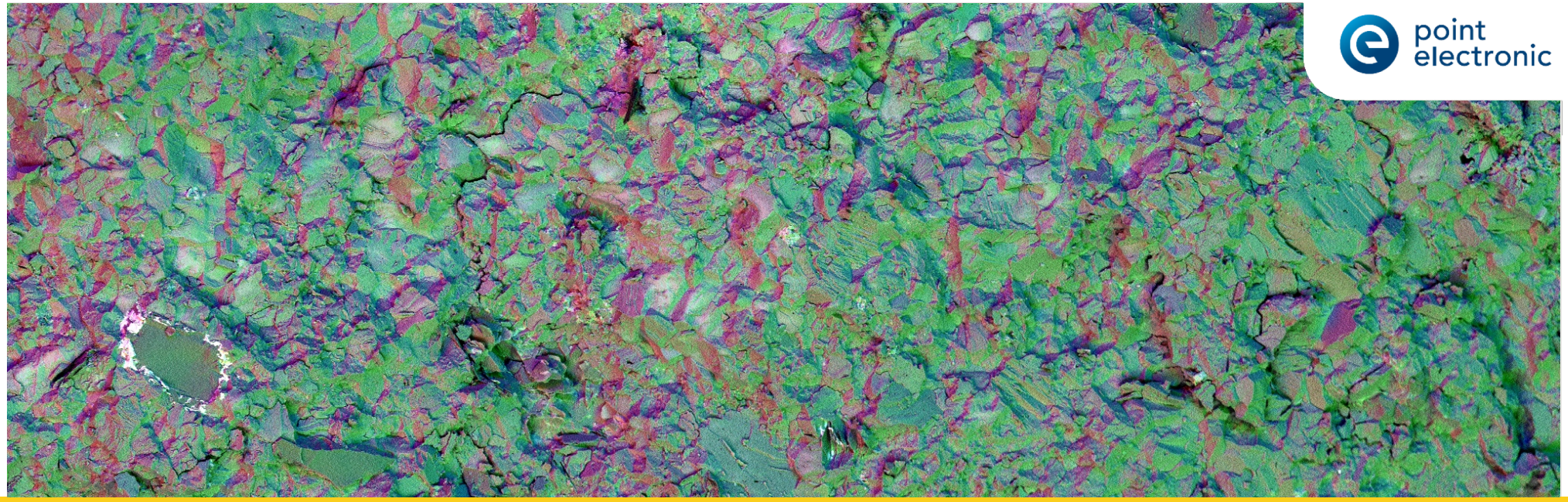

point electronic

Live quantitative BSE acquisition with standard-less calibration

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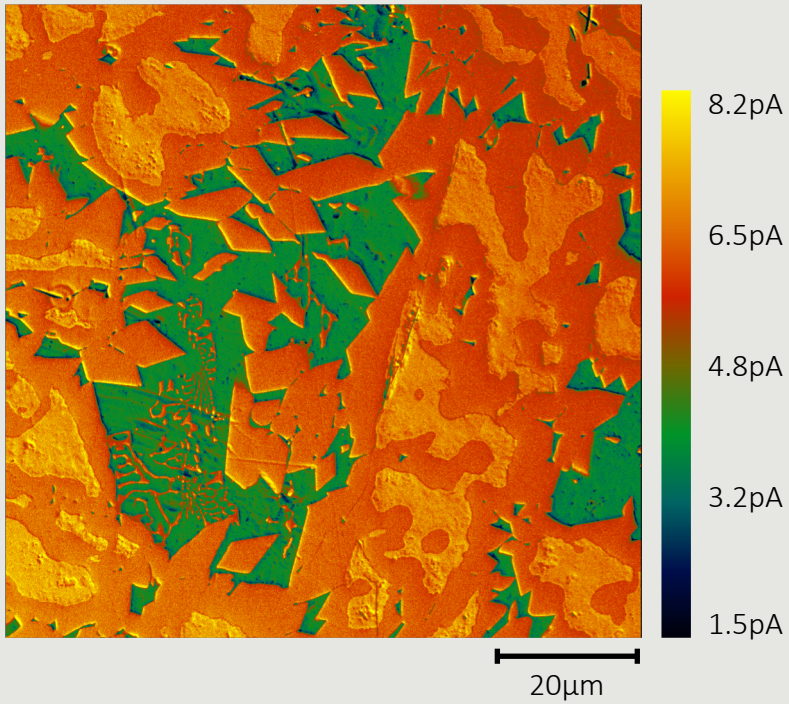
M&M 2018, Baltimore

Motivation

Enable automatic quantitative BSE (qBSE) acquisition



- Pixels have physical values, independent of acquisition settings
- Data can be compared between samples, microscopes, processing, etc.
