



## OFTEN COPIED – NEVER EQUALLED

- Sealed Tube – stable and highly brilliant
- Air-cooled – ecological and reliable
- Focusing / Collimating – high-end 2-dim Multilayer Optics
- Light & Small – easily installed to a diffractometer
- Maintenance free – sustainable with low cost of ownership

## $\mu$ S meets your requirements

The Incoatec Microfocus Source  $\mu$ S is available in different configurations for protein crystallography, chemical crystallography, small-angle scattering and material research. It combines the superb performance exceeding that of the traditional 5 kW-class rotating anode sources with the easy handling of sealed tube systems. The  $\mu$ S is available with Cu, Mo, Ag and Cr radiation. The X-rays can be focused as well as collimated. The beam size depends on the optics properties and the geometry of the experiment. It is generally in the range of 50 to 500  $\mu$ m at the sample position. Main applications are illustrated below. Further results from our application lab are available as application notes. Our customers' publications give a closer insight into the amazing possibilities of the  $\mu$ S. The latest results can be downloaded from our website.

## $\mu$ S for Small-Angle Scattering SAXS

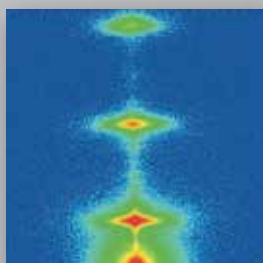
- Cu anode
- integrated into Bruker AXS Nanostar
- collimated beam with 0.5-1 mrad divergence
- high performance SAXS and GISAXS in the lab
- ideal for customized systems
- approver for the latest detector technology
- suited for solid as well as liquid samples
- in-situ measurement of nano-ordering possible

## $\mu$ S for X-ray Diffraction

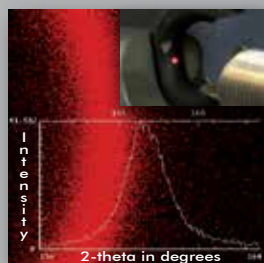
- Cu, Mo, Cr anode
- combined with all modern detectors
- integrated into the Bruker AXS D8 Discover

for the following applications:

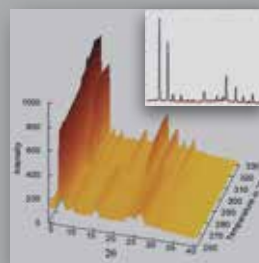
- powder diffraction
- stress analysis
- reflectometry
- texture measurements
- micro-diffraction
- surface diffraction
- PDF (pair distribution function)
- semiconductor industry (Bruker AXS Fabline)



GISAXS of a Mo/Si multilayer with a Bruker Nanostar with Cu- $\mu$ S (by P. Šiffalovič, Bratislava)



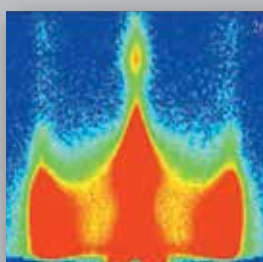
Stress determination of a steel part with a Cr- $\mu$ S on a Bruker GADDS (by H. Göbel, München)



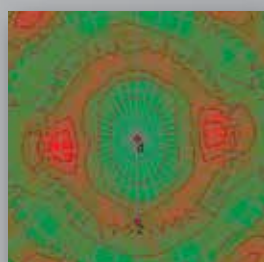
Diffraction pattern and profile fitting of Cu phthalocyanine measured with Cu- $\mu$ S and imaging plate detector



Diffraction pattern of a  $\text{CaCO}_3$ -cuttlebone measured with Mo- $\mu$ S and imaging plate detector



GISAXS of silver nanoparticles on a Langmuir film measured with Cu- $\mu$ S and Dectris detector by P. Šiffalovič



Pole figure of a brass sheet measured with Cu- $\mu$ S on a Bruker GADDS system



Measurement of textured  $\text{BaHfO}_3$  nanoparticles deposited on YBCO with Cu- $\mu$ S on a Bruker GADDS system



Diffraction pattern of  $\text{LaB}_6$  measured with Mo- $\mu$ S and a Mar imaging plate detector

... – the options are endless

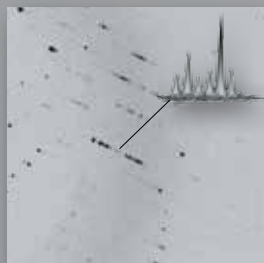
## $\mu$ S for Chemical Crystallography

- Cu, Mo and Ag anode
- dedicated optics for X-ray analysis of powders and single crystals
- integrated into Bruker AXS equipment for chemical crystallography
- can be combined with all modern 2-dim detectors
- structure determination of single crystals and powders
- charge density studies
- high-pressure crystallography

