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# Optical Analysis of High-Yield Fission Products for Nuclear Forensics Applications

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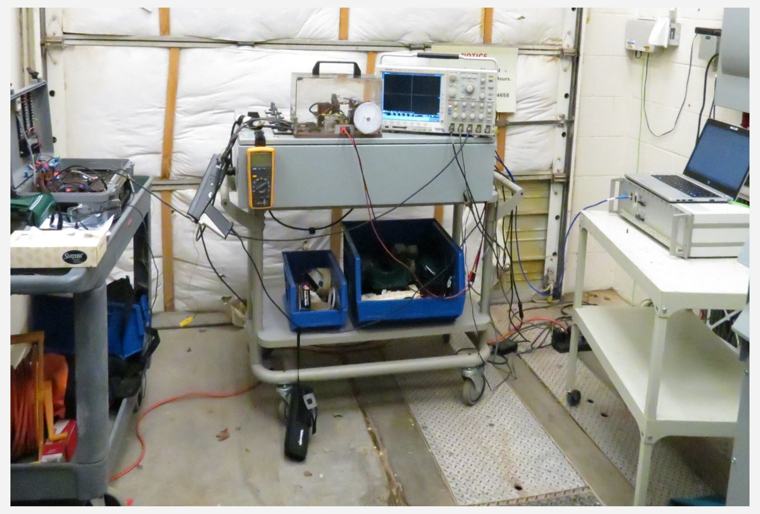
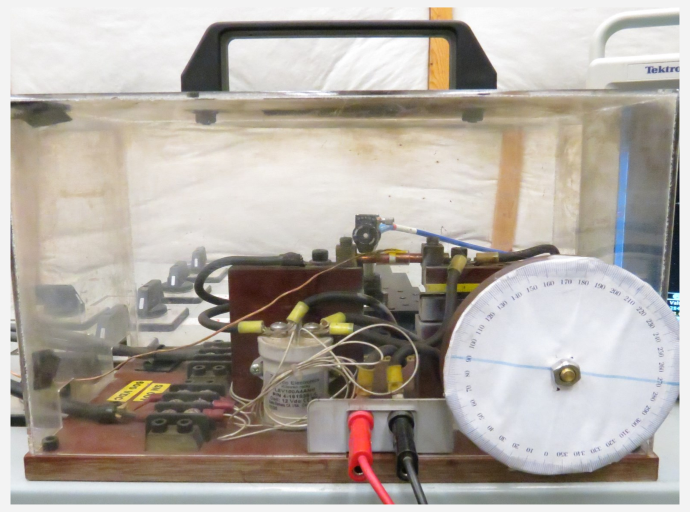
## Introduction

Analysis of radioactive material has been improving over many years, allowing rapid detection and accurate identification of many elements of interest to the nuclear forensics technical field. However, special challenges arise when dealing with high-yield fission products which have very long or very short half-lives. Optical emission spectroscopy (OES) offers an interesting alternative to established analytical methods, for materials that do not have a well-defined or easily obtainable radioactive signature. With the development of new prototypes to generate microplasmas, the combination of microplasma technology and OES may offer a quick, efficient method for analyzing air samples in a post-detonation scenario. It is known that OES spectra allow for identification of elements in a generated plasma, but this poster shows promising results that suggest that quantitative amounts of elements in the plasma and plasma temperatures may also be calculated. Further steps to broaden the scope of this experiment and potential applications of this research are outlined.

## Arc-Fault Experimental Setup





The S2000 Ocean Optics Spectrometer is coupled to a CCSA2 cosine corrected detector using a fiber optimized for high transmission efficiency in the UV-VIS wavelengths. The detector is positioned to collect signals from the electric discharge of the plasma.

The arc-fault is triggered within the plastic box, between two electrodes (cathode/anode) with a small gap separating them. They may or may not be covered with a polycarbonate sheath. A thermocouple., voltmeter, and oscilloscope collect data from the system.

