Rapid, Accurate and In-Situ Quantification of Lead for Drinking Water Applications

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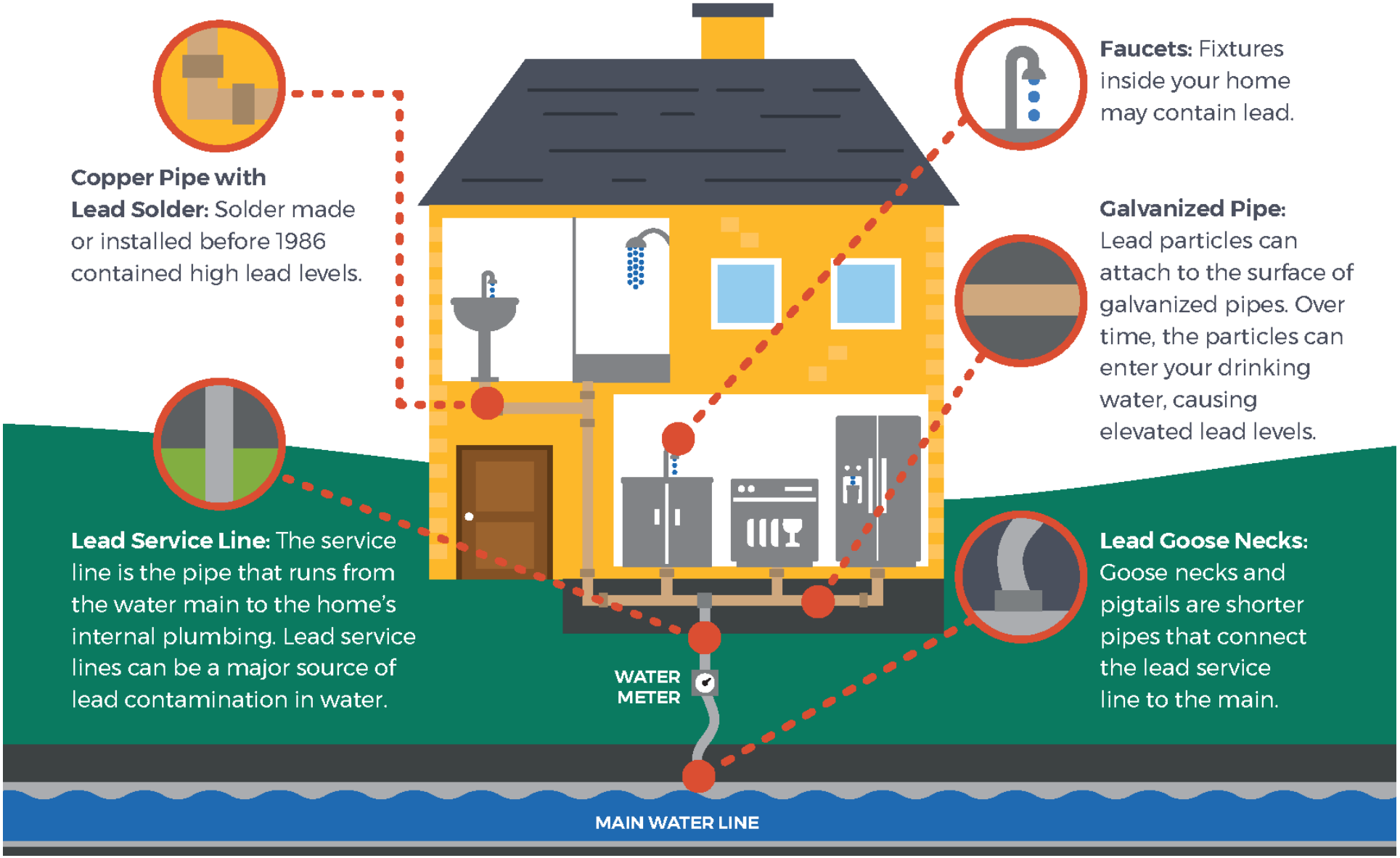
Definitive results. Decisive actions.

