

Corona Discharge-Based Gas Pump Miniaturization

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Summary

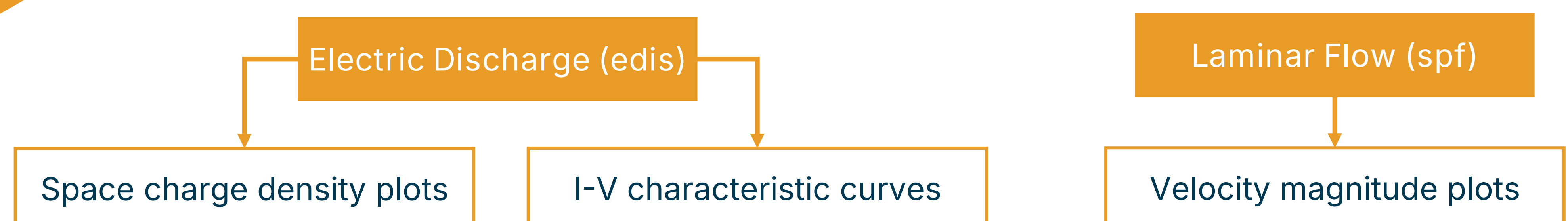
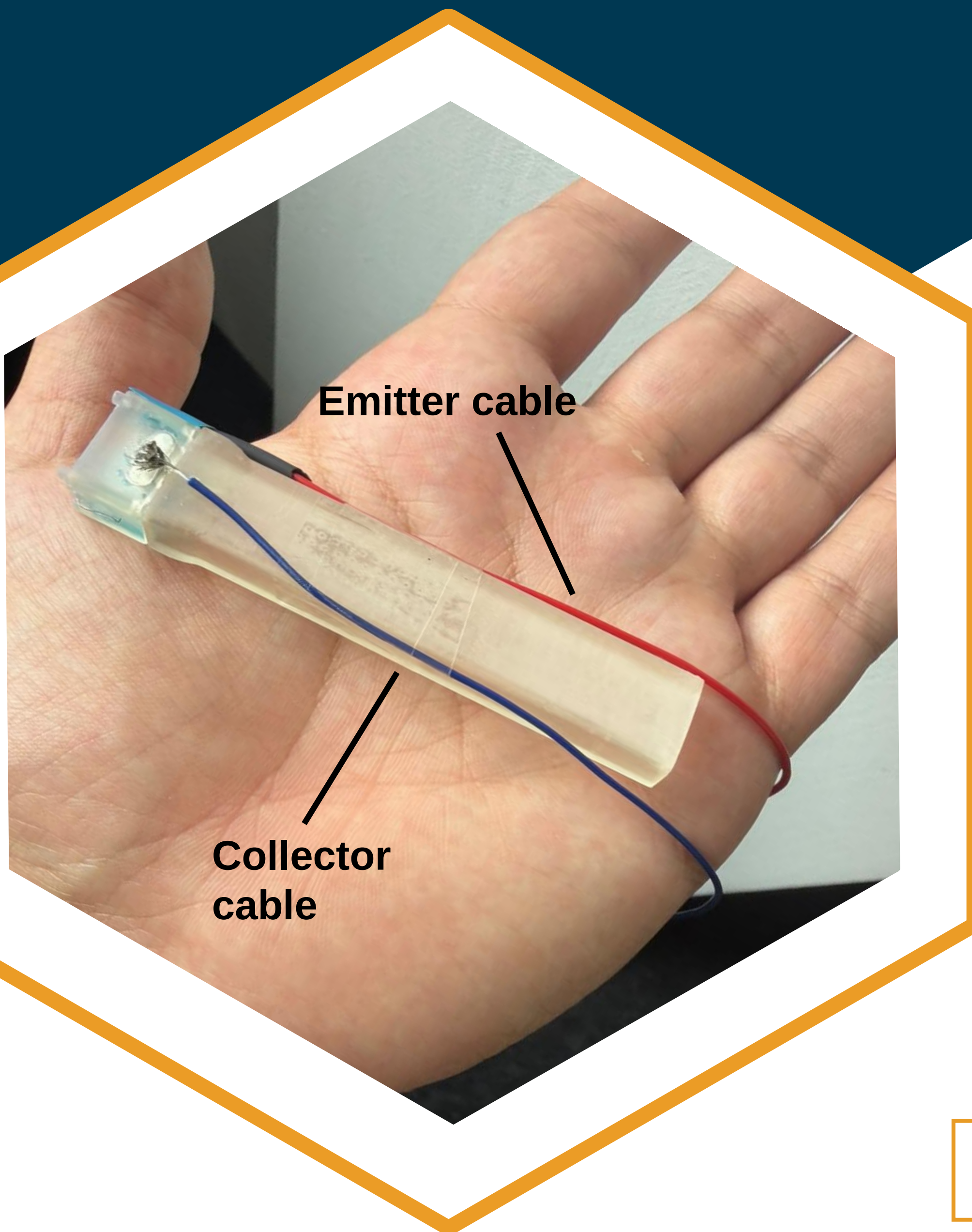
The present work couples Electric Discharge and Laminar Flow studies to simulate corona discharge electrode configurations, and their potential for miniaturized gas pump devices. It investigates the impact of scale reduction on the corona onset of the system, its power consumption and produced flow. Additionally, it compares the performance of two different geometries on how effectively they deliver air flow, and displays the importance of the gap between electrodes in the miniaturization process.