- Material properties can then be extracted, e.g. density, topography

Workflows

Software and hardware must be designed for, and calibrated for qBSE

Beam current → Sample geometry → Sensor gain → Amplifier settings → Image acquisition → Image data

- **Offline workflow**
  - SEM, BSE and sample configuration is fixed
  - Calibration samples provide ADC to density conversion
  - Density of target material is interpolated
- **Online workflow**
  - Every component (analogue or digital) is factory calibrated
  - Calculations and algorithms are applied live on the microscope
  - Quantitative data is easily extracted/exported

Data format

Data must include additional intensity calibration parameters

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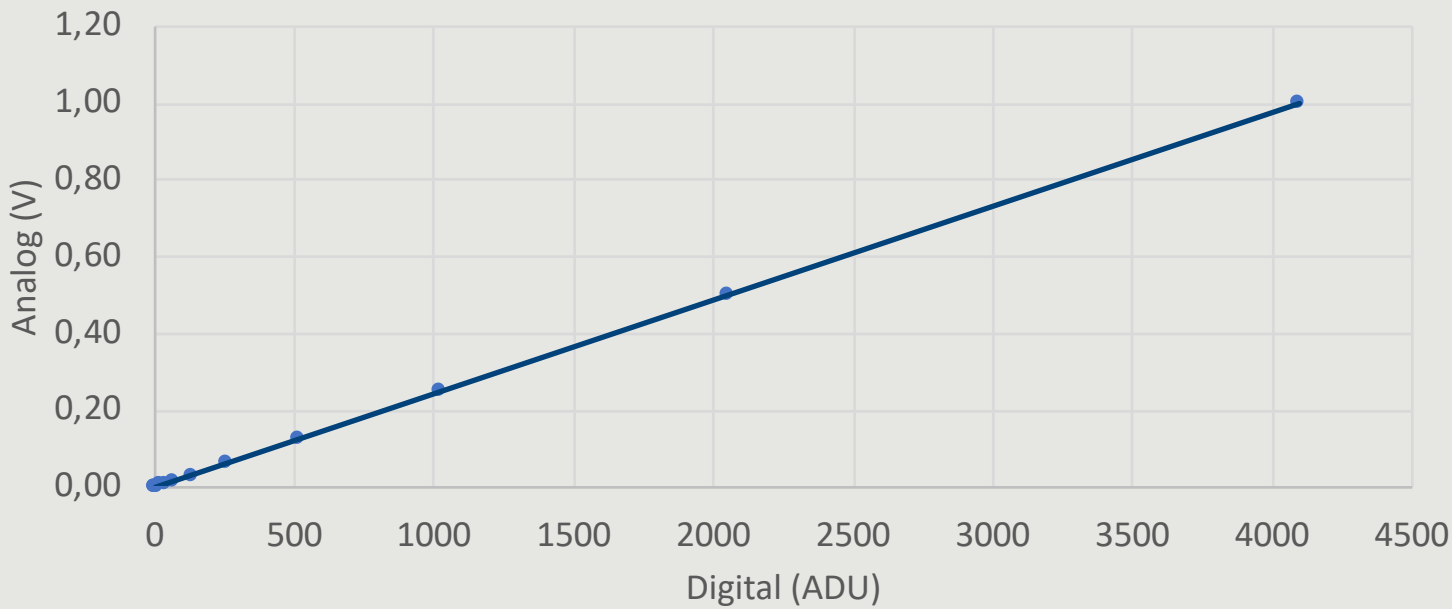
```

- Raw image data is standard 16-bit multi-page TIFF
- Full calibration information is standard XMP metadata (in TIFF file)
- Scan and intensity calibration is assembled by the viewing software

Analogue to digital conversion

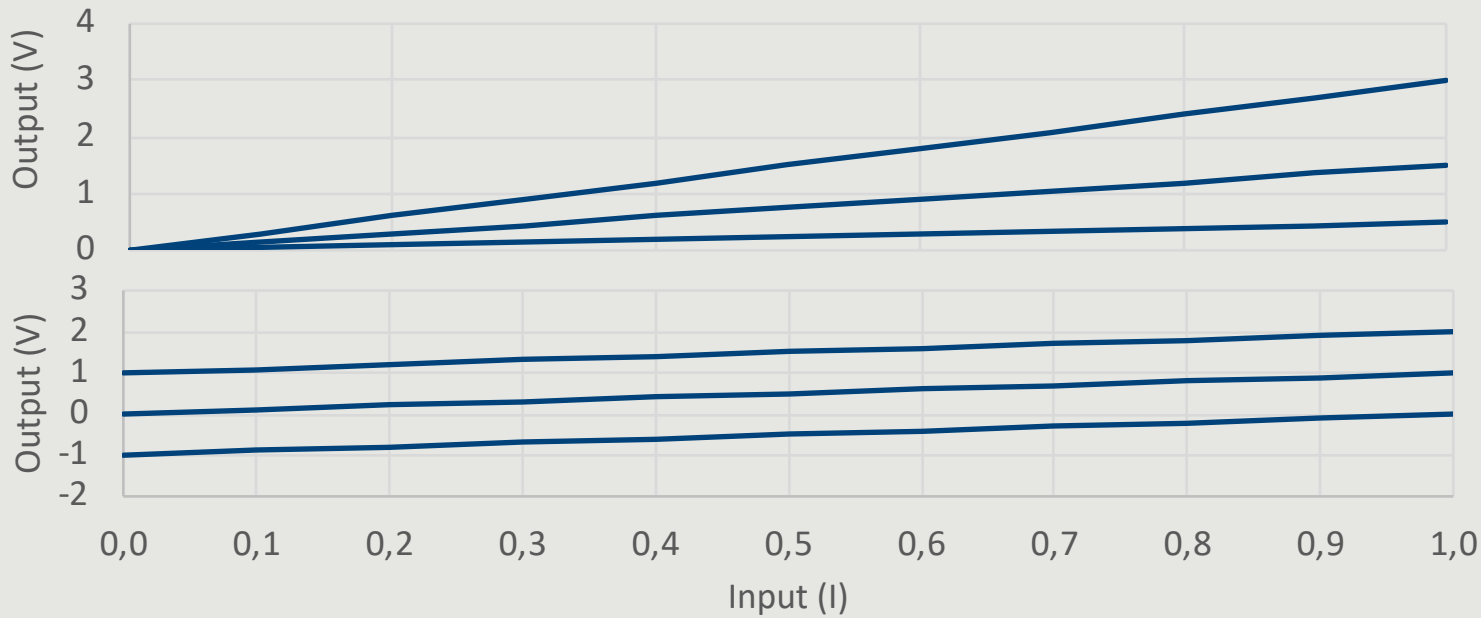
Calibrates digital units (12-bit) to input signal (V)



- Calibration information is stored in firmware – factory calibration
- All signal channels are treated the same – 4Q BSE systems
- Data from different acquisition systems can be compared directly

