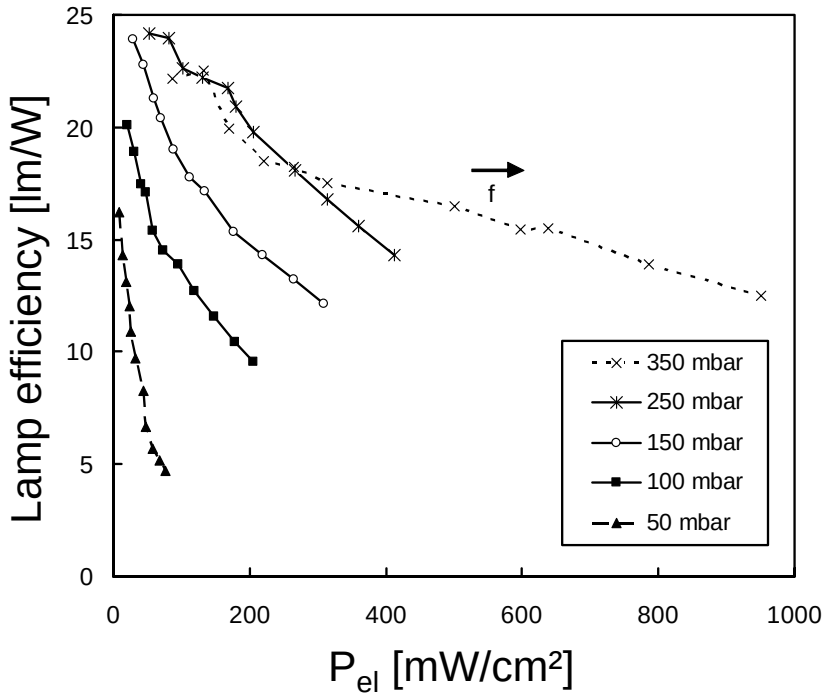




- maximum plasma efficiency ~ 52 % (at P_{el} = 0,07 W/cm²)
- plasma efficiency declines to ~ 34 % (at P_{el} = 0,8 Wcm²)
- why is the efficiency declining?

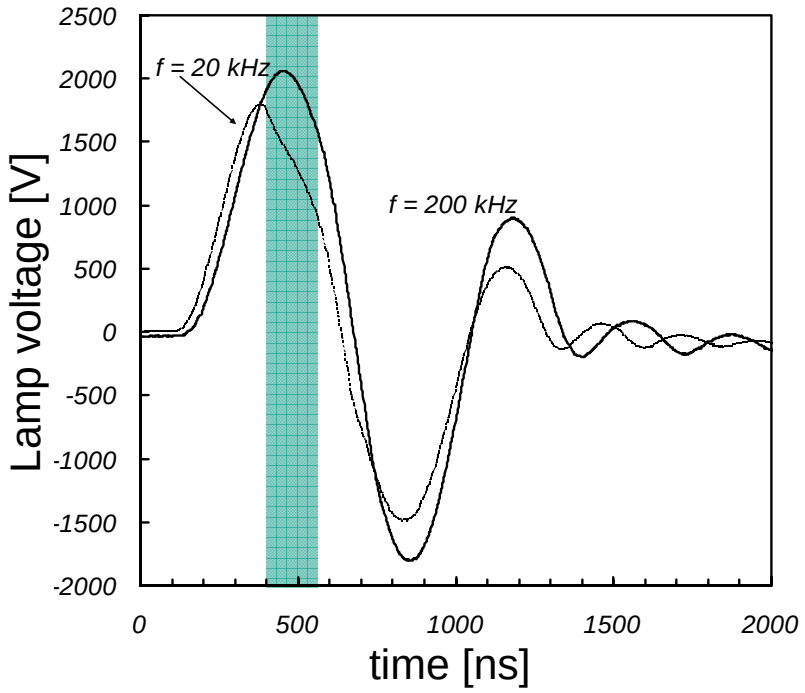
Results for flat lamp: power and efficiency

