TECHNICAL SPECIFICATIONS

X-ray source	20...190 kV, 4/10/25 W, submicron spot size, 5-position filter changer; Open (pumped) X-ray source with double stage electron optics; Target material – W standard; Cu, Mo, Ag optional
X-ray detectors	3 Mp active pixels CMOS flat panel 1920x1536 pixels and 11 Mp cooled CCD 4032x2670 pixels
Reconstructed image formats	*Flat panel:* 1920x1920x1160 pixels (central position) 3776x3776x1160 pixels (two offset positions) *CCD:* 4032x4032x2272 pixels (central position) 8000x8000x2272 pixels (two offset positions)
Reconstruction speed	1 min 12 sec for a reconstruction of 2K x 2K x 1K from 600 projections 11min for a reconstruction of 4K x 4Kx 2K from 1319 projections
Object positioning	Direct drive air bearing with integrated micro-positioning stage using piezo-drives (5.5 mm travel)
Detail detectability	100 nm
Scanning volume	Maximum diameter 204 mm, length 200 mm, weight 25 kg
Radiation safety	<0.5 µSv/h at any point 10 cm from the instrument's surface (measured at 190 keV, 4 W power on target)
Power supply	100-130 V or 200-240 V AC, 50-60 Hz, 2.5 kW + 1.5 kW for compressor (peak current at start of 65 A)

The system is supplied with closed loop water chiller and oil-free air compressor with necessary particle filters and air dryer.

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

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SkyScan 2211

● Multiscale X-Ray Nanotomograph

Innovation with Integrity

MICROTOMOGRAPHY

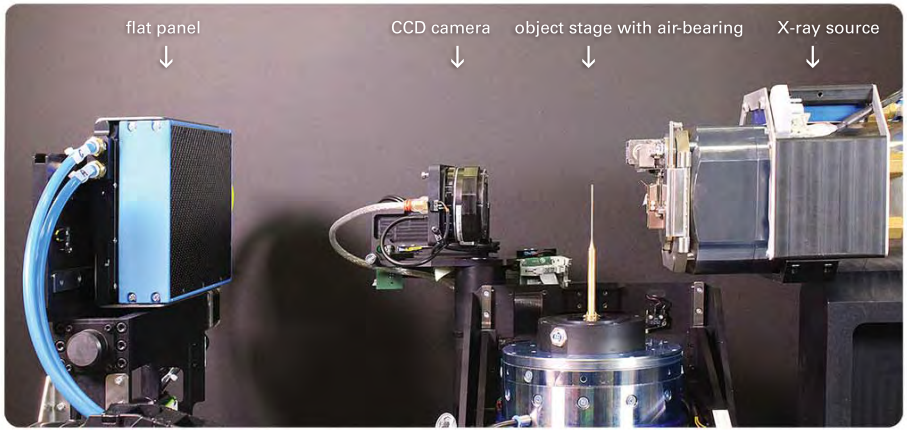
SkyScan 2211
Multiscale X-Ray Nanotomography System

The SkyScan 2211 MULTISCALE X-ray nanotomograph covers the widest range of object sizes and spatial resolutions in one single instrument. It opens unique possibilities for 3D imaging and exact modeling of materials in a number of applications, such as oil and gas exploration, composite materials, fuel cells, electronic assemblies, etc.

