ImageHeadstart .eu

Breakthrough Computer Vision Applications in the Micro World: Consortium of Research Organizations for Industry 4.0

Interreg
EUROPEAN UNION
Austria-Czech Republic
European Regional Development Fund

Jihočeská univerzita
v Českých Budějovicích
University of South Bohemia
in České Budějovice

ÚTAM AV ČR, v. v. i., Centrum excelence Telč

Donau-Universität Krems
Universität für Weiterbildung

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UPPER AUSTRIA
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ImageHeadstart news no. 5

INTRODUCTORY MESSAGE

The Interreg project ImageHeadstart brings together researchers from different imaging disciplines in an interdisciplinary attempt to push the advancements in microscopy and computed tomography. Our goal is to make these advances available to a wide range of companies in the cross-border project region of the Czech Republic and Austria. After more than two years of collaboration, we implemented several activities and are successfully on the way to bring research facilities and the industry constantly closer. The participation in multilateral workshops, information sessions, consultations, and trade fairs in 2022 has hence resulted in numerous new fruitful partnerships between academia and industry. In addition, we continued our research efforts - also despite the difficulties caused by the omnipresent pandemic - in order to continuously develop new methods in biomedical and industrial imaging.

Prof. Sascha SENCK

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FOUR-POINT BENDING DEVICE FOR X-RAY SCANNER

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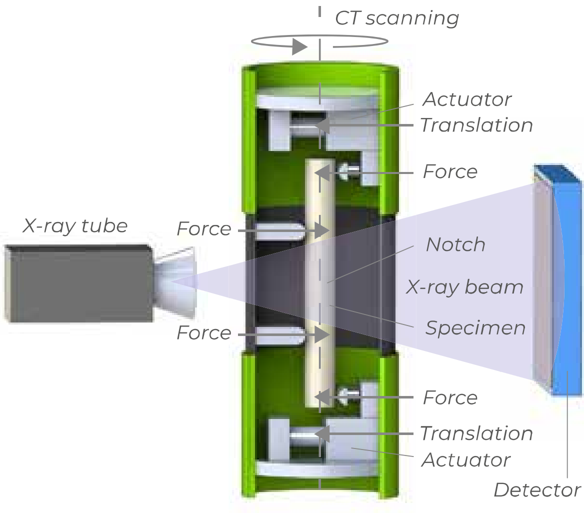
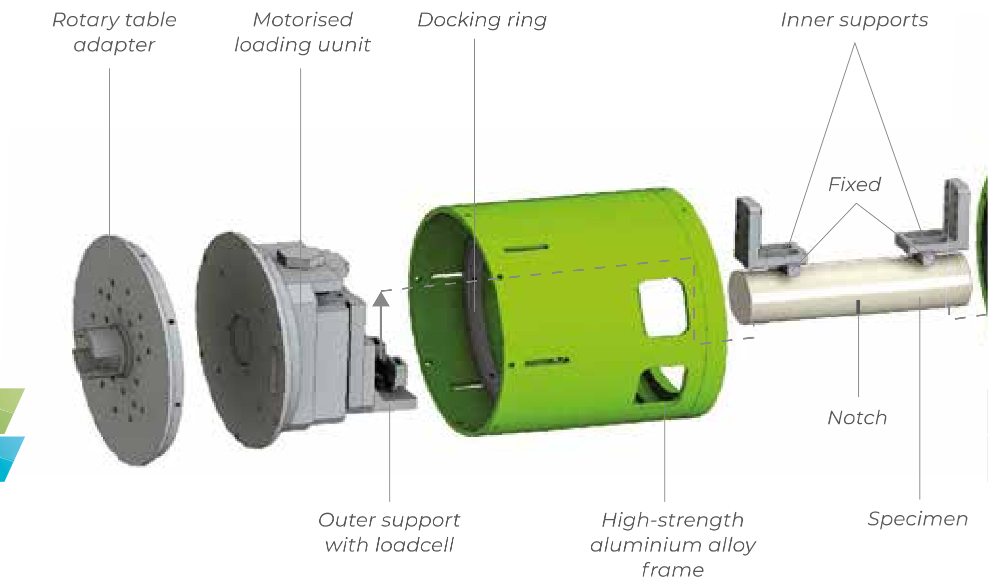
Overview



Four point bending device was developed for crack propagation observation in CT device. Disadvantage of a standard three-point bending experiment is the function of the bending moment with an extremum at a single point. This cause high demands on the precision of the support geometry, the geometry of the specimen and its placement between supports. These problems can be overcome using the four-point bending arrangement with constant moment between the inner supports. Another important aspect to be considered is the orientation of the specimen investigated. The horizontal orientation of the sample which is normally used together with the loading supports



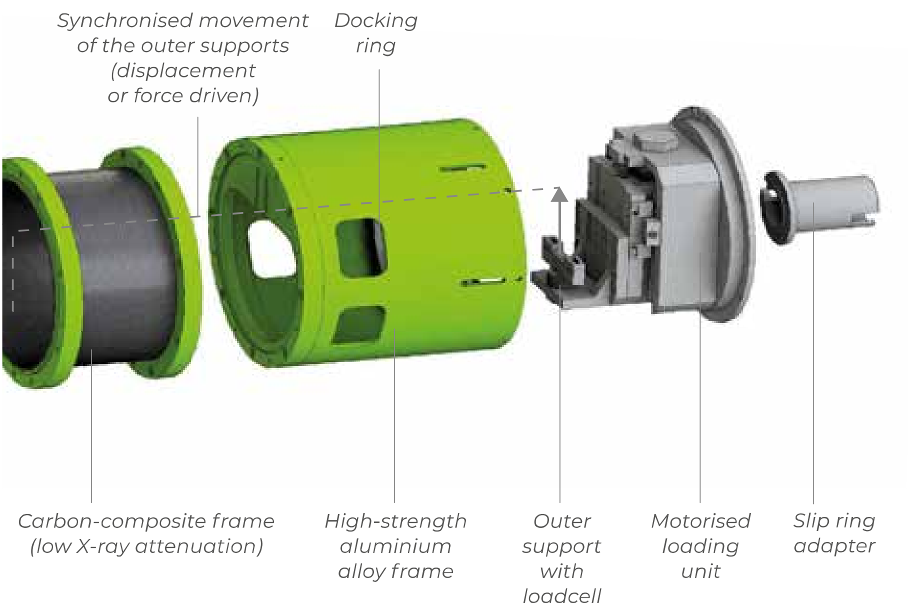
covering parts of the radiograms caused limitations in terms of contrast and resolutions. Therefore the specimen in the newly developed device is oriented vertically with its longitudinal axis identical with the rotational axis of the CT scanner.
The four-point bending setup is composed of three main components: a pair of motorized loading units with integrated movable outer supports, a pair of stationary inner supports, and the cylindrical load bearing frame housing the loaded specimen together with the components of the loading device.
To ensure high contrast in the acquired radiograms, the part of the loading frame located inbetween the inner supports was manufactured from carbon fibre composite (T700S carbon fibres, MTM57 series epoxy resin) with low attenuation of X-rays with the nominal thickness 1.95 mm.

