The Use of Silver Microparticles for Spectrum Emission Enhancement During Laser-Induced Breakdown Spectroscopy of Bacterial Specimens

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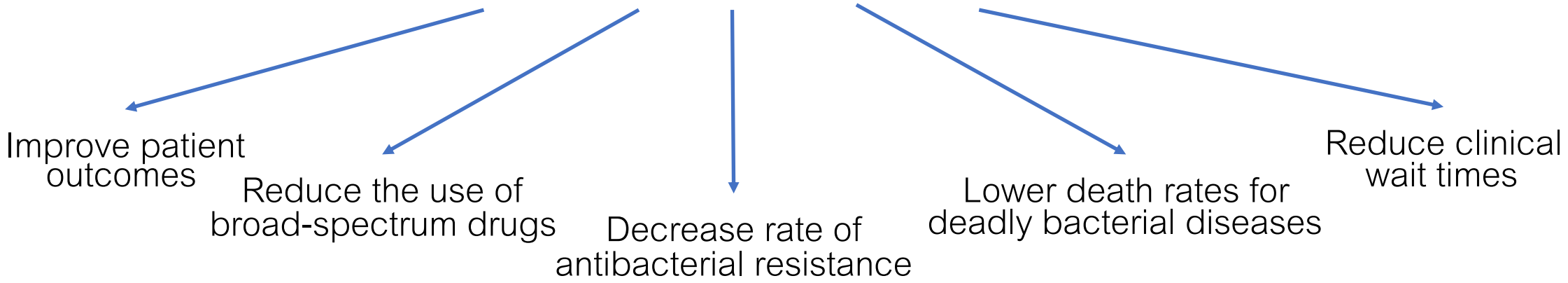
Motivation

The antibacterial resistance crisis is an ongoing global concern.

- Current methods to diagnose bacterial infections require 2-3 days
- Lack of technology for immediate diagnosis ⟶ use of broad spectrum drugs

Goal: Develop rapid technique to diagnose bacterial infection in a clinical setting.



What is LIBS?

- Laser based spectrochemical technique
- Rapidly determines elemental composition

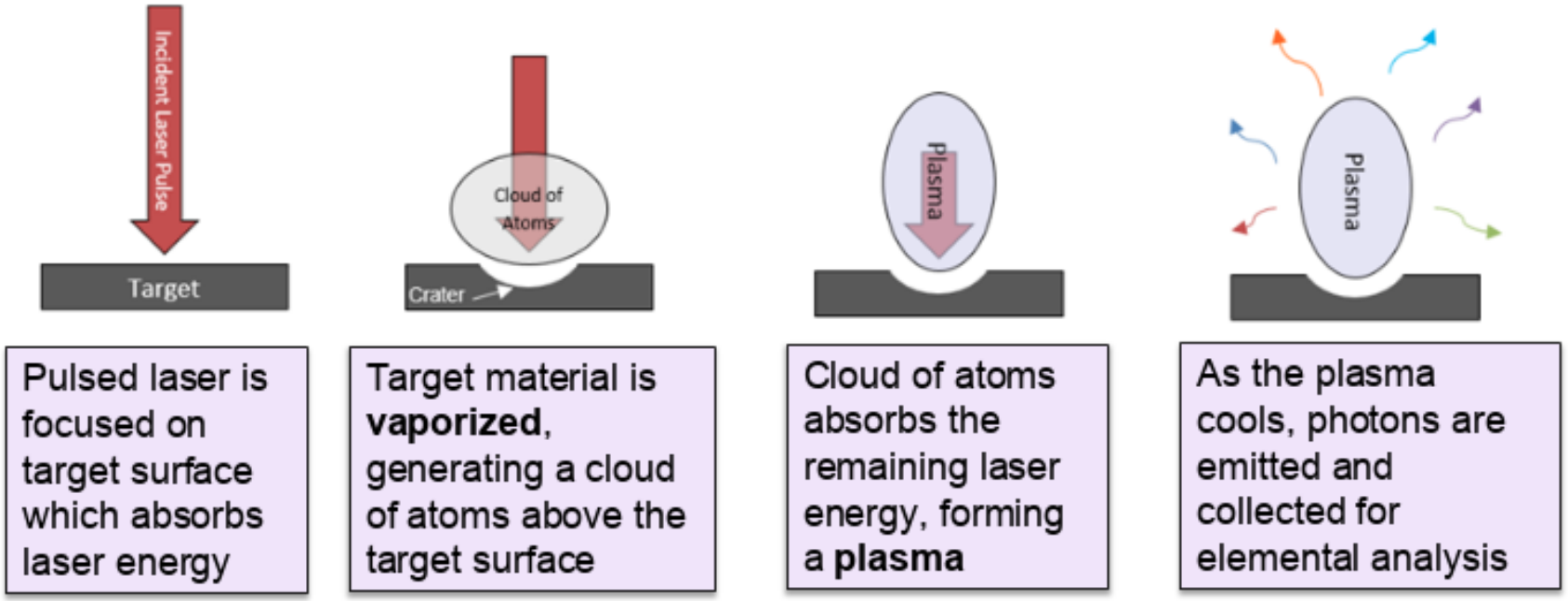


Figure 1: Schematic of LIBS process

Experimental Set-Up

- 1064 nm, 10 ns, 10 Hz
- 8 mJ/pulse at target
- Argon purge chamber
- Matched parabolic reflectors
- Echelle spectrometer