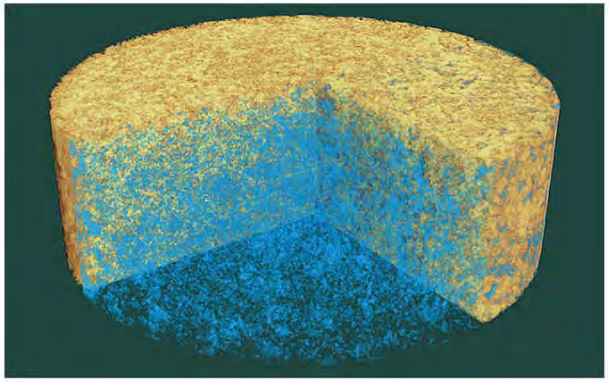
From micro to nano

Widest Range of Object Sizes and Spatial Resolutions

- Pixel sizes down to 100 nm for exceptional imaging detail,
- X-ray source acceleration voltage from 20 kV to 190 kV, submicron spot sizes and water cooling for stability,
- Unique versatility by combining two cooled X-ray detectors in one system:
  - 3 Mp flat-panel for high X-ray energy and large field of view,
  - 11 Mp CCD for optimal submicron resolution.
- Image reconstruction up to 8000 x 8000 x 2272 pixels after a single scan,
- World's fastest hierarchical 3D reconstruction (InstaRecon®) program with x10 to x100 speed-up,
- Precision air bearing rotation stage with <50 nm accuracy,
- Maximum sample diameter of 204 mm and sample height of 200 mm,
- Maximum object weight of 25 kg,
- Integrated anti-vibration granite platform with pneumatic leveling,
- Integrated micro-positioning stage with precise piezo-drives,
- Export of reconstructed results to phones and tablets for 3D volume rendering (iOS and Android),
- Images can be saved in multiple file formats, including DICOM, TIFF, JPG, BMP and PNG as well as AVI-format movies,
- Fully shielded for maximum safety.



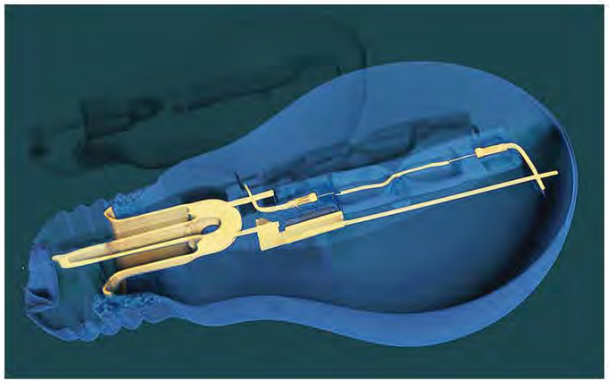
Best results for any application



Geology, Oil and Gas Exploration

3D volume rendering showing the pore network in blue and calcite matrix in yellow

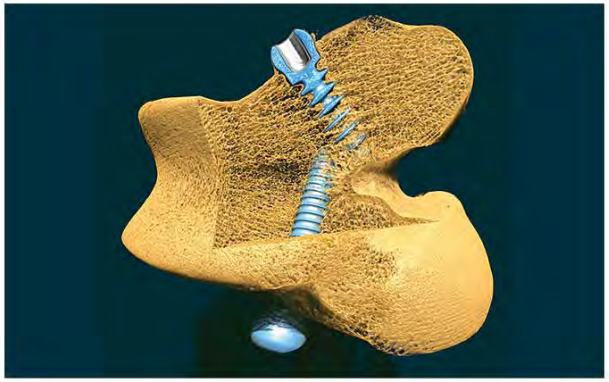
Scanning protocol:
22 µm isotropic voxel size,
190 kV, 0.5 mm Mo filter,
1536x1920x1000 rec. volume



Lighting

3D volume rendering of a halogen light bulb showing broken filament in yellow

Scanning protocol:
47 µm isotropic voxel size,
135 kV, 0.5 mm Al filter,
1536x1920x1978 rec. volume



Implants

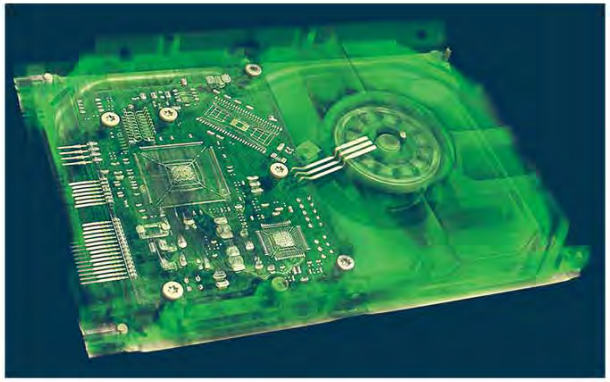
Sheep distal femoral condyles (knee bone) with two titanium orthopedic implant screws of 5 mm diameter

