The Albanova Nano Fabrication Facility

Nano technology for basic research and small commercial enterprises

Director: Prof. David Haviland

Nano-Lab Philosophy

- Nanometer scale patterning and metrology
- Broad spectrum of user research, stimulate new ideas
- Graduate students post docs are users, help maintain
- Small technical staff, minimal administration
- Flexible environment for basic research
  - Direct writing techniques, small series production
- Wide variety of materials
- Small format for machines

Used by many institutions in Stockholm

KTH MAP ,Kista

KTH Applied Phys., Albanova
Nanophysics
Bio Med. X-ray
Laser Physics

KTH S3,campus

KTH –other
Surface Chemistry
Biotechnology

Companies:
Cobolt, Lingvita,
Spintronix
KIMAB

SU Physics, Albanova
Exp. Cond. Mater Physics
Quantum Optics

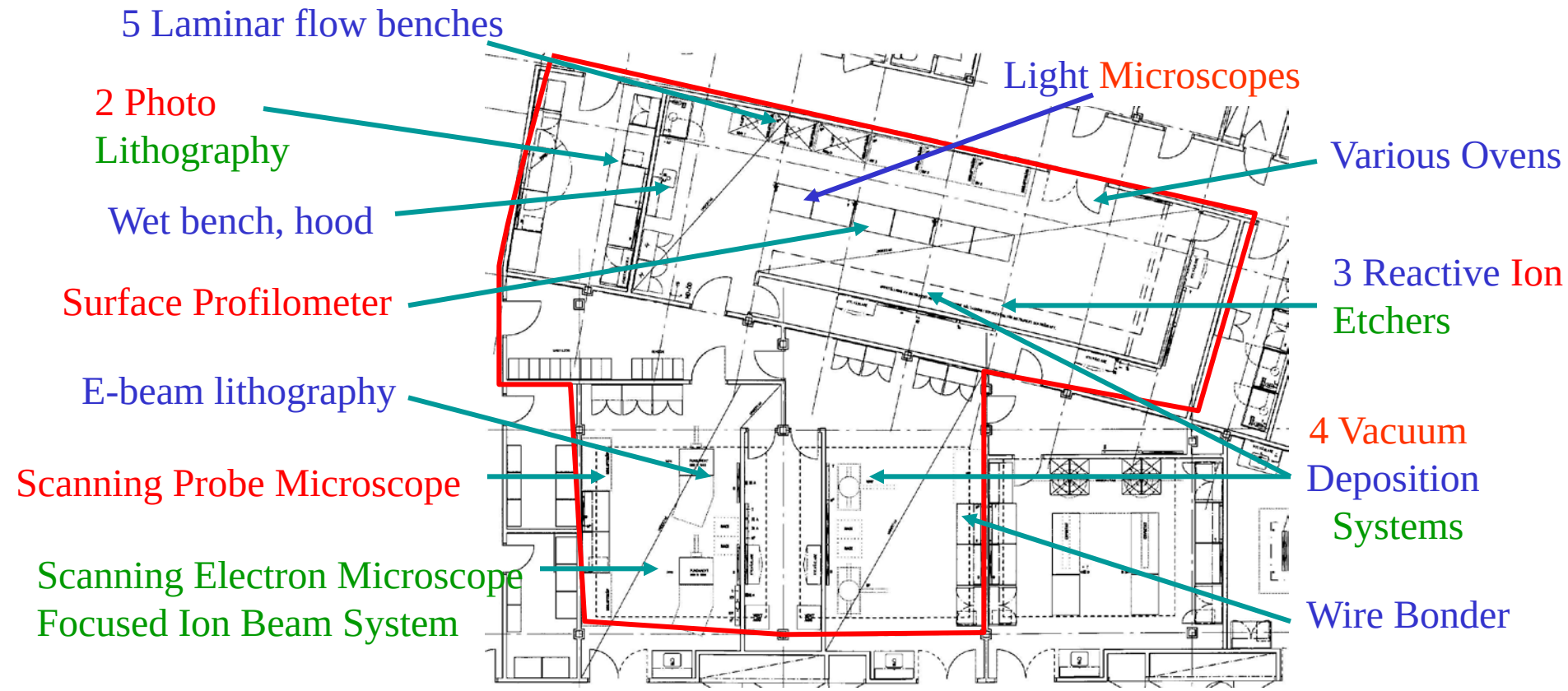
Funding:

Phase 1: 9 M SEK K A Wallenberg

Phase 2: 10 M SEK K A Wallenberg

Phase 3: 7 M + 3M SEK K A Wallenberg +VR

(+ ca 4.5 M SEK: VR, G. Gustafsson, KTH Start-up, Misc.)



