Pulsed Laser Deposition of a Silver Film For Laser-Induced Breakdown Spectroscopy Emission Enhancement of Bacteria

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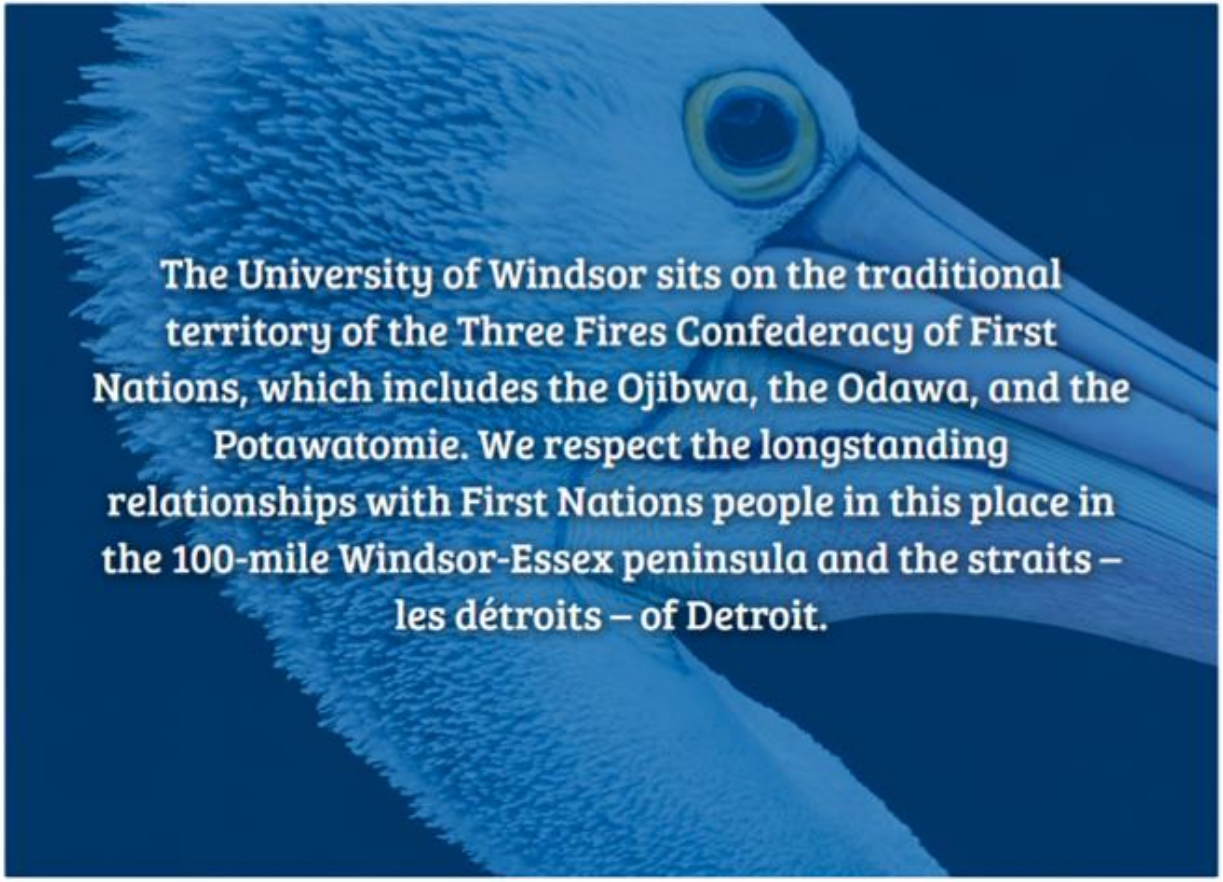

The University of Windsor sits on the traditional territory of the Three Fires Confederacy of First Nations, which includes the Ojibwa, the Odawa, and the Potawatomie. We respect the longstanding relationships with First Nations people in this place in the 100-mile Windsor-Essex peninsula and the straits – les détroits – of Detroit.