Scanning protocol:
37 µm isotropic voxel size,
130 kV, 0.5 mm Mo filter,
1920x1920x1431 rec. volume

Electronics

3D volume rendering showing the electronic components inside a hard disk drive

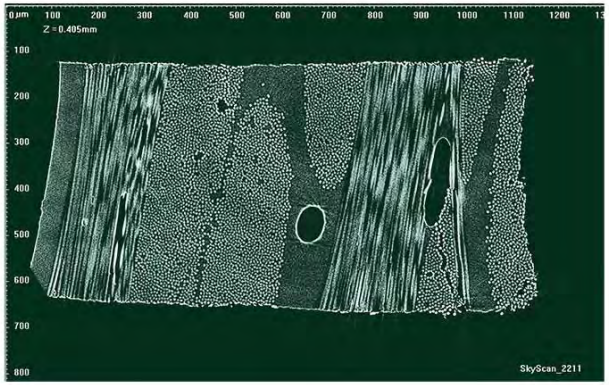
Scanning protocol:
35 µm isotropic voxel size,
190 kV, 0.5 mm Mo filter,
1536x3776x1801 rec. volume



Composites

Carbon-fiber reinforced plastic (CFRP)

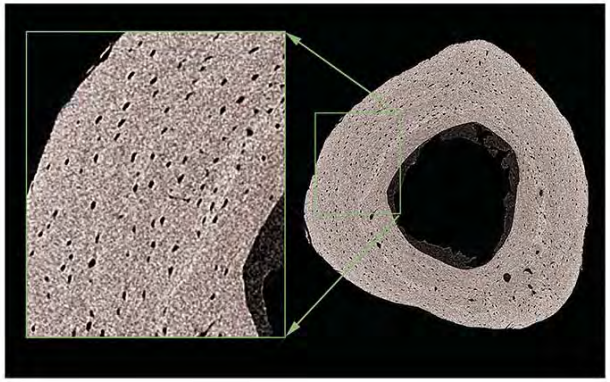
Scanning protocol:
0.35 µm isotropic voxel size
50 kV, no filter,
Single slice with 2340x3721 pixels,
region of interest from
4032x4032x1140 rec. volume



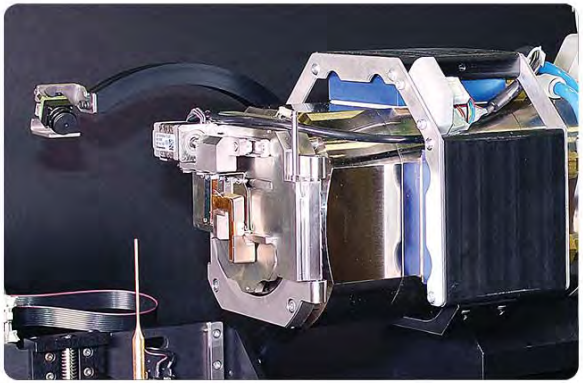
Bone

Submicron image of a mouse distal tibia showing osteocyte lacunae, blood vessels and hypermineralised seams

Scanning protocol:
0.5 µm isotropic voxel size,
50 kV, 0.5 mm Al filter,
4032x4032x2400 rec. volume



