Ozone Generation with a Flexible Solid-State Marx Generator

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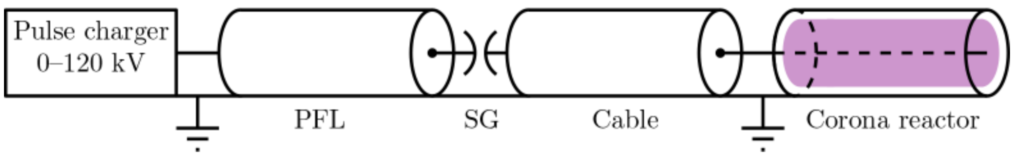
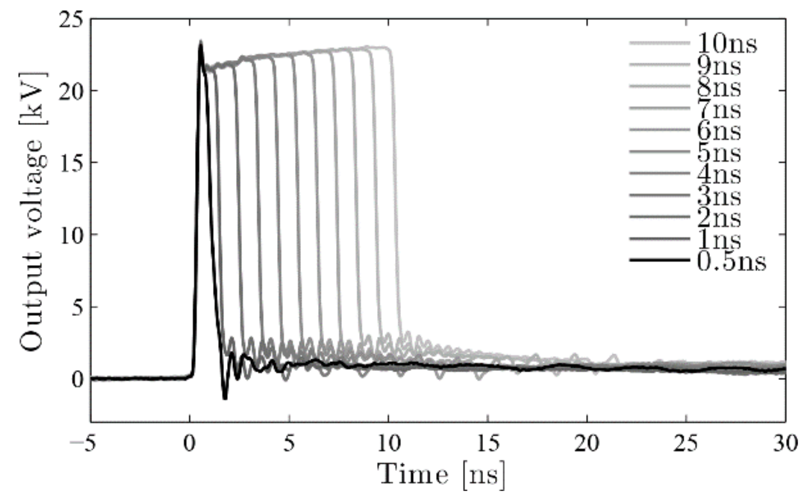
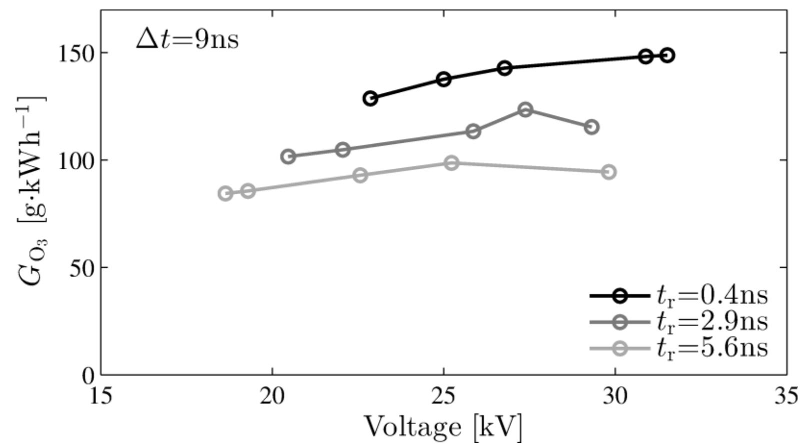
Previous results: high-efficiency ozone generation







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:

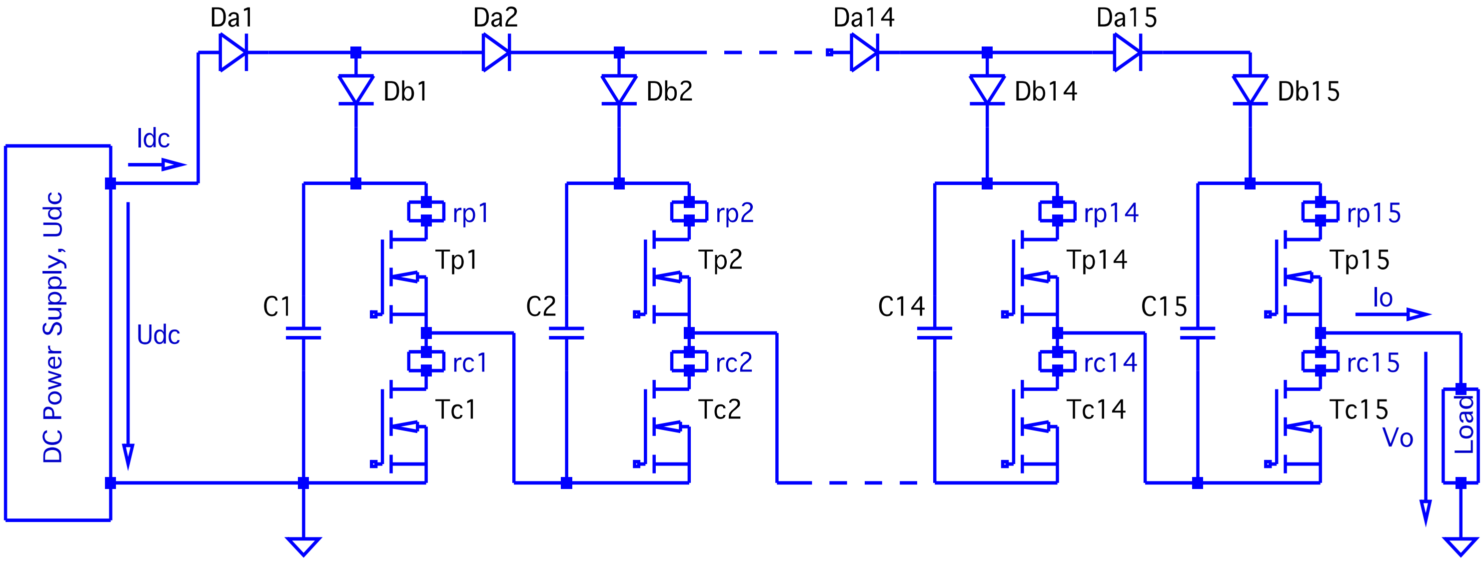
- Use flexible solid state Marx generator for robust, practical ozone generation