345 m^2 total - 285 m^2, clean room 500 – 2000 part. / ft^3
Lab coat , hair net, latex gloves, clean benches

AlbaNova
FYSIK ASTRONOMI BIOTEKNIK

KTH VETENSKAP OCH KONST

UNIVERSITET STOCKHOLMS

Nano Fab Lab, Stockholm Sweden

Albanova Nanofabrication Facility

Equipment

E-beam lithography
Booking FBMS upgrade
Dual beam system
Booking
SPM/AFM/STM
Booking
Profilometer
RIE, Ar, O_2
RIE, BCl_3, Cl_2
Mask aligner
Booking
Projection mask aligner
Multi target Sputtering System
UHV E-gun sputtering
HV E-gun deposition
Booking
UHV E-gun / Ion gun Bonder
Laminar flow benches
Optical microscope, DIC, DF
Opt. micr. 5 Mpix camera
Opt. micr., yellow lab
Fluor. micr. w. cooled CCD
Stereoscope
Resist spinner
Resist spinner #2
Hotplate
Hotplate #2
Clean water
Carbon coater
Evacuated oven
Ultrasound, vari-power

Useful links

Usage and Safety
Activty Report (pdf)
Resist data limited access
Clean-room partcle count
Nano-Fab-Lab Wiki
NanoFabLab users, phonelist
Service and labs, phonelist
Chemical database

- Joint KTH SU laboratory facilities, with broad user spectrum
- Nano and micro scale fabrication, imaging and metrology
- Graduate students and post docs are users
- Low overhead costs, flexible lab environment for exploratory research

KTH Applied physics and SU Physics jointly run this facility located in AlbaNova University Center There are about 30 active users from several departments at KTH and SU. If you are interested in access, contact director Prof. David Haviland or manager Dr. Anders Liljeborg.

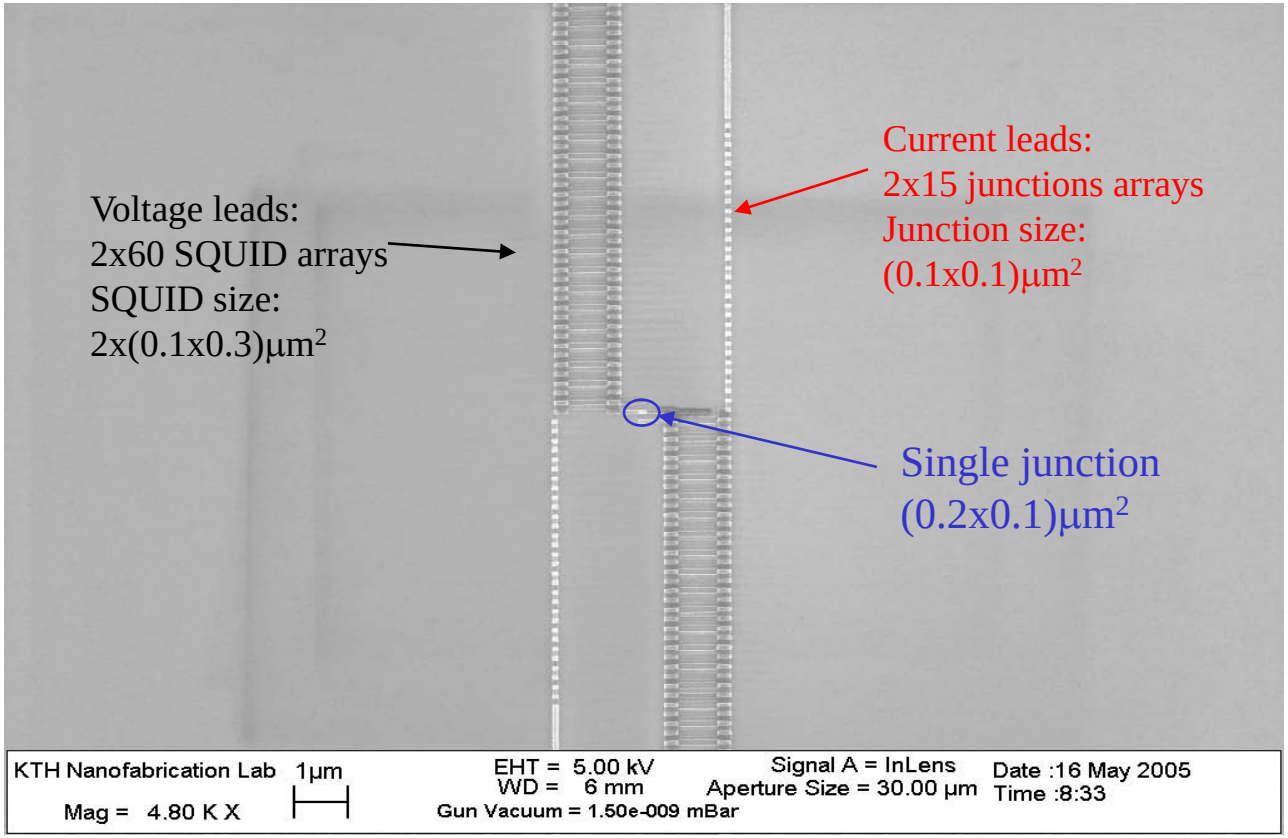
Most of the equipment has been financed by grants from the K. A. Wallenberg Foundation.