Amplification

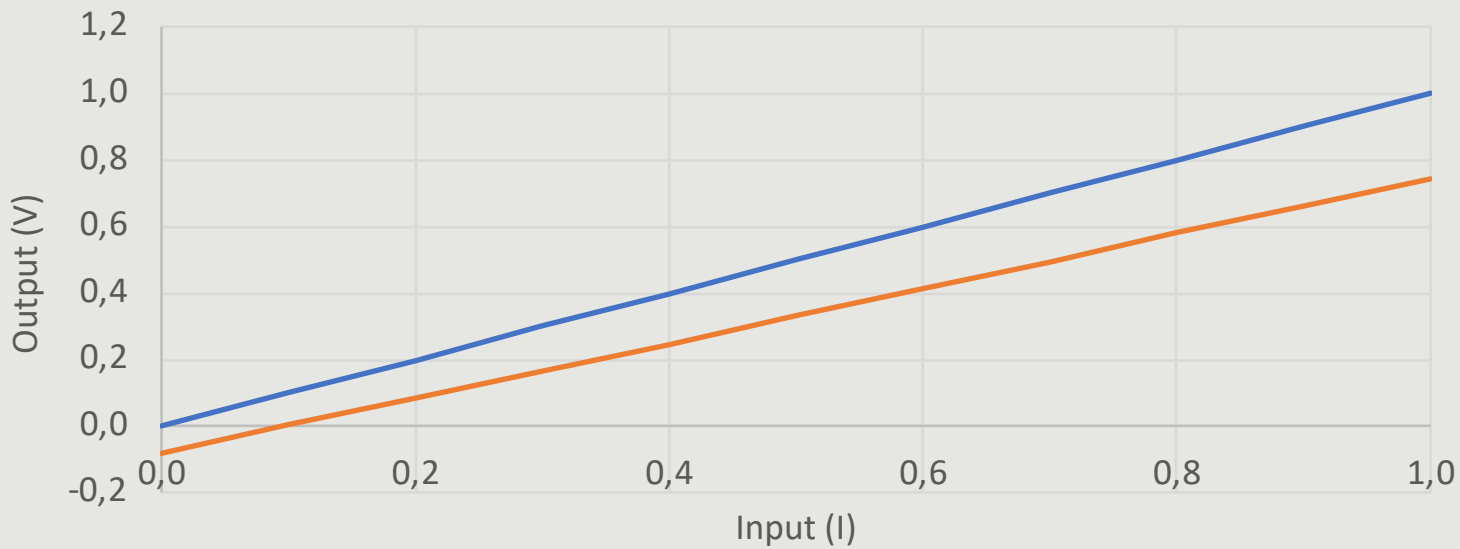
Calibrates the user-controlled brightness and contrast



- Calibration information is stored in the firmware – factory calibration
- Each signal channel is treated independently
- Current measurement is independent from brightness and contrast

Signal corrections

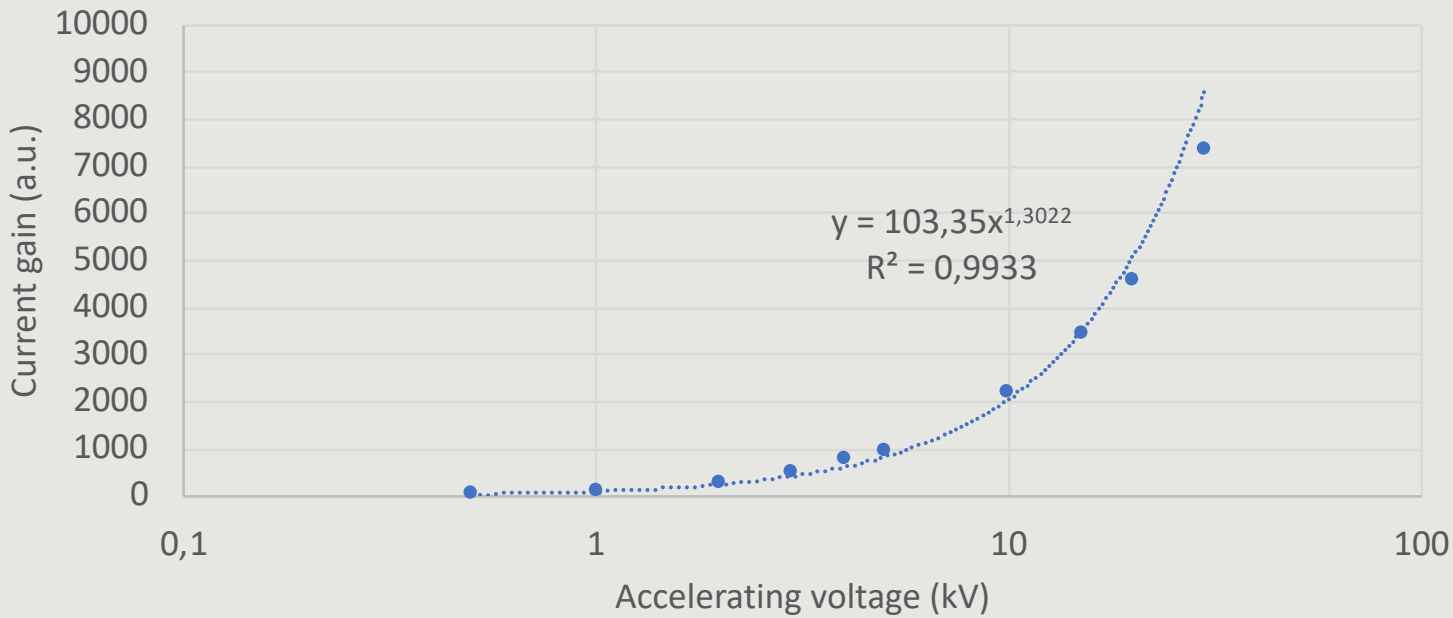
Corrects for offset and gain variations between BSE segments



- Offsets relate to leakage currents, and are corrected with an output offset
- Gain variations between segments are corrected with a normalisation gain
- Dark and bright corrections are well defined – automatic routines

