Vibrational Excitation of CO2 by Nanosecond Discharges at Atmospheric Pressure
Erwan Pannier, Valentin Baillard, Christophe O. Laux

► To cite this version:
Erwan Pannier, Valentin Baillard, Christophe O. Laux. Vibrational Excitation of CO2 by Nanosecond Discharges at Atmospheric Pressure. 70th Gaseous Electronics Conference (GEC), Nov 2017, Pittsburgh, United States. hal-01866573

HAL Id: hal-01866573
https://hal.science/hal-01866573
Submitted on 19 Feb 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
**Motivation**

CO₂ dissociation efficiency is maximized with high vibrational excitation (Tvib) and low heating (Trot) [1]. Nanosecond Repetitive Pulses (NRP) are more efficient than DBD (2) at similar reduced field (E/N). Why?

- Electromagnetic interferences → shielded reactor design
- Room air absorption → optical train purged for absolute calibration
- Spatial fluctuations (hydrodynamics) → spatially resolved spectra
- Signal-to-dark ratio ~ 1/400 → phase locked capture of dark drift
- Camera mists ← post-processing detection algorithm
- 2D: Large data generation (~ 8 hrs, 200 Gb / full spectrum)
- Atmospheric pressure: broad, overlapping lines

**Challenges**

- Electromagnetic interferences
- Room air absorption
- Spatial fluctuations (hydrodynamics)
- Signal-to-dark ratio ~ 1/400
- Camera mists
- 2D: Large data generation (~ 8 hrs, 200 Gb / full spectrum)
- Atmospheric pressure: broad, overlapping lines

**Nonequilibrium LBL Model**

- Energy Levels: CO₂, C₂S₃D₄000
- CO₂: Dunham expansion
- Spectral Database: CO₂, C₂S₃D₄000
- LBL Model: Precomputed Spectra
- Multislab LBL Model: Compare with experimental
- (Instrumental slit function)

**Fitting tools:**
- update slabs params
- Distribution: overpopulation factors allow arbitrary non equilibrium distributions of vibrational levels; rotational ~ Boltzmann

**Experimental Setup**

- Measurements:
  - CO₂: T_E, T_N
  - mid-IR Absolute optical emission spectroscopy (OES), time-resolved (10 µs), spatially resolved (500 µm)
- CO₂: T_E, T_N
- Broadband IR Absorption measurement in post-discharge

**Data**

- Time resolved (µs)
  - 0-30 µs
  - 30-60 µs
  - 60-90 µs
- Frequency effect
  - 10 kHz
  - 20 kHz

**Nonequilibrium LBL Model**

- CO₂ vib / rot coupling: E = E_vib + E_rot + E_coupling. In CD3 polyad nomenclature (p,j,c,N) we chose E_vib = E(p,0,c,N), E_rot = E(p,j,c,N) = E_vib
- CO₂ low lying level (HITRAN rotation vs polyads)
- COS vib / rot coupling: E = E_vib + E_rot + E_coupling. In CD3 polyad nomenclature (p,j,c,N) we chose E_vib = E(p,0,c,N), E_rot = E(p,j,c,N) = E_vib

**Refining**

- the LOS model with partial binning → 1D profile
- Abel inversion
- fit on the optically thin region

**Loss Model**

- Fixed & fitted parameters
  - Plasma
  - Post-discharge
    - P: 1 atm
    - Tₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑelectron
  - N₂O: 403 ppm
  - N₂: 20 µm
- Fit with global absorption
  - 7 fitting parameters

**Fitting method**

- Radiance & transmittance per slab (high and low resolution)
- Total LSR (convolved with slit function)
- Best fit parameters: Tvib = 1400 ± 30 K, Trot = 1400 ± 75 K, N₂O = 0.34, N₂ = 0.03

**Results & Conclusions**

- Synergic effect: vibrational excitation of CO₂ increases for frequencies f > f_vib ≈ 12 kHz
- Synergic effect: vibrational excitation of CO₂ increases for frequencies f > f_vib ≈ 12 kHz

**Next step:** compare measured vibrational populations with predictions of a 0D-kinetic model

---