Advanced key components for uncompromised image quality

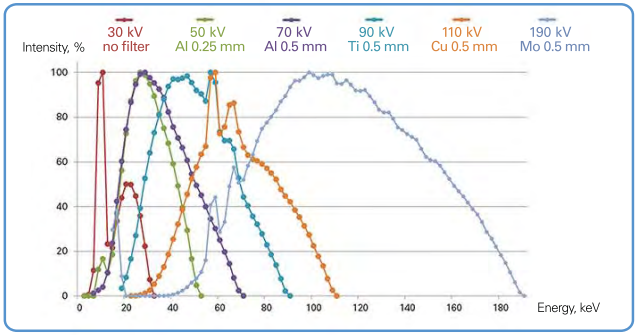


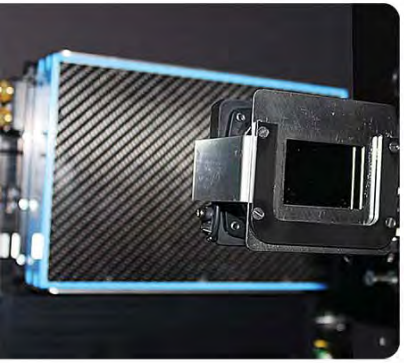
High Performance X-Ray Source

The SkyScan 2211 has an open type micro- and nano-focus X-ray source which can operate between 20 to 190 keV, with a maximum power of 4 W (optional 10 W and 25 W diamond target available). Two electromagnetic lenses 'shape' the electron beam prior to impinging on the X-ray target, allowing the source to operate in high power mode (5 µm spot size), microfocus mode (2 µm spot size) or nanofocus mode (submicron spot size). The standard target material for X-ray generation is tungsten. Alternatively, to obtain a better contrast for specific materials, the tungsten target can be easily changed to a Cu, Mo or Ag target.

Fine Tuning of the X-Ray Energy Window to the Absorption in an Object

A motorized five-position filter and collimator assembly is mounted in front of the X-ray source. Standard filter set includes 'no filter' (for CT using the full X-ray spectrum) and 0.5 mm Al, Ti, Cu and Mo filters, which can be changed as required. This set-up offers the flexibility to precisely tune the maximum X-ray energy emitted by the source and the minimum energy cutoff, allowing the operator to select the optimal energy window for any particular object.





Unique Versatility of Two X-Ray Detectors

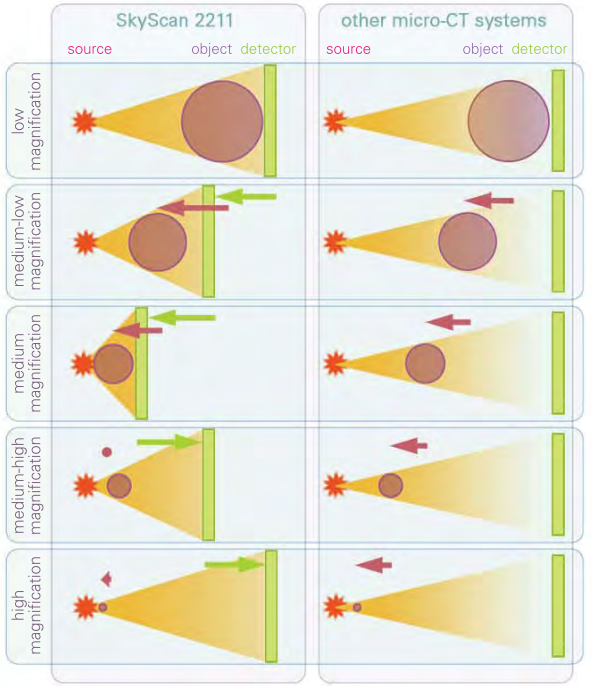
The SkyScan 2211 is equipped with 2 different X-ray cameras – a 3 megapixel active pixel CMOS flat-panel and an 11 megapixel CCD camera. This set-up allows the user to select the most appropriate detector based on the desired resolution and sample size / absorption characteristics and switch between detectors from the control program. The flat-panel detector has a 1944 x 1536 pixel array and can be used in central or two offset positions to obtain 6 megapixel images. The detector includes temperature control by an external chiller to stabilize the dark-current signal. The detector is mounted on a linear stage, allowing it to adjust the distance between source and flat-panel, offering automatically variable geometry for fastest possible scanning.

The 11 MP camera contains a large-format CCD sensor offering 8000 x 2670 pixel imaging in offset scanning mode. The camera contains a solid-state cooling element to stabilize the CCD's operating temperature within +/- 0.1°C, avoiding the need for temperature-dependent recalibration. The entire CCD unit is mounted on a motorized rotating arm and can be flipped in and out of the X-ray beam.

