SkyScan 1294

- Phase-Contrast Desk-Top
  X-Ray Microtomograph

MICROTOMOGRAPHY

Innovation with Integrity

Phase-Contrast X-Ray Microtomography: A New Way to See The Invisible

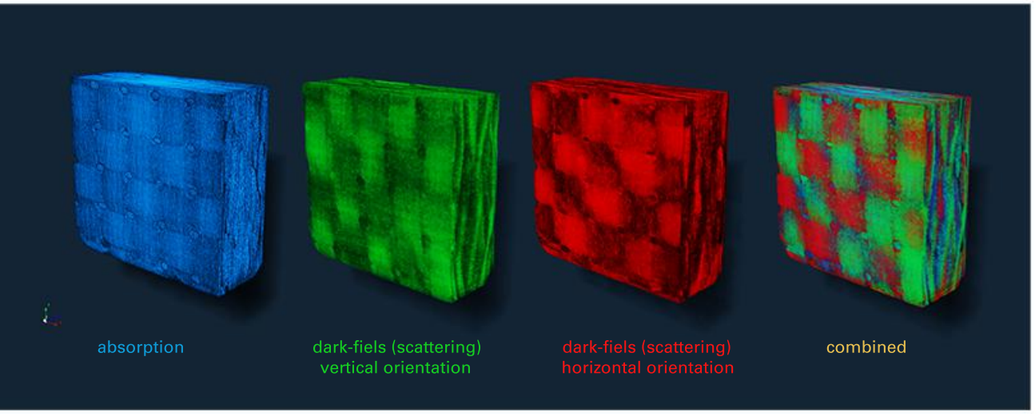
A new way to reveal previously invisible features of objects non-destructively and in 3D is realized in the world's first commercially available phase-contrast desk-top microtomography scanner, the SkyScan-1294. On top of traditionally observed local object absorption, the system allows you to reveal local X-ray refraction and scattering in object features, far beyond reconstructed pixel sizes.

The new SkyScan-1294 is based on the unique technology of phase-contrast imaging with polychromatic X-rays patented by the Paul Scherrer Institut at the Swiss Light Source (Zurich, Switzerland) and licensed to Bruker microCT for commercialization.

World's first phase-contrast micro-CT

- simultaneous extraction of absorption, differential phase and dark-field (scattering) images,
- three-grating X-ray interferometer with 30keV design energy,
- microfocus 100W X-ray source, 20-60keV peak energy,
- five position filter changer for energy window selection,
- 11 megapixel cooled CCD X-ray detector,
- compact, fully shielded desk-top instrument,
- world's fastest hierarchical InstaRecon® 3D reconstruction,
- touchscreen control for main functions,
- surface and volume rendering, export results to phones and tablets.

