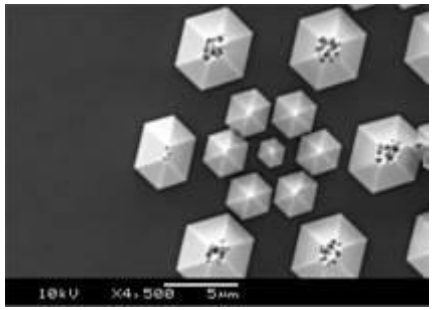
Raith

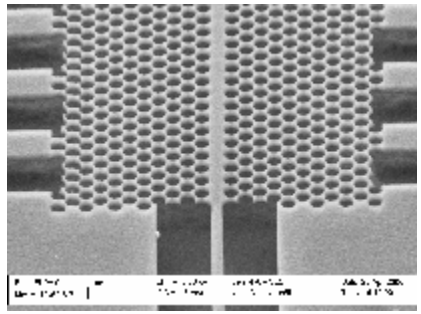
INNOVATIVE SOLUTIONS FOR NANOFABRICATION AND SEMICONDUCTOR NAVIGATION

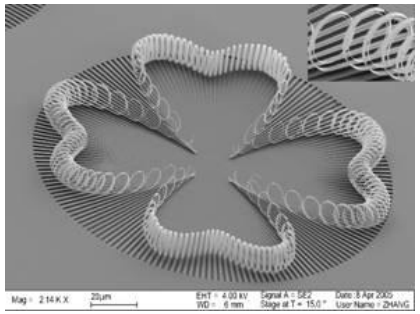
"Extending electron and ion beam lithography schemes to innovative nanofabrication processes"

Frank Nouvertné

Raith GmbH, Hauert 18, 44227 Dortmund, Germany







Taken from Raith best picture award image gallery

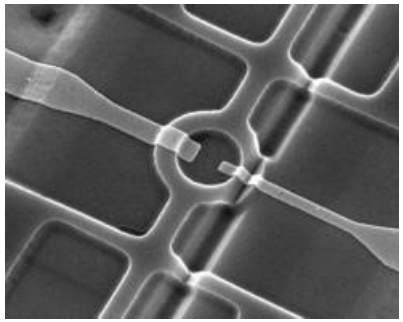
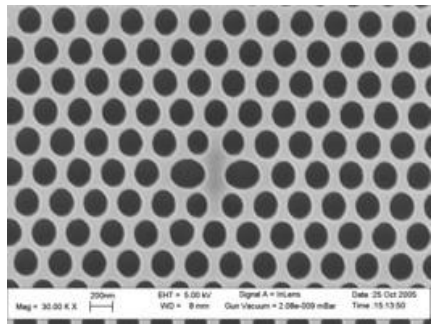
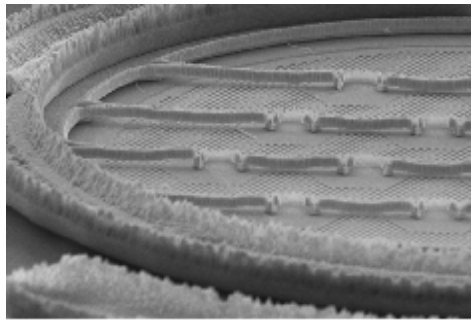
Outline

Raith
INNOVATIVE SOLUTIONS FOR NANOFABRICATION AND SEMICONDUCTOR NAVIGATION

1 Introduction / Motivation

2 Innovative Nanofabrication schemes

- Combined Lithography, Electron Beam Induced Deposition (EBID) and Nanomanipulation (NMT)
- “Large area” stitching error free applications
- 3D patterning

Taken from Raith best picture award image gallery

Raith company profile

# of employees at Raith Dortmund: 80

# of employees at Raith USA Inc. New York: 10

# of employees at Raith Asia Ltd. Hongkong: 3

Raith customers and products

E-beam lithography

Ion-beam lithography

Nanofabrication & Nanoengineering

RESEARCH
Universities & Institutes

E-beam lithography

Automation

Efficiency

PROTOTYPING
Nanocentres

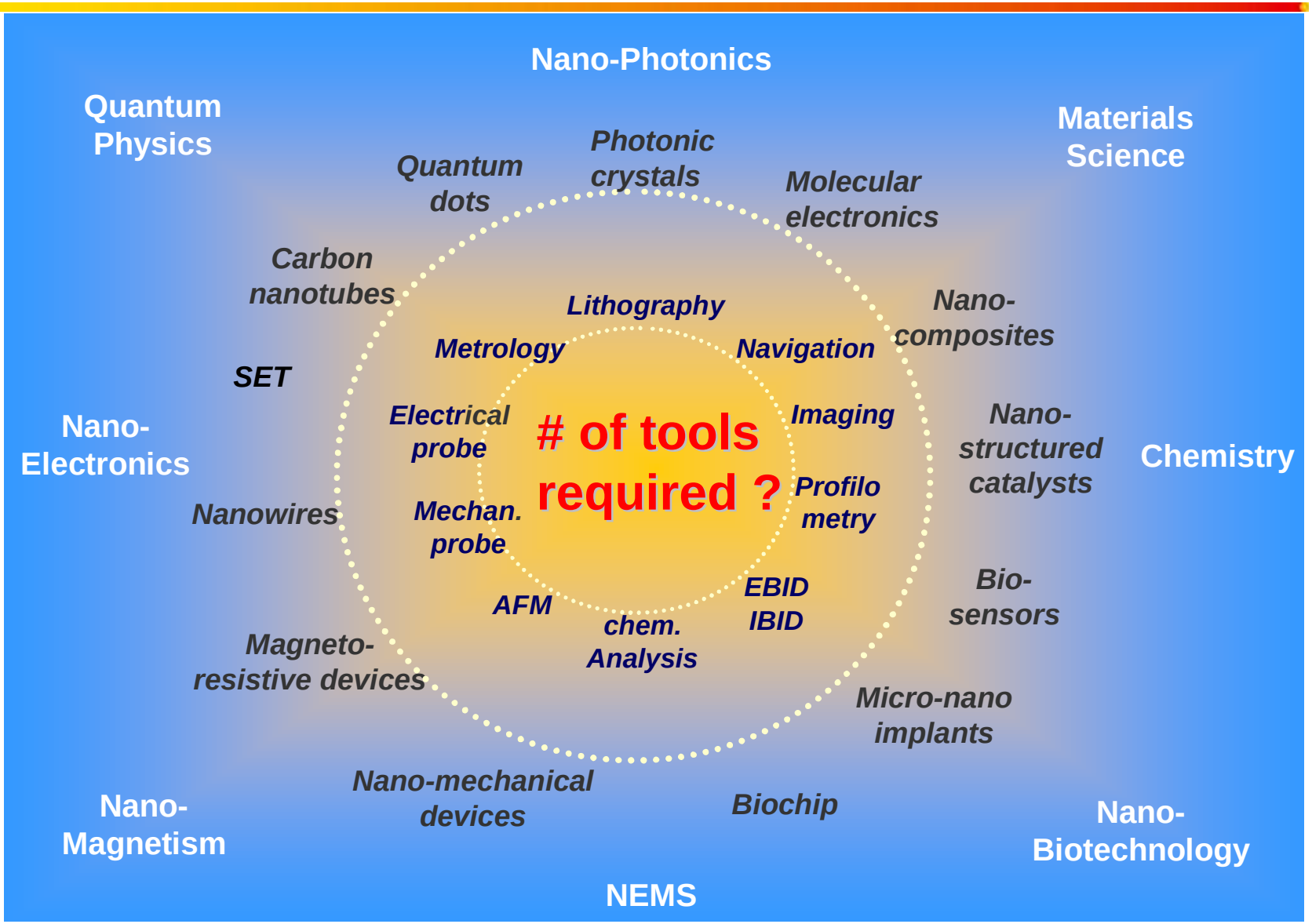
Nanofabrication – Why this session ?

„Nanofabrication is the design and manufacture of devices with dimensions measured in nanometers“ …

(http://whatis.techtarget.com/definition/0,,sid9_gci518307,00.html#)

Buzz words: Bottom up/down
light interference/optical/e-beam-lithography
nano (contact) imprint
self assembly …

Motivation – Nanofabrication Disciplines



Motivation – Nanofabrication Application Trends

- Nowadays nanotechnology/nanofabrication challenges imply ...
  - high degree of nanoscale integration
  - efficient and reliable nanofabrication of 0D- to 3D-nanostructures
  - interfacing the nano- to the macroscopic world
- Recent and future trends complementing „classical lateral structuring“
  - transition 2D – 3D (e.g. NEMS, Nanofluidics, NIL ...)
  - structuring of non-planar surfaces (e.g. Nanooptics)
  - in situ relocation, assembly, modification and characterisation (e.g. CNT, graphene, composites, Nanowires/-whisker)
  - Multiple-project tasks on a single sample
- => increasing need for innovative nanofabrication schemes and multi-purpose tools with highly integrated subsystems

Some „Universal Tool“ Vendors

DCG Systems

ZEISS

FEI COMPANY™

ULVAC ULVAC-PHI, INC.