Homepage

- Simple, Functional, not Sexy
- Practical user-oriented
- Manuals, Dos and Don’ts
- Up-to-date with problems, fixes

Josephson Junction Arrays for Circuit QED

David Haviland, Applied Physics, KTH

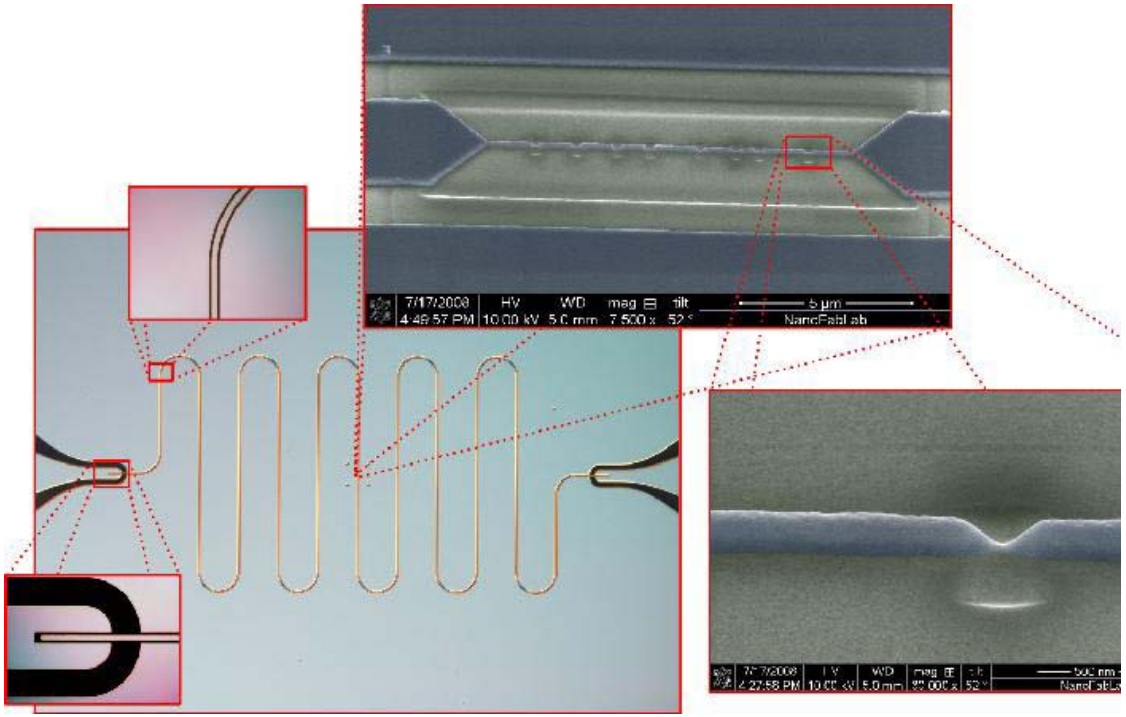


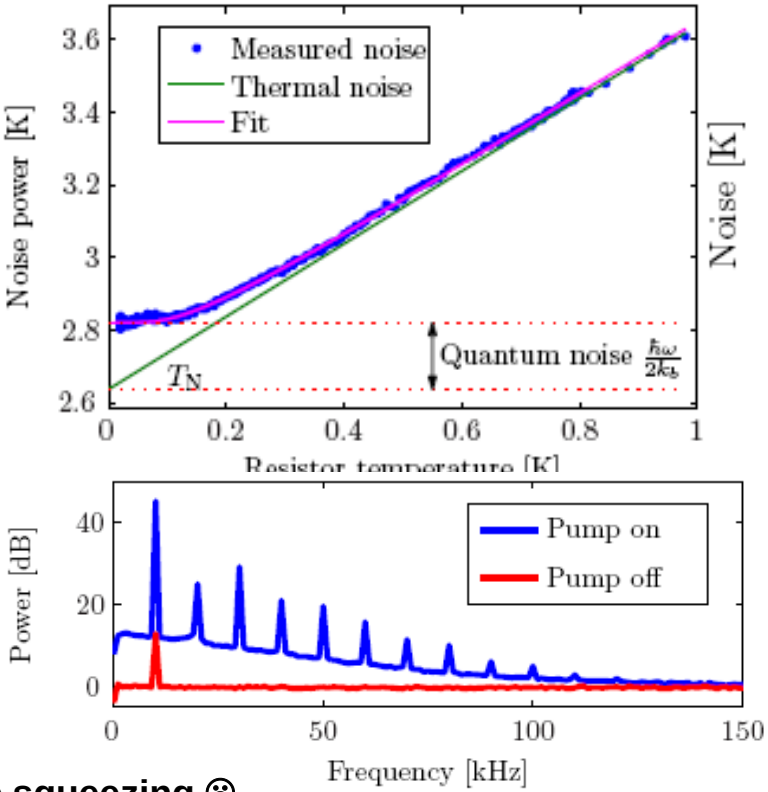
- 800 tunnel junctions in circuit
- SQUID's give tunable Josephson coupling.
- High impedance gives Coulomb blockade of superconducting condensate.