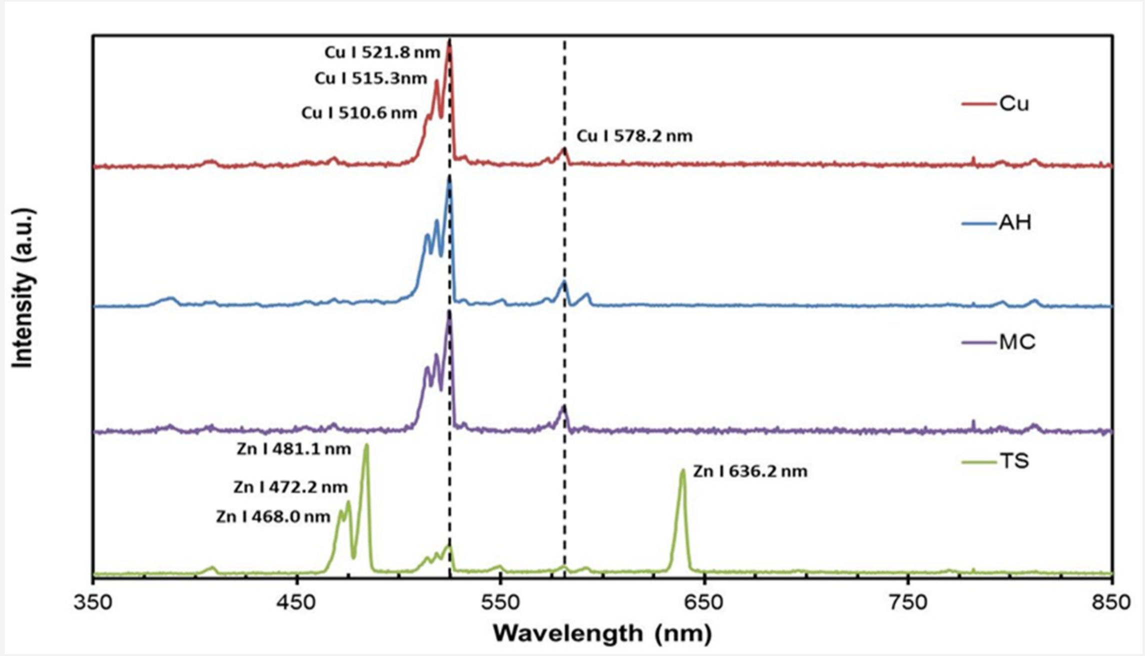
## Process

- Constant power is applied to the electrodes through a pair of DC power cables.
- Electric current ionizes the air between the electrodes. The surface and core elements of the electrodes may also become ionized.
- A continuous plasma forms between the electrodes.
- The electric current further causes electrical breakdown of the air, causing the air to be electrically conductive.
- This electric breakdown is termed arc discharge or electric arc, and a ongoing electric discharge from the plasma forms, creating continuous visible sparks and sometimes fire.
- The spectrometer processes the light as a function of wavelength.

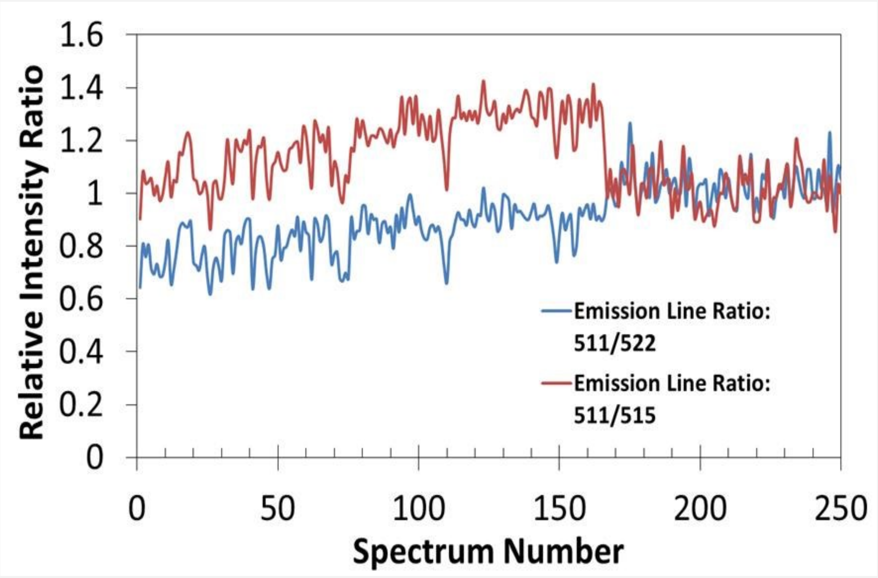
## Preliminary Results

✓ Qualitative identification of elemental peaks in the generated plasma's spectra is possible.

