COVALENT METROLOGY

Welcome

COVALENT METROLOGY

LASER ABLATION INDUCTIVELY COUPLED PLASMA MASS SPECTROSCOPY: NOT JUST ROCKS

SPEAKER:

Lucas Smith
Director of Business Development for the Americas,
Teledyne CETAC

February 10, 2022 | 11am PT

TELEDYNE CETAC TECHNOLOGIES
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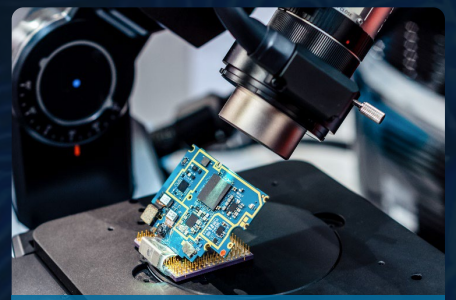
COVALENT METROLOGY

COVALENT METROLOGY

Silicon Valley-based analytical labs and platform delivering quality data and expert analysis for advanced materials and device innovation



Comprehensive Solutions Stack

50+ cutting-edge instruments, offering 100+ Techniques

Analytical Services

Advanced Modeling

Method Development

Temp. Staffing Solutions

Affordable and Fast

Fast Turnaround Times, No Expedite Fees

Volume Savings

Instant Access to Data and Reports in Secure Portal

Flexible Business Model

Custom Consulting Solutions and Certified Onsite Support

Training and Certification on Instrumentation

Co-op and Tool-Share Opportunities

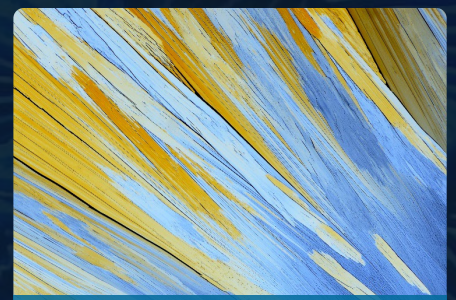
Laboratory Audits

Rich Network of Partnerships

Rigaku, Anton Paar, ThermoFisher Scientific, Asylum Research an Oxford Instruments company, Keyence, J.A. Woollam, TA Instruments, PVA TePla, Teledyne CETAC Technologies Everywhereyoulook, Horiba Scientific, Digital Surf

Partner to World's Leading Instrument Manufacturers and Labs

Expanding Instrumentation, Lab Connections and Learning



Who We Are, Who We Serve

500+ Clients, 40-60 Added / Quarter

50+ People, 14 PhDs

Cutting-edge Analytical Capabilities

Lab Location: Sunnyvale, CA

Covalent Technical Groups and Organization

COVALENT METROLOGY

PCBA, Semiconductor, and Electronic Device Metrology & Failure Analysis

- DPA / Mechanical Cross-section
- Dye & Pry Test
- EBIC / OBIC failure analysis
- Hot Spot Detection
- IR Imaging / Emission Microscopy
- NIR Imaging
- Root-Cause Failure Analysis

Electron Microscopy and Scanning Probe Microscopy

- AFM & Advanced AFM Modes (EFM, KPFM, MFM, PFM)
- Scanning Acoustic Microscopy (SAM)
- SEM (+ EDS)
- FIB-SEM (+ EDS)
- S/TEM (+ EDS / + EELS)
- Nano-indent / Nano-scratch

Optical Microscopy & Spectroscopy

- Chromatic Aberration
- Digital Optical Microscopy
- FTIR and ATR-FTIR
- Laser Scanning Confocal Microscopy
- Spectral Ellipsometry
- UV-Vis-NIR Spectroscopy
- White Light Interferometry

X-Ray Characterization

- X-Ray Diffraction (XRD)
- X-Ray Reflectometry (XRR)
- Micron-spot ED-XRF
- WDXRF
- Micro-computed X-ray Tomography (Micro-CT)
- 2D X-ray Inspection & X-ray Radiography

Elemental / Chemical Composition Analysis

- EPMA
- GD-OES
- GC-MS
- ICP-MS and LA-ICP-MS
- Raman Microscopy & Spectroscopy
- NMR (1D or 2D; solid / liquid)

Particle Analysis

- Dynamic Light Scattering (DLS)
- Laser Diffraction Particle Size Analysis (PSA)
- Particle Zeta Potential

Material Property Characterization

- DSC
- DMA & TMA
- Rheometry
- TGA
- Surface Zeta Potential
- Porometry / Porosity
- Gas Adsorption
- Gas Pycnometry
- Foam Density
- Tap Density

Surface Spectroscopy Analysis

- Dynamic-SIMS
- ToF-SIMS (Static-SIMS)
- Ion Scattering Spectroscopy (ISS)
- Ultraviolet Photoelectron Spectroscopy (UPS)
- X-ray Photoelectron Spectroscopy (XPS)

Covalent Partners

TELEDYNE CETAC TECHNOLOGIES
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- Teledyne CETAC is a global leader in the development of advanced sample-introduction and sample-handling equipment for elemental analysis
- Partnership with Covalent announced in Fall, 2021 to:
  - Jointly investigate and develop new applications for Teledyne's element analysis tools
  - Bring cutting-edge analytical chemistry solutions to Covalent clients
- First Teledyne instrument installed at Covalent is the *Iridia Laser Ablation System*

Other Covalent Partners

Rigaku
ThermoFisher SCIENTIFIC
Anton Paar
KEYENCE
J.A. Woollam
PVA TePla
Asylum Research an Oxford Instruments company
TA Instruments
Digital Surf
HORIBA Scientific

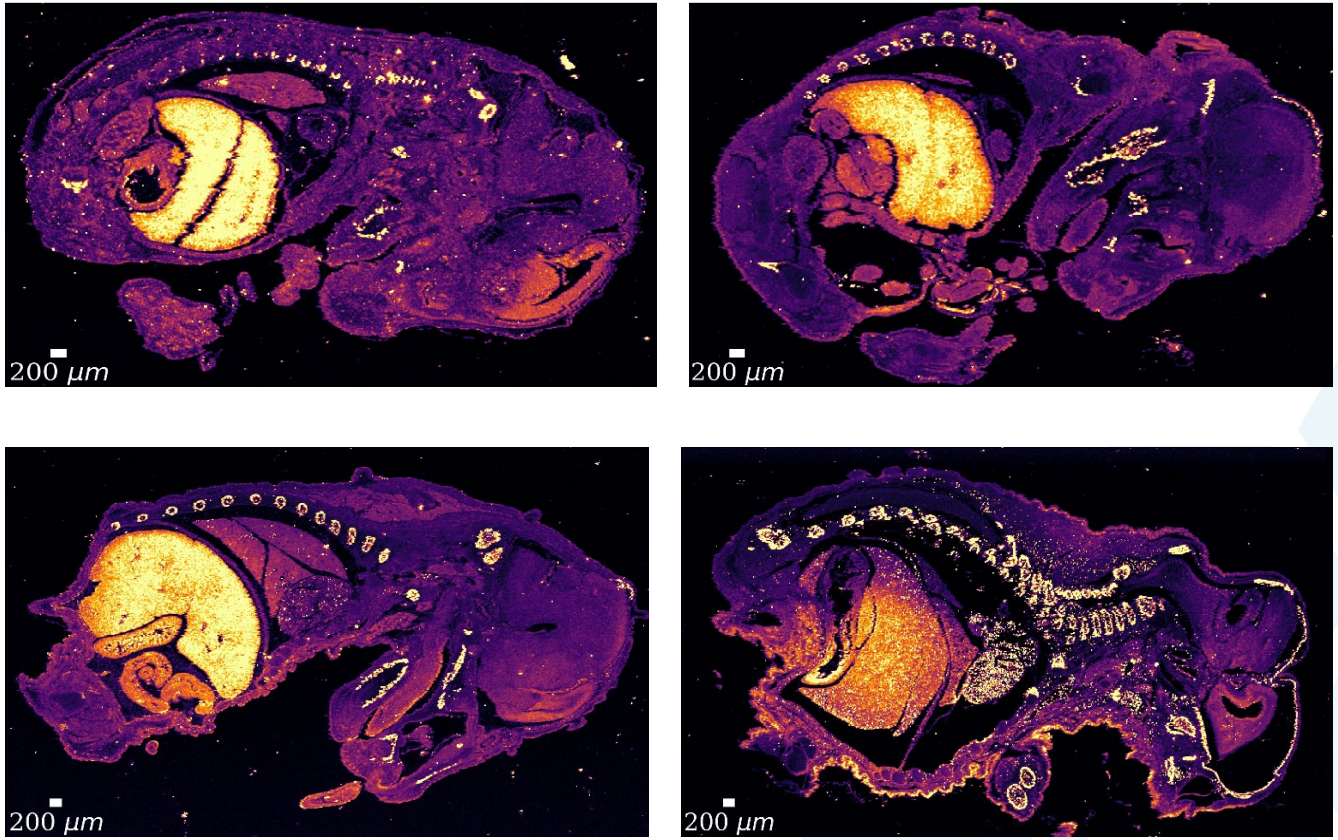
Lucas Smith

Director for Business Development for the Americas,
Teledyne CETAC

- Degrees in Microbiology and Biochemistry from The University of Michigan (Go Blue!)
- Manages laser opportunities and customer relationships throughout the Western Hemisphere
- Member of the Teledyne team for just over 7 years
- Prior to joining Teledyne Lucas held a variety of roles at
  - Pfizer Pharmaceuticals
  - LECO Corporation
- Performed mobile analytics for the US Navy & Airforce

Content

- What is laser ablation ICP-MS?
- Why laser ablation (advantages vs disadvantages)
- Laser ablation vs other analytical techniques
- Spatial Analysis
- Volumetric Ablation
- Application examples
- Q&A



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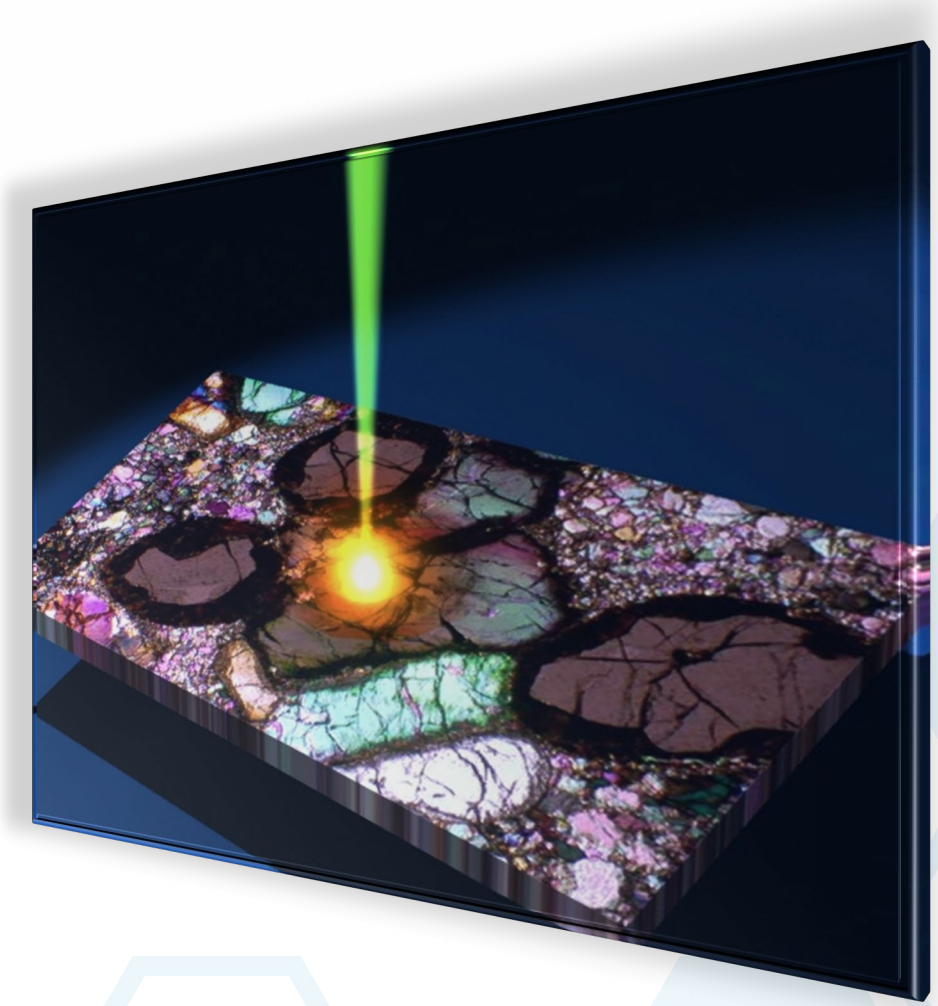
What is Laser Ablation?

- A laser ablates a solid sample and delivers material directly to the ICPMS for elemental analysis
- Eliminates dissolution step and most sample prep
- Maintain spatial resolution



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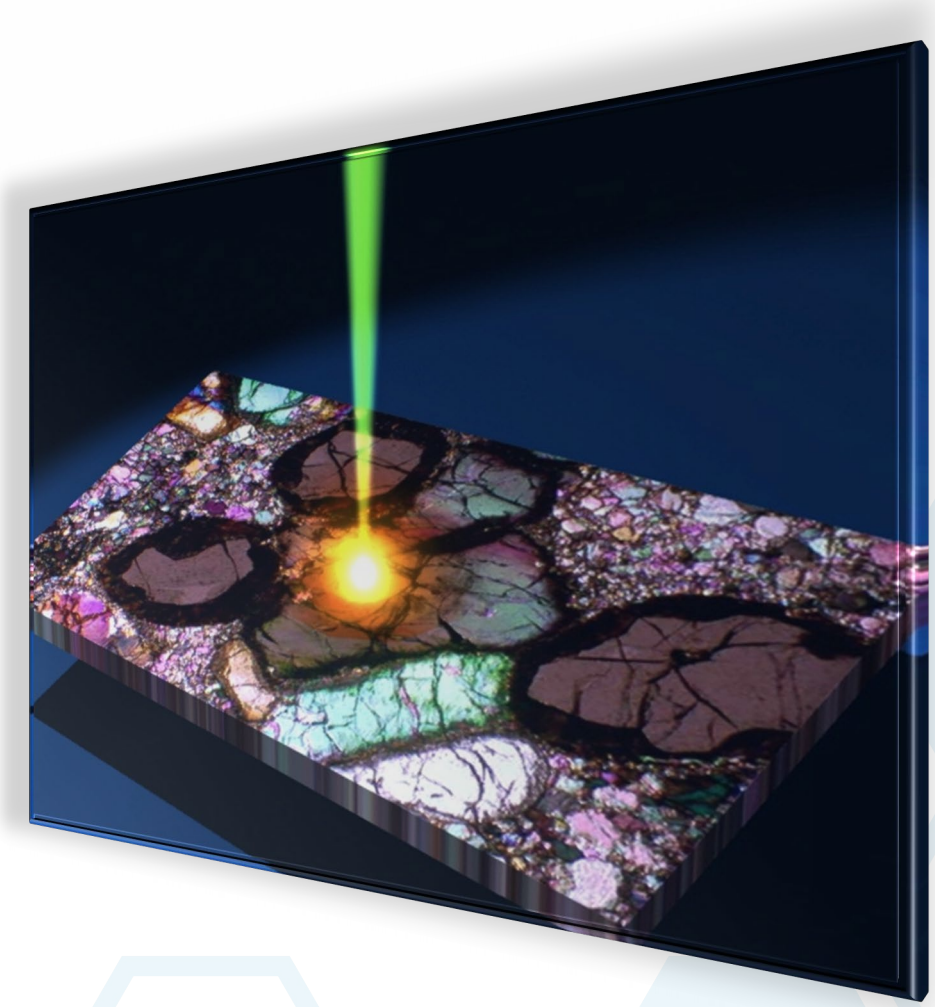
Why Laser Ablation?