Discover new imaging modalities

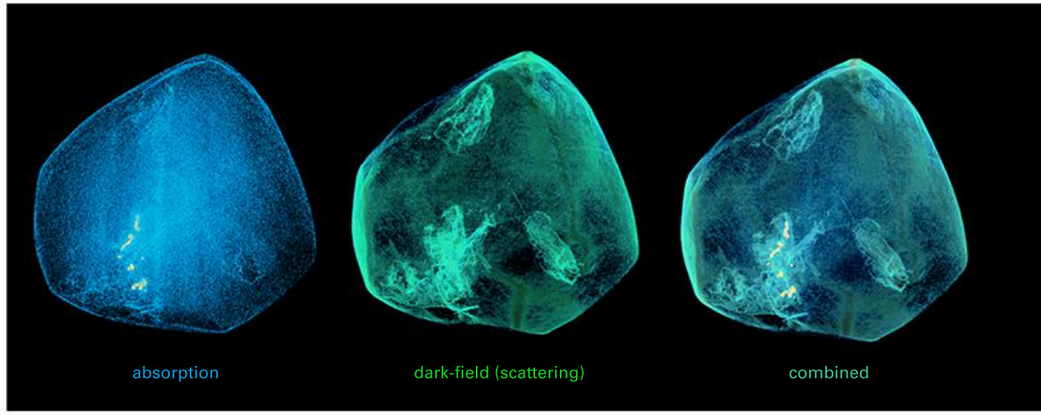


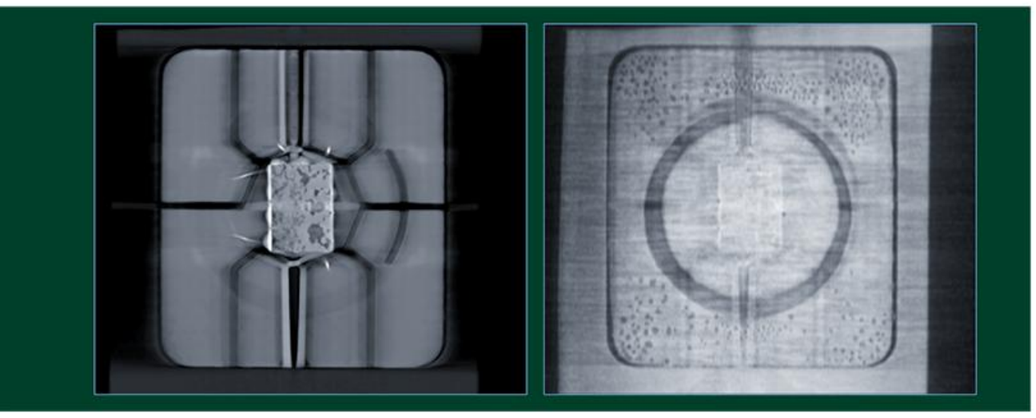
COMPOSITES

Carbon-fiber reinforced plastic (CFRP) contains carbon-fiber fabric with bundles in two orthogonal orientations. Shown 3D volume rendering reveals object morphology in absorption contrast and also orientation-selective information for carbon fibers in dark-field (scattering) contrast. The combined image visualizes both fiber orientations and plastic filler simultaneously.

DIAMONDS

3D volume rendering of a 5 carat rough diamond: absorption contrast visualizes the external surface and metal-oxide inclusions. The scattering image clearly displays all internal defects as well as a massive carbon (graphite) cluster in the left bottom corner. This cluster can be visually seen as a black inclusion, but does not appear in the absorption image due to identical chemical composition of graphite and diamond.