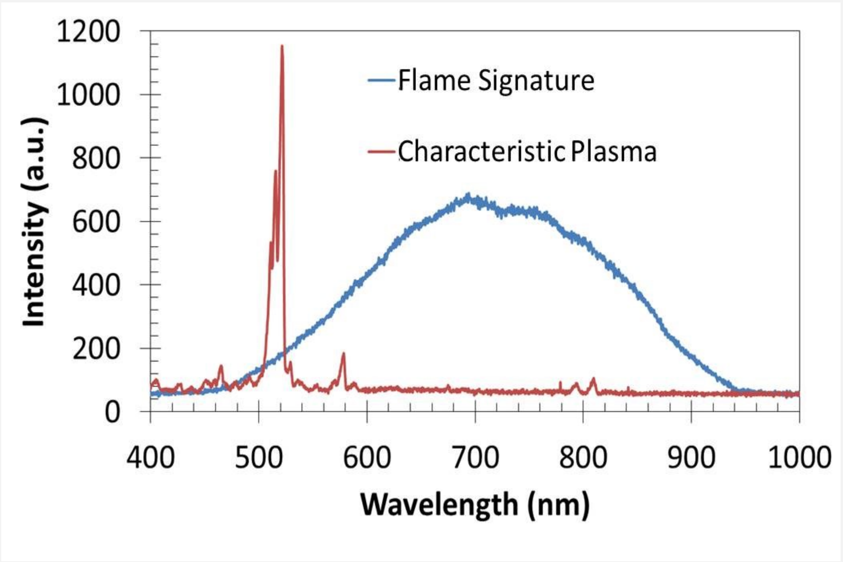
- AH, MC, and TS refer to solar connectors that were used as electrodes for principal experiments.



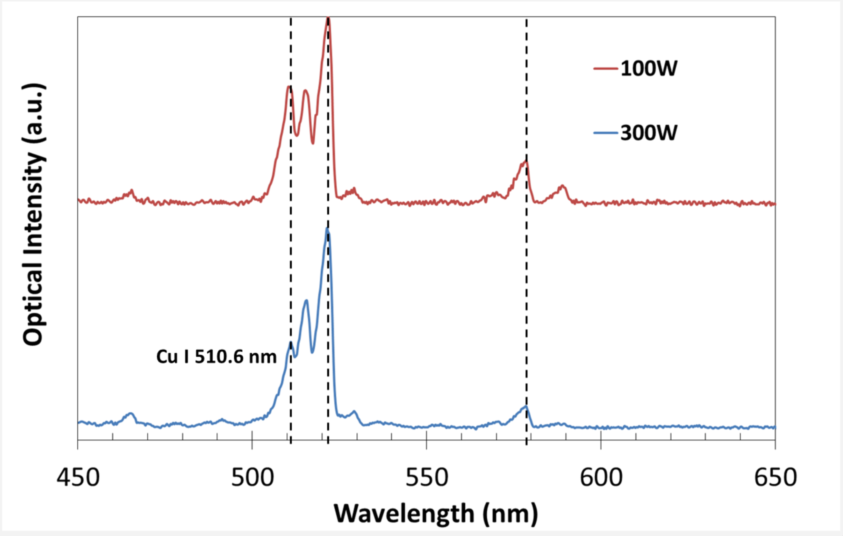

✓ Patterns of increasing or decreasing plasma temperature can be spectrally detected using peak intensity ratios of characteristic lines.




✓ Blackbody emission can be distinguished from characteristic elemental emission.