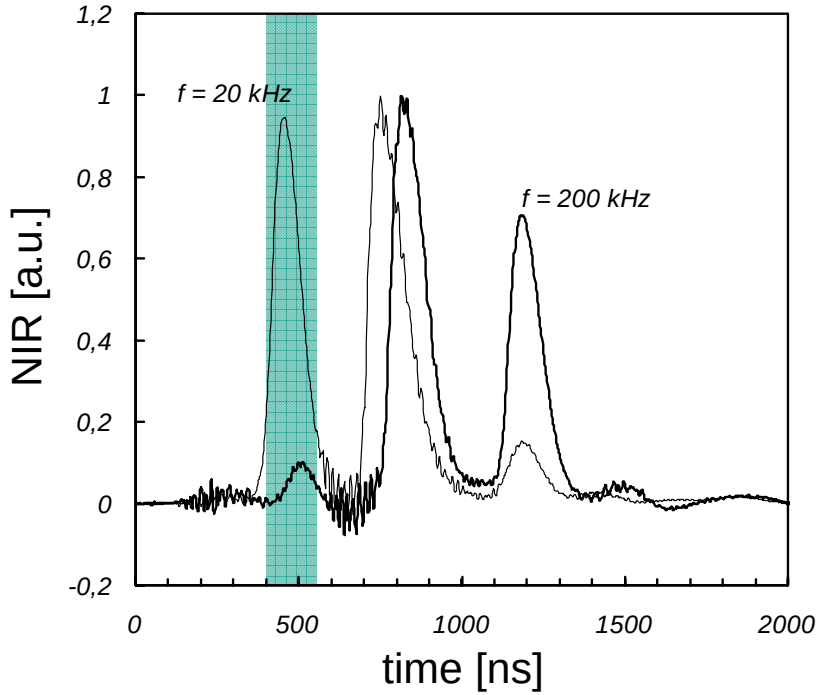




- comparable results for flat lamp as for silica lamps
- above p = 200 mbar slight pressure dependency when repetition rate is adjusted