Source: AJ+, Al Jazeera Jan 8th 2016

Sources of **LEAD** in Drinking Water



Copper Pipe with Lead Solder: Solder made or installed before 1986 contained high lead levels.

Faucets: Fixtures inside your home may contain lead.

Galvanized Pipe: Lead particles can attach to the surface of galvanized pipes. Over time, the particles can enter your drinking water, causing elevated lead levels.

Lead Service Line: The service line is the pipe that runs from the water main to the home's internal plumbing. Lead service lines can be a major source of lead contamination in water.

Lead Goose Necks: Goose necks and pigtails are shorter pipes that connect the lead service line to the main.

Current monitoring procedure

GC/MS :

- Expensive
- Skilled labor required
- Dedicated system and team
- Time consuming
- Not deployable

Colorimetric assay:

- Not quantitative
- No speciation
- Interferences

Raman spectroscopy

1920s 

1990s 

2000s 

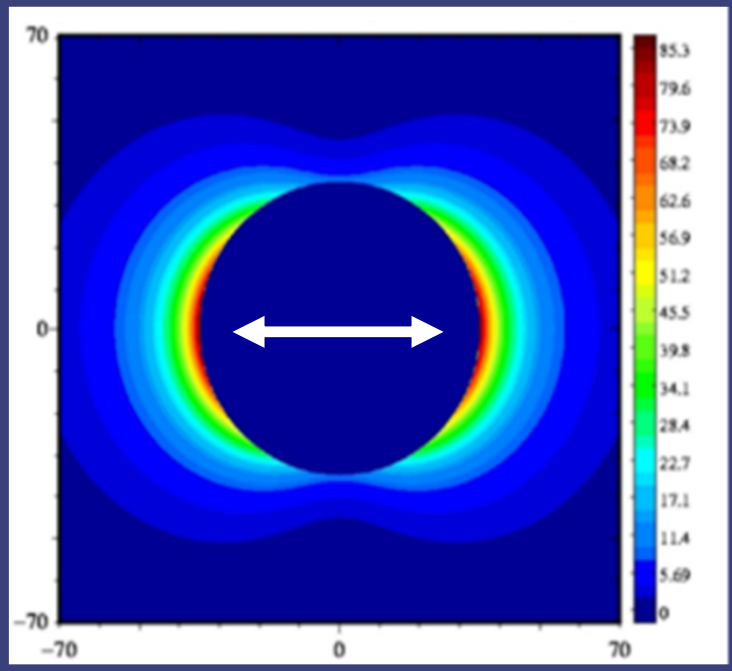
Optical telecommunications drove technology needed for portable, in-line, and compact Raman spectroscopy

But Raman is weak

- $\sigma_{NR} \sim 10^{-30}$ cm^2/molecule
- **1 in 10 million photons**

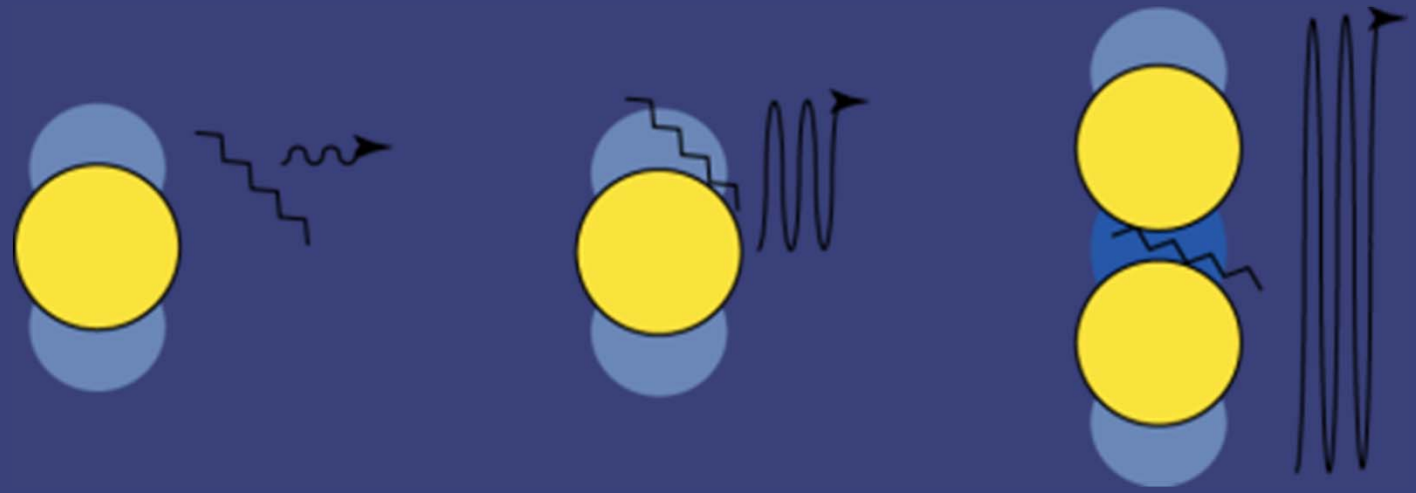
Surface-Enhanced Raman Scattering (SERS)