- Rapid, sensitive multi-element detection at sub-ppm levels.
- Eliminates (most) labor-intensive sample preparation
- Can sample virtually any material (including liquids)
- Flexible method development
- High spatial resolution of microfeatures
- Sample mapping and depth profiling capabilities
- No contamination of reagents from digestion/dilutions steps



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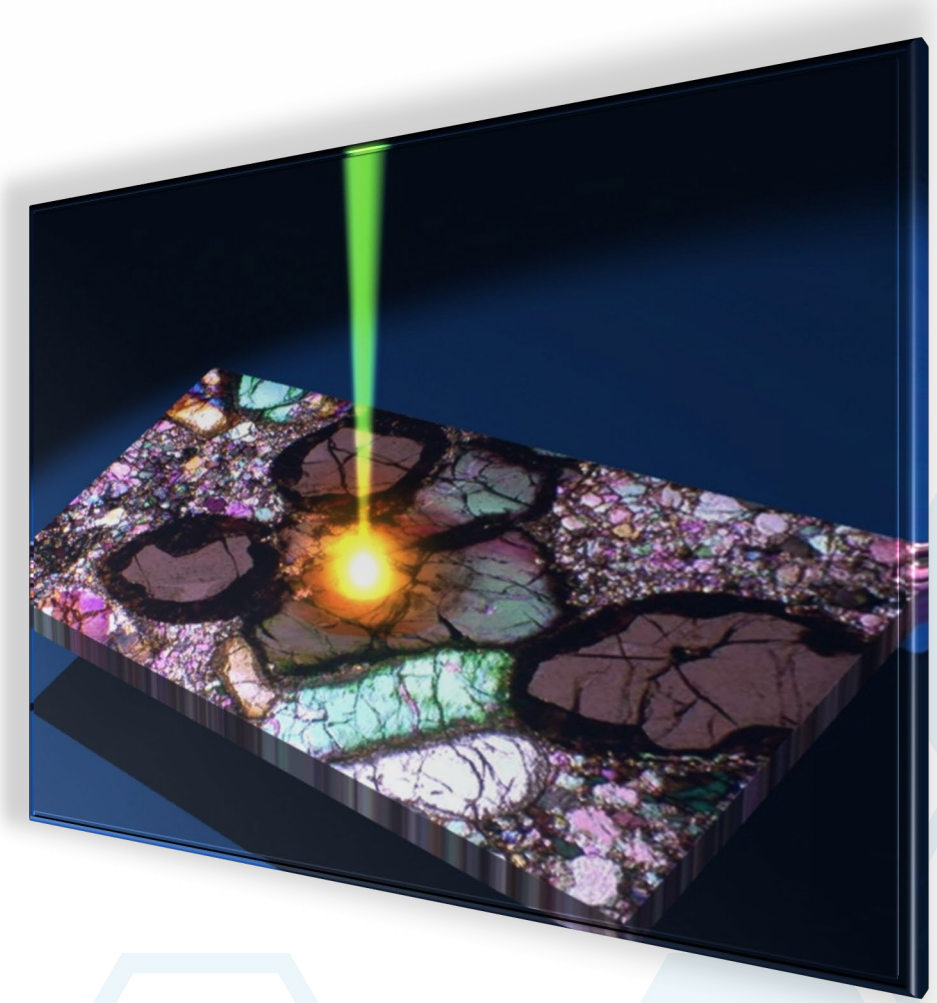
Challenges of the Technique

- Historically difficult acquiring standards
- Upper limit in sensitivity due to detector saturation
- (micro)Destructive technique
- Initial cost



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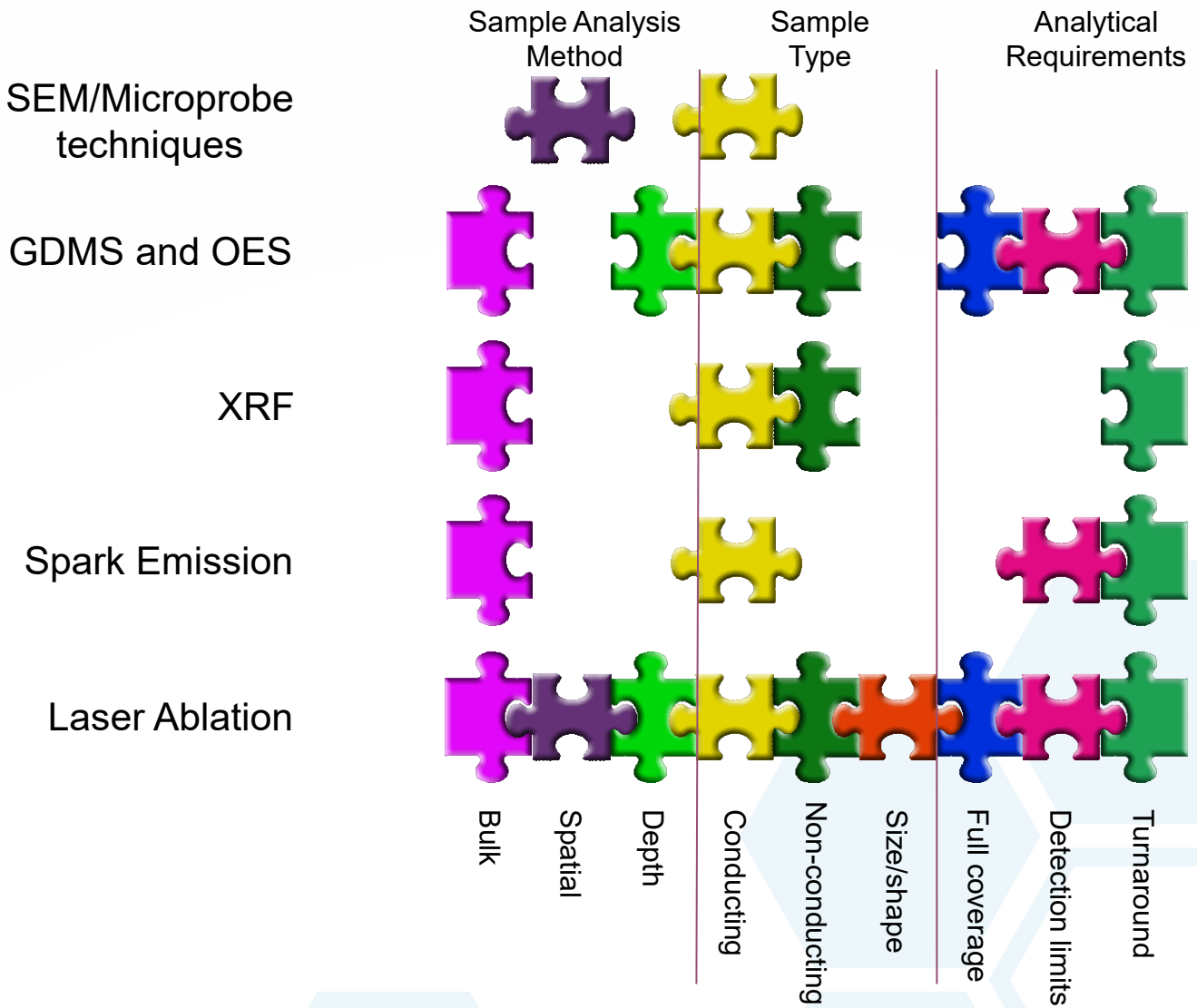
Laser Ablation vs Other Techniques



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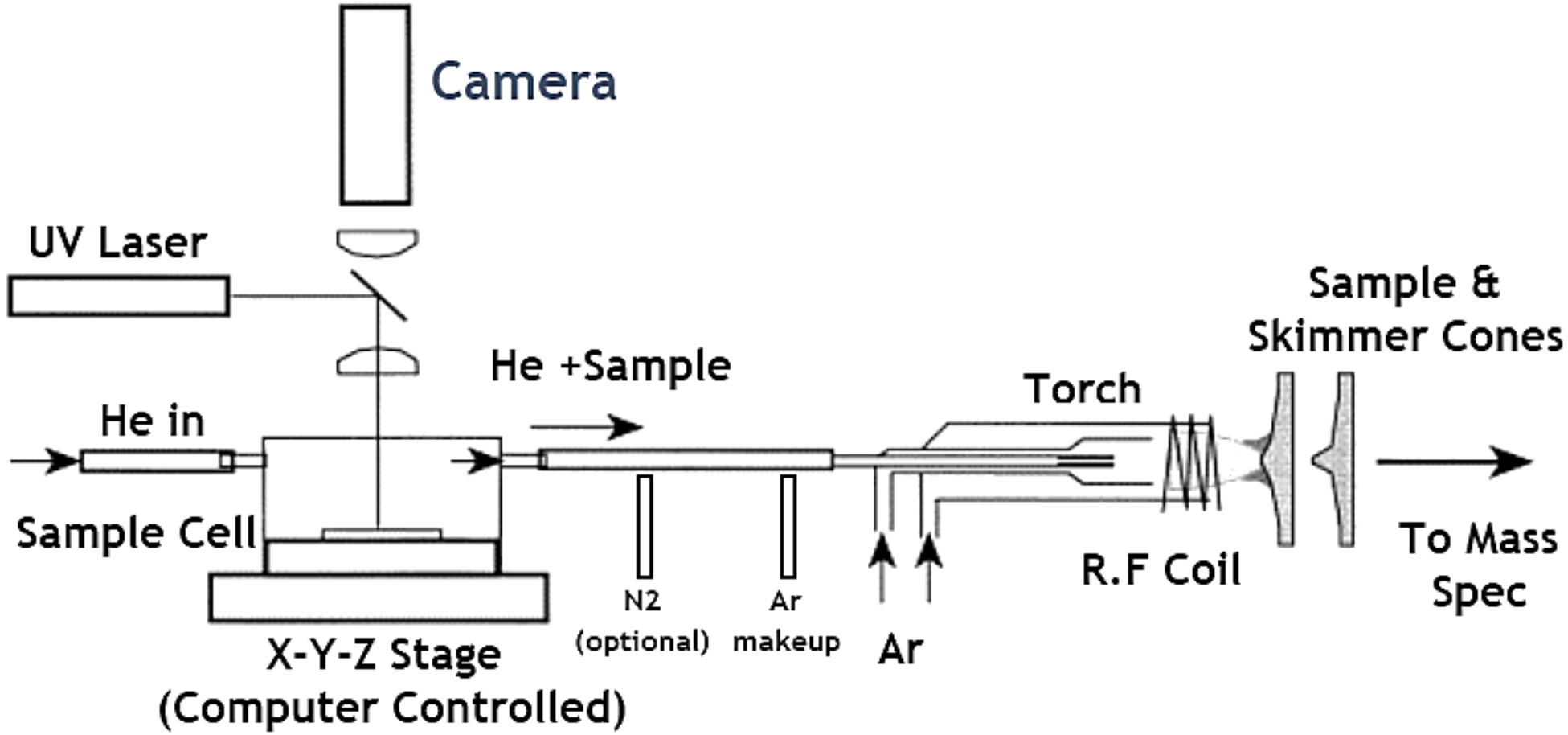
What is Laser Ablation ICP-MS?



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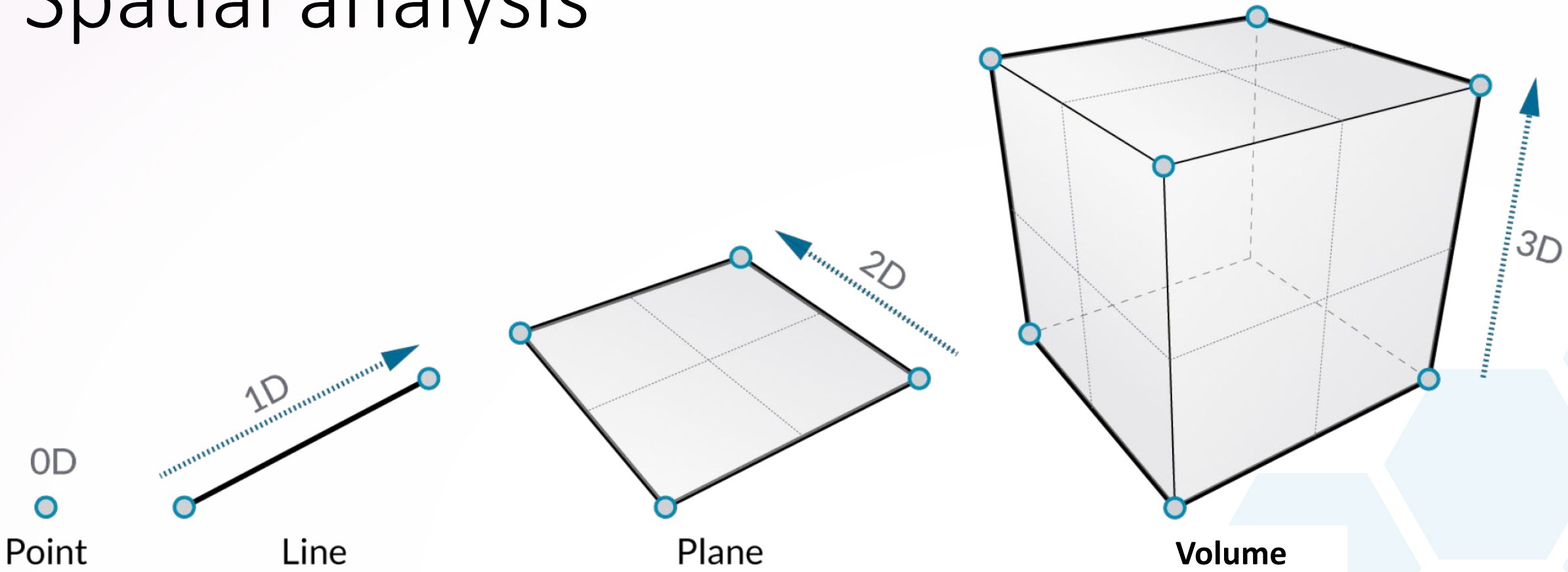
References: Hu et al, J. Anal. At. Spectrom., 2008, 23 & Eggins et al, Applied Surface Science 127-129 (1998)