Phase-Charge Duality of a Josephson Junction in a Fluctuating Electromagnetic Environment.
S. Corlevi, W. Guichard, F.W.J. Hekking and D. B. Haviland. Phys. Rev. Lett. **97**, 096802 (2006)

Superconducting microresonators for Parametric amplification and quantum noise squeezing

David Haviland, Applied Physics, KTH Albanova





Amplifier Noise temperature 440 mK, no noise squeezing ☹

E. Tholén, A. Ergul, K. Stannigel C. Hutter and D. B. Haviland. Proc. Nobel Symp. on Quantum,Phys. Scr. 014019 (2009)

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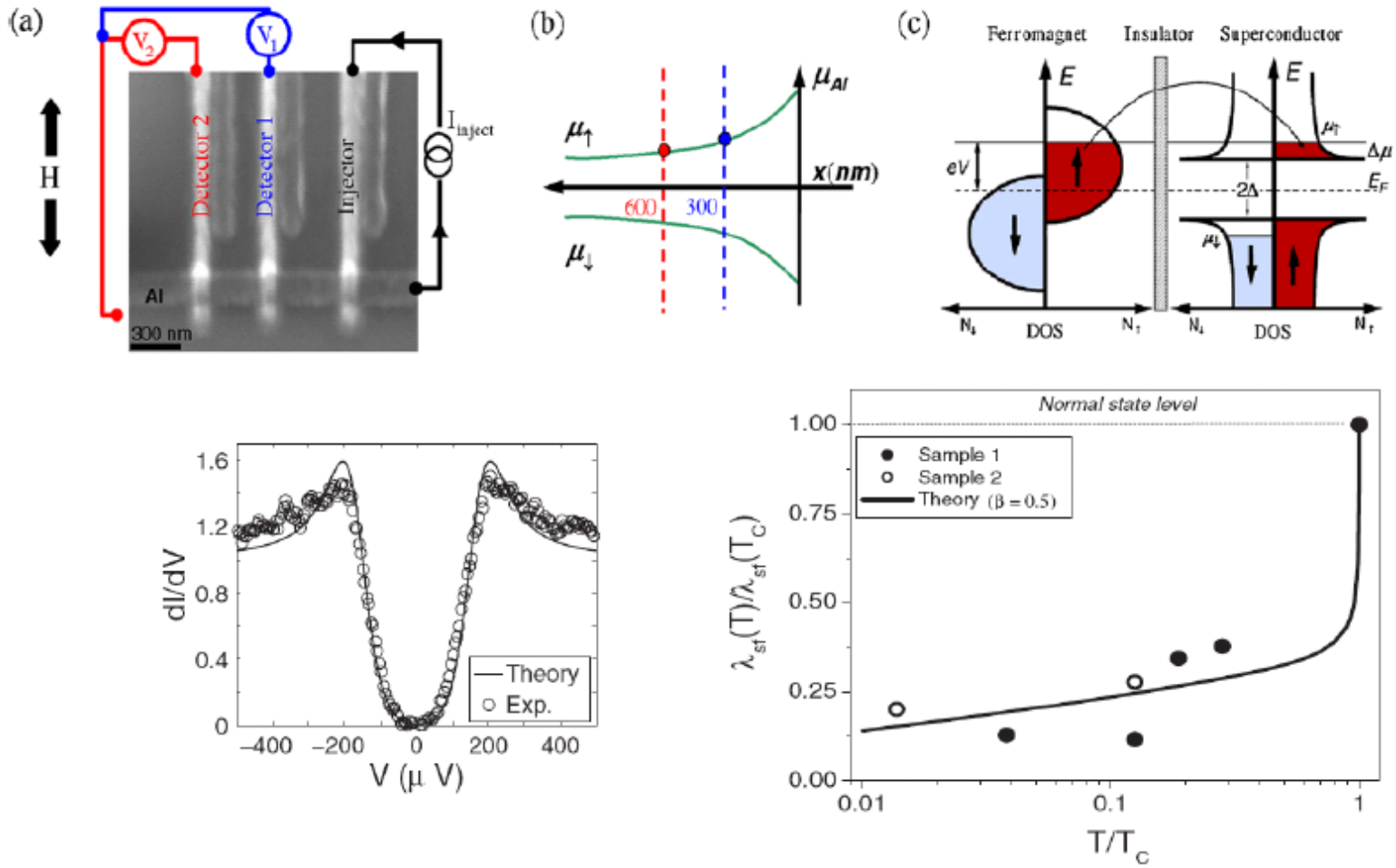
Nano Fab Lab, Stockholm Sweden

Spin Transport in Mesoscopic Superconductors

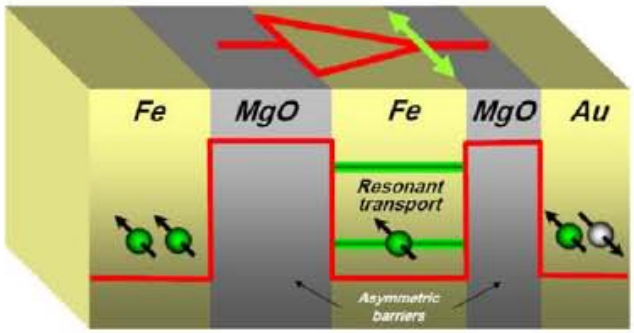
Vladislav Korenivski , Applied Physics, KTH Albanova

