Variable Inner Detector Angle STEM

Visualising diffraction contrast in semiconductor nanowires

J. M. Persson*, R. S. Pennington, J. B. Wagner, C. B. Boothroyd, R. E. Dunin-Borkowski

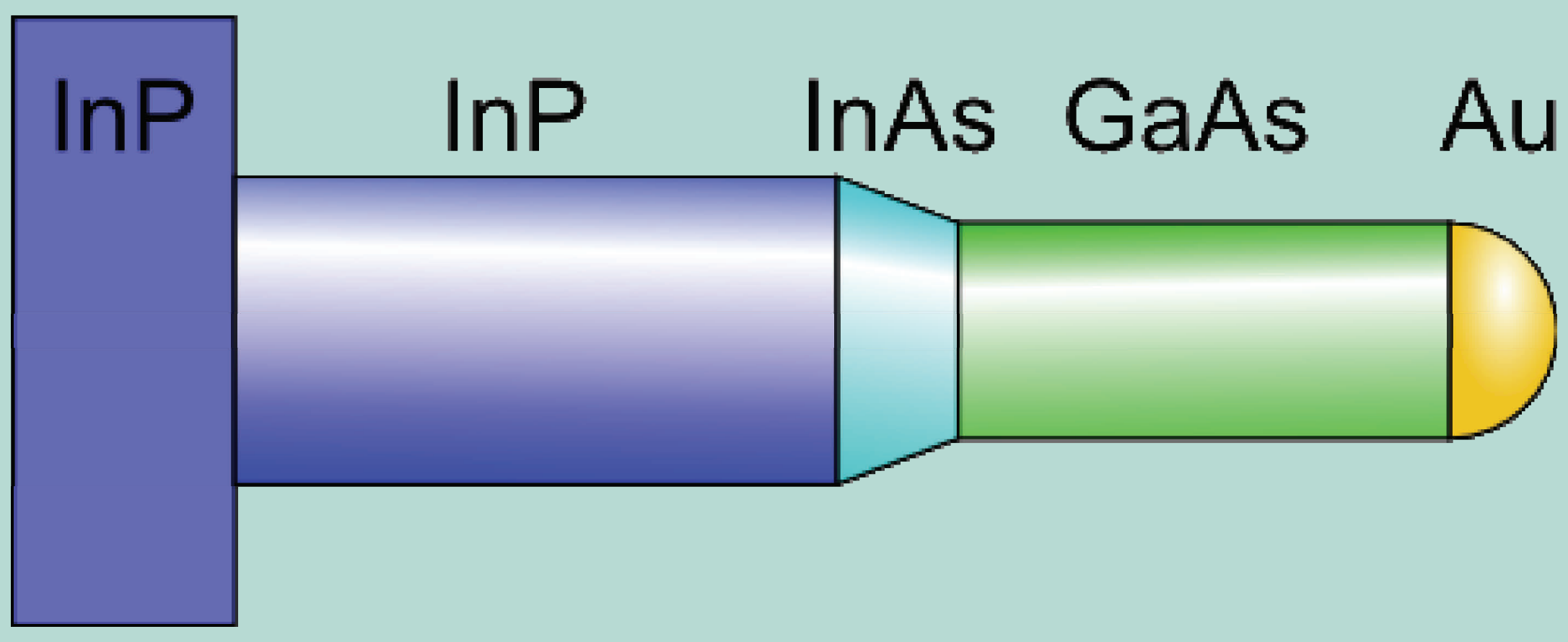
Center for Electron Nanoscopy, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark

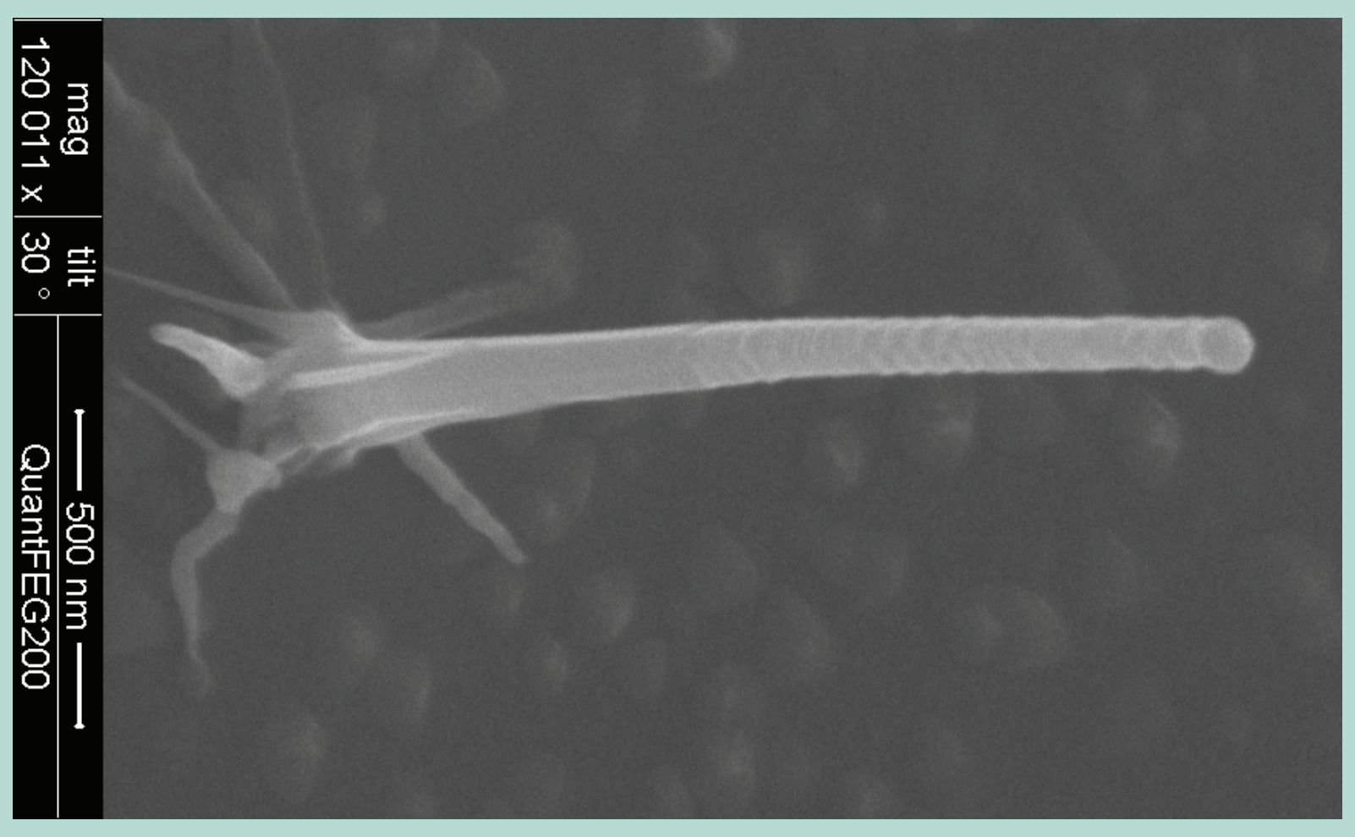
* johan.persson@cen.dtu.dk

Introduction

Semiconductor nanowires have attracted considerable attention for use in applications such as solar cells, light emitting diodes and new transistor designs [1]. a knowledge of defect structures in these wires is critical [2]. Here we propose using thin annular detectors in a scanning transmission electron microscope (STEM) to map the positions of defects such as dislocations in semiconductor nanowires. We test this method on a heterostructure nanowire that shows both changes in mass-thickness contrast and in diffraction contrast from crystallographic defects.