- At a rough metal surface
  - Increased field intensity
  - Which means increased Raman signal
- SERS activity quantified by Enhancement Factor
  - EF range: 1 - 10^{10}



Multi-particle effects

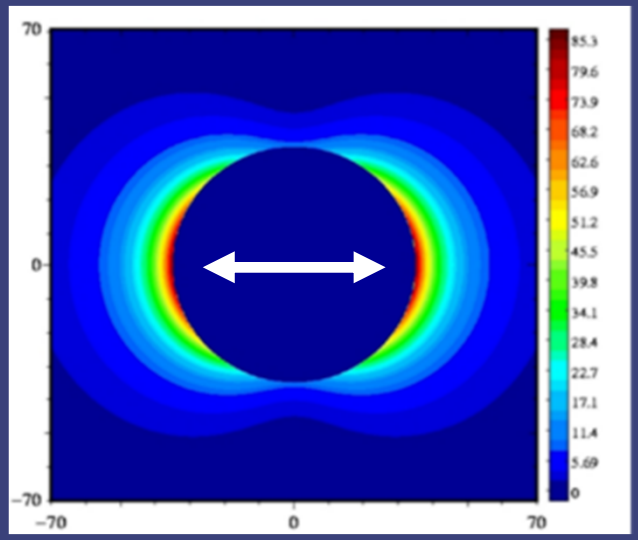
Nanoparticles (gold/silver) enable **ppb-level** detection



"Hot Spots"

Analyte / substrate interaction

- The SERS effect requires an interaction at the surface – within a couple nanometers



- Analyte must
  - Interact with the substrate
  - Interact with a linker molecule
  - Change the properties of another SERS-active molecule
- Gold nanoparticles: many options to control surface properties

Raman spectrometer equipment

Instrumentation

- 785-nm, 60-mW at substrate
- Cooled (-20°C) CCD detector
- 200-2000-cm^{-1}, 4-cm^{-1} resolution

Why not widely used?