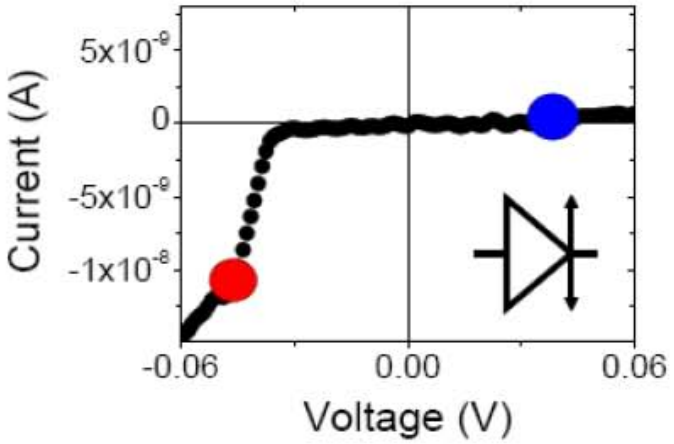


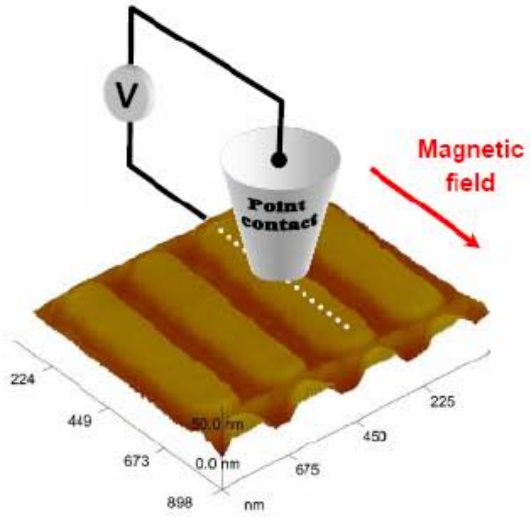
Spin injection and relaxation in a mesoscopic superconductor, N. Poli, J. P. Morten, M. Urech, A. Brataas, D. B. Haviland, V. Korenivski, Phys. Rev. Lett. 100 (2008) 136601