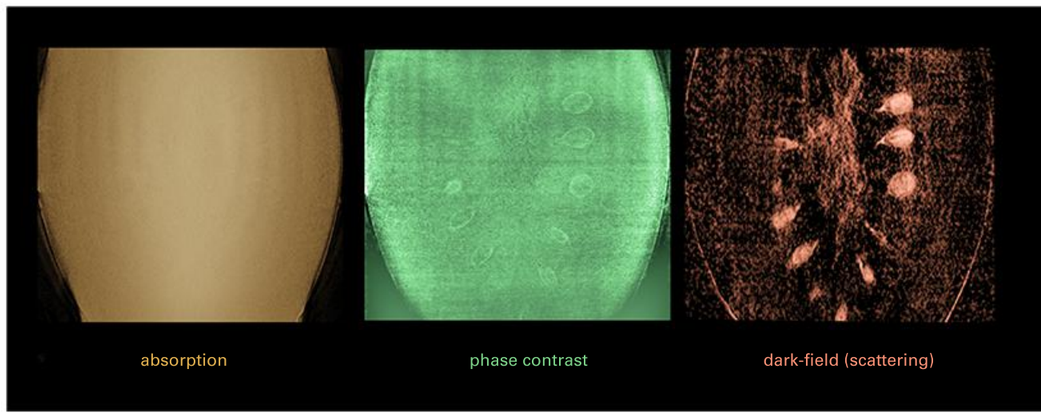


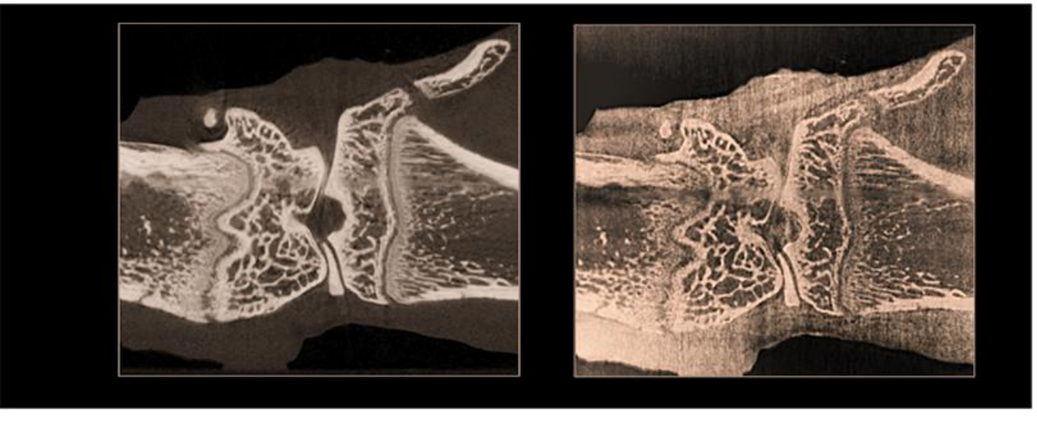
ELECTRONICS

The electronic chip in credit cards is attached to the reverse side of the metal contacts. This virtual slice through the reverse side of chip insert in absorption contrast (left) displays all metal contacts,the die attach and thin wires for connections to the contacts. The phase-contrast virtual slice (right) reveals details of the glue layer with air bubbles,used to attach the chip assembly to the plastic frame of the card and chip encapsulation.

FOOD

The adsorption image through a tomato (left) shows very few internal details, but phase-contrast (middle) and especially dark-field images (right) show all internal details including the water and air transportation network and seed traces.



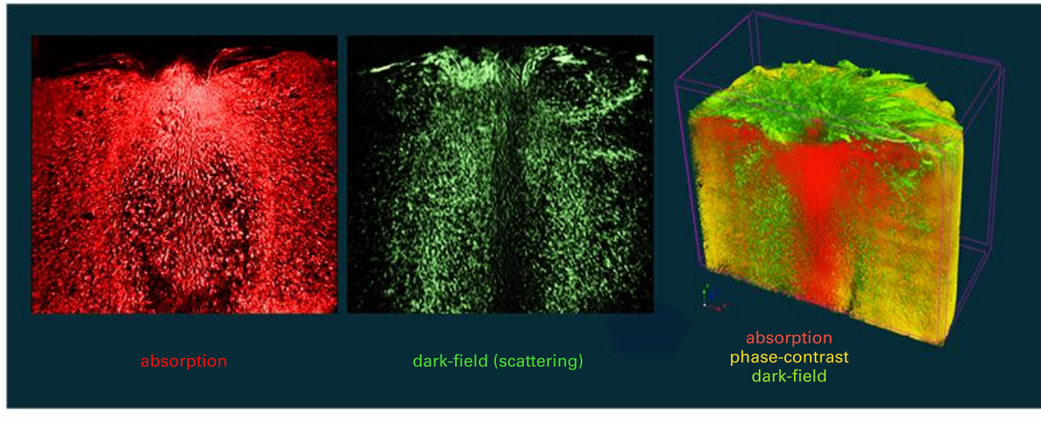


BIOMEDICAL

Reconstructed virtual slice through a rat knee in absorption contrast (left) allows clear imaging of bone microarchitecture, but not of surrounding soft tissues. The virtual slice obtained from the same place in phase contrast reveals more details in the soft tissue including cartilage and ligaments between the bones.

FOOD

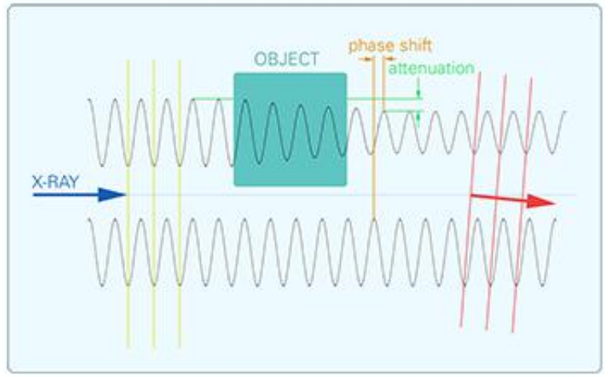
The reconstructed slice of a strawberry's internal structure in absorption contrast displays most morphological features. The dark-field (scattering) adds significant functional information on the water transportation network connected to the leaves at the top.