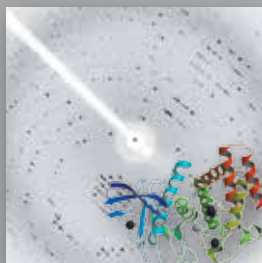


## $\mu$ S for Protein Crystallography

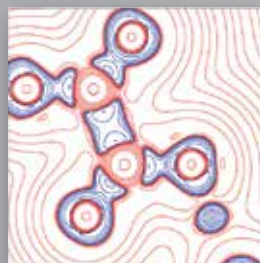
- flux density above traditional 5 kW-class rotating anodes
- dedicated optics for low divergence and very small samples below 100  $\mu$ m
- integrated into Bruker AXS equipment for biological crystallography
- lowest maintenance & highest convenience
- replacement for 5 kW-class rotating anodes, fully integrated into your image plate or CCD system
- protein structure determination
- SAD (single wavelength anomalous dispersion) phasing
- protein screening



Resolving a 202 Å cell axis with a Cu- $\mu$ S MX (by H. M. Holden, Madison).



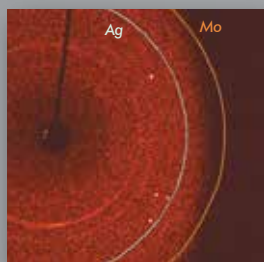
Typical diffraction pattern and structure model of Thermolysin (by A. Heine, Marburg).



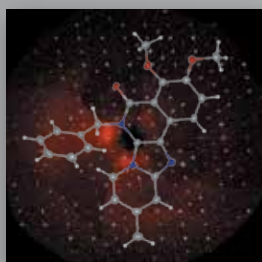
Laplacian of the electron density of Oxalic Acid (by C. W. Lehmann, Mülheim).



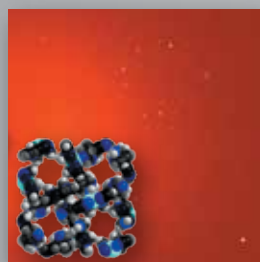
Laplacian of the electron density at the Co atom in  $\text{Sc}_3\text{Co}(\text{C}_2)_2$  (by W. Scherer, Augsburg).



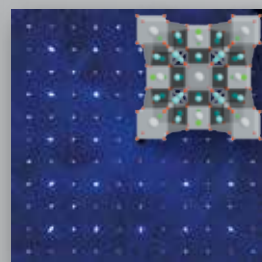
Diffraction pattern of a Gabapentin crystal in a diamond anvil cell (by F. P. A. Fabbiani, Göttingen).



Simulated precession pattern and molecular structure of an isoquinoline (by D. Stalke, Göttingen).



Diffraction pattern and molecular structure of a MOF compound (by R. W. Seidel, Mülheim).



Simulated precession pattern of the mineral Murdochite  $\text{PbCu}_6\text{O}_7(\text{Cl},\text{Br})_2$



# Manufacturing & Technology

The  $\mu$ S is a high-brilliant microfocus source which consists of a sealed tube, a multilayer optics and a high voltage generator. The production and assembly of all key components are carried out in-house.

The  $\mu$ S is equipped with the latest generation of Montel Optics, the so-called Quazar Optics, which can be up to 15 cm in length. The coating of these multilayer optics is produced using the highly reliable and precise method of magnetron sputtering. With various types of sputtering systems different sizes of substrates ensure a cost-effective production (fig 1). The plasma inside the high-vacuum chamber (fig 2) enables the deposition of single layers in the sub-nanometer range down to a precision of 0.2%. The high quality of multilayer structure is displayed in the transmission electron microscopy image of a standard multilayer (fig 3). To maintain a high standard in quality all optics are measured at several positions with X-ray reflectometry. Figure 4 shows the reflectometer with which standard measurements (fig 5) are carried out. The film thickness can be calculated from the position of the first Bragg peak. Figure 6 shows the thickness of a multilayer pair along the length of the substrate and displays the allowed range of deviation for a Quazar Optics. In the next step the multilayer optics are mounted and pre-aligned in our patented optics housing guaranteeing high stability (fig 7).