Sensor gain

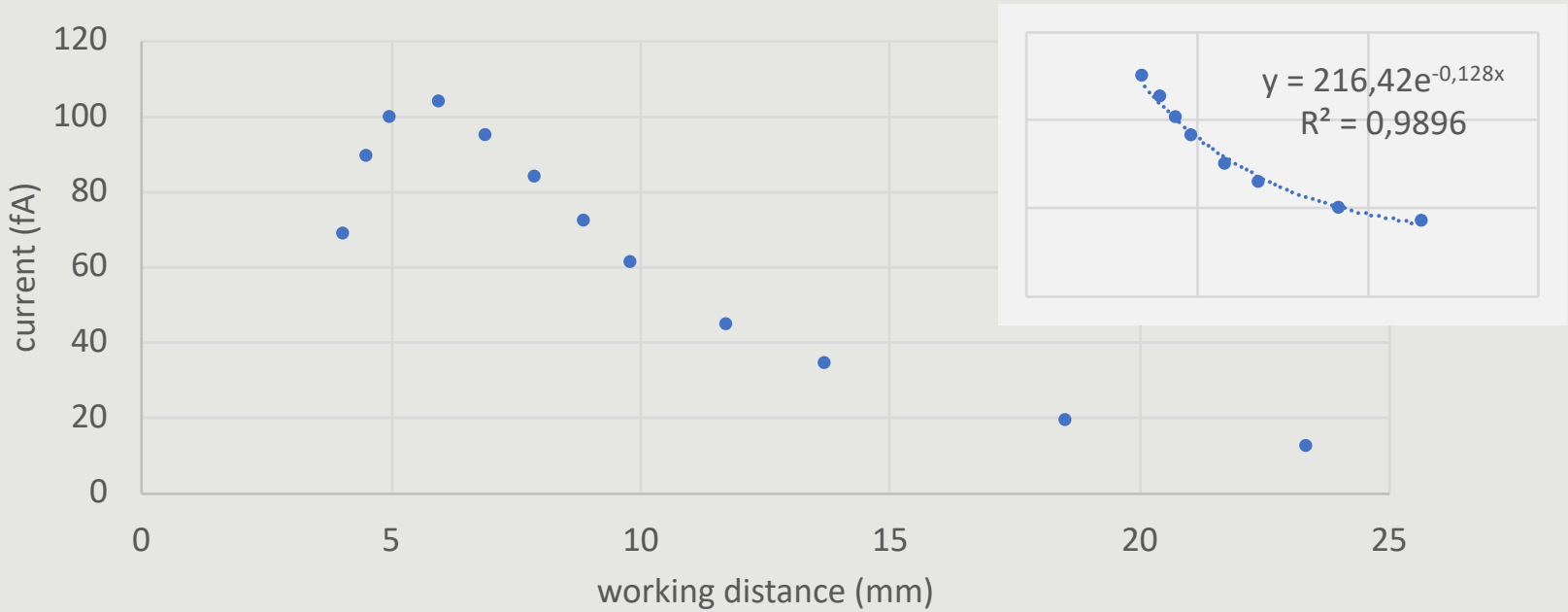
Calibrates the current gain as a function of acceleration voltage



- Current is amplified due to generation of electron-hole pairs
- Amplification is stronger for higher energy electrons
- Allows for comparison of images at different acceleration voltages

Working distance

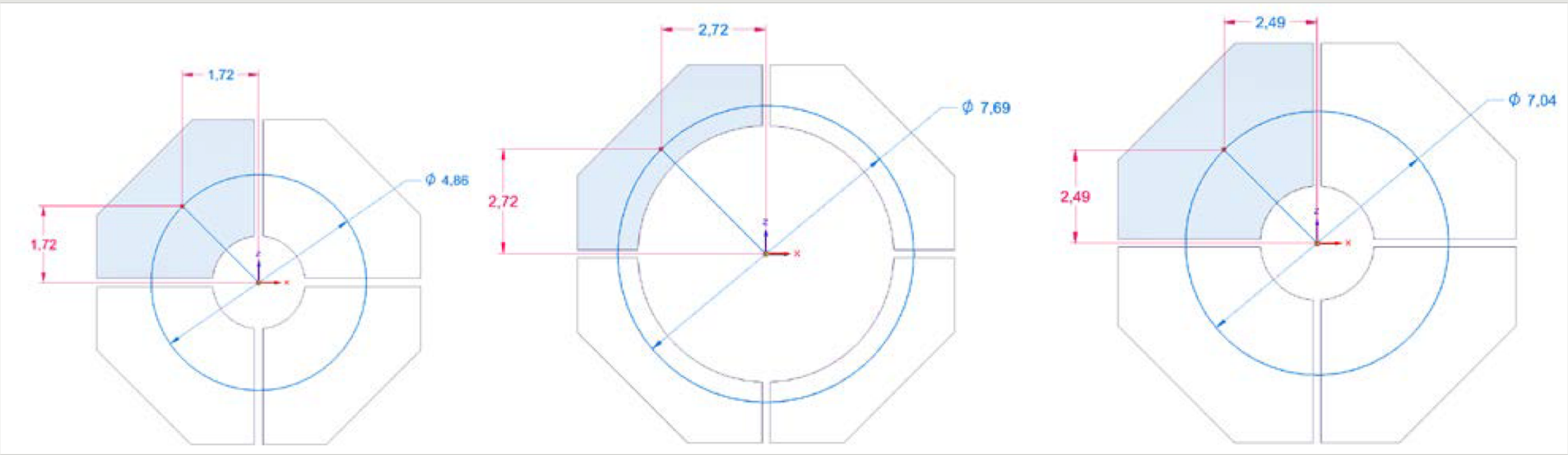
Calibrates the collection efficiency as a function of working distance



- Electrons are lost outside the detector, when working distance is long
- Electrons are lost in the inner hole, when working distance is small
- Loss of electrons is measured and can be accounted for.

