Electron kinetics in fast-pulsed discharges

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1. Introduction

Predictive tools for non-equilibrium low-temperature plasmas (LTPs) should describe properly the kinetics of electrons, responsible for stimulating plasma reactivity. Here, we focus on plasmas produced in N_2-O_2 gaseous mixtures, aiming to deliver a KInetic Testbed for PLASMa Environmental and Biological Applications (KIT-PLASMEBA) [1], comprising the development of simulation tools and the critical assessment of collisional-radiative data.

In this framework, we have developed the LisbOn KInetics Boltzmann solver (LoKI-B) [2], an open-source simulation tool that solves a time and space independent form of the two-term electron Boltzmann equation (EBE), for non-magnetized non-equilibrium LTPs created from different gases or gas mixtures. The simulation tool gives a microscopic description of the electron kinetics and calculates macroscopic quantities, such as electron rate coefficients and transport parameters, which are key for solving global models [3]. Indeed, LoKI-B is coupled to a Chemistry solver (LoKI-C), that receives these parameters as input data.

Recently, there has been increasing interest in non-equilibrium LTPs created by fast-pulsed discharges, because of their potential advantages in different technological applications [4]. However, due to the lack of readily available time-dependent EBE solvers, several assumptions are usually made to incorporate the electron kinetics into the corresponding chemistry models: introducing effective source terms that account for the electron-impact creation of excited species [5], or considering a quasi-stationary situation for electrons [6,7] solving a time-independent form of the EBE for the different (and time varying) values of the reduced electric field, *E/N*.

2. Results

We have studied the temporal evolution of the electron kinetics in a dry-air (80% N_2 - 20% O_2) pulsed-discharge, excited by a reduced-field with the form

$$E/N = 100\sqrt{\frac{t}{10^{-6}}}\exp\left(-\frac{t}{10^{-6}}\right)\ \text{(Td)} \quad . \qquad (1)$$

The simulations compare the results obtained when solving the time-dependent EBE with those of the quasi-stationary assumption. To carry out this analysis, we have extended the capabilities of LoKI-B, allowing for time-dependent calculations of the EBE.

Figure 1 shows the temporal evolution of the electron-impact ionization rate coefficients for N_2 and O_2, along with the reduced-field pulse. For times below 10^{-6} s, the results of the quasi-stationary solution deviate considerably from those obtained with the time-dependent EBE, overestimating the electron rate coefficients. This effect is due to the instantaneous relaxation of the electron energy distribution function in the quasi-stationary approach.

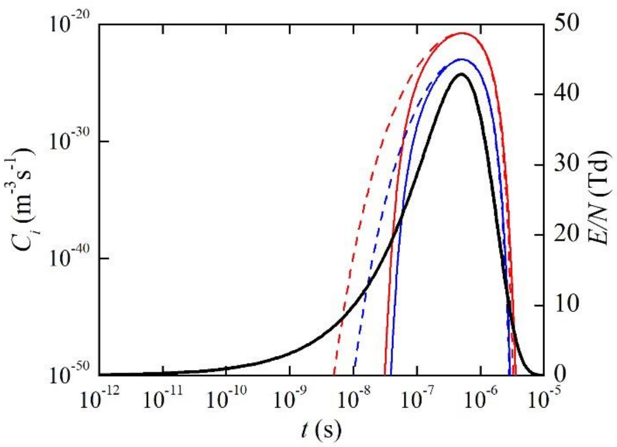

Fig. 1 Electron ionisation rate coefficients for N_2 (blue) and O_2 (red), considering a time-dependent (solid) or a stationary (dashed) solution of the EBE. The black-solid line represents the reduced electric-field pulse, given by equation (1).

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