Specification

- Load capacity 1250 N/support
- Min. velocity 0.2 μm/s
- Max. velocity 1000 μm/s
- Precision 10 μm
- Repeatibility 5 μm
- Sensitivity 1 μm
- Stroke 16.5 mm
- Spec. length 185 – 285 mm
- Spec. dia. 0 – 45 mm
- Mass ca. 15 kg
- Sampling rate 50 Hz
- Dimensions ⌀ 220 × 493 mm

Features

- Real-time data logging
- CNC controlled with custom SW
- Closed-loop control system
- Linear magnetic encoders
- Rotary slip rings



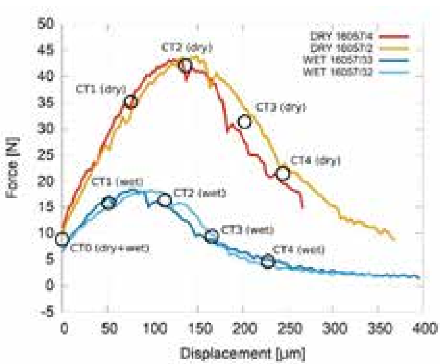
Accessories

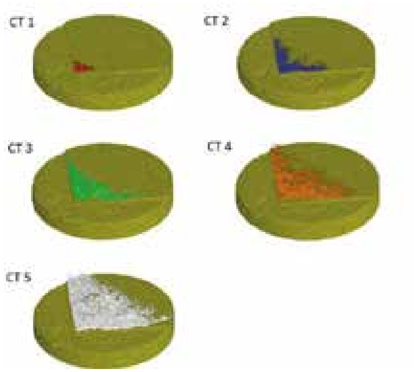
The device is delivered in wheeled safety transport case and equipped with following accessories:

- mounting and docking kit
- calibration kit
- instrumented calibration block
- slip ring extenders
- cables with length up to 7 m

Application

Cylindrical samples of a sandstone with a chevron were subjected to four-point bending. During the loading procedure, several XCT scans were acquired. The reconstructed 3D images were processed using differential tomography and digital volume correlation algorithms to investigate the crack propagation[1].





[1] *Vavrik et al.: Local fracture toughness testing of sandstone based on X-ray tomographic reconstruction, Int. J. Rock Mech. Min. Sci. 138 (2021) 104578, DOI 10.1016/j.ijrmms.2020.104578*

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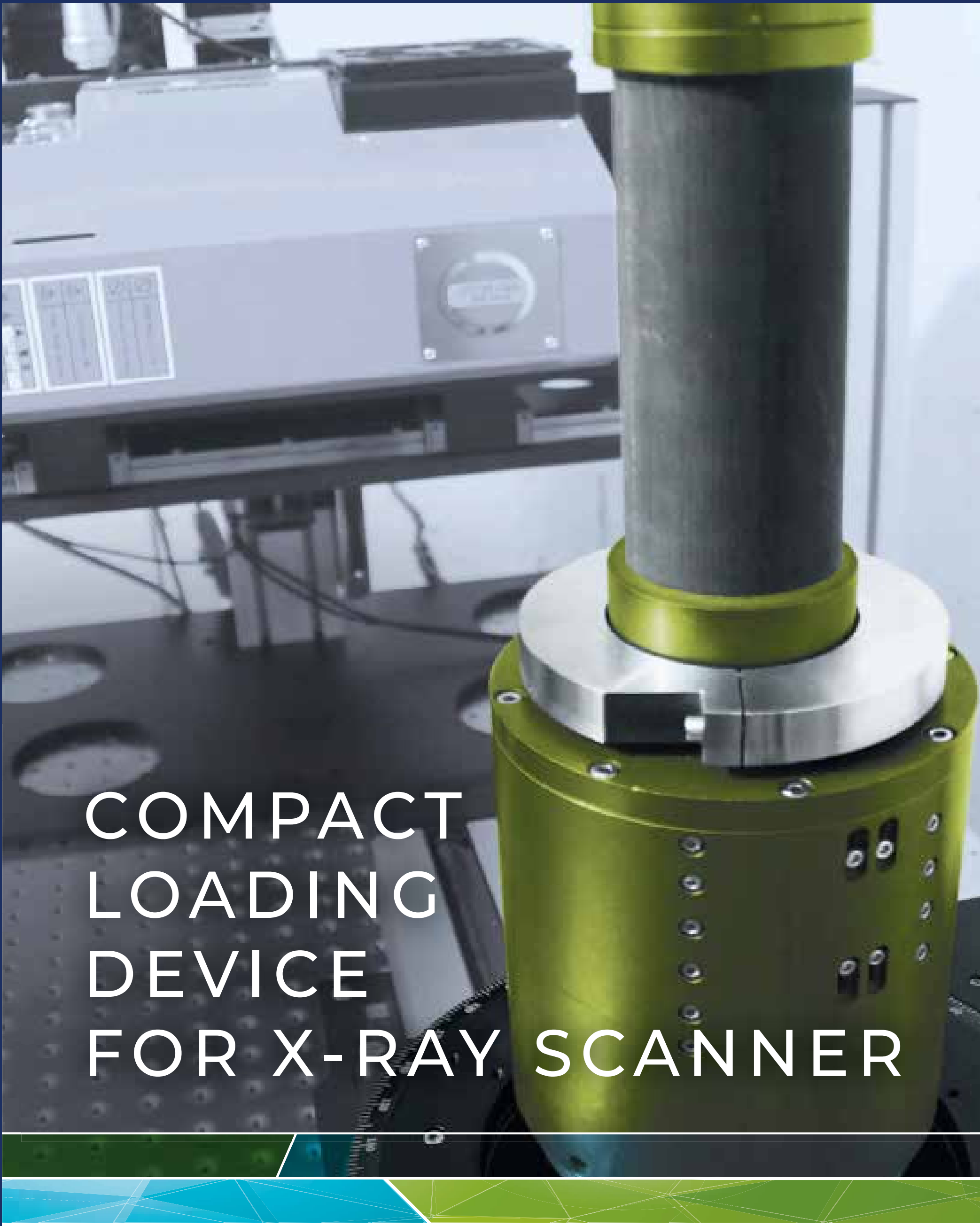

COMPACT LOADING DEVICE FOR X-RAY SCANNER

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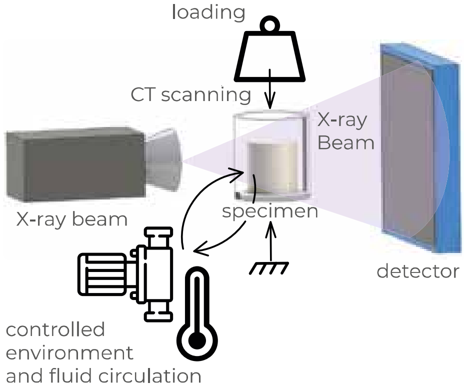
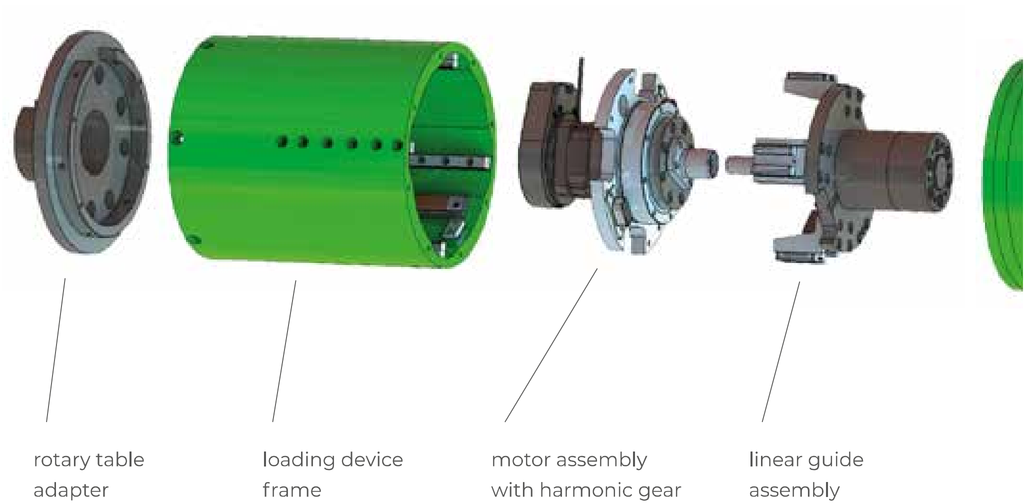
Overview

The table top loading device is designed for investigation of the deformation behaviour of materials and constructs with complex internal (micro)structure. Compact design together with the carbon fibre composite frame make this device compatible with laboratory X-ray micro-tomography scanners for time-lapse and on-the-fly imaging.