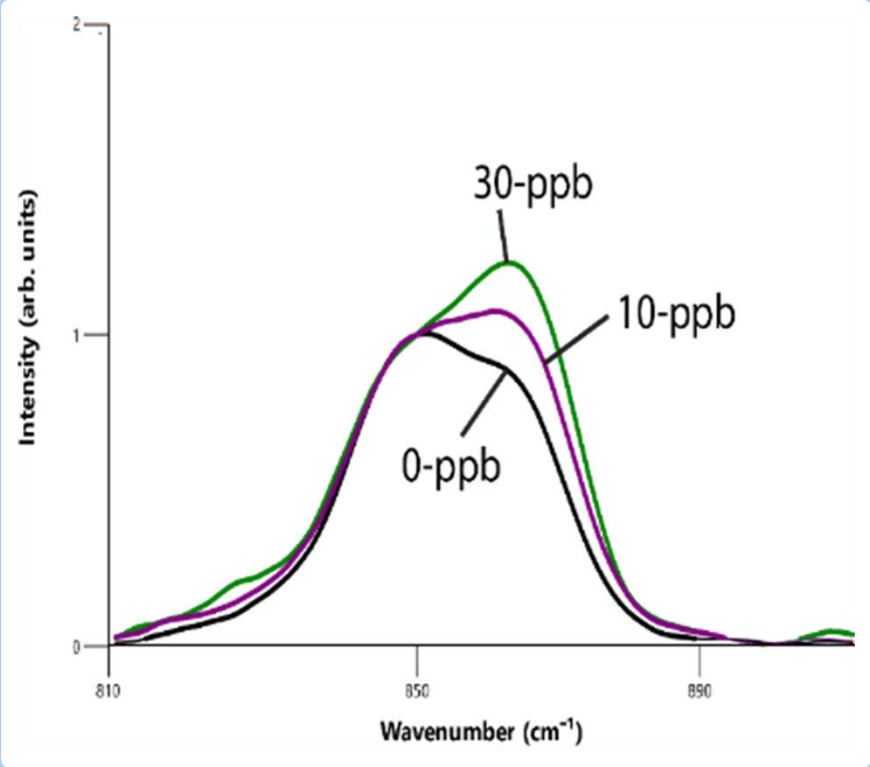
- Achilles' heel: reproducibility
  - Variations in substrate properties
  - Stochastic nanoparticle alignments
- One reviewer: "SERS doesn't work"

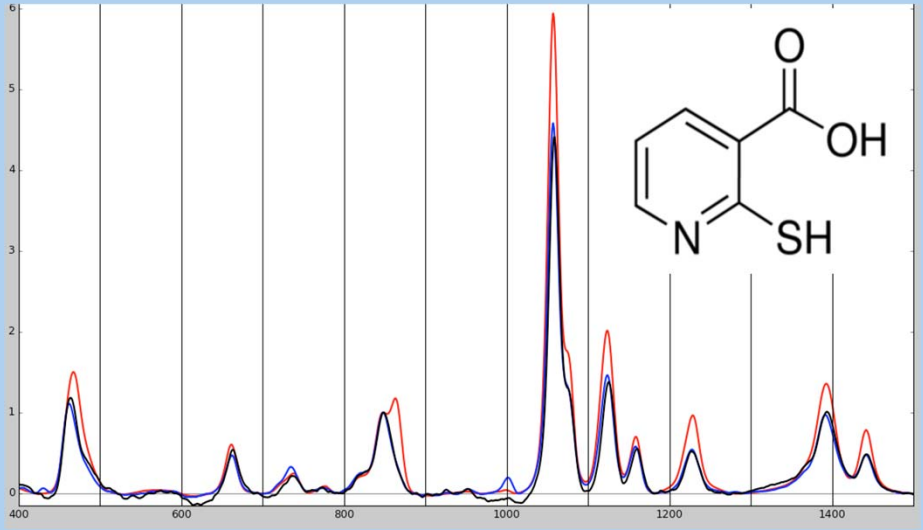
OndaVia has made SERS a quantitative, repeatable method using:

- Internal standards
- Nanoparticle structure
- Surface modifications
- Intelligent software

Surface modification using 2-mercaptoisonicotinic acid *

* Tan E., Yin P., Lang X., Zhang H., L. Guo. A novel surface-enhanced Raman scattering nanosensor for detecting multiple heavy metal ions based on 2-mercaptoisonicotinic acid functionalized gold nanoparticles (2012), *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy,* Vol 97, p1007-1012.