Spatial analysis



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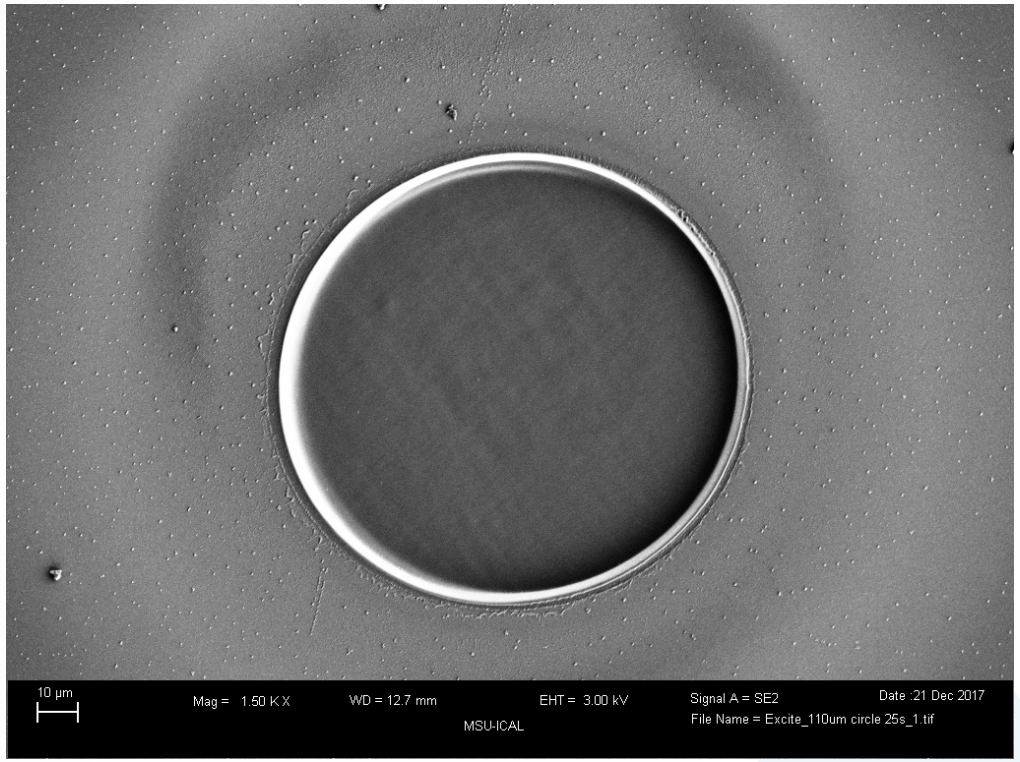
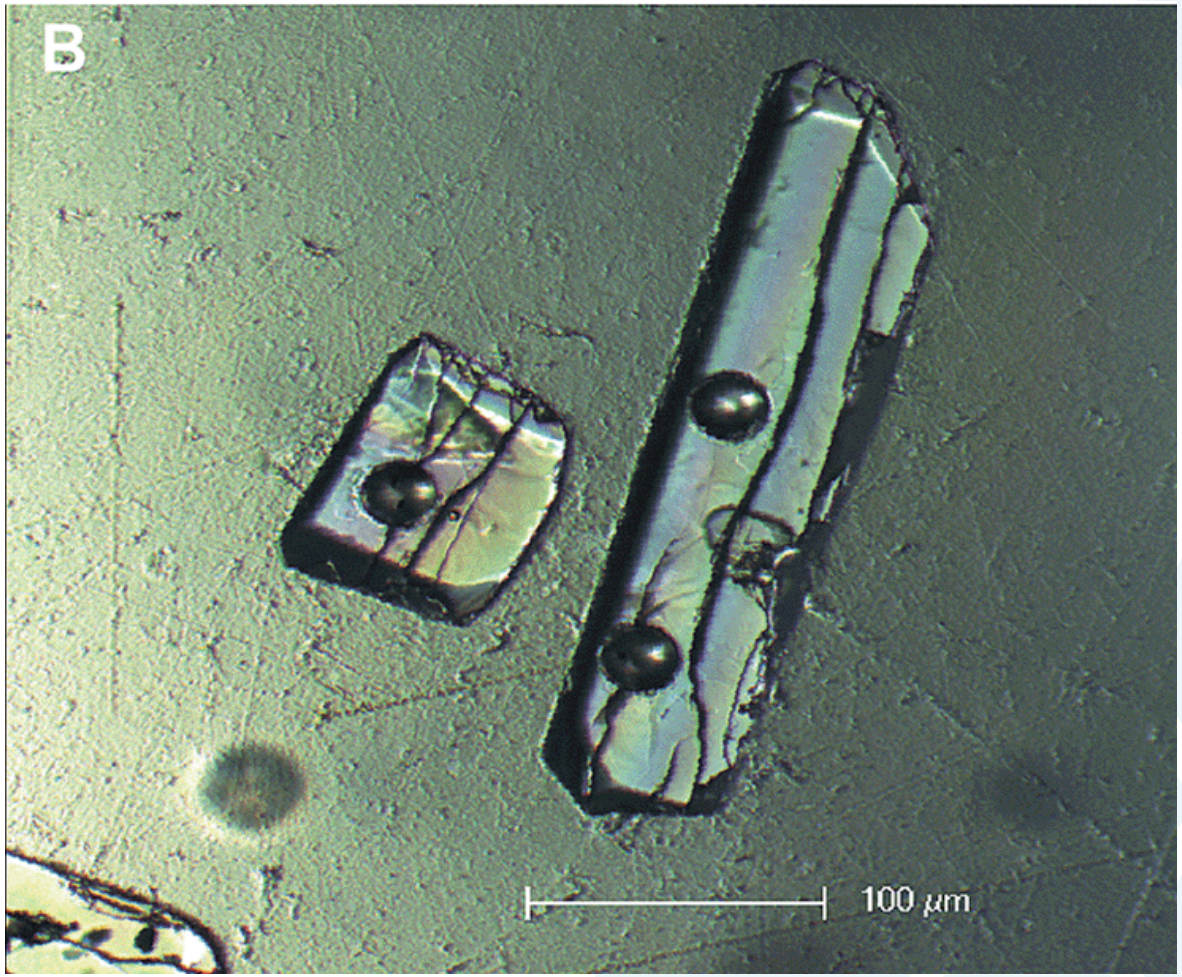
Courtesy of Dr. Maurizio Petrelli, University of Perugia

Spatial analysis

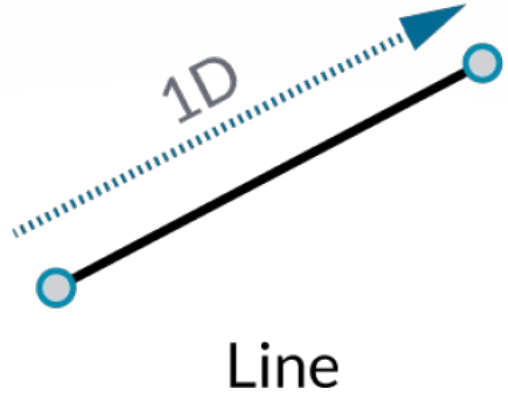
- 0D – Single Spot - this is (still..!) the typical LA-ICP-MS analysis
- Suitable for bulk analysis, depth profiling, isotope ratio, etc.





Courtesy of Dr. Maurizio Petrelli, University of Perugia

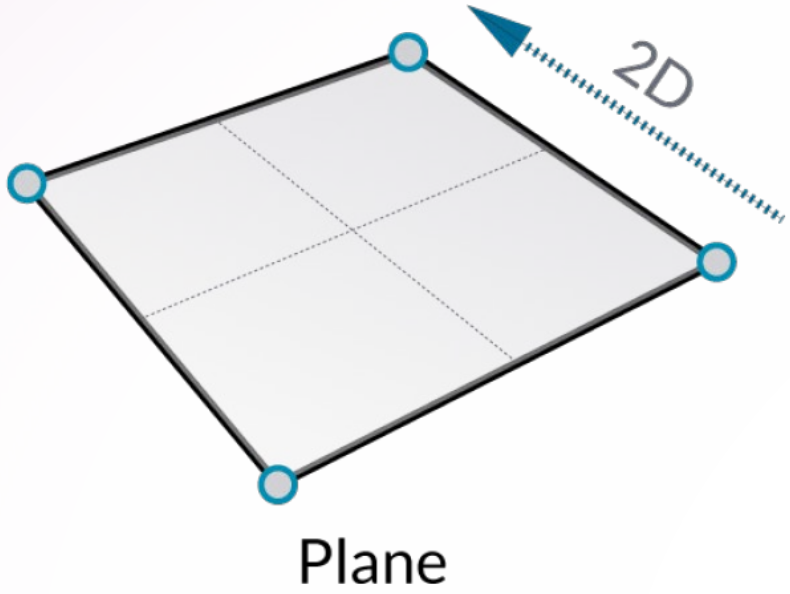
Spatial analysis



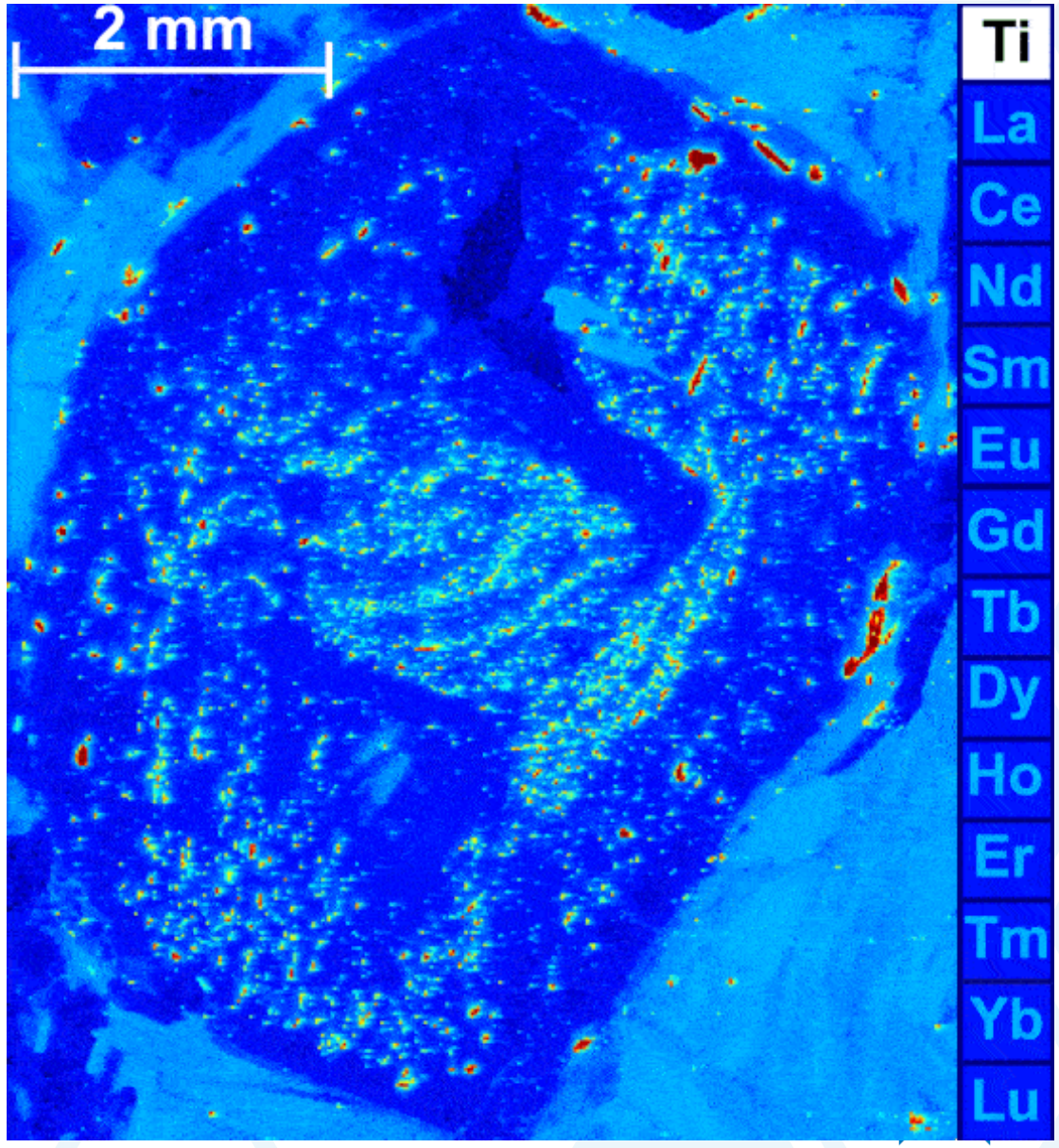
- 1D – Transect
- Useful for the study of diffusion profiles, bulk analysis of homogeneous samples (e.g., Particles trapped on filters, etc.)

Ogrizek, M., Jaćimović, R., Šala, M., & Kroflič, A. (2021). No more waste at the elemental analysis of airborne particulate matter on quartz fibre filters. *Talanta*, *226*.

Spatial analysis

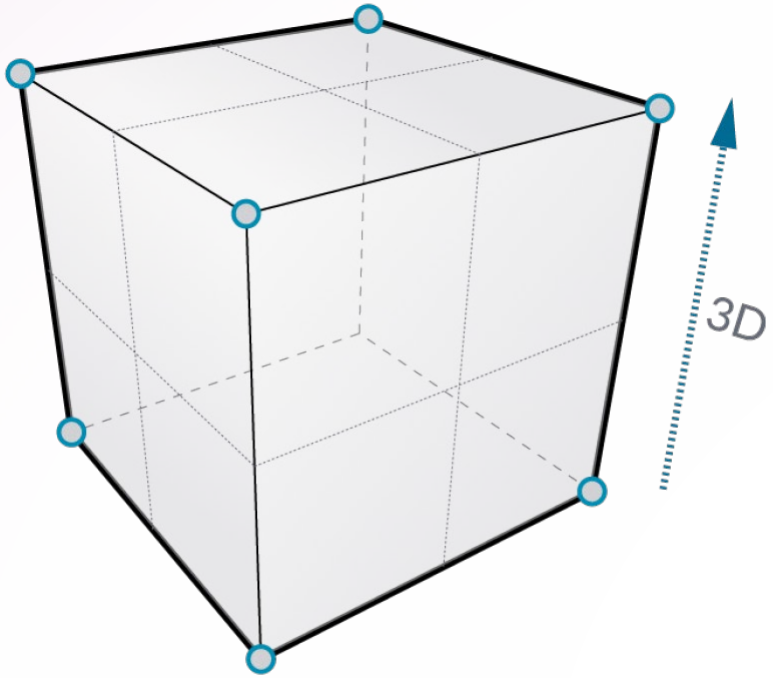


- 2D – the spatial distribution of elements (isotopes) in samples



Metamorphic garnet from the Eastern Carpathians (Romania)
Courtesy of Dr. Gavril Sabau, Geological Institute of Romania

Spatial analysis



Solid

- 3D – the spatial distribution of elements (isotopes) in 3D

Zircon from the Ditrau alkaline massif (Eastern Carpathians, Romania).
Courtesy of Dr. Gavril Sabau, Geological Institute of Romania

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GHENT UNIVERSITY
A&MS Atomic and Mass Spectrometry
HDP