Available accessories allow to perform compression, tension, and bending experiments. For biomechanical testing and tissue engineering applications, the experiment can be performed under controlled ambient conditions using integrated bioreactor. Thin 3-ply carbon fibre frame with diameter of 56 mm, thickness of 0.45 mm and load capacity of 3 kN is delivered as a standard loading chamber. Optionally, a small diameter tube (20 mm) with load capacity of 1 kN is available for micro-testing and a metallic frame designed for general loading procedures performed out of micro-CT scanner are available.





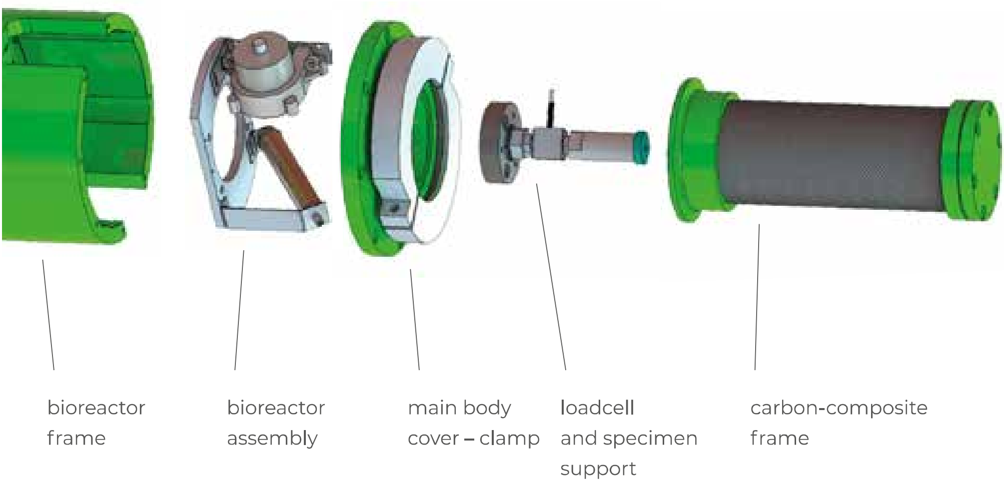
The device can be fully integrated into customized as well as standard imaging systems. Control is performed by the RaPo software supporting monotonic, low-cycle, and creep testing.

Specification

- Load capacity 3000 N
- Min. velocity 0.1 µm/s
- Max. velocity 100 µm/s
- Absolute position accuracy 20 µm
- Position repeatability 1 µm
- Position tracking sensitivity 0.25 µm
- Stroke 30 mm
- Sampling rate 200 Hz
- Mass ca. 8 kg
- Dimensions Ø130x465 mm (with bioreactor)

Features

- Real-time data logging
- CNC controlled w. custom SW
- Linear magnetic encoders
- Rotary slip rings



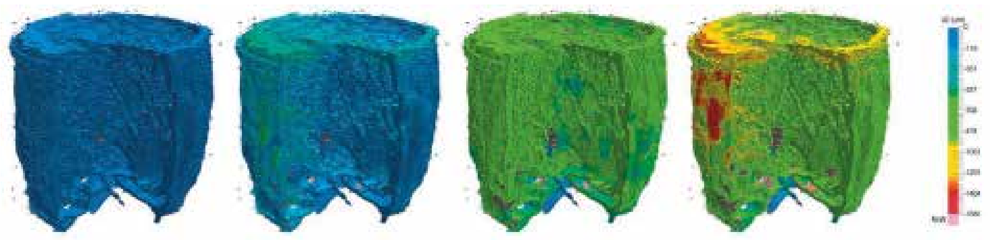
Accessories

The device is delivered in wheeled safety transport case. Loading frame can be customized and equipped with various accessories.

- 20 mm carbon frame for micro-testing
- metallic frame for non-X-ray procedures
- adapter for three-point bending
- heating and cooling stages
- customized loading plates/grips
- environmental chamber

Application

A bone scaffold was subjected to the continual compression and simultaneously scanned in the computed tomography scanner. Deformation characteristics were evaluated using digital volume correlation (DVC) method on the reconstructed volumetric datasets[1].



Visualisation of the deformed full-scale voxel model of the scaffold's microstructure showing the displacements during the loading procedure.

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[1] *Kytyr, D. et al., Deformation analysis of gellan-gum based bone scaffold using on-the-fly tomography, Mater. Des. 134 (2017) 400, DOI:10.1016/j.matdes.2017.08.036*

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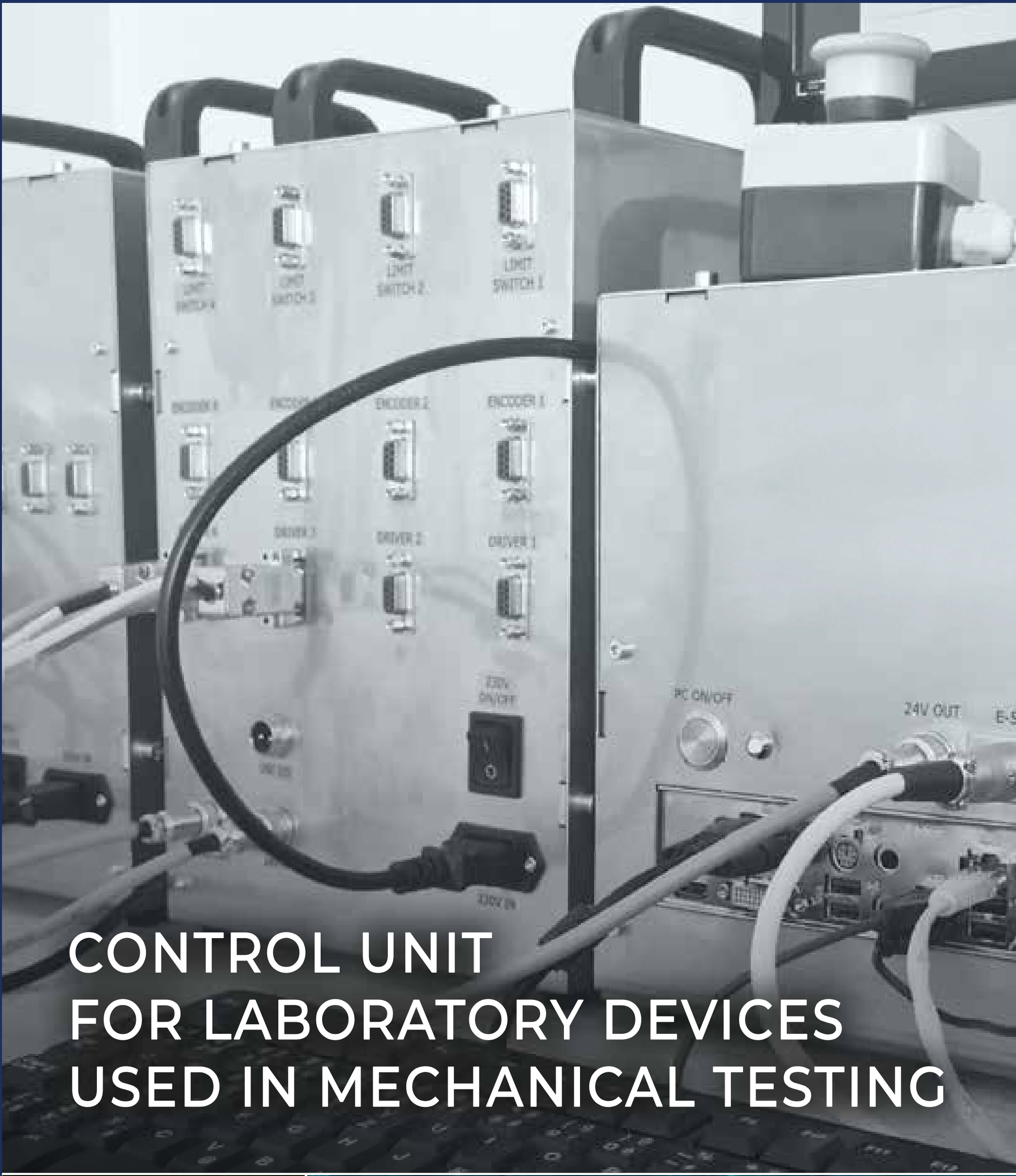