The microfocus source consists of two parts: firstly an X-ray tube mounted and aligned inside the cooling body and secondly an upper housing part containing the fans, the electronic controls and the safety shutter system. Figure 8 shows how these two parts are assembled. Due to the low weight it is possible to mount the  $\mu$ S on all kinds of standard goniometers and positioning stages, making a customer-specific integration into existing setups possible. This type of installation has been carried out successfully for numerous customers.

For the electronic control of the  $\mu$ S an intelligent X-ray generator has been developed that is also produced in-house (fig 9). From the first  $\mu$ S model on, we have implemented a sensor inside the optics housing that closes the shutter if the multilayer is not used in vacuum (the brilliant X-ray beam would otherwise destroy the optics by producing ozone). Our new  $\mu$ S High-Brilliance is even more advanced as the generator collects additional information on the properties of the tube and the optics. Additionally, parameters such as the ramp rate of the tube or system failures are monitored. This monitoring system ensures a better and faster customer support. Furthermore, for safety reasons the shutter between source and optics can only be opened if the optics housing is mounted correctly. Customer-specific wishes such as individual safety circuits or motorized optics alignment are fulfilled by our experienced electronics group.

After manufacturing every  $\mu$ S is tested in our X-ray lab (fig 10). The beam profile is measured with a calibrated detector and the intensity of the beam is checked and recorded. This value is the benchmark which needs to be achieved at the customer's site after the  $\mu$ S has been installed. Our complete production chain ensures that every single  $\mu$ S is most accurately manufactured and characterized before leaving our company. Our in-house development is a guarantee for the customer that the  $\mu$ S product range is continuously being improved and special customer requirements are met quickly at a good price performance ratio.



fig 1

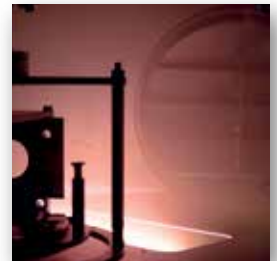


fig 2

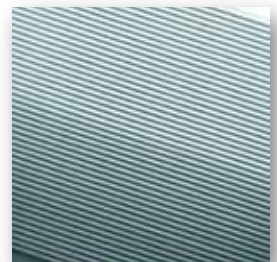


fig 3



fig 4

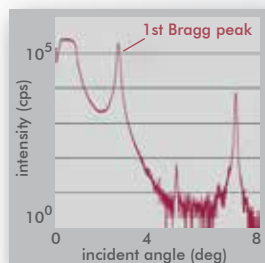


fig 5

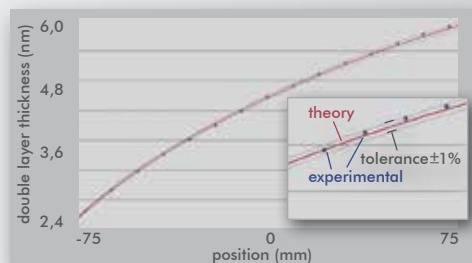


fig 6



fig 7



fig 8



fig 9



fig 10

# The Microfocus Source

$\mu$ S inside:

## Tube Housing

- high-performance air-cooling
- new shutter with optoelectronic monitoring for longer life-time
- labelled LEDs for the sake of clarity

## X-ray Tube

- sealed tube
- microfocus spot at anode ( $< 40 \mu\text{m}$ )
- easy replacement
- wavelength: Cu, Mo, Ag or Cr
- long life-time  $>> 3\text{y}$

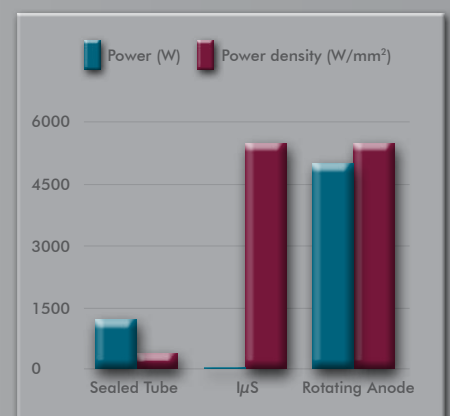


## Tube: the main principle

The  $\mu$ S provides a highly brilliant X-ray beam in a power range of 10-50 W. It reaches an amazing performance by using air-cooling and a low-power sealed tube. The  $\mu$ S is a microfocus source as the focal spot of the electron beam on the anode only has a diameter of 20-50  $\mu\text{m}$ . Incoatec offers all typical anode materials like Cu, Mo, Ag and Cr.

Due to the higher surface-to-volume ratio of the focal spot compared to the old 1-2 kW sealed tubes, the  $\mu$ S has an improved heat conductivity and thus allows significantly increased power densities. With values larger than 5 kW/mm<sup>2</sup> the performance of the  $\mu$ S is comparable to 5 kW-class rotating anodes (see graphic).