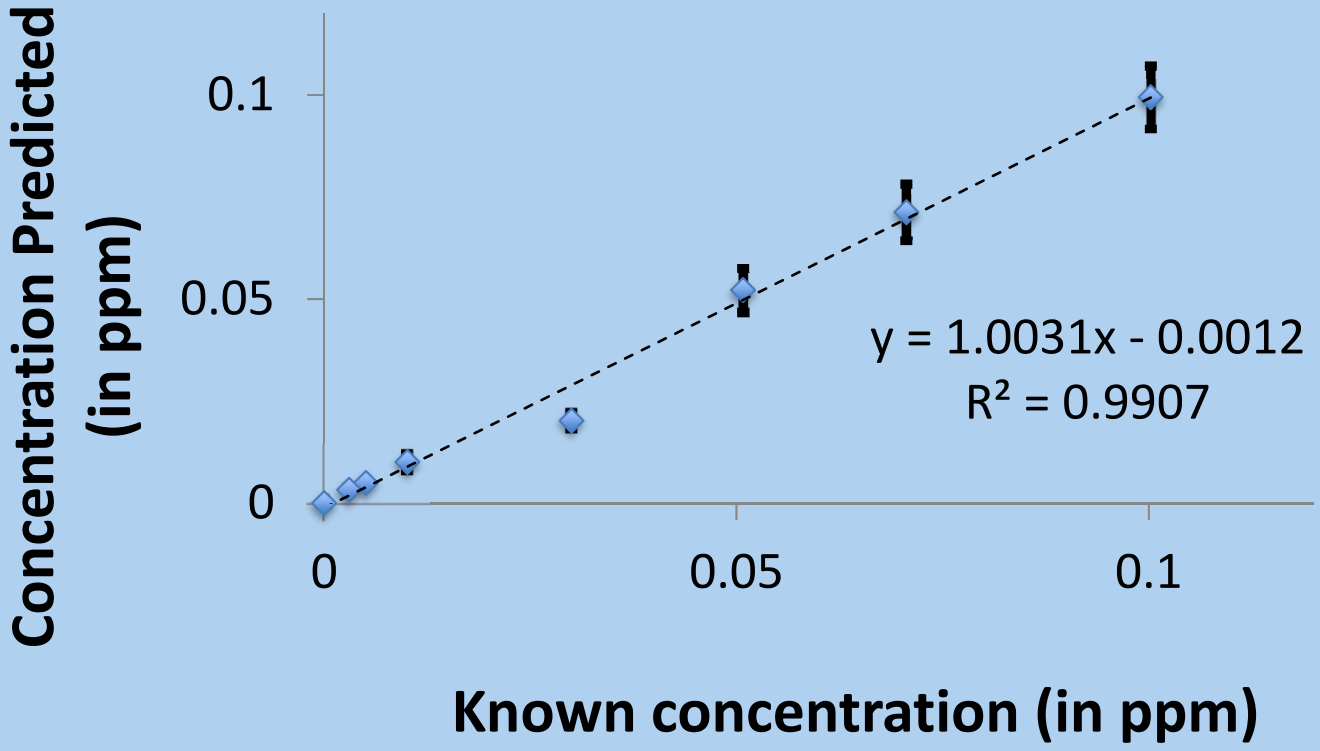
Quantitative SERS

- Calibration and interferences:
  - Standard Addition (lead and sodium sulfide)
  - Accuracies of better than 10% reported with presence of competing ions

- Simple Standard Operating Procedure allows for quick analyses:
  1. Prepare 6 vials of 0.9 ml of sample
  2. Add 0.1 ml of DI, 25, 50, 75, 100 ppm of Lead and 1 ppm of sulfide in
  3. Add to each vials 40 ul of a 2-MNA with NaCl solution
  4. Wait 10 min
  5. Mix with Nanoparticles
  6. Measure each vial