TESCAN DIGITAL MICROSCOPY IMAGING

Raith INNOVATIVE SOLUTIONS FOR NANOFABRICATION AND SEMICONDUCTOR NAVIGATION

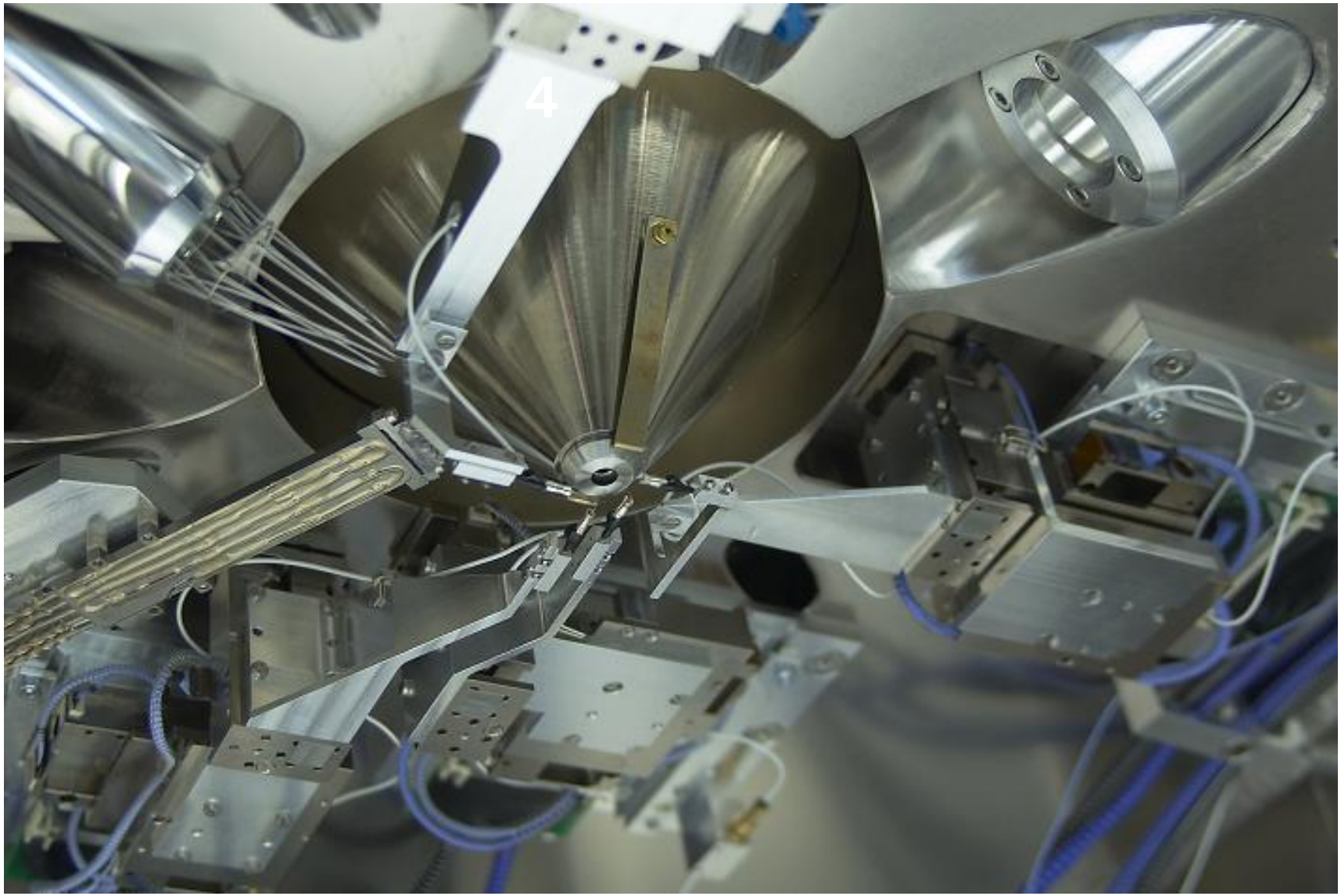
HITACHI Inspire the Next

SII

JEOL

Raith

A Look inside – System Integration

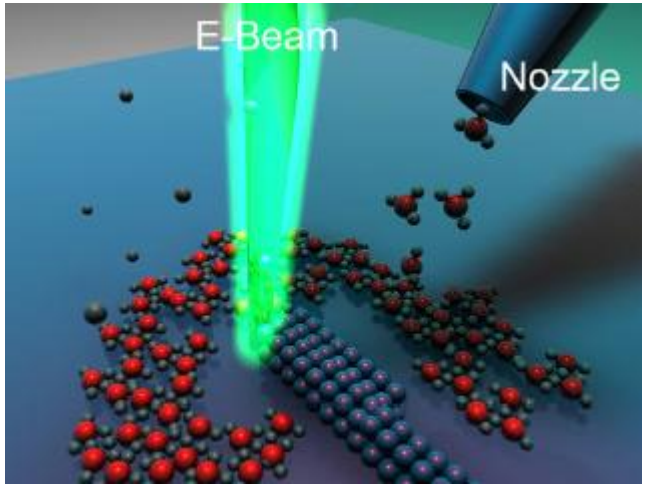


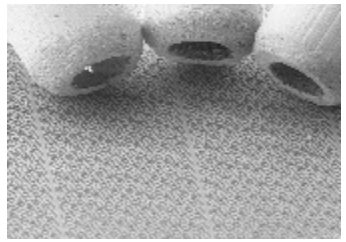
Motivation – „The“ Universal Tool ...

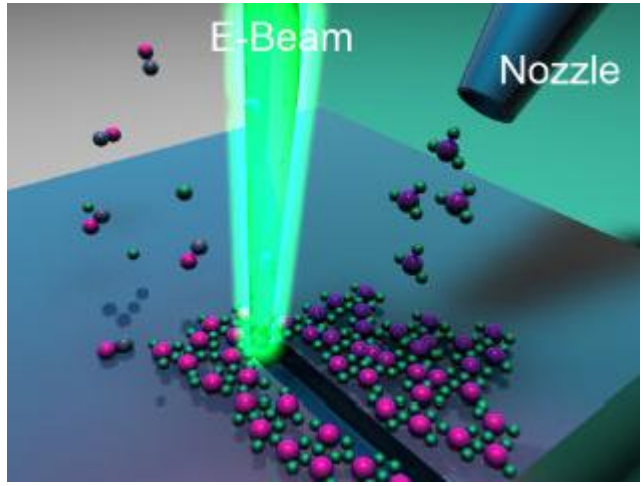
... does not exist !

What is EBID ?

EBID = Electron Beam Induced Deposition

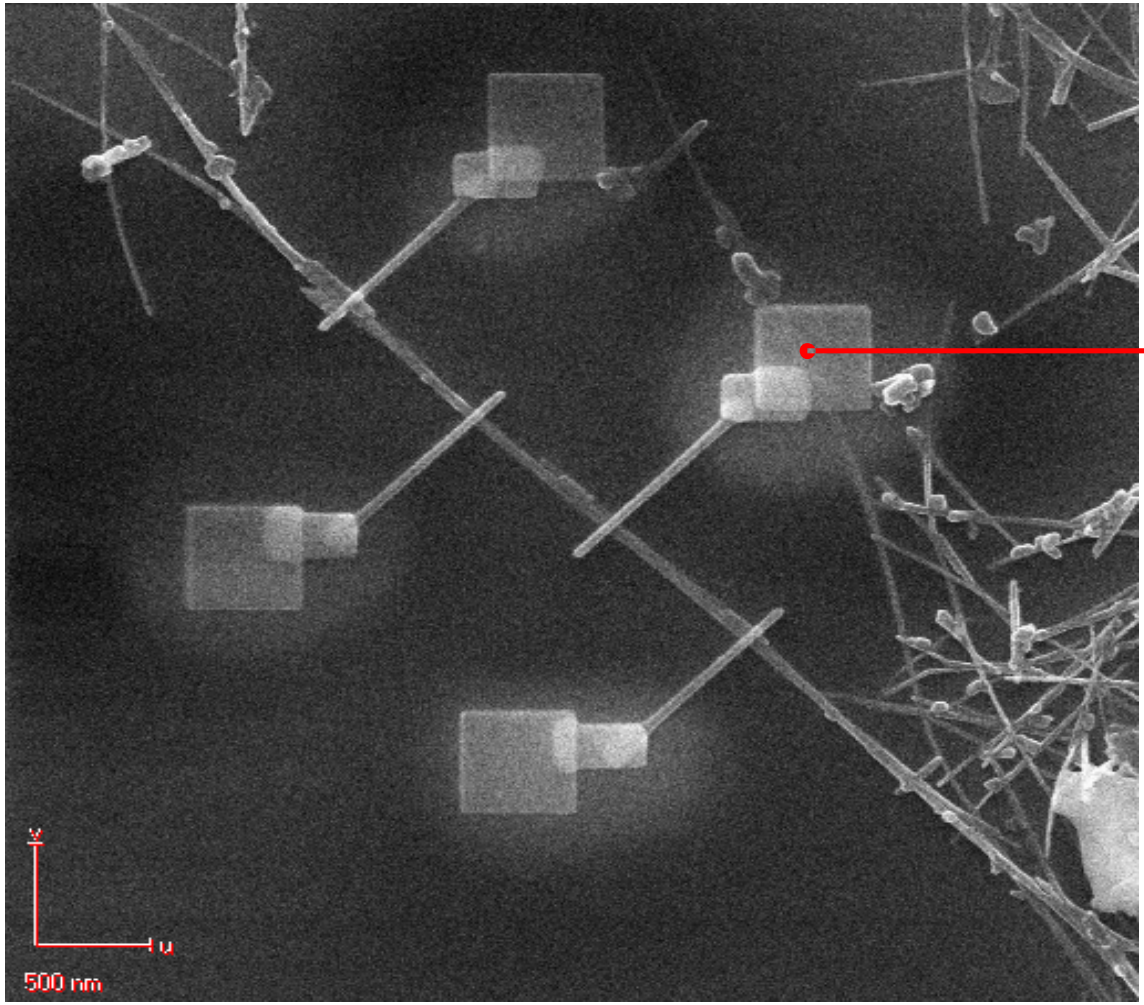






EBIE = Electron Beam Induced Etching

Innovative Nanofabrication Schemes - Contacting CNTs

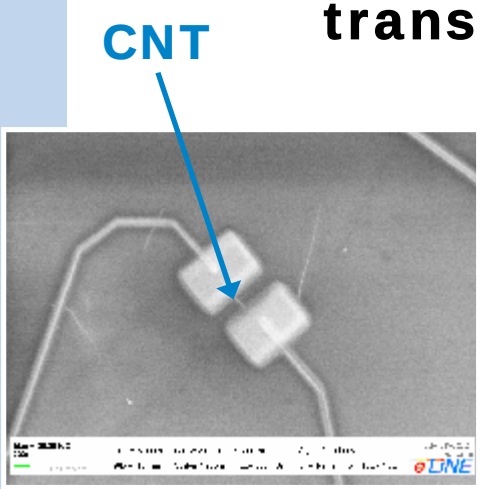


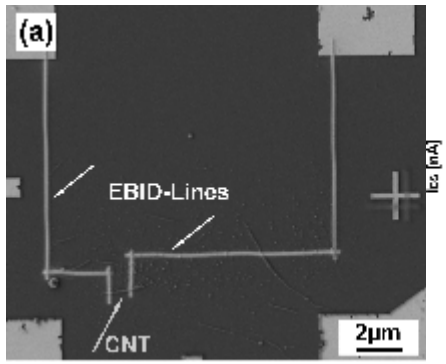
Contact pad for „Nano-Manipulator“

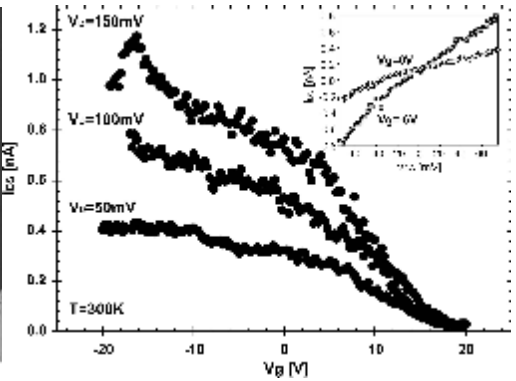
„Wiring“ of CNTs on SiO_2-sample (by metalorganic precursor deposition)
S. Bauerdick, Raith inhouse

Innovative Nanofabrication Schemes - Contacting CNTs

- **Interfacing CNTs to macroscopic world using**
  - **relocation (precise stage smart navigation)**
  - **state-of-the-art imaging for identification**
  - **Electron beam induced deposition process (EBID) for contacting CNTs to prestructured large pads**
  - **Nanomanipulators alternatively as probing tips for transport/conductivity measurements**