Surface orientation

Multiple BSE signals provide surface orientation information

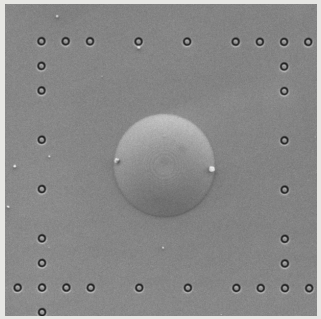


- Position and orientation of segments is known – geometry is well controlled
- Signals are acquired at the same time – differences in signal give additional information
- Signals are quantified – comparison and algorithms are possible

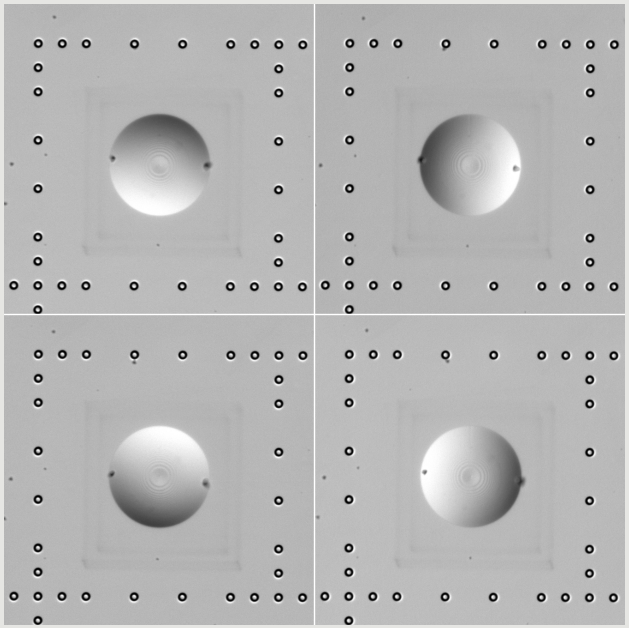
Test object

High resolution structure manufactured with FIB

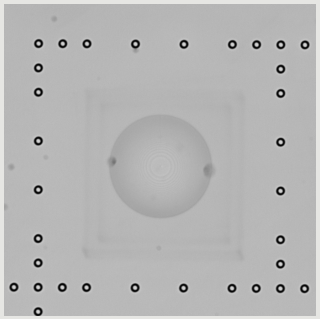
