Applied material analytics with neutrons and synchrotron radiation.

Way beyond the laboratory scale.

anaxam
analytics for advanced manufacturing

You are an industrial company and have discovered a tricky problem with your product?

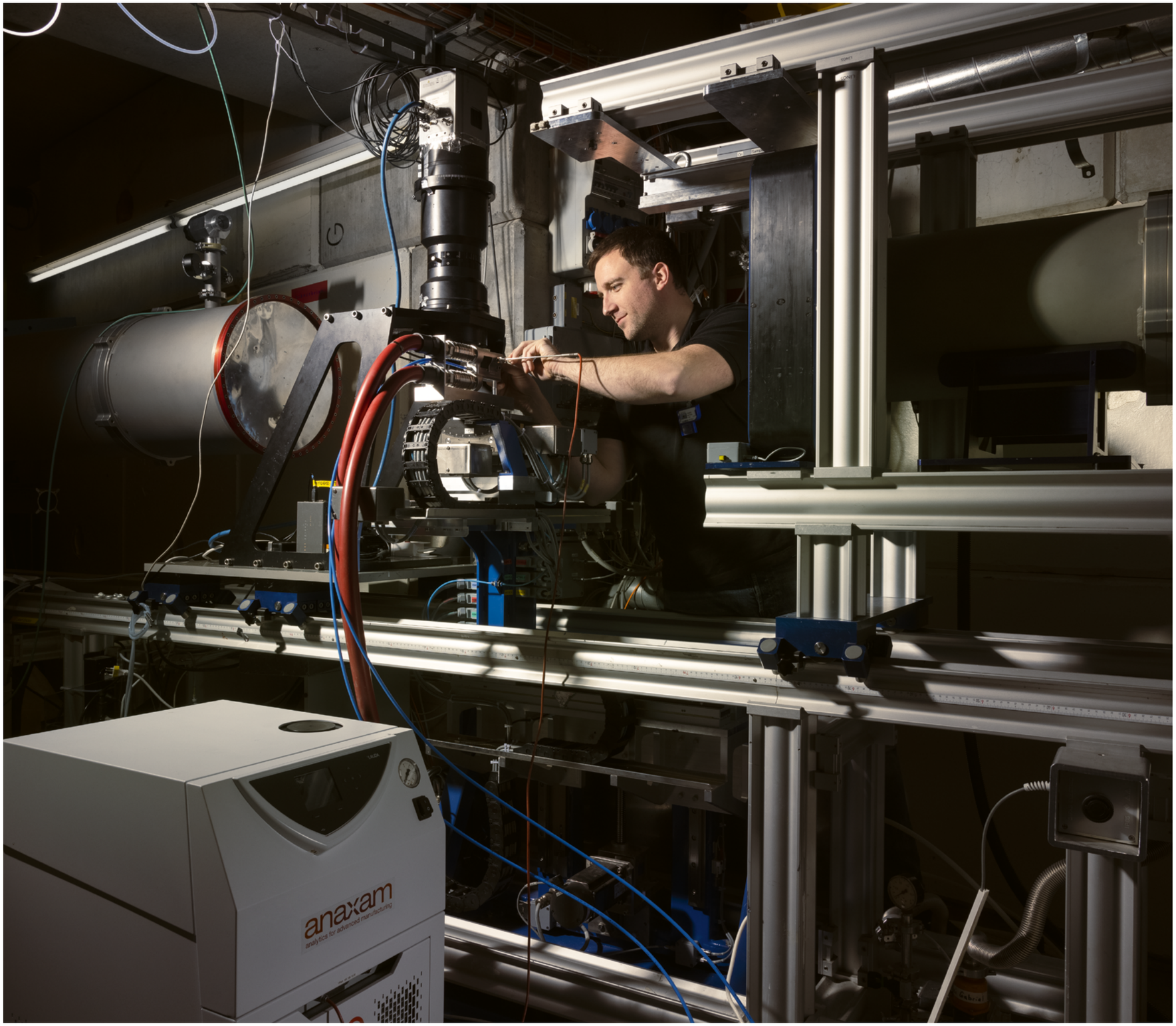
Is it a problem with **materials, design,** or **manufacture?** To find a solution, we give you access to **state-of-the-art material analytics** originally developed for cutting-edge fundamental research. Thanks to the services we offer, these capabilities are now available **for industrial challenges.** Our applied analytics **services** are based on investigations at internationally renowned large research facilities, including the Swiss Spallation Neutron Source SINQ and the Swiss Light Source SLS at thePaul Scherrer Institute PSI.

Compared to laboratory-scale X-ray investigations, **material analytics with synchrotron radiation** can enable completely new kinds of insights, since the photon flux delivered by the synchrotron source is **10,000,000,000 times higher,** and thus the views inside materials are **much more detailed,** for example in terms of resolution, real-time studies, and high sample throughput. **Material analytics with neutrons** can only be carried out at large research facilities. This is particularly beneficial when it comes to seeing through metals.

As a customer, you benefit from our innovative analysis methods in the areas of **imaging, diffraction, scattering,** and **spectroscopy.** In addition to material analysis, we implement **customized infrastructures** in order to reproduce **customer reality** for the analytics services.

Thus, the **analytics services** provided by ANAXAM **go way beyond the analytics achievable on a laboratory scale** and are unique in Switzerland.

Dr. Christian Grünzweig
Managing Director/CEO



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What we can do for you

Overview of ANAXAM

- ANAXAM is a technology transfer center.
- ANAXAM is a non-profit organization.
- ANAXAM provides industry access to advanced analytics methods using neutron and synchrotron (X-ray) radiation that were originally developed for basic research. The large research facilities of the Paul Scherrer Institute (PSI) are primarily used for this.
- ANAXAM collaborates with industry based on the “public-private partnership”.
- ANAXAM is headquartered in Villigen, in the Canton of Aargau, Switzerland.
- ANAXAM was founded in 2019 by the Paul Scherrer Institute (PSI), the University of Applied Sciences and Arts of Northwestern Switzerland (FHNW), the Swiss Nanoscience Institute (SNI), and the Canton of Aargau.

The ANAXAM core team, from left to right:

Matthias Wagner
Acting Managing Director/CTO

Dr. Vladimir Novak
Project Manager

Dr. Christian Grünzweig
Managing Director/CEO

Benedict Ammann
Technician

Dr. Cynthia Chang
Project Manager/CSO

Philippe Würsch
Technician

- ANAXAM is a member of the Alliance of Advanced Manufacturing-Technology Transfer Centers (AM-TTC). The AM-TTC Initiative is a measure of the Swiss federal action plan on digitalization in education, research, and innovation. The goal of the action plan is to promote innovation and accelerate knowledge transfer by providing the needed infrastructure.
- ANAXAM's goal is to support industrial customers during the entire life cycle of their products and processes with its analytic competences, so that they are able to bring innovative and high-quality products to market. For this purpose, ANAXAM offers material analytics way beyond the laboratory scale. The analytics offered focus on product and process optimization, quality control, quality assurance, and downstream tests in the advanced manufacturing processes for these products.