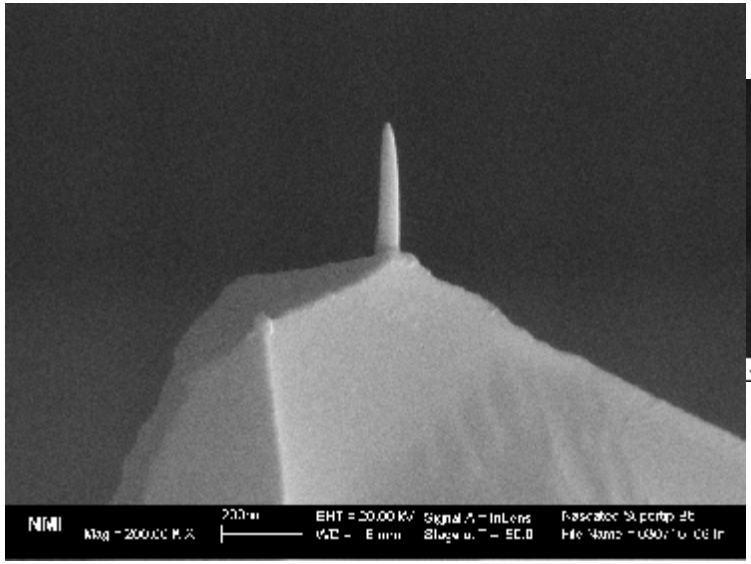


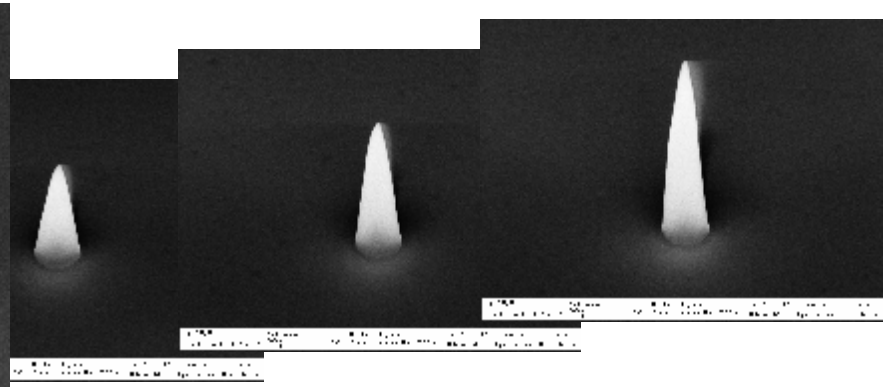


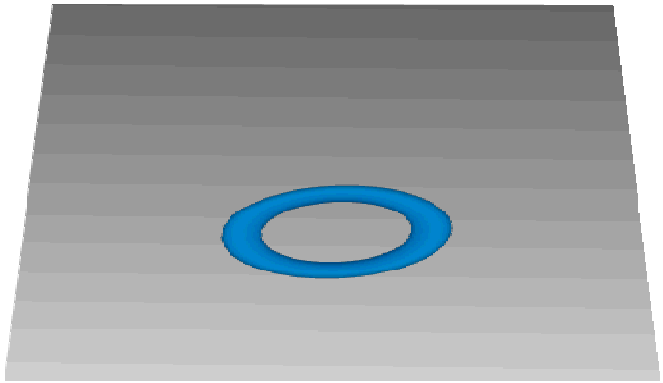


S. Bauerdick et al., J. Vac. Sci. Technol. B, Vol. 24, No. 6, Nov/Dec 2006

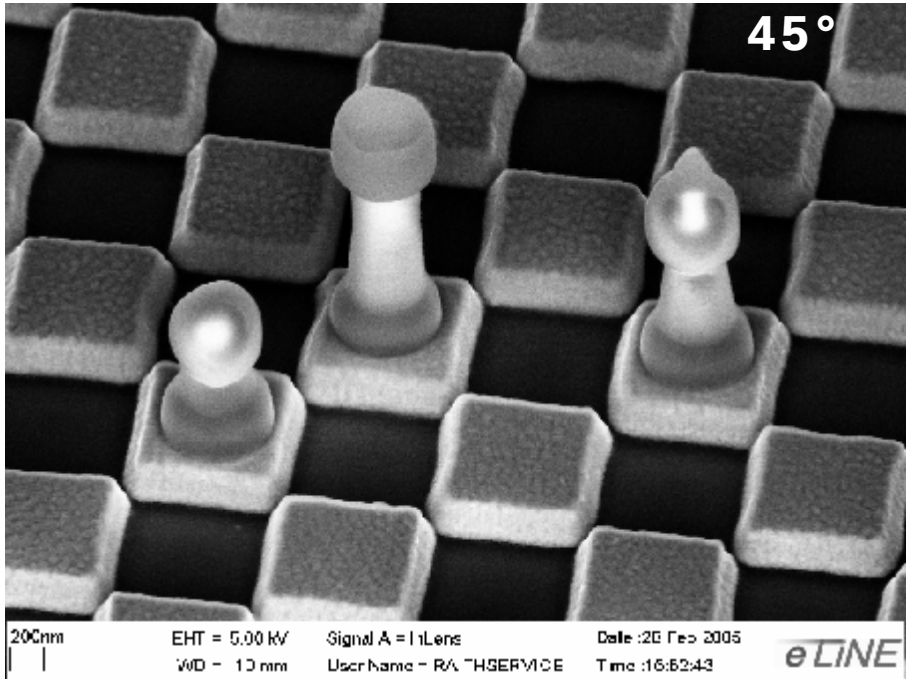
Innovative Nanofabrication Schemes - 3D EBID



