Helios 5 Laser Hydra System

Fast high-quality subsurface and 3D characterization at millimeter scale with nanometer resolution

The Thermo Scientific Helios 5 Laser Hydra System delivers unmatched capabilities for extreme large-volume 3D analysis, Ga-free sample preparation, and precise micromachining. Featuring an innovative, fully integrated femtosecond laser, it offers fast material removal rate with high cut face quality.

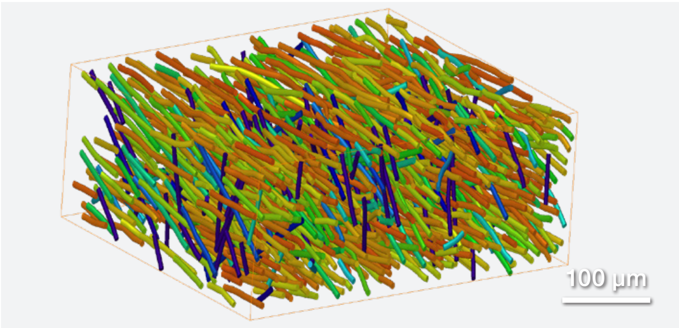
The Thermo Scientific™ Helios™ 5 Laser Hydra System is part of the fifth generation of the industry-leading Helios family. It combines the innovative Thermo Scientific Elstar™ SEM Column, for ultra-high-resolution imaging and excellent analytical capabilities, with a new novel multiple ion species plasma focused ion beam (PFIB) column delivering exceptional performance at all operating conditions. The addition of a femtosecond laser enables *in situ* ablation at unprecedented material removal rates for fast millimeter-scale characterization at nanometer resolution.

Statistically relevant subsurface and 3D characterization

The femtosecond laser provides the capability to cut materials orders of magnitude faster than a Ga FIB. For many materials, a large cross-section of hundreds of microns can be created within 5 minutes. Featuring a different removal mechanism (ablation vs ion sputtering), the laser can easily process challenging materials, such as non-conductive or ion-beam-sensitive samples; for example: glass, ceramics, hard and soft polymers, biomaterials, graphite, etc. Moreover, a protective coating to reduce charge or to mitigate curtain artifacts is not needed, further saving time and increasing total throughput.

The Helios 5 Laser Hydra System is designed with all three beams (SEM/FIB/laser) pointing at a single coincident point, enabling very short laser/ SEM switching times and no vacuum transfers. This provides high-precision in situ feedback, making it a unique solution for fully automated, ultra-large-volume 3D characterization using laser tomography.

Key Benefits
Fast material removal for millimeter-scale cross sections with a material removal rate up to 15,000x faster than a typical Ga FIB
Statistically relevant subsurface and 3D data analysis by acquiring much larger volumes within a shorter amount of time
Accurate and repeatable cut placement with triple beam coincidence on the sample
Fast characterization of deep subsurface features via extraction of subsurface TEM lamella or chunks for 3D analysis
High-throughput processing of challenging materials such as non-conductive or ion-beam-sensitive materials
Fast and easy characterization of air-sensitive samples without the need to transfer samples between different instruments for imaging and cross-sectioning
All capabilities of proven Helios 5 Hydra platform, including high-quality Ga-free TEM and APT sample preparation and extreme high-resolution imaging capabilities