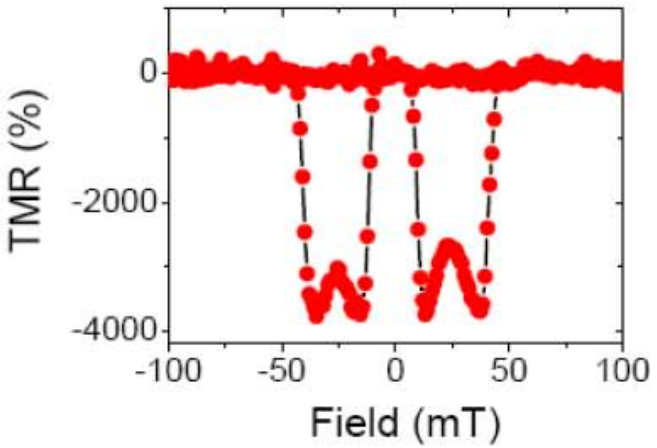
Spin Diode

Vladislav Korenivski , Applied Physics, KTH Albanova







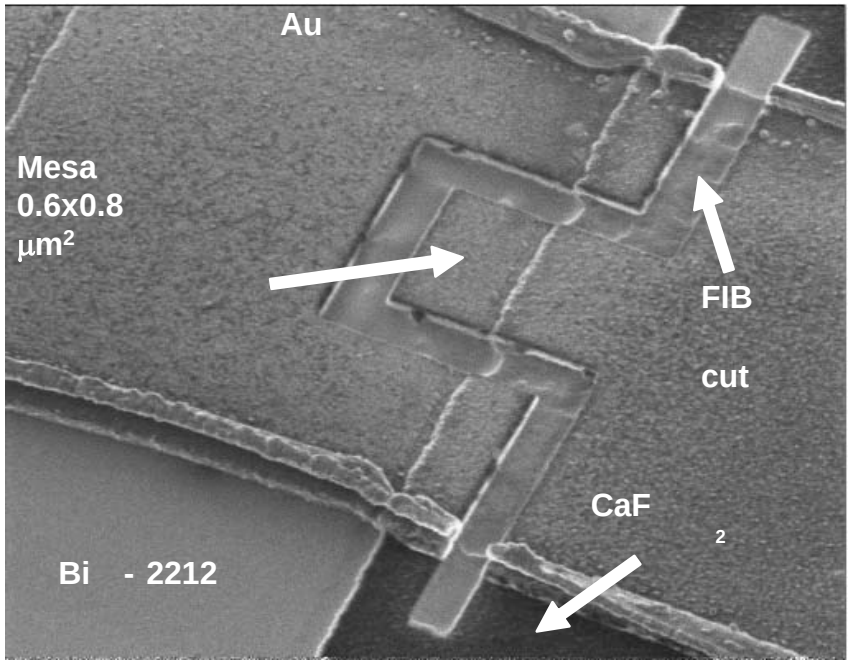


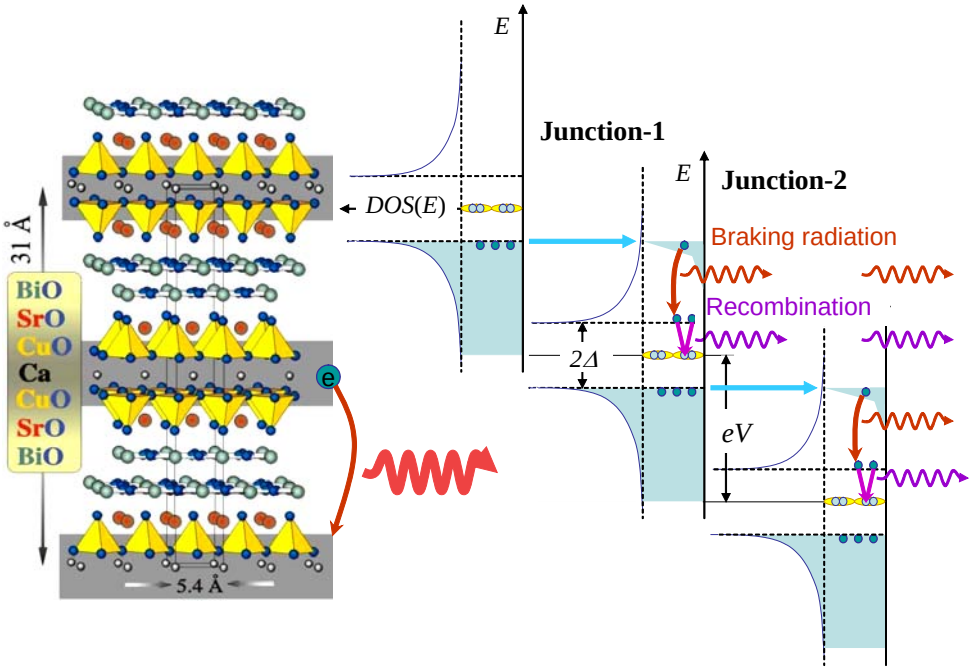
Spin Diode Based on Fe/MgO Double Tunnel Junction, A. Iovan, S. Andersson, Yu. G. Naidyuk, A. Vedyaev, B. Dieny, V. Korenivski, Nano Letters 8 (2008) 805

Intrinsic tunneling in high Tc superconductors and natural atomic superlattices

Vladimir Krasnov, Dept. Physics, SU Albanova

Quantum cascade phenomenon in $Bi_2Sr_2CaCu_2O_8$ single crystals





V. Krasnov, Phys. Rev. Lett. 97, 257003 (2006)

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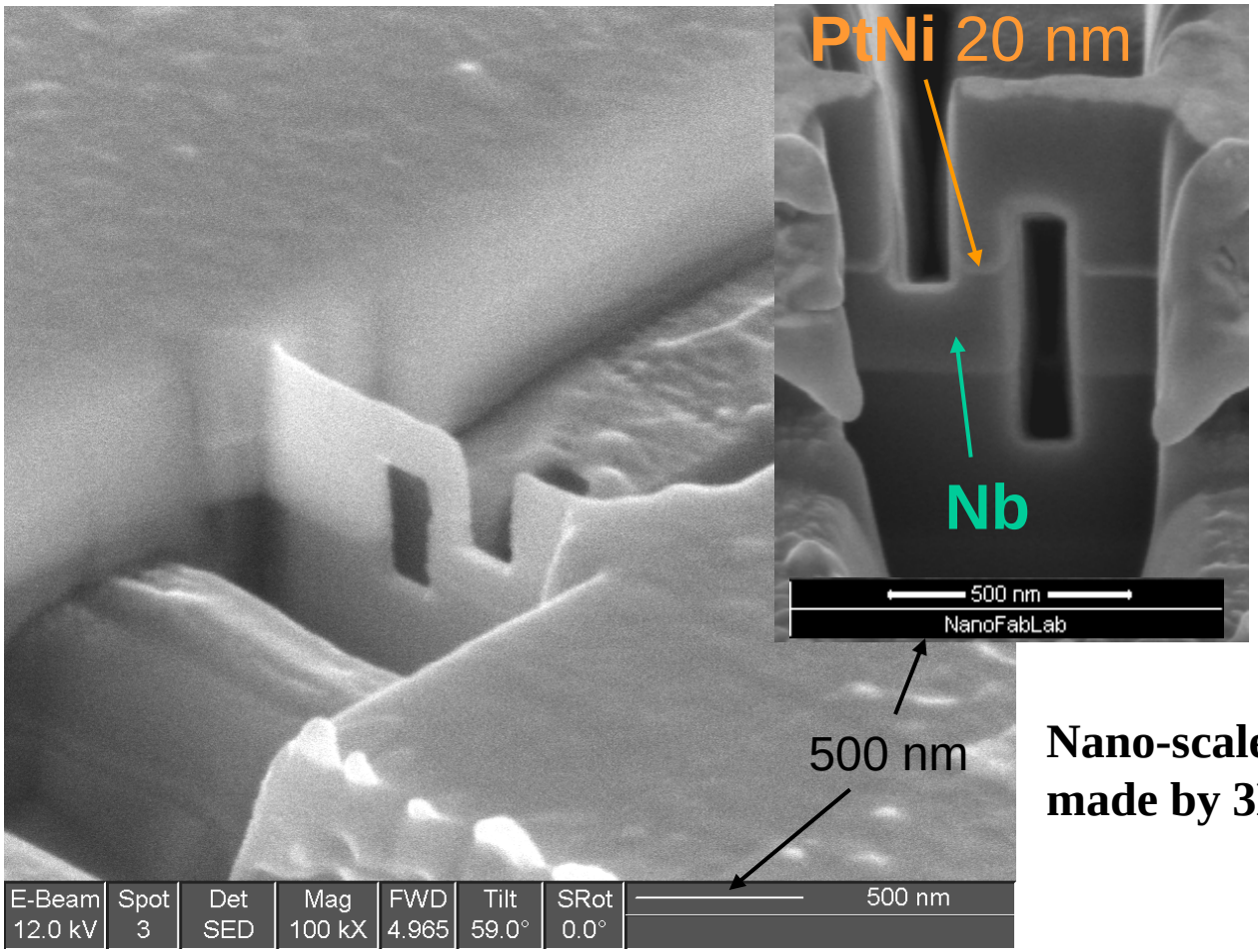
Nano Fab Lab, Stockholm Sweden