Reasons to work with ANAXAM

- Our cutting-edge analytics that go way beyond what is available on a laboratory scale
- Our tailor-made infrastructure that enables us to reproduce the customer's reality for analytical services
- Our unique platform for exchange of knowledge and know-how between industry and top-level research
- Our one-stop-shop mentality
- Our industrial and scientific know-how and experiences in various fields of application
- Our highly advanced analytical techniques in the fields of imaging, diffraction and spectroscopy, based on the large-scale facilities at the Paul Scherrer Institute (PSI)

We break through the limits of analytics

With respect to:

- spatial resolution
- real-time investigations
- contrast modality
- sample throughput

Material analytics way beyond the laboratory scale

We make it possible for industry to gain access to state-of-the-art material analytics originally developed for basic research and now available to address industrial challenges. Our applied analytics services are mainly based on use of the Swiss Spallation Neutron Source (SINQ) and the Swiss Light Source (SLS), large research facilities run by the Paul Scherrer Institute (PSI). The image to the left shows the two facilities from a bird's-eye view. SLS is marked with an x for X-rays, SINQ with an n for neutrons.

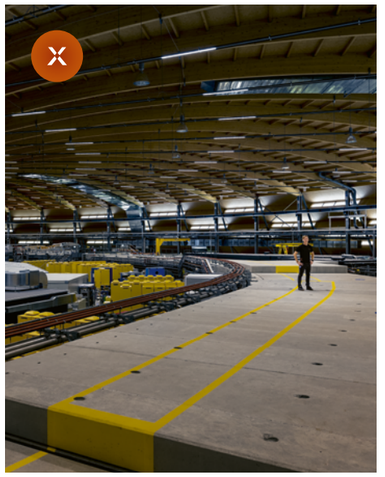
Factor of 10 billion
Our synchrotron analytics can enable new insights, since the photon flux delivered by the synchrotron source is higher than that of laboratory-scale sources by the gigantic factor of 10 billion (10,000,000,000).

Our neutron analytics techniques are only possible at large research facilities and are unavailable in any form at the laboratory scale.

The two photos below show inside views of SLS and SINQ. The person on the left is at SLS, standing on top of the accelerator enclosure. Under his feet, synchrotron light is emitted by electrons moving at nearly the speed of light on a circular path with an overall circumference of 288 meters. The person on the right is standing in the enormous hall housing the neutron source SINQ. The large, light blue concrete blocks shield a so-called target, a piece of metal that, when hit by a proton beam, shoots out neutrons.

Way beyond the laboratory scale
Given the dimensions of these facilities that we use for our analytic methods, it is understandable that our services go way beyond what is possible at the laboratory scale. They are also unique in Switzerland.

That is what material analytics way beyond the laboratory scale means to us: With the help of neutron and synchrotron radiation, we are pushing the limits of material analytics.

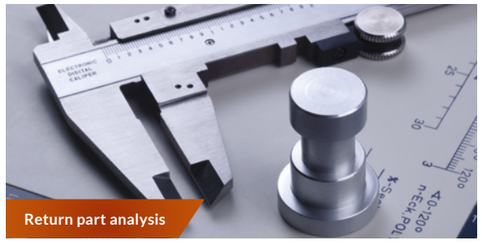


Our analytics for various fields of application

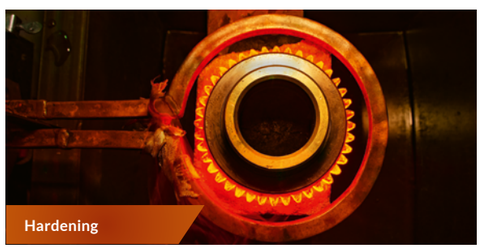
We're convinced that our analytics can help you improve your materials, products, and processes in a wide range of application fields.

Industries

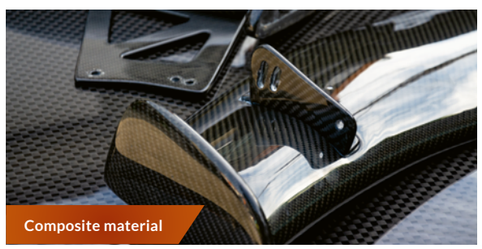
Products



Processes



Materials



Our analytics support your complete product life cycle

You want to overcome the challenge, no matter where it lies: Whether in raw or engineered materials, in the concept phase, during the product development process, or when your product is already on the market but needs further optimization – we at ANAXAM can find the solution that fits.

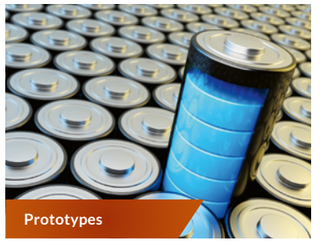
Material
Construction materials
Functional materials
Metallic materials
Raw materials
Powder materials
...

Process & product development
Concept phase
Product design
Prototypes
Process development
Production ramp-up
...

Product in market
Life cycle evaluation
Process optimization
Product optimization
Quality analysis
Return part analysis
...

