Characterization of atmospheric pressure ns-pulsed plasma jets properties through advanced optical diagnostics

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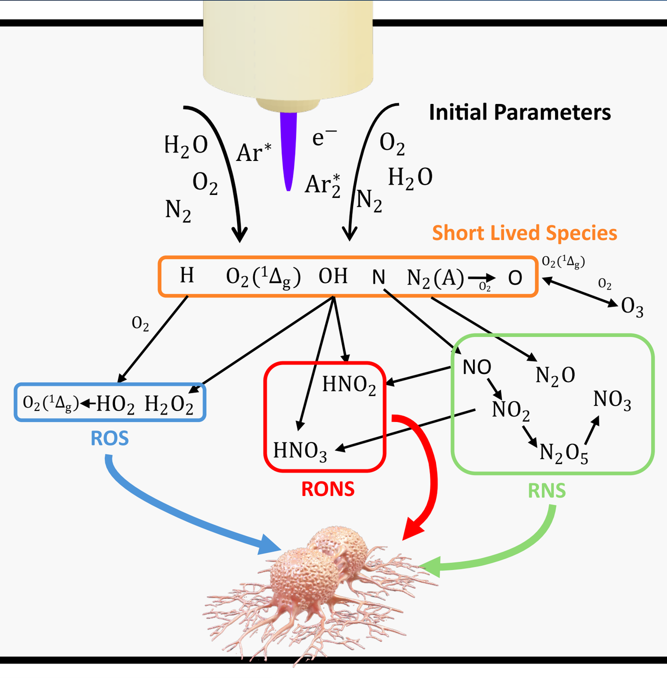
Motivation

Cold atmospheric plasma uses its electric field to generate reactive species. Optimizing excitation modes through electron impact allows precise plasma chemistry control [1], while high-resolution diagnostics enable effective time- and space-resolved monitoring, advancing therapies in oncology, wound healing, and infection control.



Redox therapy

Plasma medicine is based on the use of reactive oxygen species (ROS) and reactive nitrogen species (RNS) to induce targeted biological effects. ROS drive oxidative stress, triggering cell death and modulating immune responses. RNS influence signaling pathways, inflammation, and vascular regulation. Their interplay enhances plasma therapy's precision for various types of treatments [2-3].

Aim

How can we adapt plasma parameters to target RONS (or specific RONS mixtures) and provide a specific biological outcome?

Aim 1. Create and optimize a biocompatible plasma source
Aim 2. Investigate the effect of the source parameters on its chemical reactivity
Aim 3. Develop a treatment method linking the source parameters to a biological output

Optical Diagnostics

Electric-Field Induced Second Harmonic

- Crossed-beam configuration for enhanced spatial resolution [4]
- Amplification 143-fold of classical E-FISH through homodyne amplification in an inline configuration [5]
- High sensitivity reaching 1.7 V/(cm Hz$^{1/2}$) to polarity change of the plasma [5]

Laser Induced Fluorescence (1- and 2-photon)

- Optical Parametric Oscillator allows for excitation of molecules
- Measurement of density of NO (LIF), OH (LIF), N (TALIF) and O (TALIF) ground state density
- Spatial and temporal resolution of the species can be made