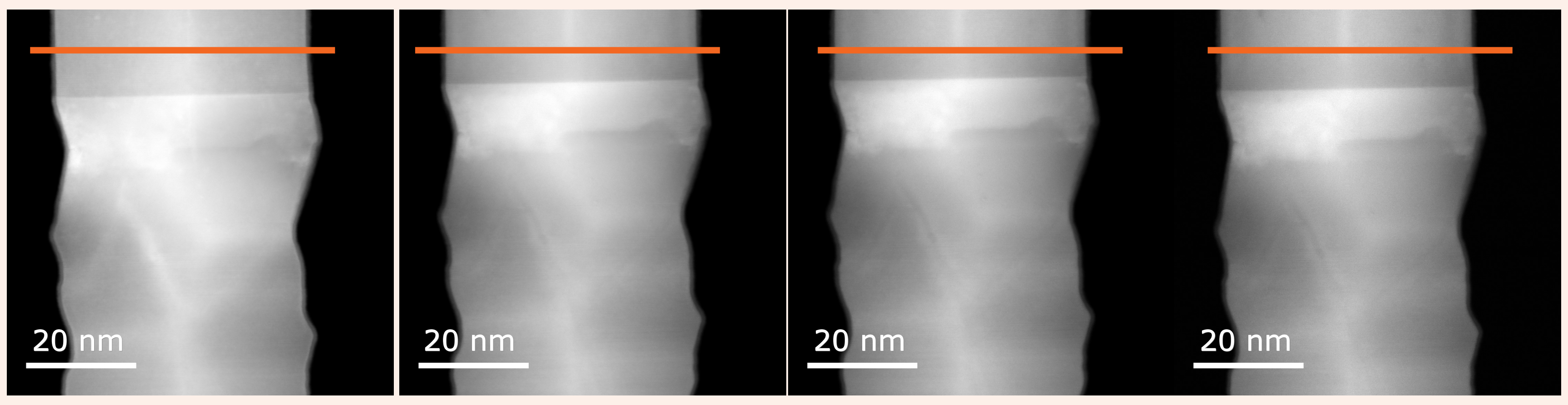
Heterostructure Nanowires





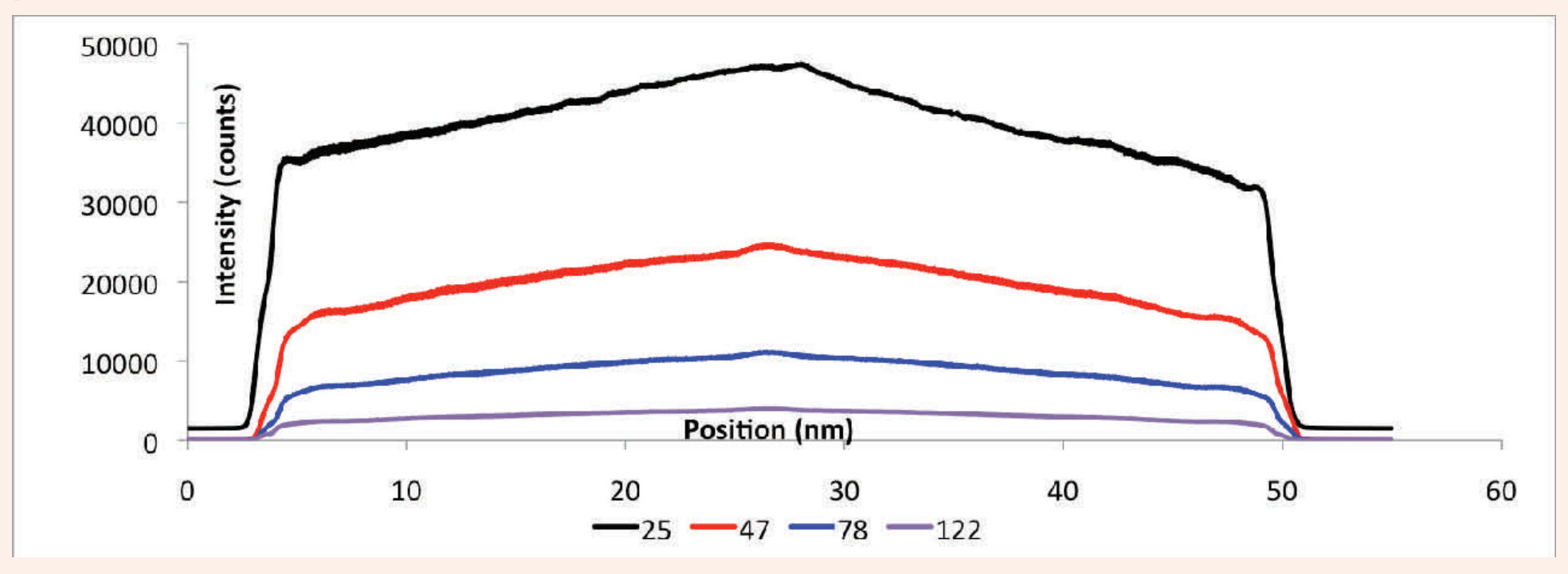
InP-InAs-GaAs axial nanowire heterostructures were grown using metal organic chemical vapour deposition (MOCVD) [3] and prepared for TEM by mechanical exfoliation onto a lacey carbon TEM grid. The transition region between InP and GaAs was found to contain InAs (see [3]).