Example: Electromobility


Raw material


Prototypes


Life cycle evaluation

Example: 3D printing


Powder materials


Process development


Product optimization

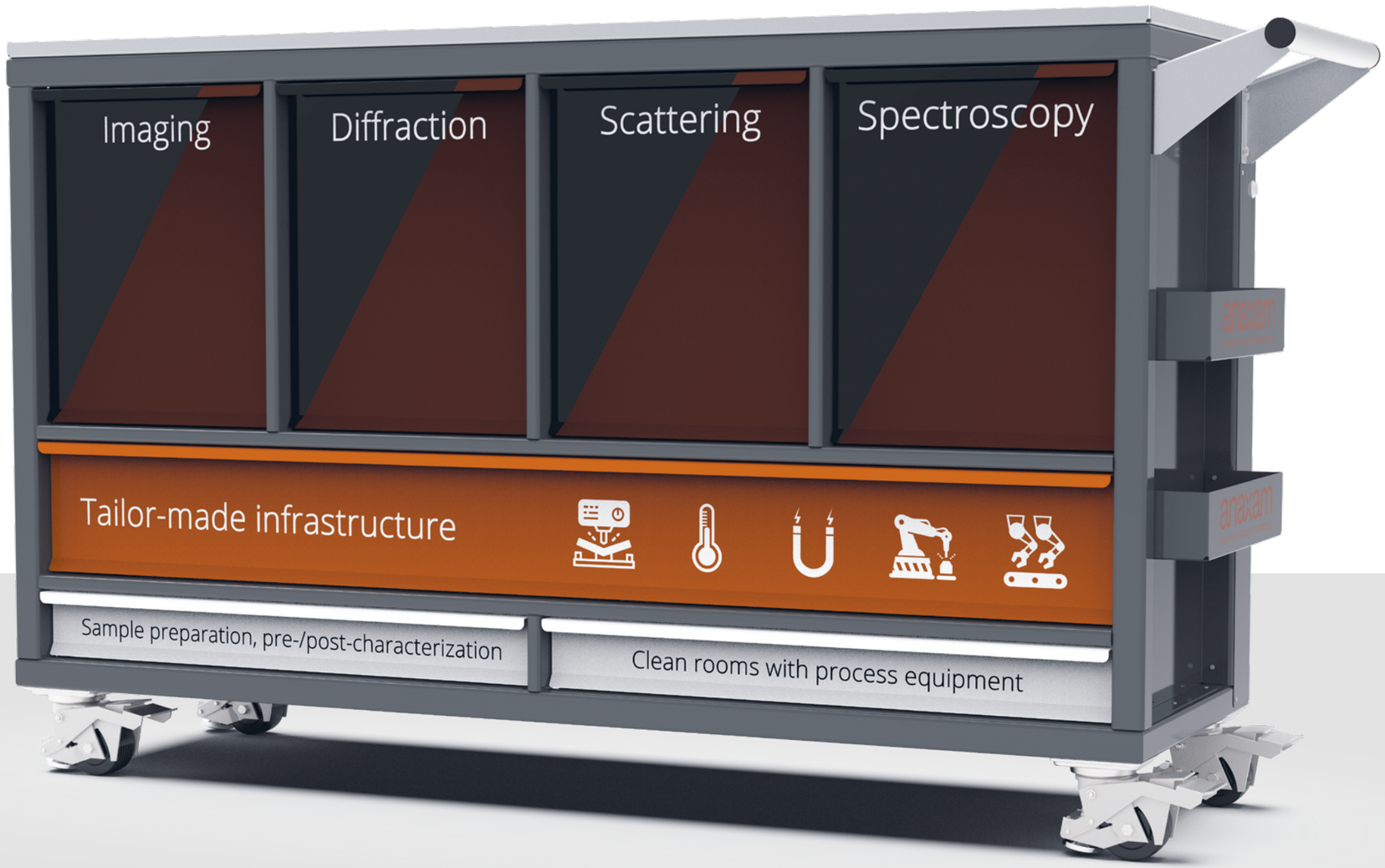
What we offer you

WHAT WE OFFER YOU

Overview of our services

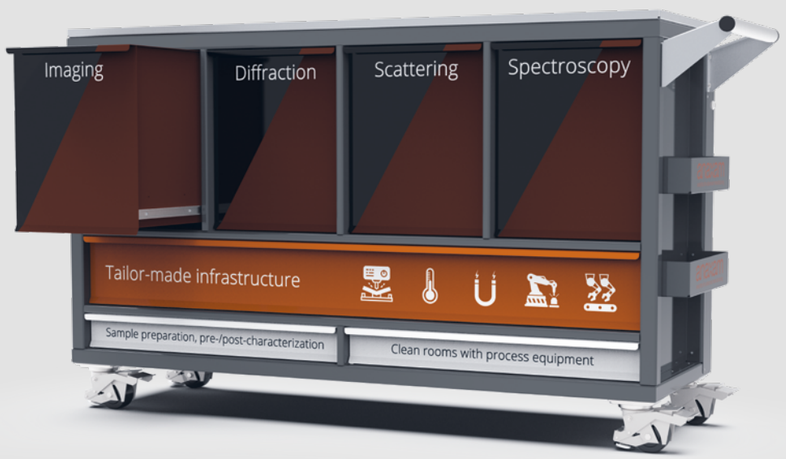
In our tool cart, there is a solution that will fit your needs.

Your product doesn't yet meet your requirements and you are looking for a solution? For especially tricky problems, whether they stem from issues with materials, design, or production, we offer you access to investigation methods that were originally developed for basic, cutting-edge research but can now be used to address industrial challenges as well.



Here you will find examples of customer projects where our ANAXAM tool cart has already proven its usefulness:

Imaging



Neutron and Synchrotron CT – Two complementary non-destructive inspection methods

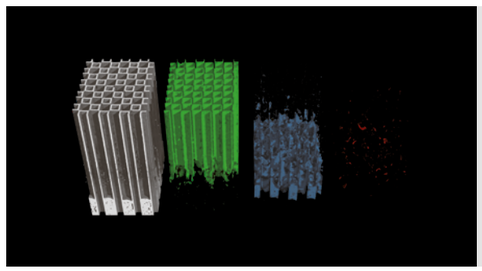
Continuous improvements in material properties and production processes in industry mean that more sophisticated analytic techniques are required. Imaging methods such as computed tomography (CT) provide a three-dimensional view of the interior of objects without destroying them.

Neutron and synchrotron CT offer possibilities to examine samples with **higher spatial resolution** and **high sample throughput** in **real time.** The data thus obtained form the basis for further **analysis options,** as described on the right.

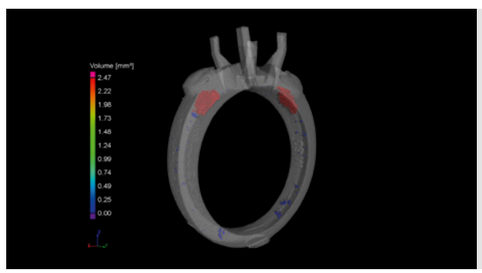
Technical details of neutron and synchrotron CT
Selection of detailed information

Information	Neutron CT	Synchrotron CT
Field of view	5 x 5 mm² – 400 x 400 mm²	0.3 x 0.4 mm² – 16.6 x 14 mm²
Spatial resolution	8 – 150 µm	0.16 – 6.5 µm
Temporal resolution	150 Hz in 2D	20 Hz in 3D
Energy range	2.3 – 25 meV	8 – 45 keV
Wavelength	1.8 – 6 Å	1.5 – 0.3 Å
Bandwidth	10 %	0.02 %
Flux	~ 10^{7} – 10^{8} cm^{-2} s^{-1}	~ 10^{14} cm^{-2} s^{-1}