CONTROL UNIT FOR LABORATORY DEVICES USED IN MECHANICAL TESTING

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Overview

Control unit together with expansion modules enable the control of a wide range of custom laboratory devices primarily in the field of the material and biomedicine research equipped by the stepper or servo motor actuators. Expansion modules are connected to the control unit via daisy-chain bus and in the basic configuration the control system can operate with four stepper motor positioning stages and one servo motor positioning stage. The control system also provides support for the external/internal limit switches and encoders.

To satisfy the research specific needs (e.q. measurement of force, temperature etc.) the control unit includes multifunctional DAQ device (T7, Labjack corporation, USA) with 14 analog inputs (16- to 18-bit), 2 analog outputs (12-bit), 23 digital I/O, and up to 10 digital counters/timers. For measurement of the low-level signals such as bridge circuits (e.g. strain gauges) and thermocouples is the DAQ device equipped by the two-channel instrumentation amplifier with the user selectable gain.

The control unit is based on the micro-ATX or mini-ITX standard and optimized to achieve the low system latency of a control procedure, especially designed in an open-source project LinuxCNC. Thus, the architecture of the control system fully supports the RaPo control software.

Control unit (micro-ATX configuration)

Stepper motor expansion module

Functionality

Specification of the basic configuration (with one stepper and one servo motor expansion modules)

- control up to four stepper motor positioning stages
- control of one servo motor of positioning axis
- support connection of external/internal encoders and limit switches
- daisy-chain bus connection of expansion modules
- hardware architecture based on products of Mesa Electronic
- in micro-ATX configuration supports up to eight high speed RS-422 or RS-485 serial devices
- provides multifunctional DAQ device: 14 analog inputs (16- to 18-bit), 2 analog outputs (12-bit), 23 digital I/O, and up to 10 digital counters/timers.
- two-channel instrumentation amplifier for connecting of various sensors (strain gauges, thermocouples)
- emergency stop functionality
- modular and portable design
- powered by OS Linux with real-time kernel
- full support and optimization for the RaPo control software

Servo motor expansion module

DETEX testing solution: the control unit with the servo motor expansion module for control of the uni-axial loading device (nominal force 25 kN) suitable for X-ray imaging.

Control unit (micro-ATX configuration) with the servo (voice-coil actuator) motor and stepper motor (two-axis table) expansion modules for the control of the micro-indentation stage.

Control unit (mini-ITX configuration) with the stepper motor expansion module for control of the uni-axial loading device (nominal force 3 kN) suitable for X-ray imaging.

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SOFTWARE FOR REAL-TIME CONTROL OF LABORATORY DEVICES

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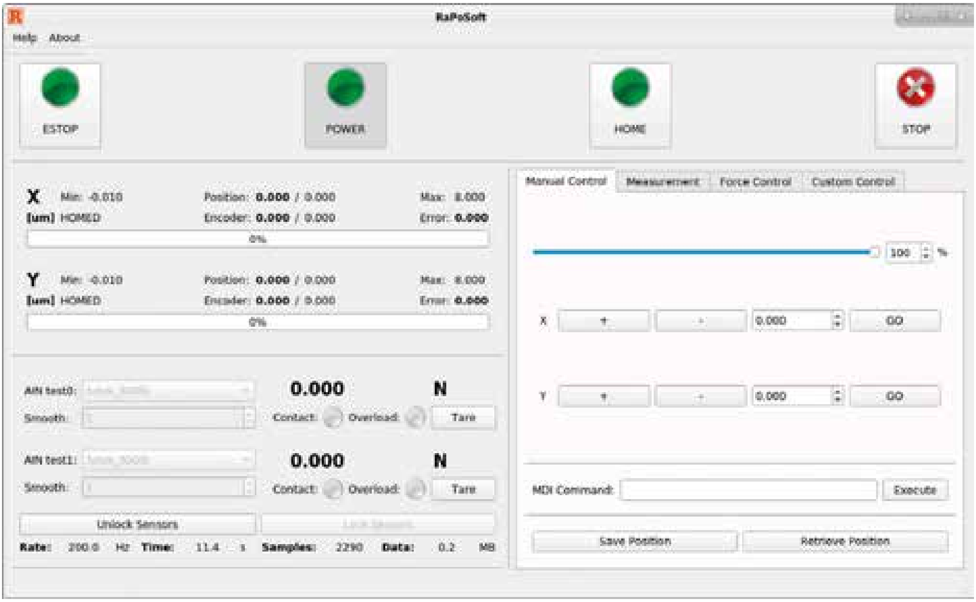
Overview

The RaPo is a modular software tool for real-time control (positioning and data acquisition) of wide range of custom laboratory devices primarily in the field of material and biomedicine research. The software allows single- or multi-axial loading, testing under controlled ambient conditions and simulation of physiological processes. All these experimental procedures may be combined with optical or X-ray imaging.

The software is capable of high-precision measurement with sampling rate up to 500Hz. The positioning precision is up to 50nm. The output data are contained in an ASCII based text file.

The software tool is based on an open-source project LinuxCNC. The control software is written in Python programming language and uses the LinuxCNC Python Interface to communicate with LinuxCNC internals through Python. For Graphical User Interface (GUI) development, a Qt framework in cooperation with PyQt binding for Python was used.



RaPo graphical user interface

LinuxCNC
open source CNC
machine controller

Python
high-level and general-purpose
programming language

QT
widget toolkit for creating
graphical user interfaces

Functionality

Multi-channel data acquisition, various types of sensors

- load cells
- thermometers
- acoustic sensors
- high-resolution CCD cameras, X-ray data

Experimental procedures

- displacement-driven loading
- force-driven loading – linear force, cyclic loading, custom functions
- controlled sample environment (temperature + fluid flow)

Displacement-driven loading

- linear loading
- custom functions from sampled data

Force-driven loading

- feedback using load cells
- linear force: F(t) = a*t + b
- cyclic loading: sine, square, triangle, sawtooth (fatigue testing)
- custom functions from sampled data

Controlled sample environment

- sample temperature controlled by circulating medium[1]
- controlled flow rate of the fluid
- preserving, stimulating and aggressive media[2]
- fluid flow controlled using a pump driven by DC motor

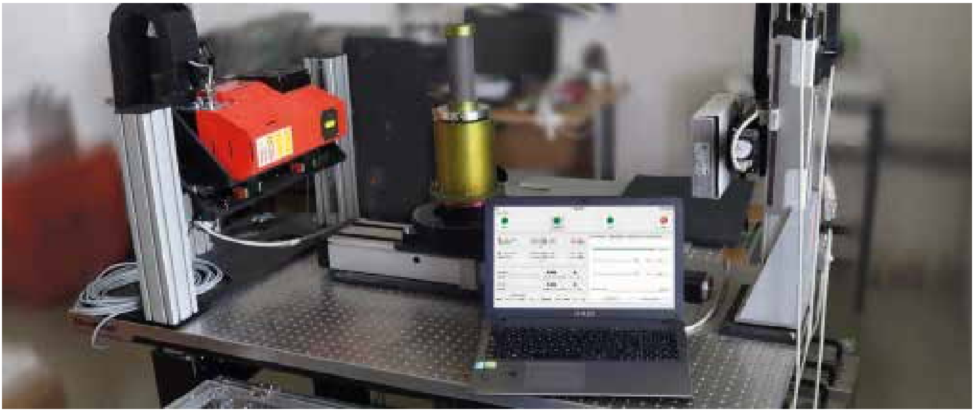
Real-time plot of the obtained data

Programmable scripting interface through Python (for creating complex and fully automated experimental methods)

