Advancements in X-ray diffraction residual stress measurements – Xstress DR45

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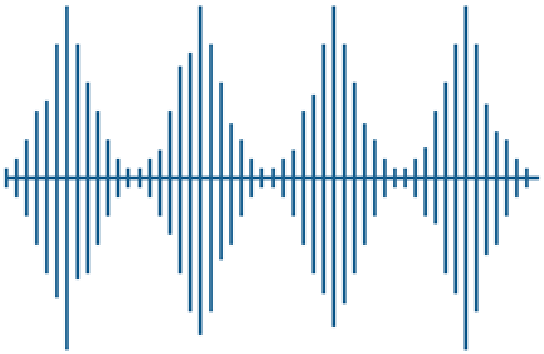
Measure for success

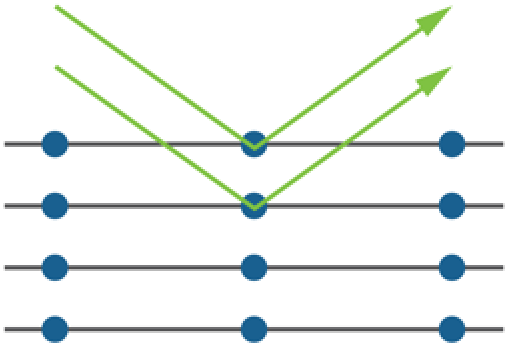
NOVA INSTRUMENTS

Stresstech

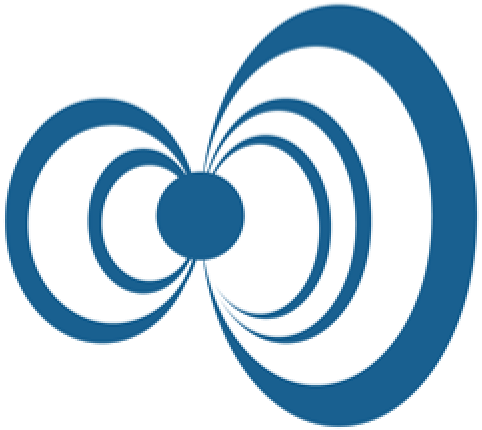
40 years of experience providing inspection instruments and measurement services



Barkhausen Noise



X-ray Diffraction



ESPI Hole-drilling

Stresstech Group

CUSTOMER VALUE STATEMENT

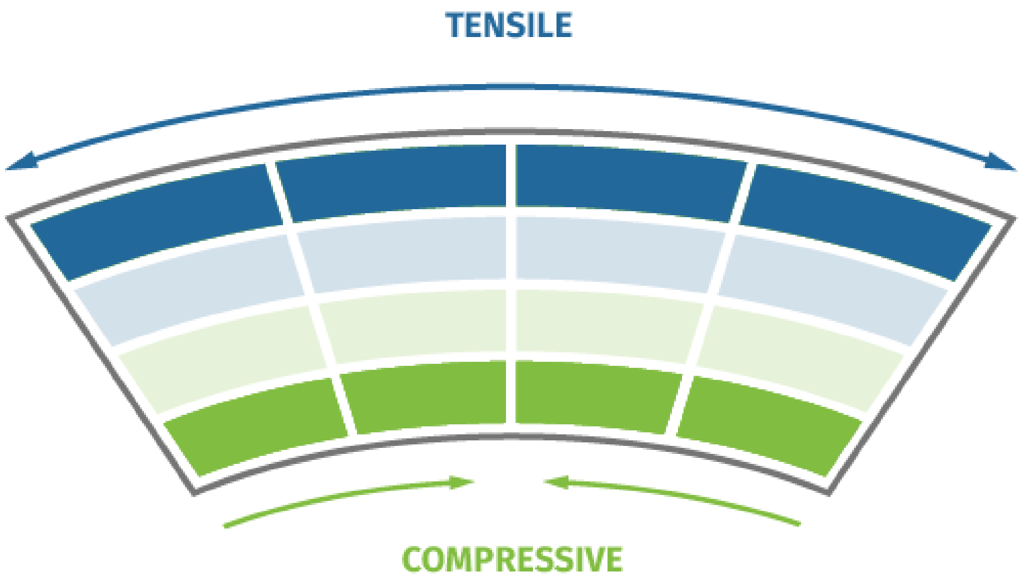
With Stresstech solutions, **you can improve and control the quality of your manufacturing process** where material properties can change during the machining or heat treatment processes.

Residual stress

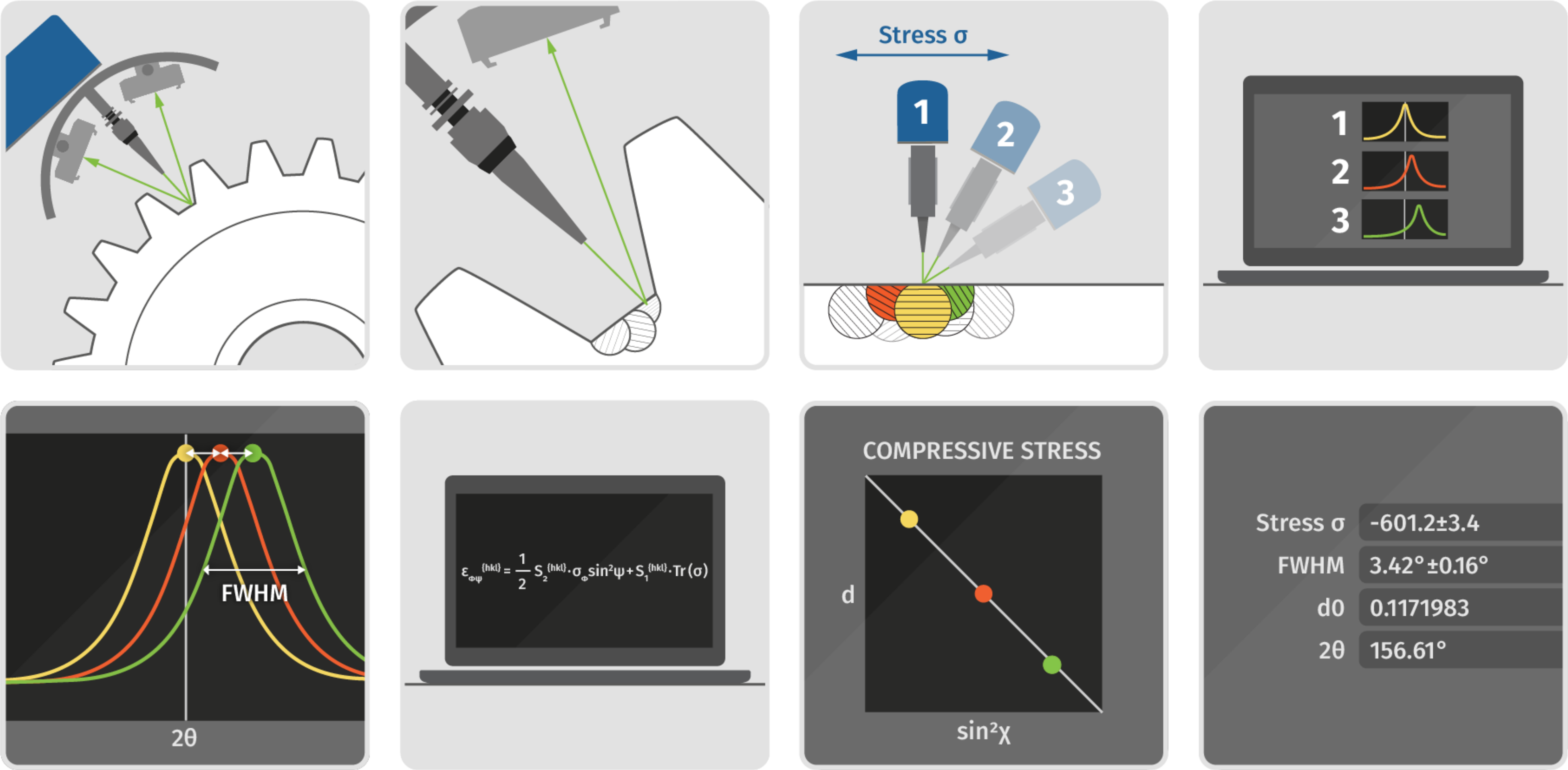
Residual stresses are spontaneously in equilibrium as