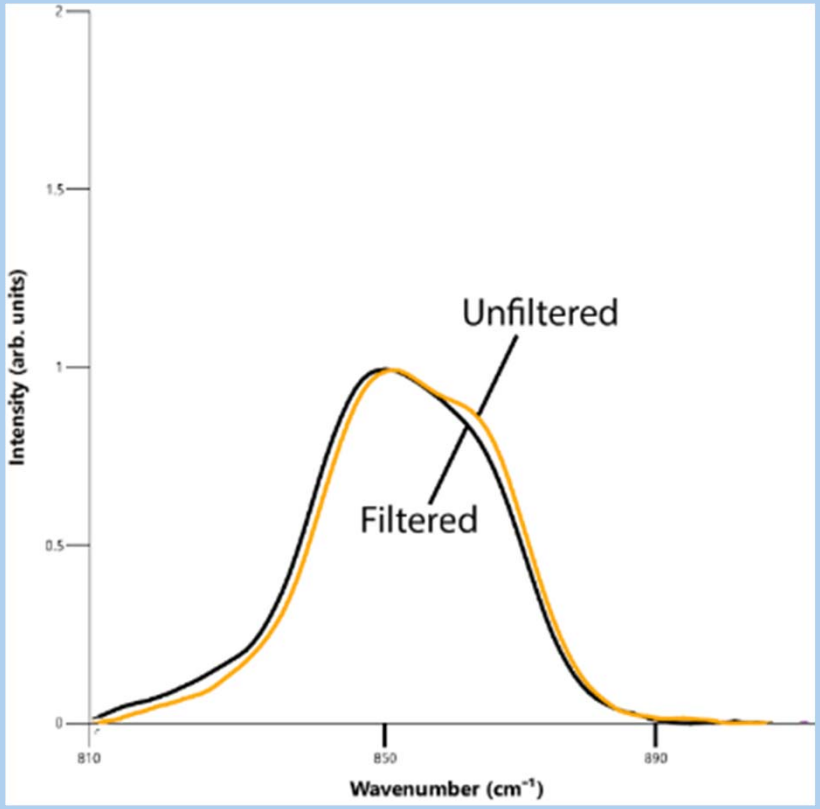
Lab Standard Calibration Curve

- Wide dynamic range of interest 0 - 100ppb
- Accurate quantification better than 10%.