Huiskamp *et al.*, *IEEE T Plasma Sci*, vol. 43, pp. 444-451, 2015
Huiskamp *et al.*, *J. Phys. D: Appl. Phys.*, vol. 50, 405201 [16pp], 2017

Solid-state Marx generator

Marx generator developed at Energy Pulse Systems:

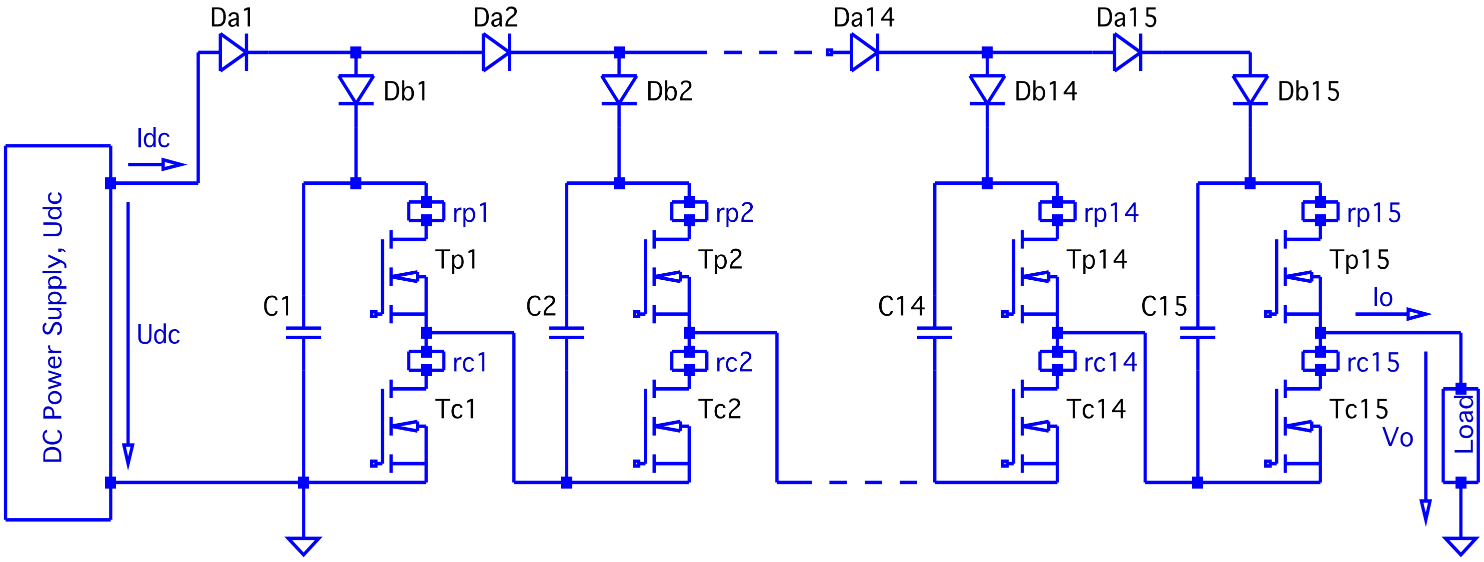
- Up to 15 kV pulses (15 stages of 1 kV)
- Pulse duration: variable from 200 ns to 100 µs
- Repetition rate up to several kHz
- Burst mode operation possible (burst frequency up to 200 kHz)



Redondo, L. M., et al. "Solid-state Marx generator for the compact linear collider breakdown studies." *IPMHVC 2016*, 187-192, 2016