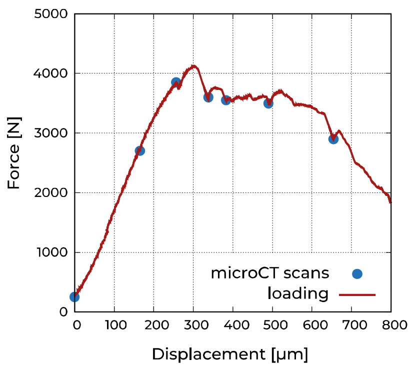
1) heating and cooling platforms for operation in 0-80 °C

2) simulated body fluid, purified water, corrosive fluids, etc.

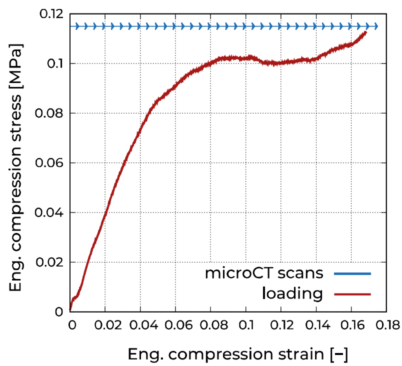
Application



The software used for the overall control of the laboratory X-ray micro tomograph with integrated in-situ loading stage for mechanical testing under controlled ambient conditions.



Loading curve of titanium construct prepared by additive manufacturing observed by time-lapse microtomography.



Deformation behaviour of gellan gum based bone scaffold observed by on-the-fly microtomography.

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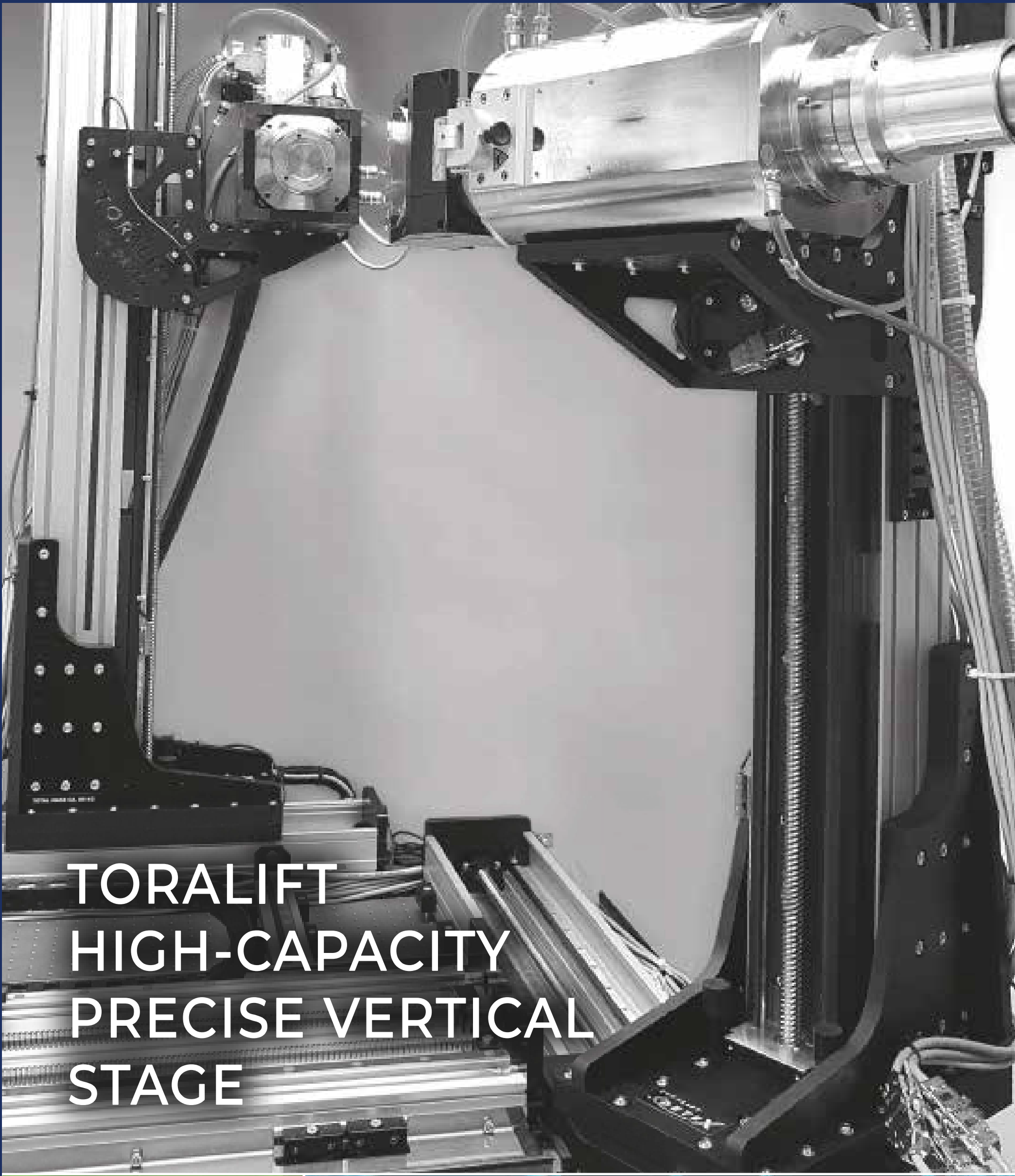

TORALIFT HIGH-CAPACITY PRECISE VERTICAL STAGE

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TORALIFT

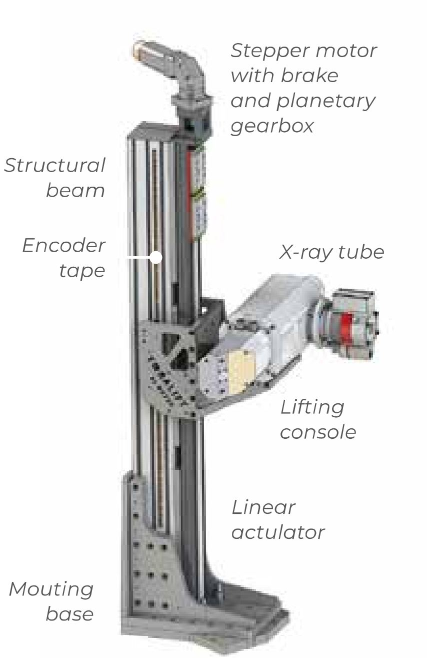
Vertical stage tube with linear actuator, stepper motor and high precision angled planetary gearbox which is used for X-ray tube positioning. The lift is equipped with high precision absolute linear magnetic encoder for closed-loop position control.

