



Dielectric Barrier Discharges for Gas Treatment

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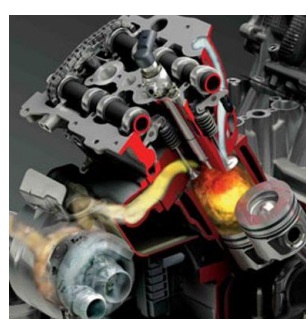
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Treatment of NO_x pollutants in the gas outlet of various industrial processes employing non-thermal plasma has interesting prospects. Recently, the reactor design and plasma/catalyst mixed systems have been the main directions investigated for performances enhancement. Improvements in the control of the electrical energy injection by means of the power supply are still required to achieve efficient and practical applications.

In order to carry out parametric investigations (DBD reactors and power supplies), an automated test bench has been set up. The test bench controls the gas conditions, acquires real-time measurement of the electrical variables and gas analysis through a data acquisition interface, and fully controls the power supply (square current pulses).

MOTIVATION

DIESEL engines: Low carbon monoxide (CO) and hydrocarbon (HC) emissions
High **particulate matter (PM)** and **nitrogen oxides (NO_x)** emissions.



After treatments
technologies

Diesel Oxidation Catalyst (DOC)

Diesel Particulate Filter (DPF)

Selective Catalytic Reduction

Lean NO_x Trap (LNP)