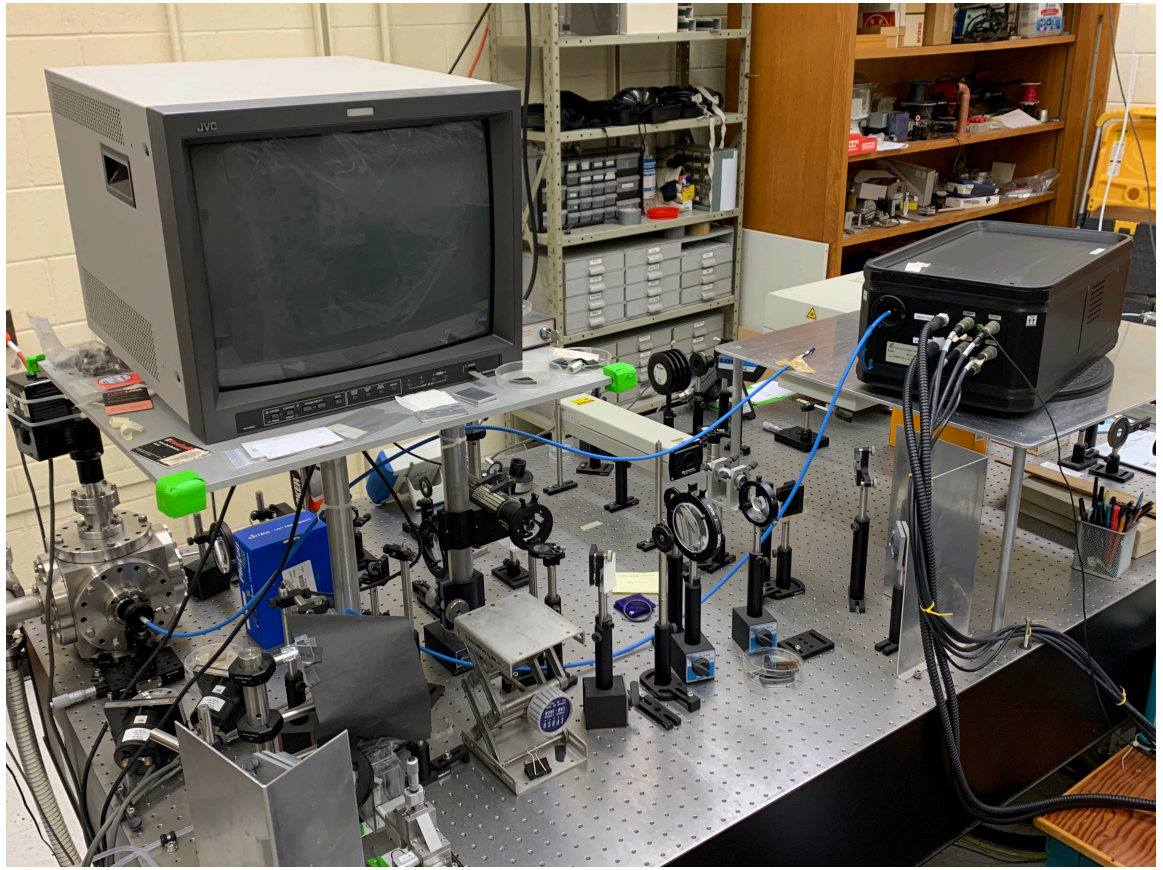


Figure 2: LIBS experimental set-up.