- **tensile residual stresses** which are detrimental
- **compressive residual stresses** which are beneficial

Tensile and compressive stress formation on a bent sample



Residual stress determination with X-ray diffraction (XRD)



1D vs. 2D X-ray Detector

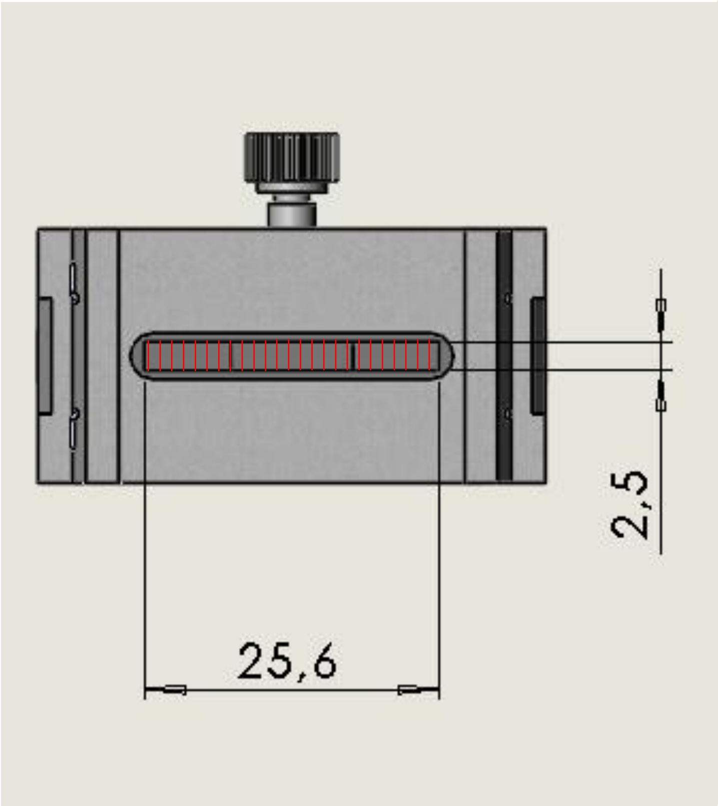
1D detector

- 1 × 256 pixel NMOS linear image sensor
- Efficiency to detect X-rays < 5 %
- Not designed for X-ray detection
- Small active area
- Wears from X-ray radiation

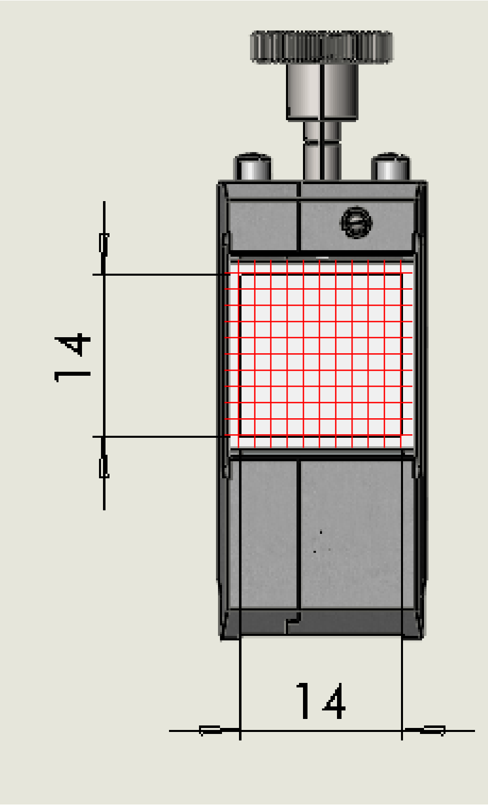
2D detector

- 256 × 256 pixel CMOS array detector
- Efficiency to detect X-rays > 95%
- Large active area
- No dark current

1D

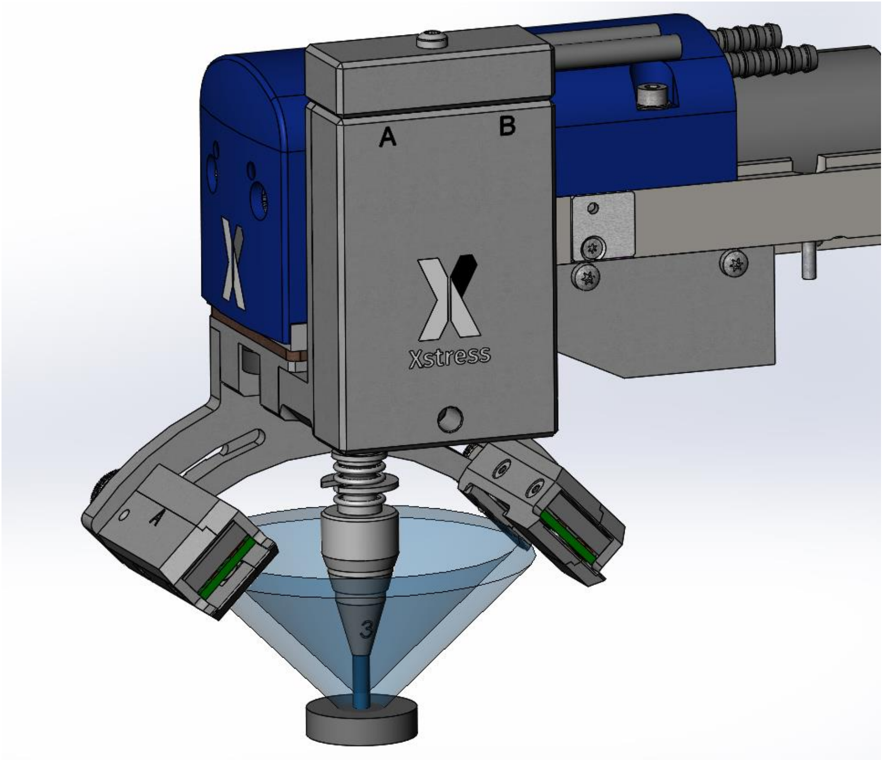


2D

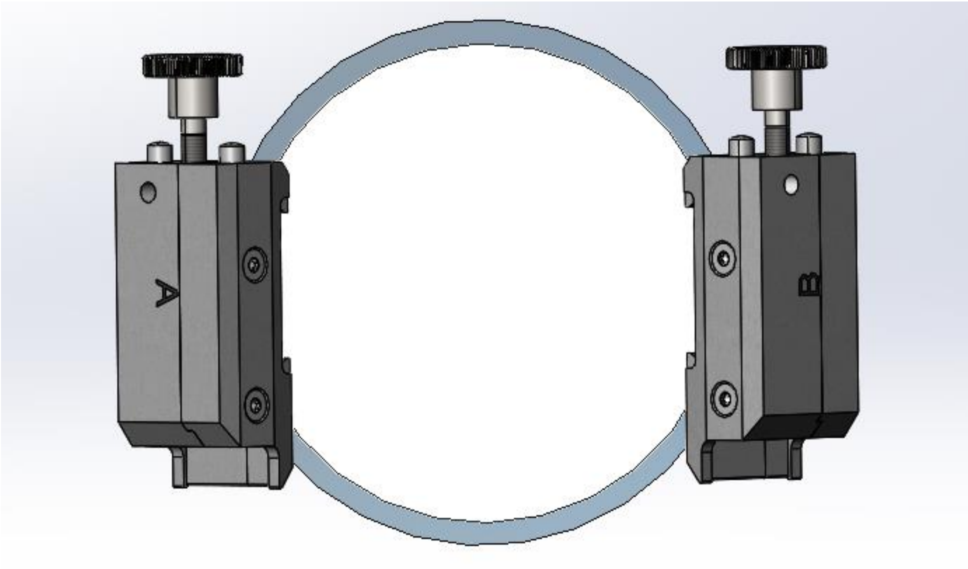


X-ray detection in XRD

X-rays coming through the collimator are diffracted from the sample as a **cone**