Automatically variable acquisition geometry

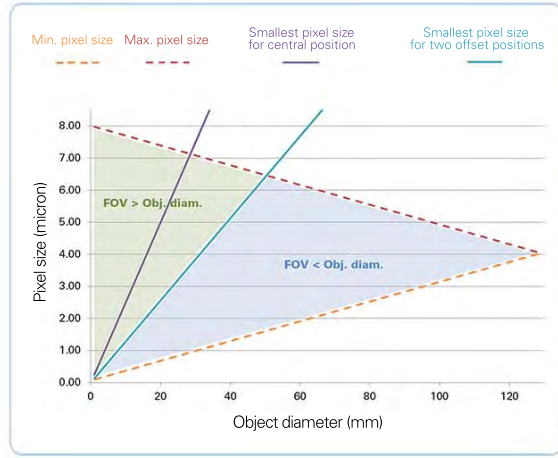
Variable Scanning Geometry for the Best Scan at Any Magnification

When making tomographic scans with the flat panel detector, the SkyScan2211 utilizes the automatically variable acquisition geometry invented by Bruker microCT to reduce scanning time and to increase the scanning quality. Most other commercially available micro-CT systems use a static acquisition geometry where the X-ray source and X-ray detector are separated by a fixed distance and the image magnification is adjusted by moving the object between them. Increasing the source-detector distance, to extend the magnification range, reduces quadratically the intensity of the X-ray beam at the detector which results in a steep increase in scan time. To escape this dilemma the SkyScan2211 uses automatically variable scanning geometry. At high and low magnifications, the distance between the source and the detector is set to its maximum. At intermediate image magnifications, both object and detector are moving towards the source until they reach the most compressed geometry possible for the selected pixel size. Such an adaptive scanning geometry allows an improvement in quality or a reduction of scan time compared to a traditional fixed scanning geometry. For all camera positions the calibration in stored in the control software in advance and automatically updated during acquisition geometry modifications.

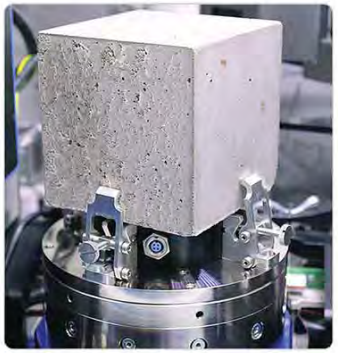


Doubling Scanning Size and Reconstruction in Region of Interest

When scanning in CCD mode, it depends on the object diameter and the chosen pixel size if the sample fits inside the field of view (FOV). The graph on the right depicts the pixel size range (max. and min.) as a function of object diameter. The field of view can be increased by using an offset scan to help visualize larger objects at higher magnifications (green area). For even larger objects, truncated scanning – which involves rotating the object while keeping the central portion in the FOV to allow proper image reconstruction – can be used (blue area). Alternatively the system can be switched to flat-panel scanning to allow image acquisition for larger object sizes.



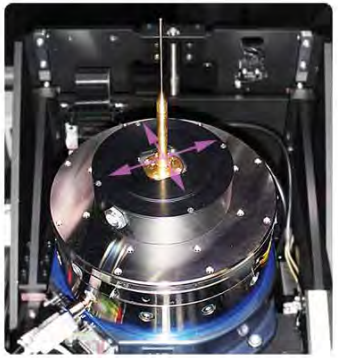
Stages for any type of objects and for *in-situ* examination



Air Bearing with Direct Drive for Precision Rotation

The object stage is equipped with a high-precision air bearing which can support up to 25 kg sample weight. With a cogging-free direct drive motor, it offers minimal wobble and radial motion error. The radial motion error is smaller than 50 nm. An integrated high performance encoder offers arcsec level of angular positioning accuracy for perfect imaging results.

The air bearing is mounted on a linear stage to enable height adjustment of the sample. A second linear stage moves the object stage with air bearing perpendicular to the X-ray beam and allows a precise alignment of the system to the central line between the emission point inside the X-ray source and central column of CCD camera and flat-panel sensor.