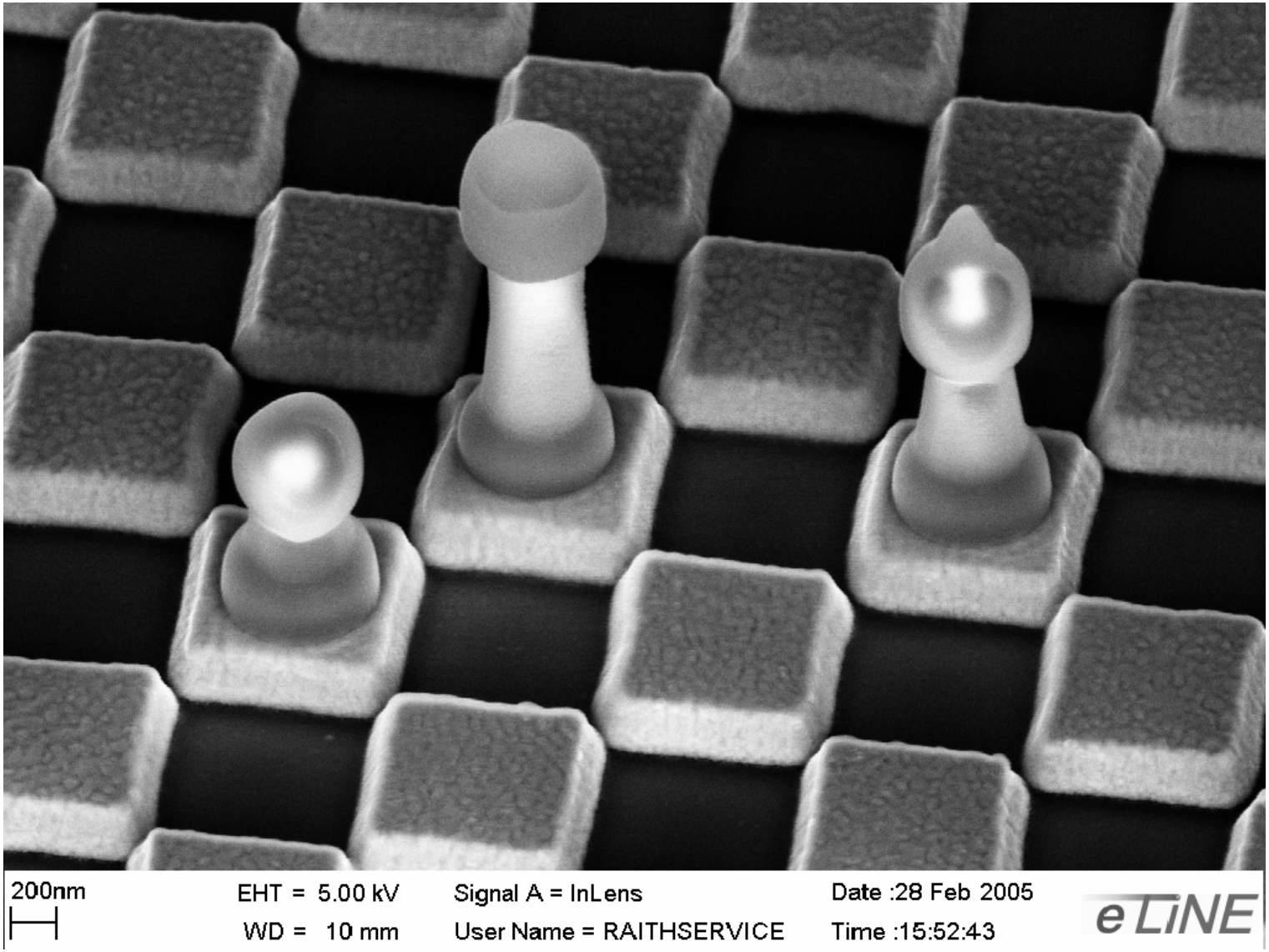




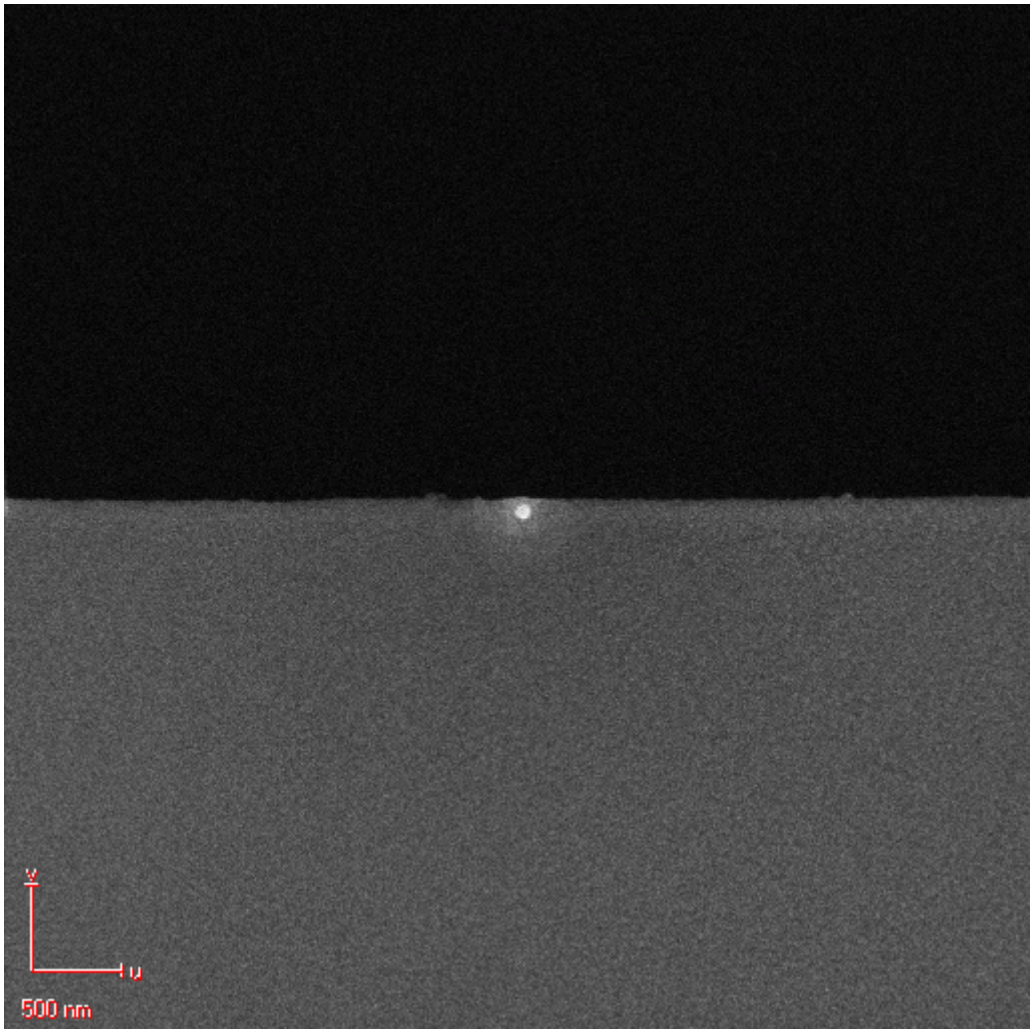
3-D nano chess



3D-EBID

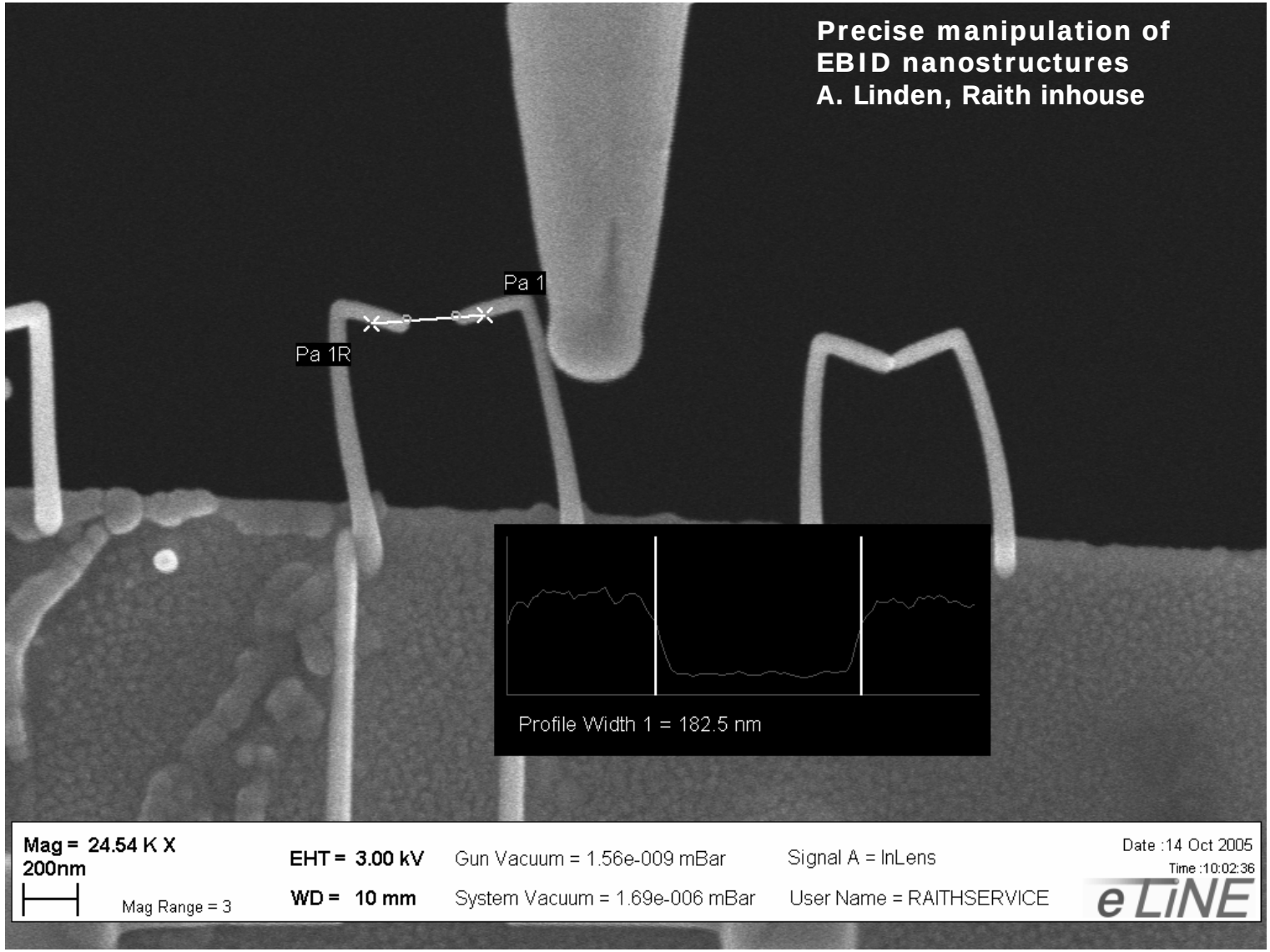


3D-EBID and nanomanipulation thereof



EBID and manipulation of small nanostructures
A. Linden, Raith inhouse

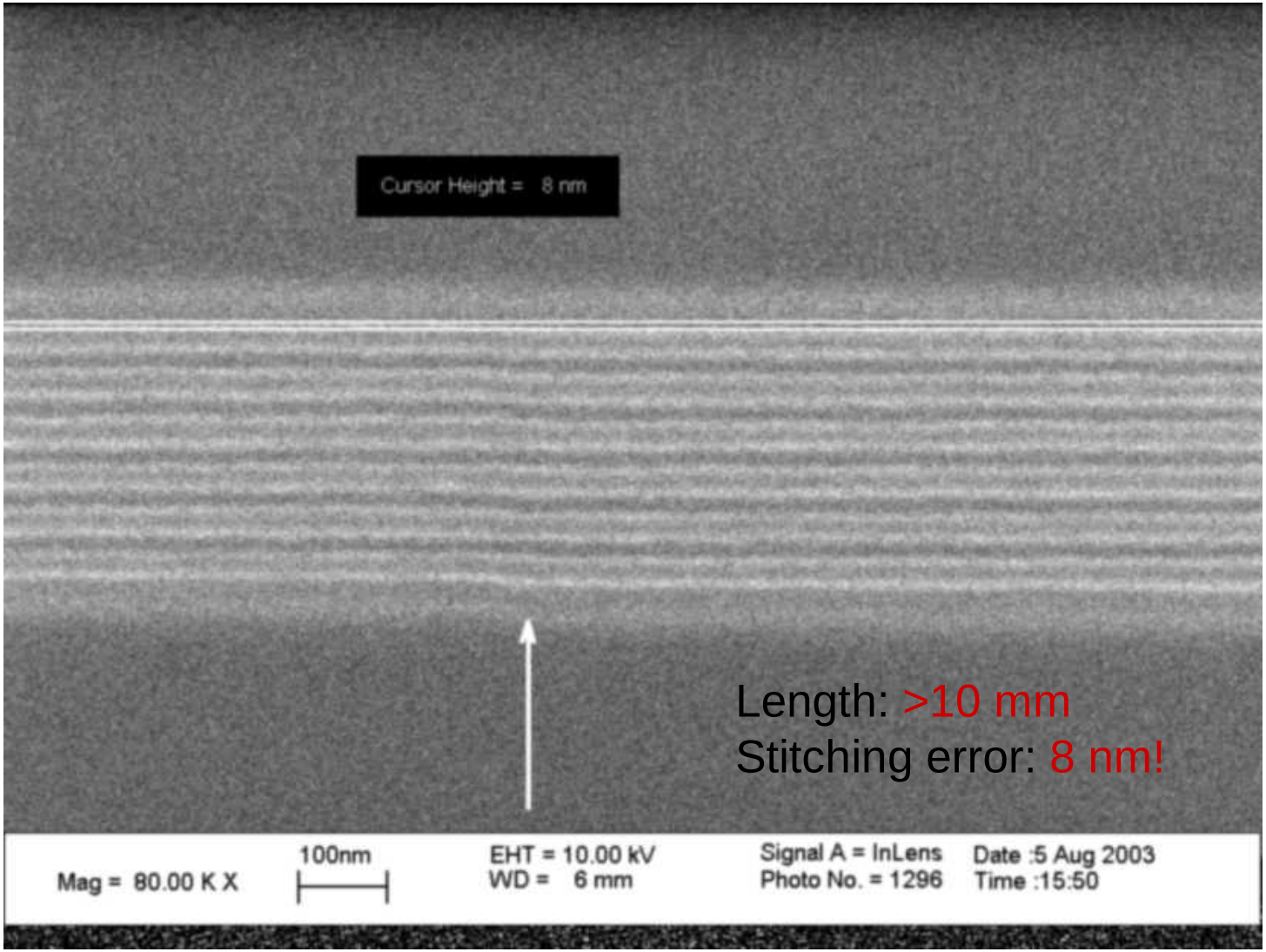
3D – EBID and precise *nano* manipulation



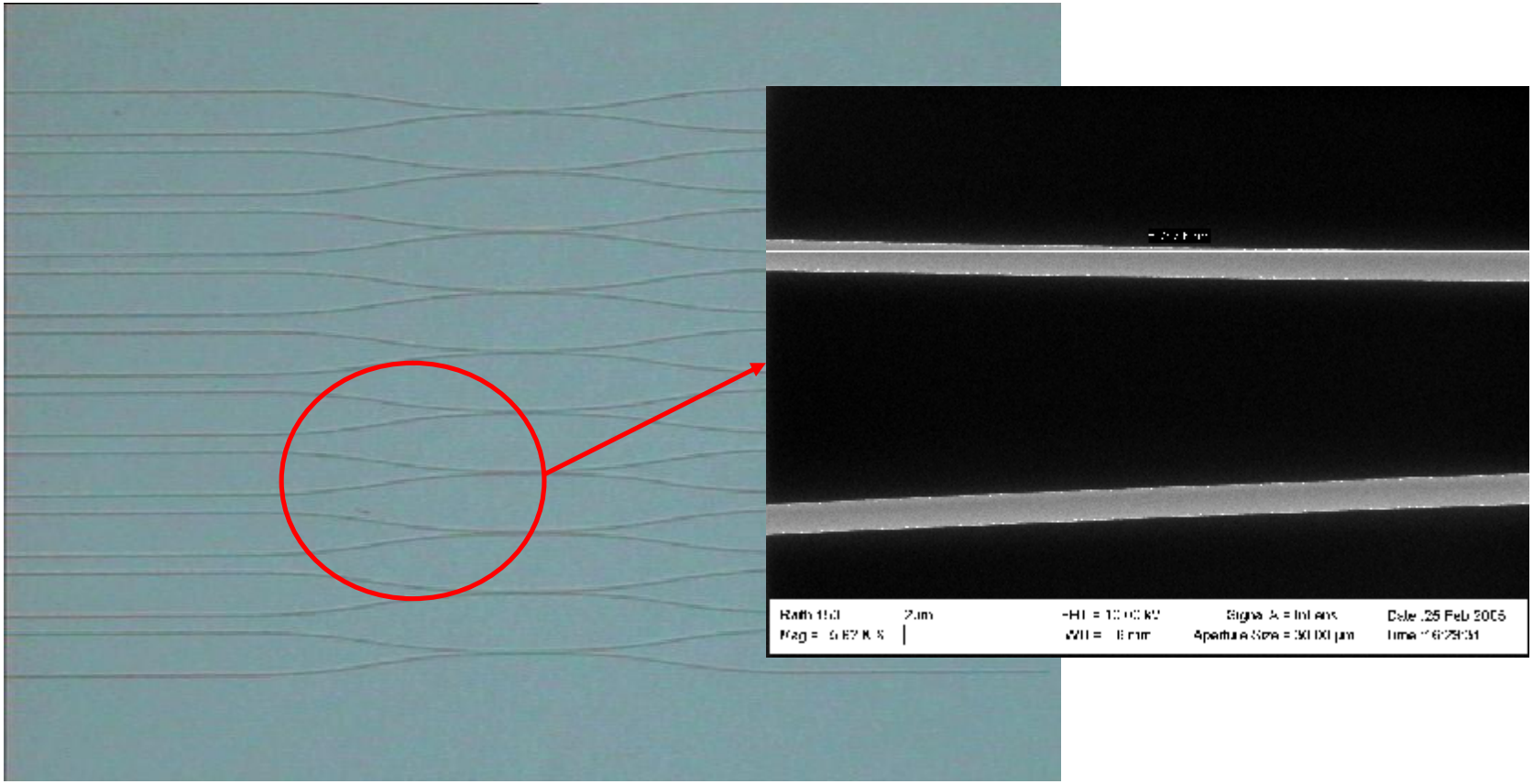
Innovative Nanofabrication Schemes

- **Exposure mode using electron and/or ion beams for:**
  - **“Large area” nanofabrication (>> ~ 100µm) with**
  - **Elongated and seamless, stitching error free structures with a length of mm to several cm**