Non-thermal Plasma

PM Reduction

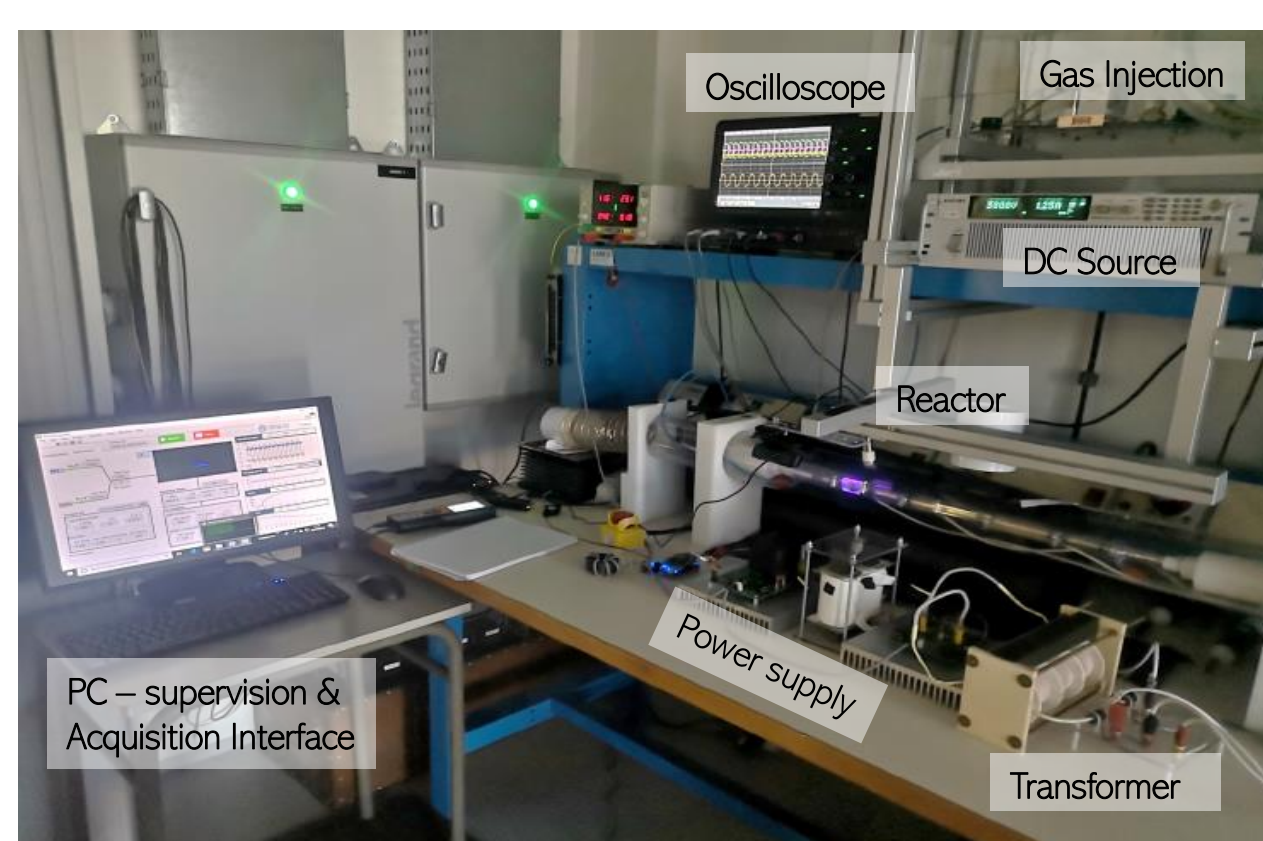