Introduction/Motivation

The corona discharge is a self-sustained, weakly luminous discharge formed in highly non-uniform electric fields between at least two electrodes with different radii of curvature. So far, its potential for micro-scale gas pumping remains largely unexplored, with only a few selected studies evaluating their potential performance, with most of the state-of-the-art surrounding smaller scale corona discharges being allocated to the study of the discharge itself ([1]), and the possible damage caused to electronic components when exposed to it [2].

Aim/Methods

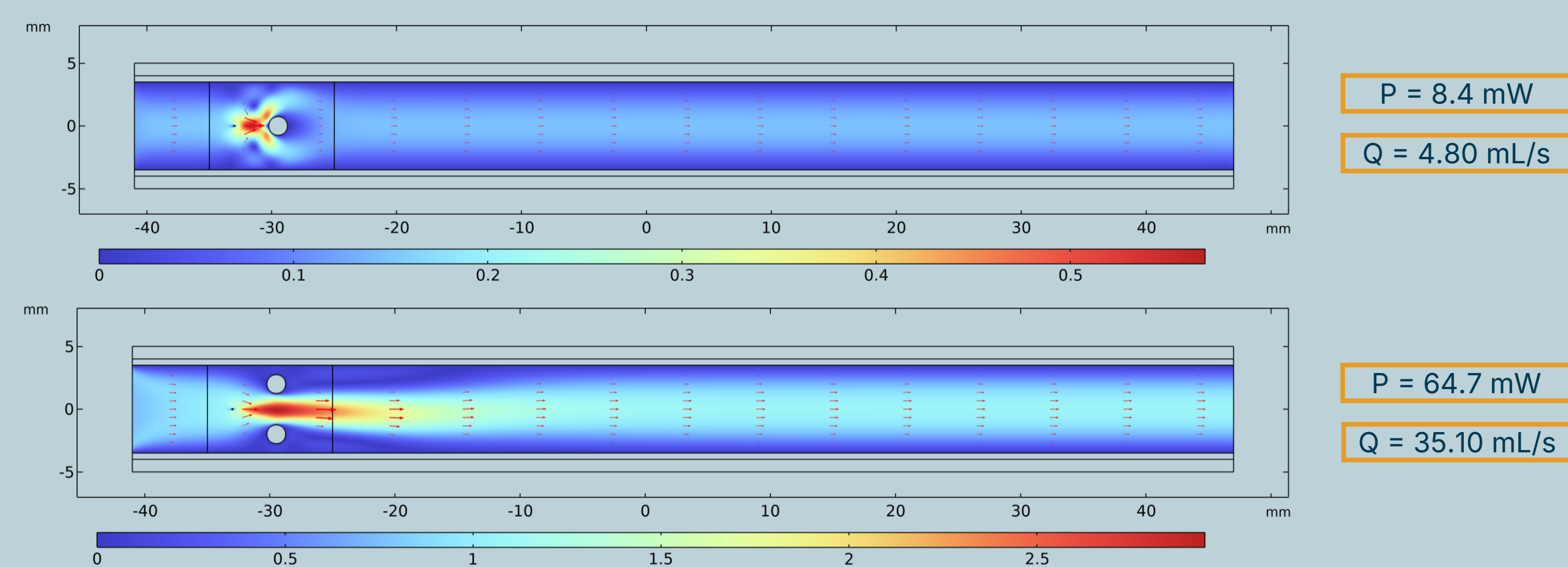
The study, fabrication and characterization of small-scale corona devices, considering their discharge behavior and produced airflow. COMSOL Multiphysics® is used to simulate the performance of corona devices of differing geometries and scales.