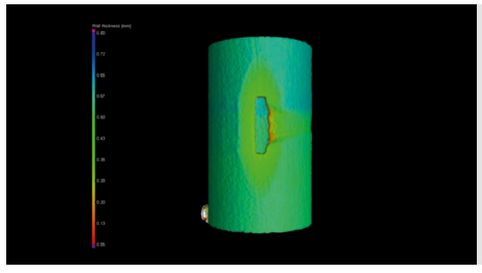
Imaging is used as a qualitative and quantitative measurement technique with the following analysis capabilities:



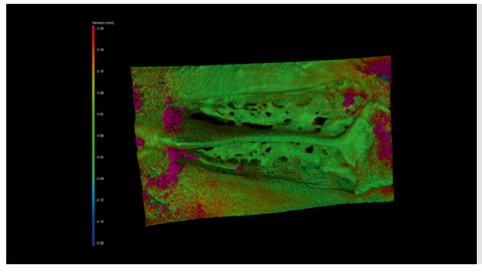
Material distribution analysis in 3D
- Visualization of the outer and inner structures and geometries of arbitrary and complex objects
- Segmentation of the object into its individual components and materials



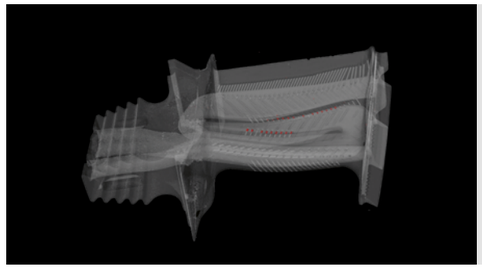
Defect and porosity analysis in 3D
- Visualization of pores, blowholes and inclusions inside arbitrary and complex objects
- Quantitative information such as size, volume, shape and associated distributions
- Determination of the total percentage of defects and porosity, and presentation of results in a histogram



Wall thickness analysis in 3D
- Quantitative determination of the wall thicknesses of arbitrary and complex objects
- Localization of areas with insufficient or excessive wall thicknesses or gaps

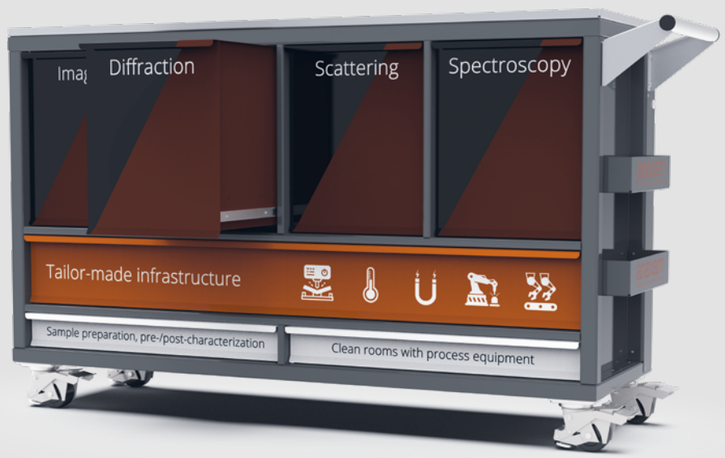


Nominal/actual comparison analysis in 3D
- Direct geometrical comparison of CT data with CAD data of arbitrary and complex objects
- Quantitative information regarding deviations in the dimensions of an object compared with its CAD drawing



Reverse Engineering
- Physical reconstruction of arbitrary and complex objects without knowledge of design data
- Determination of external and internal object geometries
- Creation of an STL file for subsequent reverse engineering to a CAD model

Diffraction



Neutron and synchrotron diffraction – two complementary methods that provide structural information

The materials that make up an industrial product often go through complicated processes before they reach their final shape and form. Every process that has been performed influences the final structure, and therefore the properties, of the product.

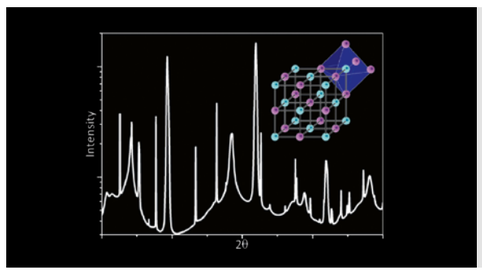
Diffraction is a method for detecting phases and their morphology. It can be used for structural characterization as well as for analysis of texture and residual stresses.

Neutron and synchrotron techniques offer investigation options with **high resolution** and **high sample throughput** in **real time.** The data thus obtained form the basis for further **analytical capabilities,** as described on the right.

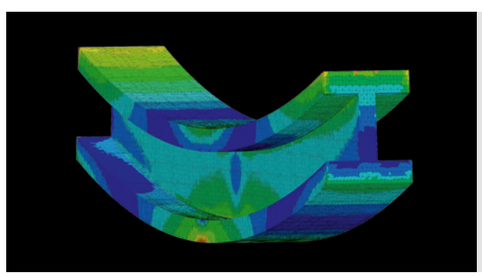
Technical details of neutron and synchrotron diffraction
Selection of detailed information

Information	Neutron diffraction	Synchrotron diffraction
Beam spot	Up to maximum 1 x 5 mm²	Down to minimum 40 x 130 µm²
Resolution	0.05 %	0.02 %
Temporal resolution	Up to 100 Hz	Up to 100 kHz
Energy range	2.3 – 25 meV	5 – 38 keV
Wavelength	1.8 – 6 Å	0.3 – 2.5 Å
Flux	~ 10^{6} cm^{-2} s^{-1}	~ 10^{13} cm^{-2} s^{-1}

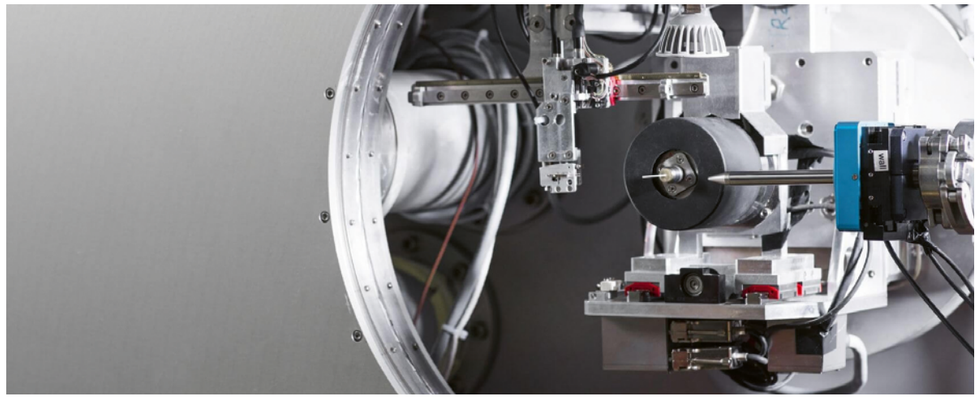
Diffraction is used as a qualitative and quantitative measurement technique with the following analysis capabilities:

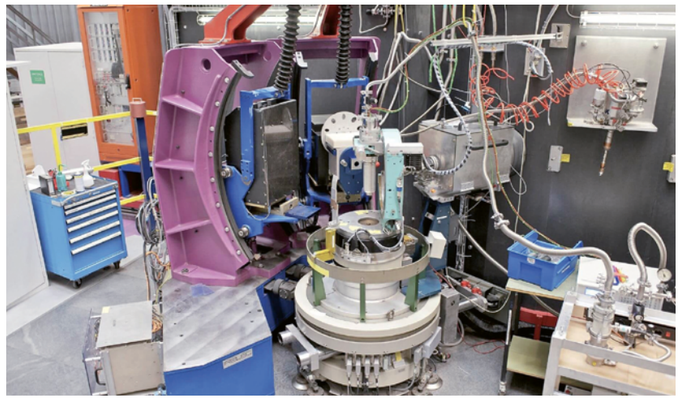


Atomic phase and structural characterization
- Identification of different phases, and the volume fraction of different phases
- Characterization of grain size
- Characterization of textures



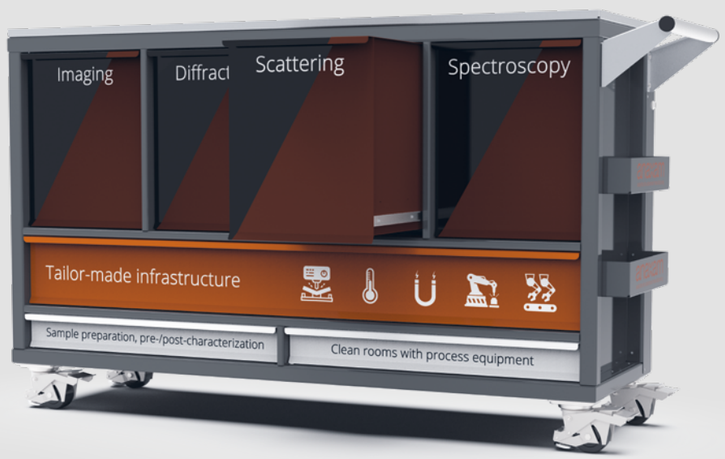
Residual stress analysis
- Quantitative analysis of strain in samples
- Differentiation of regions with different residual stresses





above: Diffraction instrument at the synchrotron
left: Diffraction instrument at the neutron source

Small-Angle Scattering



Neutron and synchrotron small-angle scattering – Two complementary methods for providing structural information

The materials that make up an industrial product often go through complicated processes before they reach their final shape and form. Every process that has been performed influences the final structure, and therefore the properties, of the product.

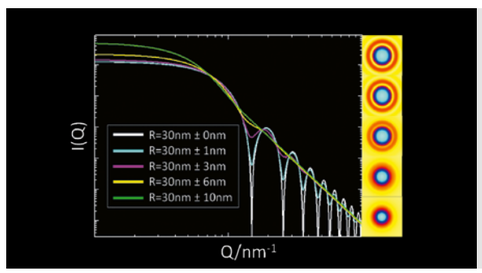
Small-angle scattering is a method for detecting phases and their morphology. It can be used for morphological characterization, such as for example the size, shape, and orientation distribution of different kinds of materials.

Neutron and Synchrotron techniques deliver **high resolution, high throughput,** and allow **real-time** investigations. The data obtained provides the basis for further **analytical capabilities,** as described.

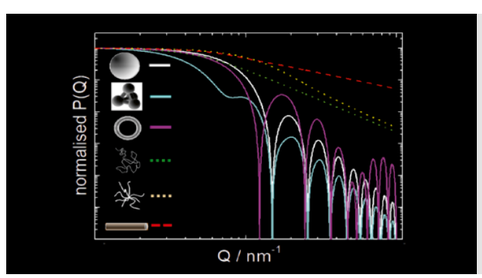
Technical details of neutron and synchrotron small-angle scattering
Selection of detailed information

Information	Neutron small-angle scattering	Synchrotron small-angle scattering
Energy range	0.05 – 4 meV	2.8 – 41.3 keV
Wavelength	4.5 – 40 Å	0.3 – 4.4 Å
Sample to detector distance	1 – 18 m	2.1 – 7.2 m
Accessible q-range	0.0006 – 1.5 $Å^{-1}$	0.0012 – 2.815 $Å^{-1}$
Resolution	$\Delta\lambda/\lambda$ = 10 %	$\Delta E/E$ = 0.02 %
Spot size	Up to maximum 2.5 x 2.5 mm^2	Down to minimum 25 x 10 μm^2

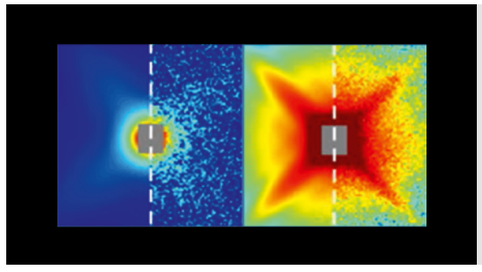
Small-angle scattering is used as a qualitative and quantitative measurement technique with the following analysis capabilities:



Size distribution analysis
- Determination of the micro- and nano-scale structures of randomly oriented systems
- Quantification of particle size distribution of poly-dispersed systems

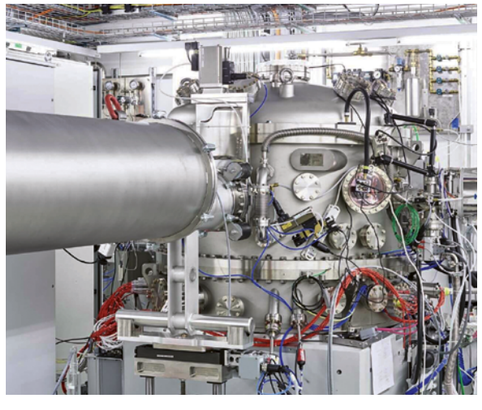


Shape distribution analysis
- Identification of external form and internal structures
- Determination of shape distributions



