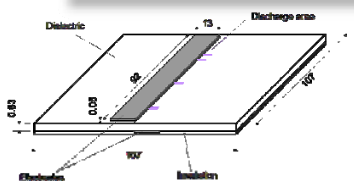
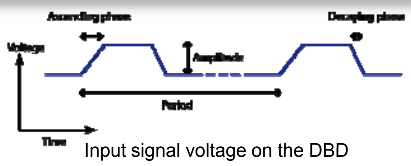
Group of Thermal Turbomachinery

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Electron temperature measurements using N2 and argon transitions in an ATP fast pulsed DBD

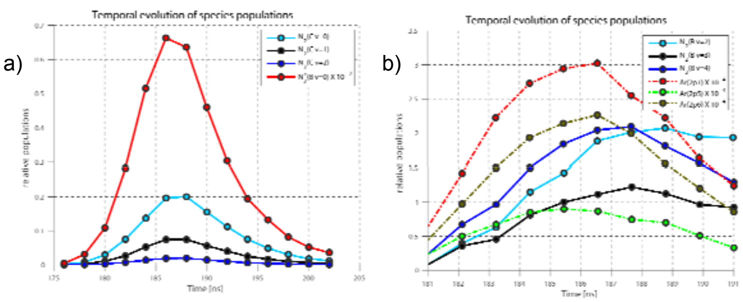
Experiment under investigation
- Dielectric Barrier Discharge in air at atmospheric pressure
- 200 [ns] duration pulsed input signals at 1 kHz
- Voltage pulse of 5 [kV] and current of 15 [A] (peak)
- Creation of a non-equilibrium plasma
- Emission of light during ascending and decaying phases





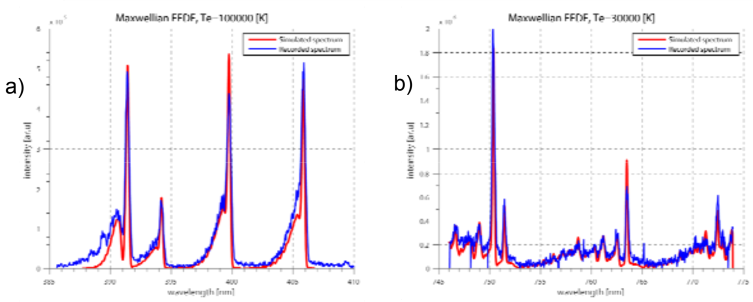
Input signal voltage on the DBD

Time resolved spectroscopy
- Time evolution of population during the discharge can be monitored with time resolved spectroscopy
- Acton 750 mm focal length spectrometer used with grating 600 g/mm
- PI-max ultra fast camera mounted on the spectrometer allowing for nanosecond time resolution
- Large number of image accumulations required, up to 200'000
- High repeatability of the experiment is needed



Evolution in time of excited states relative populations during ascending phase of the discharge for two spectral zones: a) centred at 400 [nm] and b) centred at 760 [nm]

Results
Determination of electron temperature using two different sets of transitions, assuming a Maxwellian EEDF

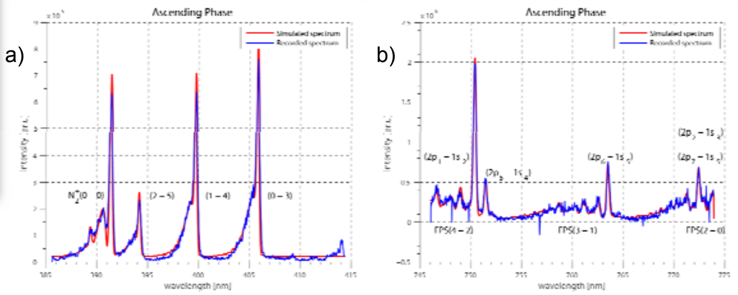


Recorded (blue) and simulated (red) spectra assuming an electron temperature of a) 100000 K and b) 30000 K

Conclusion: the EEDF is not Maxwellian for these conditions!

A computer code was developed to simulate diatomic and atomic transitions :
- Lines location and rotational intensity factors are computed by diagonalization of Hamiltonians for the upper and lower state
- Every vibrational band is computed separately
- A least square fit is performed to compare recorded and computed spectrum
- Population of radiating species can be determined
- Transitions investigated:

$$N_2(C^3\Pi_u(v'=0,1,2) - B^3\Pi_g(v''=3,4,5))$$
$$N_2^+(B^2\Sigma_u^+(v'=0) - B^2\Sigma_g^+(v''=0))$$
$$N_2(B^3\Pi_g(v'=2,3,4) - A^3\Sigma_u^+(v''=0,1,2))$$
$$Ar(2p_1 - 1s_2), Ar(2p_2 - 1s_3), Ar(2p_5 - 1s_4),$$
$$Ar(2p_6 - 1s_5), Ar(2p_7 - 1s_3)$$

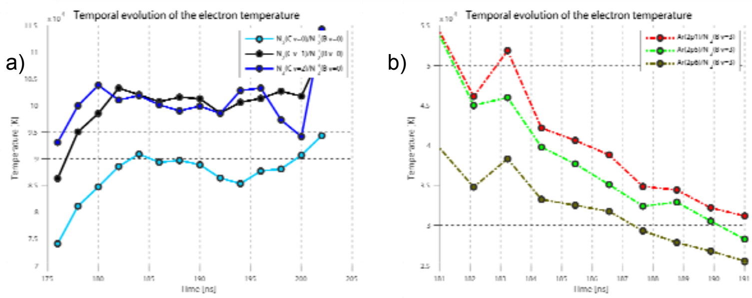


Recorded (blue) and simulated (red) spectra for two spectral zones: a) centred at 400 [nm] and b) centred at 760 [nm] (t=185 [ns])

Experimental investigation of EEDF
- Electron energy distribution function (EEDF) can be determined via OES
- Use of a simple collisional radiative model allows to link emission spectrum with EEDF:

$$\underbrace{n_e \cdot \int_{E_0}^{\infty} \sigma(E)\sqrt{\frac{2E}{m}}\, f(E)dE}_{PRODUCTION} - \underbrace{(\sum k_i^Q[Q]+A_i)n_i}_{DESTRUCTION} = \frac{\partial n_i}{\partial t}$$

Where n is the excited population, k the quenching rate, [Q] the quencher population, A the emission coefficient, σ the excitation cross section
- Relative intensities of different transitions provide information on the EEDF
- Accurate excitation cross sections and quenching rates needed
- Requires an assumption on the form of the EEDF, Maxwellian (1 parameter Te) or more complicated



Evolution in time of the electron temperature as determined with two different sets of excited states ratios: a) N2 (SPS)/N2+(FNS) and b) Ar(2p)/N2 (FPS)

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FNS fund N° 200020-121990