Solid-state Marx generator circuit operation

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



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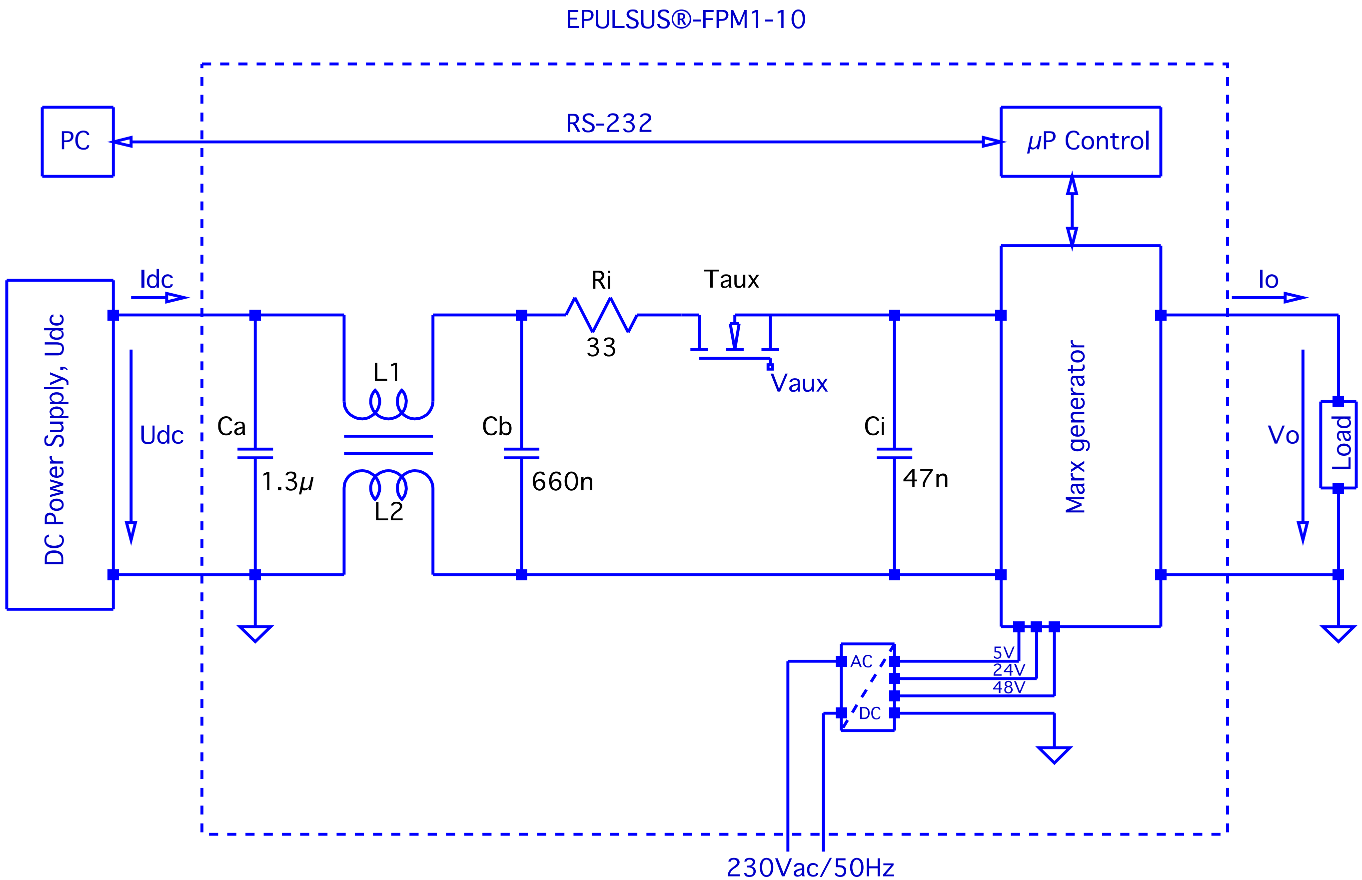
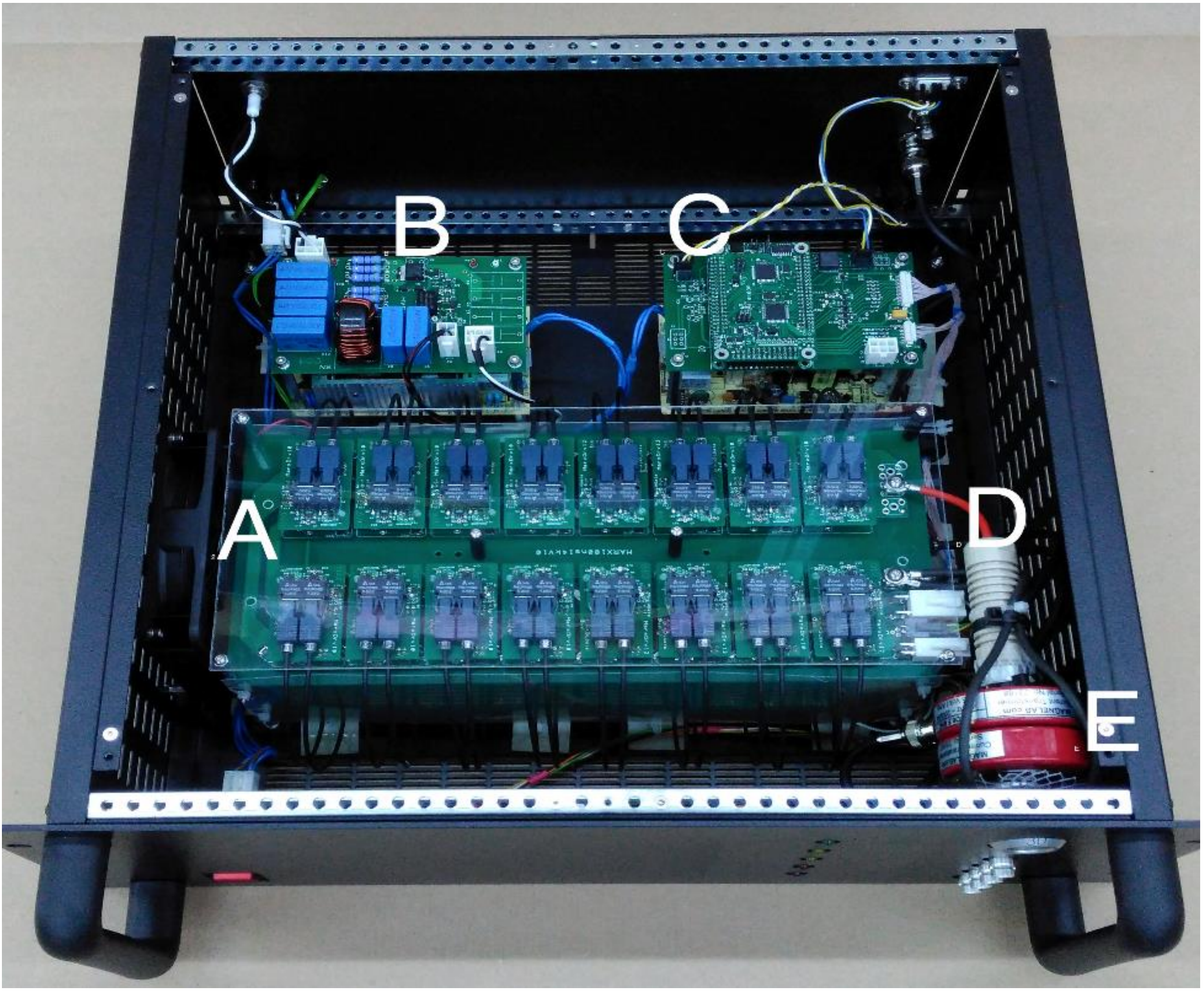
Total system