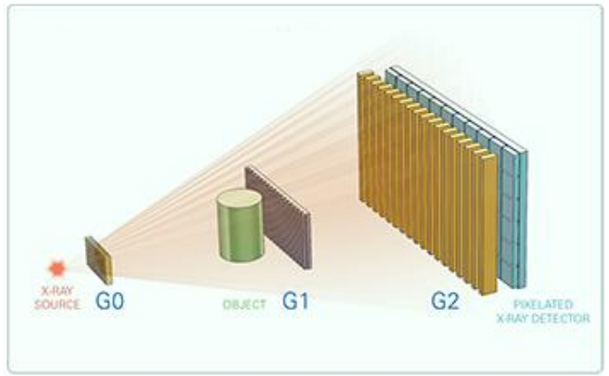
How Does the Phase-Contrast Scanner Work?

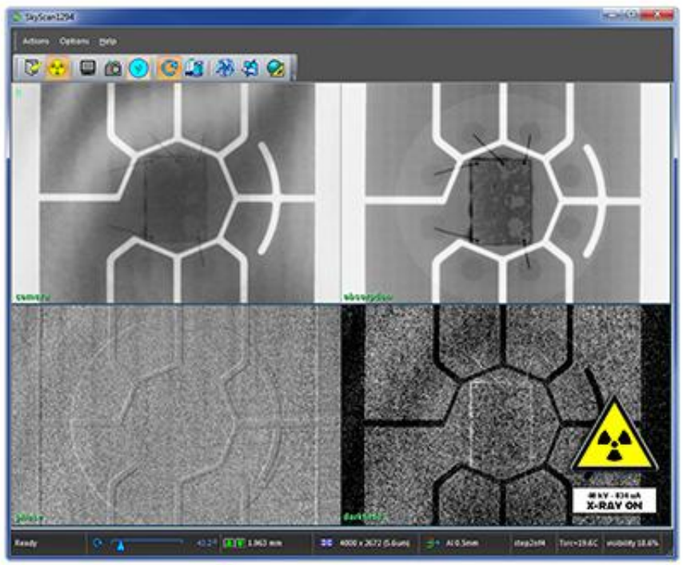
OBSERVE THE DIRECTIONS OF WAVES

While passing through the object, the X-ray beam changes. It loses some intensity by object absorption and changes also the wave phase because of differences in propagation speed. The wavefront behind the object becomes modulated by object absorption and changes the direction of propagation due to phase shift. Conventional X-ray cameras are not sensitive to the direction of incoming X-rays and can detect only absorption in the object. At the same time the directional part may contain information about object details without significant absorption and at sizes much smaller than can be distinguished by a particular camera.



To recover phase-shift information, it should be converted to an intensity signal detectable by the X-ray camera. Such a conversion is performed by a special set-up named the Talbot-Lau X-ray interferometer, which contains several absorption and phase-shift gratings with micron-size pitch. The phase grating G1 creates interference pattern with local maxima and minima of intensity. If the object changes the direction of the primary beam, the pattern becomes locally shifted. The absorption grating G2 strips this pattern and converts it to intensity modulation, which can be detected by relatively large pixels in the detector. To create the necessary conditions for interference, an additional absorption grating G0 in front of the X-ray source divides the primary beam into a large number of spatially correlated thin beams. All gratings are precisely aligned to each other.





SIMULTANEOUS MODALITIES

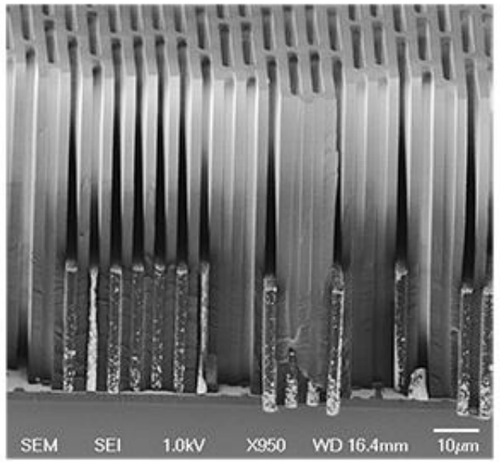
The X-ray interferometer described above allows the converting of local phase shifts in the object to intensity modulation, which can be detected by the camera together with absorption information. To separate information from the phase-shift from the absorption information, one of the three gratings is moved through several positions inside a single grating pitch. Such movement creates sinusoidal modulation for every pixel of the camera. By comparing sine curves with and without the object in every pixel, the phase shift and scattering information can be separated from the absorption information.

All types of information are extracted in a single calculation process and can be displayed on-screen simultaneously. The camera image is shown in the top left corner, the absorption image - in the top right part, the phase-contrast image at the bottom left and the dark-field (scattering) at the bottom right.