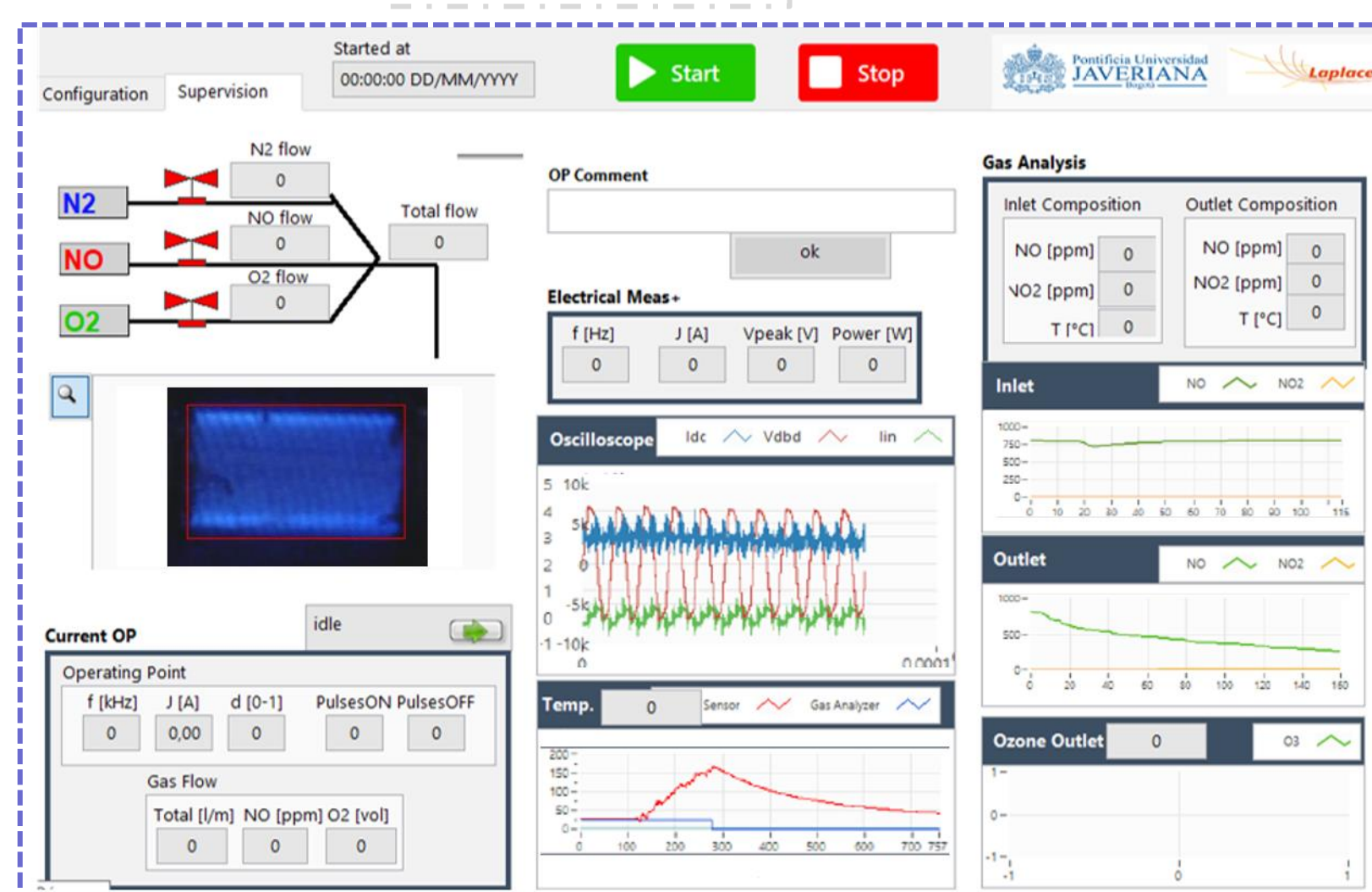
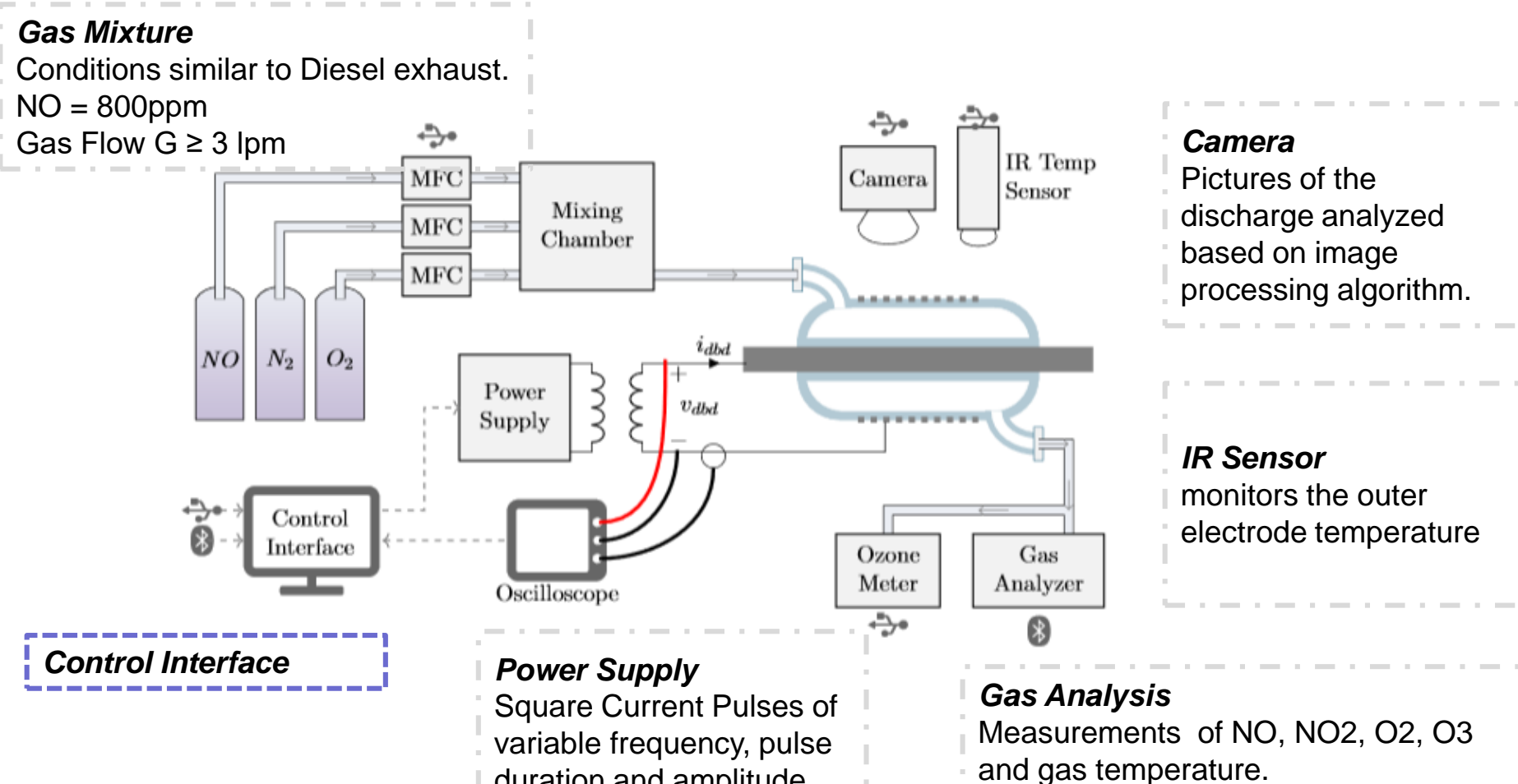
NO_x Removal