Stitching vs. FBMS mode for nanofabrication

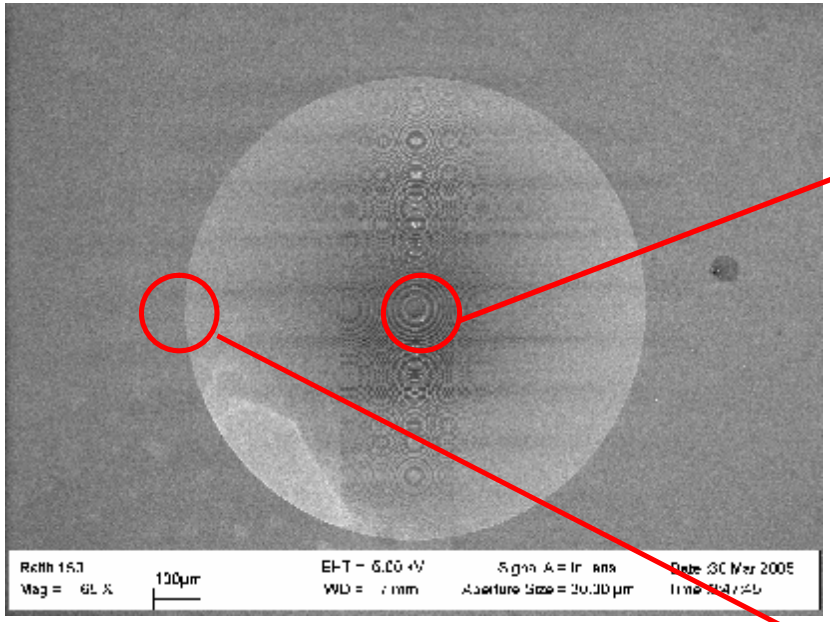


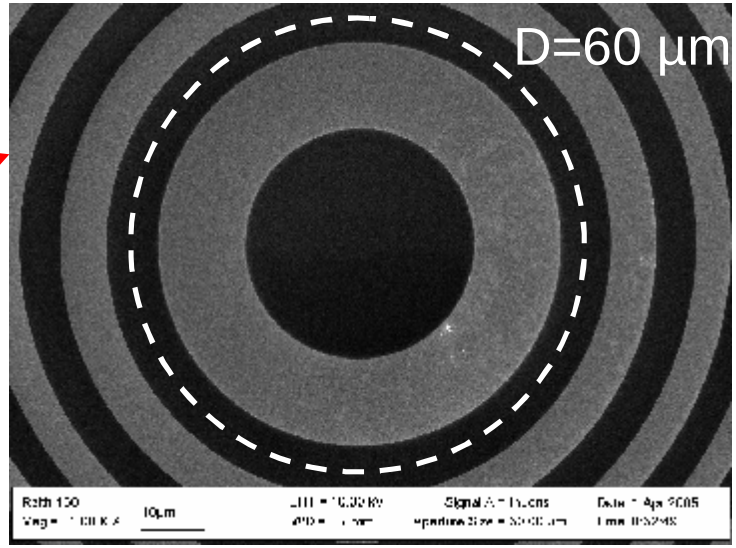
FBMS: optical waveguides

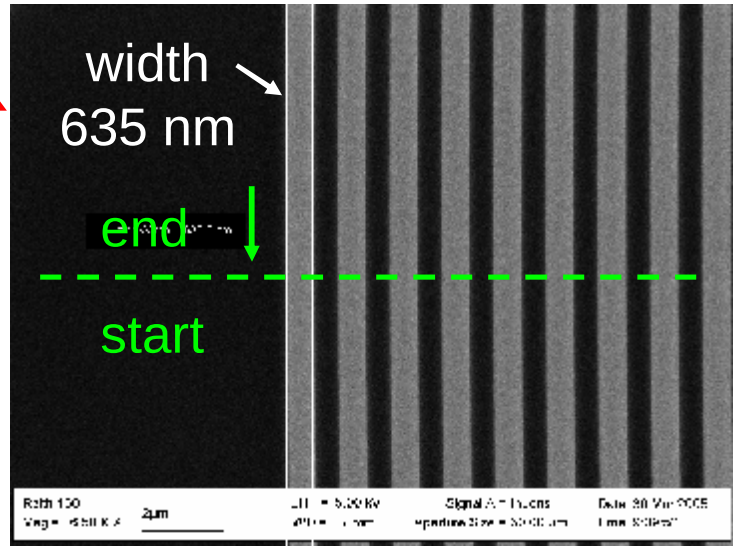


minimum waveguide losses due to stitching-free FBMS writing!