Motivation

Current methods of bacterial identification in clinical settings are contributing to the ongoing antibiotic resistance crisis:

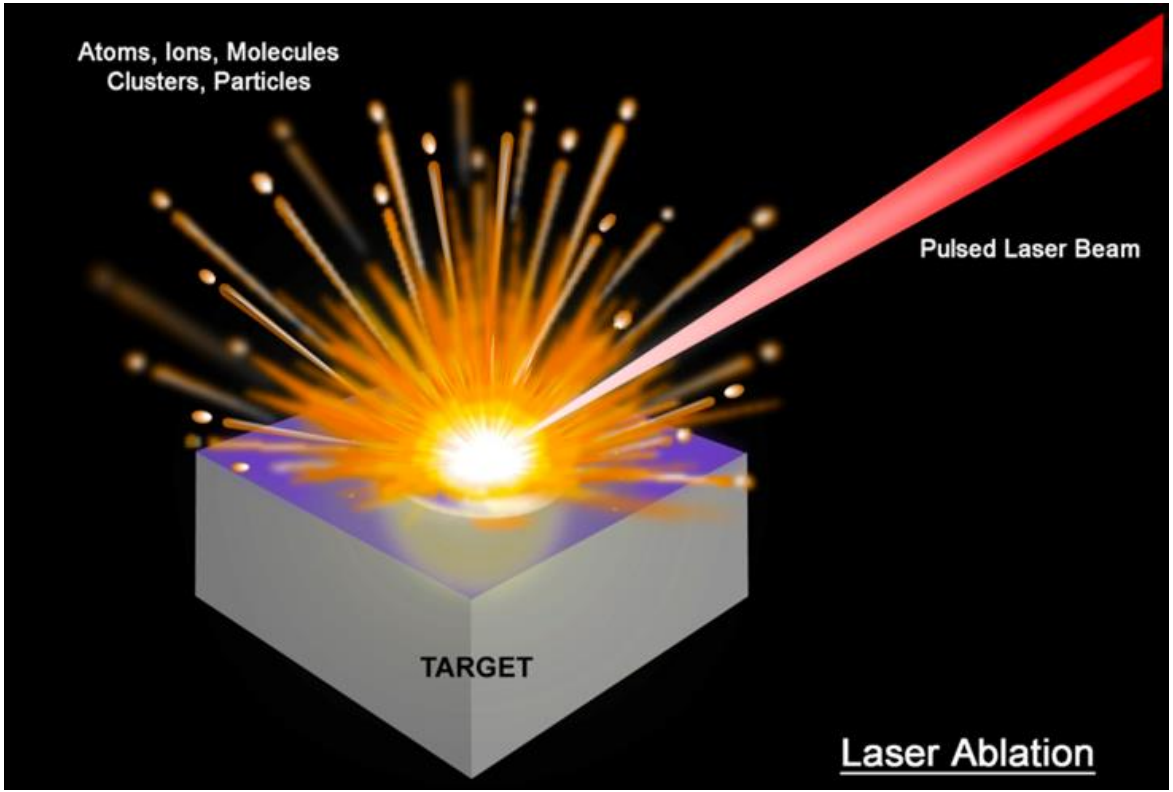
- ➔ They are slow (take 2-3 days)

We use laser-induced breakdown spectroscopy (LIBS) on bacteria to identify and classify the bacteria species

- ➔ It's very fast (under 1 min)

What is LIBS?

A spectrochemical technique used to rapidly determine elemental composition



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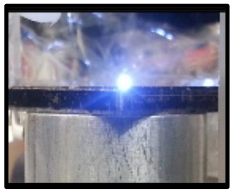
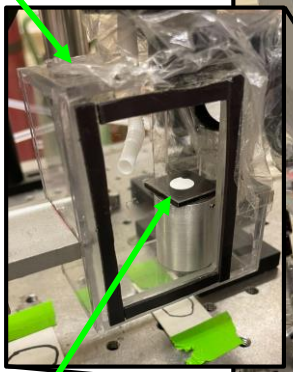
LIBS Experimental Setup