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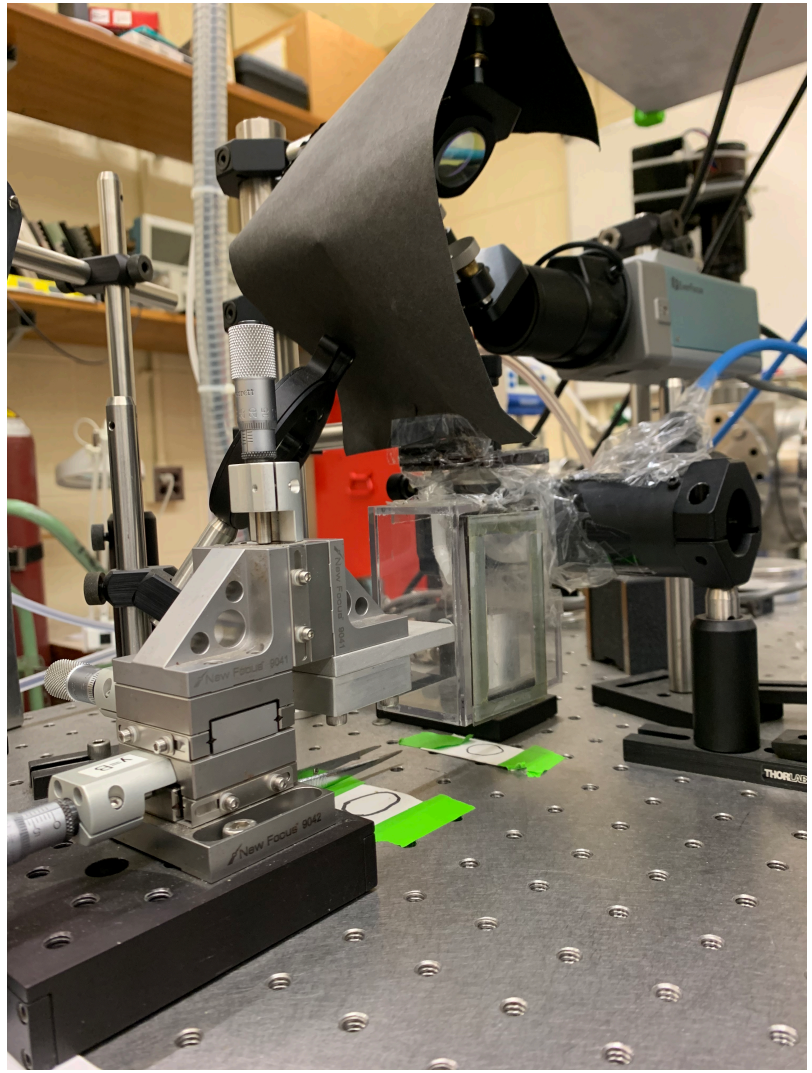
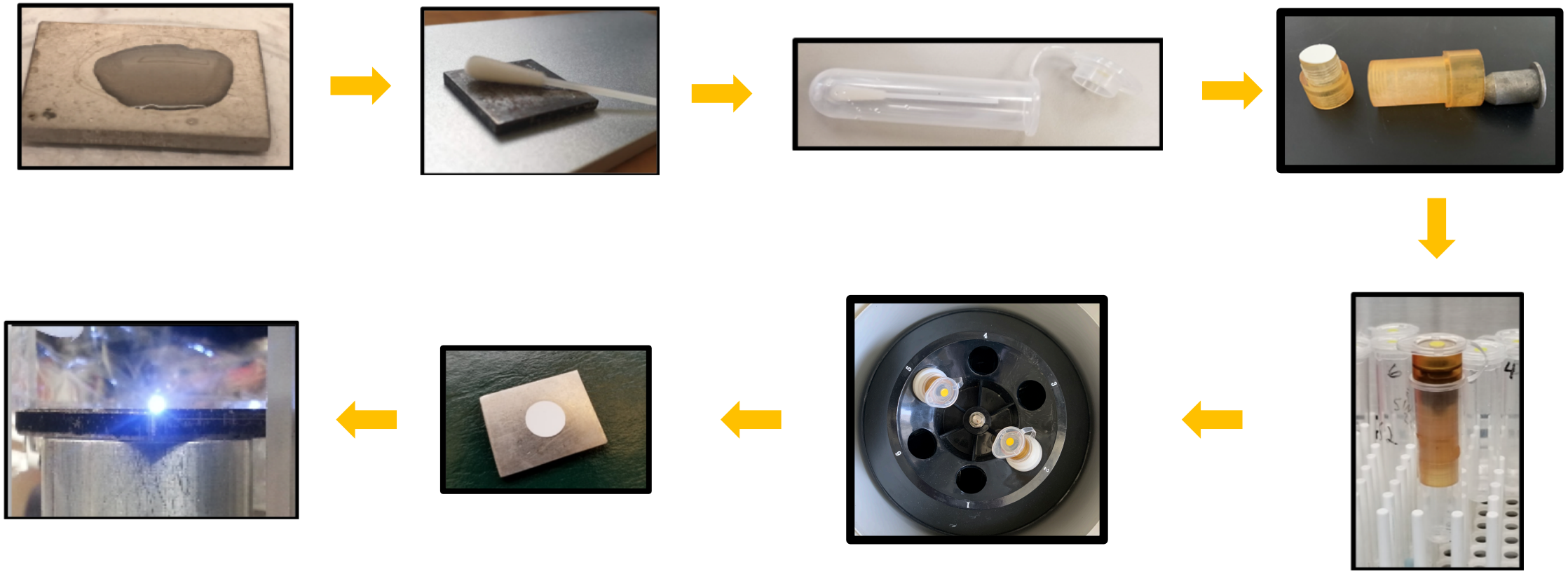