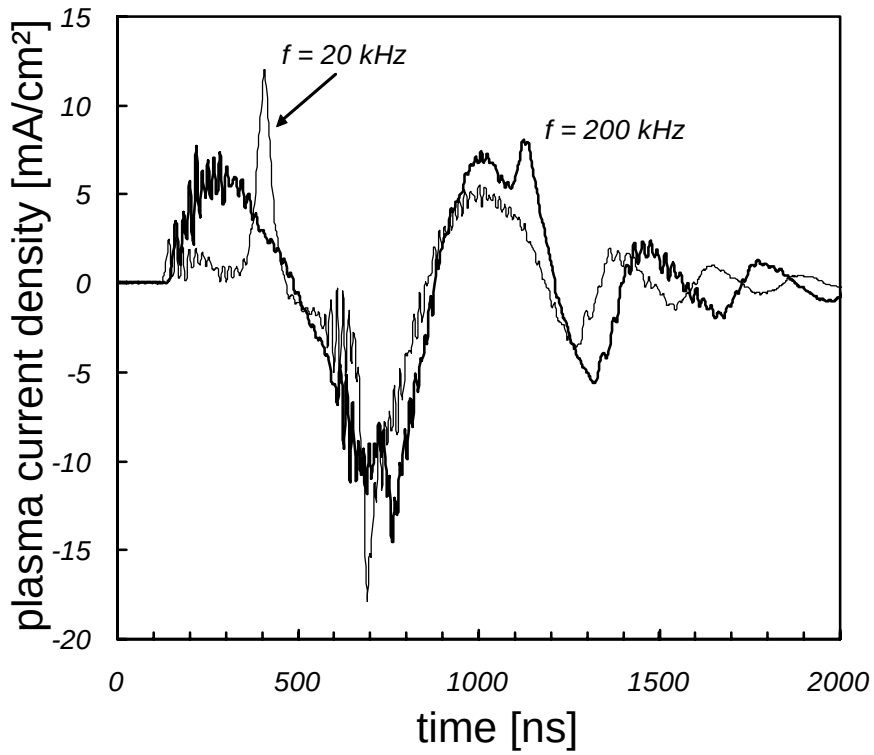
Results for flat lamp: voltage and IR

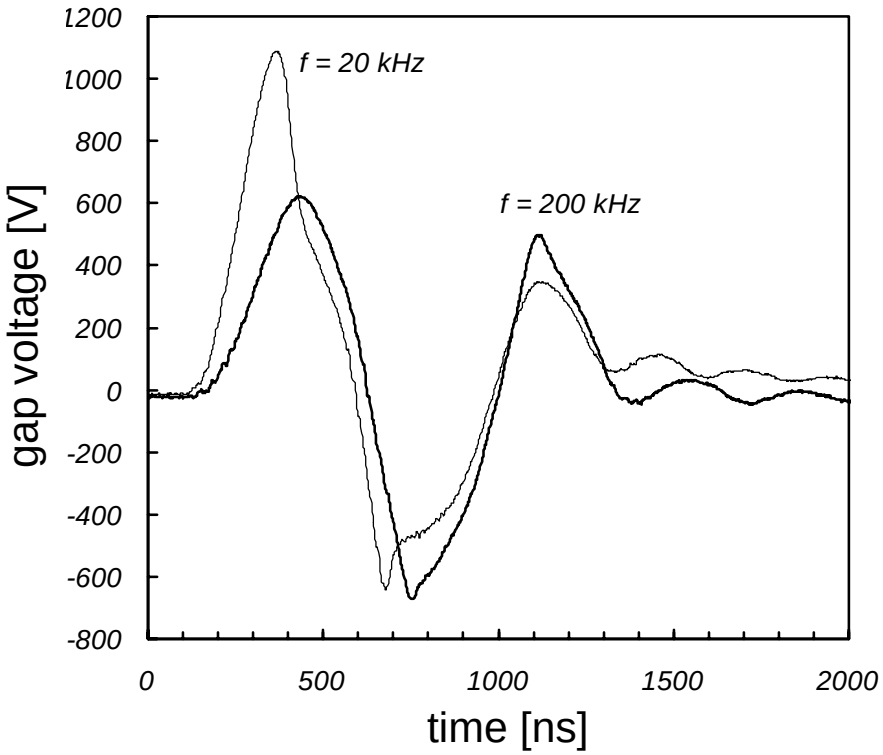




- pulse shape matched for double ignition
- for f = 200 kHz no ignition in first positive half-wave, despite voltage excite ignition voltage

Results for flat lamp: pre ignition current and gap voltage





- Due to high frequency increasing plasma current density before ignition, that separates the remaining charges and lowers the gas gap voltage.
- Plasma becomes a glow discharge.

Summary

- VUV goniometer to measure the total radiance of a lamp between 115 nm and 1700 nm
- Measurements of power density and efficiency for high power Xe_2^* DBDs
- Limiting factors:
  - Transition into filamented discharge
  - Remaining charges and plasma current density

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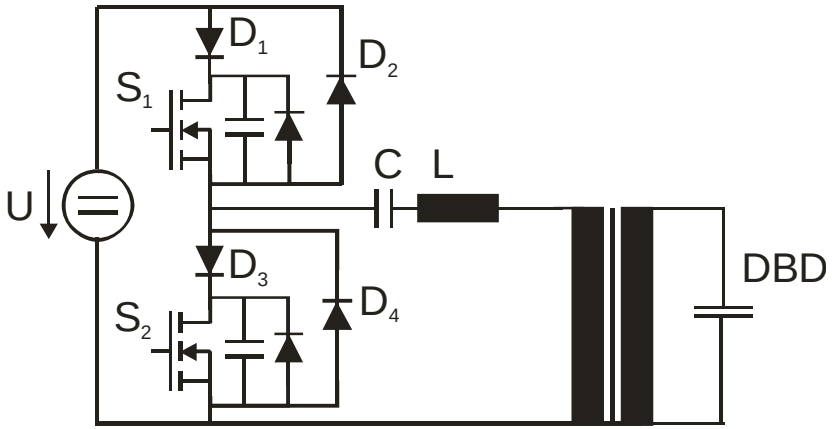
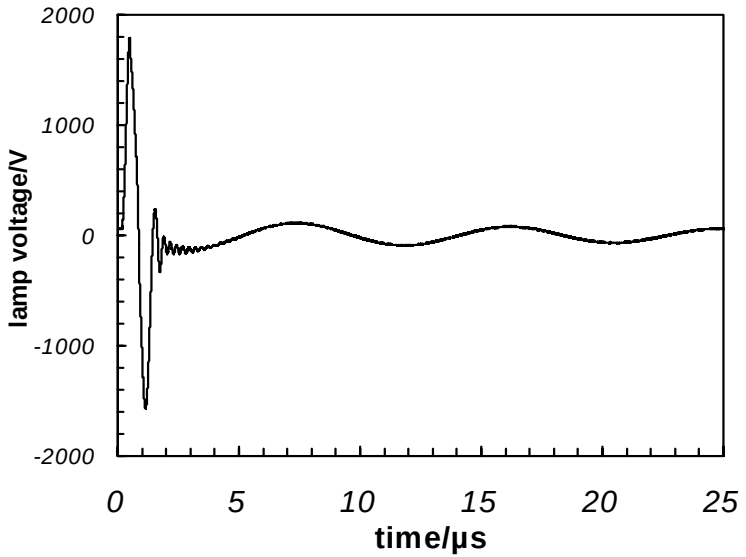
Thank you for your attention.

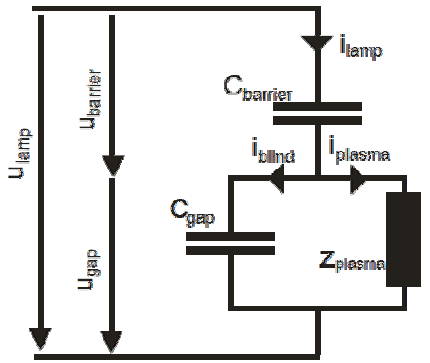
Experimental setup
ECG





Electrical excitation / measurement

- resonant pulse ECG as current source
- measurement of plasma current i_{plasma}
- measurement of gap voltage u_{gap}



Roth, M., Neiger, M., 21. IDRC, Nagoya, 2001, p. 893-896