Inner Detector Angle (IDA) Dependence

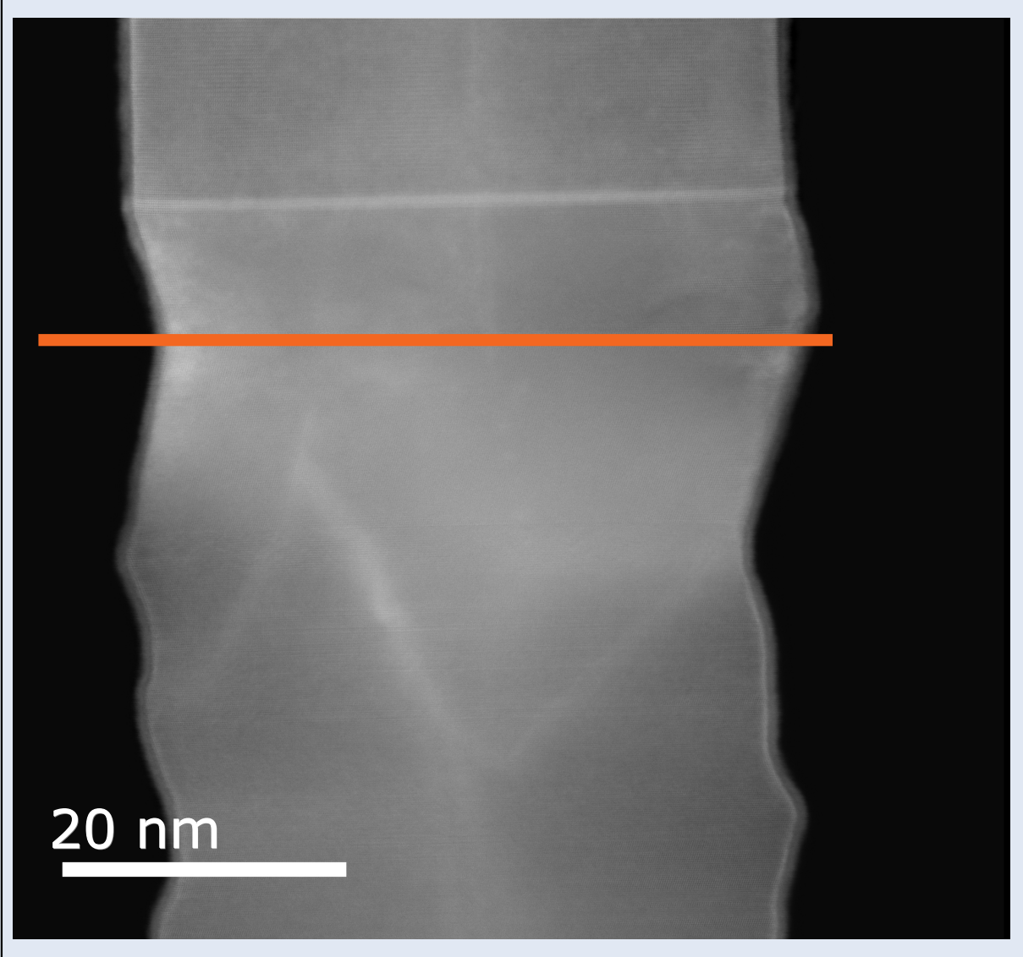


25 mrad IDA *47 mrad IDA* *78 mrad IDA* *122 mrad IDA*

The figures show annular dark-field (ADF) STEM images of the InP-InAs-GaAs heterostructure transition region. In these images, diffraction effects compete with mass-thickness contrast. To a first approximation, the recorded intensity is expected to increase approximately linearly with thickness and to vary with atomic number as Z1.7-2 [4]. However, in practice it can depend strongly on inner detector angle, and diffraction effects can be significant at low and intermediate collection angles.