SE



4-quadrants BSE



BSE average

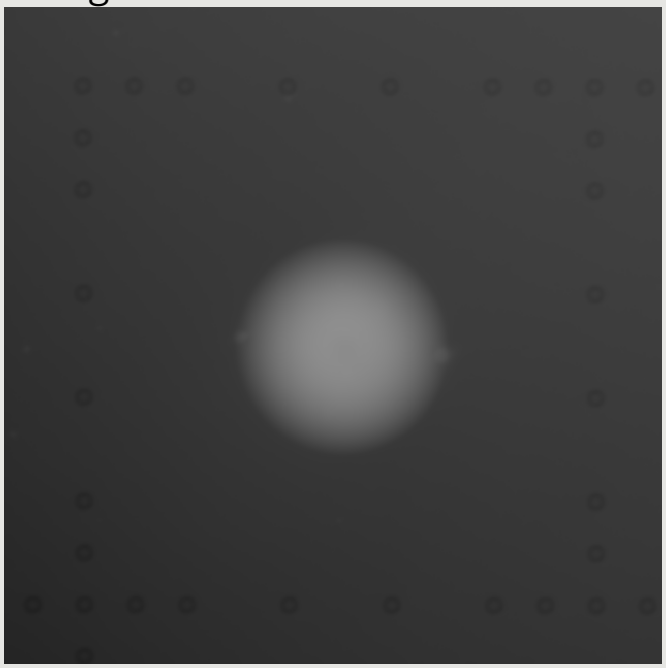


- Deposited dome-shaped structure for testing calculation of height
- Milled donut-shaped structures for automatic identification

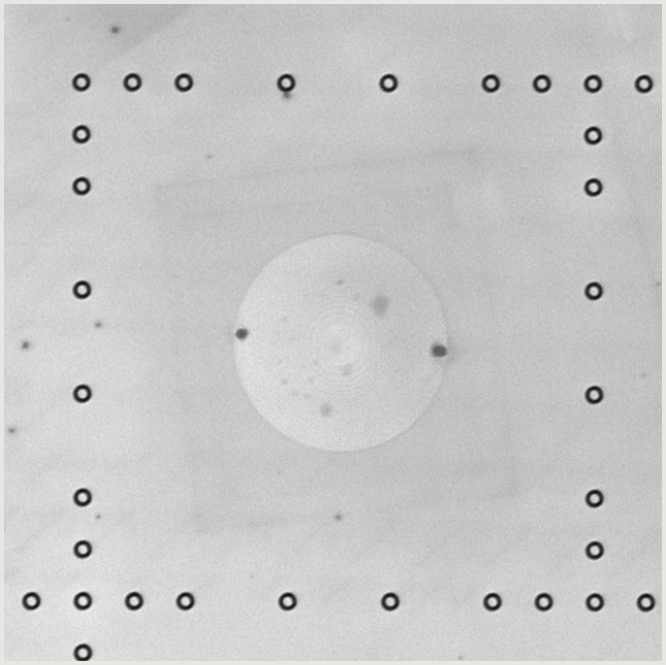
Height and composition

Shape-from-shadow reconstruction algorithm

Height



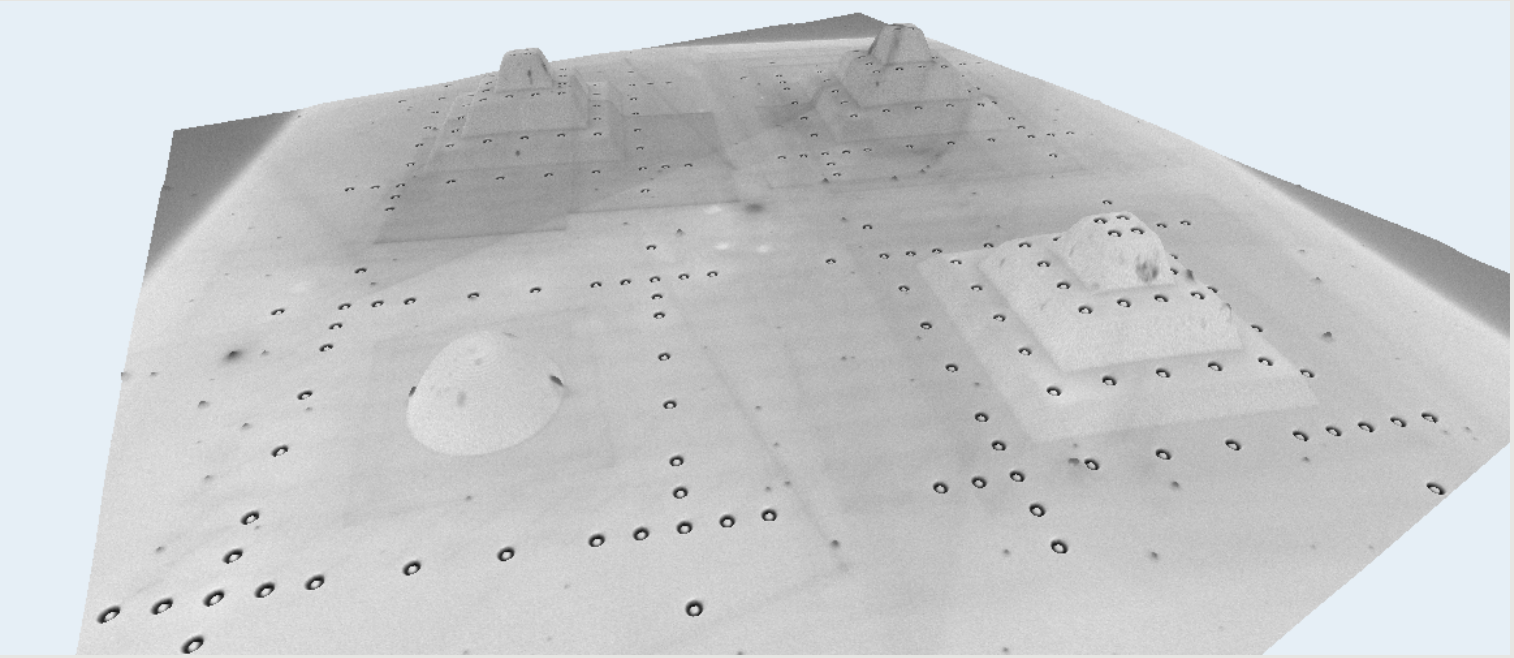
Composition



- Height is calculated in nm units – resolution depends on kV
- Composition is calculated in current units – total backscattered electrons