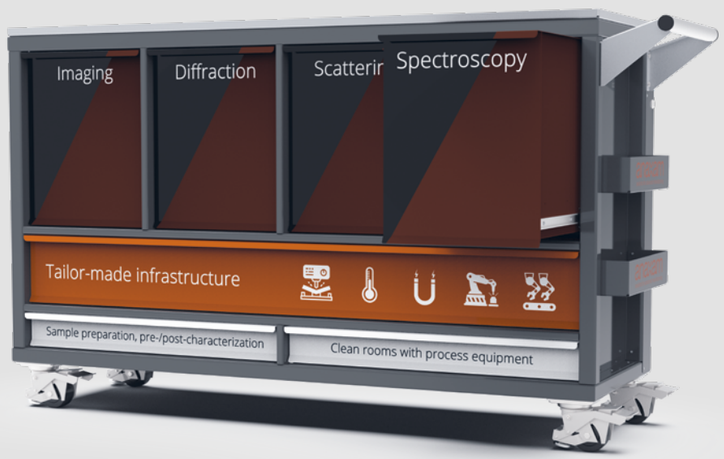
Orientation analysis
- Determination of alignment of structures

Small-angle scattering instrument at the neutron source (SANS-I)



Small-angle scattering instrument at the synchrotron source (cSAXS)

Spectroscopy



Neutron and synchrotron spectroscopy – Two complementary methods for obtaining chemical information

In many cases, the properties of a material are greatly influenced by the precise arrangement of the atoms in the material as well as by the presence of trace impurities. **Spectroscopy** is a method, which is highly sensitive to local chemistry, chemical composition and related properties.

Synchrotron spectroscopy allows high transmission with light elements, and strong contrast with heavier elements. **Neutron spectroscopy,** on the other hand, allows strong contrast with light elements, and higher transmission with heavier elements.

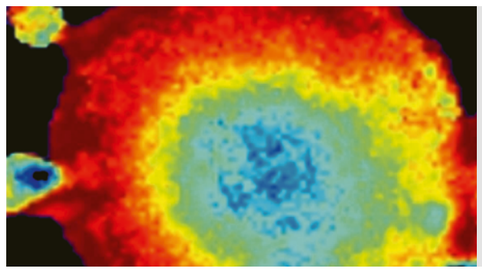
This means that the two methods offer different yet complementary contrast possibilities.

Both neutron and synchrotron spectroscopy, two different yet complementary forms of spectroscopy, deliver **high spatial resolution, high throughput** and **real-time** investigations. The data obtained provides further analytical capabilities, as described on the right.

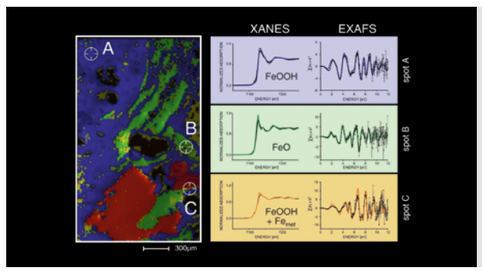
Technical details of neutron and synchrotron spectroscopy
Selection of detailed information

Information	Neutron spectroscopy	Synchrotron spectroscopy
Spot size	40 x 40 mm^2	1 x 1 μm^2
Resolution	$\Delta\lambda/\lambda$ = 10 %	$\Delta E/E$ = 0.02 %
Temporal resolution	Up to 1 Hz	Up to 100 kHz
Energy range	2.3 – 25 meV	0.5 – 40 keV
Wavelength	1.8 – 6 Å	0.3 – 24.8 Å
Flux	~ 10^7 – 10^8 cm^{-2} s^{-1}	~ 10^{12} mm^{-2} s^{-1} (monochromatic)
		~ 10^{11} mm^{-2} s^{-1} (focused, monochromatic)

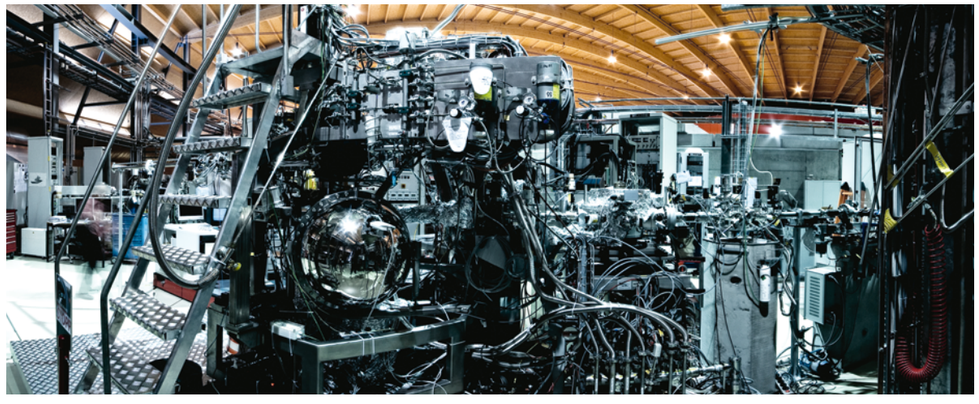
Spectroscopy is used as a qualitative and quantitative measurement technique with the following analysis capabilities:

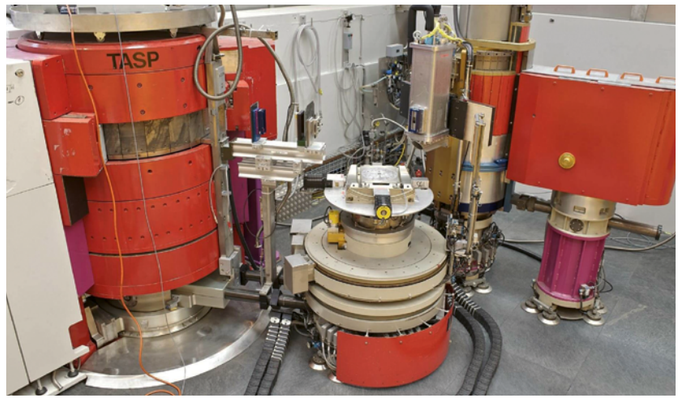


Chemical imaging analysis
- Identification of the quantitative distribution of chemical elements
- Identification of boundaries of domains with different chemical composition
- Identification of trace element or dopant distribution
- Identification of local chemical reactivity



Chemical characterization
- Characterization of neighboring atomic arrangements of molecular structures
- Characterization of oxidation states





above: Spectroscopy instrument at the synchrotron source
left: Spectroscopy instrument at the neutron source

Tailor-made infrastructure

Tailor-made infrastructure – Reproducing customer reality for the analytical services

Dedicated equipment is essential to guarantee the best possible experimental conditions when performing customized experiments. Tailor-made infrastructure could include, for example, devices that allow the investigation of samples **in-situ** and **in-operando** under various environmental conditions.

In addition to the ability to vary measurement conditions, infrastructure in the form of automated sample manipulators is important in order to provide a **higher sample throughput,** leading to more efficient use of available beam time, and standardization of results. An overview of the possibilities for **tailor-made infrastructure** can be found below.

We are looking forward to supporting your analytical inquiries with our tailor-made infrastructure.