Electrode geometry and air flow

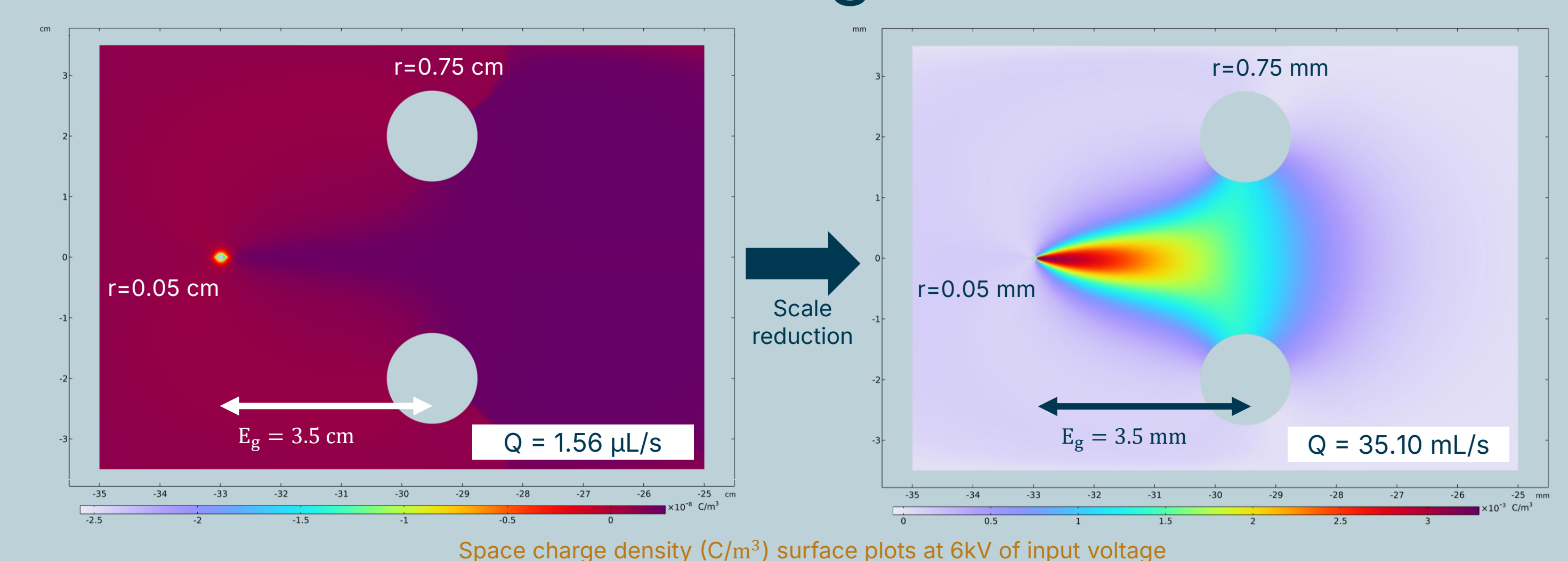
Two equidistant collector wires instead of one lead to:

- Higher space charge density, current and power (P)
- Higher flow velocities and flow rates (Q).
- Less flow recirculation, narrower "jet" profiles.