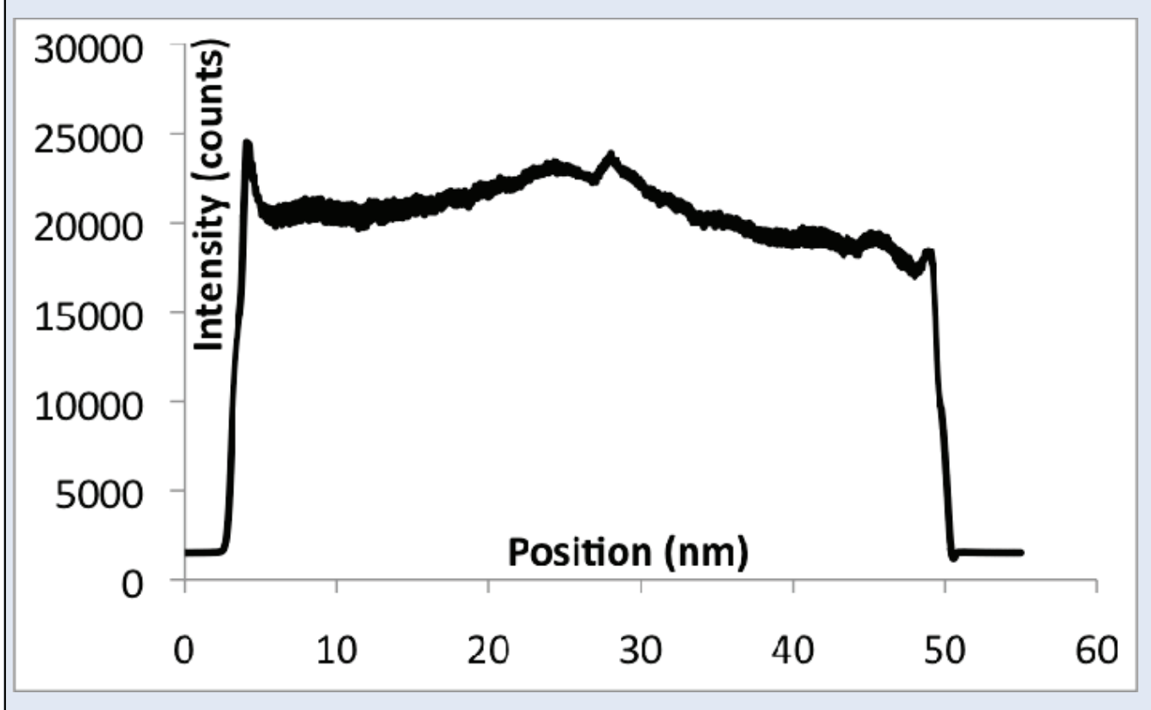
Thin Annular Detector

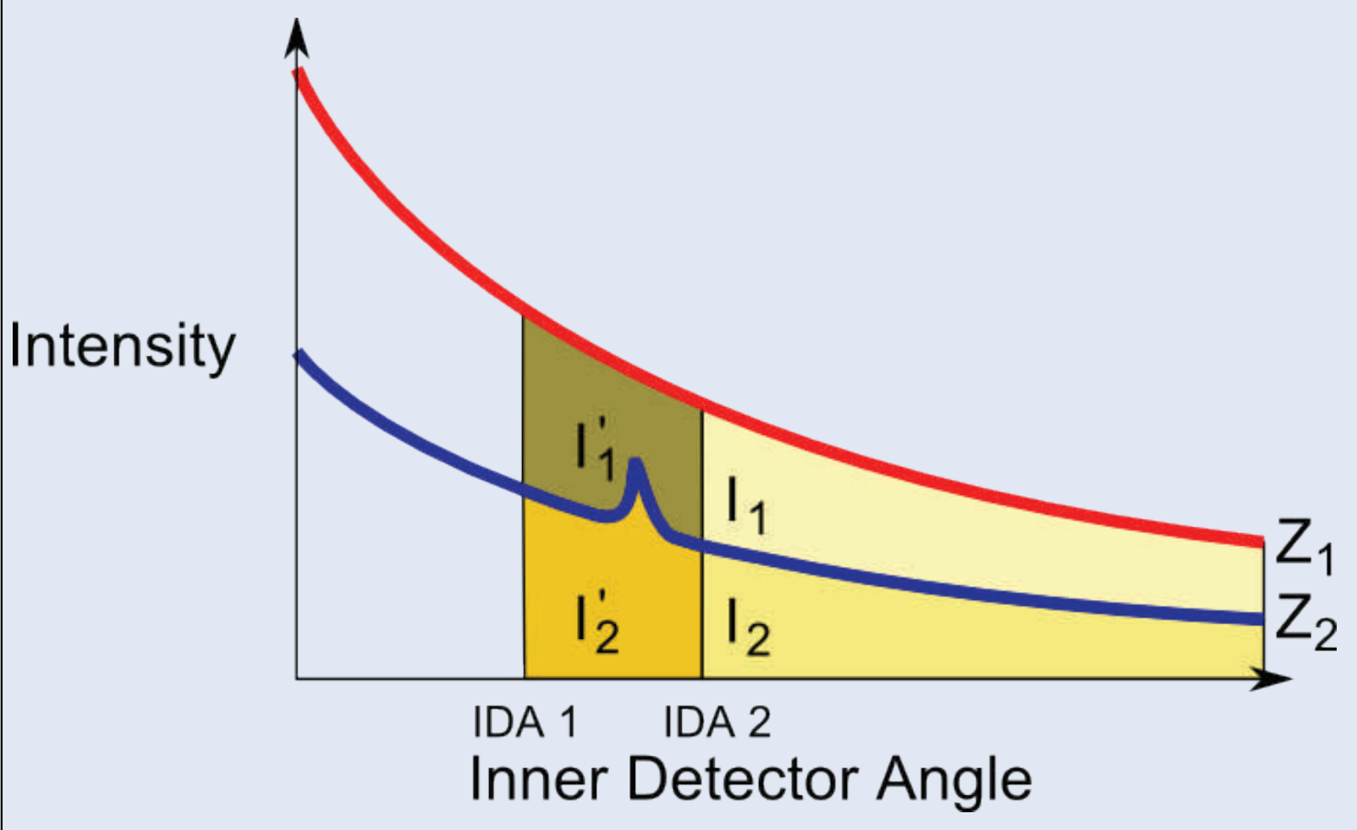