FBMS: zone plates

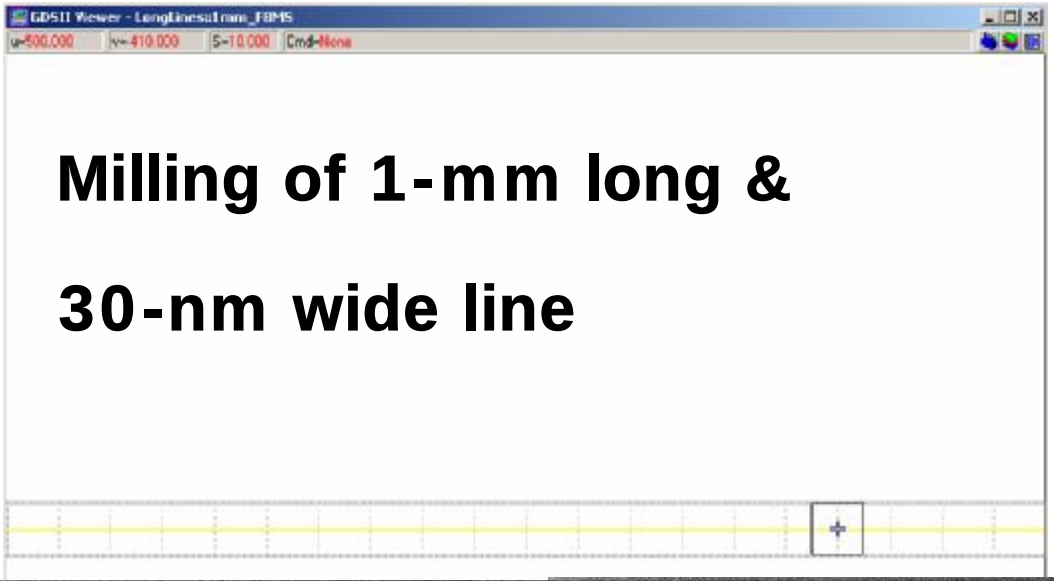


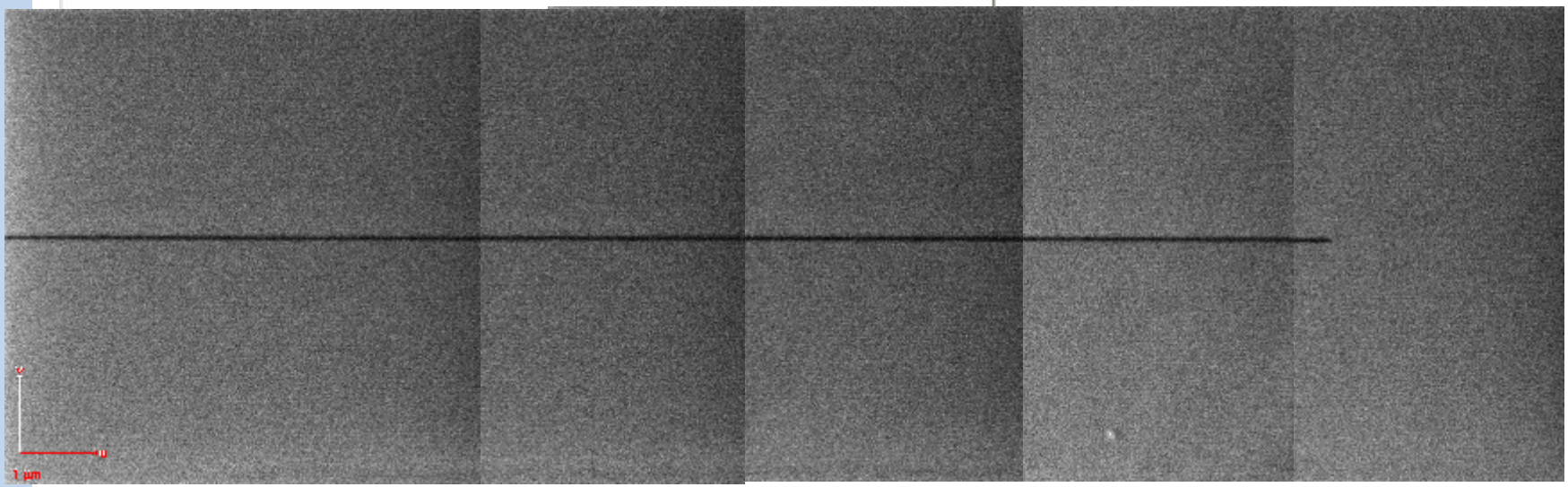




195 different FBMS path widths in a single exposure

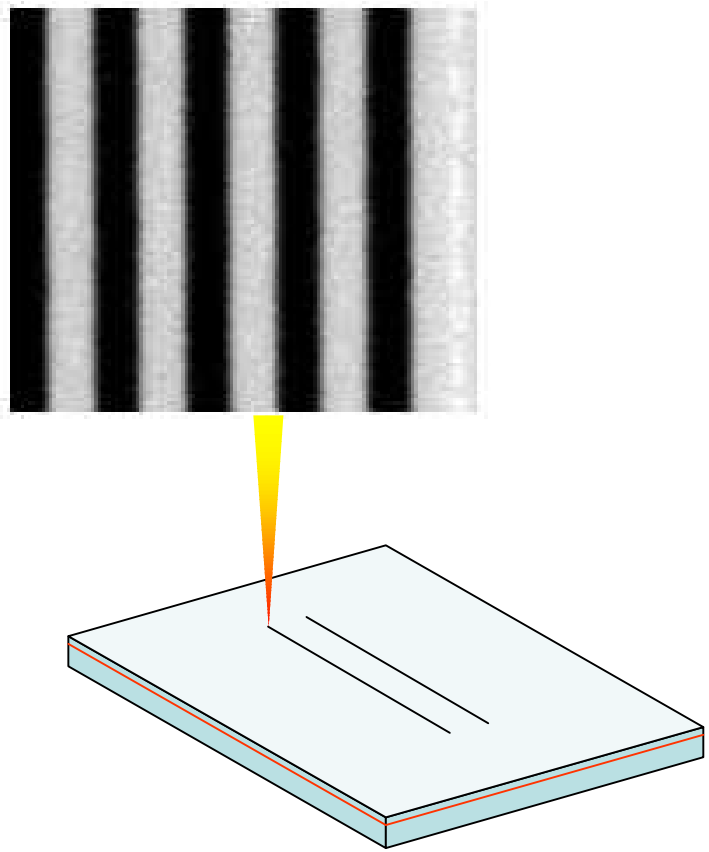
FBMS: Milling long lines



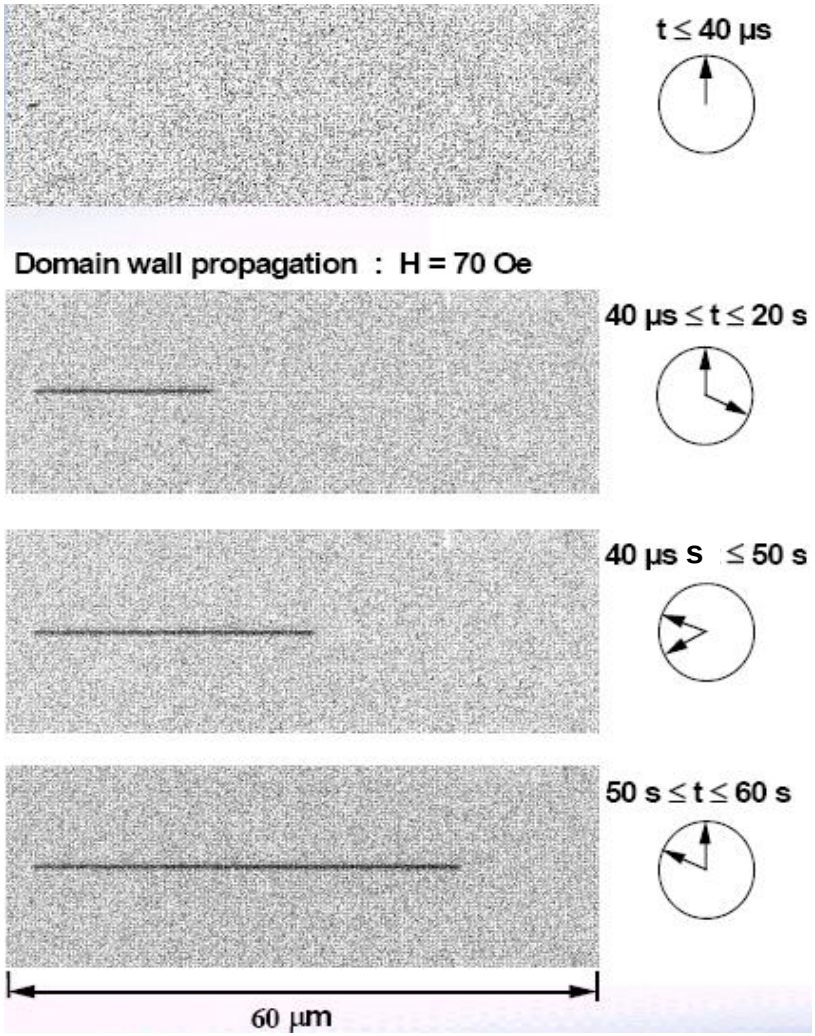


Tayloring magnetic domain walls

MOKE microscope of structured Pt/Co/Pt films



Pt/Co(0.6nm)/Pt
Spacing between lines: 900 nm



J. Ferre et. al., e.g. J. Appl. Phys. 2004

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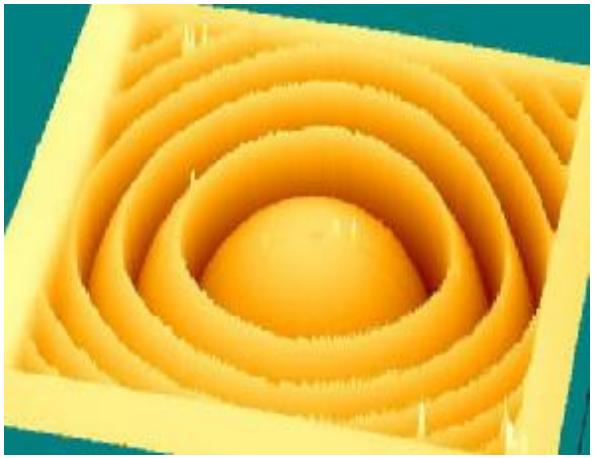
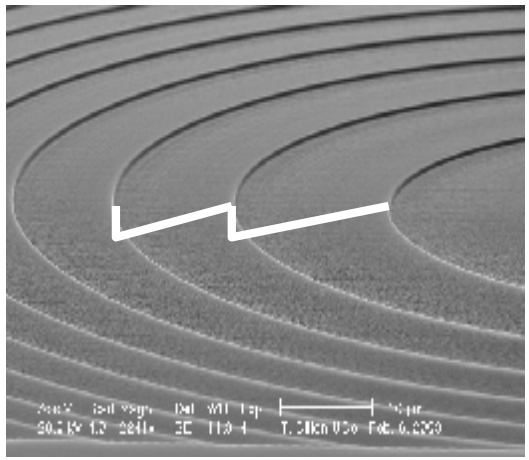
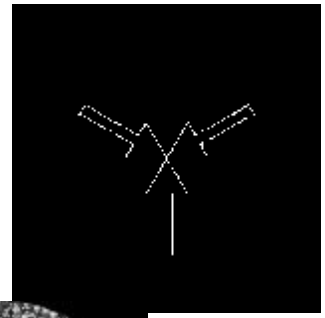
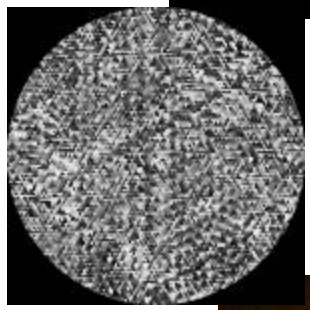
INNOVATIVE SOLUTIONS FOR NANOFABRICATION AND SEMICONDUCTOR NAVIGATION

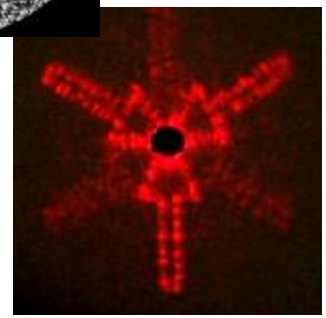
3D-Nanofabrication







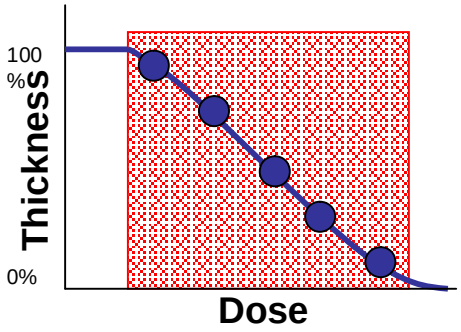




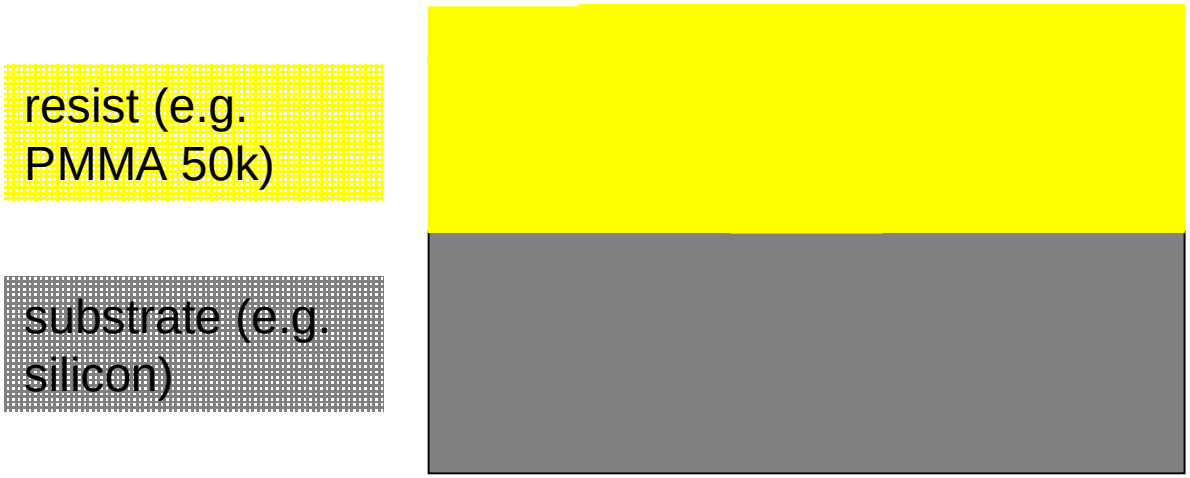
3-Dimensional Nanofabrication

- **precise 3D-features required for e.g. :**
  - **optical / diffractive elements**
  - **Nanoimprint master fabrication**
  - **Phase holograms**

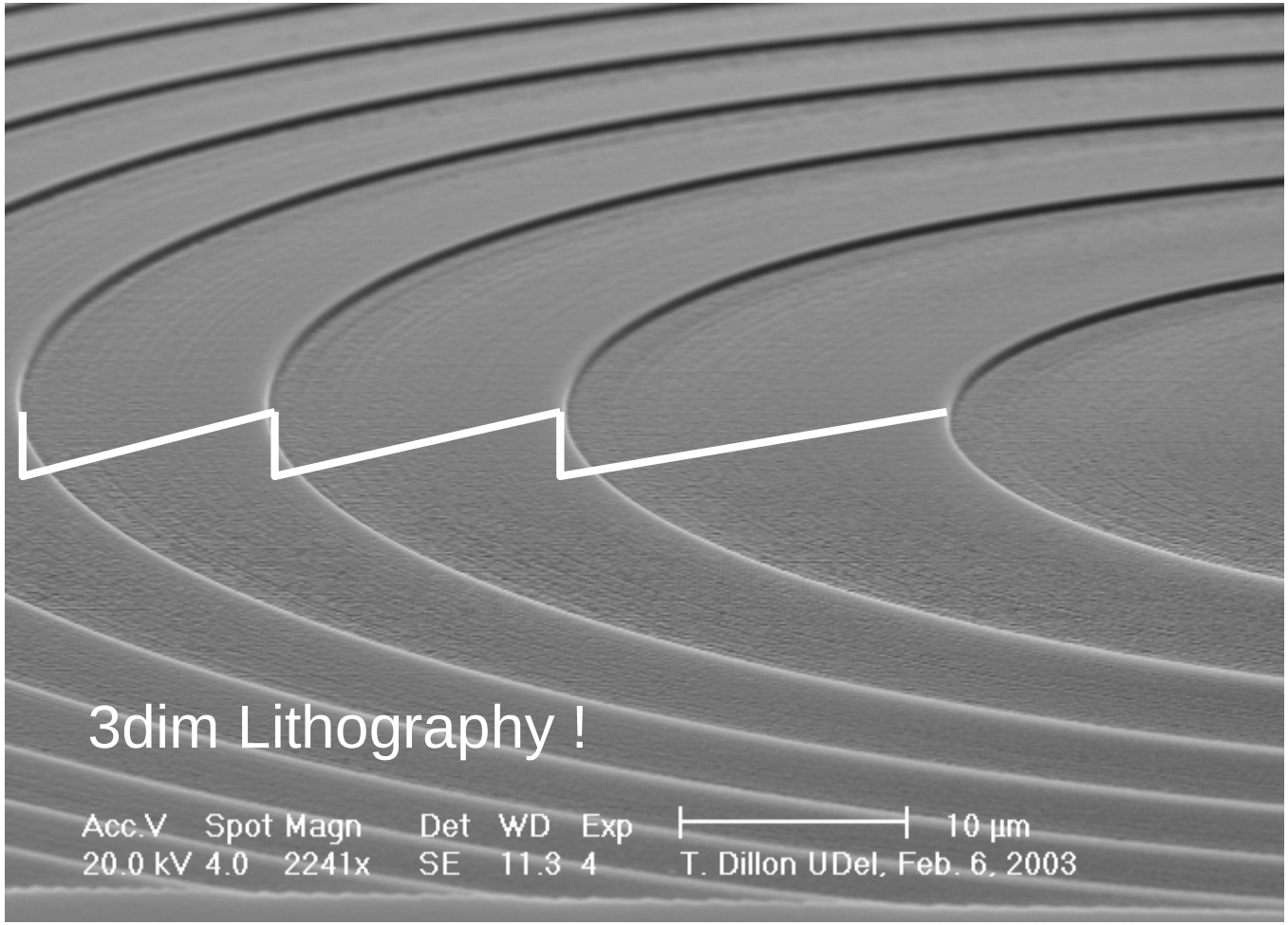
3D–Lithography – how does it work ?