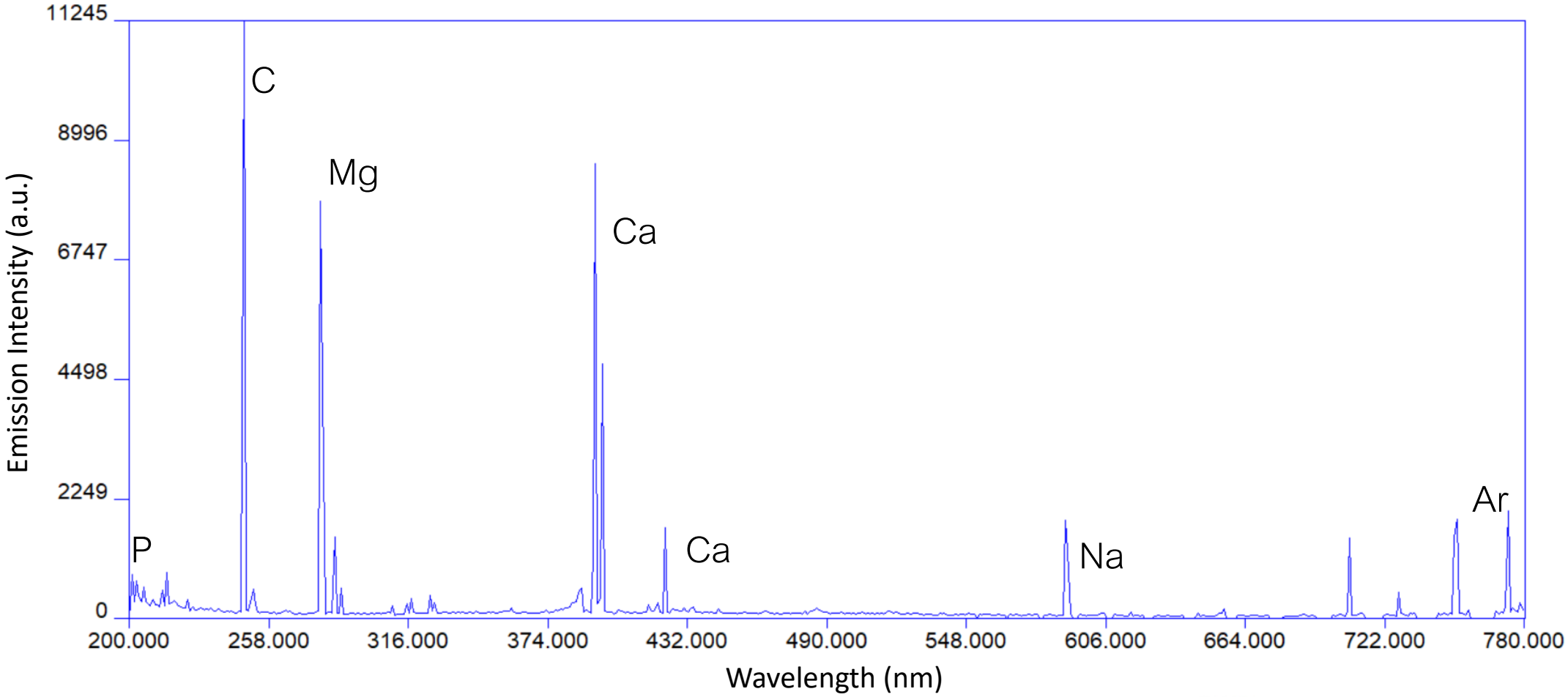
Figure 3: Argon chamber containing LIBS target

Sample Preparation



LIBS Spectrum

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



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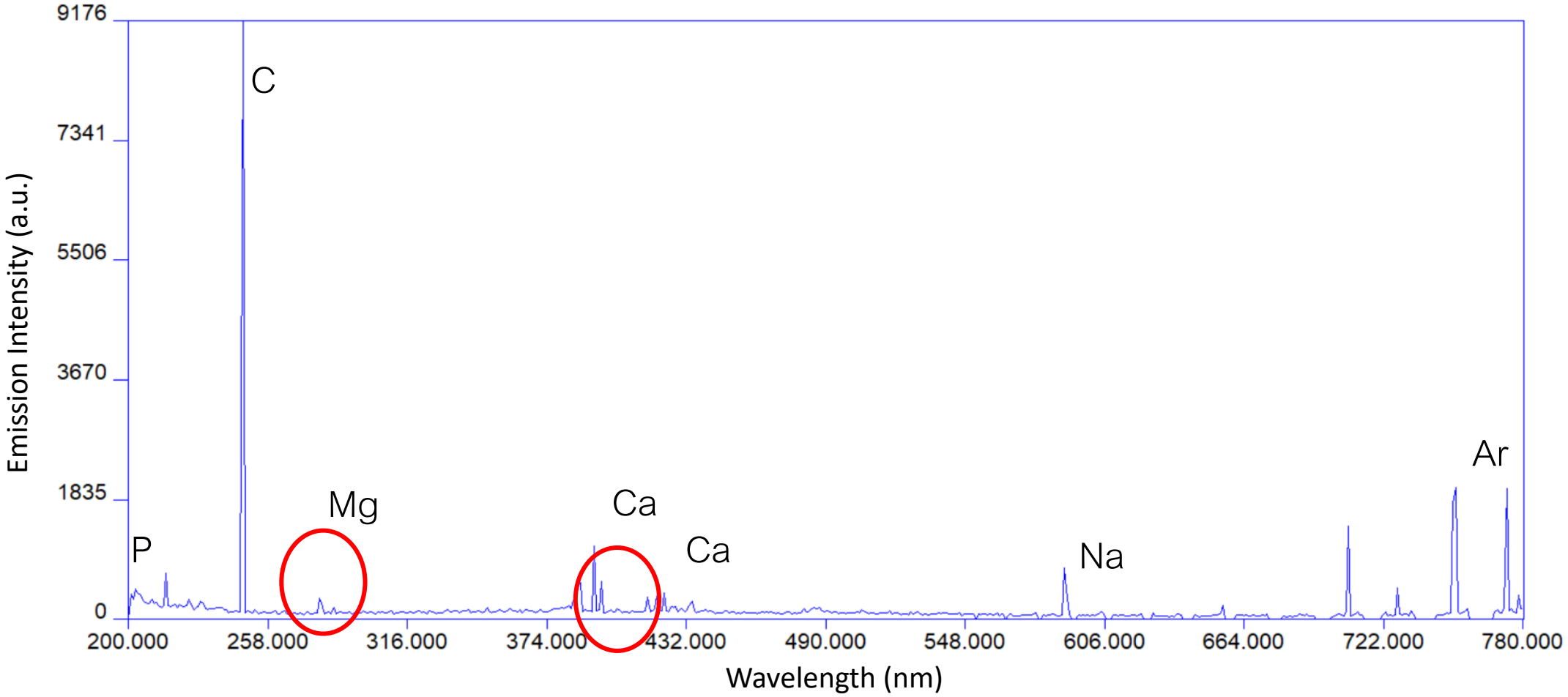

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Nanoparticles/Microparticles

Nanoparticles have been investigated to increase LIBS signal to noise ratio. [1]

- attributed to plasmon resonance
- similar to SERS

What about microparticles?