Nd:YAG 1064 nm laser, 10 ns pulse duration, 10 Hz pulse frequency

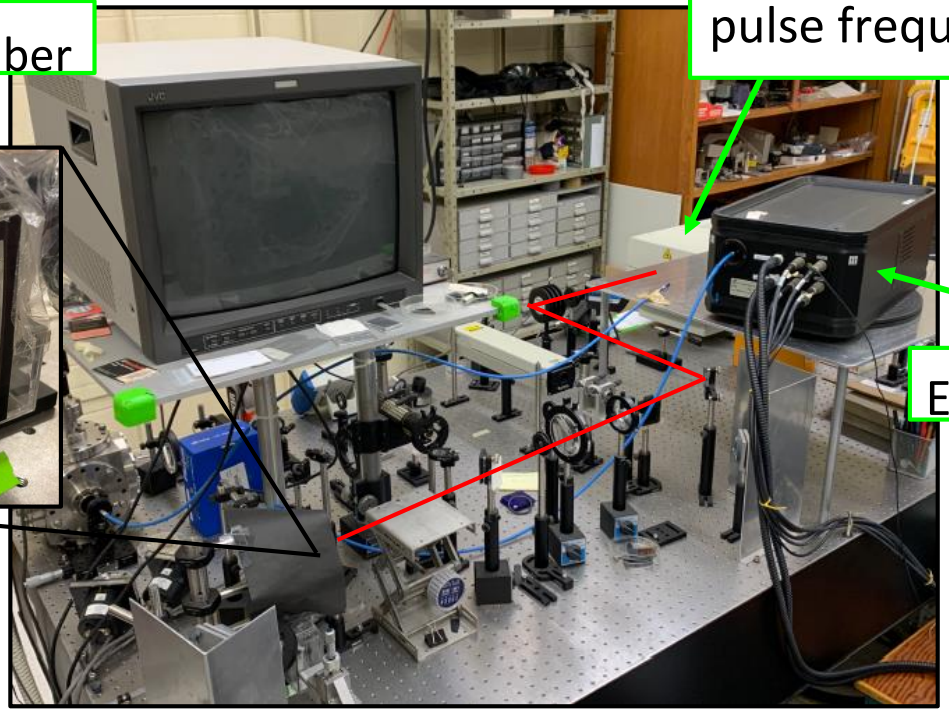
Argon purge chamber

Bacteria sample being ablated





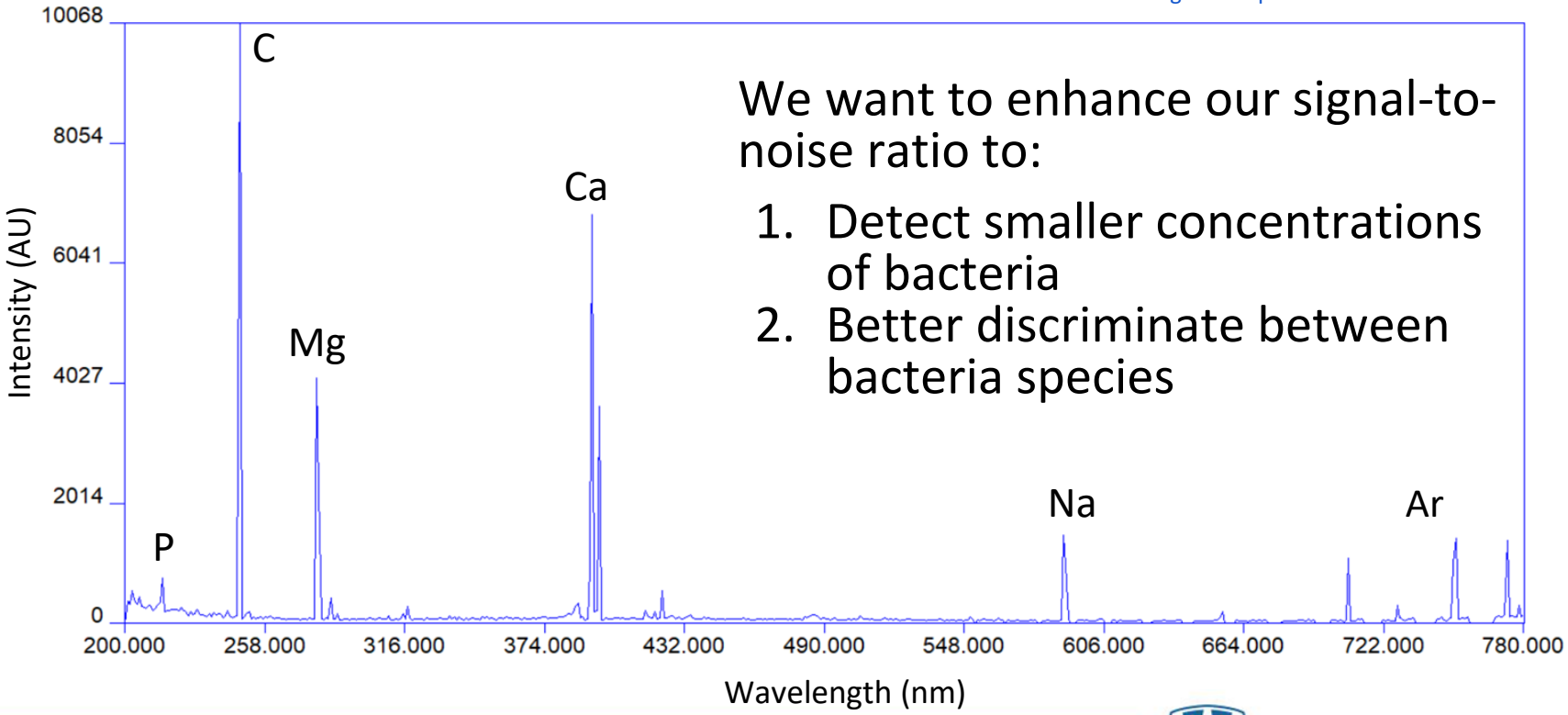
Bacteria deposited on nitrocellulose filter