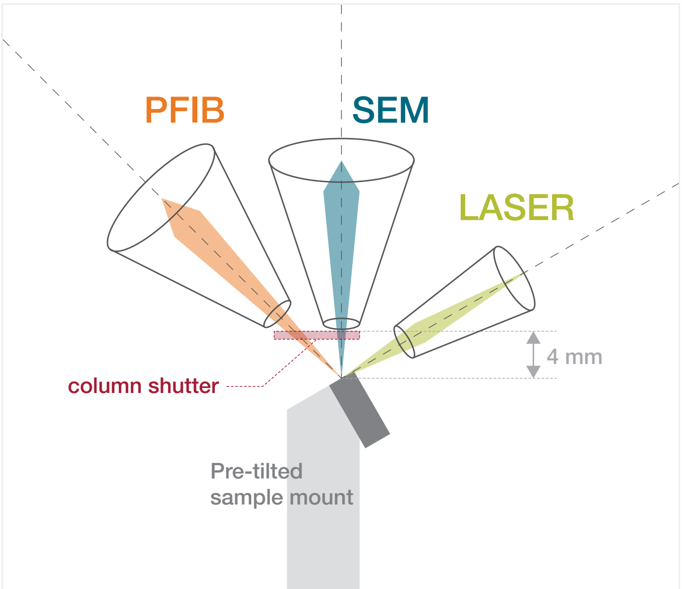


Laser tomography of a carbon-fiber-reinforced composite in epoxy.

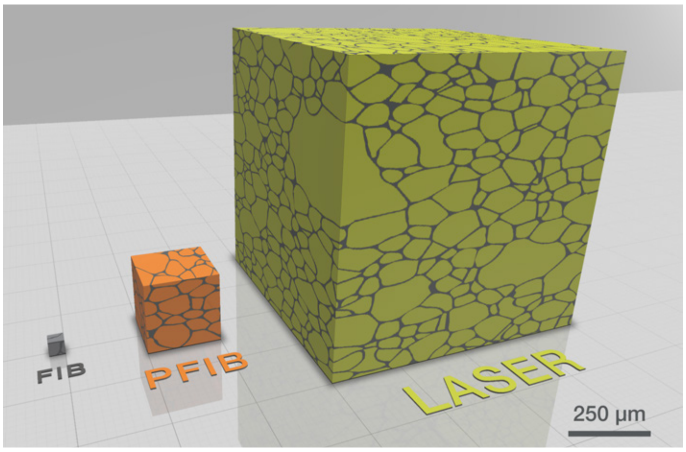
High-quality, large-volume analysis

The ultra-short duration of the femtosecond laser pulses introduces almost no artifacts while delivering much higher sitespecific accuracy compared to traditional mechanical polishing techniques, where, for example, delamination is often an issue. The femtosecond laser induces no heat impact, no microcracks, and no melting effects. In most cases, femtosecond laser-milled surfaces are clean enough for direct SEM imaging, and the quality is often sufficient for surface sensitive EBSD mapping. When it is necessary to improve the surface quality even further, a short PFIB polishing procedure can be used to reveal ultra-fine features. Compared to a Ga FIB, plasma-based FIB optimally complements the femtosecond laser to maintain high throughput.

Built on the proven Helios 5 Hydra platform, this instrument incorporates a suite of state-of-the-art technologies and provides high performance for common "FIB-SEM" use cases, such as high-resolution TEM and atom probe tomography (APT) sample preparation and extreme highresolution SEM imaging with precise materials contrast.



Schematics of Helios 5 Laser Hydra. Three beams converging at a single coincident point allow fast switching between SEM imaging and laser processing, provide accurate and repeatable cut placement, increase throughput, and enable 3D characterization.



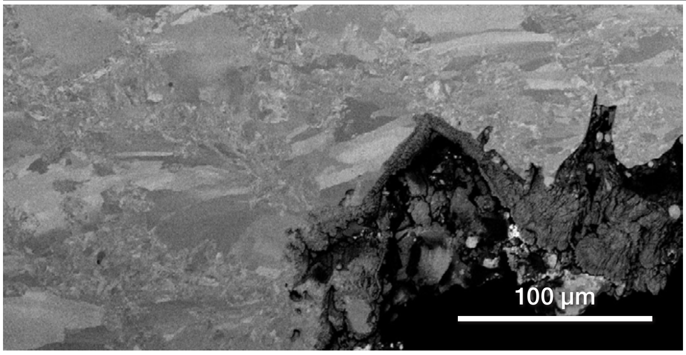
Comparison of representative 3D volumes acquired within the same amount of time with FIB, Plasma FIB, and femtosecond laser.