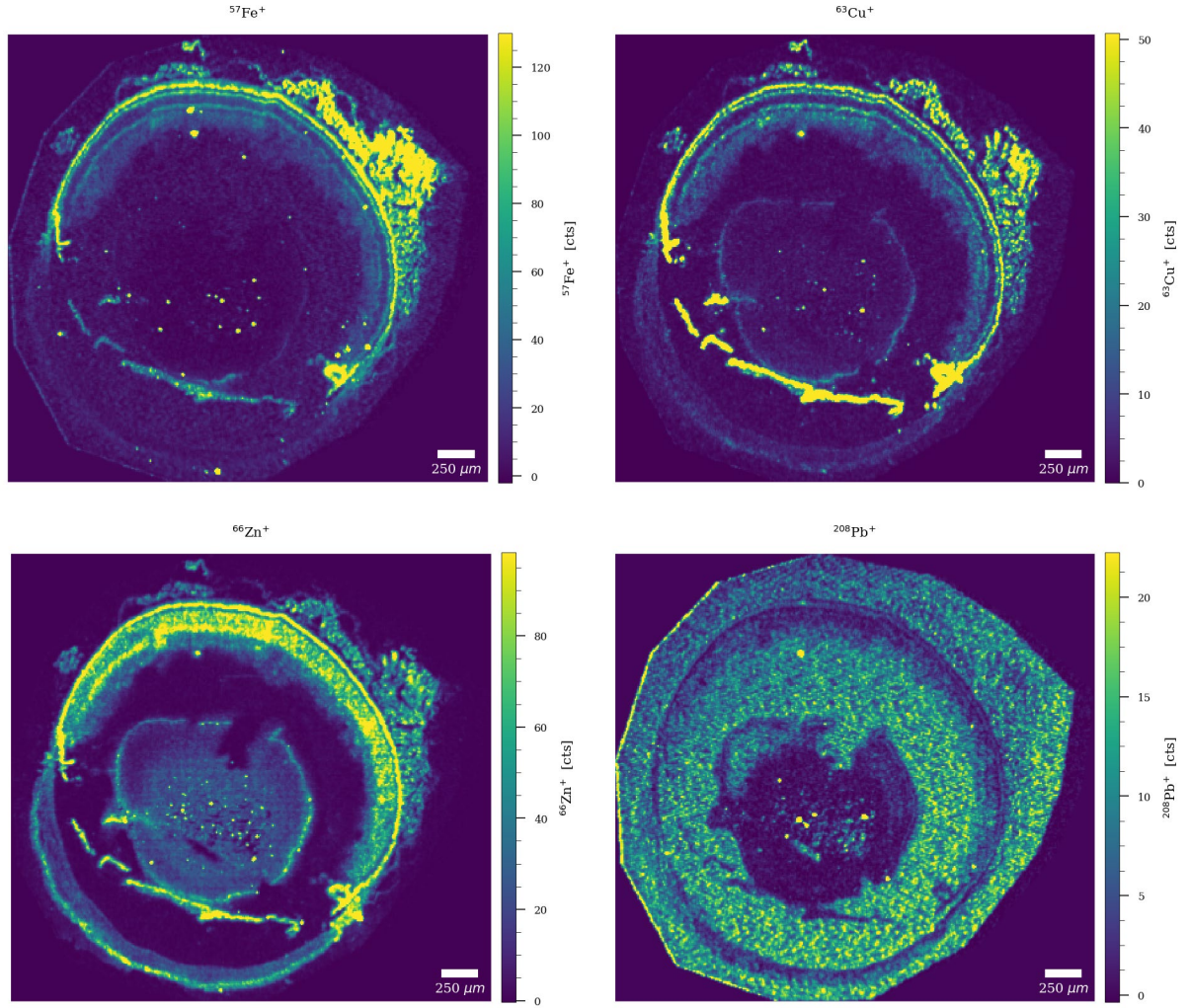
Data Collected at 375Hz

Mouse eye

- 3.0mm diameter
- Unpublished data

10 µm resolution
375 Hz

- Agilent 8900 ICP-MS
- Cobalt *Long Pulse* cell
- Parameters optimized and images generated with Teledyne HDIP software
- **5 elements measured**
  - C^{13}, Fe^{57}, Cu^{63}, Zn^{66}, Pb^{208}



50 minutes

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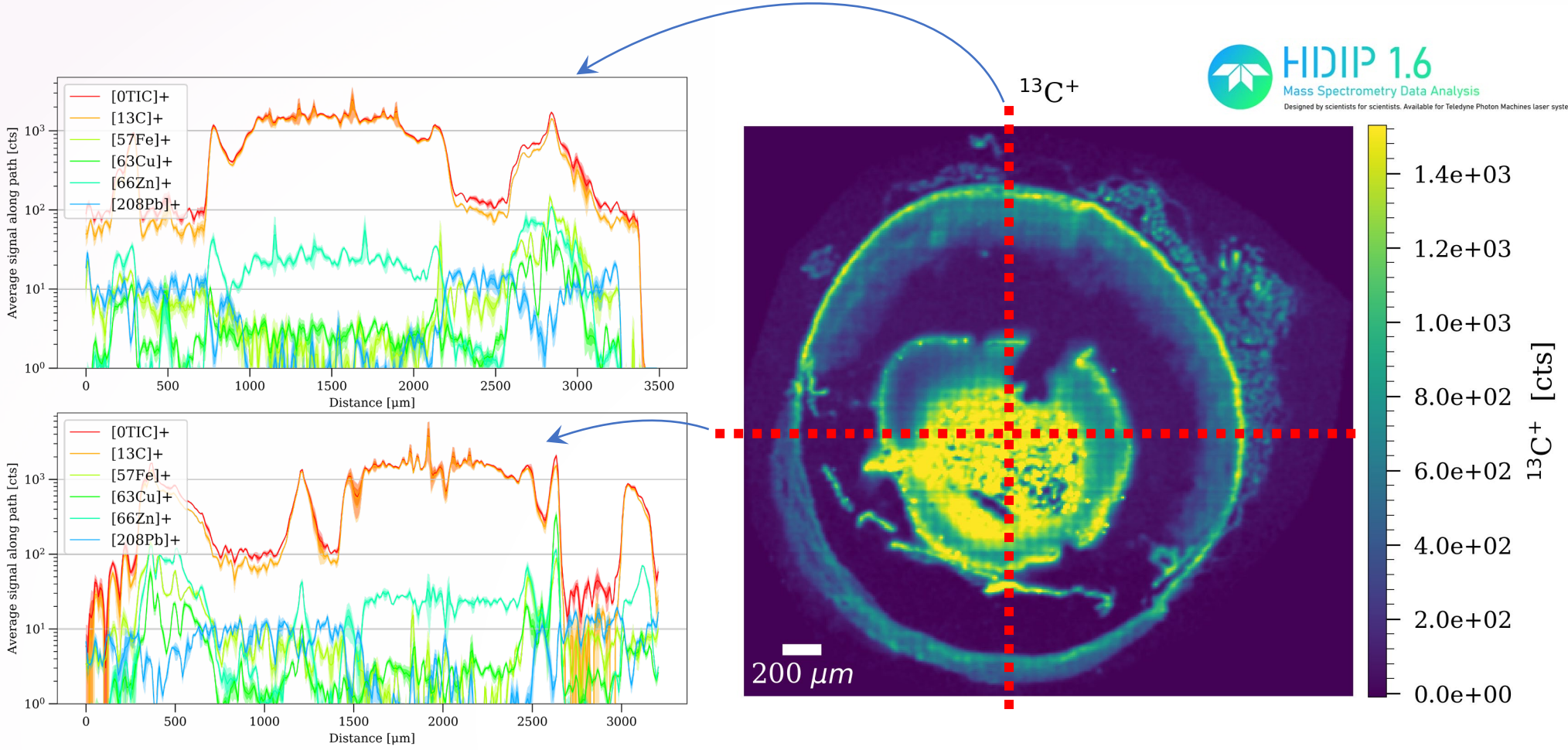
HDIP 1.6
Mass Spectrometry Data Analysis
Designed by scientists for scientists. Available for Teledyne Photon Machines laser systems.

NATURAL HISTORY MUSEUM

Sheffield Hallam University

Horizontal & Vertical Data Transects



Transects extracted with Teledyne HDIP software

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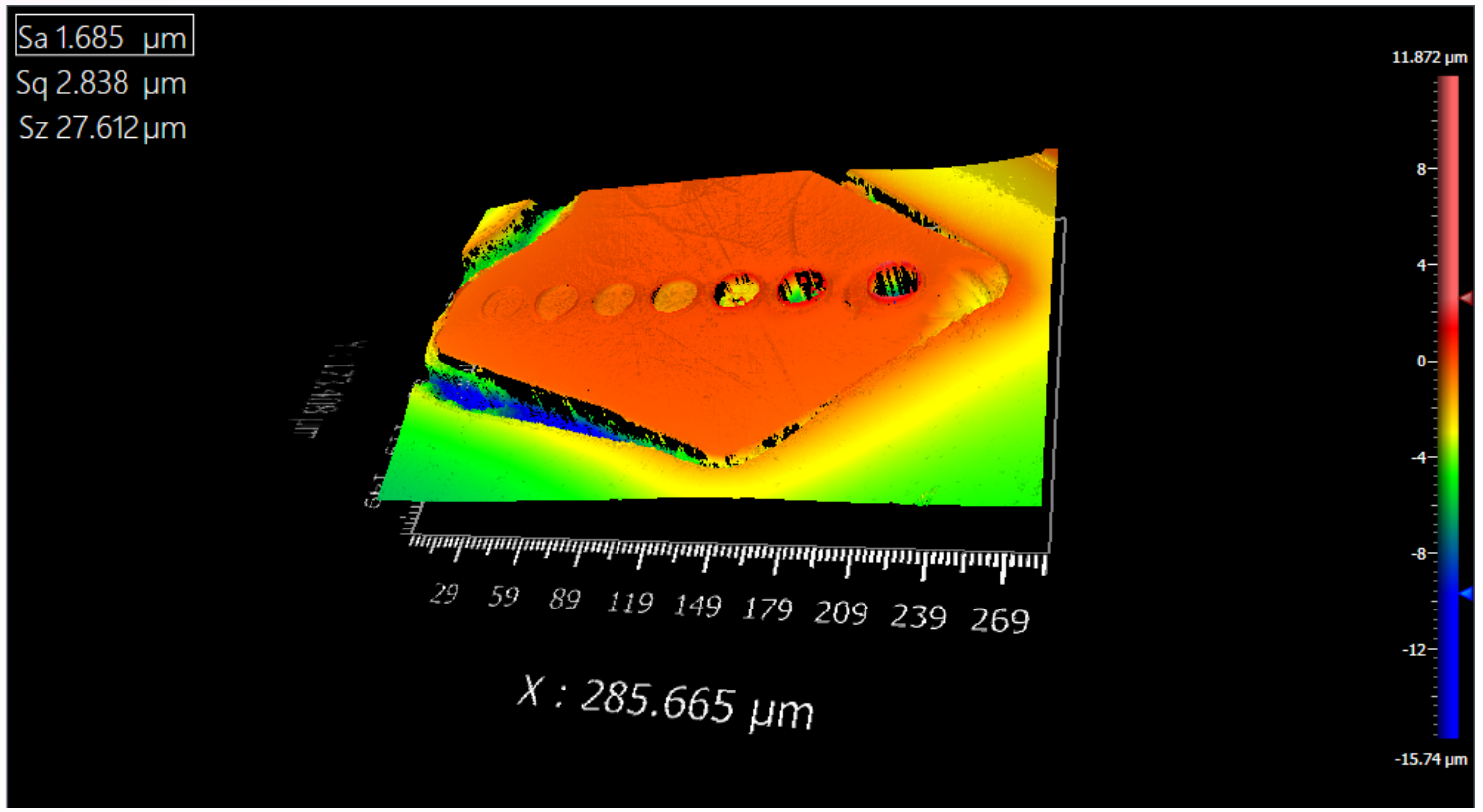
NATURAL HISTORY MUSEUM

Sheffield Hallam University

Volumetric Ablation – for Depth Profiling and Thin Film Analysis



FC-1 zircon

3 Jcm^{-2} (measured at the sample surface)

10 Hz

20 µm spot

1, 5, 10, 20, 50, 100 and 157 pulses

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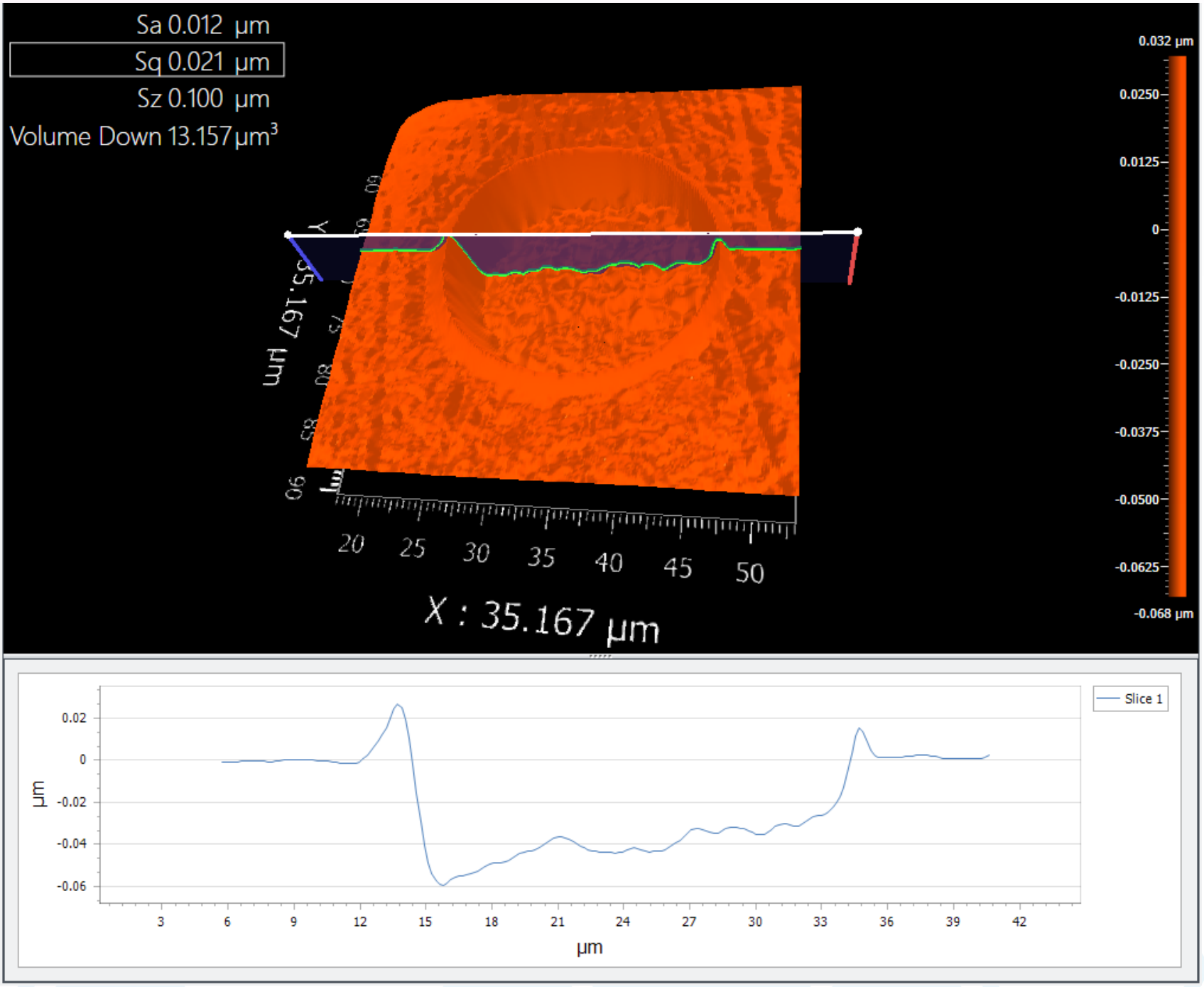
NATIONAL INSTITUTE OF CHEMISTRY