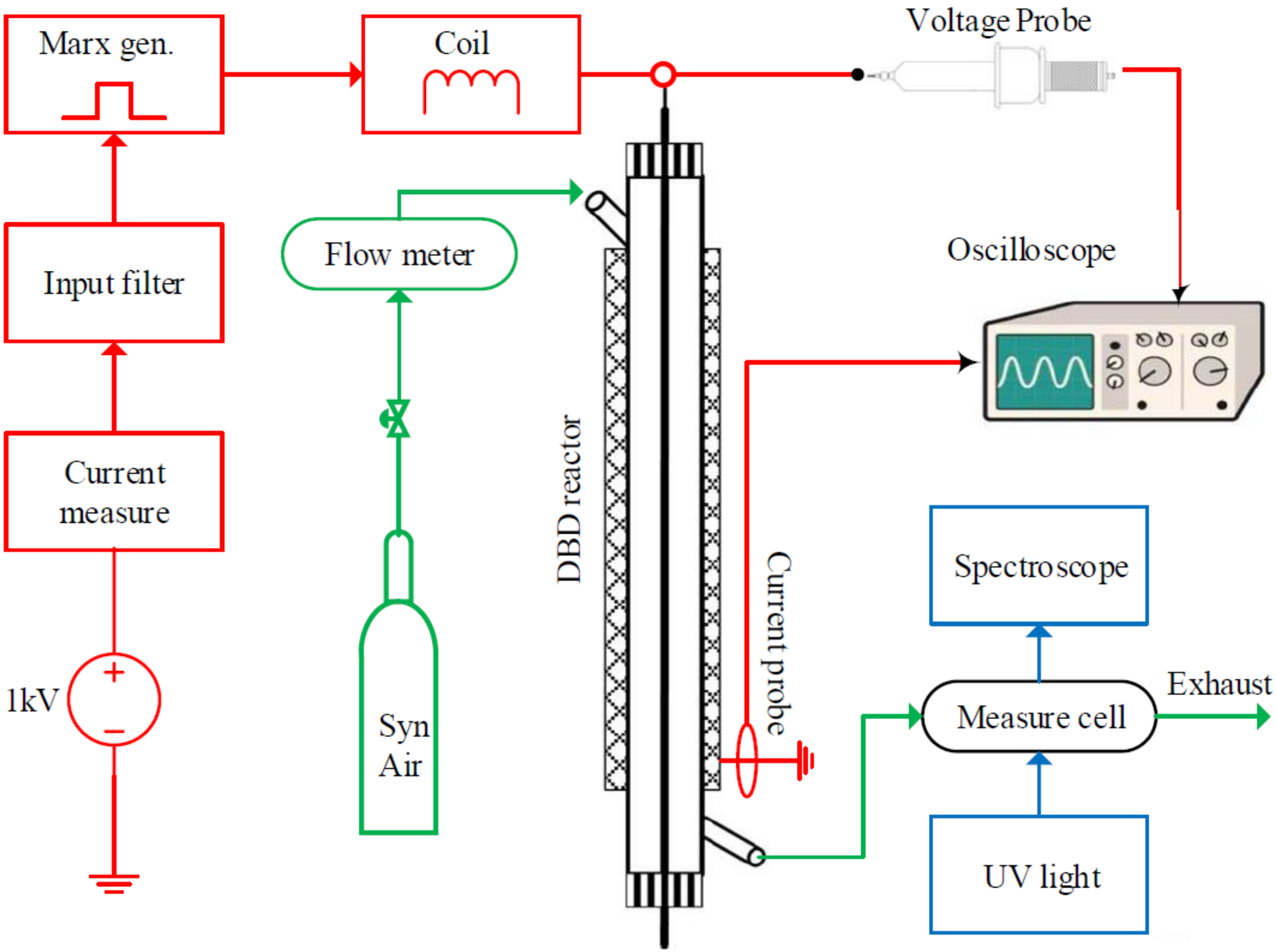
- DC PSU decoupled with filter (and with Taux during pulsing)
- Marx controlled with µP (programmed from PC)