25 mrad minus 48 mrad

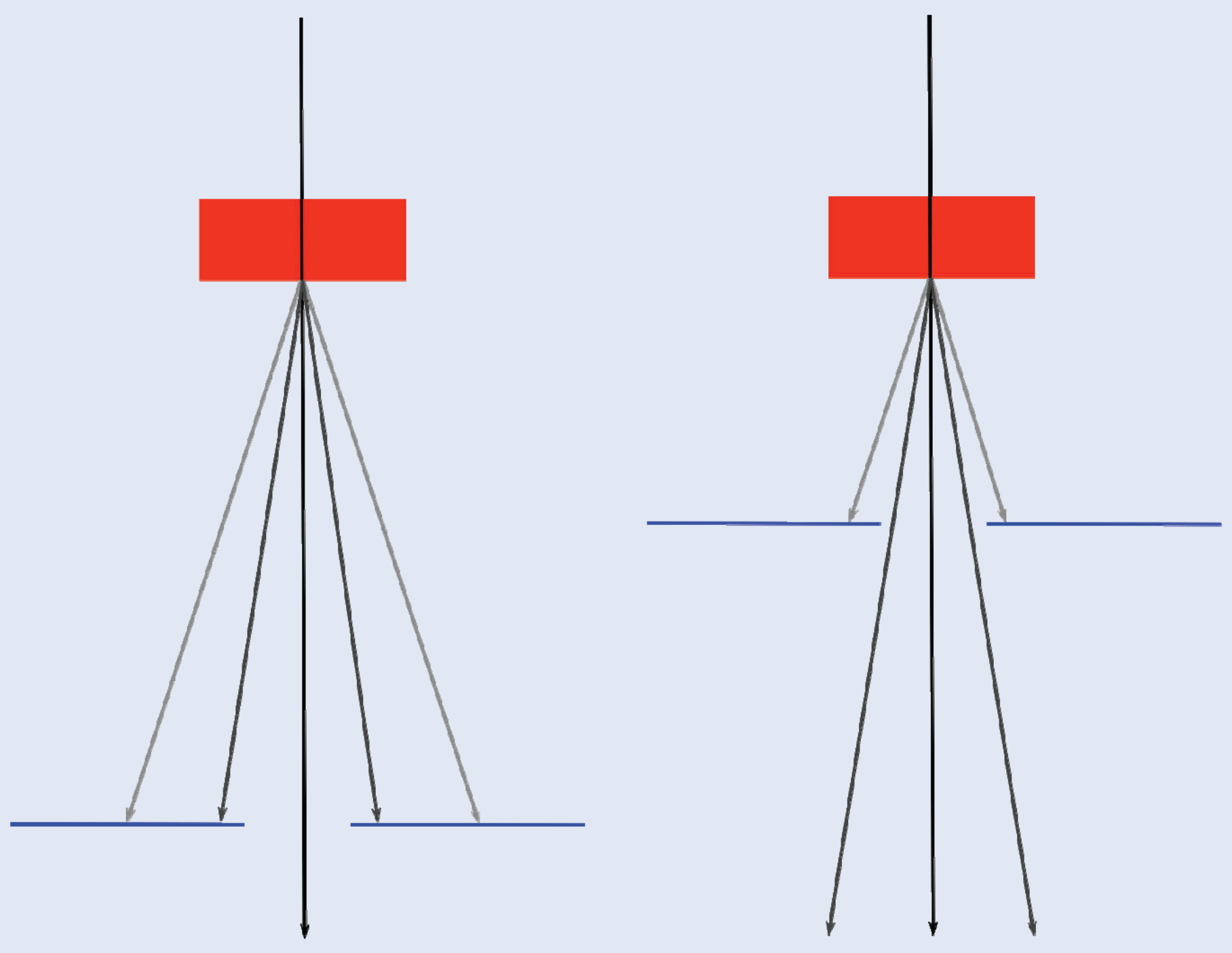
A thin annular detector can be emulated by subtracting ADF images of two different camera lengths with constant beam intensity/dwell time.