Diffraction from above



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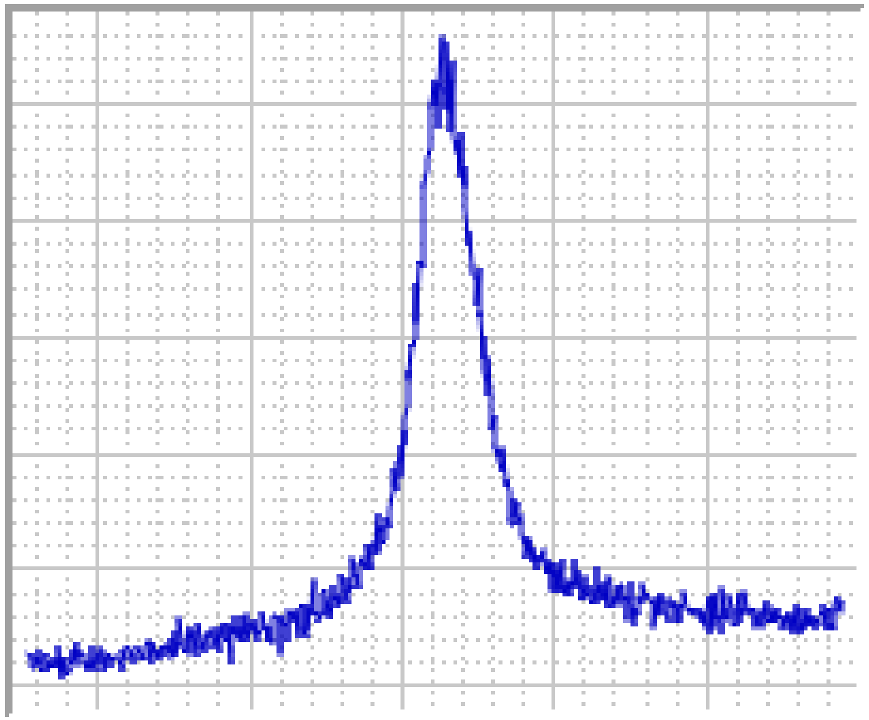
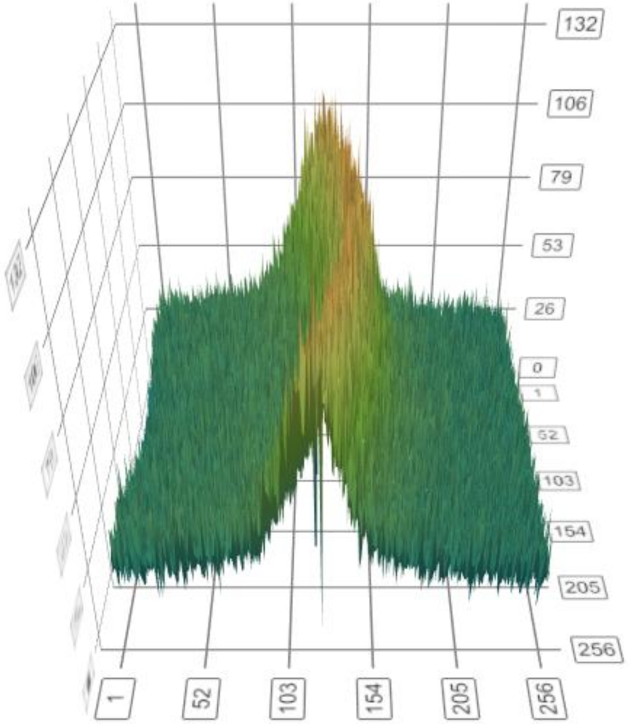
1D vs. 2D X-ray Detector