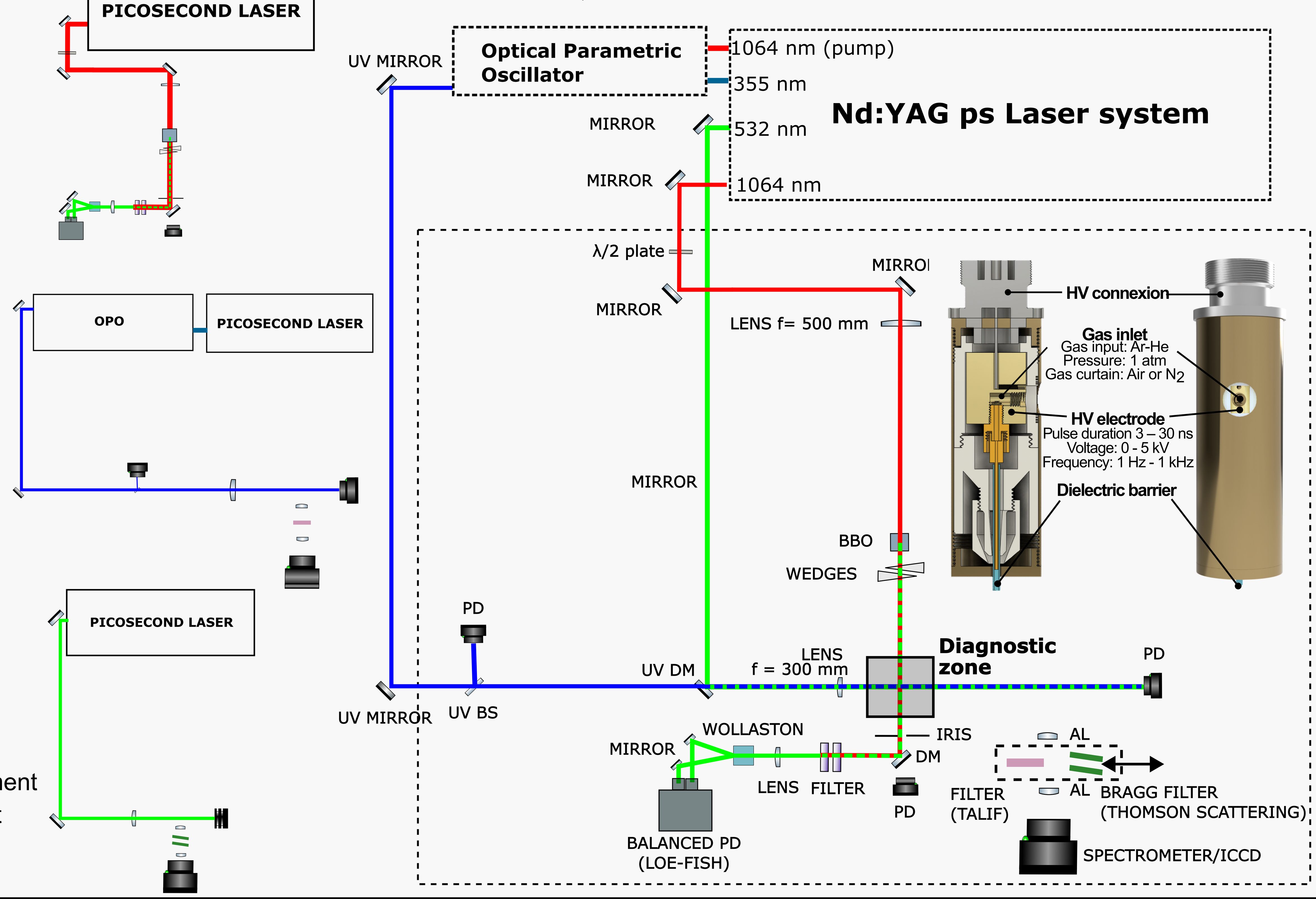
Tunable Laser Absorption Spectroscopy

- Optical Parametric Oscillator allows for quick and reliable wavelength tuning (190 nm to 2300 nm)
- Dual photodiode system measurement allows for real-time tracking of signal absorption

Thomson Scattering

- Temporal resolution of electron density and temperature
- Limited invasiveness allow for precise and accurate measurement
- Measurements of incoherent type of Thomson scattering event

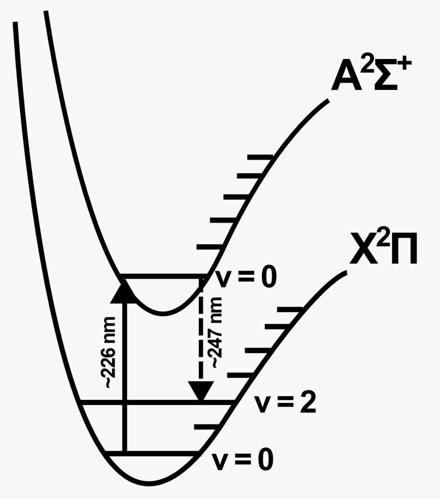
COMPLETE QUADRUPLE-DIAGNOSTIC BREADBOARD