CO HC Removal

NON-THERMAL PLASMA

Formation of free radicals, molecular dissociations and different reactions capable of destructing pollutants in exhaust emissions at **low temperature without harmful waste**

TEST-BENCH

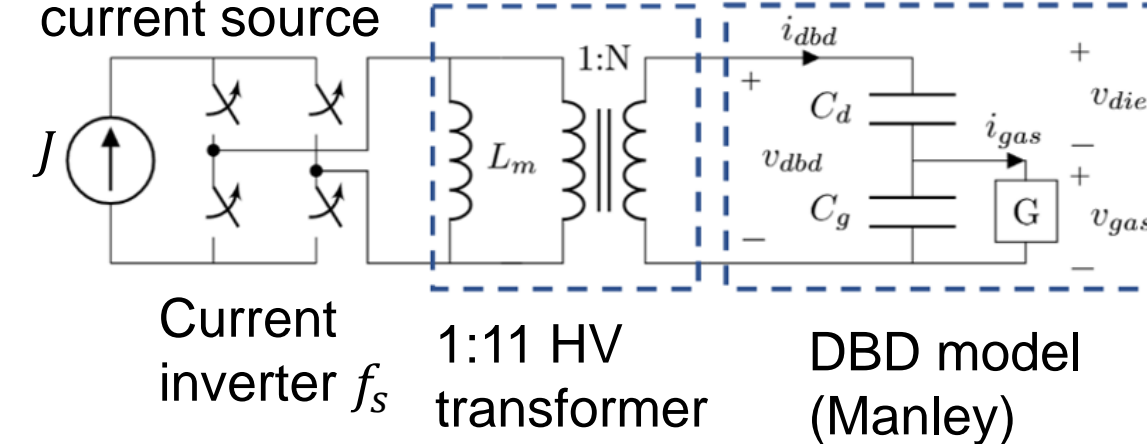


Supervision program:

- + Standardizes experiment (storage, equipment's setup)
- + Defines & controls schedule
- + Controls operating conditions (gas mixture & flow, elec. DOF)
- + Runs scripts – matlab, python (parameters identification, waveforms analysis)
- + Automatizes results acquisition
- + Updates a database for all operating points & experiments