What the detector sees

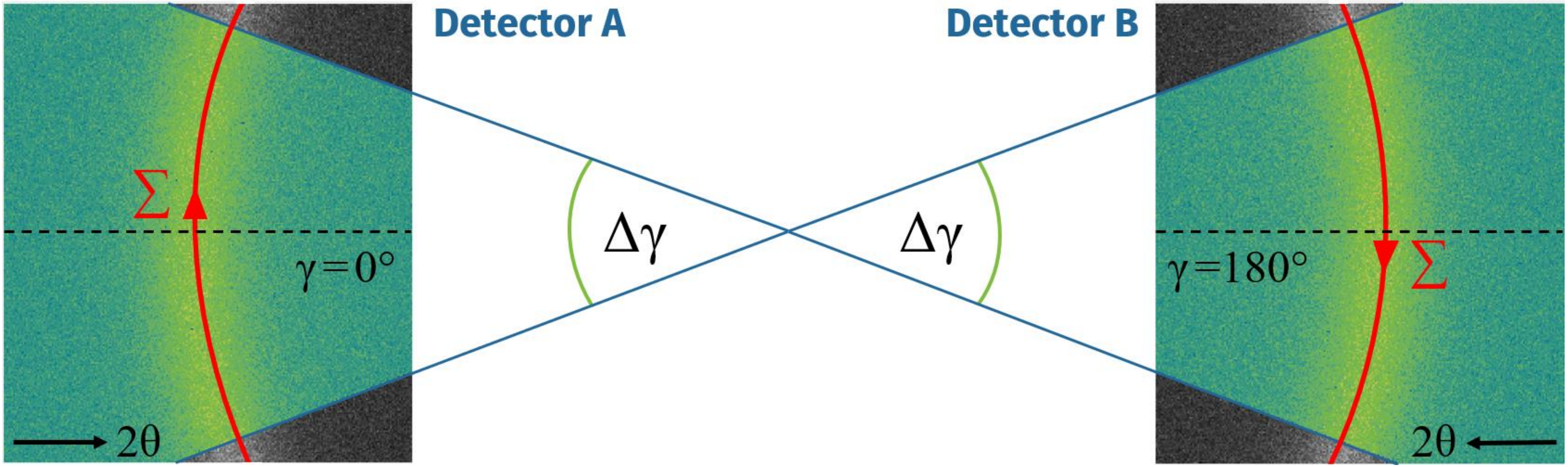
1D detector



2D detector



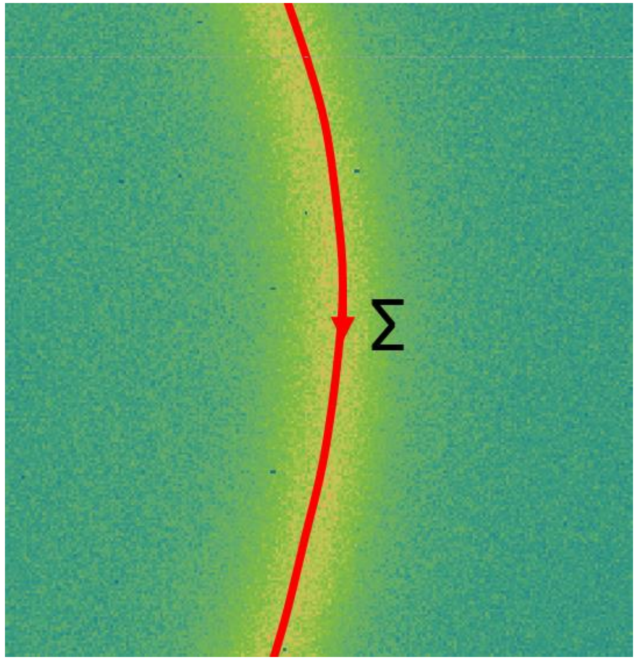
2D Area Detectors geometrics



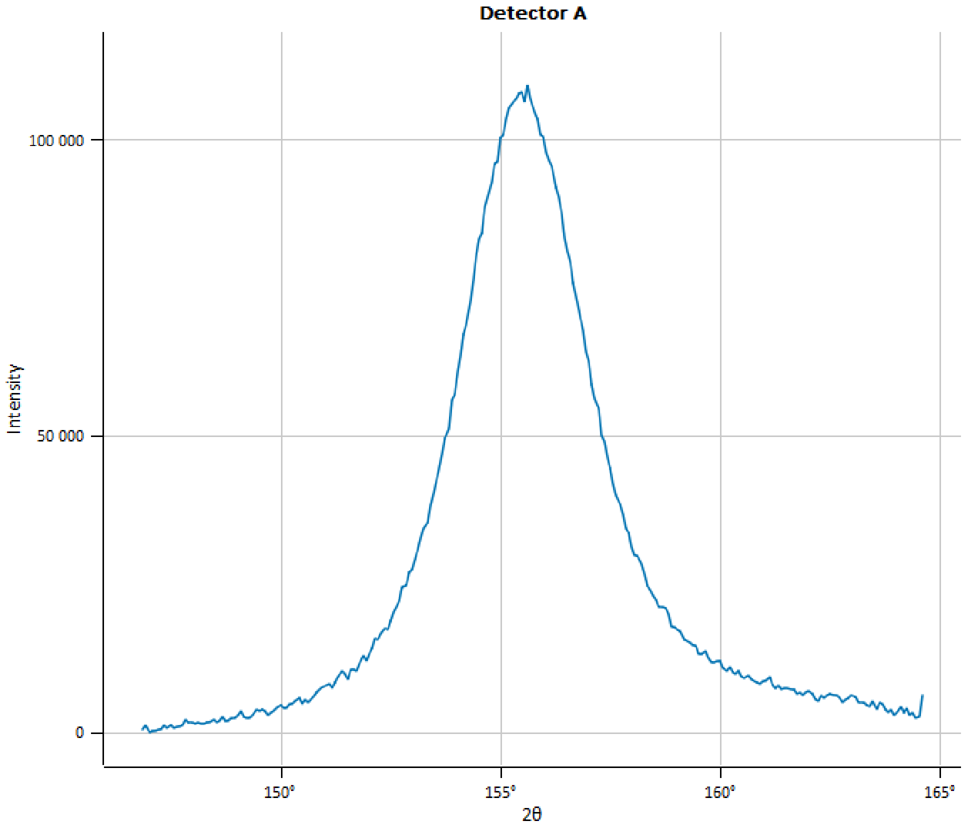
- Additional degree of freedom in γ-direction

From 2D to 1D data

To use the standard $Sin^2\Psi$ method 1D data is needed



Data is integrated along the diffraction ring

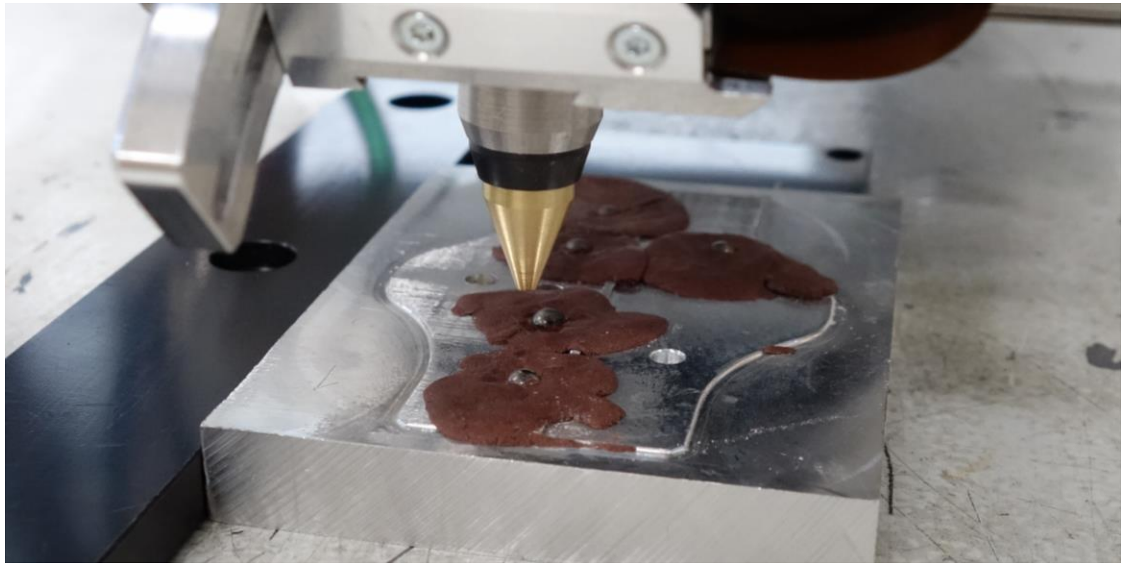


Data collection time shortened at least two orders of magnitude

Application – 1D vs 2D technology

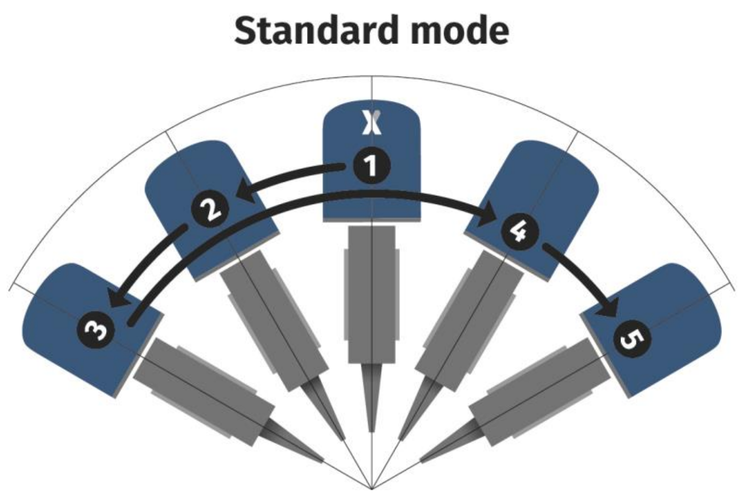
Small spot size

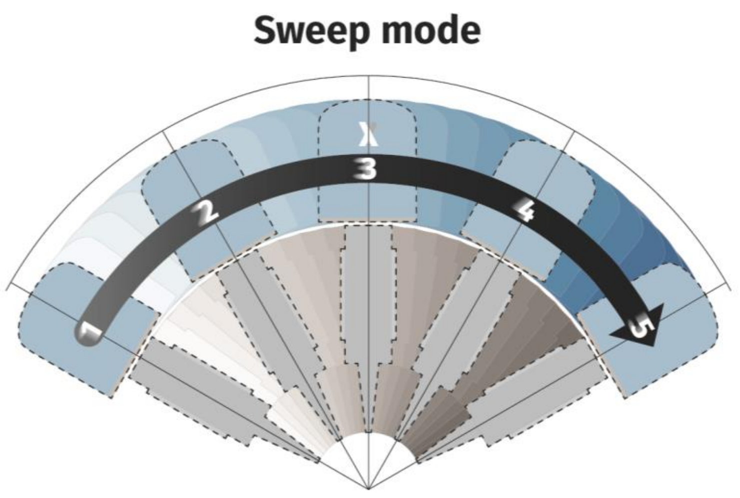
- ✓ Residual stress depth profiles were measured from small bearing balls