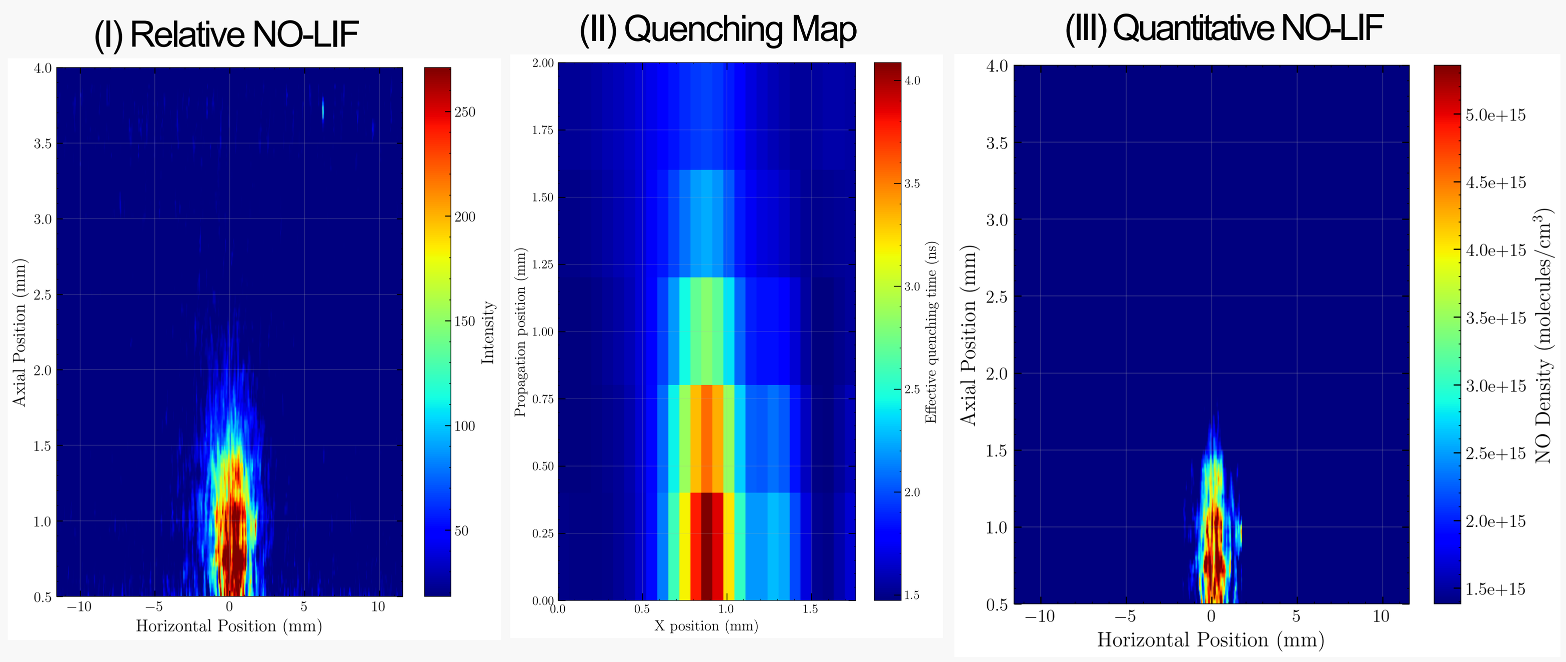


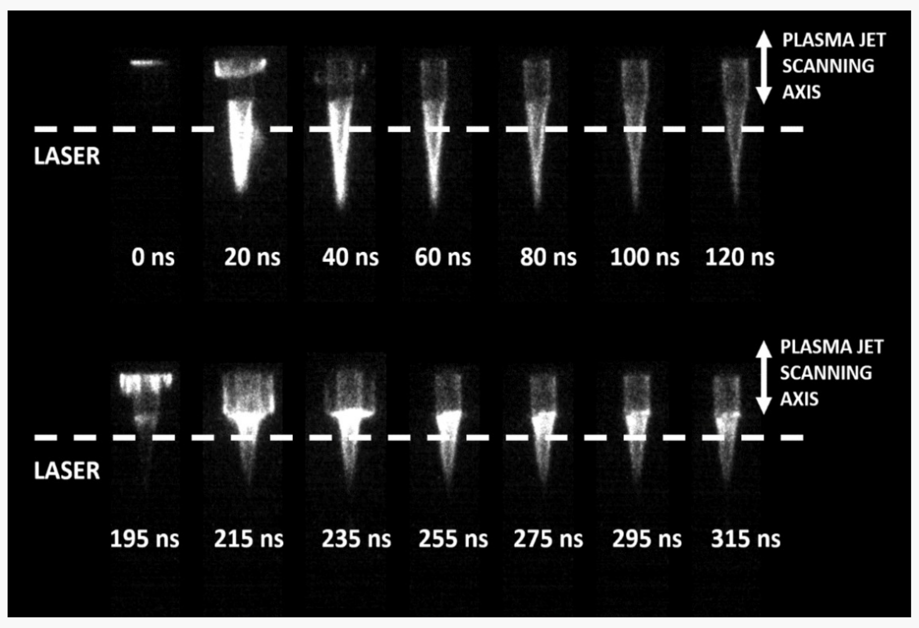
Quantitative NO-LIF

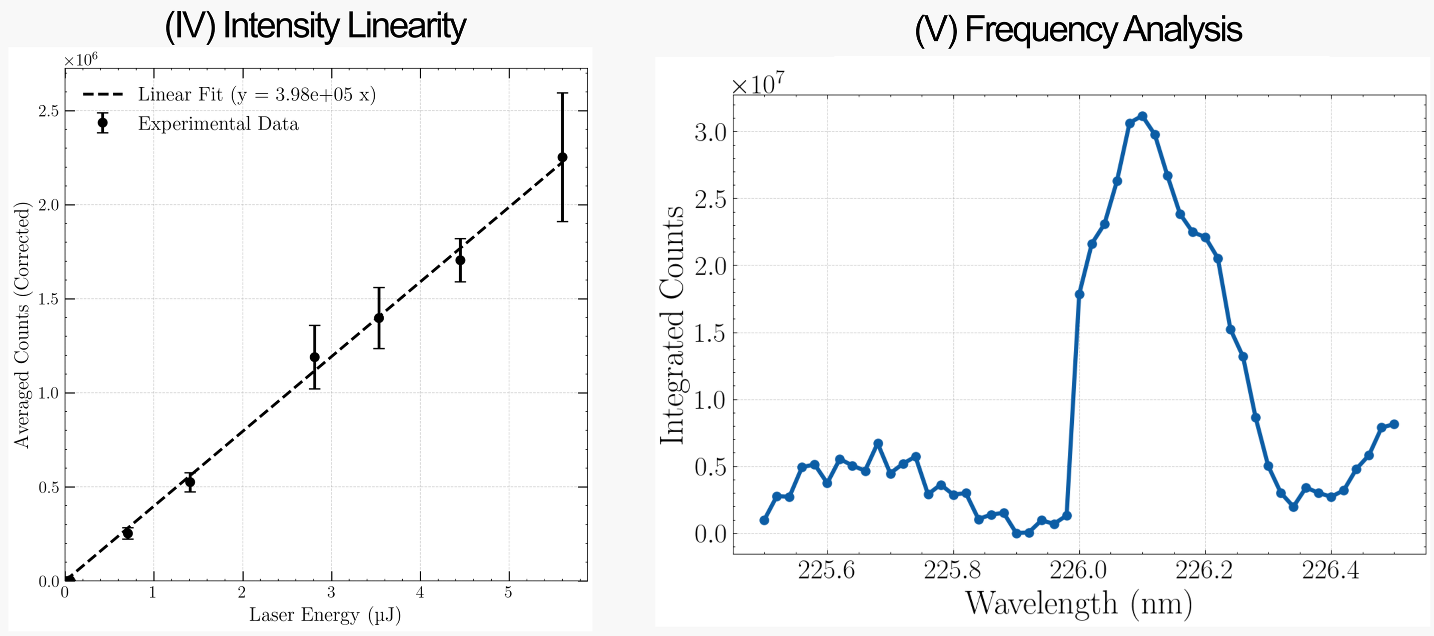
Experimental Parameters:

- Laser energy: 5.6 µJ
- Pulse duration: ~ 5 ps
- $\lambda_{excitation}$: 226 nm
- $\lambda_{emission}$: 247 nm
- Filter: 248 ± 10 nm
- Calibrated with N_2/NO mixture (99% / 1%)