✓ Peak ratios of characteristic elements vary as a function of power

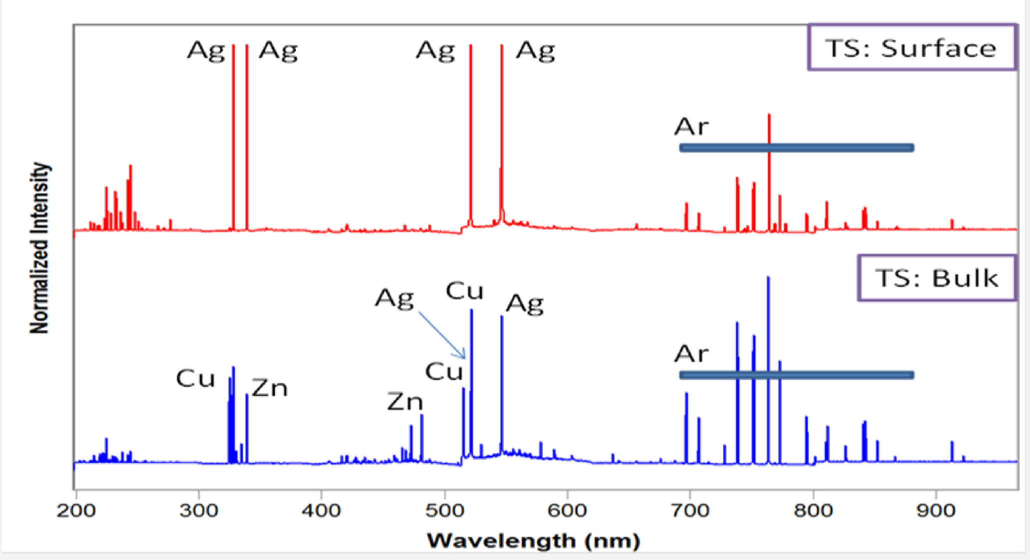



## Steps Forward

- Using the arc-fault experimental setup to test standard reference materials containing elements of interest, such as fission products or uranium-containing materials.
  - Criteria: 1) Very long or very short half-life, 2) High-yield fission product, 3) Not commonly used in industry, and 4) Low natural (crustal) abundance.
- Calculating plasma temperature at the time of electrical discharge using the Boltzmann equation and the quantum transitions that the spectral lines represent.
- Study standard reference materials across various analytical techniques (LIBS, OES, ICP) as a metric for the accuracy of the arc discharge spectra.
- Quantitatively calculating plasma elemental composition
- Systematically examining how spectral lines and peak ratios change as a function of power or current, and the influence of these factors on plasma temperature.

## LIBS Analysis

✓ Identifies the elements in the electrodes with high levels of accuracy (well-defined lines from the LIBS handbook or NIST database) to compare to OES data.




✓ Shows different elemental compositions between the surface coatings and the core of the electrodes.

| Part i.d. | Cu (324.7, 327.3, 515.3, 521.8 nm) | Sn (284.0, 286.3, 317.5, 326.2, 380.0, 452.6 nm) | Ni (239.5, 338.1, 341.5, 352.5, 361.9 nm) | Zn (468.16, 472.35, 481.17, 636.25 nm) | Ag (328.07, 338.26, 768.88 nm) |
|---|---|---|---|---|---|
| AH (surface) | Y | Y | N | N | N |
| AH (bulk) | Y | Y | Y | N | N |
| MC (surface) | Y | Y | N | N | N |
| MC (bulk) | Y | Y | N | N | N |
| TS (surface) | N | N | N | N | Y |
| TS (bulk) | Y | N | N | Y | Y |

## Potential Application: MHCD

- Microhollow cathode discharge system
- Electric current between electrodes causes electric discharge from gas in a hollow, ring-shaped cathode.
- Smaller cathode rings allow for higher pressure, needed for high glow discharge of atmospheric air.
- Advantages: small, portable, low power draw.
- Challenges: generating a system that will draw atmospheric air into the cathode hole, optimizing cathode hole diameter/high pressure for ambient air applications.

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