Depth profile measurement with 0.3 mm collimator, Cr tube, 5/5 tilts, 3 directions		
System	**Exposure time**	**Total measurement time**
Xstress G2R, 1D (Hamamatsu)	300 s	5 h 46 min
Xstress DR45, 2D (Advacam)	3 s	3 min 1 s

Continuous movement measurement



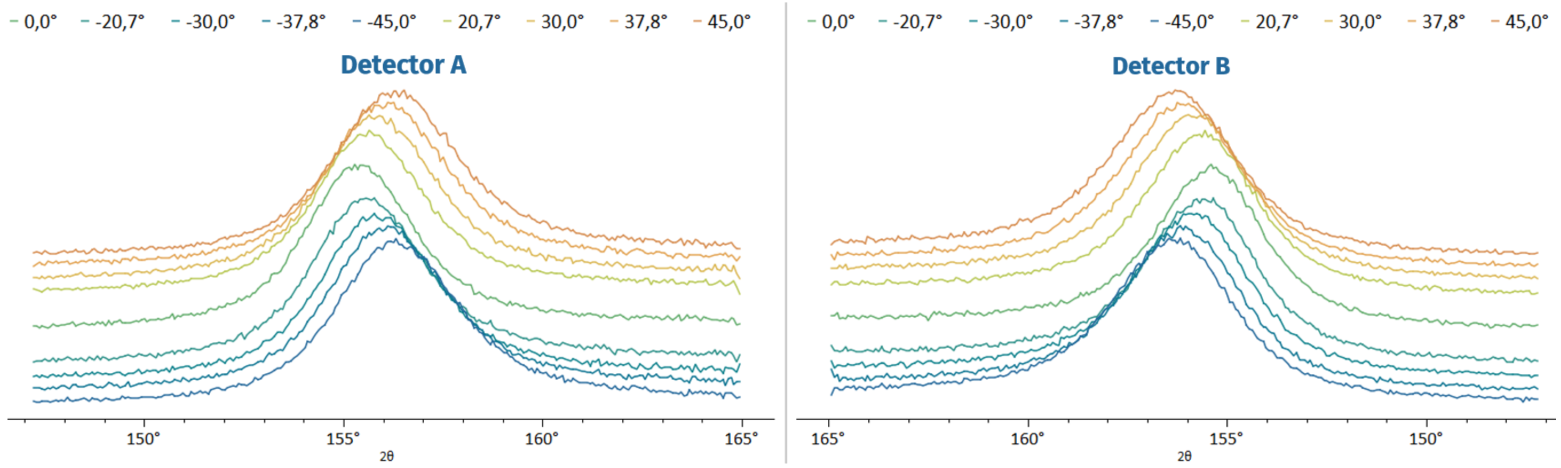


- Discrete tilt steps
- Move-stop-measure-repeat
- Number of tilt angles ≥ 9
- Exposure time per tilt angle ≥ 1 s
- Total measurement time ≥ 30 s

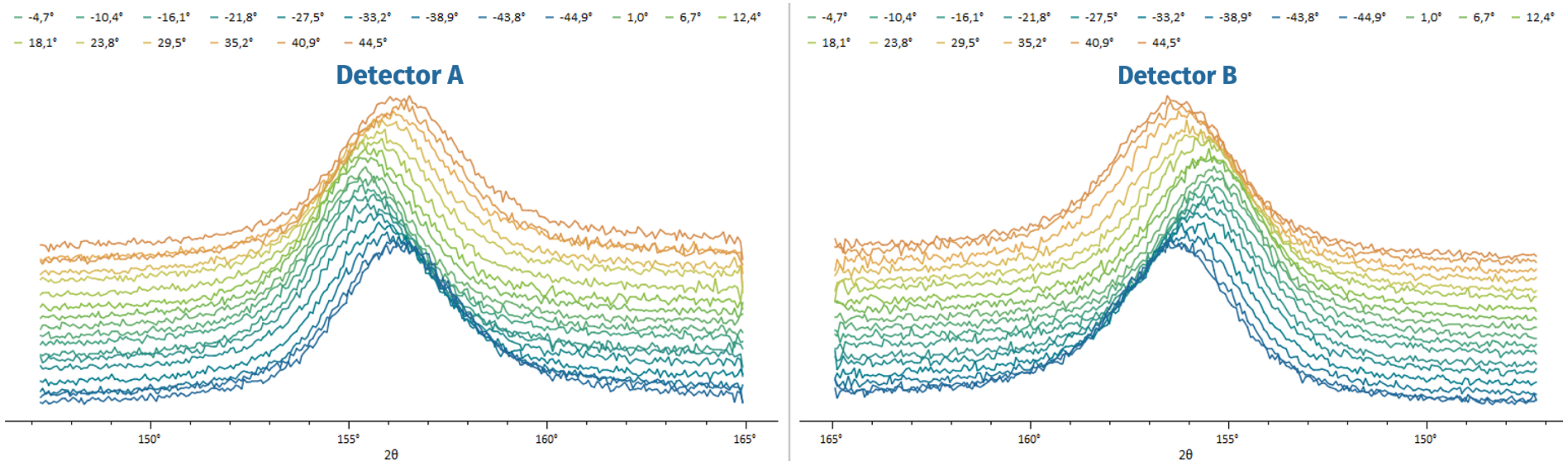
- Continuous tilt movement
- Number of tilt angles ≥ 18
- Total measurement time ≥ 5 s
- ”unnecessary” movements omitted