Helios 5 Laser Hydra System enables new applications

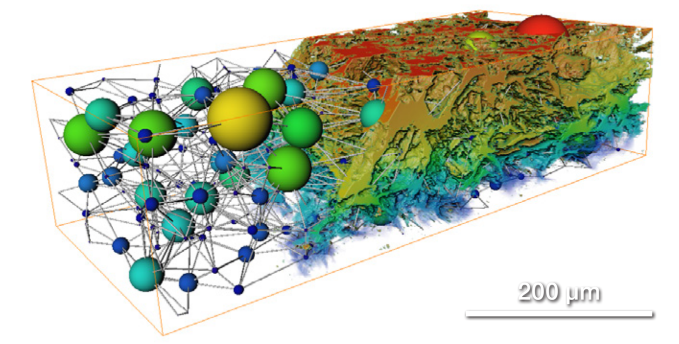
- Large-volume cross-sectioning for rapid failure analysis
- Fast access to buried subsurface layers often not accessible by (P)FIB
- Fast, precise micromachining of complex shapes, tensile rods, chunks, microCT specimens, etc.
- Millimeter-scale 3D laser serial sectioning, including analytical characterization with EDS or EBSD
- Easy and fast characterization of air-sensitive samples (e.g., batteries) with femtosecond laser processing and highresolution SEM imaging in the same vacuum chamber
- Fast, high-quality processing of challenging materials (e.g., carbon-based, ion-beam-sensitive, and non-conductive materials)
- Extended range of correlative microscopy with deep subsurface sample extraction

Overview of Helios 5 Laser Hydra System applications

Metals (conductive)

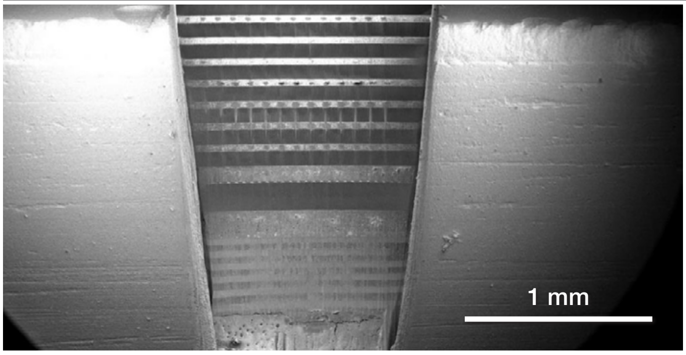


Steel produced by additive manufacturing.

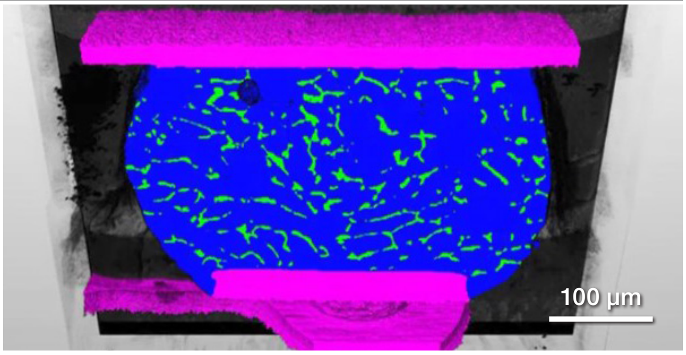


3D quantitative analysis of Li-ion battery graphite anode.

Semiconductors (conductive/non-conductive)

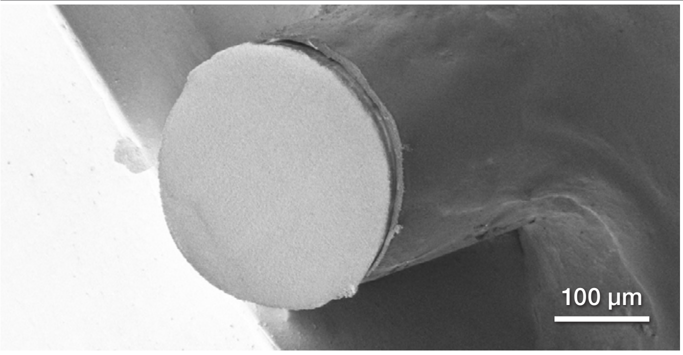


GPU stack.