POWER SUPPLY

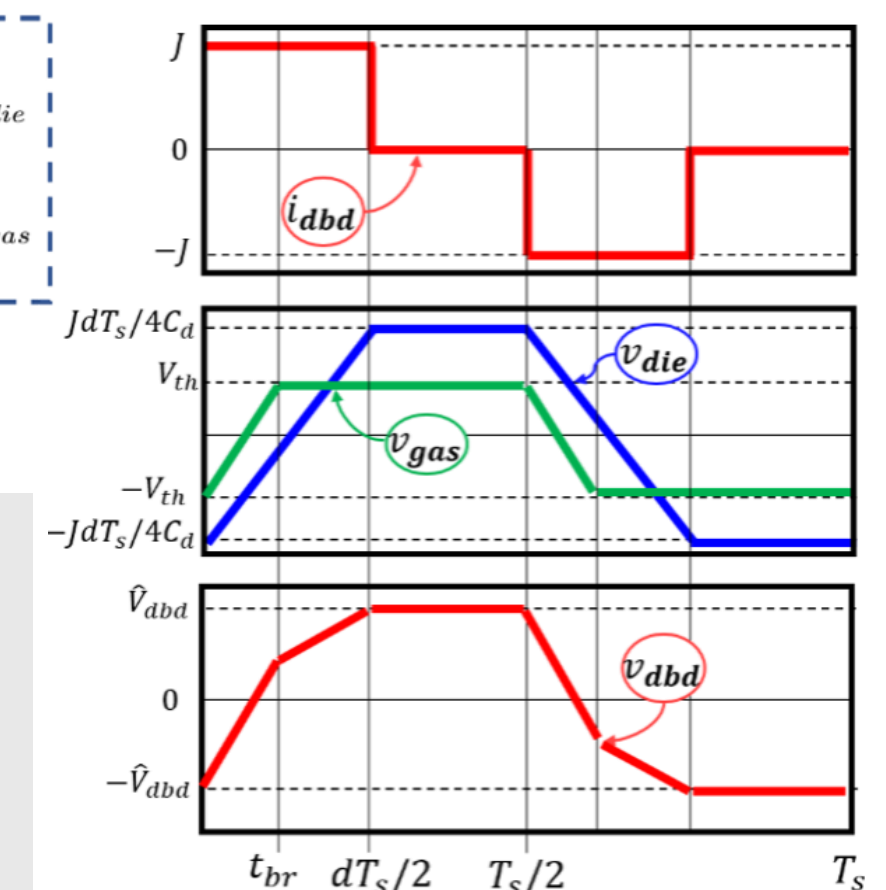
J controlled
current source



Current inverter f_s 1:11 HV transformer DBD model (Manley)

$$E_{abd} = J d V_{th} T_s - 4 C_g V_{th}^2$$

$$\hat{V}_{abd} = V_{th} \left(1 + \frac{C_g}{C_d} \right) + \frac{P_{abd}}{4 f_s V_{th} C_d}$$



DOF: + current amplitude J ,
+ frequency f_s (period T_s),
+ pulse duration T_{pulse}

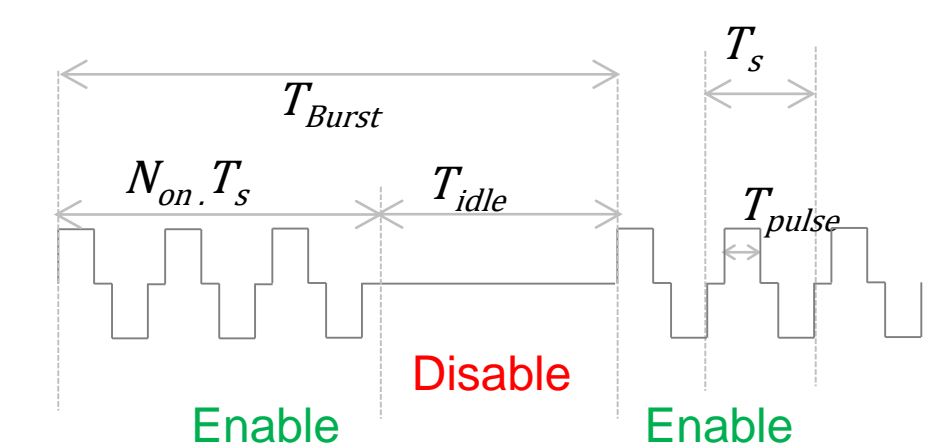
→ pulse energy control E_{abd} , hence P_{abd}
(timescale: $T_s = 1/f_s$)

BURST MODE

$$\langle P_{abd} \rangle_{T_{Burst}} = \frac{\sum_{n=1}^{n=N_{ON}} E_{abd_n}}{T_{Burst}}$$