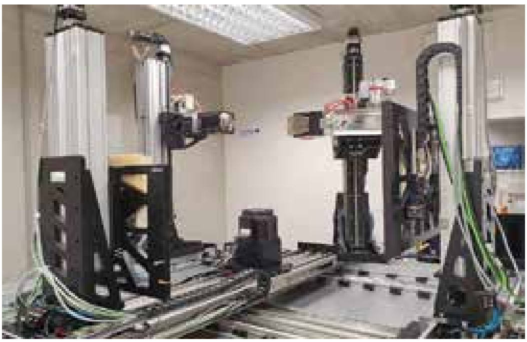
Important components

▸ Linear actuator	HIWIN KK10020x-1280A2
▸ Planetary gearbox	Apex Dynamics AFR060-P041200302, ratio 1:7
▸ Motor	Servo Drive, stepper V35493 with brake
▸ Linear encoder	Renishaw RLS, LMA10

Parameters

▸ Overall mass	ca. 85kg
▸ Load capacity	150 kg
▸ Stroke	985 mm
▸ Main beam	aluminium profile 120 x 120 mm
▸ Frame	aluminium alloy EN-AW-6082





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ÆSPEX

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Camera-based, AI-powered intelligence mining system

Get instant feedback on consumer needs, their profiles and future behavior

aex.ai

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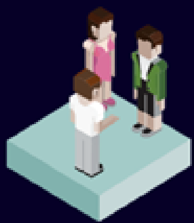
...are the customers?

Type of smart camera application	Where... 	Who... 	Why... 
Retail	• Advertisement • Services optimization	• Customer profile mining • Security • Surveillance	• Product optimization • Development strategy
Entertainment			
Public spaces		• Security • Surveillance	• Throughput improvement • Development strategy • Population studies
Transit facilities	• Advertisement • Services optimization • Safety		
Military and enforcement	• Access control • Safety		• Counterintelligence

One solution can be applicable to many cases

Imagine a surveillance system of future:

- In place analysis, no compression artefacts
- Hard realtime, 25 fps, low network footprint

- Single platform
- Linearly scalable
- Cost-effective, no GPU needed

- Everything in browser, mobile support
- Low latency realtime view
- Fully interactive, rich statistics

Discover how it could be useful for you:

- People counting
- Crowd flows estimation
- Customer profile mining
- Accurate hourly statistics
- Visitor activity assessment
- See behaviour feedback immediately

Core team

Kirill Lonhus

Data explanatory analysis and complex systems artisan, PhD

CEO & CSO

Maxim Karpov

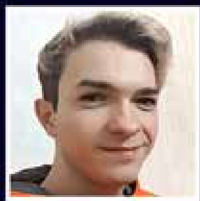
Security exprety, full (hardware ⇔ web) stack dev, MSc

Principal dev

Dalibor Štys

Image processing evangelist, complex systems, Prof.

Foreign relations



Ivan Larin

Keeping us people oriented, BSc

Web design & dev

We have a team, vision and bootstrapped product in our hands.

Looking for seed investment, contact us:

Product, RnD & cooperation:

loki@aex.ai   t.me/jl8kii

Technical & Infrastructure:

mk@aex.ai   t.me/makkarpov

Location: currently Czech Republic

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Nanotruth

Return of the real light microscopy and much more

with technology tradition dating back to 1919

Simplest possible sample preparation:

The Nanotruth works with unlabelled samples. Labelling is typically used for the visualisation of certain types of chemical composition, and typically suppresses other types of composition and many details. By spectral analysis, we may distinguish all different chemical compositions, i.e., all components in the sample.

Large field of sight:

Usage of full frame camera chips allows us to observe the size of the movie format remembered from the old times. We still retain the detail of 300 nm resolution despite a small pixel size and unique interpolation technology in 32–256-dimensional spectral space.

Resolved by chemical composition

The mathematical discovery of quasispectralanalysis allows us to assign absorption or reflected light spectrum to each image point. The clustering of spectra allows us to effectively classify the image points into chemically different regions. We obtain chemical resolution instead of chemical labelling.

Suitable for all known applications of light microscopy

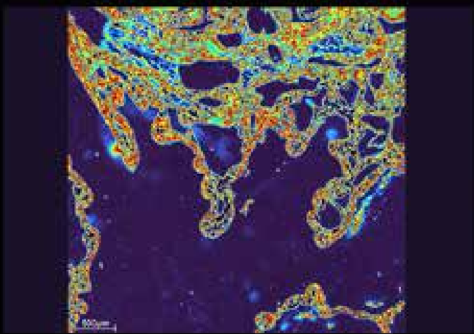
Contact: stys@jcu.cz Dalibor Štys

Simplest possible tissue section preparation in histology.

The whole histological section of 1×1.5 cm^2 was captured in a one-shot image in 0.1 ms.

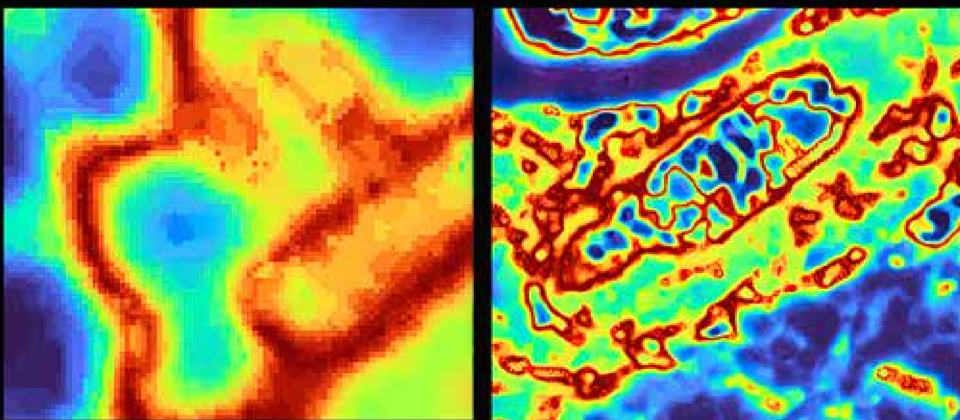
The sample was prepared without chemical labelling.

The spectral resolution brings information fully equivalent to specific fluorescence labelling and better than chemical labelling.



A spectrally labelled sample

The whole section



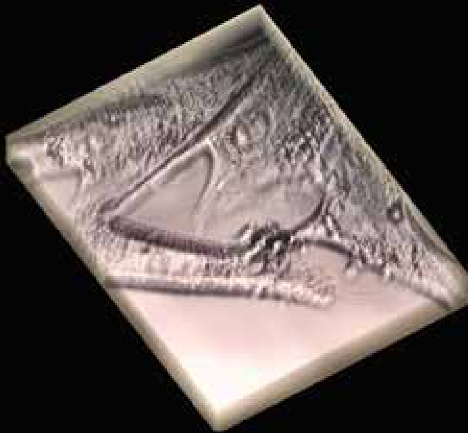
Magnification of the labelled sample shows the level of detail.

Current technologies compose histological sections from 17 000 images.

The whole tissue is labelled into spectrally distinguished specific tissues. The spectral analysis enables the recognition of all kinds of tissue in one slide.

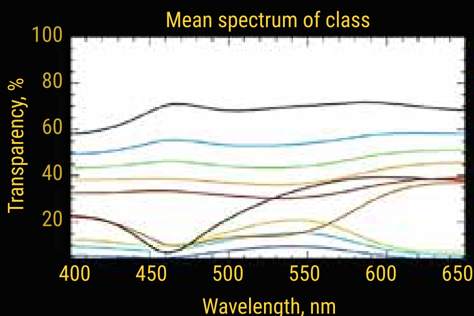
A spectrally resolved 3D structure of a living cell

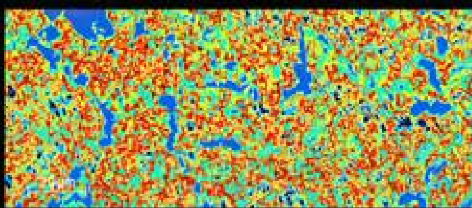
The whole stack of light transmission images of living human dermal fibroblasts was captured, and each level was spectrally analysed. The result was a reconstruction into a form resembling the observation in the daylight. The result is structurally equivalent to scanning confocal microscopy and provides complete tissue mapping without labelling.