Echelle spectrometer

Typical LIBS Bacteria Spectrum

E. coli
2 µs delay after plasma initiation
20 SCFH Argon environment
Single laser pulse



We want to enhance our signal-to-noise ratio to:

1. Detect smaller concentrations of bacteria
2. Better discriminate between bacteria species

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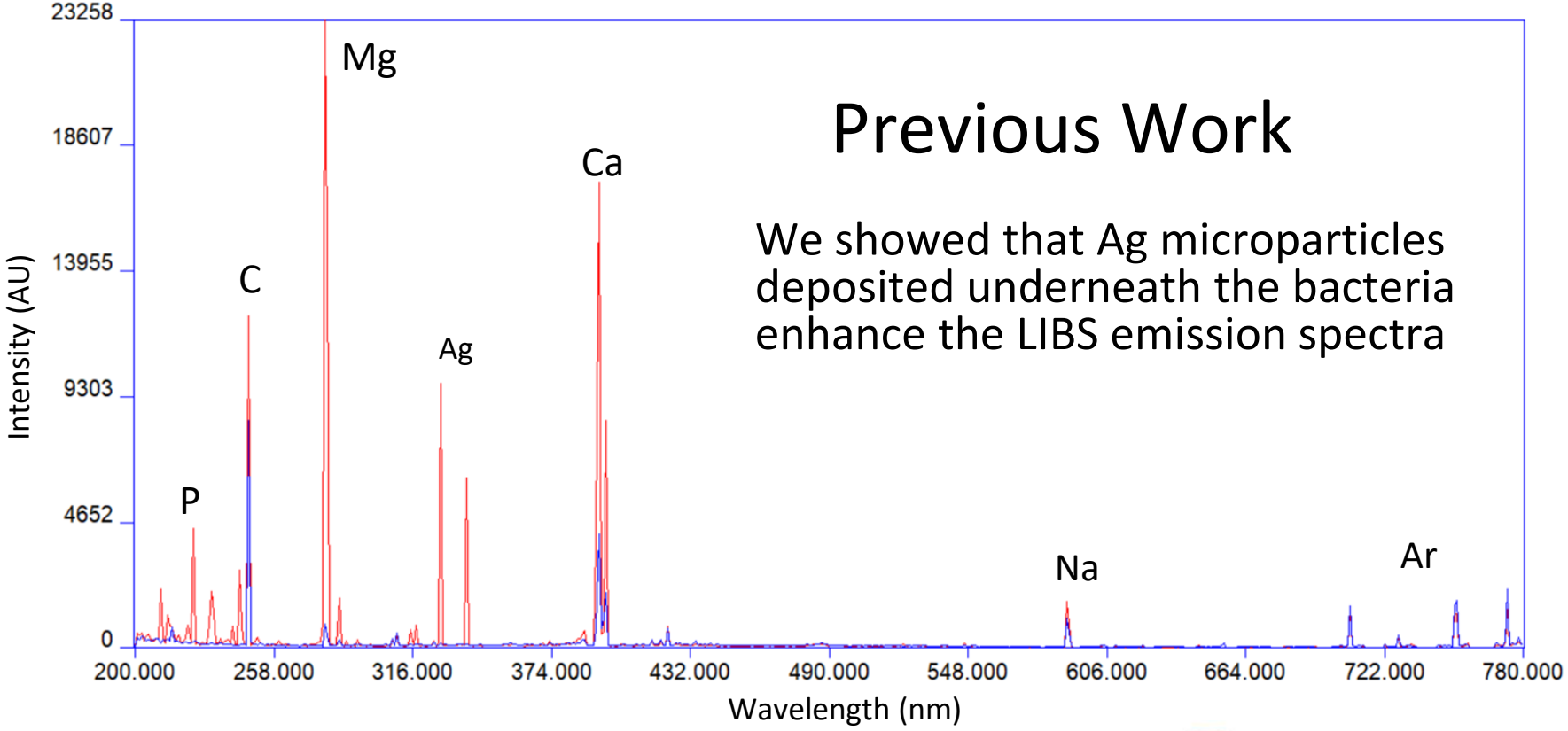
Red: with silver microparticles
Blue: without silver microparticles