Hybrid Superconductor-Ferromagnet Components for Quantum Electronics

Vladimir Krasnov, Dept. Physics, SU Albanova



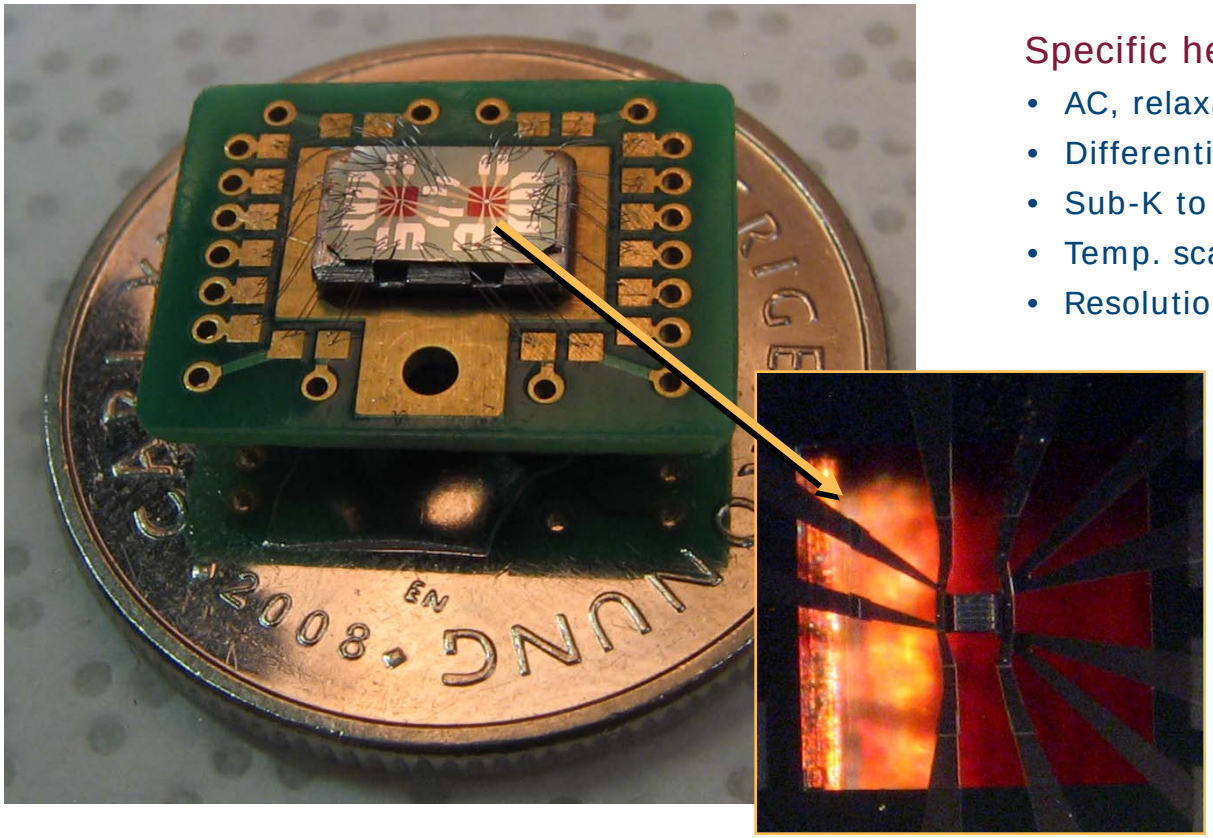
Nano-scale SFS junctions made by 3D FIB sculpturing