- cheaper
- easier to obtain
- has not been investigated

Figure 5: Bottle of silver microparticles.

1. De Giacomo, A., Dell'Aglio, M., Gaudiuso, R., Amoruso, S., & De Pascale, O. (2012). Effects of the background environment on formation, evolution and emission spectra of laser-induced plasmas. *Spectrochimica Acta Part B: Atomic Spectroscopy*, *78*, 1-19. https://doi.org/10.1016/j.sab.2012.10.003

Construction of Chamber

Chamber was built to reproducibly disperse microparticles evenly:

- Hollow cube with opening
- Filter Holder
- Chamber stopper

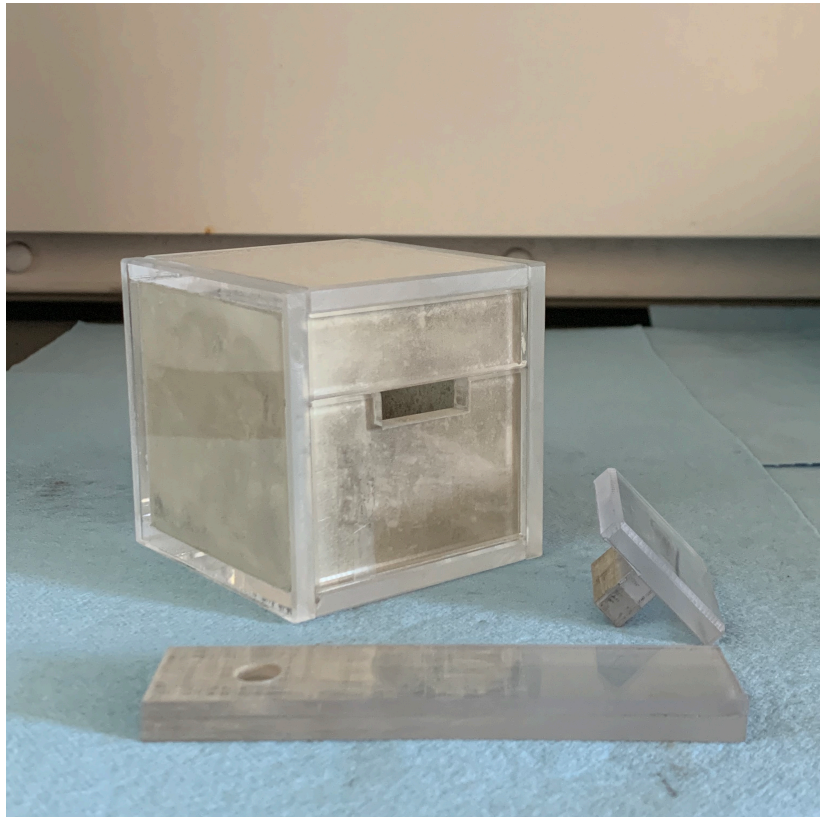

Figure 6: Chamber to disperse microparticles with stopper and filter holder.

Microparticle Deposition Technique

- Optimization of three times to achieve even and reproducible dispersal:
  - **Shaking time** for particles to disperse in the chamber
  - **Waiting time** for the filter holder to be be inserted
  - **Settling time** for the dispersed microparticles to settle on the filter

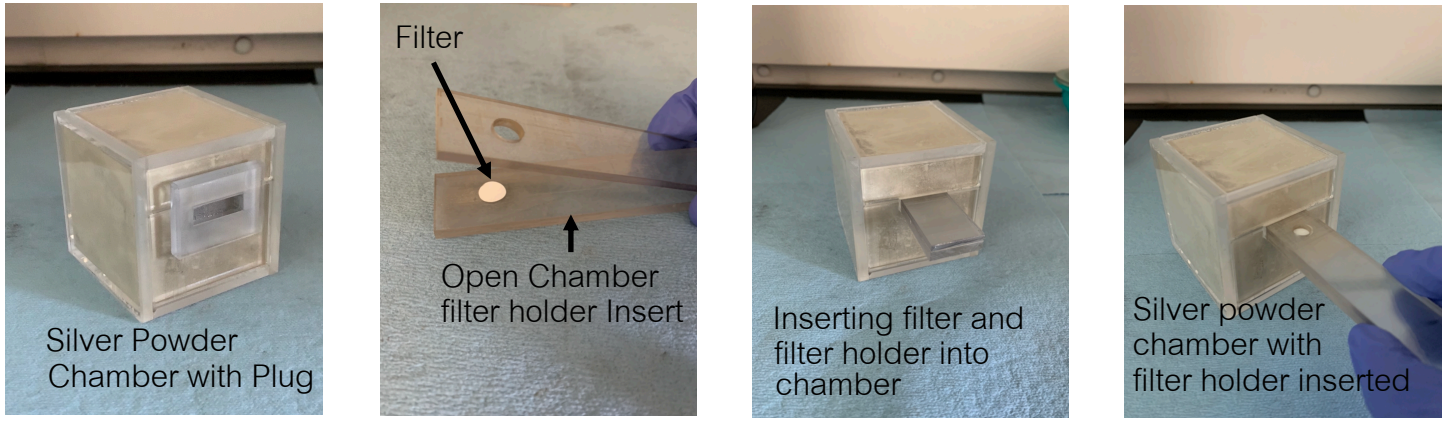

Figure 7: Pieces of microparticle chamber and inserting filter holder into chamber.