- **Results significantly depend on:**
  - **Specific resist properties**
  - **Proximity effect control**
  - **and more …**
    (e.g. resist development, further processing …)

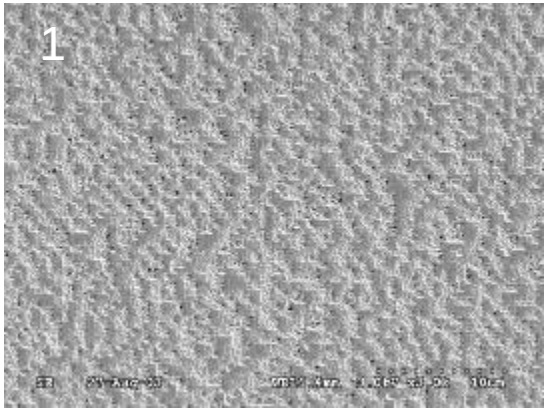


3D-Lithography – Fresnel lens



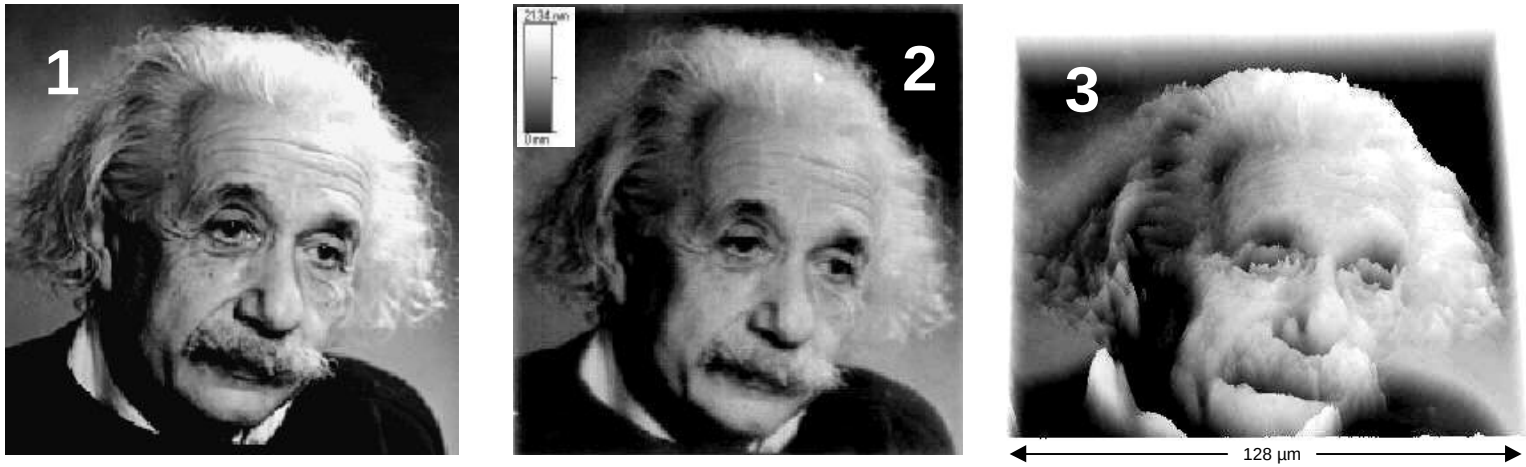
T. Dillon, University Delaware, USA

3D-Lithography – Phase Holograms



1: Grey scale phase hologram exposed in resist
2: Reconstructed image of keyboard hologram
PIDC, Taiwan

3D-Lithography – BMP import



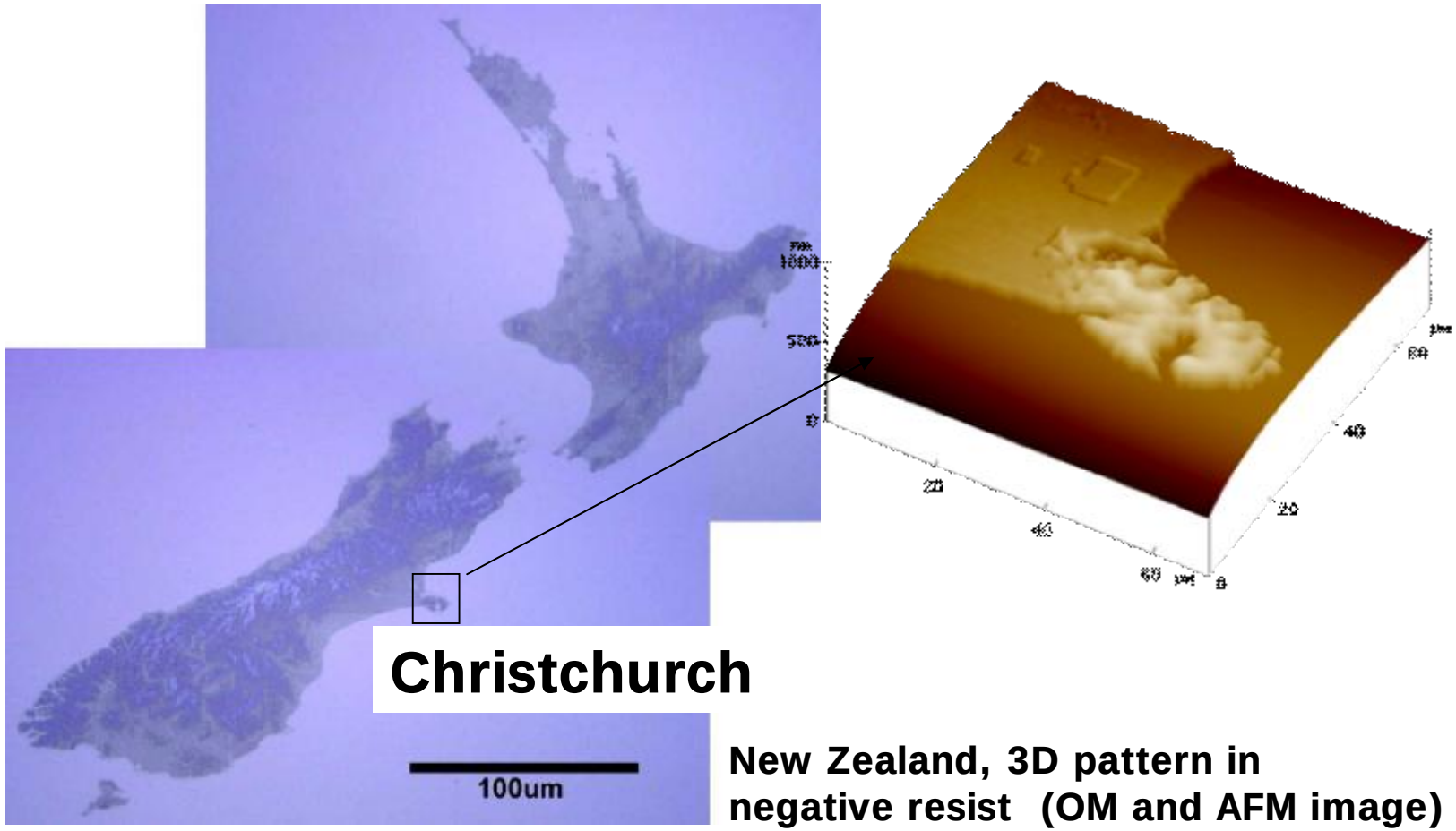
3D-Lithography

1: TIFF-Image 2: AFM-image of 3D-pattern, developped in PMMA

3: 3D-view of AFM-image in 2 to visualize height profile

H. Raith, Raith inhouse

3D lithography – topographical data

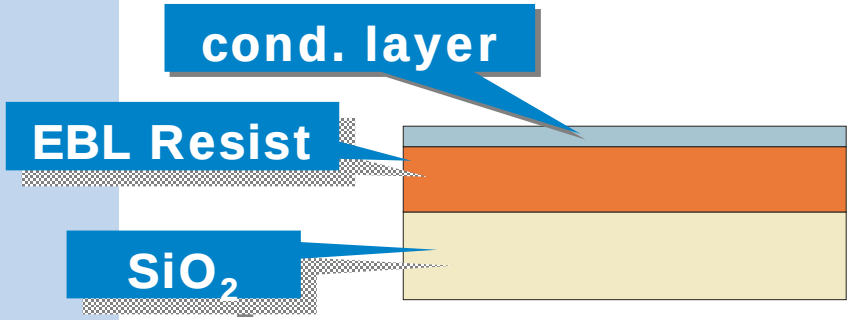


New Zealand, 3D pattern in negative resist (OM and AFM image)

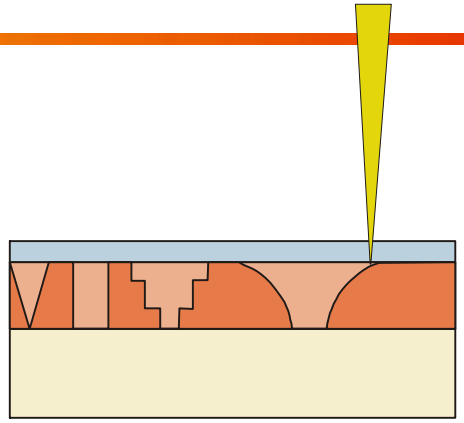
M. Konijn, University of Canterbury, Christchurch, New Zealand


Welcome to Raith NanoWorld
fabricated by ionLiNE
2 µm

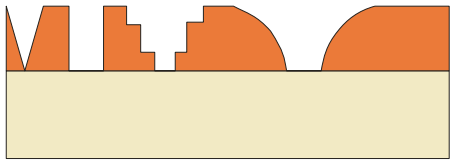
3D Mold Fabrication scheme



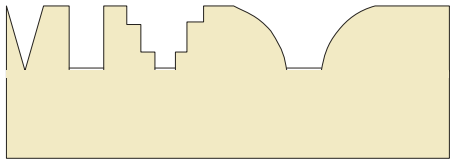
1. spin coating of EBL Resist and conductive layer



2. EBL with varying exposure doses



3. development of the resist pattern



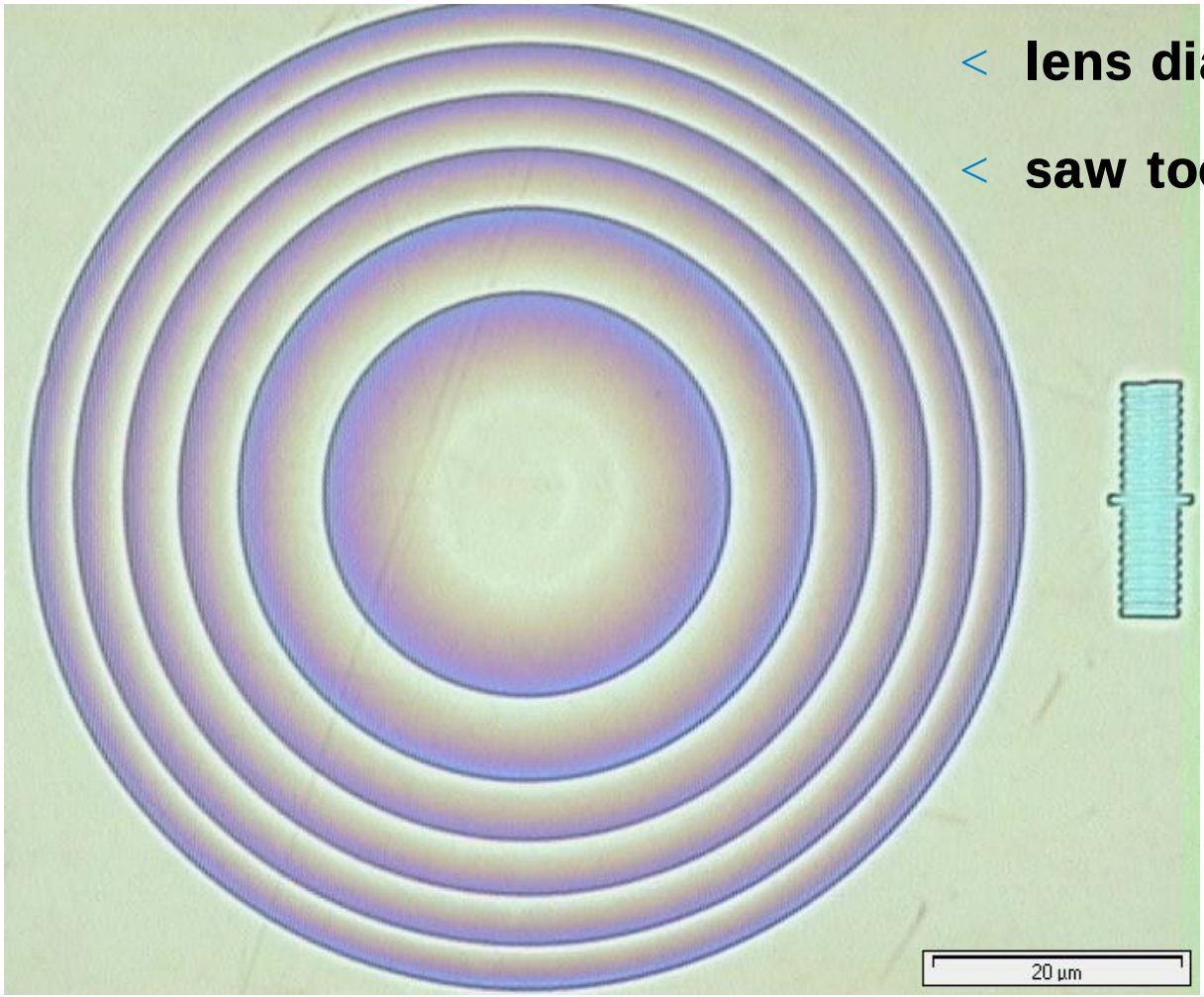
4. pattern transfer into the SiO_2 substrate