Practical implementation

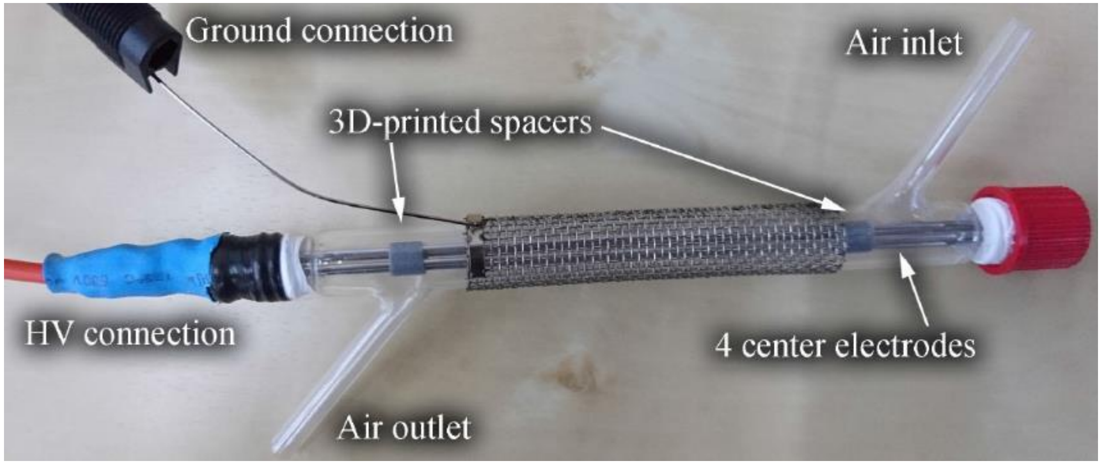


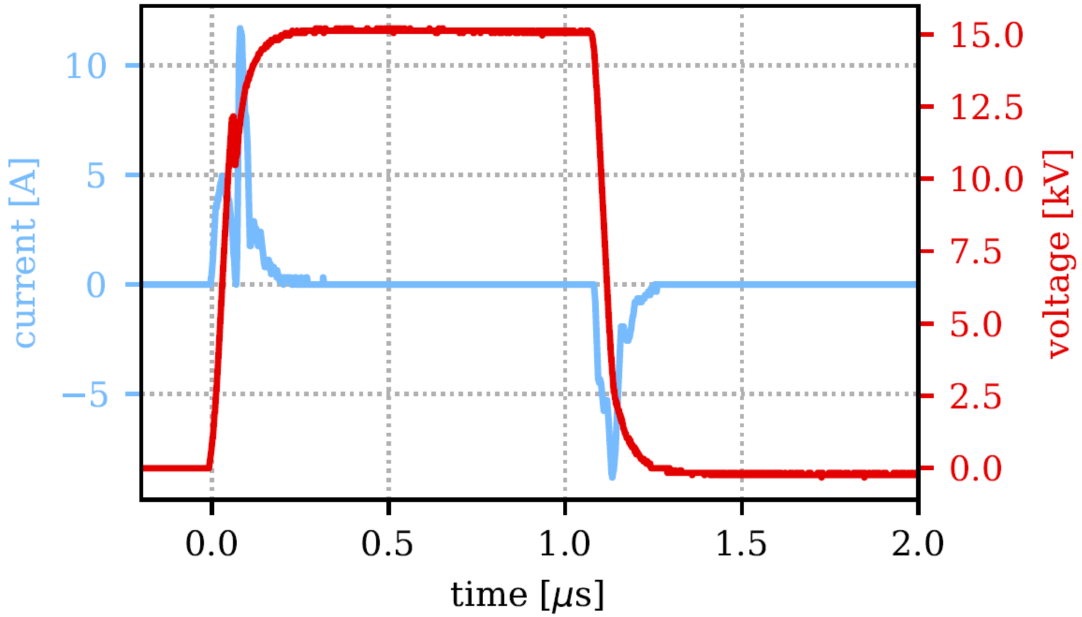
A: Marx generator
B: Input filter
C: Control board
D: HV connector
E: Current sensor

Experimental setup



DBD plasma


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


current [A]
voltage [kV]
time [μs]
10
5
0
−5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0.0
0.5
1.0
1.5
2.0