Quantitative analysis in real world samples

- Filtered vs. Unfiltered



Tap water expected	Averages measured
8.3	8.8
4.5	4.2
2.2	2.3
1.1	1.3
0.00	0.06

Ultra compact solid state spectrometer

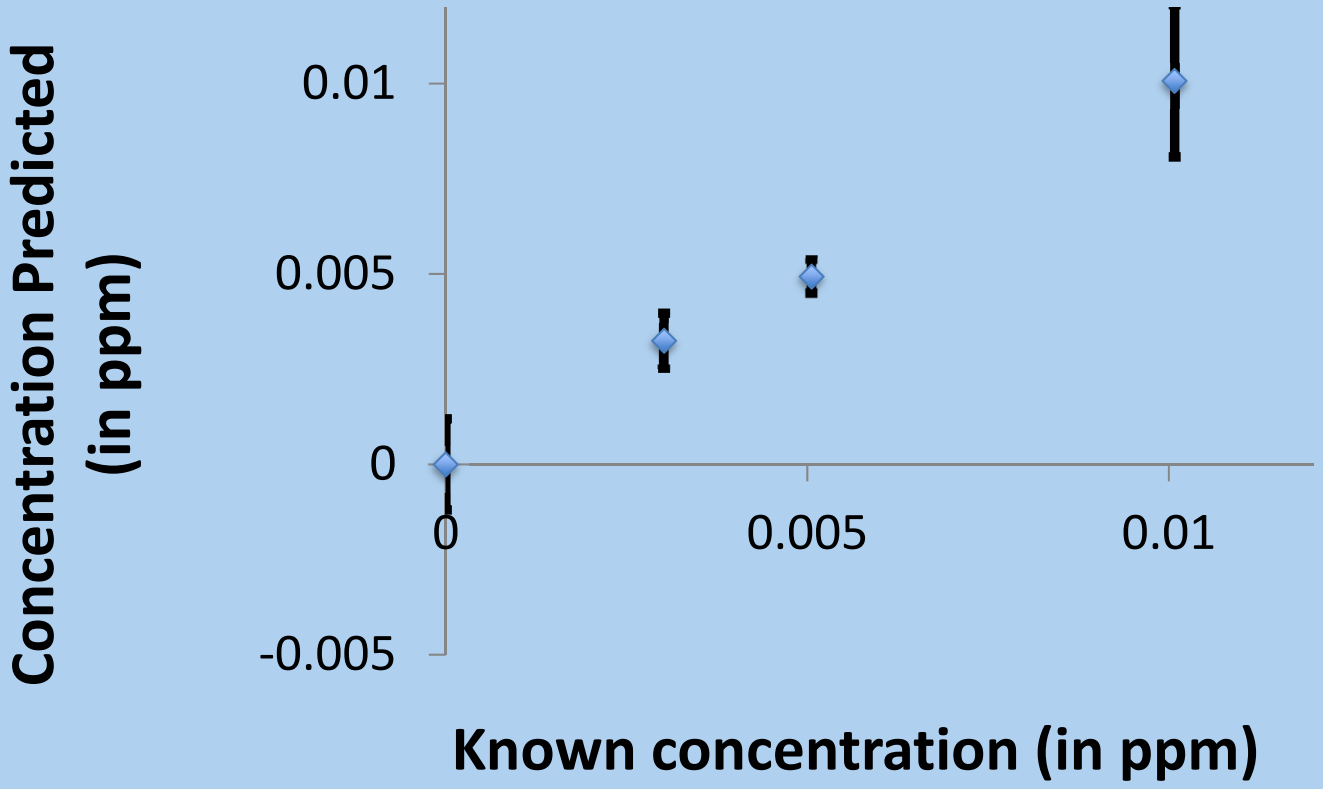
Instrumentation

- 785-nm, 50-mW,

  10 um slit, No temp control
- APS-CMOS Detector
- 200-2000-cm^{-1}, 5-cm^{-1} resolution

Lab Standard Calibration Curve

- Accurate quantification better than 10%.



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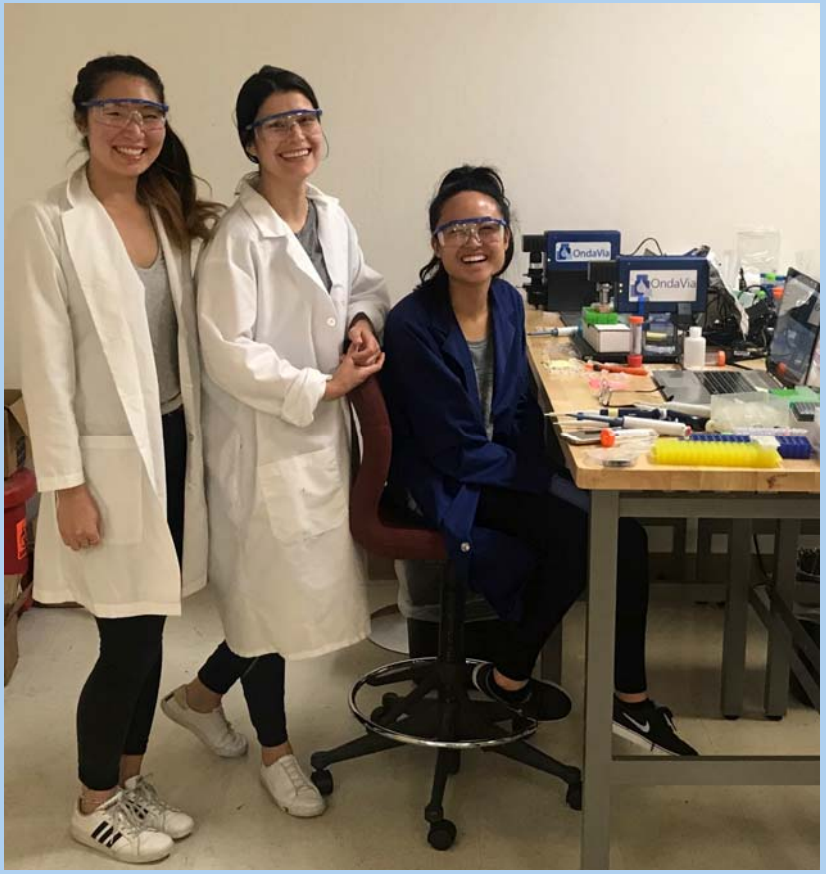

And to…

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