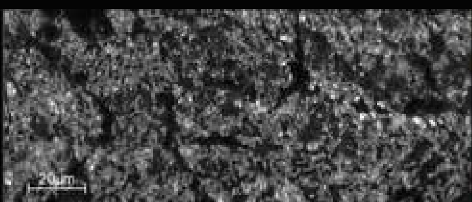


Steel surface

Upper left – spectra of individual steel components, right – component distribution. Lower left – img at 555 nm, structurally resolved, right – img in simulated sunlight. Nanotruth imaging identifies alloy components and their structural analysis, i.e., complete, and automated objective assessment of metal quality.







Minimal workload and minimal material costs of sample preparation

The sample is used in the native form without any chemical or mechanical modifications.

Simplest possible image collection in a single shot, time-lapse, z-scan, and any combination of these at the lowest possible light exposure. The large sensor size enables coverage with a complete sample with an expected microscopic resolution. Any type of experiment may be realized as a combination of a time-lapse with a z-scan.

Guaranteed best achievable image quality

The spectral analysis enables the creation of images at wish.

Autofocus for multiple focal planes

The experiment for critical samples is performed at a multitude of focal planes. Important focal planes are selected in the postprocessing phase.

Maximal information yield and new lossless image storage format

We obtain a full spectrum for each data point. Clustering into 256 clusters provides the “8-bit” resolution; the spectra are stored in the alphanumeric file heading. This dataset may be restored into an image very that is almost identical to the original 16-bit image.

utimately universal spectrometer

UU´SPE

Mechanically robust, ultra-cheap
UV-VIS-IR light
pocket spectrometer

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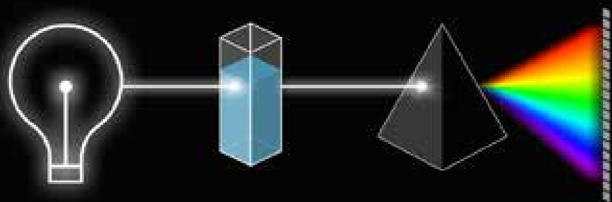
The problem – unreliable information

Light spectrum is the prominent tool of both human and machine perception of the outside world.

Is my home crafted food stable?

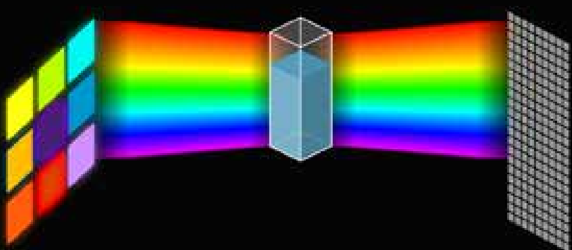
Does my water cleaning station operate correctly?

Classical solution – a tabletop spectrometer



- Contains precise mechanics and optical elements destroyed by shaking
- Immobile and intrinsically expensive
- Not robust, needs regular calibration and maintenance
- Interpretation of results requires a trained specialist

Our solution – minimal size RGB-camera based spectrometer



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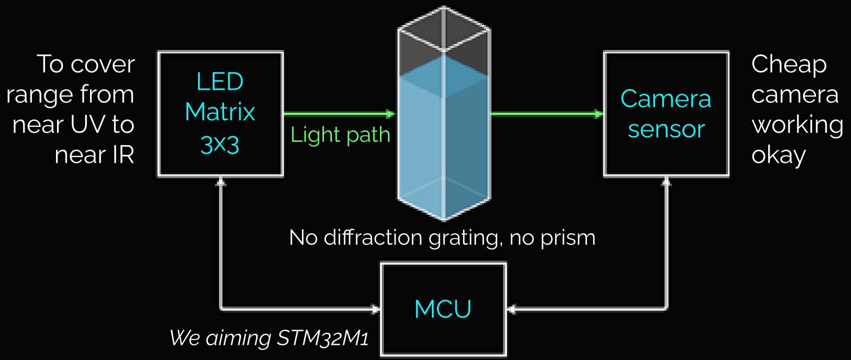
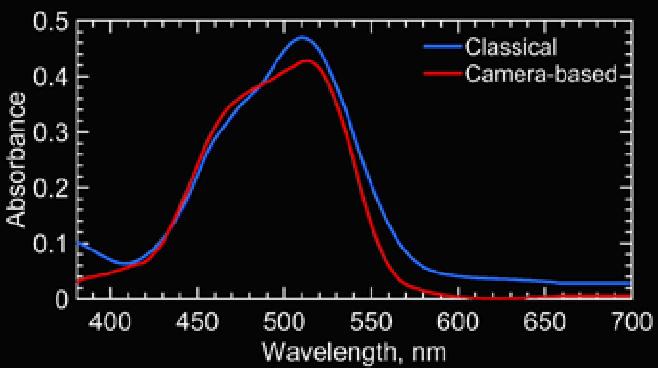
Highlights



- Compact, no mechanics, robust
- Cheapest possible production
- Produces continuous absorption spectrum
- All configurations are possible, such as, e.g., flow-through cuvette, orthogonal detector positions or double detectors
- Could work in harsh conditions, vibrations, etc
- Acquisition 6 s (could be 0.4 s), processing 20 s (could be 8 s); feasible for observing transient processes
- Fully digital; results will be accessible through Bluetooth in place



The wavelength range could be from 380 to 760

Accuracy ~5 nm, precision ~3 nm

In the final device, the accuracy/precision can be 1 nm.

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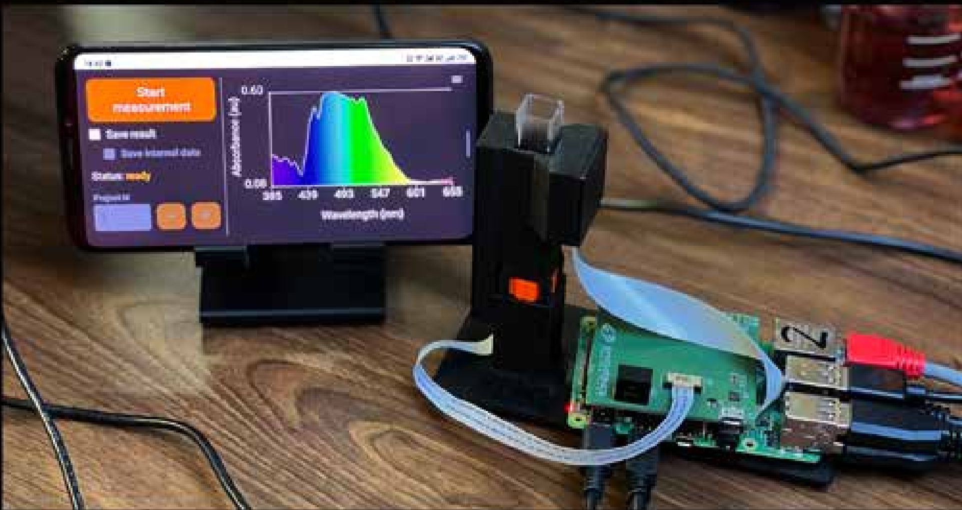
Readiness: working prototype

We not only invented the principle, mathematics and design, but also battle tested it.



Our aim

To make spectrophotometer measurement inexpensive, durable, and efficient in any real craft, industry, or quality control laboratory and in outdoor hobby activities that feed data to any consequence analysis.