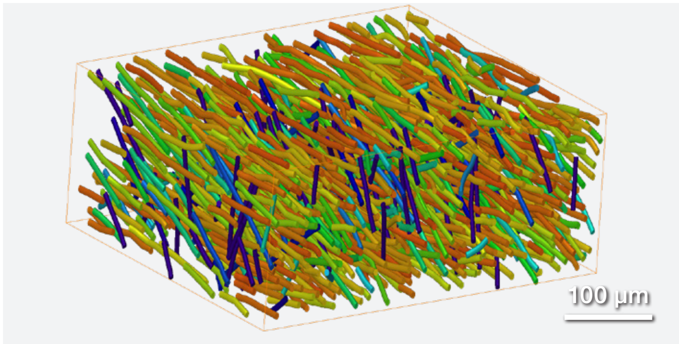


3D reconstruction of a solder bump.

Polymers (non-conductive, electron beam-sensitive)

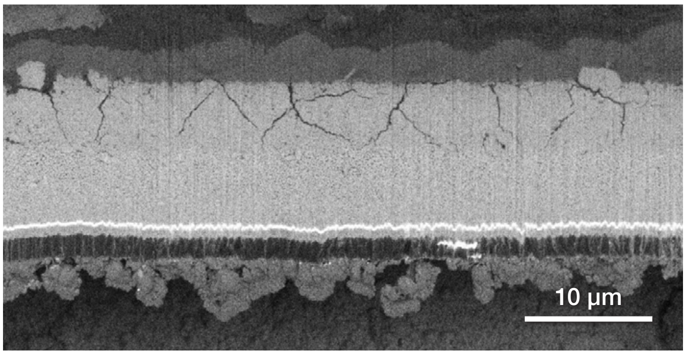


Nylon 6.6 (textile).

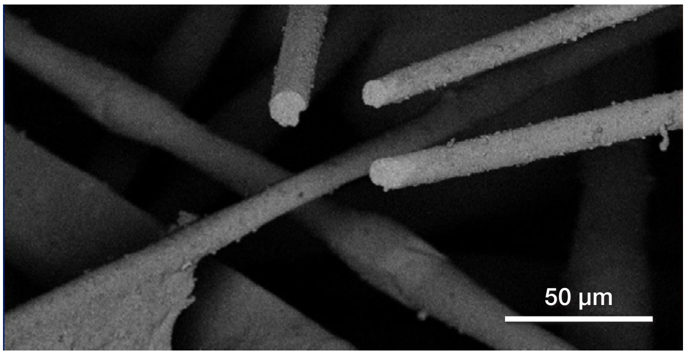


Carbon-fiber-reinforced epoxy composite.

Glass/ceramics (non-conductive, thermally sensitive, shock-sensitive)



Packaged solid-state battery.



Glass fibers.

Description	FIB	PFIB	Femtosecond Laser
Max volume*	40x40x40 µm^3	200x200x200 µm^3	2,000x2,000x1,000 µm^3
Max current	65 nA	2.5 µA	~1 mA (ion-beam-current equivalent)
Slicing current**	10 nA	180 nA	74 µA
Spot size	1–4 nm	15 nm–15 µm	15 µm

* Typical max volumes acquired within the same amount of time.
** 3D slicing currents used in practice for many materials.

Femtosecond laser specifications		
Laser integration	Fully integrated in the chamber with the same coincident point of all 3 beams (SEM/FIB/laser), enabling accurate and repeatable cut placement and 3D characterization.	
First harmonic	Wavelength Pulse duration	1,030 nm (IR) <280 fs
Second harmonic	Wavelength Pulse duration	515 nm (green) <300 fs
Optics	Coincident point Objective lens Polarization	WD = 4 mm (same as SEM/FIB) Variable (motorized) Horizontal/vertical
Repetition rate	1 kHz–1 MHz	
Beam position accuracy	<250 nm	
Protective shutter	Automated SEM/FIB protective shutter	
Software	Laser control software Laser 3D serial sectioning workflow Laser 3D serial sectioning workflow with EBSD Laser Scripting*	
Safety	Interlocked laser enclosure (Class 1 laser safety)	

* With optional Thermo Scientific AutoScript™ 4 Software

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