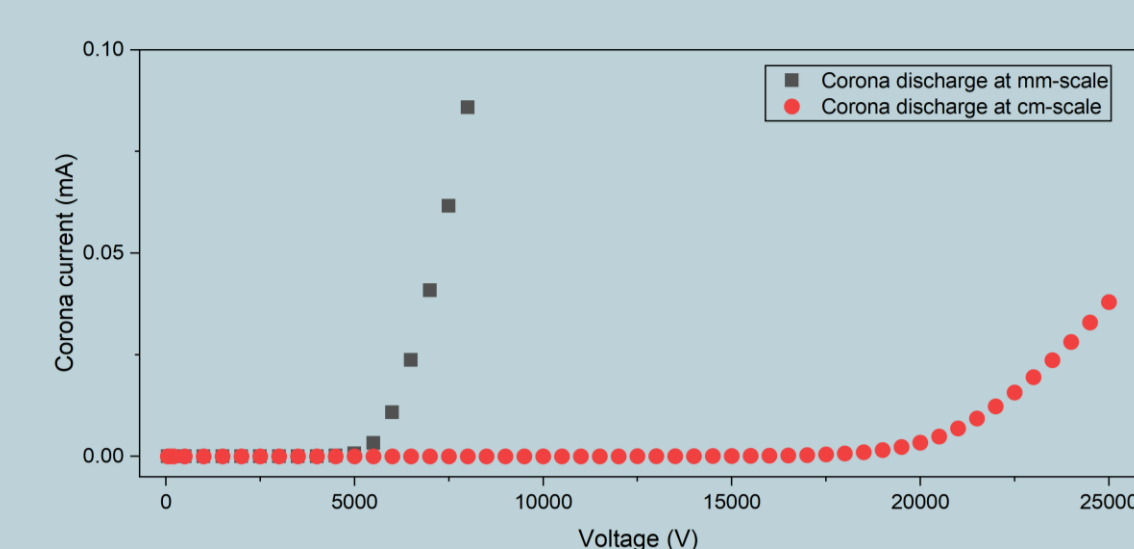


Surface plots of velocity magnitude (m/s) of a wire-to-wire corona discharge with an applied voltage of 6 kV, emitter radius of 0.05 mm and collector radius of 0.75 mm, containing one collector (top), and two collector wires (bottom)