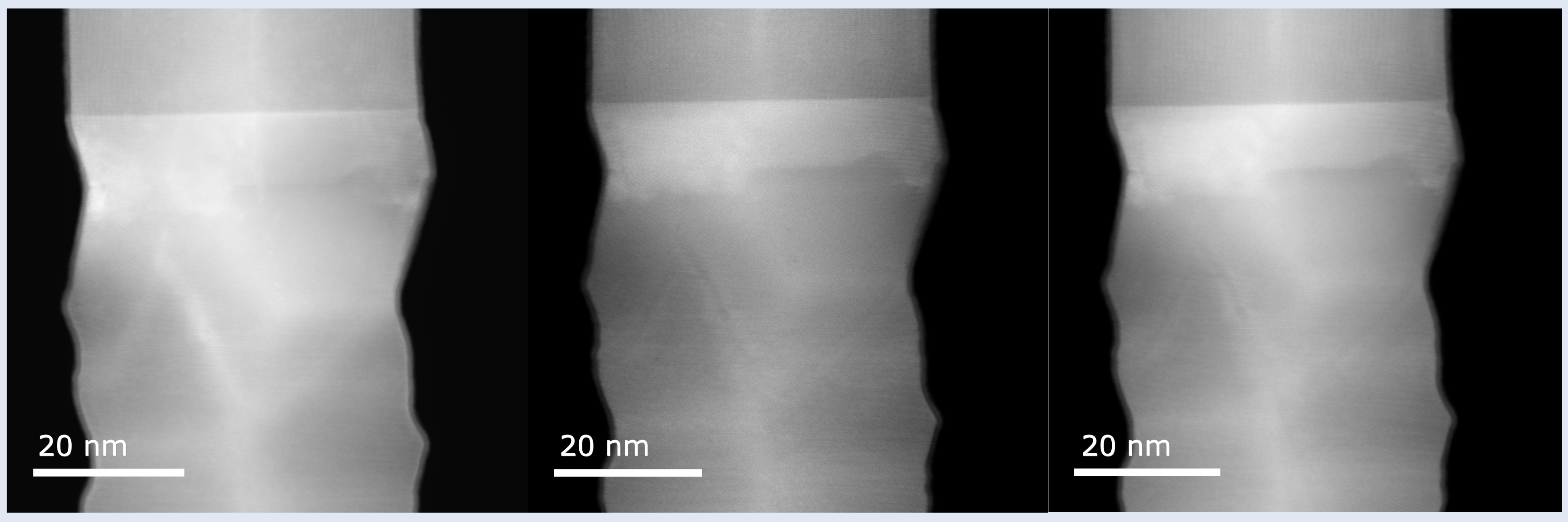
The image on the left shows the result of applying such an approach to enhance diffraction contrast and to suppress mass-thickness contrast. Interesting changes in interface contrast and at the edge of the nanowire are also observed in the difference image.





Conceptual schematic of setup





25 mrad minus 122 mrad *47 mrad minus 122 mrad* *78 mrad minus 122 mrad*

Subtraction of a high-IDA image from a low-IDA image yields less useful contrast differences, possibly due to the large difference in image intensities. The mass-thickness contrast in the middle region is still clearly visible. Dynamic scaling may help in the future.

Conclusions

Preliminary results illustrating the use of ADF STEM to analyse defects in semiconductor nanowires have been presented. Future work will involve scaling of the intensities in images before subtraction, as well as division rather than subtraction of images. If successful, the approach could in principle be combined with electron tomography to provide three-dimensional information about both localized defects and strain.

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References:
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