Microparticle Deposition Technique

- Experiment design: Filters weighed before and after five settling times of 10 s, 20 s, 30 s, 40 s, and 50 s
  - 10 seconds: not enough time for microparticles to settle on filter
  - 50 seconds: too many microparticles settling on the filter
  - 30 seconds was optimal

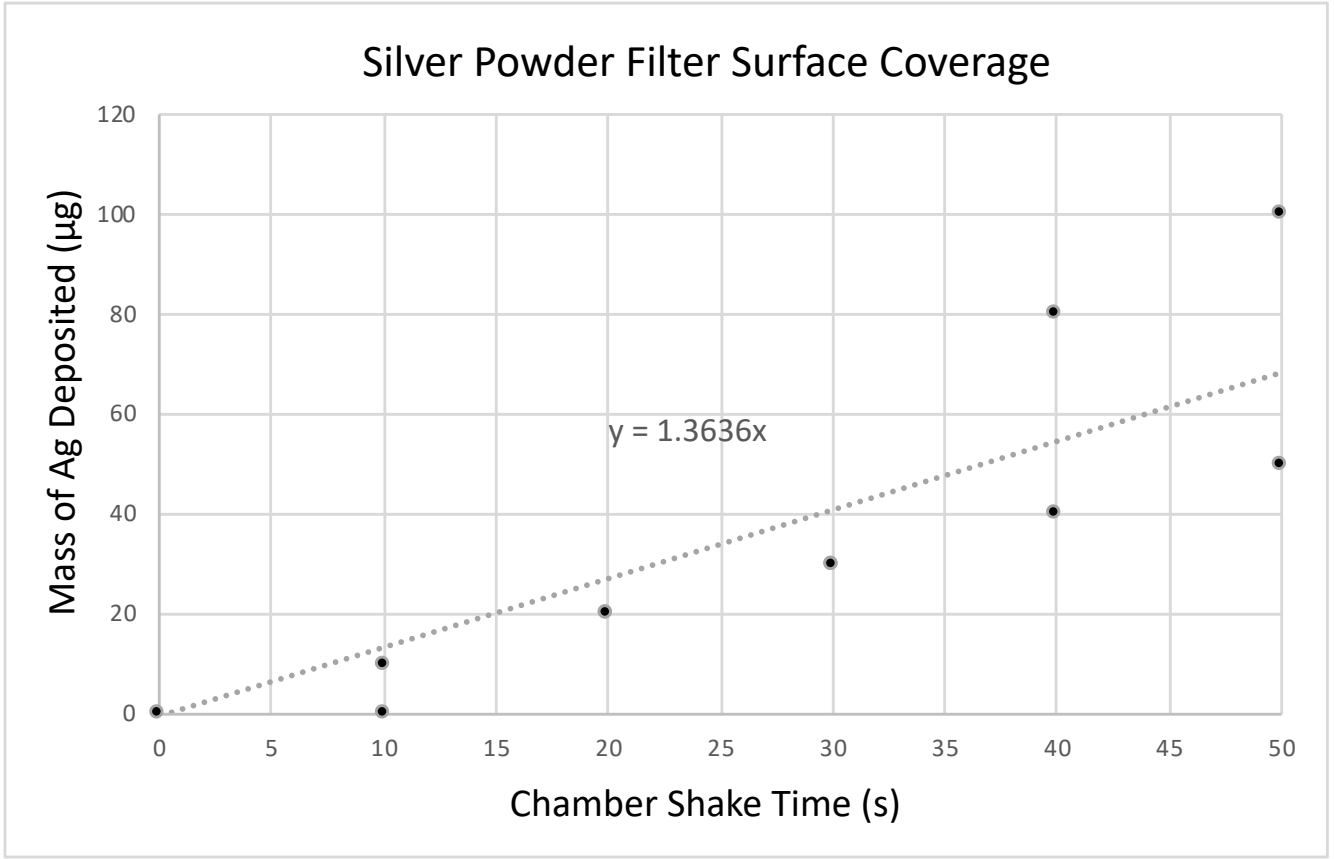

Figure 8: Mass of deposited silver microparticles plotted against settling time with line of best fit.