Lower frequency (F_{Burst}) power adjustment

burst ratio $M_{Burst} = N_{ON} \times T_s / T_{Burst}$ and T_{Burst} : additional DOFs

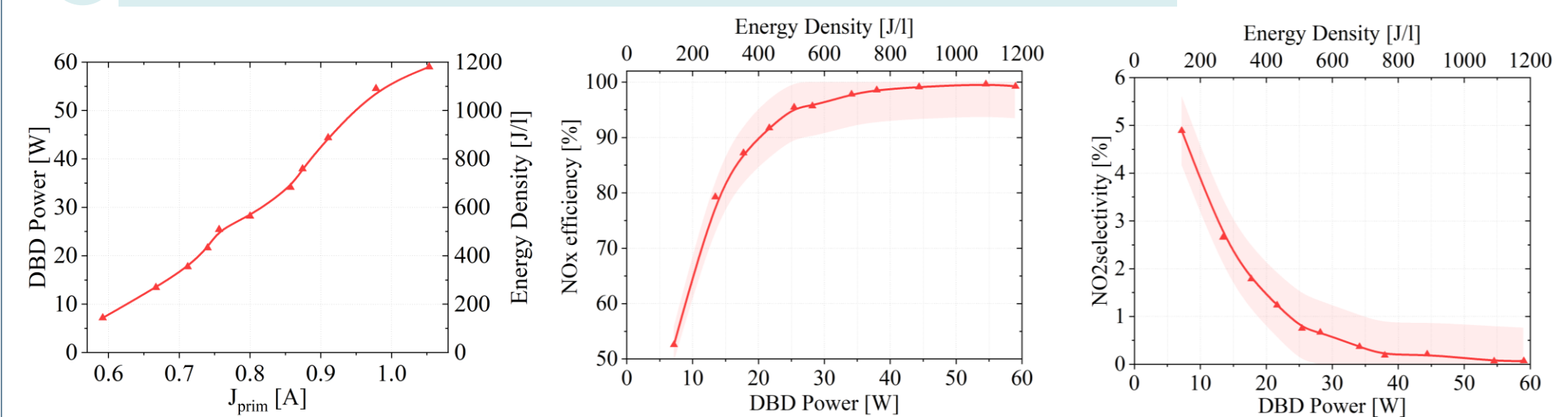


RESULTS

Definitions

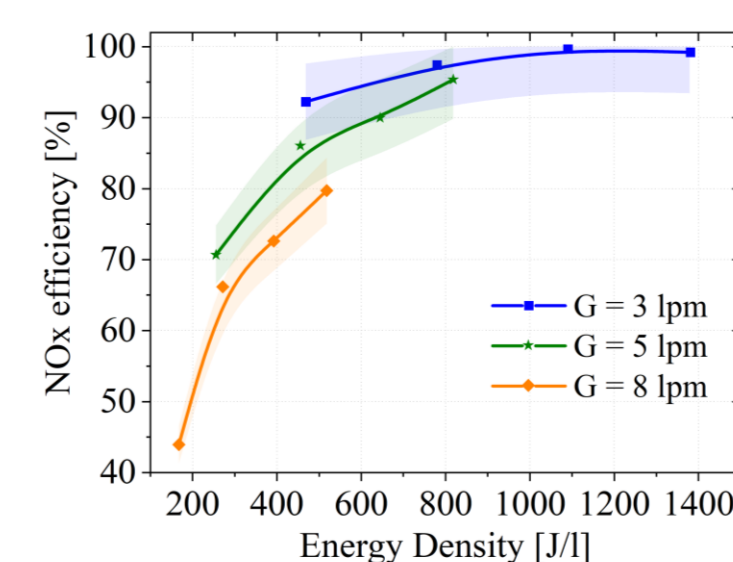
$$NO_x \text{ efficiency} = 100 \frac{NO_{x0} - NO_{xf}}{NO_{x0}} [\%] \quad NO_2 \text{ selectivity} = 100 \frac{NO_{2f}}{NO_0} [\%] \quad \text{Energy Density} = \frac{P_{abd} \cdot 60}{G} [J/l]$$