Integrated Micro-Positioning Stage

A micro-positioning stage mounted on top of the air bearing allows the user to precisely center the object on the rotation axis, helping to obtain the largest field of view. This also allows the selection of truncated scan regions within samples that are larger than the field of view.

The micro-positioning stage consists of two orthogonal piezo stages, controlled via multiple slip rings incorporated into the central part of the air bearing. This set-up allows unlimited object rotation with low friction and high reliability. A four-pin connector mounted on the side of the micro-positioning stage provides control of additional Bruker microCT stages for *in-situ* examination.

Object Stages for *In-Situ* Examination

The material testing stage (MTS) can be used to apply symmetrical controlled compression or tension to an object, allowing tomographic scans during applying force. It can be supplied with different load cells offering maximum compression or tension force of 42, 210 or 440 N with a maximum travel of 5.5 mm.

The other stages, such as heating and cooling stages, allow for micro-CT scanning under controlled object temperature above or below ambient. The heating stage can keep an object at a temperature up to +85°C. The cooling stage allows scanning an object at sub-zero temperature down to 30°C below ambient.

Software for reconstruction, analysis and realistic visualization

Bruker microCT provides a comprehensive software suite which is continuously updated via free downloads.

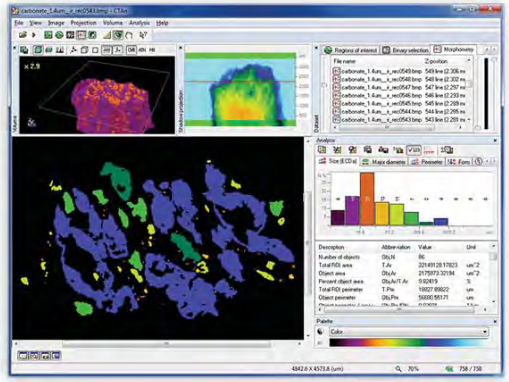
Multiple Reconstruction Engines

The software for 3D reconstruction **NRecon** allows creating large format virtual slices through the object based on acquired X-ray projection images. It is supplied with three reconstruction engines, which can be selected by users. The first one – NRecon Server – uses the power of all available cores of the processors (CPU) for parallel reconstruction. The second one – GPURecon Server – involves the graphical card processors (GPU) to accelerate the reconstruction. Both reconstruction engines are based on the filtered back-projection algorithm. The third reconstruction engine - InstaRecon® - utilizes an unique hierarchical reconstruction algorithm, which allows x10...x100 speed-up compared to the conventional filtered back-projection algorithm on the CPU and x2...x10 speed-up compared to GPU-accelerated reconstruction.

reconstruction time: full volume / single slice	1K (615 slices)	2K (1229 slices)	4K (2459 slices)	8K (2255 slices)
NRecon (CPU)	2m 46s / 0.270s	24m 28s / 1.194s	4h 16m / 6.233s	15h 42m / 25.075s
GPURecon (GPU: 1 NVIDIA Quadro K4000, 3 GB)	51s / 0.083s	11m 12s / 0.547s	4h 1m / 5.892s	13h 14m / 21.132s
InstaRecon® (CPU)	16s / 0.026s	1m 15s / 0.061s	8m 2s / 0.196s	1h 13m / 1.952s

2D / 3D Image Processing and 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 allow hand drawing, selection of standard shapes and editing regions of interests in key slices with automatic interpolation to the full volume. **CTAn** contains hundreds of embedded functions with the possibility to build tasklists and to execute user-created plug-ins.



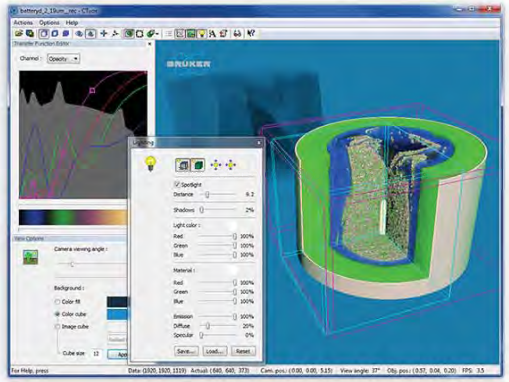
^ *example of a size distribution using* ***CTAn***

3D Visualization by Surface Rendering

CT-Volume or "**CTVol**" uses surface-triangulated models and provides a virtual 3D viewing environment, flexible and rich in features, to give users a wide range of options for a 3D presentation. Any volume can be exported in STL-format for 3D-printers to create a physical copy of the scanned objects.