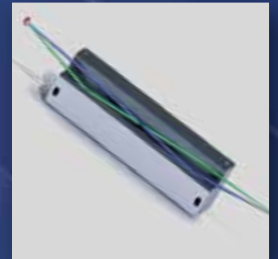
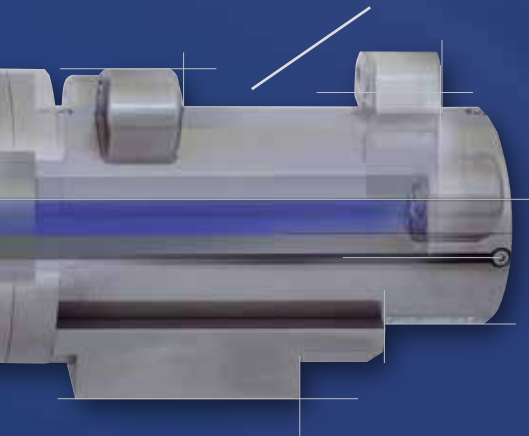
The brilliance cannot be increased by the optics, therefore it is of utmost importance to achieve the highest possible brilliance within the tube. Consequently, it is best to combine the tube with a multilayer optics as opposed to other types of optics, as this ensures that the small focal spot is directed to the sample with the highest possible brilliance conservation.



# The Optics

## Multilayer Optics

- Quazar Optics: Montel type 2-dim beam shaping
- focusing, collimating or hybrid
- multilayer design optimized for source properties and application geometry
- simple alignment & stable position
- evacuated housing for minimal air-scattering & maximal optics protection
- motorized alignment (optional)
- variable divergence slit (optional)



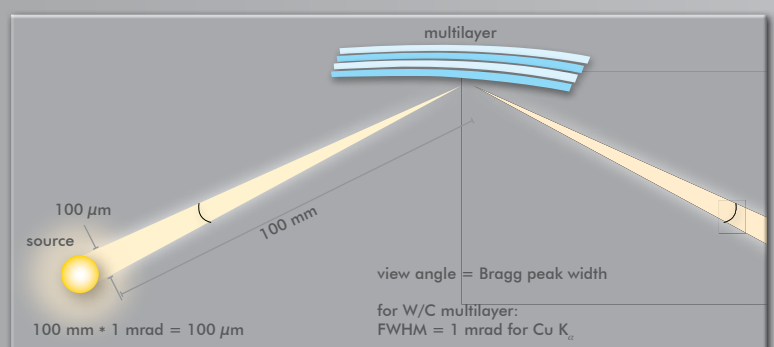
## Customized Engineering

- integration in all common safety circuits
- fully compliant with Machinery Directive 2006/42/EC
- component recognition available
- individual mechanical adaptation
- fully implemented into Bruker AXS software and safety system

## Optics: the main principle

Multilayers are best suited for beam formation and monochromatization of X-rays. Applying Bragg's law X-rays are collected in a solid angle of approximately 1 mrad e.g. at W/C multilayers and are redirected with a reflectivity larger than 80 % while simultaneously suppressing  $K_{\beta}$ -radiation. To take account for the varying incident angles, the multilayer requires a lateral gradient of the layer thickness. It is possible to focus the incident beam with an elliptically shaped substrate. A collimation is achieved with a parabolically shaped substrate. A 2-dim shaping of the beam is possible by combining and fixing two multilayer mirrors side-by-side in an L-shape. This assembly is called Montel optics. In this geometry the beams are doubly reflected and thus the monochromatization effect is squared.

The graphic illustrates that the multilayer optics are an ideal combination for X-ray sources with a focal spot diameter well below  $100 \mu\text{m}$  on the anode. With larger sources the range of incident angles increases. Therefore, the multilayer optics can only reflect the incident beam partially as the other X-rays do not fulfil Bragg's law. Generally, the optics can be designed to meet customer's needs. Hence, there are optics exhibiting e.g. low divergencies or high flux densities with spots on the sample varying from some  $10 \mu\text{m}$  up to the mm range.