Scale reduction advantages



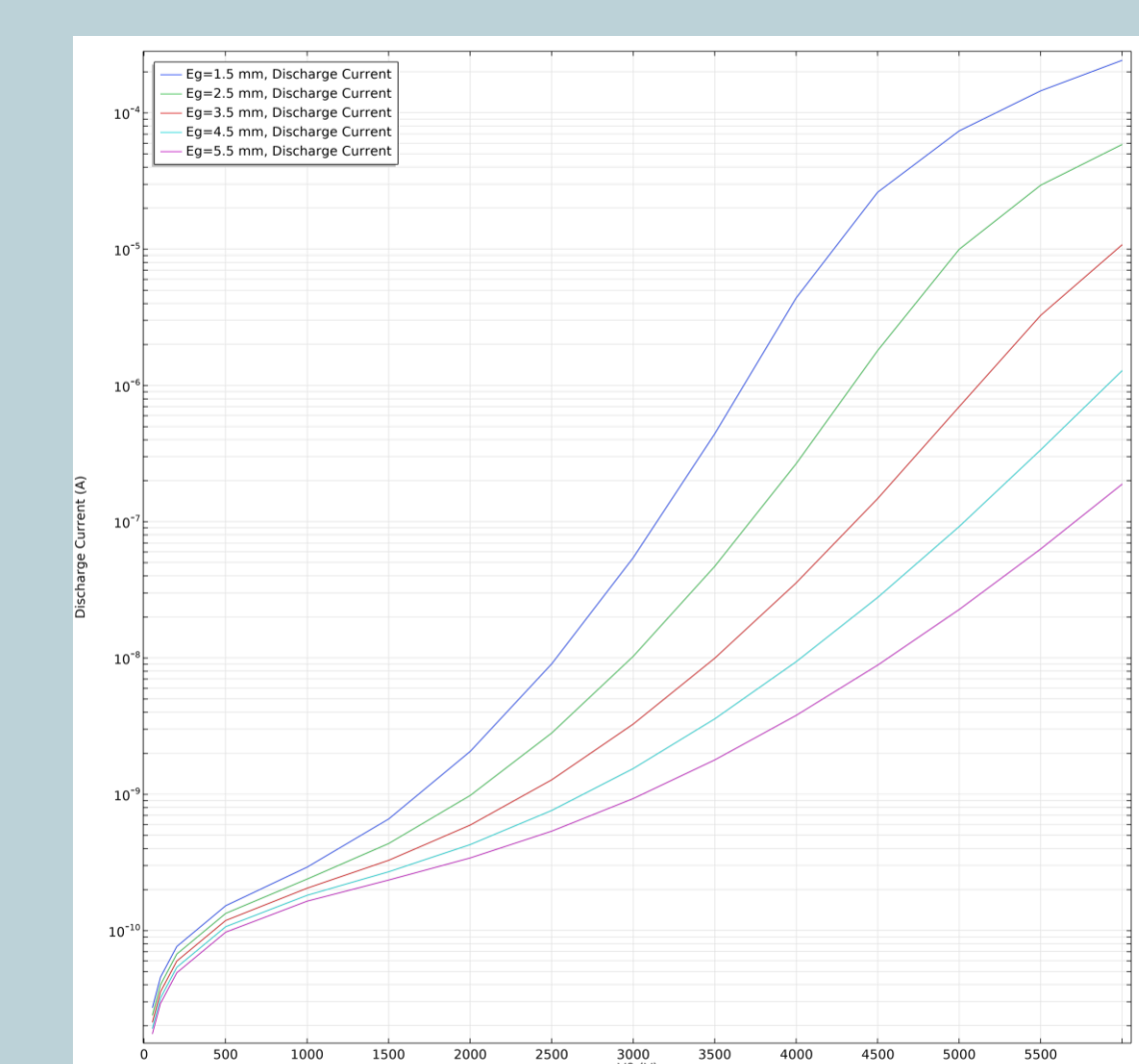
Space charge density (C/m³) surface plots at 6kV of input voltage