Millions of Tiny Slots in Every Grating

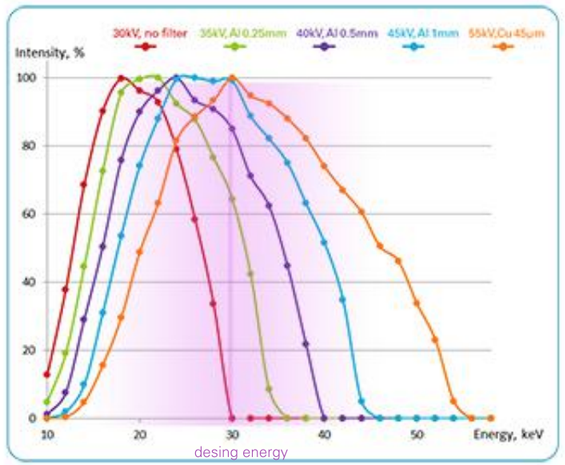
UNIQUE X-RAY GRATING TECHNOLOGY

Getting an X-ray interferometer to work at a relatively high X-ray energy range - tens of keV - requires a very special approach for fabricating the absorption gratings. The absorbing layers should be thin enough to fit a micron-range pitch of the grating and at the same time should produce significant attenuation along the X-ray beam. To get absorbing layers in the gratings with extremely high aspect ratio, a metal with very high absorption coefficient (gold) is deposited onto slots of specially created silicon substrate. The substrate contains millions of thin parallel slots produced by a unique Deep X-ray Lithography process. As shown in the image of the grating edge from a scanning electron microscope, every slot in such a substrate is partially filled by a gold layer to ensure exact alignment and overall accuracy of this micron-size structure over the full surface of the grating with a size of several centimetres.



Easy tuning for best results

ADJUSTABLE BAND OF X-RAY ENERGIES



Using the X-ray interferometer for phase-contrast retrieval imposes certain restrictions on the acceptable range of X-ray energies. The system includes an X-ray source with peak energy tunable in the range 20-60 keV and an automatic filter changer with five positions to cut out low X-ray energies. Selecting the proper combination of peak energy in the source and energy filter allows tuning of a narrow band of energies according to the absorption of the object under investigation.

The design energy of the X-ray interferometer is 30keV. The interferometer can tolerate energies in the range of 50-150% of the design energy with some reduction of phase retrieval efficiency. At the same time the thin gold layers in the absorption gratings become more transparent with increased energy, which reduces phase-contrast retrieval efficiency at high energies. This is why all pre-sets for energy window are selected in such a way that the highest one exactly fits the design energy and others are gradually shifted toward the low-energy region.

TOUCHSCREEN CONTROL

The user interface of the SkyScan1294 system is simple and intuitive. The instrument can be controlled from the computer screen and also from the embedded force-sensitive touchscreen. The touchscreen allows selection of scanning protocol, adjusting object position, opening / closing specimen chamber and control of imaging and scanning. Where multiple scans are started from the touchscreen, the software will automatically save the acquired data to separate subfolders with incrementally assigned folder names and dataset file prefixes. Full flexibility of scanner functionality is achieved by a straightforward standard Microsoft Windows user interface on the control workstation. It allows flexible adjustment of all X-ray source and detector settings as well as control of all scan parameters. Any set of complete instrument settings can be saved as a user configuration, allowing reload of all settings by one click for future scans.

Software for reconstruction, analysis and realistic visualization

All micro-CT scanners from Bruker microCT, including the SkyScan 1294, are supplied with a comprehensive software suite and supported by unlimited free access to software updates available for download from the Bruker microCT website.