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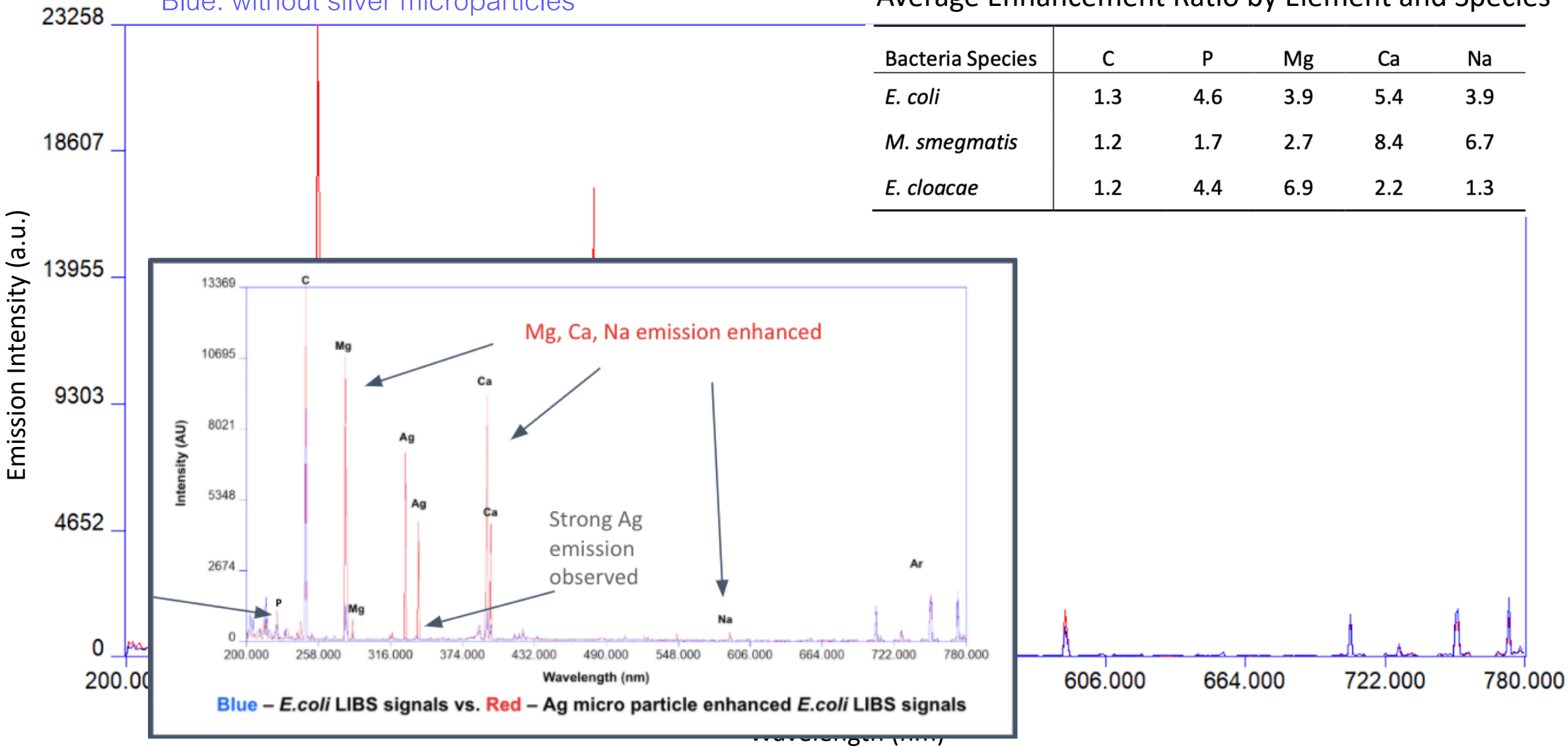
Red: with silver microparticles

Blue: without silver microparticles

Average Enhancement Ratio by Element and Species

Bacteria Species	C	P	Mg	Ca	Na
E. coli	1.3	4.6	3.9	5.4	3.9
M. smegmatis	1.2	1.7	2.7	8.4	6.7
E. cloacae	1.2	4.4	6.9	2.2	1.3



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Conclusion

- With the construction of a chamber we were able to evenly disperse silver microparticles on a filter
- 30 second settling time, 39 μg $\pm$ 17 μg
- 75 micron-diameter ablation crater $\rightarrow$ 3.3 ng/ laser shot
- Average enhancement ratio of 4-5
- microparticle enhancement due to increased plasma temperature and density (free electrons contributed from microparticles not resonance)