FC-1 zircon

3 Jcm^{-2}

10 Hz

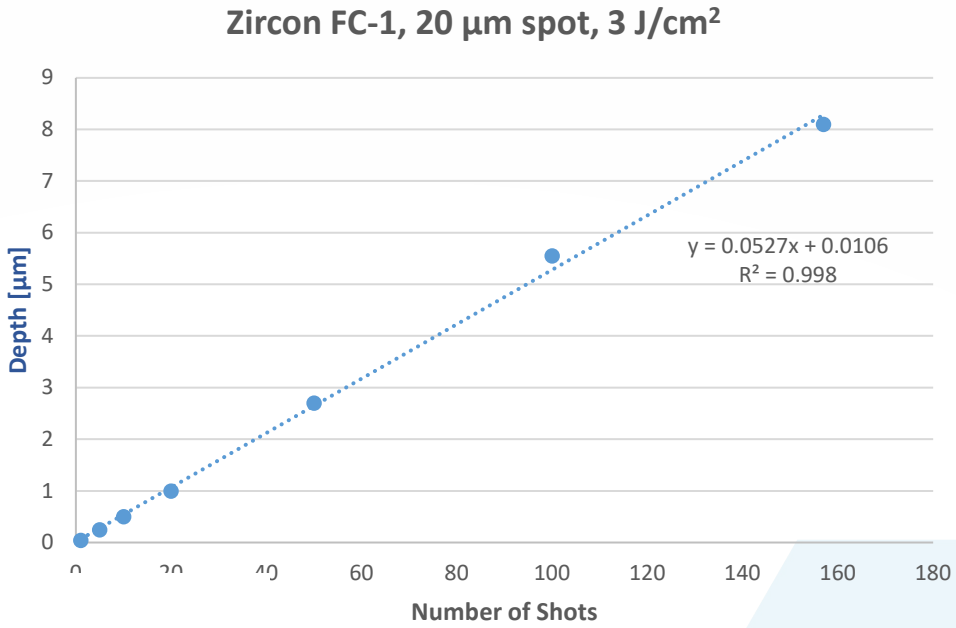
20 µm spot

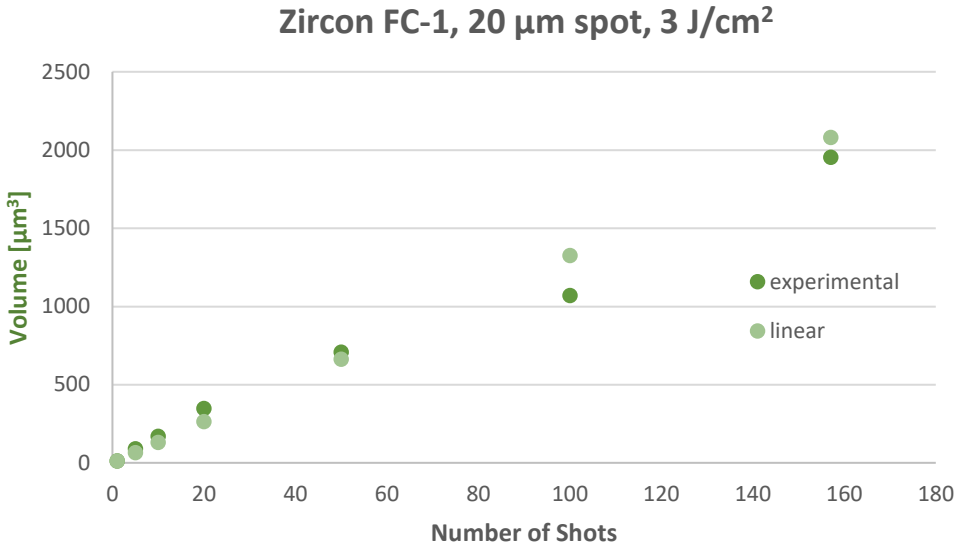
1 pulse

NATIONAL INSTITUTE OF CHEMISTRY

Volumetric Ablation – for Depth Profiling and Thin Film Analysis

Shots	Depth	Volume	Expected
1	0.04	13.26	13.26
5	0.25	91.56	66.28
10	0.5	171.0	132.6
20	1	349.0	265.1
50	2.7	708.5	662.8
100	5.55	1070	1326
157	8.1	1954	2081





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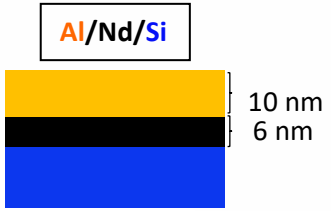
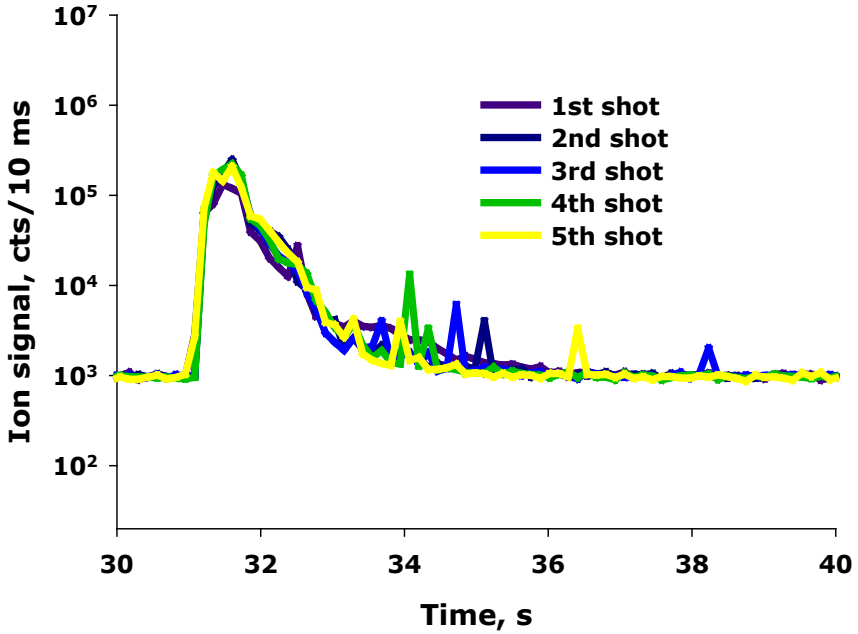
Thin Film Analysis

Ion signal evolution for 5 individual laser pulses

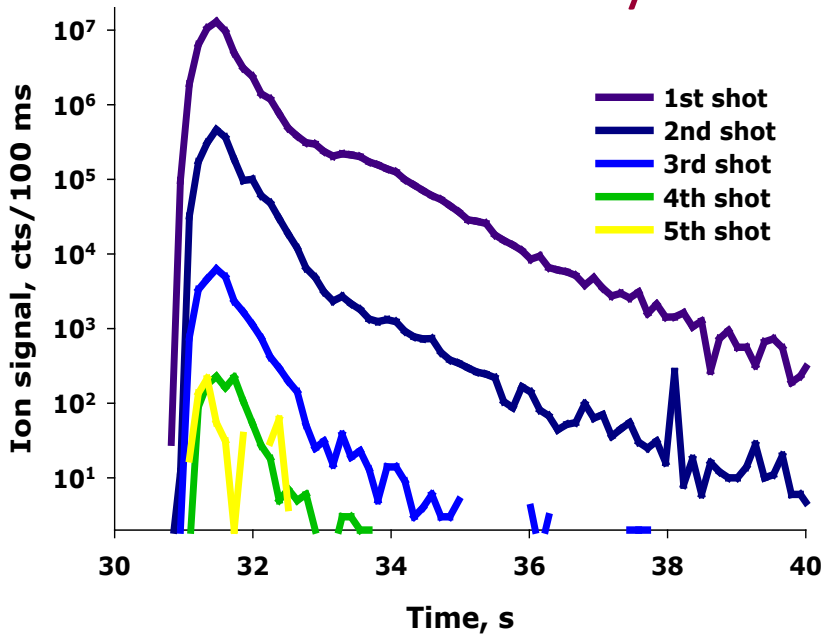
Sample: 6 nm Nd internal layer



$^{29}Si^{+}$ - Substrate



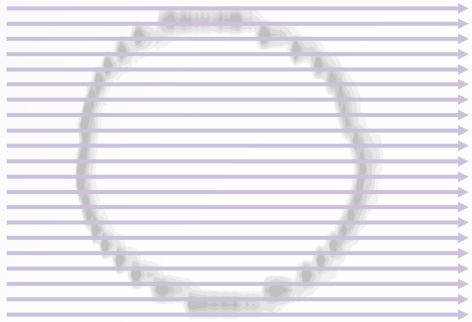
$^{146}Nd^{+}$ - Internal layer

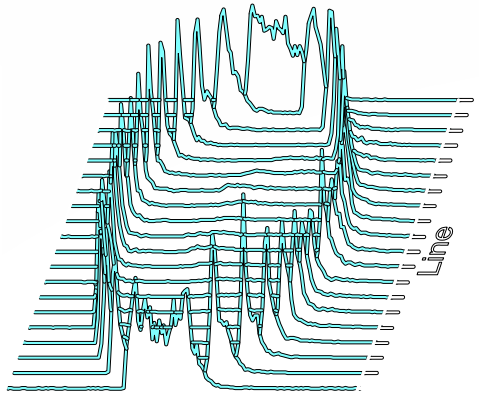


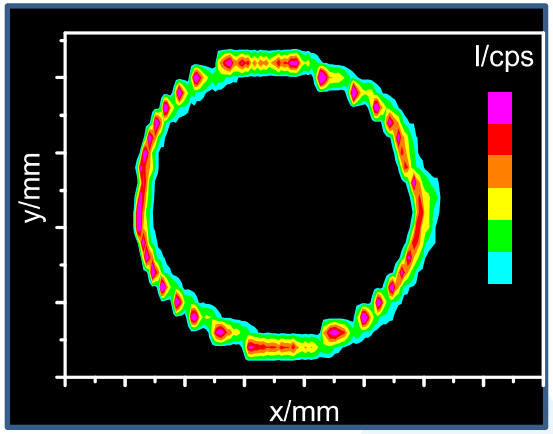
High energy laser pulses can remove thin layers within a few laser pulses

Pisonero *et al*, Winter Plasma Conference 2013

Elemental Imaging – Basics of Map/Image Generation







Line-by-line ablation

Transient ion traces

Ion intensity image

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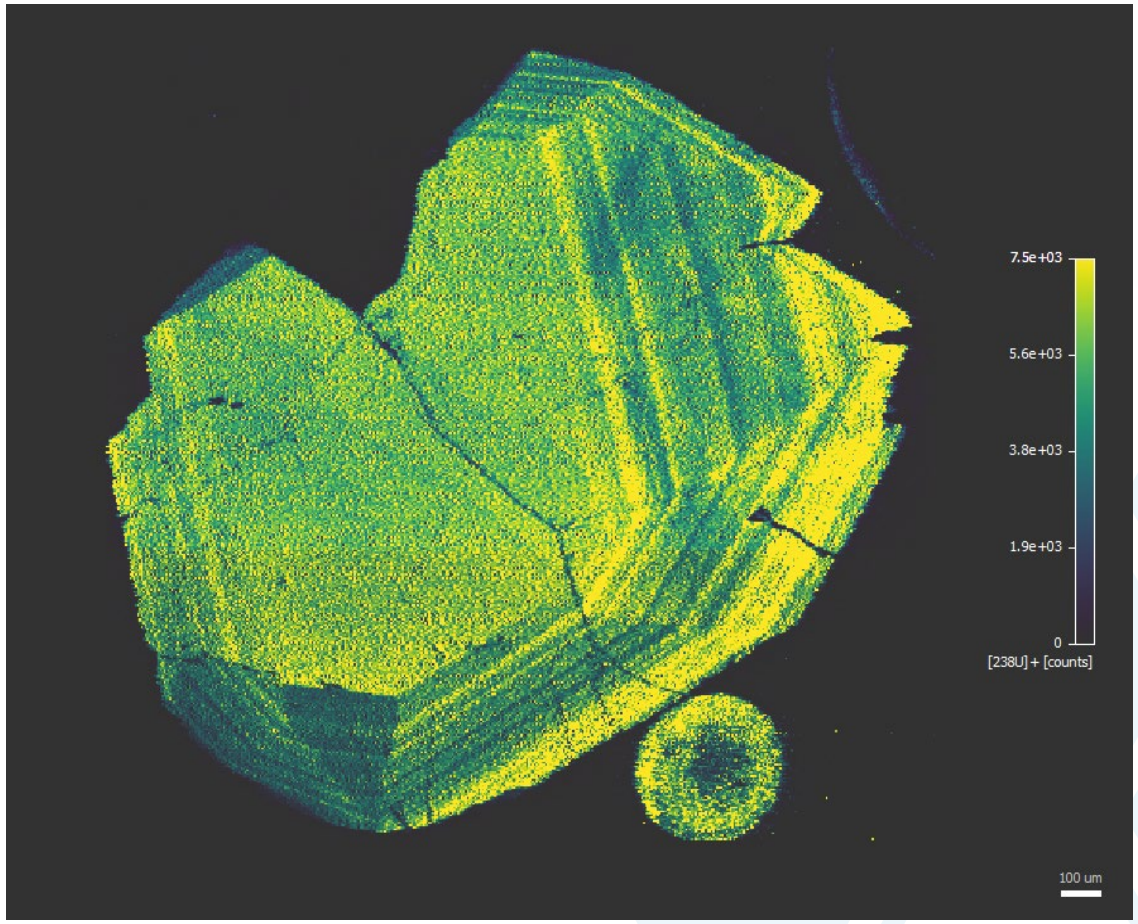
Köppen et al, University of Muenster