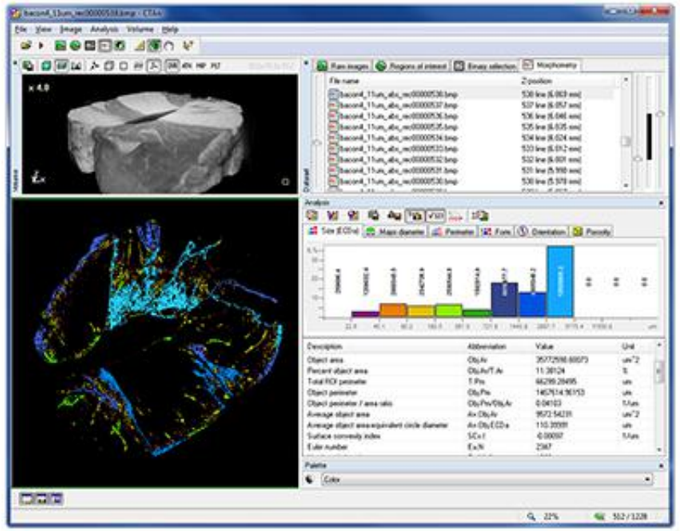
WORLD'S FASTEST RECONSTRUCTION

The 3D reconstruction software supplied with the system includes three reconstruction engines, which can be used by an operator's choice: multithreaded reconstruction by CPU, GPU-accelerated reconstruction (both use a filtered back-projection algorithm) and the world's fastest InstaRecon® reconstruction, which utilizes a unique hierarchical algorithm with incredible speed-up using CPU only.

	RECONSTRUCTION TIME FOR FULL VOLUME (SPEED-UP)		
	1000x1000x613 pixels from 720 projections	2000x2000x1225 pixels from 1200 projections	4000x4000x2456 pixels from 1800 projections
NRecon multithread CPU reconstruction	3 m 55 s	44 m	4 h 47 m
GPURecon GPU-accelerated reconstruction	1 m 30 s (x2.6)	11 m 14 s (x4)	2 h 15 m (x2.1)
InstaRecon® hierarchical reconstruction	34 s (x7)	2 m 26 s (x18)	14 m (x20.5)

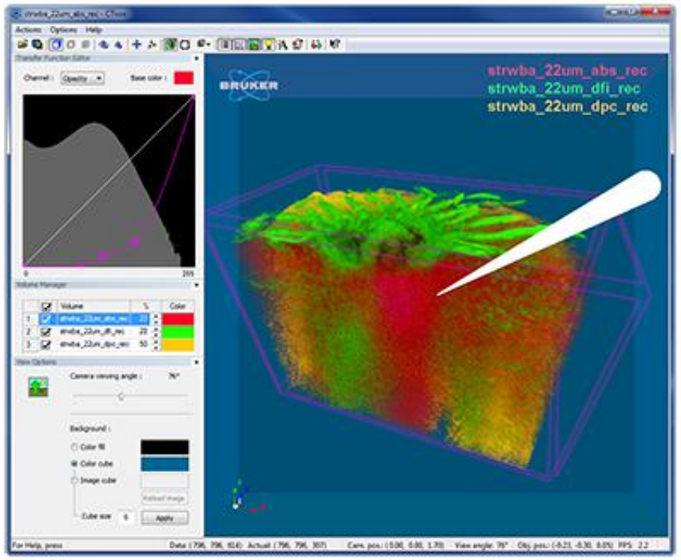
2D / 3D IMAGE ANALYSIS

CT-Analyser or "CTAn" allows accurate and detailed study of micro-CT results for morphometry and densitometry. Powerful, flexible and programmable image processing tools allow a wide range of segmentation, enhancement and measurement functions for analysis inside any slice or 3D volume. Versatile volume of interest selection tools allows free hand drawing, selection of standard shapes and editing regions of interests in key slices with automatic interpolation to full volume. CTAn contains hundreds of embedded functions with the possibility to execute any sequence of tasks step by step, create tasklists for automated batch-analysis and execute user-created plug-ins.



3D VOLUME RENDERING

The volume rendering program CTVox displays a set of reconstructed slices as a realistic 3D object with intuitive navigation and manipulation of both object and camera, a flexible clipping tool to produce cut-away views and an interactive transfer function control to adjust color and transparency. The lighting and shadowing with selection of properties of the material surfaces produces fully realistic visualization. A "flight recorder" function allows fast creation of "fly around" and "fly through" animations based on simple selection of several key frames with automatic interpolation in between. Imaging possibilities include stereo viewing and displaying multiple datasets, obtained from single or different modalities. It allows display of absorption, phase contrast and dark-field (scattering) information simultaneously in 3D with individual adjustment of opacity profiles and color schemes.