(taken into account right from the beginning in initial lithography step)

All following experiments performed in collaboration with RWTH Aachen, AMO

Imprint of optical elements

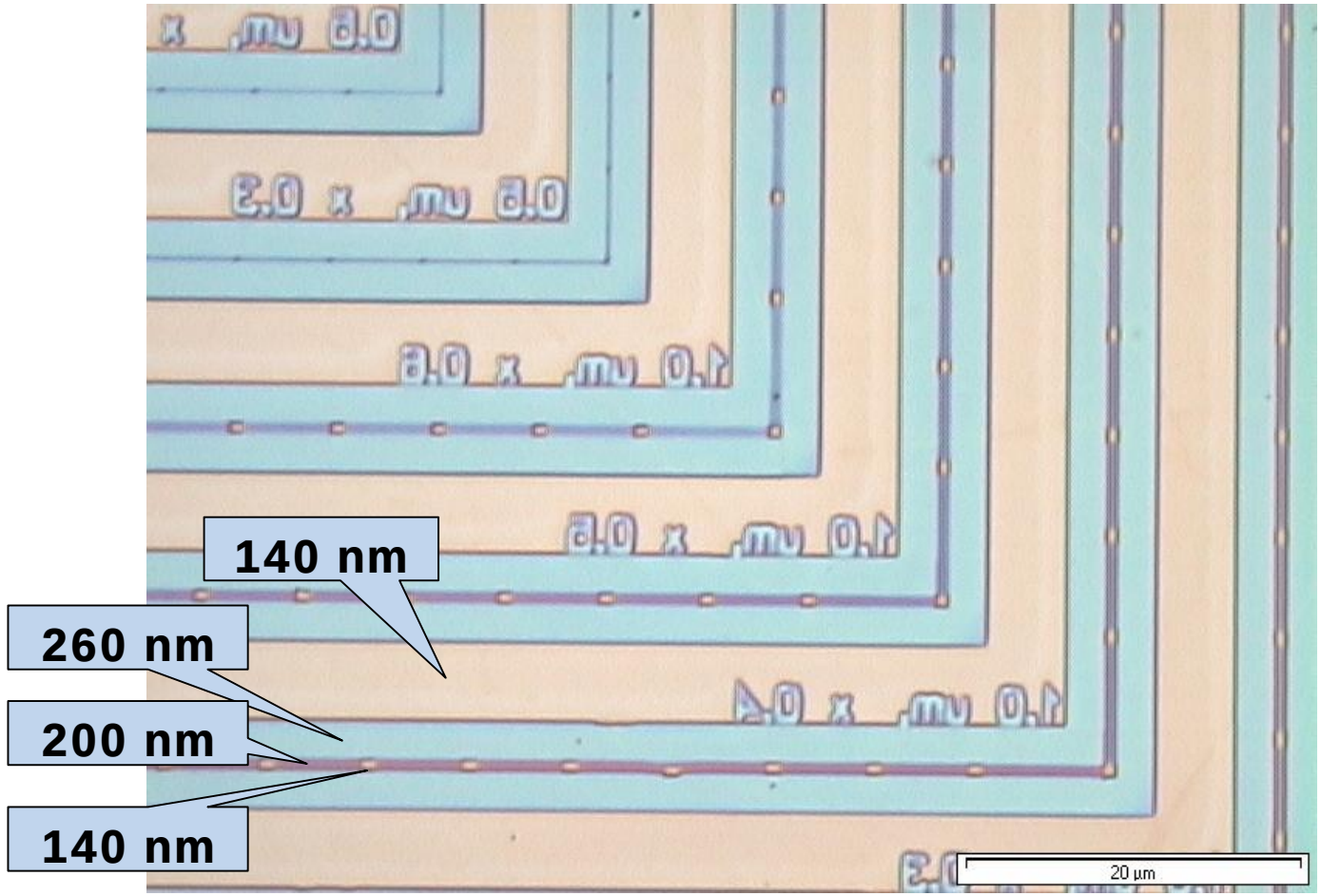
3D Replication of Fresnel Lens (optical micrograph)



- lens diameter 80 µm
- saw tooth profile

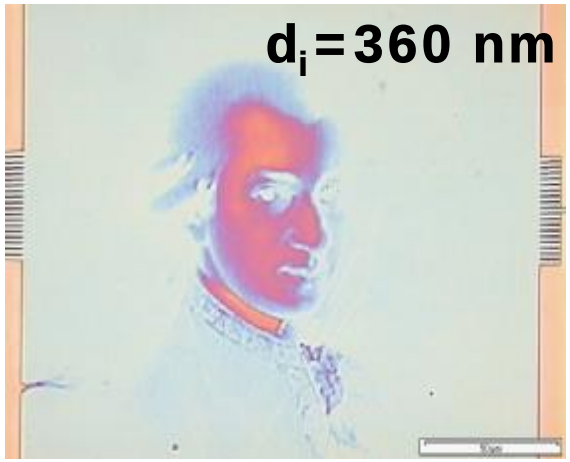
Template manufacturing for Imprint

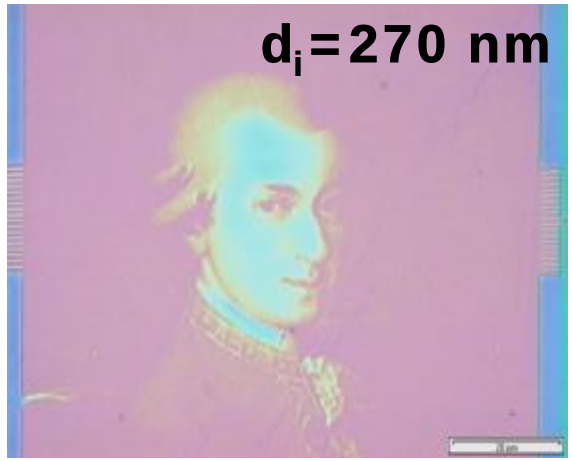
3D Replication of vias & wires (optical micrograph of test structures)



Imprinting of images

3D Replication of image files (optical micrographs)





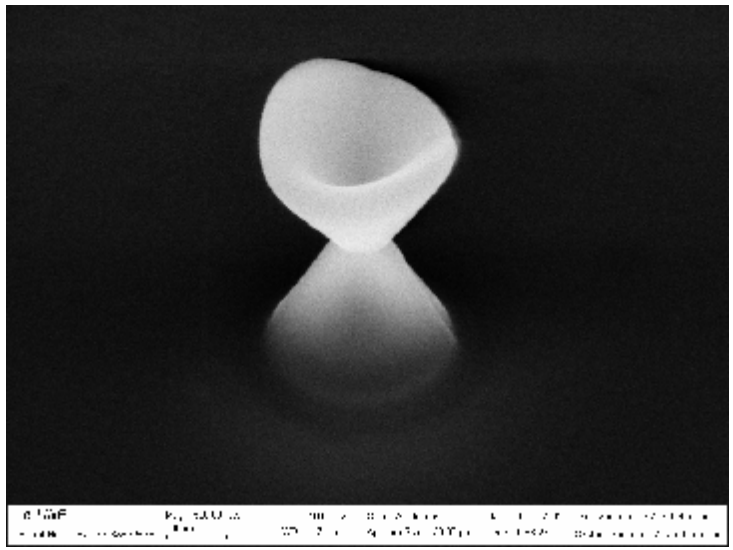
d_i initial imprint resist thickness

Color caused by interference and different resist thickness !

Thank you for your attention !

QUESTIONS, PLEASE !!!

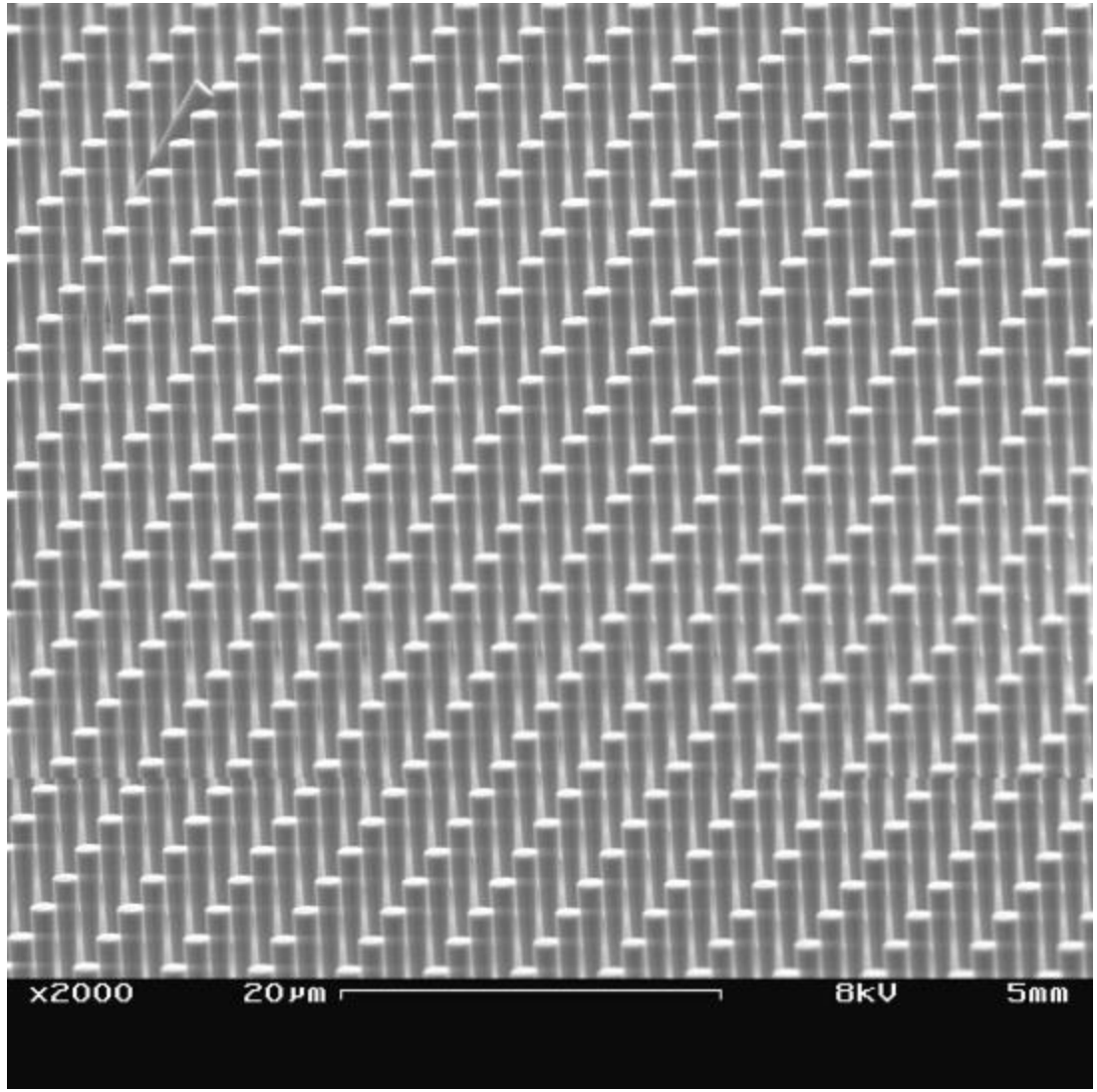
... or prefer a cup
of tea / coffee ?



Thank you !

Questions ?

If you are not too tired yet, try to find the imperfection !



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