3D Visualization by 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 animations based on a simple selection of several key frames with automatic interpolation in between.



^ *volume rendering of a D-size battery by* ***CTVox***

Your results are always with you

Mobile Volume Rendering

A mobile version of the CTVox program can be downloaded for free from the AppStore or GooglePlay, allowing 3D results to be sent directly to a mobile device via a cable or wireless network for real-time volume rendering. This allows realistic visualization with 3D object manipulation, adjustments to opacity and colors, virtual cuts, etc.

The rendered data and color schemes are stored in the local memory of the mobile device, and do not require a network connection during manipulation. A large number of reconstructed datasets can be loaded to the memory of a mobile device, allowing the user to study image results on the move, share them with colleagues and demonstrate at meetings.

Automatic E-mail Reporting

The SkyScan2211 control software will send you an e-mail after the scan is done. The e-mail includes a direct link to the dataset folder of the scan results. 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.

Flexible Image Formats

All SkyScan 2211 software use a standard DICOM format (compliant with the DICOM 3 convention), and can provide results in Windows readable formats such as PNG, BMP, JPG and TIFF images, and AVI movies.

If required, images can be converted between formats using the supplied Format Converter. This allows the user to easily rename, resize, rescale and renumber individual images or full datasets, as well as combine multiple sets of reconstructed slices.

Comprehensive support on software and training courses

Software Updates

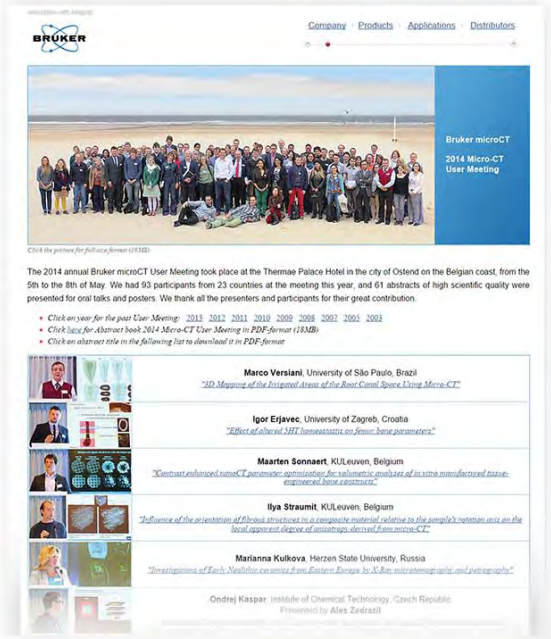
All SkyScan 2211 users have unlimited free access to all instrument control and application software updates, with new versions available from www.bruker-microct.com.

Users can also e-mail info@bruker-microct.com for technical or application support.

Training Courses, Micro-CT Annual Meetings and the 'Bruker MicroCT Academy'

All SkyScan 2211 customers are provided with basic training at the time of instrument installation, followed by more in-depth training at a later date. A five-day system and software training course is also available, covering three major topics: image acquisition, image reconstruction and data analysis / visualization. Held throughout the year at the company's headquarters in Belgium, this course combines the basic theoretical background of microCT scanning with as much hands-on experience as possible.

Bruker microCT also organizes an annual MicroCT Meeting 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 system. An invitation to the next MicroCT Meeting and the abstracts of presentations from the previous meetings can be found at www.bruker-microct.com



The 'Bruker microCT Academy' is an educational network for the hundreds of groups around the world using SkyScan instruments. A monthly newsletter provides technical tips and information on existing applications, keeping users updated on new methods and innovations. Academy users also gain access to a database with detailed application and technical notes, and can provide feedback through questions and suggestions for improvements in instruments and software.