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Plasma with a Feedback Loop: Real-Time Control for Plasma Medicine

Recent advances in artificial intelligence and machine learning are giving researchers new ways to control electrically charged gases, bringing us closer to improved cancer treatments, faster wound healing, and more effective sterilization methods.

CHICAGO—Gases composed of charged particles that remain safe to touch, coined low-temperature plasmas (LTPs), provide a unique platform for generating highly reactive molecules (e.g., hydroxide or OH) without the need for elevated temperatures. The rapid production of these molecules plays a critical role in a wide range of biomedical applications, from surface treatments to promising new approaches for treating life-threatening diseases.

Controlling how LTPs interact with biological materials remains one of the central challenges in biomedical plasma research. One of the defining advantages of LTPs over other sources of chemical reactivity is their ability to rapidly alter reactive-species production pathways. This capability enables real-time feedback control systems that dynamically tailor plasma chemistry to the specific needs of biological, chemical, or

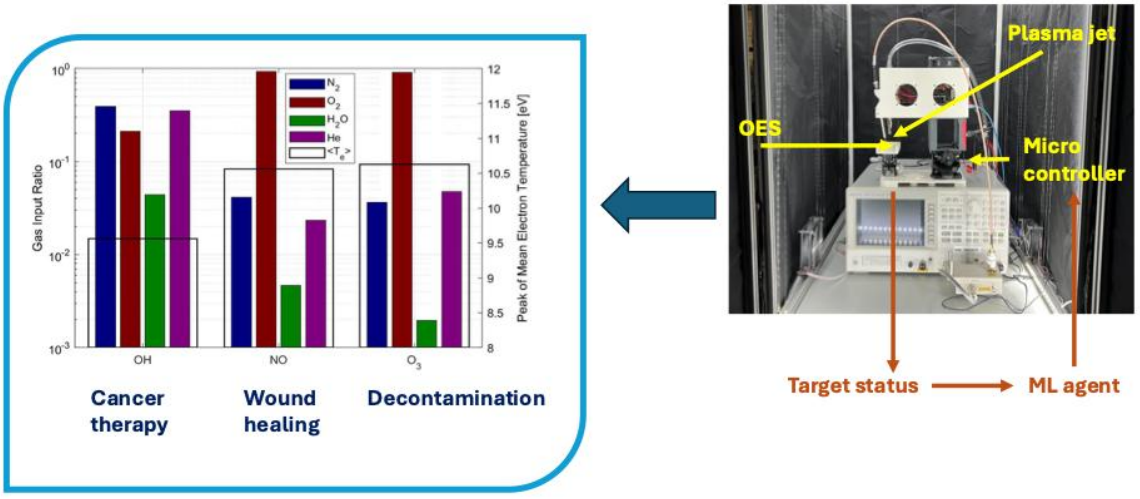


Figure 1: Right photo is adaptive plasma set up. Target status is recording and ML agent inform discharge control parameters leading to adaptation. Left image: Representative optimization results: Examples of gas composition and peak electron temperature conditions for maximizing key species (OH, NO, O_3) across different application scenarios.

environmental applications. To realize this vision, an adaptive plasma platform integrated with artificial intelligence (AI) and machine learning (ML) is under development [1-5].

Recently, reactive plasmas have been applied to human tissue for therapeutic purposes, creating a new field called "plasma medicine." The expanding range of plasma applications—including cancer therapy, wound healing, sterilization, agriculture, food processing, and environmental remediation—demands intelligent control systems that can adapt plasma characteristics in response to the treated biological or chemical system. Preliminary results from researchers at The George Washington University demonstrate the feasibility of adaptive plasma control while highlighting the need for robust ML models grounded in the fundamental physics of plasma processes as shown schematically (Figure 1). Such models are essential for developing AI-driven, high-precision, and highly repeatable LTP platforms.

By using an AI-based method to interpret the light emitted from these plasma sources, called optical emission spectroscopy (OES), researchers can determine in real-time which chemical species are being produced and how their concentrations are changing over time. Even as environmental conditions change over time (e.g., humidity rising or falling), the ML algorithm adjusts experimental inputs to achieve the same therapeutic outcomes. Using an advanced optical analysis technique (Fourier transform spectroscopy) on the OES spectra combined with a predictive chemical kinetics model revealed how the ML algorithm was able to capture additional patterns related to cell viability status, which helps to improve the accuracy and reliability of the AI-controlled LTP model.

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Abstract

FI02/6 Physics of adaptive cold atmospheric plasma and its application in biomedicine

Session FI02: Joint DPP-GEC Session: Computational, Low Temperature and Dusty Plasmas
9:30 AM–12:30 PM, Tuesday, November 3, 2026
Room: Hilton Chicago, International South, Second Floor

References

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