Previous Work

We showed that Ag microparticles deposited underneath the bacteria enhance the LIBS emission spectra

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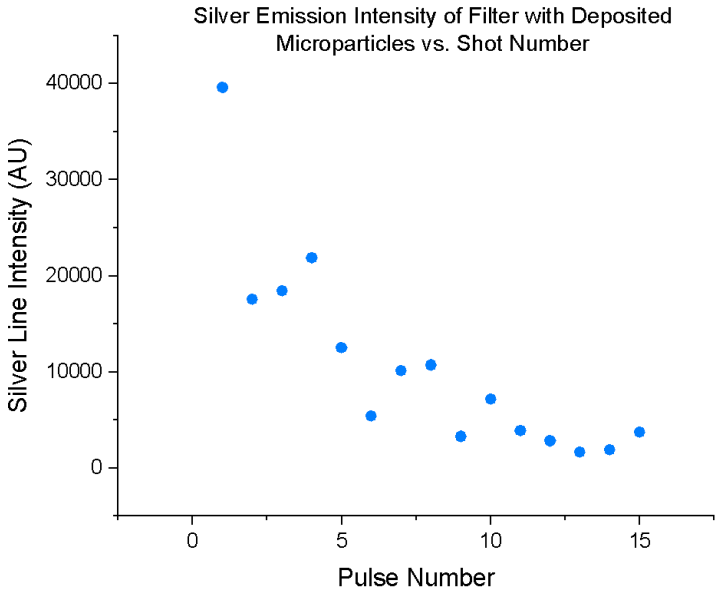
Problems:

- Silver microparticles were displaced due to plasma shockwave resulting in decreasing intensity in subsequent pulses
- Because silver was not deposited uniformly, enhancement was very inconsistent between laser pulses



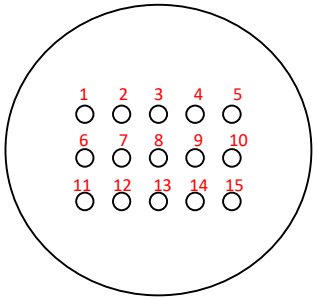


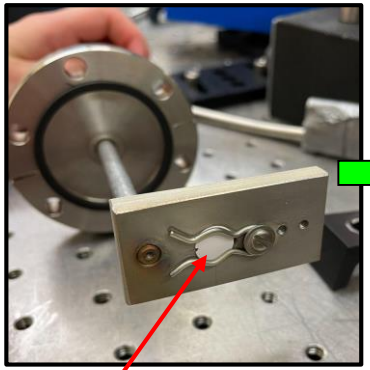
Illustration of 15 pulses on a filter

Proposed solution: pulsed laser deposition of a thin film (not microparticles)

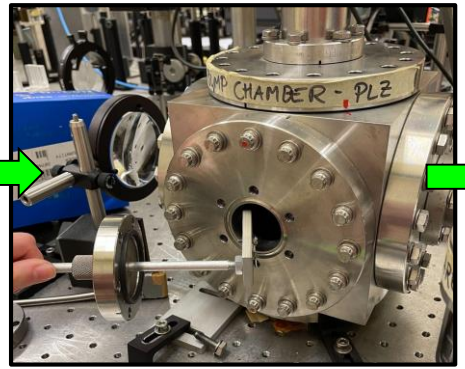
Pulsed Laser Deposition

A high-power pulsed laser beam is focused onto a target (silver) inside a vacuum chamber. The target is vaporized in a plasma plume which deposits it as a thin film on the substrate (filter).