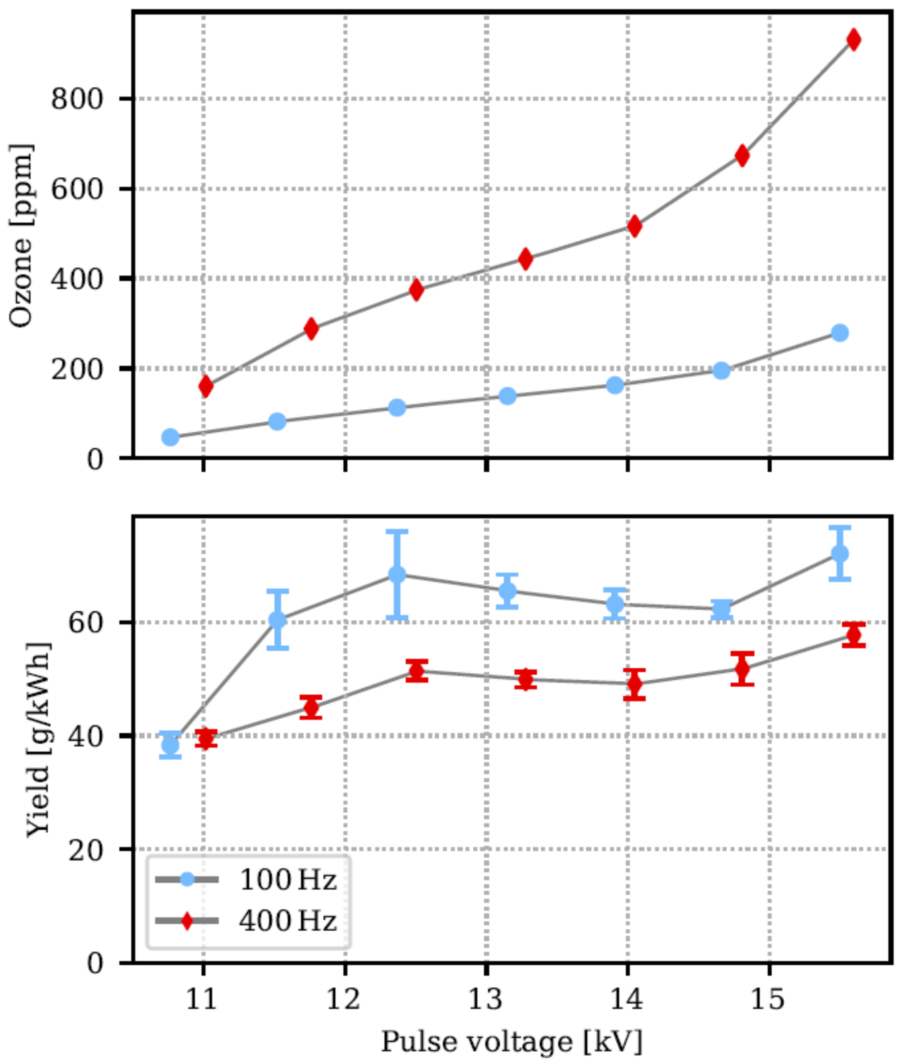
Results: voltage

Ozone yield calculation

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

Results

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



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ENERGY PULSE SYSTEMS

Results: air flow

Ozone yield calculation

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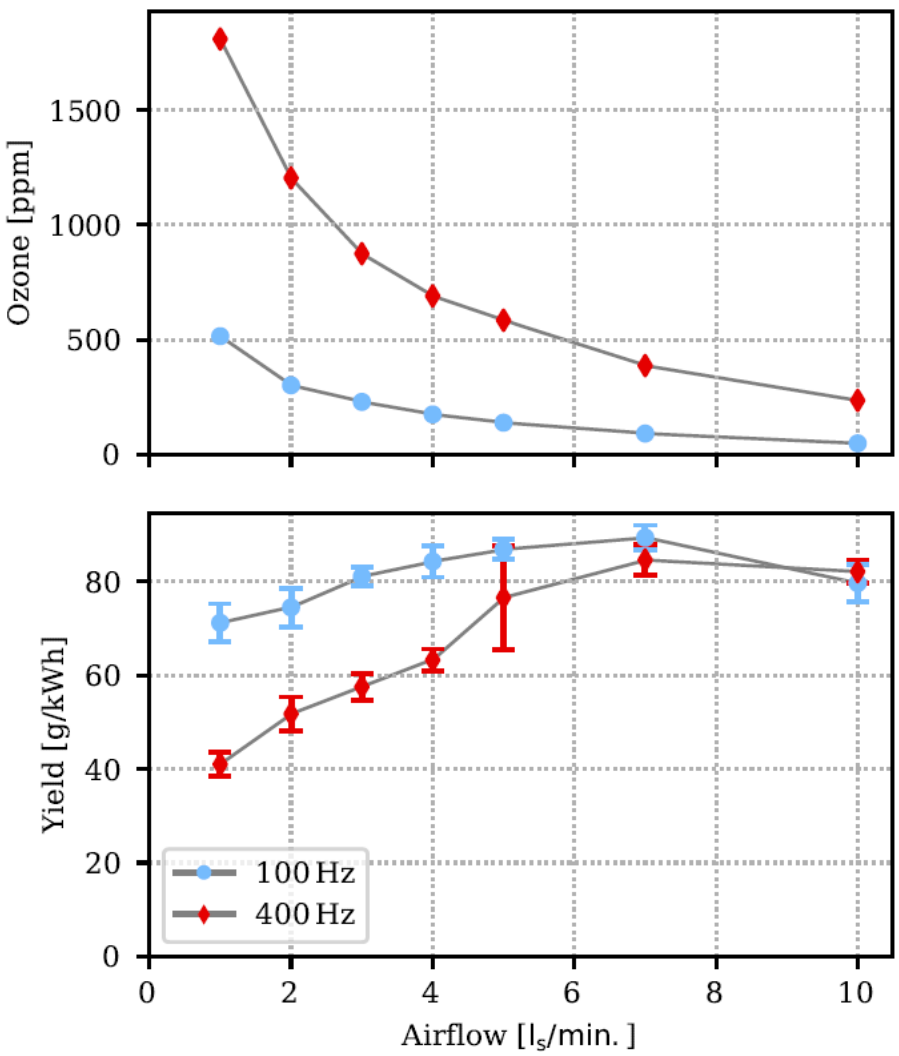
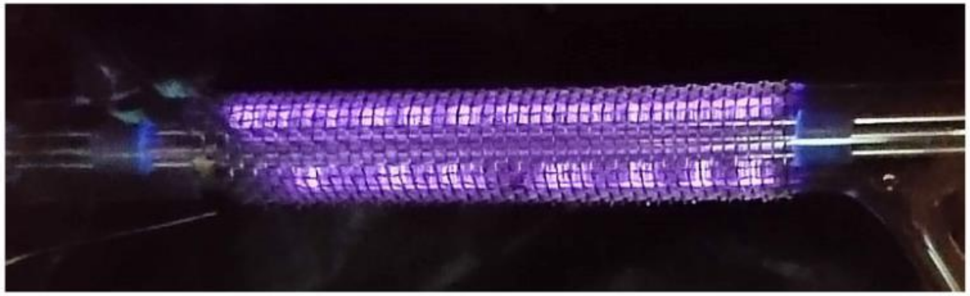
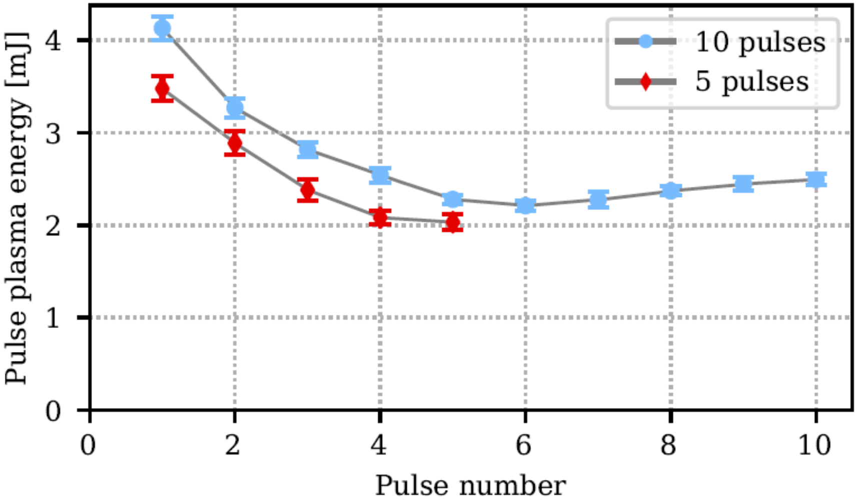