Elemental Imaging

	A	B	C	D	E	F	G	H	I	J	K	L	M
8	0.096912	0.114887	0.583607	0.660054	0.852923	0.218161	0.397852	0.78179	0.633538	0.383446	0.096522	0.502717	1.18885
9	0.146324	0.161749	0.464136	0.69083	0.623064	0.204618	0.404379	0.787971	0.633808	0.384757	0.198939	0.33847	1.19359
10	0.16358	0.155945	0.601307	0.395216	0.692919	0.485034	0.198672	0.556445	0.57554	0.364166	0.13546	0.333279	1.07667
11	0.235245	0.048706	0.774869	0.412034	1.03772	0.49413	0.396634	0.292094	0.385738	0.438952	0.193673	0.304141	1.02072
12	0.39712	0.14578	0.842969	0.40835	0.946479	0.643883	0.193839	0.556434	0.453219	0.189042	0.234477	0.263653	0.662822
13	0.228604	0.079104	1.19217	0.830759	1.16044	0.536759	0.131089	0.130565	0.244766	0.250621	0.202918	0.497544	0.532865
14	0.259311	0.237749	0.864093	0.823291	1.2092	0.696092	0.162978	0.415797	0.220872	0.089312	0.210114	0.775358	0.56165
15	0.390668	0.190997	1.06221	0.999354	1.30664	0.866227	0.227986	0.176978	0.086577	0.13053	0.248586	0.472006	0.35736
16	0.104634	0.409608	1.61818	1.43177	1.31183	0.545197	0.293767	0.264986	0.16443	0.072054	0.091039	0.754845	0.253603
17	1.16384	0.385957	1.65124	0.798049	1.56494	0.66774	0.415711	0.573101	0.046124	0.074338	0.611663	0.610238	0.226235
18	0.369656	0.715347	1.53221	6.00476	1.38987	1.05974	0.666762	1.13793	0.026259	0.211942	0.457764	0.350029	0.116701
19	0.352381	1.07845	4.65948	2.63666	1.17151	1.08914	0.720548	1.27075	0.068776	0.145108	0.386675	0.258985	0.04538
20	0.505702	1.10533	1.41073	1.47368	1.21054	0.930509	0.639065	0.895207	0.026999	0.050367	0.28623	0.430147	0.12626
21	0.599119	0.896266	0.525086	1.20172	1.30803	0.803165	0.563338	0.772326	0.156519	0.096277	0.404549	0.324726	0.103211
22	0.414209	0.801911	0.843391	1.09828	1.25331	0.985016	0.449396	0.53338	0.099202	0.072237	0.305811	0.368388	0.133242
23	0.366787	0.768113	0.531492	1.07642	1.11176	0.987023	0.758482	0.611338	0.056195	0.045279	0.151004	0.23329	0.064937
24	0.458827	0.845649	0.824528	1.03083	1.07516	1.18947	0.514221	0.293982	0.159779	0.113608	0.22589	0.171253	0.041933
25	0.716285	0.663331	0.689056	0.820868	1.02739	1.16858	0.718875	0.474105	0.100959	0.083564	0.164511	0.105662	0.083173
26	0.819503	1.24763	1.42895	0.707344	1.52214	1.09088	0.763535	1.13511	0.033873	0.142139	0.167168	0.099386	0.043056
27	0.912334	2.01484	1.20841	0.724997	1.44369	1.09532	0.917739	1.39346	0.048793	0.14082	0.097433	0.074208	0.03787
28	1.15607	3.04507	1.26789	0.62716	1.25552	0.793643	1.00461	0.989637	0.03223	0.085011	0.113863	0.018183	0.098037
29	1.15575	2.83549	1.06188	0.610768	1.54787	0.909811	0.55543	1.672	0.064739	0.10096	0.171191	0.05557	0.056548
30	1.12294	1.72703	0.717315	0.934489	1.30029	1.02686	0.785505	1.44898	0.024459	0.053282	0.110676	0.115487	0.096095
31	1.67334	1.15917	0.571676	0.631869	1.5819	0.646488	0.656882	1.15551	0.027585	0.079305	0.118181	0.086831	0.154575
32	1.6434	0.868305	0.285532	0.760374	1.91634	0.746576	0.729745	1.14162	0.033734	0.076443	0.050522	0.097287	0.204627
33	1.65086	0.671309	0.166098	0.58059	1.78824	0.983115	0.774283	1.11937	0.034717	0.162403	0.054783	0.087952	0.131606
34	1.30019	0.857228	0.160557	0.581421	1.67726	2.02466	1.25894	0.751958	0.016627	0.103778	0.056284	0.066515	0.162199
35	1.00326	0.564484	0.228819	0.760232	1.27207	1.84559	1.43669	0.496919	0.041127	0.173992	0.057838	0.080648	0.181131
36	0.775591	0.41202	0.417392	0.642002	0.946925	1.4467	1.69969	0.354116	0.054937	0.128461	0.08167	0.083234	0.138208
37	0.662539	0.370612	0.532953	0.636069	0.983973	1.55404	1.32917	0.202616	0.021751	0.119431	0.072847	0.085618	0.138608
38	0.463375	0.31527	0.358647	0.586981	1.13203	1.17624	1.12798	0.188072	0.03207	0.065468	0.060936	0.055543	0.088213
39	0.540517	0.30932	0.42259	0.42403	1.23246	0.904797	0.651712	0.114582	0.110343	0.144098	0.092224	0.05494	0.060053
40	0.38211	0.329588	0.45556	0.863497	0.902195	0.664446	0.376653	0.074541	0.080114	0.064662	0.094256	0.129623	0.165235
41	0.421603	0.392585	0.279268	0.932795	0.900197	0.355988	0.44882	0.091691	0.170302	0.099841	0.138096	0.078876	0.125028
42	0.390633	0.381289	0.360255	0.811816	0.628627	0.361066	0.198197	0.126083	0.085758	0.11067	0.039471	0.077577	0.05944
43	0.347463	0.272831	0.298817	0.742719	0.252145	0.301427	0.175459	0.117354	0.067837	0.076817	0.032003	0.072841	0.083575



Courtesy of Dr. Gavril Sabau, Geological Institute of Romania

TELEDYNE PHOTON MACHINES
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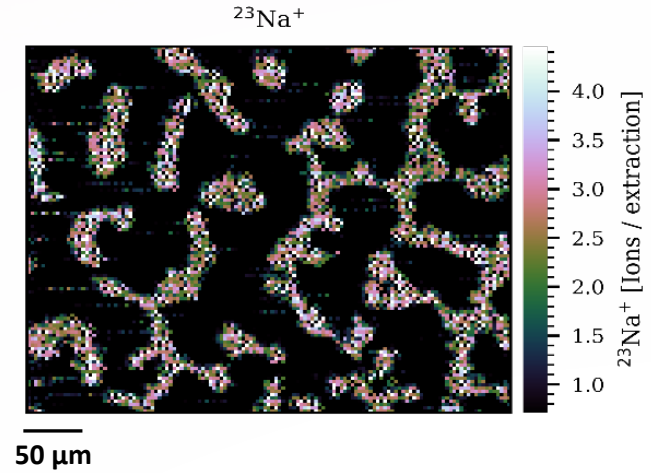
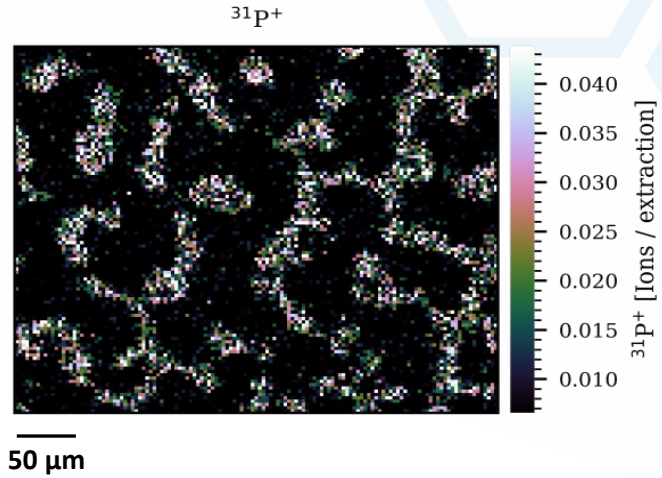
GHENT UNIVERSITY
A&MS Atomic and Mass Spectrometry
HDP

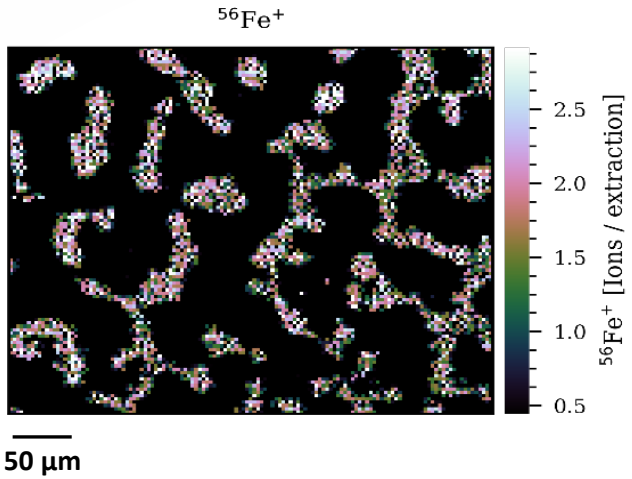
Elemental Imaging

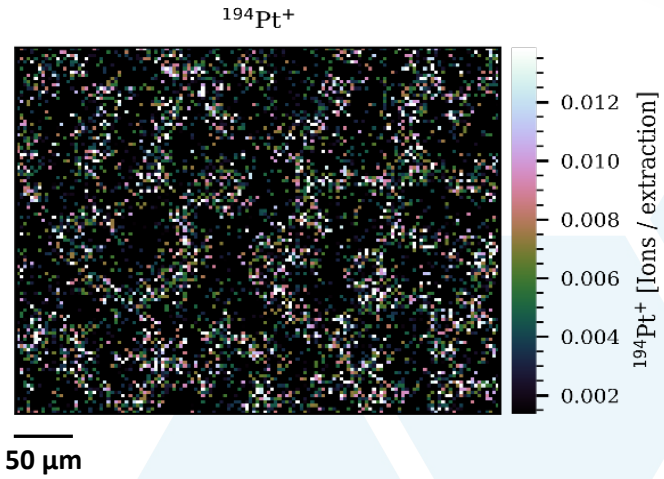
- Red blood cells of a patient after cisplatin chemotherapy (Courtesy of Dr. Sarah Theiner, University of Vienna)

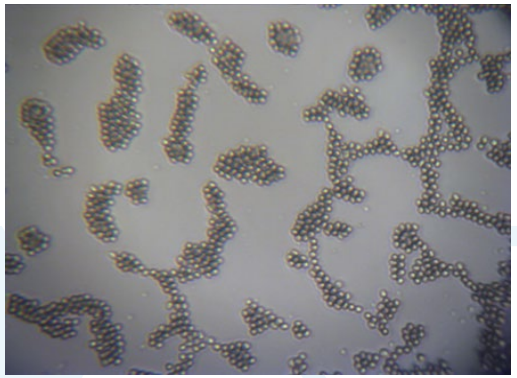
- 2 µm resolution
- 100 Hz
- Dosage: 4
- Imaging Time: 20 min











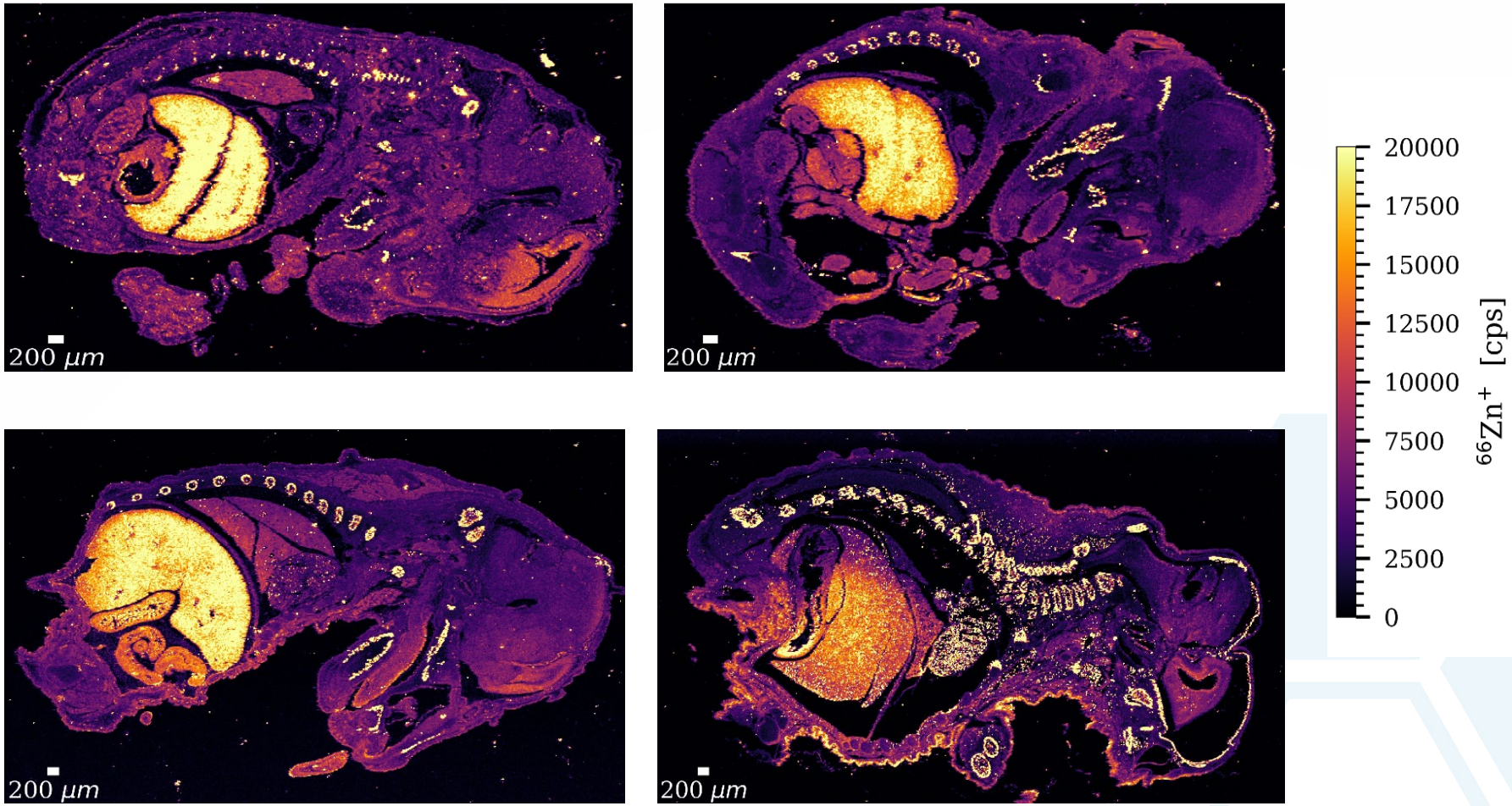
TELEDYNE PHOTON MACHINES
Everywhereyoulook™

universität wien

Elemental Imaging

- Mouse Embryo (unpublished data)
- 5 µm thickness, deparaffinized prior to analysis
- 8 hours analysis time for 18 samples

- 19um Spot
- Dosage: 1
- Energy Density: 0.93 J cm^2
- Scan Speed: 2 mm/s
- Rep Rate: 100Hz



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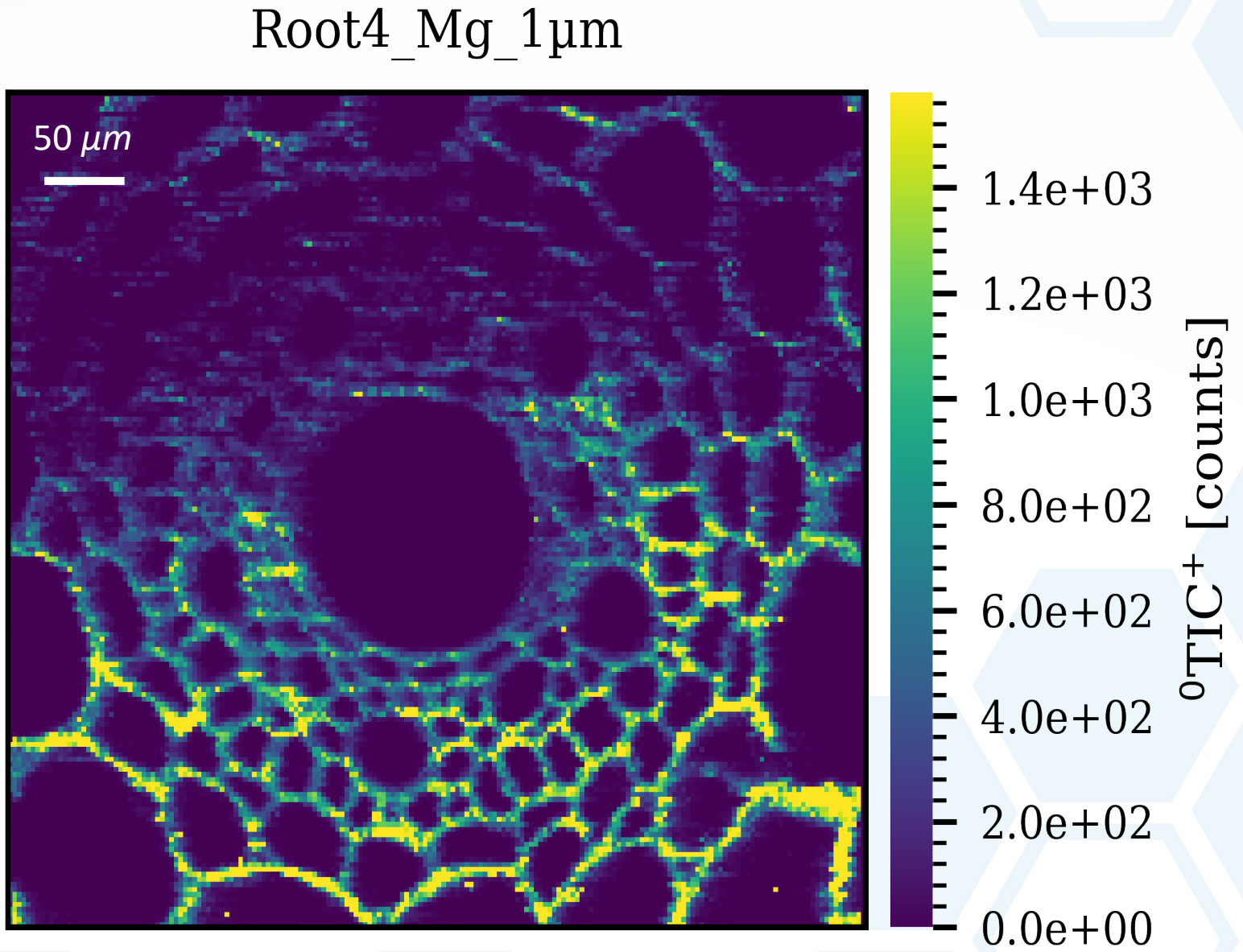
GHENT UNIVERSITY A&MS Atomic and Mass Spectrometry