1 Asymptotic relation between P_{abd} and treatment efficiency



$f_s = 80 \text{ kHz}$, $T_{pulse} = 6,25 \mu s$, $J_{prim} = [0.6, \dots, 1.1] \text{ A} \rightarrow \text{HF pulses}$
 $N_{on} = 10$, $T_{idle} = 125 \mu s \rightarrow \text{Burst mode}$
 $G = 3 \text{ lpm}$, $NO = 800 \text{ ppm}$, $O_2 = 0\% \rightarrow \text{Gas composition}$

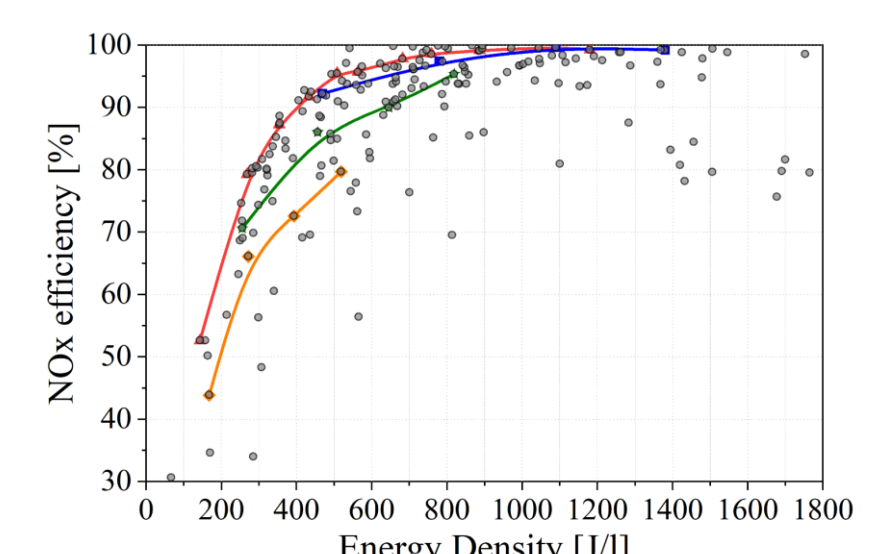
Fixed f_s and T_{pulse} , -
energy adjustment by J



2 Experimental studies of the gas conditions (G, NO, O₂) and electric parameters.

$f_s = 80 \text{ kHz}$, $T_{pulse} = 3,13 \mu s$, $J_{prim} = [1, \dots, 1,8] \text{ A}$
 $N_{on} = 10$, $T_{idle} = 125 \mu s$
 $G = 3 \text{ lpm}$, $NO = 800 \text{ ppm}$, $O_2 = 0\%$
 $G = 5 \text{ lpm}$, $NO = 800 \text{ ppm}$, $O_2 = 0\%$
 $G = 8 \text{ lpm}$, $NO = 800 \text{ ppm}$, $O_2 = 0\%$

Fixed f_s and T_{pulse} , - energy adjustment by J



3 +300 experiments in burst mode at different conditions

Approx. 600 minutes of automated experimentations

CONCLUSIONS

System / process level:

For a gas mixture of N₂/NO

- + Very promising NO_x removal (up to 99%)
- + Low NO₂ selectivity (up to 0 %)

+ Prominent importance of reactor temperature

+ Very strong impact of step-up transformer parasitic elements (L_k , L_m , C_p)

Current best performances:

Efficiency higher than 97% at $ED \approx 530 \text{ J/l}$

Results obtained at:

$f_s = 80 \text{ kHz}$, $T_{pulse} = 6,25 \mu s$, $J_{prim} = 1.2 \text{ A}$
 $N_{on} = 10$, $T_{idle} = 125 \mu s$,
 $G = 3 \text{ lpm}$, $NO = 800 \text{ ppm}$, $O_2 = 0\%$