# Installations

## Integration into complete systems

- for single crystal diffractometry
- for material science
- for small-angle scattering (SAXS)



*Bruker AXS X8 PROSPECTOR*



*Bruker AXS D8 DISCOVER*



*Bruker AXS D8 VENTURE*

## Upgrades of equipment

- for all types of systems
- replacement of rotating anode generators and sealed tubes



*upgrade on a Huber goniometer, Durham*



*replacement of a RU-200 rotating anode, Boulder*



*IµS combined with mar dtb, Marburg*

## Customized solutions

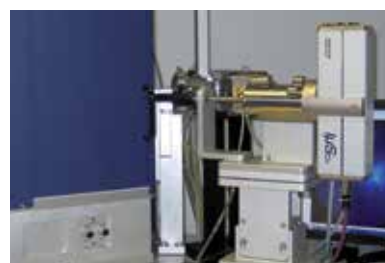
- SAXS/GISAXS for liquids in the lab
- in-situ measurements
- customer-specific unique setups



*IµS+Pilatus detector for (GI)SAXS, Bratislava*



*replacement of an old 18 kW Siemens RAG, Halle*



*IµS combined with STOE diffractometer, Mainz*

## More than 150 systems worldwide with highly satisfied customers

The  $\mu$ S is used in chemical and pharmaceutical companies as well as nanotechnology and semiconductor companies and other businesses involved in materials analysis. In particular, academic and governmental institutions belong to our clientele. The  $\mu$ S is currently implemented as a key component in more than 150 diffractometry instruments (up to 6/2011) and has been integrated into new equipment of companies such as Bruker AXS, Marresearch or STOE. Incoatec has also installed the  $\mu$ S as an upgrade for existing diffractometers. For these, our production group takes care of the adaptation, our service team installs on-site and the application specialist carries out the first measurements - all in strict accordance with current safety regulations.

We guarantee with our good reputation the highest level of technology and customer support.

## Selection of firsthand customer statements

„For one year now our  $\mu$ S has been in use regularly for screening purposes, without us worrying about the X-ray source“, „The  $\mu$ S completely meets our expectations.“, „I suppose that funding restraints are the only reason not to go with the two- $\mu$ S setup.“, „The only negative aspect is that we can now collect data on such poor samples that we have to spend much more time on refining disordered and otherwise troubled structures.“, „Apart from the superior data quality, it was the prospect of air cooling and low-maintenance which were our main reasons for purchasing ...“, „... absolutely meets up to our expectations ...“, „... is excellent ...“, „... very satisfied ...“, „... working free from defects and without significant loss in intensity ...“



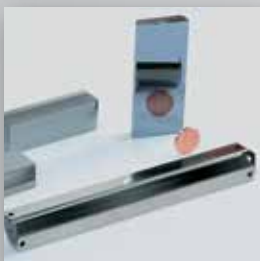
Your partner for X-ray optics and microfocus sources!

# History of $I\mu S$

## History of $I\mu S$

- 1995 Beginning of multilayer X-ray optics development at GKSS Research Centre
- 2001 2-dim beam shaping with Montel Optics
- 2002 Foundation of Incoatec
- 2006 Launch of Cu- $I\mu S$  for biological crystallography and small-angle scattering
- 2007 1st Cu- $I\mu S$  installed at the Center for Structural Biology, Kiel, Germany
- 2007 Mo- $I\mu S$  developed for chemical crystallography
- 2008 New Helios MX Optics for  $I\mu S$  and rotating anodes for protein crystallography
- 2009 1st Ag- $I\mu S$  installed at the Institute of Inorganic Chemistry, Göttingen, Germany
- 2010 100th  $I\mu S$  installed at the Fédération Chevreul (CNRS) in Lille, France
- 2011 Launch of the  $I\mu S$  High-Brilliance

For more information on Incoatec and our microfocus solutions please contact us at:  
[sales@incoatec.de](mailto:sales@incoatec.de) or visit our website at [www.incoatec.de](http://www.incoatec.de)



Incoatec – Your Partner for X-ray Optics and Microfocus Sources: Incoatec was incorporated in 2002 by former members of the GKSS Research Centre in Geesthacht near Hamburg and the Bruker AXS GmbH. We have a long history in the development of X-ray optics based on thin film technology. Incoatec manufactures all products on-site - Made in Germany. Our Optics are used in X-ray diffractometry, spectrometry and at synchrotron beamlines all over the world. Our microfocus source  $I\mu S$  sets new standards in home-lab X-ray analytics.

incoatec GmbH • Max-Planck-Str. 2 • 21502 Geesthacht • Germany  
phone: +49 (0) 4152 889381 • [info@incoatec.de](mailto:info@incoatec.de) • [www.incoatec.de](http://www.incoatec.de)

© 2011 incoatec GmbH. Printed in Germany. Order No IDO-F20-005B