KING'S College LONDON

Elemental Imaging

- Barley root section

- 1 µm resolution,
- 300 Hz
- 1 pulse/pixel
- Total Imaging Time: 3.2 min



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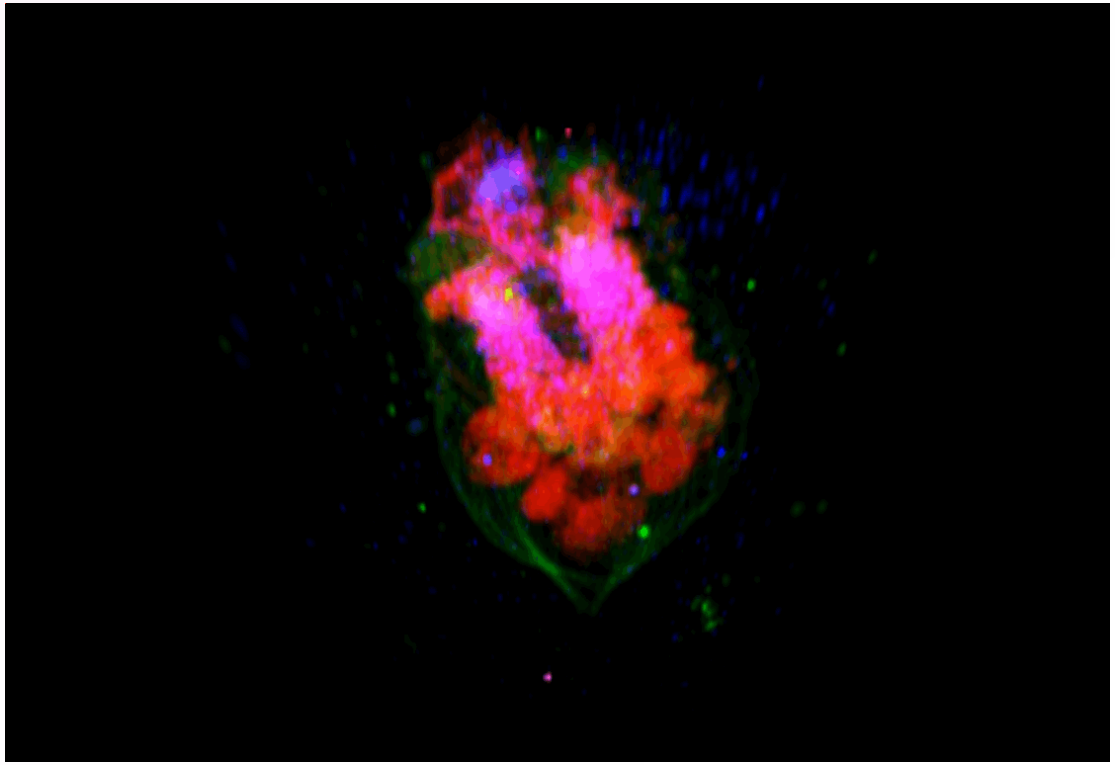
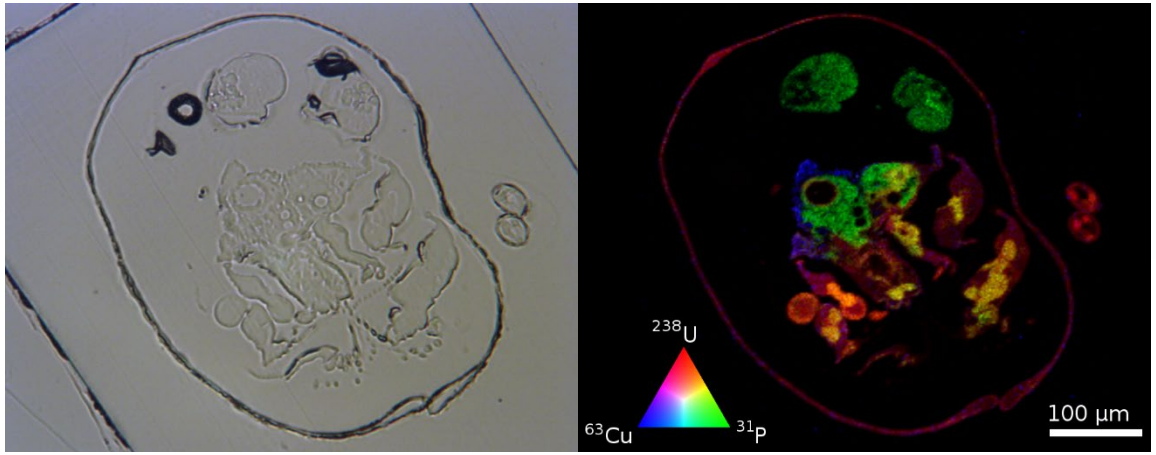
GHENT UNIVERSITY
A&MS Atomic and Mass Spectrometry

HDIP Software – Powerful Simplicity (3D Imaging)





GHENT UNIVERSITY

FACULTY OF SCIENCES

Three-Dimensional Reconstruction of the Tissue-Specific Multi-elemental Distribution within Ceriodaphnia dubia via Multimodal Registration Using Laser Ablation ICP-Mass Spectrometry and X-ray Spectroscopic Techniques. Stijn J. M. Van Malderen et Al, DOI: 10.1021/acs.analchem.7b00111

Data Collected at 400Hz

- Wheat grain (unpublished data)
- Mounted in epoxy resin and polished to give a flat surface
- Interested in zinc uptake
  - Concentration & location

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Sheffield Hallam University

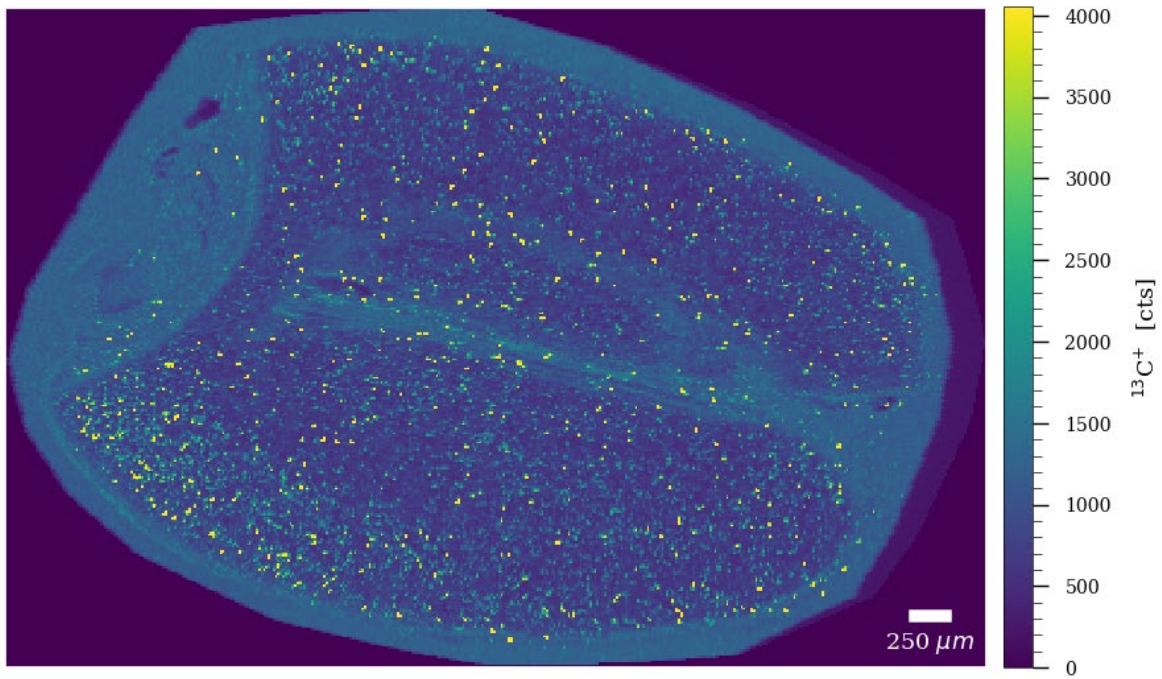
NATURAL HISTORY MUSEUM

Data Collected at 400Hz

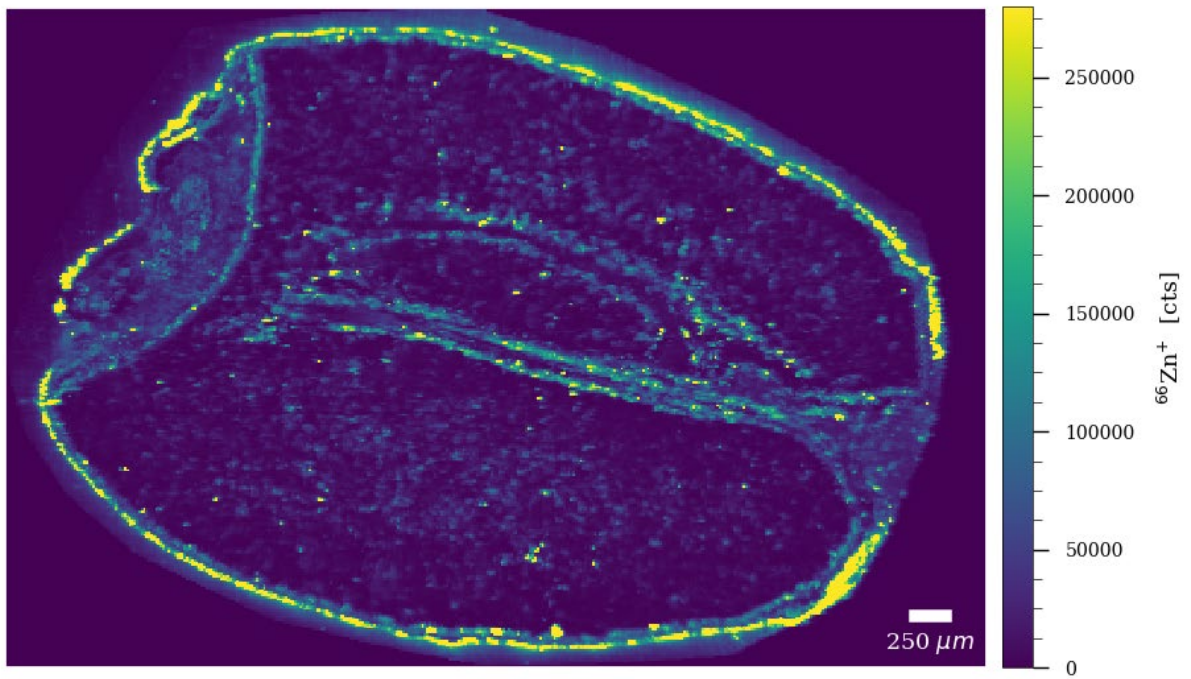
Sheffield Hallam University

NATURAL HISTORY MUSEUM

Carbon^{13}



Zinc^{66}



50 minutes

- **2 elements measured**: Carbon and Zinc
- **15 µm** circular spot; **400 Hz**
- Cobalt *Long Pulse* cell
- Agilent 8900 ICP-MS
- Parameters optimized and images generated with Teledyne HDIP software

HDIP 1.6
Mass Spectrometry Data Analysis
Designed by scientists for scientists. Available for Teledyne Photon Machines laser systems.

TELEDYNE PHOTON MACHINES
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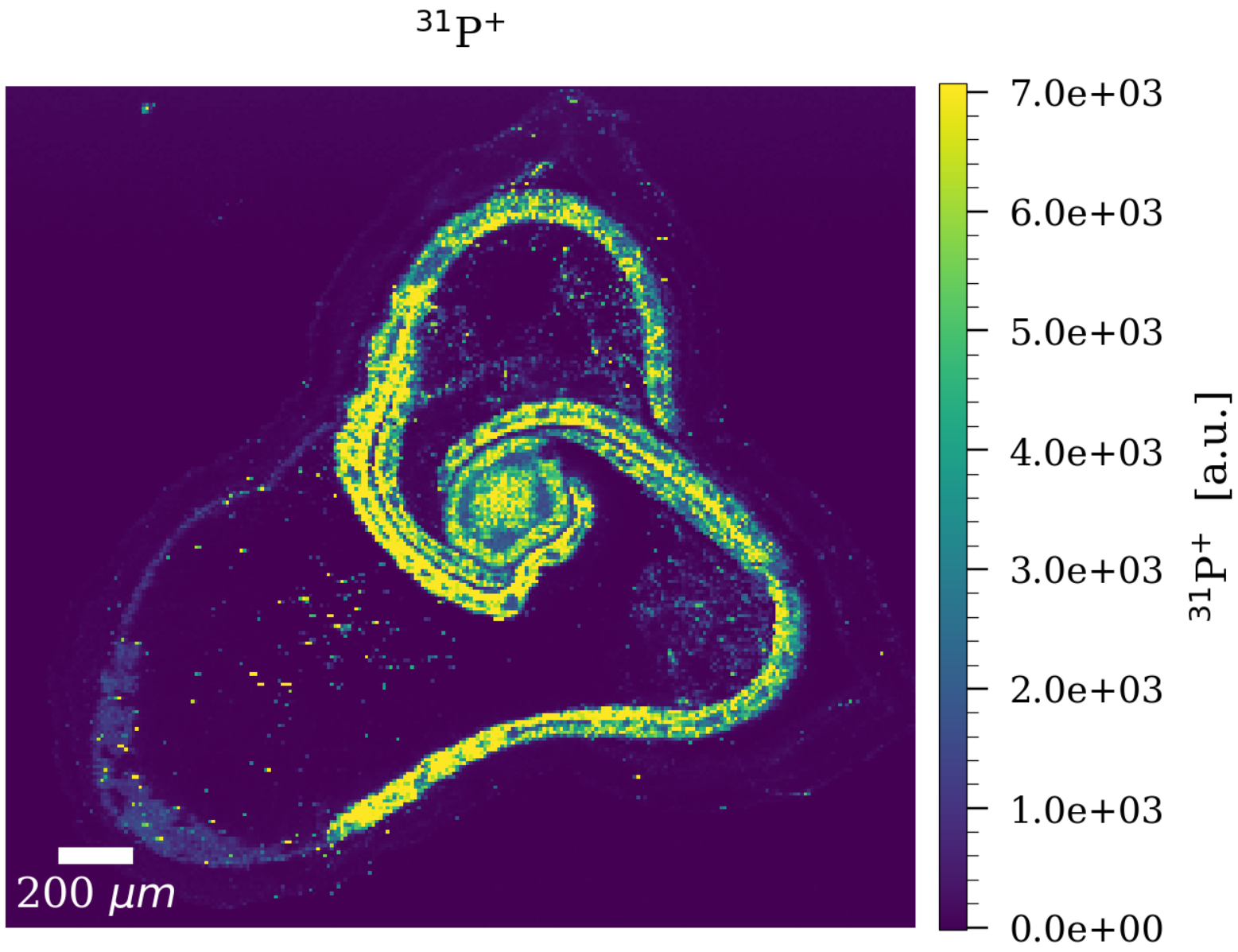
Elemental Imaging