Possibilities for your tailor-made infrastructure

Mechanical
Stress
Compression
Torsion
Pressure

Climatic
Gas atmosphere
Temperature
Humidity
Pressure

Electrical & magnetic
Magnetic fields
Electrical fields

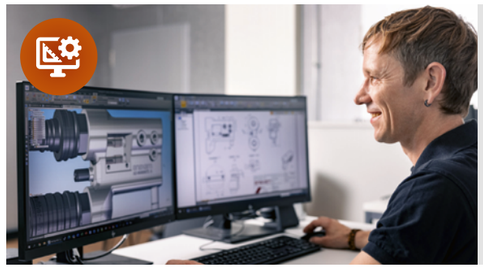
During manufacturing
In-situ
In-operando

Automation
High throughput
Sample manipulation
Reproducibility

Creation process of the infrastructure

Conception → **Design** → **Implementation** → **In operation**

Conception
- Needs analysis of the customer
- Feasibility evaluation
- Concept development
- Finalization with customer

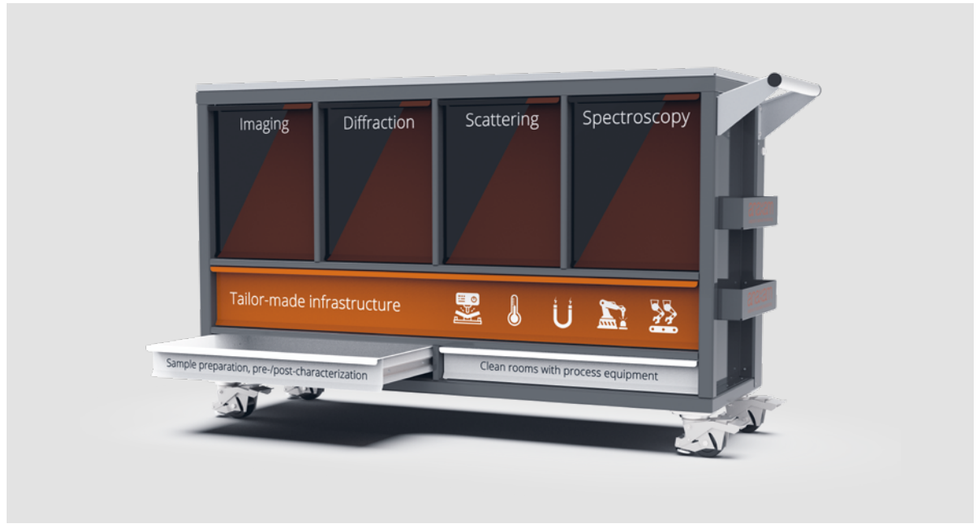


Design
- Creation of CAD models
- Creation of production drawings
- Creation of electronic diagrams
- Software planning

Implementation
- Manufacturing of the single part
- Assembly
- Programming of the control software
- Commissioning in the laboratory

In operation
- Transfer to the beamlines
- Hardware integration in the beamline
- Software integration in the beamline
- Performance of the experiment

Sample preparation and pre-/post-characterization



Supporting our analanalytical services

For some of our analytical services, samples need to be specially prepared. We provide different kinds of sample preparation, including cutting, polishing, annealing, etc.

We also offer pre-/post-characterization with various microscope types, to support and supplement our analytical services using Neutron and Synchrotron radiation.

Selection of equipment available for sample preparation and pre-/post-characterization:

Sample preparation

Variety of cutting machines
- Electrical discharge machining
- Circular saw blade cutting
- Wire cutting

Variety of polishing equipment
- Mechanical polishing up to OPS suspension
- VibroMet
- Electropolishing for SEM and TEM samples
- Ion milling

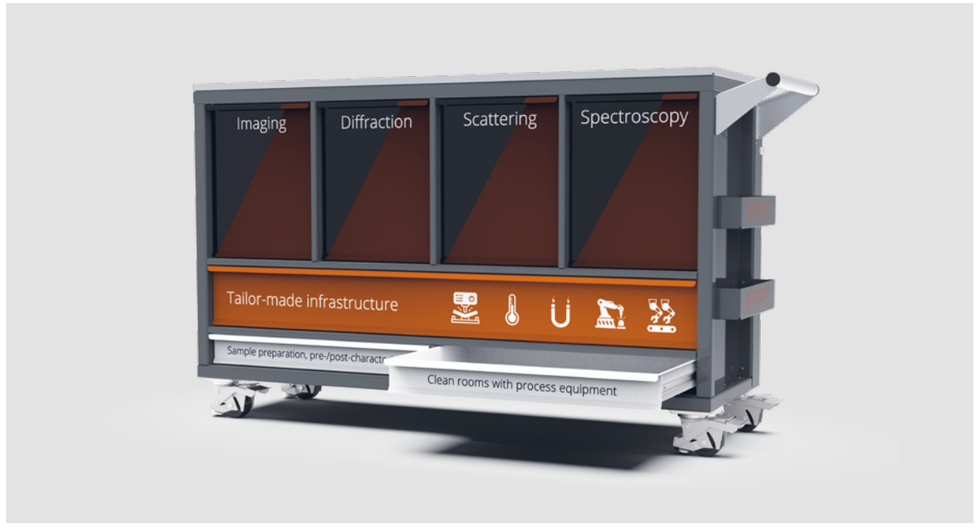
Microscopy

Electron microscopes
- SEM with different detectors
- FIB
- TEM

Atomic force microscopes
- Contact and non-contact modes
- Tapping and lift modes
- Phase imaging
- Lateral force microscopy

Light and scanning laser microscopes
- Various light microscopes
- 3D scanning laser microscopes for obtaining 3D surface profiles

Clean rooms with process equipment



Supporting our analytical services

The nanotechnology cleanroom at the Paul Scherrer Institute (PSI) is a 170 m² net clean area (hybrid class 10/class 1,000), professionally designed and equipped state-of-the-art cleanroom lab. The “processing lab” at PSI is a semi-cleanroom of ca. 150 m² with laminar flow boxes in the critical areas and a class 10,000 environment.

On the one hand, the cleanrooms with the process equipment are used to specially prepared dedicated beamline optics for improving the efficiency of our analytical services using neutron and synchrotron radiations. On the other hand, we provide industries services using the process equipment as described below.

The following clean room equipment can be used:

3D laser writer
- 200 mm direct laser writer
- Maskless lithography

Photolithography
- 150 mm mask aligner
- 200 mm mask aligner
- Displacement Talbot lithography

Electron beam lithography
- 150 mm electron beam direct writer

Dry and wet etching
- Deep reactive ion etching
- Etching with acids and alkali

Metallization
- Physical Vapor Deposition (PVD)
- Atomic Layer Deposition (ALD)
- Plasma Enhanced Chemical Vapor Deposition (PECVD)

Knowledge transfer

Make our know-how your own. Take advantage of our knowledge transfer services.