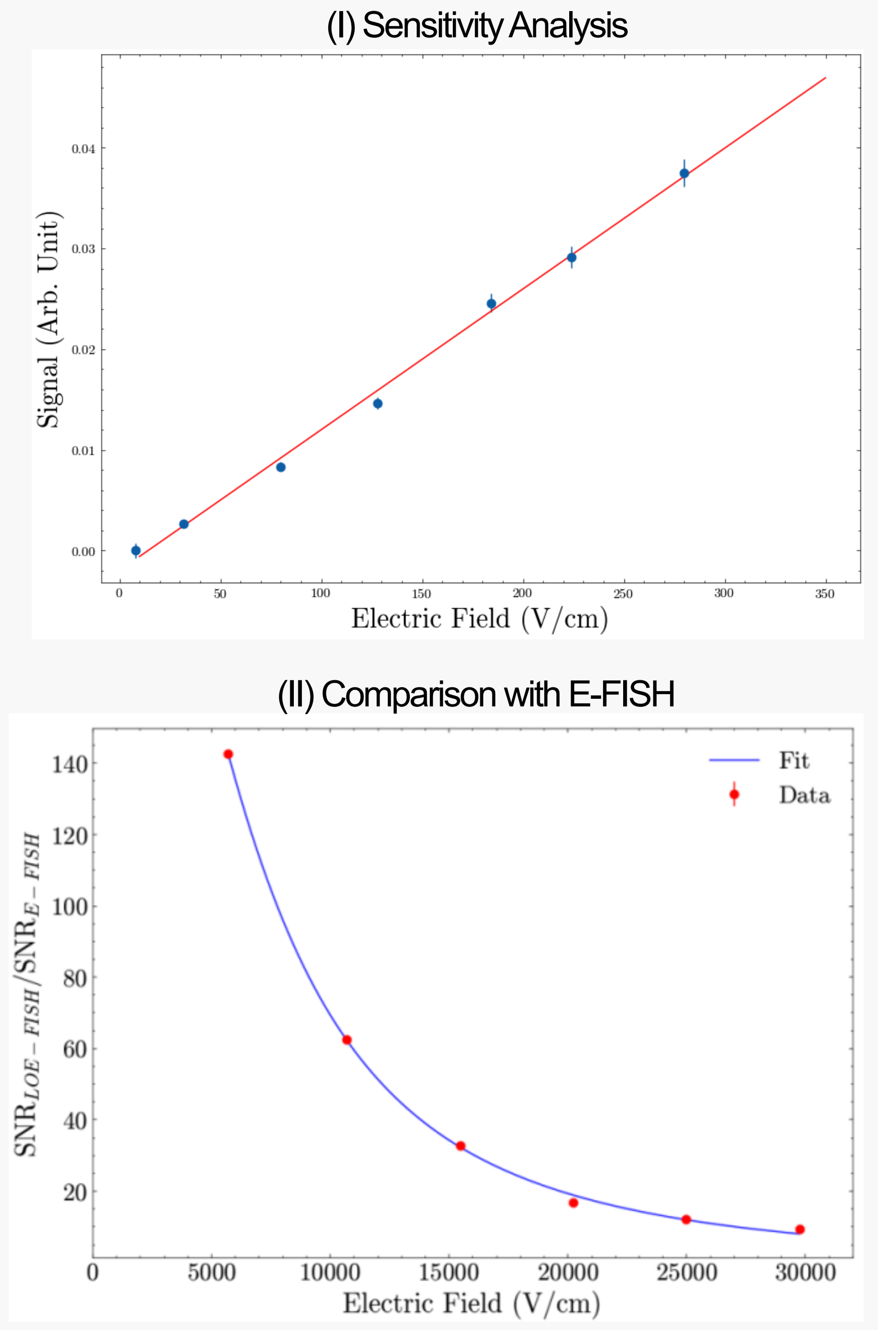








LOE-FISH



Future Work

We are establishing a comprehensive plasma diagnostic platform, which allows a near complete parametric analysis of electrical pulsing parameters, gas mixtures, and the plasma's gaseous environment. Such analysis is essential to explore different ROS and RNS production pathways, which are the foundation of many plasma applications. Advanced spectroscopic techniques such as TALIF, E-FISH, and Thomson scattering will be set up and performed on the plasma jet for a more detailed characterization.

Acknowledgement

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Reference

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