- Buckwheat section (unpublished data). Courtesy of Dr. Martin Sala, National Institute of Chemistry Slovenia

- 10 µm resolution
- 300 Hz
- 4 pulse/pixel



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NATIONAL INSTITUTE OF CHEMISTRY

Bulk Analysis

	Test 1 (10 Hz; Total Flow: 0.65 LPM)				Test 2 (50 Hz; Total Flow: 0.75 LPM)				Test 3 (50 Hz; Total Flow: 1.05 LPM)			
	[7Li]+	[89Y]+	[139La]+	[238U]+	[7Li]+	[89Y]+	[139La]+	[238U]+	[7Li]+	[89Y]+	[139La]+	[238U]+
Replicate 1 mean [cts]	2.62E+03	7.03E+03	8.89E+03	8.66E+03	8.81E+03	2.65E+04	3.20E+04	2.75E+04	8.81E+03	2.71E+04	3.25E+04	2.90E+04
Replicate 2 mean [cts]	2.66E+03	7.00E+03	8.74E+03	8.43E+03	8.97E+03	2.65E+04	3.22E+04	2.88E+04	8.84E+03	2.68E+04	3.22E+04	2.88E+04
Replicate 3 mean [cts]	2.71E+03	6.95E+03	8.68E+03	8.70E+03	8.98E+03	2.65E+04	3.24E+04	2.85E+04	9.09E+03	2.67E+04	3.24E+04	2.86E+04
Replicate 4 mean [cts]	2.74E+03	7.02E+03	8.69E+03	8.53E+03	9.13E+03	2.67E+04	3.22E+04	2.92E+04	9.03E+03	2.69E+04	3.25E+04	2.88E+04
Replicate 5 mean [cts]	2.73E+03	6.95E+03	8.85E+03	8.53E+03	9.16E+03	2.67E+04	3.26E+04	2.88E+04	9.06E+03	2.66E+04	3.22E+04	2.87E+04
Replicate 6 mean [cts]	2.81E+03	6.93E+03	8.62E+03	8.56E+03	9.09E+03	2.65E+04	3.24E+04	2.91E+04	9.06E+03	2.68E+04	3.24E+04	2.85E+04
Replicate 7 mean [cts]	2.72E+03	7.00E+03	8.81E+03	8.54E+03	9.15E+03	2.67E+04	3.25E+04	2.85E+04	8.90E+03	2.68E+04	3.25E+04	2.87E+04
Replicate 8 mean [cts]	2.68E+03	6.99E+03	8.78E+03	8.56E+03	8.96E+03	2.66E+04	3.22E+04	2.81E+04	8.95E+03	2.68E+04	3.23E+04	2.87E+04
Replicate 9 mean [cts]	2.65E+03	6.94E+03	8.75E+03	8.48E+03	8.98E+03	2.65E+04	3.22E+04	2.86E+04	8.92E+03	2.68E+04	3.25E+04	2.89E+04
Replicate 10 mean [cts]	2.65E+03	7.10E+03	8.77E+03	8.65E+03	8.92E+03	2.66E+04	3.22E+04	2.83E+04	8.95E+03	2.71E+04	3.26E+04	2.90E+04
Mean signal [cts]	2.70E+03	6.99E+03	8.76E+03	8.56E+03	9.02E+03	2.66E+04	3.23E+04	2.85E+04	8.96E+03	2.68E+04	3.24E+04	2.88E+04
Median signal [cts]	2.58E+03	6.83E+03	8.49E+03	8.21E+03	8.98E+03	2.65E+04	3.22E+04	2.85E+04	8.93E+03	2.68E+04	3.23E+04	2.86E+04
Measurement uncertainty mean (1SD) [cts]	1.65E+01	1.59E+01	2.42E+01	2.54E+01	3.41E+01	2.61E+01	5.31E+01	1.46E+02	2.89E+01	5.24E+01	3.85E+01	5.18E+01
Measurement uncertainty replicates (1SD) [cts]	5.22E+01	5.01E+01	7.64E+01	8.02E+01	1.08E+02	8.26E+01	1.68E+02	4.62E+02	9.12E+01	1.66E+02	1.22E+02	1.64E+02
Absolute total combined uncertainty on the mean (1SD) [cts]	1.66E+01	1.59E+01	2.42E+01	2.54E+01	3.42E+01	2.61E+01	5.31E+01	1.46E+02	2.89E+01	5.24E+01	3.85E+01	5.18E+01
Relative total combined uncertainty on the mean (1SD) [%]	**0.62%**	**0.23%**	**0.28%**	**0.30%**	**0.38%**	**0.10%**	**0.16%**	**0.51%**	**0.32%**	**0.20%**	**0.12%**	**0.18%**

- 0.01 s dwell time; 15 µm spot size; 3.5 Jcm^{-2}
- 10 lines of 30s each @ different lasing parameters:
  - Test 1(light green) – 10 Hz, total gas flow of 0.65 LPM (0.35 LPM in MFC1 and 0.3 LPM in MFC2)
  - Test 2 (light blue) – 50 Hz, total flow of 0.75 LPM (0.45 LPM in MFC1 and 0.3 LPM in MFC2)
  - Test 3 (light orange) – 50 Hz, total flow of 1.05 LPM (0.525 LPM in MFC1 and 0.525 LPM in MFC2)

TELEDYNE PHOTON MACHINES
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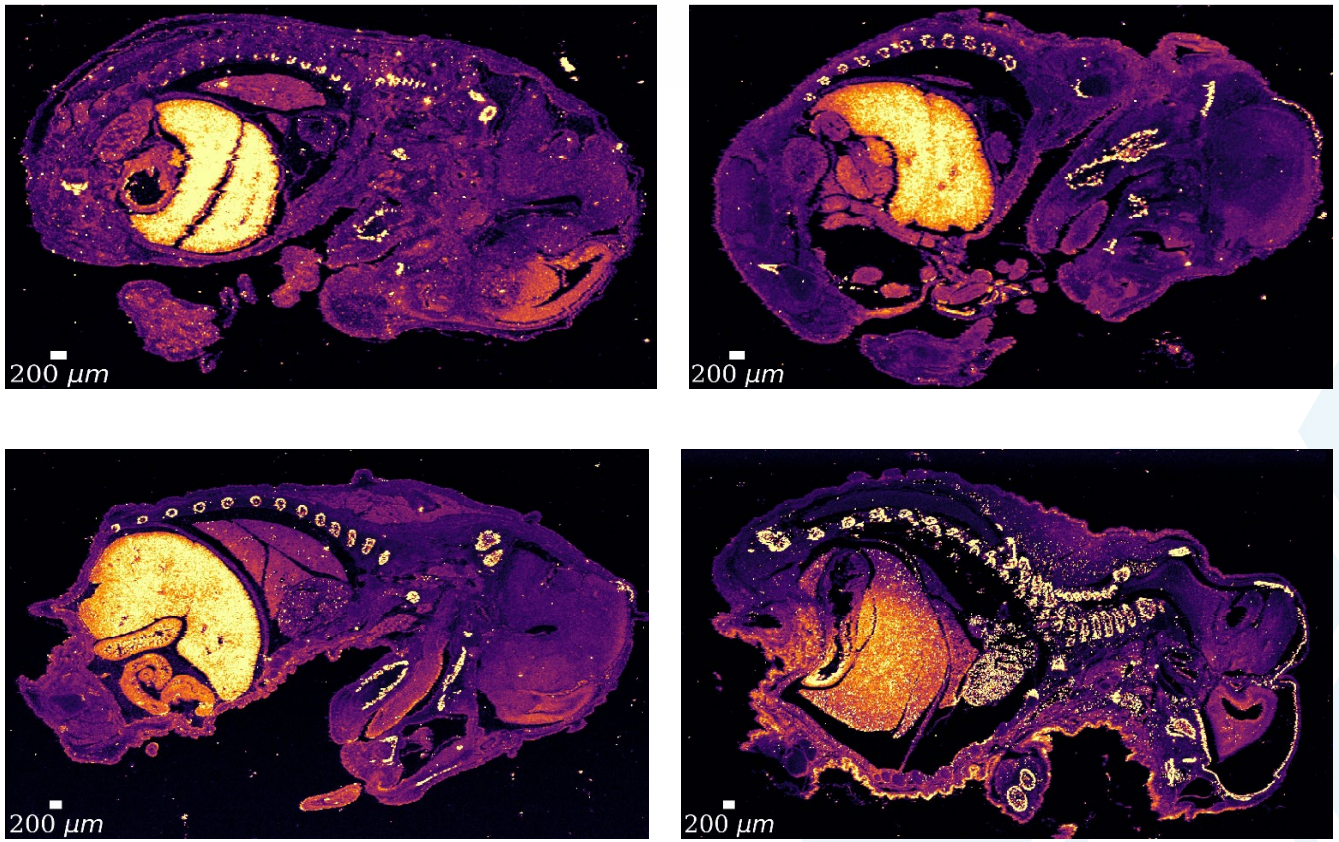
Summary

- Laser ablation provides outstanding sample flexibility
- Capable of single spot or bulk analysis
- Capable of generating sample maps in either 2D or 3D
- Technique developed need for automated data interrogation software
- An excellent addition to your “analytical toolbelt”



TELEDYNE
PHOTON MACHINES
Everywhereyoulook™

Coming Up...

COVALENT METROLOGY

Survey and Sign-Up for Calendly Appointments

COVALENT METROLOGY

Want to learn more about Covalent's

Laser Ablation ICP-MS Services?

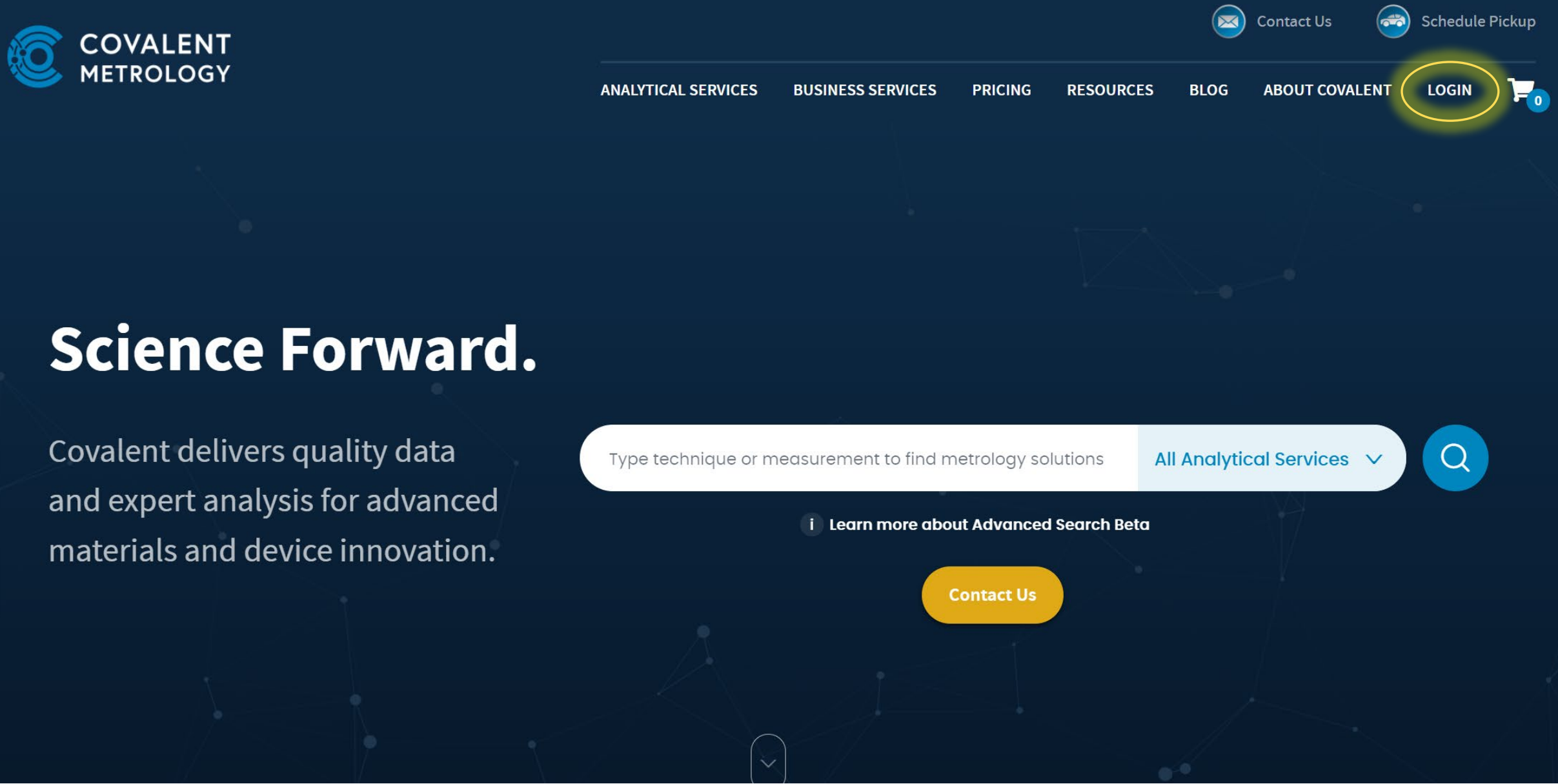
Talk with a Covalent Expert!

Schedule your Appointment Now with Calendly

- link is in the chat -

Covalent Community

COVALENT METROLOGY



Covalent Community

COVALENT METROLOGY

COVALENT METROLOGY

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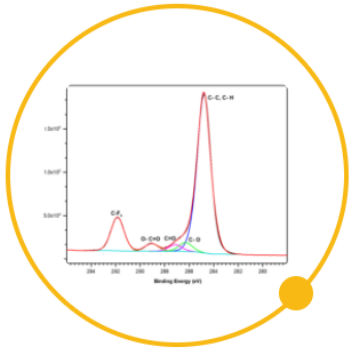

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Q & A Session

COVALENT METROLOGY

Thank you