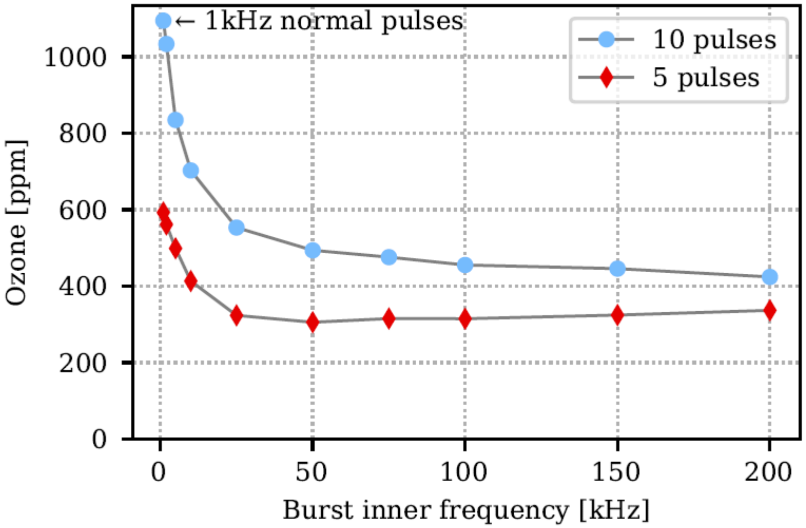
Results: burst mode

Normal operation



Burst mode operation





Results: burst mode

Results

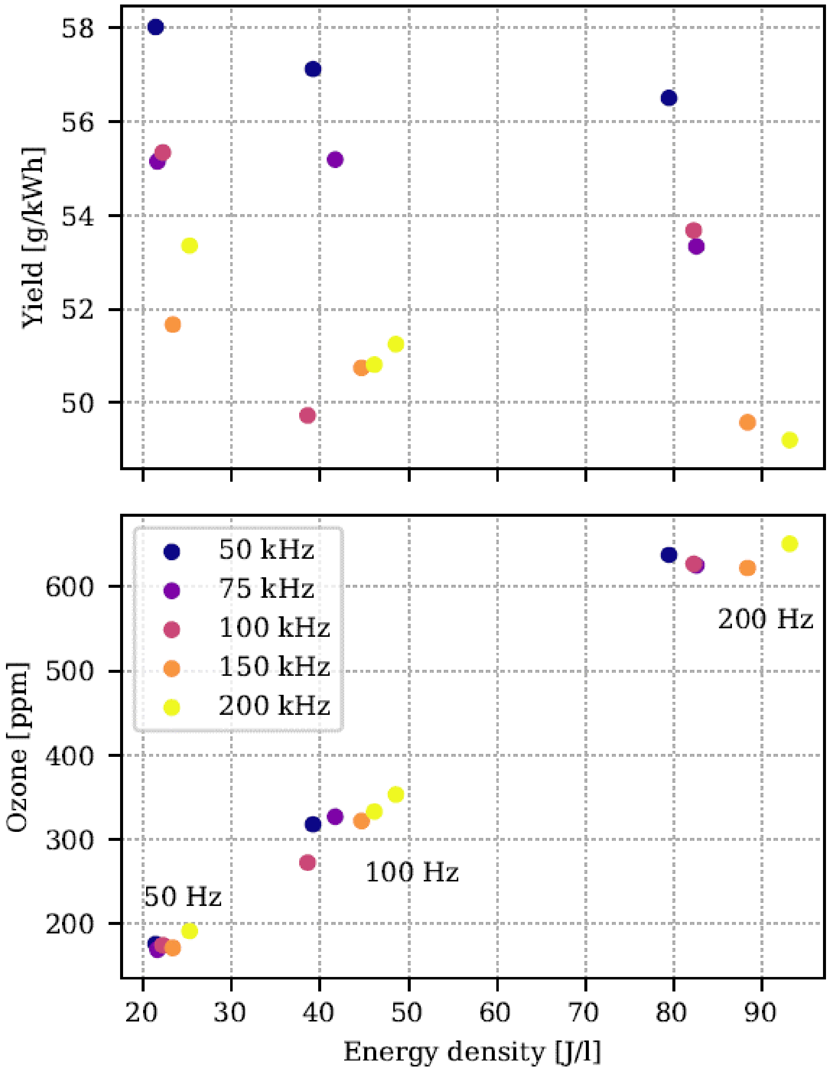
- Higher burst frequency: lower ozone yield
- Higher repetition rate: lower ozone yield