Continuous movement measurement

Standard method



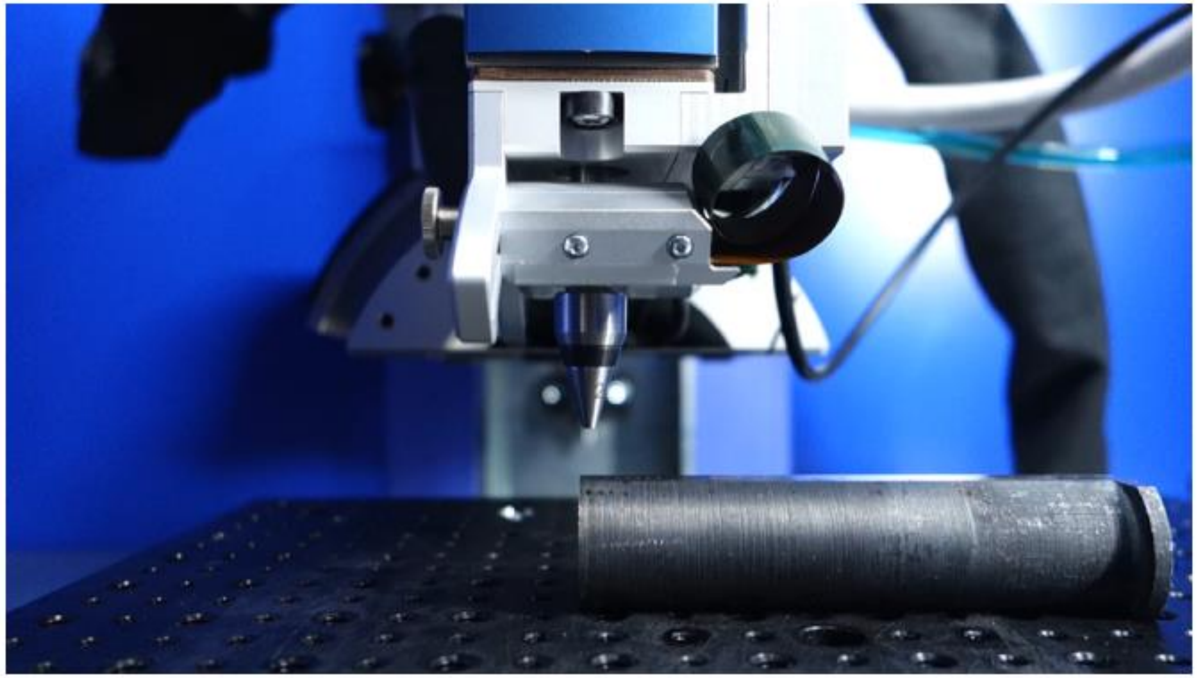
Sweep method

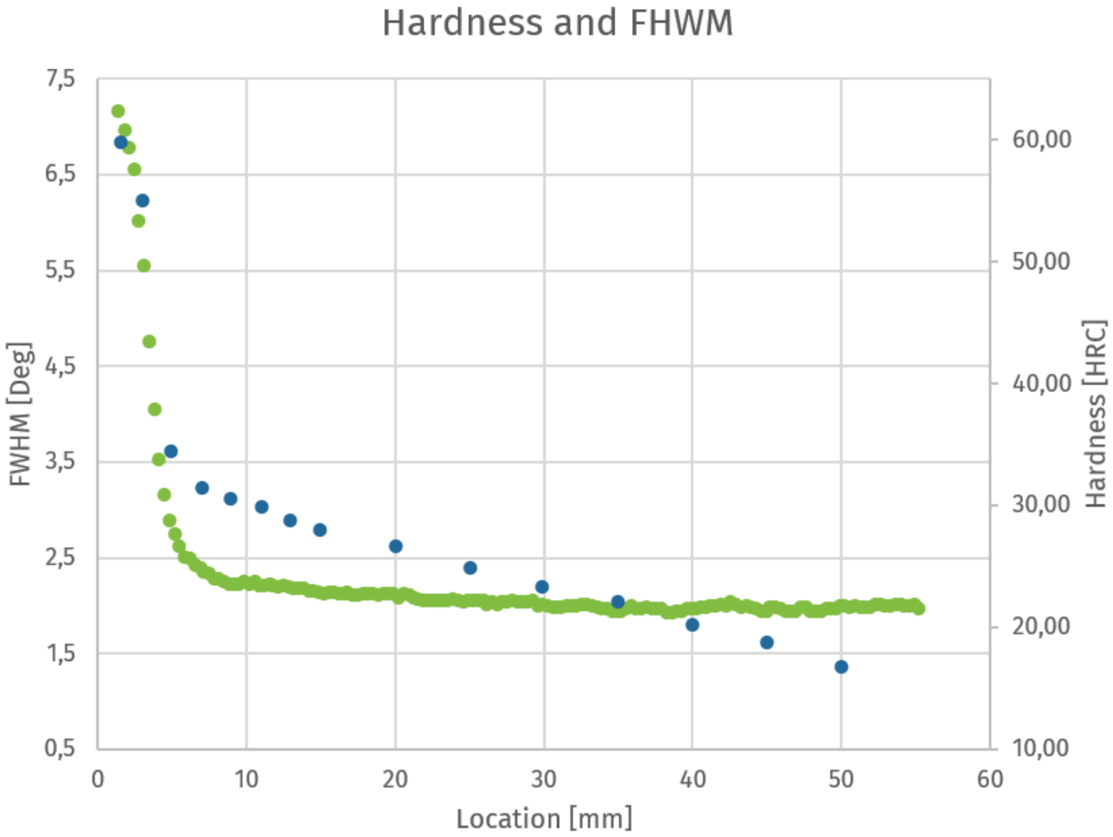


Measurement time can be shortened by a factor of 7 in the best case.

Continuous FWHM mapping with 2D detectors

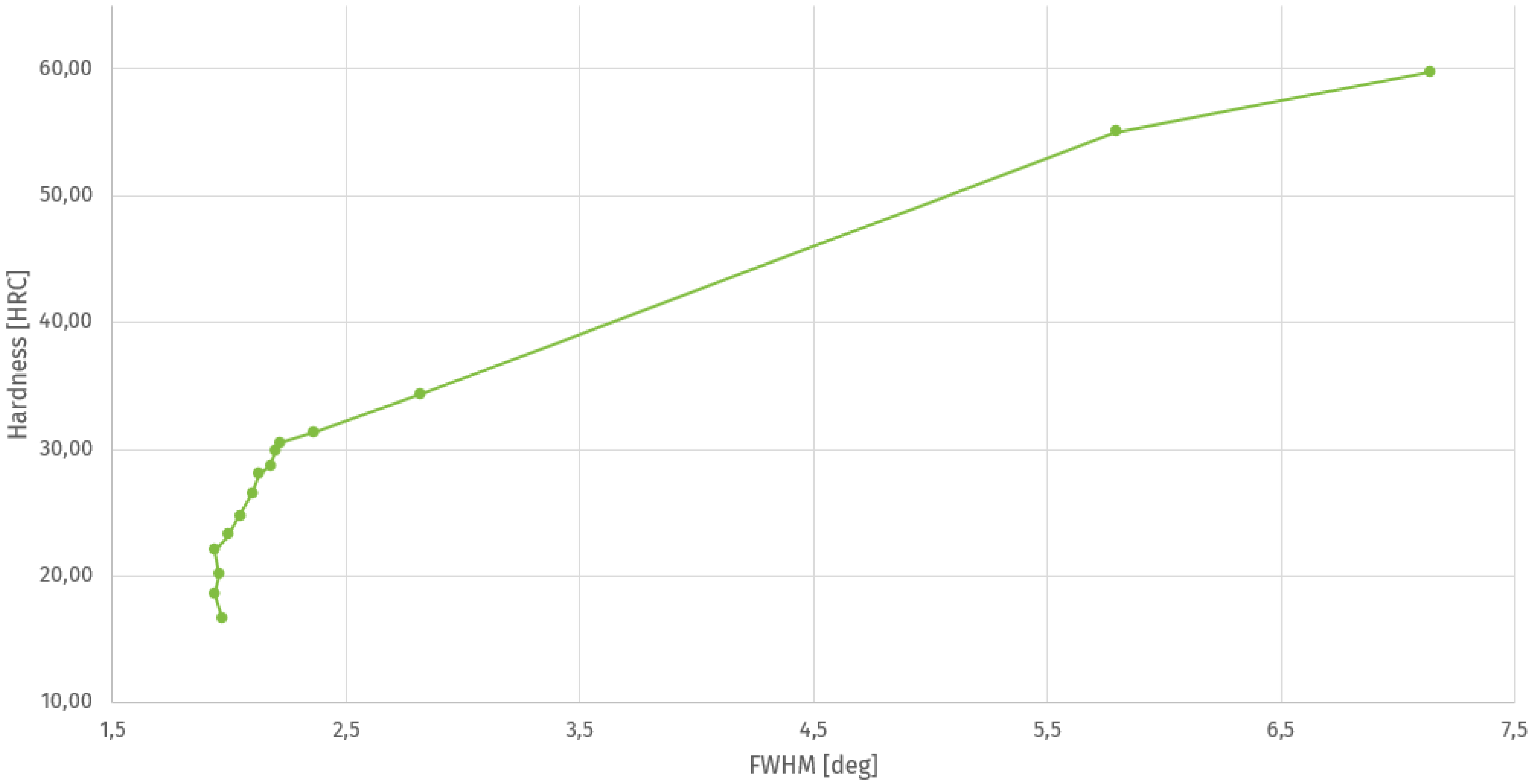
- The width of the diffraction peak correlates to the hardness of the material
- No movement of the diffractometer is needed
- Sample moves, while diffractometer collects data





