Ozone Generation with a Flexible Solid-State Marx Generator

J. J. van Oorschot¹
T. Huiskamp¹
M. Pereira²
L. M. Redondo³

¹Eindhoven University of Technology
²Energy Pulse Systems
³Instituto Superior de Engenharia de Lisboa
Previous results: high-efficiency ozone generation

Specifications
- Up to 50 kV (pos and neg)
- 0.5-10 nanosecond
- <200 ps rise time
- Up to 1 kHz
- Flushed oil spark gap

Results
- Up to 160 g/kWh ozone production
- Very efficient, but not a practical system!

New project:
- Use flexible solid state Marx generator for robust, practical ozone generation

Solid-state Marx generator

Marx generator developed at Energy Pulse Systems:

- Up to 15 kV pulses (15 stages of 1 kV)
- Pulse duration: variable from 200 ns to 100 µs
- Repetition rate up to several kHz
- Burst mode operation possible (burst frequency up to 200 kHz)

Solid-state Marx generator circuit operation

- 1kV per stage charging through diodes (and switches)
- 1.2 kV SiC MOSFETs for fast, efficient switching
  - $T_{pi}$: discharging capacitors over load
  - $T_{ci}$: discharging load and charging capacitors between pulses
- Series resistors for damping and current limiting

• DC PSU decoupled with filter (and with Taux during pulsing)
• Marx controlled with µP (programmed from PC)
Practical implementation

A: Marx generator
B: Input filter
C: Control board
D: HV connector
E: Current sensor
Experimental setup

- Marx gen.
- Input filter
- Current measure
- 1kV
- Coil
- Flow meter
- DBD reactor
- Voltage Probe
- Oscilloscope
- Spectroscope
- Measure cell
- UV light
- Exhaust
DBD plasma

- Ground connection
- 3D-printed spacers
- Air inlet
- HV connection
- 4 center electrodes
- Air outlet

Graph showing current [A] vs. time [μs]:
- Current peaks at about 10 A.
- Voltage peaks at about 15 kV.

Image of the DBD plasma device.
Ozone yield calculation

- \( E_p = \int v \times i \, dt \) [J]
- \( \epsilon = \frac{f_{rr} E_p \times 60}{F} \) [J/L]
- \( G_{O_3} = \frac{C_{O_3} \times 48 \times 3.6}{V_m \epsilon} \) [g/kWh]

Results

- Higher voltage: higher yield
- Higher repetition rate: lower yield
- Gas heating effects
Ozone yield calculation

- \( E_p = \int v \cdot i \, dt \) [J]
- \( \epsilon = \frac{f_{rr}E_p \cdot 60}{F} \) [J/L]
- \( G_{O_3} = \frac{C_{O_3} \cdot 48 \cdot 3.6}{V_m \epsilon} \) [g/kWh]

Results

- Higher air flow: higher yields
- Gas heating effects
Results: burst mode

Normal operation

Burst mode operation
Results: burst mode

Results
• Higher burst frequency: lower ozone yield
• Higher repetition rate: lower ozone yield

Explanation
• Space and surface charges dominate the discharge
• Gas heating effects

Conclusion
• Burst rate operation not efficient for ozone generation
Conclusions

- Maximum yields around 80 g/kWh vs. 160 g/kWh for faster pulses
- Promising practical application with solid-state