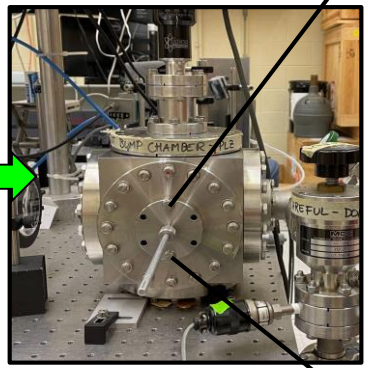
Experimental setup:



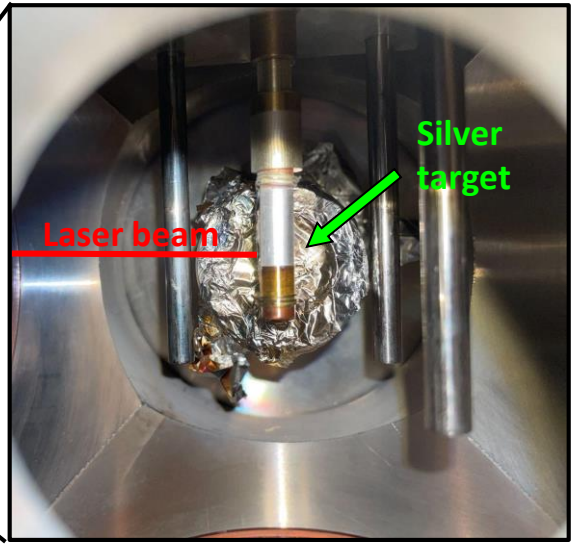
Filter on custom **aluminum filter holder**



Filter holder being inserted into **10 mTorr evacuated chamber**



Closed vacuum chamber apparatus

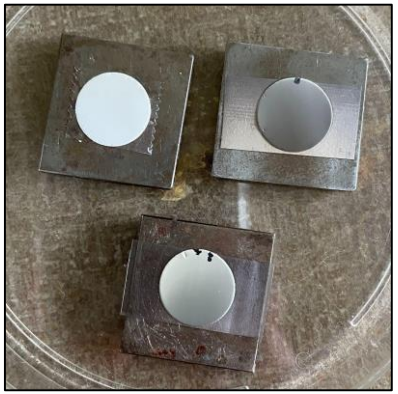


Inside the chamber

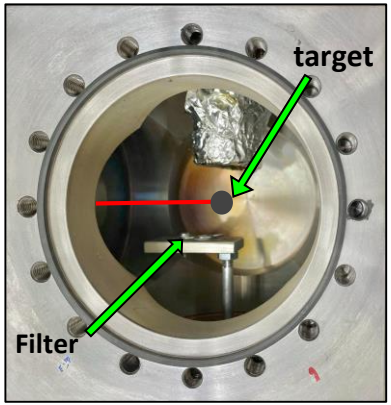
Determining Filter Location and Deposition Time

Filter location:

Brass rod



Brass coverage in various locations



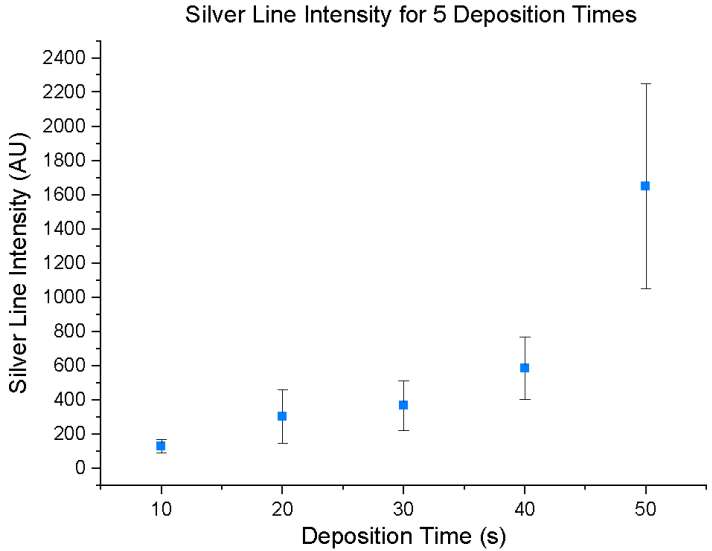
Top view of chamber

2 min deposition of silver

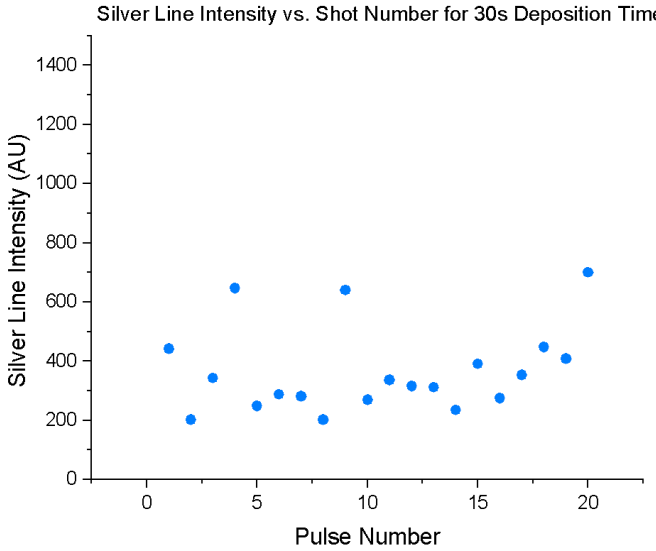
Deposition time:

- 2 min, 4 min, and 8 min sputtering times were investigated
  - ↪ Appeared to be too long, under 1 min would be investigated further with silver

Results: Uniformity of Silver Film with LIBS



Silver line intensity increases with deposition time as expected



Silver line intensity shows no decrease with subsequent pulses

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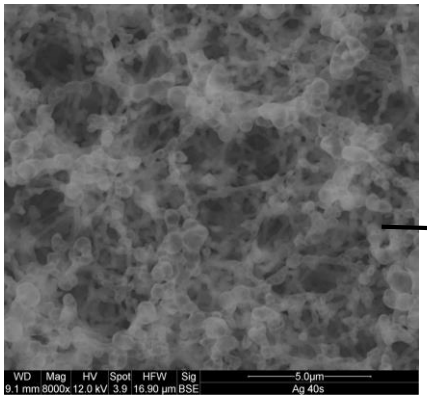
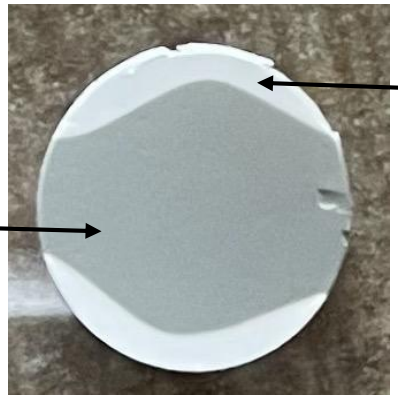
Results: Uniformity of Silver Film with Scanning Electron Microscope (SEM)

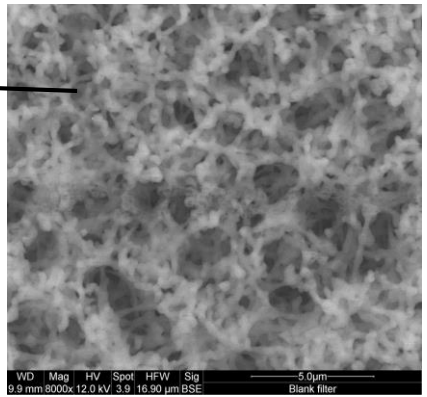
The deposition is so uniform and thin it appears the same as a blank filter