Take your results anywhere

VOLUME RENDERING FOR MOBILES

The volume rendering program supplied with the system, **CTVox**, also has its mobile versions, which can be downloaded for free from the AppStore for iPhone/iPad/iPod or from GooglePlay for Android devices. Any 3D results obtained by the system can be sent to a mobile device for realistic visualization by real-time volume rendering with 3D object manipulation, adjustments of opacity and colors, virtual cut, etc.

The results can be sent through a cable connection or wireless network. The exported rendered data and color schemes are stored in the local memory of the mobile device and do not require any connection or downloading during manipulation. A large number of reconstructed datasets can be loaded to the memory of a mobile device, allowing you to study image results while travelling, share them with colleagues and demonstrate at meetings.

AUTOMATIC E-MAIL REPORTING

The SkyScan 1294 control software can send you an e-mail at the end of a scan. The e-mail includes a direct link to the data folder containing the scan results. By a simply click on this link you can open the dataset directly. If the scanning process has been interrupted, the software will also email you a report of the details.

The e-mail notification can be flexibly configured according to local security rules for IT infrastructure.

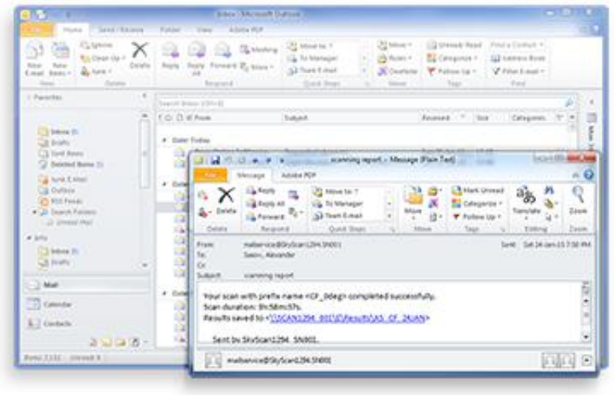


IMAGE FORMATS FOR RESULTS

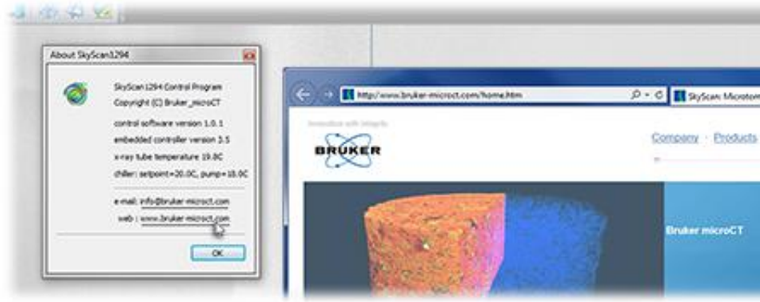
All the supplied reconstruction and application software can produce and work with DICOM format images (compliant with the DICOM 3 convention), which can be considered as an industry standard for digital imaging instruments. The programs can also interchange results in standard Windows-readable formats, such as BMP, JPG, PNG and TIFF for images and AVI for movie files.

If necessary, images can be converted from one format to another using the supplied **Format Converter** utility. This software can convert projection images and reconstructed slices from one format to another with modified size and intensity scale. It can convert separate image files or full dataset with renaming, resizing, rescaling and renumbering for combining several sets of reconstructed slices together. Another useful supplied utility named **DICOM-CT** allows the export of datasets, previously saved as JPG, BMP or TIFF files, to standard DICOM format.

Comprehensive support for best results

SOFTWARE UPDATES

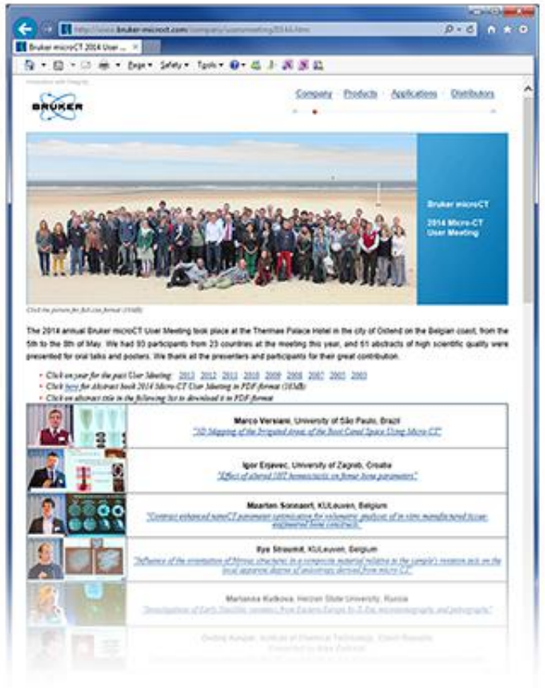
All users of Bruker microCT instruments have unlimited free access to all software updates. New versions of control and application software can be downloaded from the bruker-microct.com website. To go to the Bruker microCT website, just click on the link in the "About" box in the control program. Using the other link in the same "About" box, the operator can send an e-mail with questions or requests to info@bruker-microct.com.



