Correlation of Carbon Arc Oscillations with Voltage and Current Measurements

SULI Program Intern: **Yonry Zhu** (Ohio University)
Advisor: **Vlad Vekselman** (Princeton Plasma Physics Laboratory)

Abstract

Time-resolved current and voltage measurements along with fast frame imaging (FFI) video are obtained for a carbon arc discharge. The current and voltage are weakly correlated to arc motion in the low ablation regime and strongly correlated to arc motion in the high ablation regime. In the high ablation regime, a spike in input power is accompanied by a change in arc position while a drop in input power is accompanied by an expansion of the surrounding C_2 bubble structure

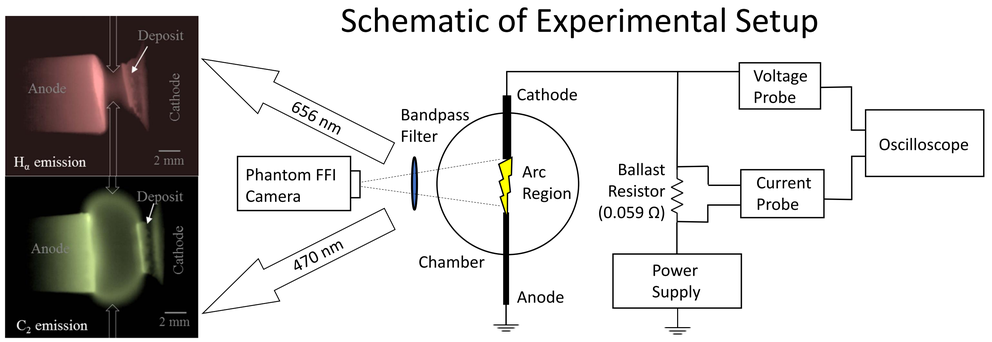
Motivation

- Carbon nanostructures, in particular carbon nanotubes, are valuable for their unique material properties
- Nanostructure synthesis by carbon arc discharge is simple, economical, and scalable
- Current carbon arc discharges have poor selectivity of the synthesized structures
- Optimization of the process requires fundamental mechanistic understanding of the discharge physics and synthesis process

Objective

- Examine and characterize any relationship between the carbon arc discharge current, voltage, and movement in low (I < 55 A) and high (I > 55 A) ablation regimes

Experimental Methods

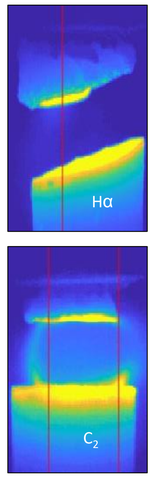


Images from [3]

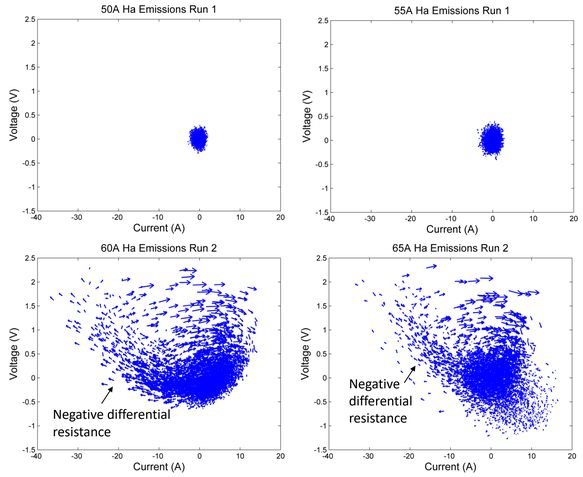
- Fill chamber with 95% He – 5% H_2 mixture at 500 torr
- Generate DC arc discharge between two graphite electrodes at a power supply output current of 50 A, 55 A, 60 A, and 65 A
- Acquire FFI video (~30 kfps) of carbon arc emissions from the core (Hα, 656 nm) and peripheral bubble structure (C_2, 470 nm)
- Image process video to track position of center of intensity of arc core and edges of bubble
- Record voltage drop across and current through the discharge with oscilloscope (~100 kHz sample rate)

Results

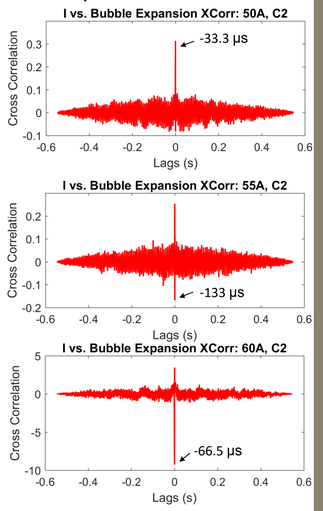
Processed Video



Typical I/V Phase Space Plots

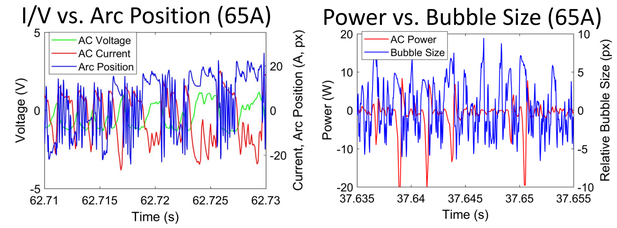


Sample Cross Correlations



Discussion

- The magnitude of voltage and current oscillations dramatically increases in the high ablation regime
- **The voltage and current oscillations are significantly correlated to the arc motion in the high ablation regime**



- Lull in arc core motion and expansion of peripheral C_2 bubble are preceded by a drop in current and power
- Movement of arc core is preceded by a spike in current and power
- Arc has negative differential resistance during bubble expansion

Conclusion

- Voltage and current oscillations are correlated to arc motion in the high ablation regime
- Data from this experiment can be used to validate future models
- Need time-resolved PLIF imaging and electrode pyrometry measurements to determine physical mechanism

References

[1] A.J. Fetterman, Y. Raitses, and M. Keidar, Carbon N. Y. **46**, 1322 (2008).
[2] S. Gershman and Y. Raitses, J. Phys. D. Appl. Phys. **49**, 345201 (2016).
[3] V. Vekselman, M. Feurer, T. Huang, B. Stratton, and Y. Raitses, Plasma Sources Sci. Technol. **26**, (2017).

Acknowledgements

This project was supported in part by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists (WDTS) under the Science Undergraduate Laboratory Internships Program (SULI)