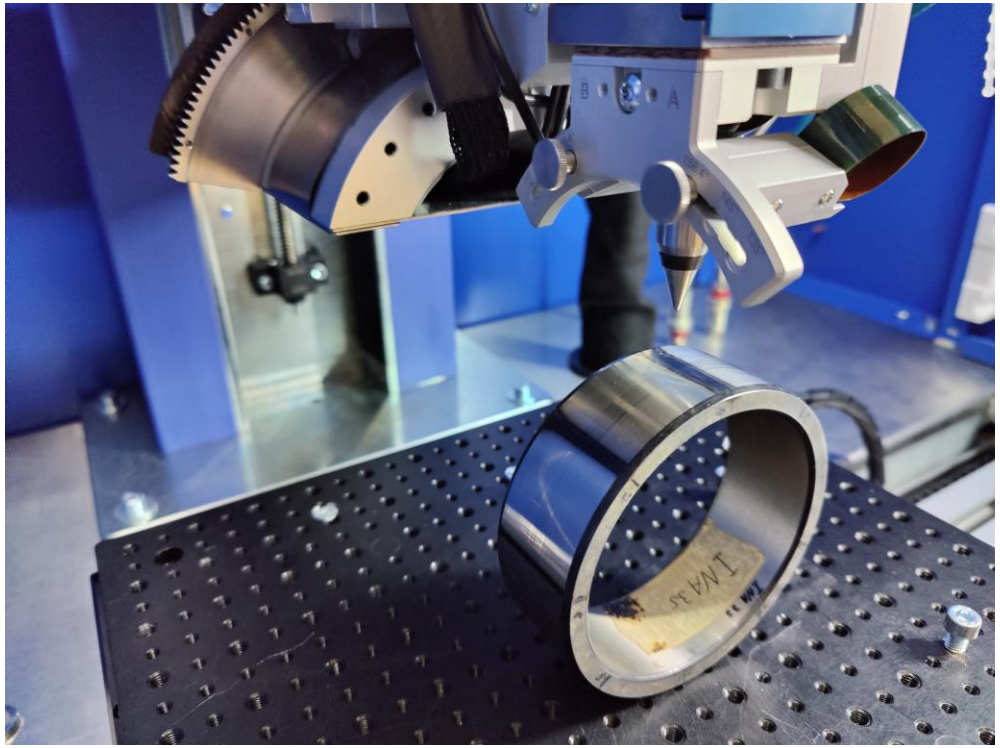
- 2mm collimator, 100ms frame length, 2mm/speed.
- For typical "sorting" applications faster speeds can be used.

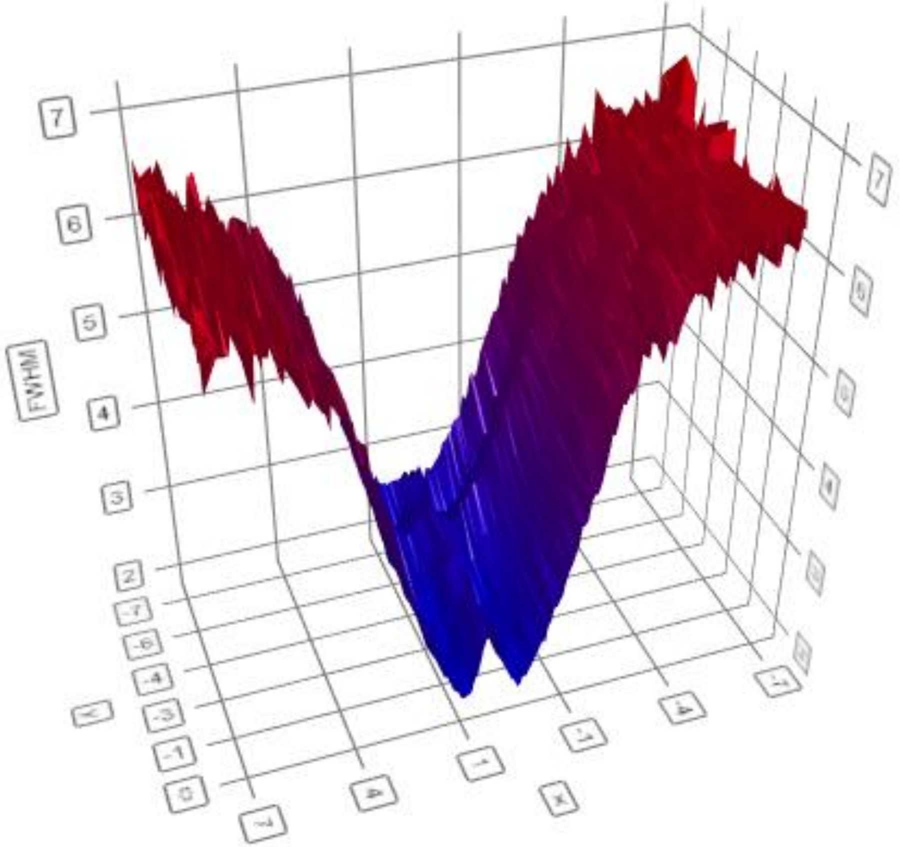
Correlation between FWHM and HRC



- Linear behavior above 30 HRC
- Loss of sensitivity at soft region

Continuous FWHM mapping



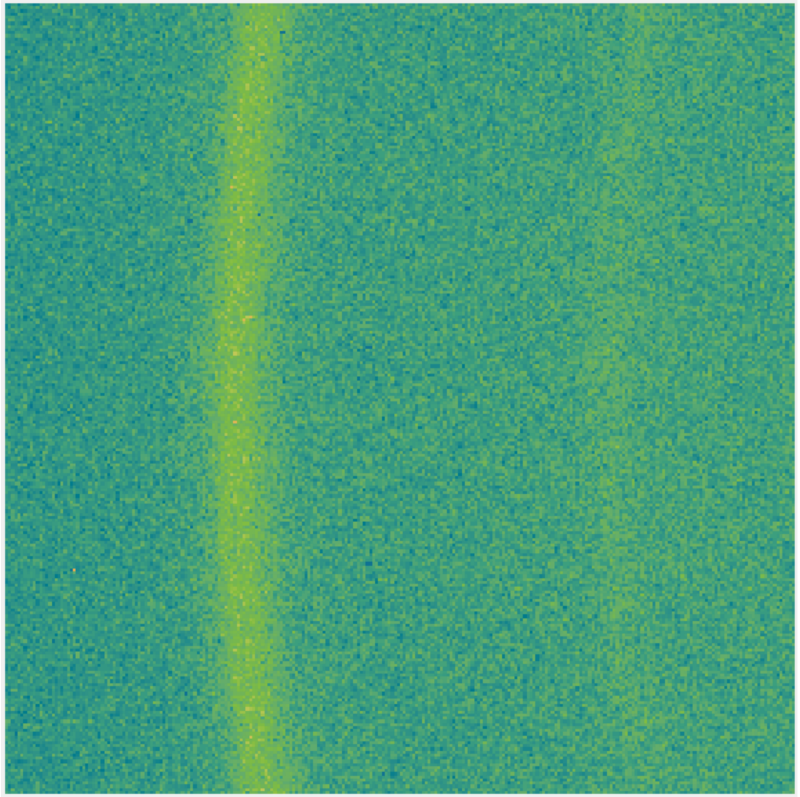


- Artificially burned bearing for BN sensor verification
- 7mm x 7mm scanning area
- Measurement time < 5 minutes
- 1600 datapoints: detailed information about the hardness distribution

Grain size information from the Debye-Scherrer ring

- The details of the Debye-Scherrer ring tell about the grain size or texture of the material
- “From how many grains are the photons diffracted from”?