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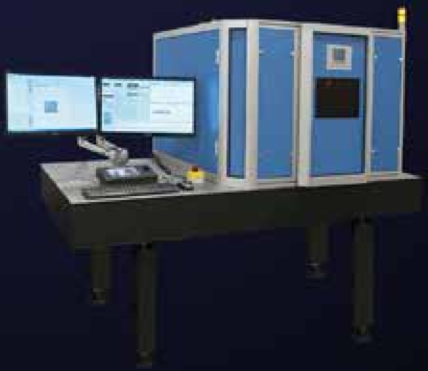
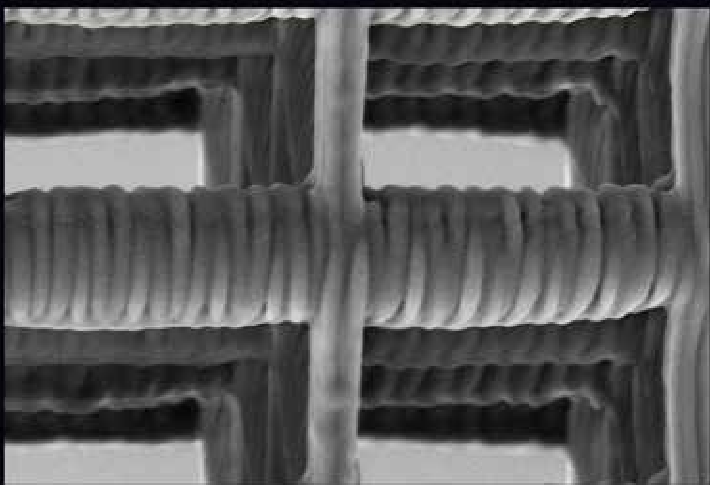
Multiphoton lithography

The research group at the University of Applied Sciences Upper Austria hosts a multiphoton lithography (MPL) instrument for production of scaffolds for various applications (e.g., tissue regeneration). MPL allows for direct laser writing of features far below the diffraction limit.



Recently, we focused on 3D structuring of scaffolds inside microfluidic channels and membranes suitable for cell growth. The used polymers are biocompatible and can be modified regarding their chemical and mechanical properties.



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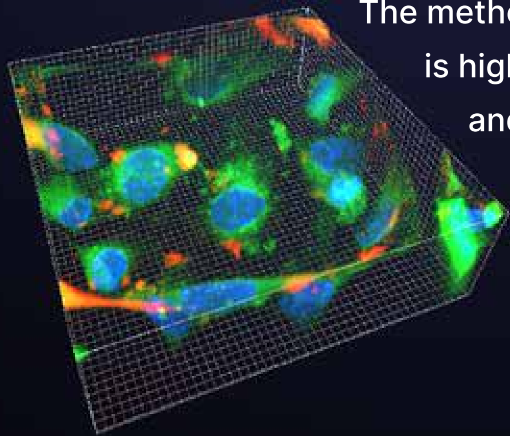
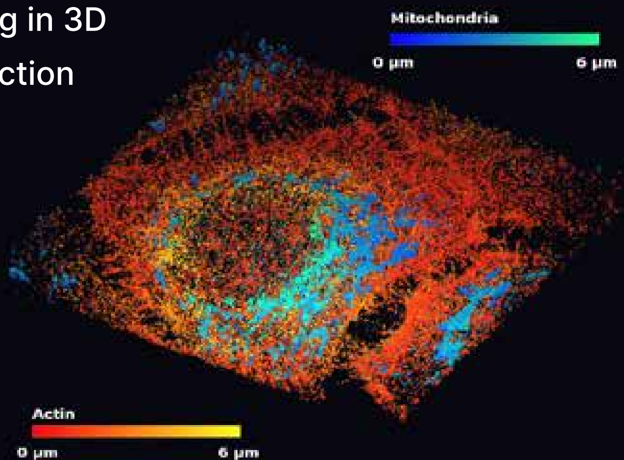
Single Molecule Microscopy

Single Molecule Fluorescence Microscopy is a key method when it comes to decipher biological processes on a molecular level for quantitative analysis of cells.



The methodology is highly sophisticated and requires advanced optics.

The instruments operating at the University of Applied Sciences Upper Austria are all custom build, controlled via custom made software capable of real-time analysis and allow imaging in 3D with a sub-diffraction resolution.



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X-ray microcomputed tomography

In addition, the Research Group Computed Tomography of the University of Applied Sciences Upper Austria houses four different X-ray microcomputed tomography (XCT) systems. Component testing is carried out on the largest system (RayScan 250E) which features two high-energy X-ray sources. High-resolution scans with a voxel size down to 200 nm are carried out on two micro-/nano-focus XCT systems (Phoenix/X-Ray Nanotom 180 and RX-Solutions EasyTom). Finally, phase-contrast and dark-field tomograms are obtained using a dedicated XCT system that was realized in the form of a Talbot-Lau grating interferometer (TLGI) featuring three gratings. Using this system, it is possible to extract additional information about the microstructural composition of an object in the form of differential phase and dark-field contrast.

The image displayed below shows an example of the multi-modal imaging capabilities of the TLGI-XCT imaging approach in the form of a fiber-reinforced PVC supply hose (diameter: 12.5 mm). In contrast to conventional XCT, TLGI-XCT provides three complementary characteristics in a single scan of the part: a) the attenuation contrast (AC), b) differential phase contrast (DPC), and c) the dark-field contrast (DFC). Due to the low density of the polymer fibers in the tube wall, fiber bundles are not visible in the AC image. DPC is more sensitive to low differences in the density of materials, e.g. two different polymers that constitute the fiber-reinforced hose. Due to the fact that DFC delivers morphological information in the sub-pixel regime depending on the local scattering power, dark field imaging delivers information that is inaccessible using conventional XCT, i.e. the single fiber bundles in the PVC matrix.

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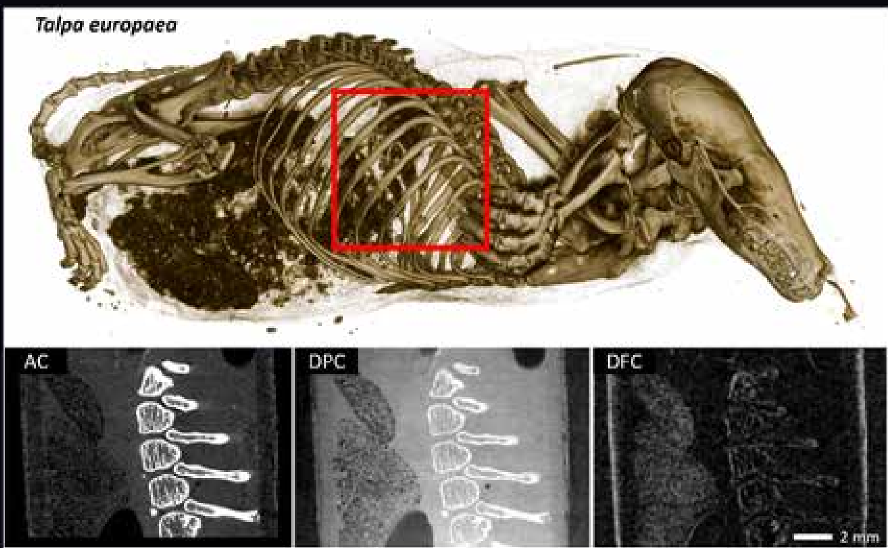
TLGI-XCT

Since TLGI-XCT provides three-dimensional data, carbon and polymer fiber-reinforcements can be visualized in high detail. The resulting volume data can be used for the non-destructive evaluation, e.g. of defects, or used as a basis for subsequent material and structural simulations.

This imaging technique originates from biomedical imaging and is currently used for the detection of lung pathologies in a clinical context. The image below shows an example of dark-field lung imaging of a European mole (Talpa europaea). The whole specimens were scanned at a voxel size of 65 µm using the RayScan 250E system. The dissected thorax was subsequently scanned using the Skyscan 1294 system. Obviously. The contrast between air and lung tissue is significantly improved. In addition, the pulmonary alveoli represent a large interface volume, at which X-rays are scattered.



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