Filter with 40s Ag

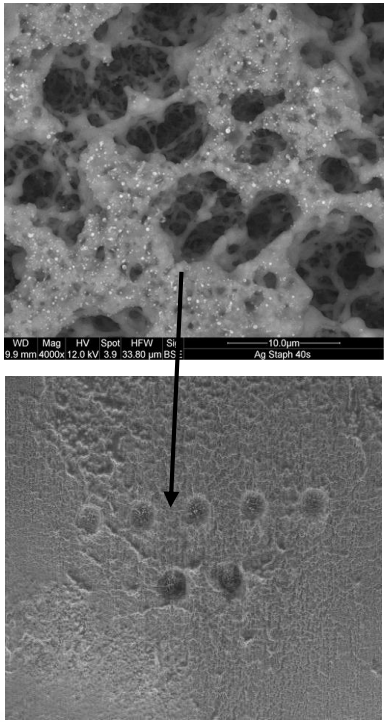


40 s deposition time Ag filter



Blank Filter

White specks = Silver nanoparticles



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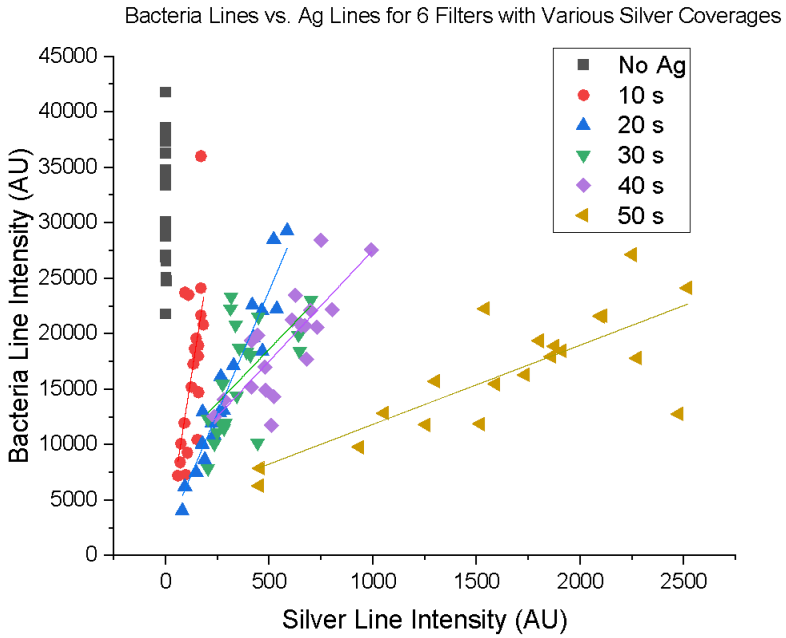
Results: Enhancement of Bacteria Spectra

Filters with more silver were not observed to have higher bacteria lines

Possible causes:

- there is not enough silver present
- the silver attenuates the laser beam before it reaches the filter



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Conclusions

- A uniform silver film was deposited as shown by SEM and LIBS
- The silver film is not disrupted by subsequent laser pulses
- No bacterial enhancement was observed regardless of deposition time

Future work

- Increase amount of silver on the filter (limited by filter performance)
- Perform pulsed laser deposition in a non-vacuum environment to produce nanoparticles
- Use a gold target instead of silver

Acknowledgements

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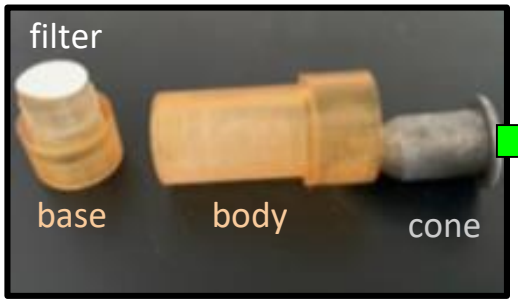
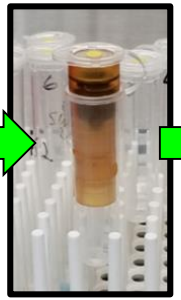
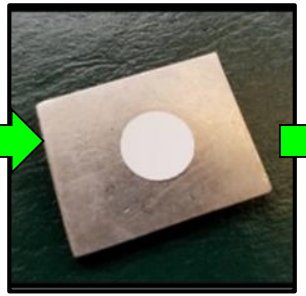
Bacterial Deposition



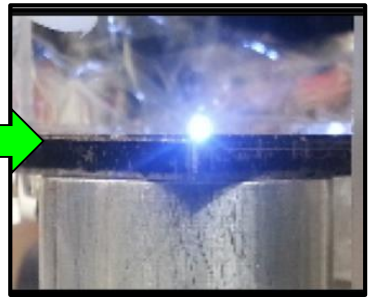
Centrifuge insert piece



Centrifugation



Sample mounted on steel piece



Sample being irradiated by laser pulse