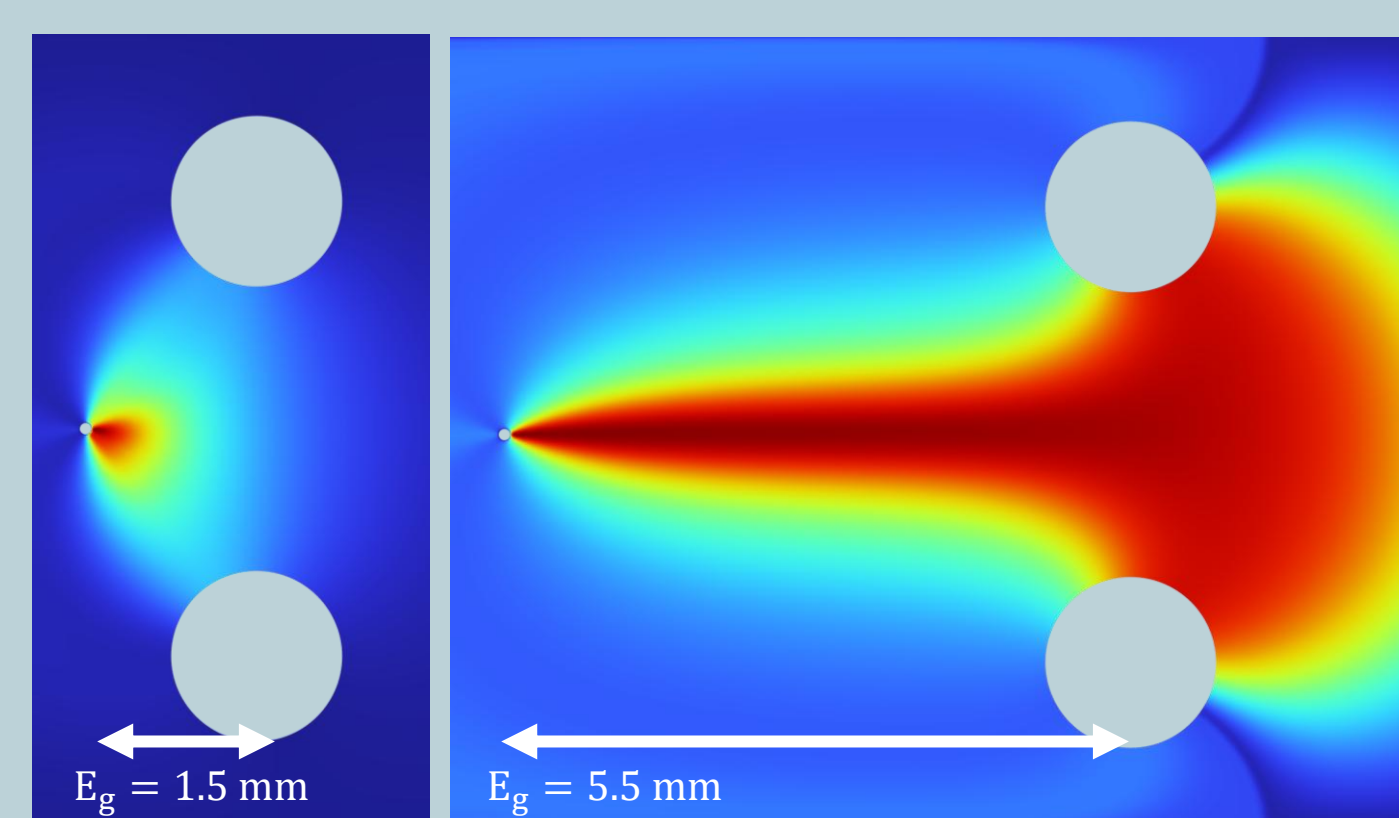
- Inception voltage reduction from about 16 kV to roughly 5 kV*.
- Higher airflow achieved with lower power (from 1.56 µL/s to 35.10 mL/s)

*These values align with Peek's law ([3]), which predicts approximately 14.95 kV and 3.35 kV, respectively, for similar geometries in the same scale.

Electrode gap variation



I/V characteristics of wire-to-wire corona discharge systems with two collectors with a varying electrode gap



- With scale reduction, we reduce the gap between the electrodes (E_g).
- Lower gaps lead to earlier coronas, as well as stronger currents [4].

Next steps

- Implement detection of regime transition: corona → spark.
- Compare simulations with experimental results, and quantify the discrepancies between them.
- Study the system in 3D, including surface plots for temperature in the walls of the channel.
- Simulate further device scale reduction.

References

- [1] A. Ongkodjojo Ong et al., "Electrohydrodynamic Microfabricated Ionic Wind Pumps for Thermal Management Applications," J. Heat Transf. 136, 061703 (2014).
- [2] Y. Sun et al., "Research on Ion Enhancement Effect in Micro-gap Gas Discharge," J. Phys. Soc. Jpn., 89, 094501 (2020).
- [3] F. W. Peek *Dielectric phenomena in high-voltage engineering*. McGraw-Hill Book Company, Inc., (1929).
- [4] J. S. Townsend, "XI. The potentials required to maintain currents between coaxial cylinders," Lond. Edinb. Dubl. Phil. Mag, 28, 163, (1914).

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