Knowledge transfer, for students as well as experts from industry, is part of ANAXAM's mission. On the one hand, we provide practical training and continuing education in our analytics methods. On the other hand, we offer a networking platform for mutual exchange between businesses and analytics service providers, where they can discuss and tackle current issues and challenges.

Our knowledge transfer services

Seminars and web-seminars
- Goal: introduction to our analytical services
- Description: lectures
- Duration: 1 to 2 hours
- Target groups: industry, science

Workshops
- Goal: deepening subject-matter knowledge
- Description: lectures, discussions, tutelage
- Duration: 3 to 6 hours
- Target groups: industry, science

Training courses
- Goal: internships, term papers, theses
- Description: supervision of thematic work
- Duration: 1 week to 6 months
- Target group: students

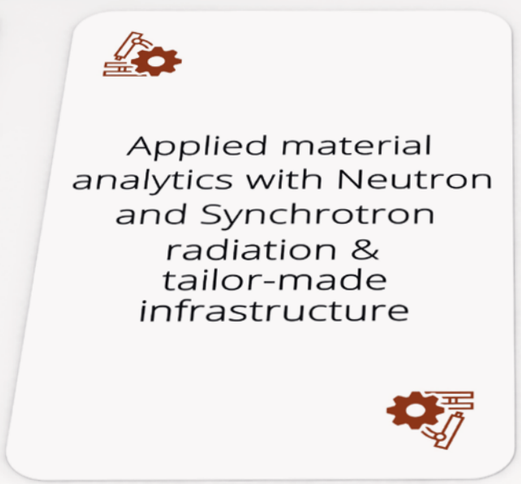
Training sessions
- Goal: familiarity with analytics methods
- Description: performance of joint experiments and data analysis
- Duration: several days to weeks
- Target group: industry

The way we work with you

THE WAY WE WORK WITH YOU

All from a single source: a winning hand for you

We put our cards on the table. You show us your challenge, and we work with you step by step to achieve a solution. Within the framework of a comprehensive and competent consultation, we work out solutions for you with the help of our applied material analytics. If necessary, we will use an infrastructure created specifically for you. We will analyze and interpret the results of our investigations in a manner that makes them easy for you to understand, and you will receive a final report. All from a single source: a winning hand for you.



Models of collaboration

Basically, we can work with you in two different ways:

Service projects

In this case we provide everything you need from a single source – from consultation to measurement, to analysis and interpretation of the results. In this way you benefit from state-of-the-art analytics methods in the areas of imaging, diffraction, small-angle scattering, and spectroscopy to solve the challenges you face.

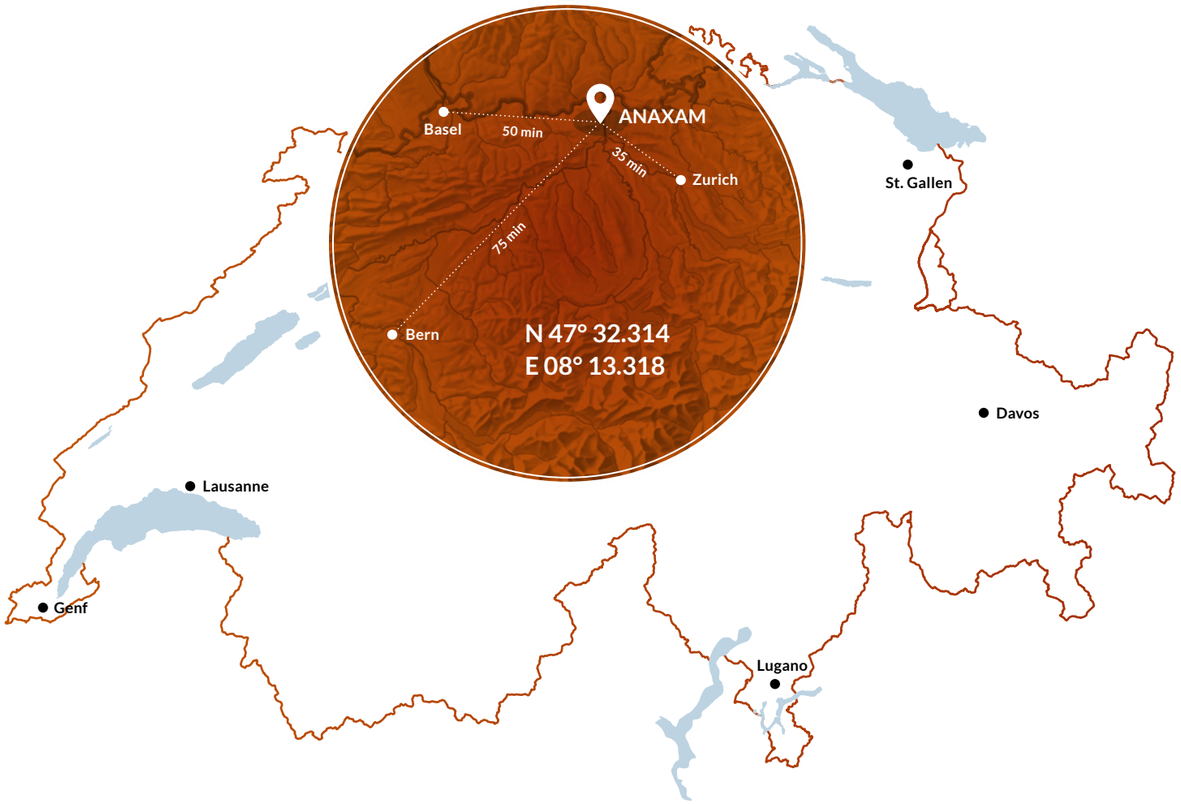
Development projects

In this case we work together with you on the development of new, customized infrastructures. These make it possible to conduct experiments under realistic test conditions.

A customized infrastructure could be an apparatus that enables real-time examination of samples under different conditions such as temperature or pressure. Or it could mean, for example, automated sample manipulators that allow a higher sample throughput. This then leads to more efficient use of available measurement time at the large research facilities, and to standardization of results. Such developments are co-financed by us, and you contribute to the project costs in the form of either money or in-kind contributions. The infrastructures developed in this way will then be available for use in later service projects for you and for other customers.

You can find us here

The business headquarters of ANAXAM is in Villigen in the Canton of Aargau, Switzerland. Here we are quite close to PSI. And it is easy to get to us: in 35 minutes from Zurich, for example, or in 50 minutes from Basel.



Do you have questions?
Please contact us by telephone or e-mail,
or use the contact form on our website.
Our team of experts will respond promptly.

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