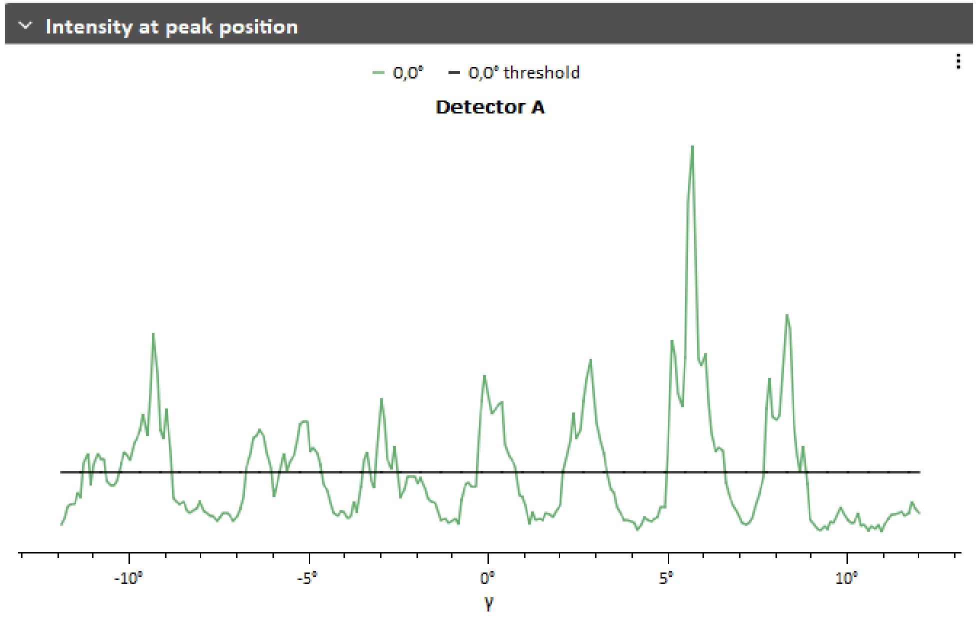
Coarse grained material



Fine grained material

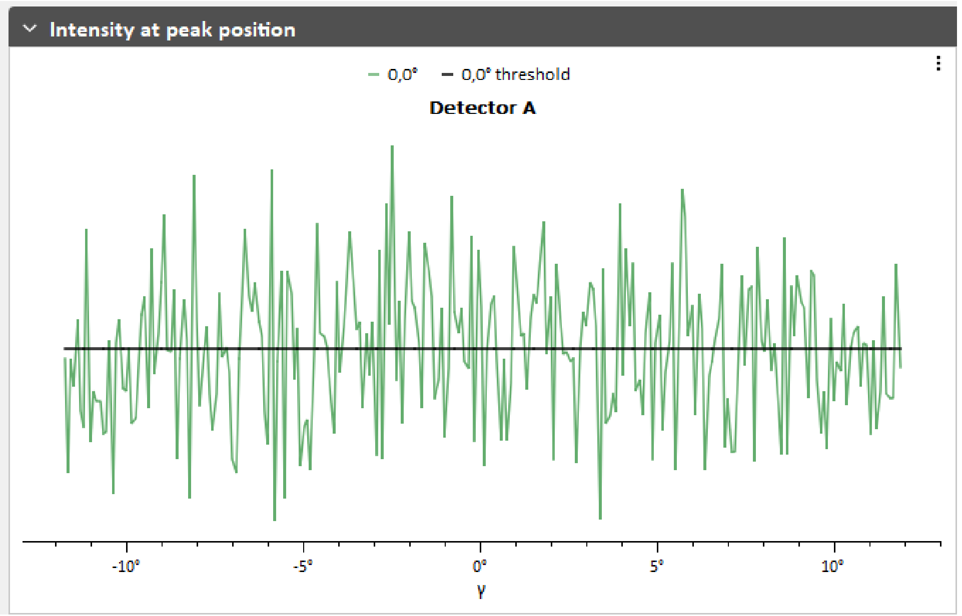
Grain size information from the Debye-Scherrer ring

- The number of “peaks” correlates to the grain size
- More peaks -> smaller grain size
- Needs calibration, but can be used to sort or identify different grain sized materials



Coarse grain

#peaks ≈ 10



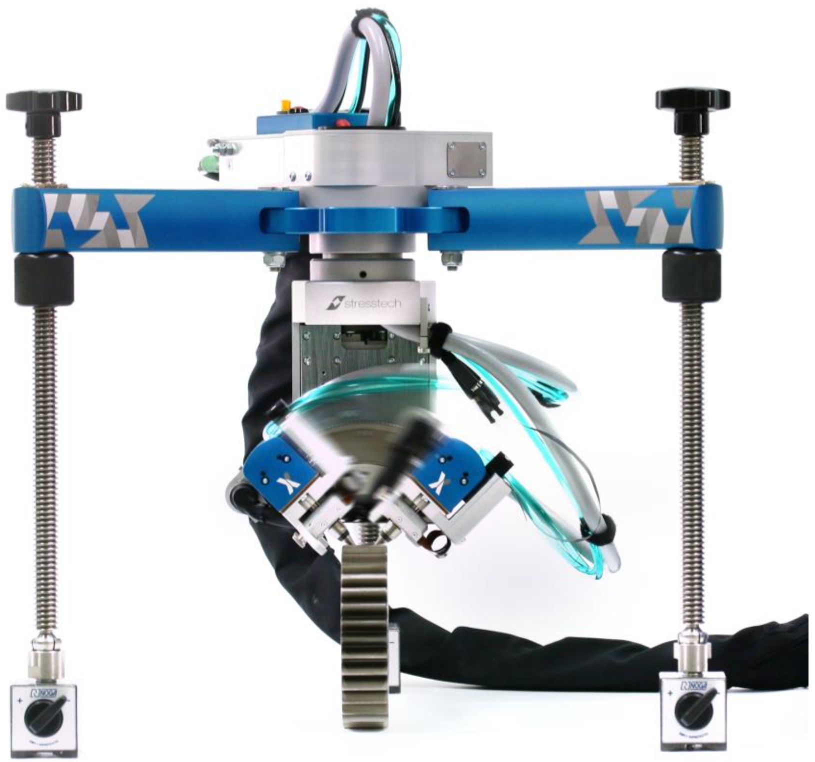
Fine grain

#peaks ≈ 100

Conclusions

Xstress DR45

- ✓ Short measurement cycle time required
- ✓ Sample material is not optimal for X-ray diffraction
- ✓ Measuring with small spot sizes (< 1 mm collimator)
- ✓ Mapping of large areas
- ✓ Additional information about the sample microstructure



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