3D view of height and composition

Composition is rendered as texture on the 3D model of the surface



Acknowledgements

- point electronic GmbH

  Marcus Joachimi: electronics design

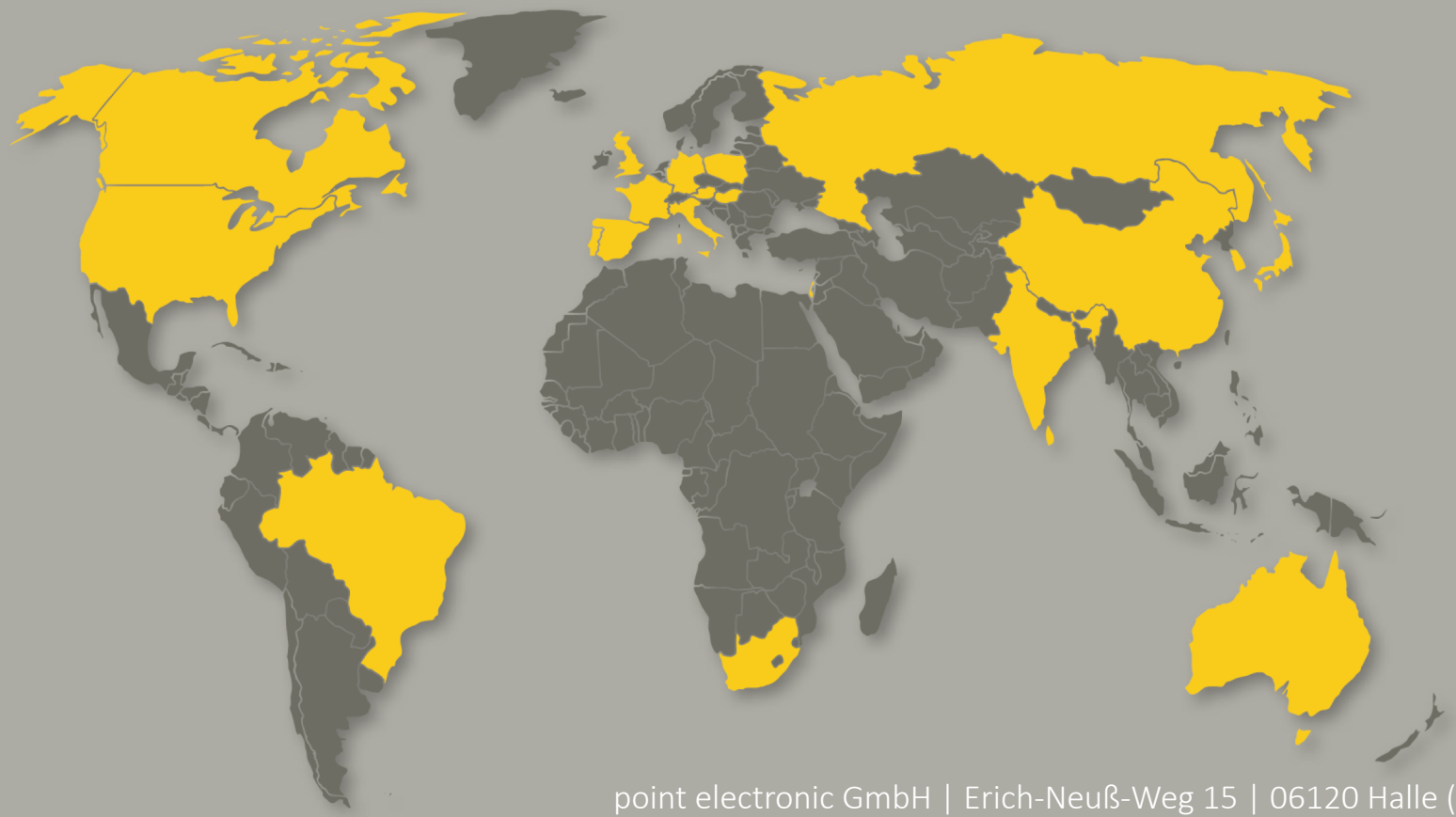
  Michael Zabel: software development

  Matthias Hemmleb: algorithm development – SEM topography

- PNDetector GmbH

  Maximilian Schmid: detector and mechanics design

  Andreas Liebel: detector design



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