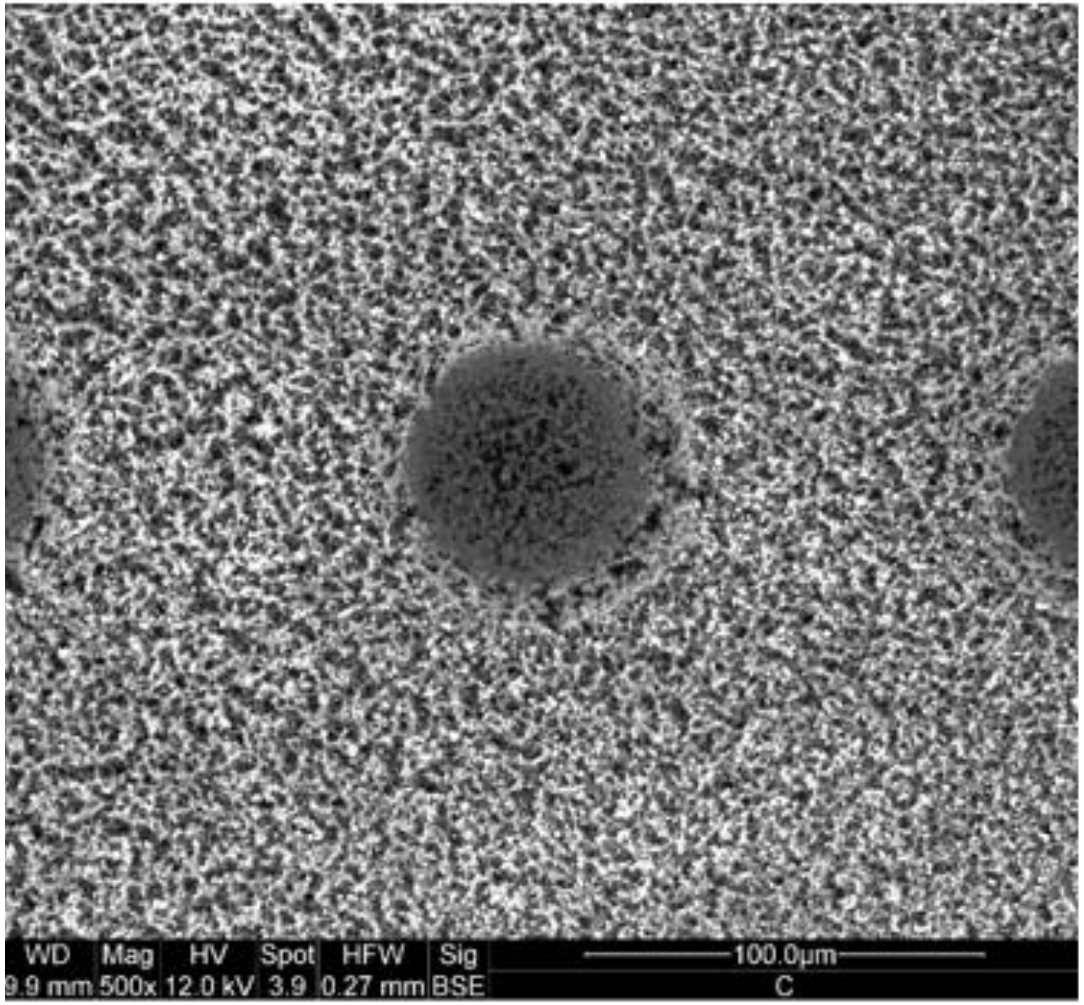

Figure 10: SEM Image of filter with silver microparticles surrounding ablation craters.

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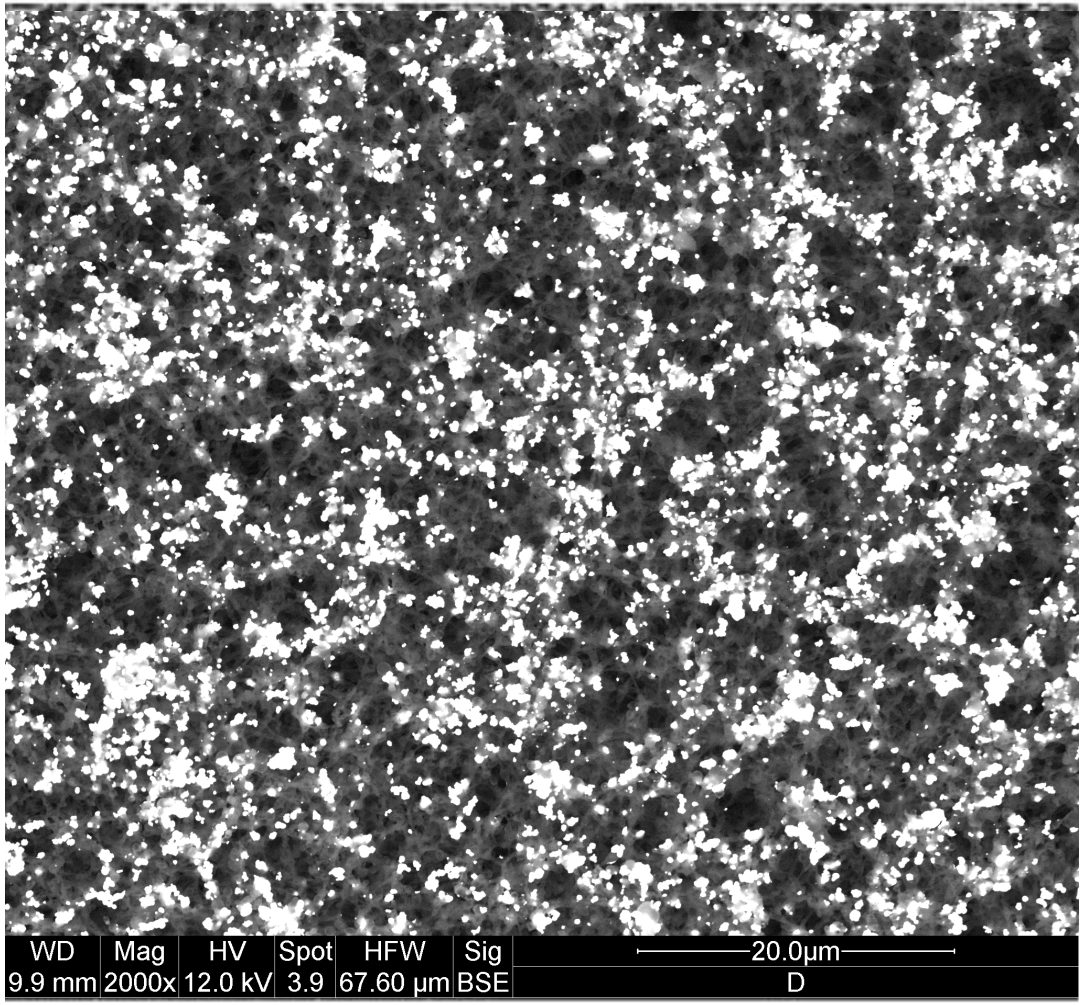

Figure 11: SEM Image of filter with silver microparticles.

Future Work

- Investigate if nanoparticles are a more efficient solution to boosting spectrum signals
- Investigate other metal microparticles
- Improve method for microparticle deposition in chamber
- More accurate investigation of settling and waiting times

Figure 12: Silver microparticle brim on filter.

Thank You