Explanation

- Space and surface charges dominate the discharge
- Gas heating effects

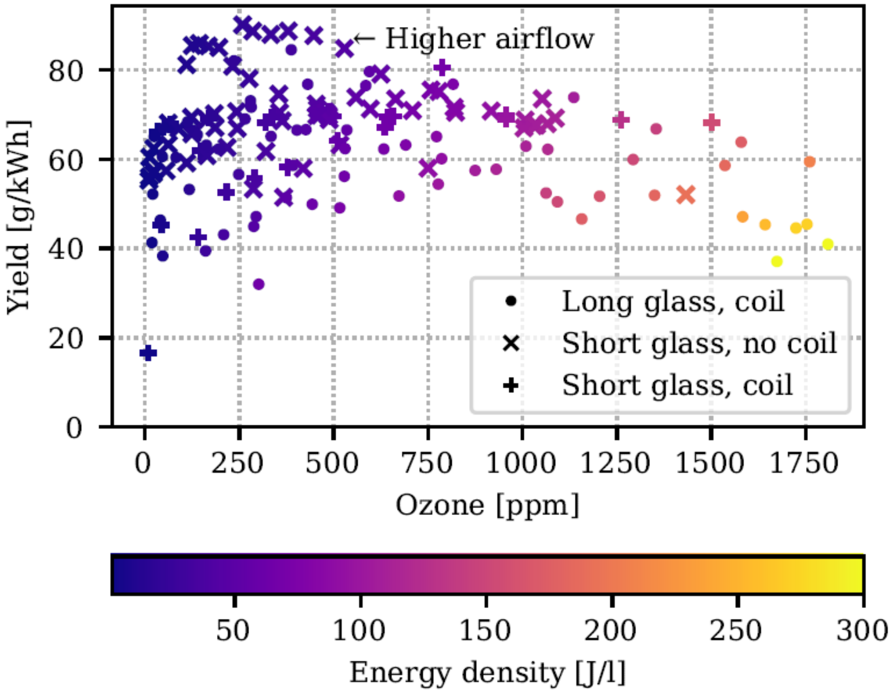
Conclusion

- Burst rate operation not efficient for ozone generation

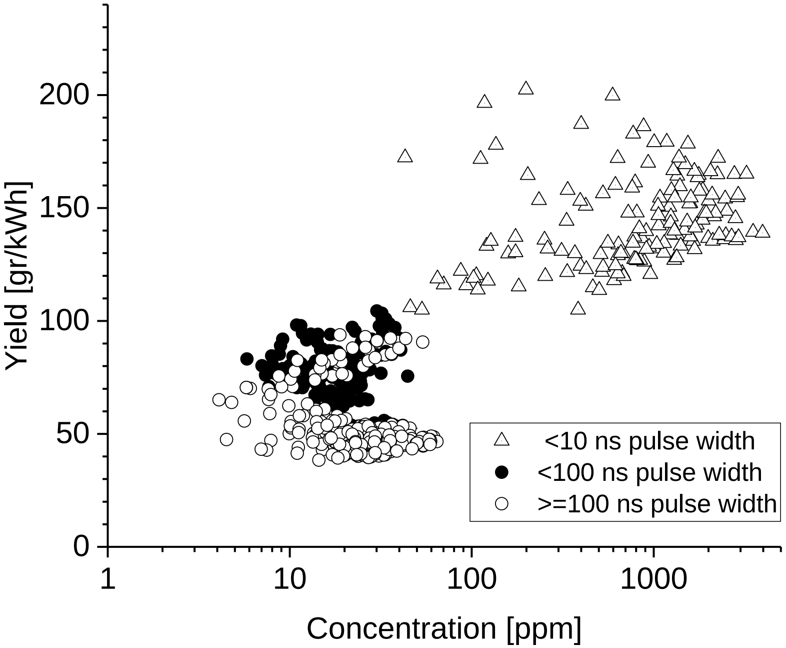


Overall results

Solid state (this work)



Spark-gap based (previous work)



Conclusions

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

Thank you for your attention