ADVANCED TRAINING COURSES, MICRO-CT ANNUAL MEETINGS

Bruker microCT offers a combination of both system and software training that covers three major topics: image acquisition, image reconstruction and data analysis/visualisation. These 5-day courses are held several times per year at Bruker microCT headquarters in Belgium. The goal is to combine the basic theoretical background of microCT with as much hands-on experience as possible. After installation of every system, the new customers will receive first initial training, and later advanced training either on-site or by course attendance, at the user's choice.

Bruker microCT also organizes an annual MicroCT meetings in the form of a 3-day scientific conference combined with training workshops. Intensive exchange of knowledge and experience helps new and skilled users to find the way to get the best results from their microCT imaging. Invitation to the next MicroCT annual meeting and abstracts from presentations in the previous MicroCT meetings can be found at www.bruker-microct.com



'BRUKER MICRO-CT ACADEMY'

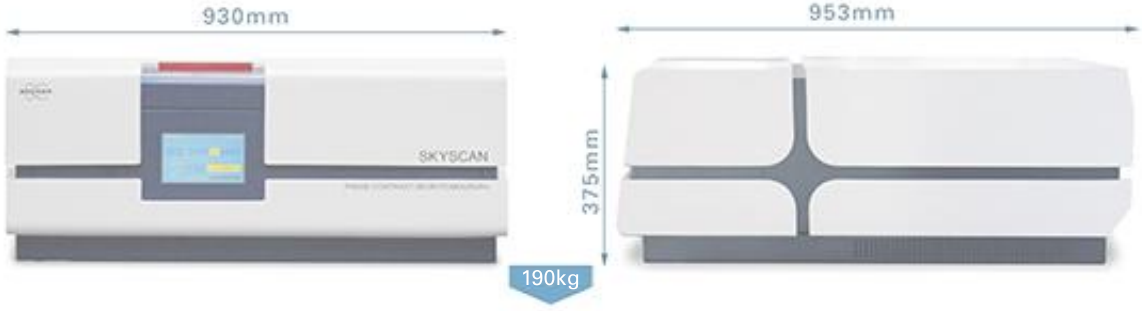
The "Bruker microCT Academy" is an efficient educational network for the hundreds of groups who are using SkyScan instruments. It includes a monthly newsletter with application and technical tips and keeps users updated on new methods, developments and company news.

Through participation in the Academy our users gain access to a database with detailed application and technical notes and provide feedback with questions and suggestions for improvements of our instruments and software.

TECHNICAL SPECIFICATIONS

X-ray source	20-60kV, 100W, 30µm spot size, 5-position filter changer
X-ray detector	11Mp cooled CCD, 4000 x 2672 pixels, 12.5µm pixels
Nominal resolution (pixel size on the object)	<5.7µm at any location in the scanned volume
Scanning space	22mm in diameter, 60mm in length, 22mm in diameter, 14mm in length in a single scan
Reconstructed volume (after a single scan)	up to 4000 x 4000 x 2450 pixels
X-Ray interferometer	3-grating Talbot-Lau, 5-axis motorized alignment
Phase stepping	Piezo drive 30µm travel, 2nm accuracy
Radiation safety	<1µSv/h at any point on the instrument surface
Dimensions, weight	930W x 953D x 375H mm, 190kg
Power supply	200-240V AC, 50-60Hz, 2 x 6A (including workstation)
Internal workstation:	
Processors	Dual multicore Intel XEON
Memory (RAM)	128GB / 1866MHz
Disk space (HDD)	4TB (4 x 1TB, RAID0) + 512GB Solid State Drive
Monitor	24"UltraSharp LED LCD (1920x1200 native resolution)

Bruker microCT is continually improving its products and reserves the right to change specifications without notice.



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