AlbaNova FYSIK ASTRONOMI BIOTEKNIK

Nano Fab Lab, Stockholm Sweden

Nanocalorimetry for thin films and mg to sub-ug crystals

Andreas Rydh, Department of Physics, Stockholm University



Specific heat capacity

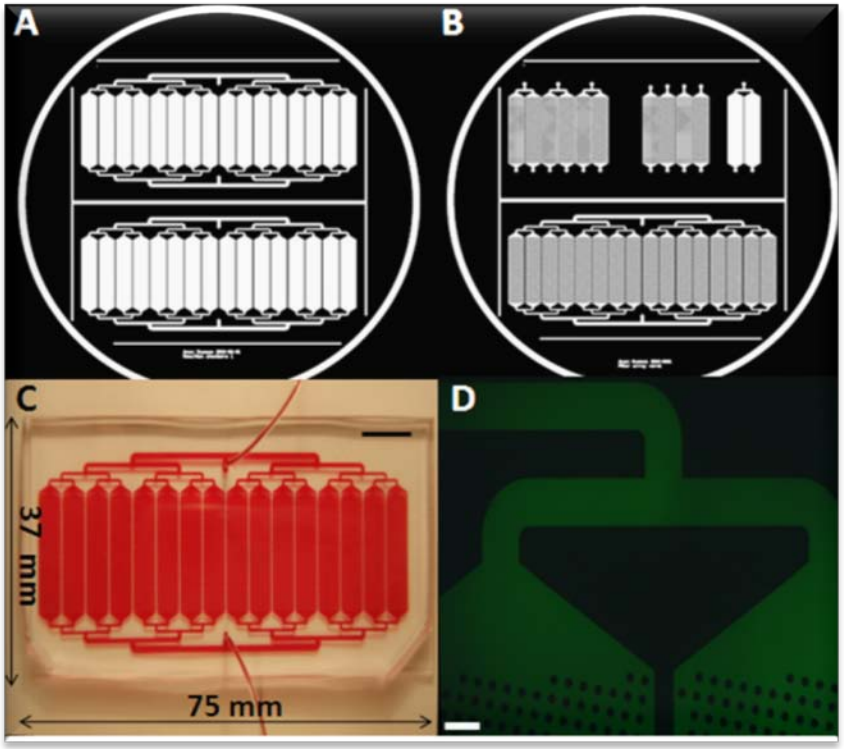
- AC, relaxation methods
- Differential setup
- Sub-K to 400 K
- Temp. scan 100 K within cell
- Resolution: 1 in 10^4 to 10^5

Si_3N_4: 150 nm
area 1 x 1 mm^2
30-50 nm layers

Membrane-based calorimetry for studies of sub-microgram samples
S. Tagliati, A. Rydh, R. Xie et al., Journal of Physics: Conference Series **150**, 052256 (2009).

Microfluidic devices for blood diagnostics

Aman Russom, Applied Physics, KTH



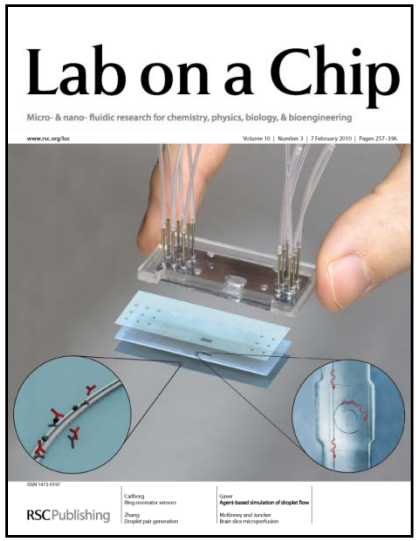
(A-B) Mask designs, and (C-D) PDMS based microfluidic devices functionalized with antibodies. Scale: 250µm

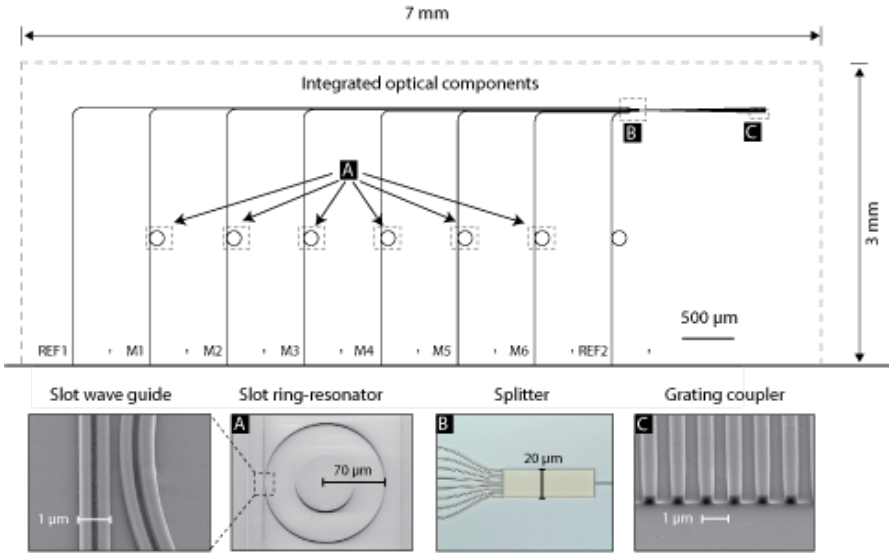
- Microfluidic based cell capturing assay
- Parallel-plate immunoassay devices
- Application: capturing of white blood cells and bacteria from blood

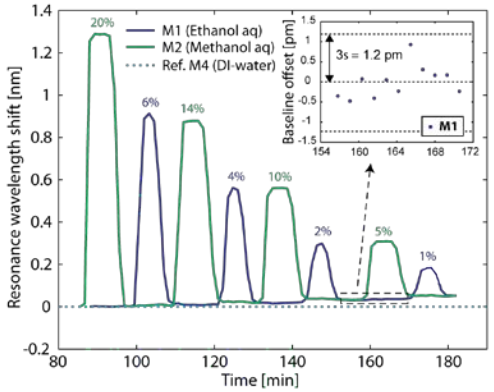
Dean-coupled inertial focusing for ultra-high throughput particle filtration.
S. Ardabili, J. Gantelius, J. Kowalewski, H. Brismar and A. Russom.
Micro Total Analysis Systems, Groningen Netherlands, Oct 2010. (accepted)

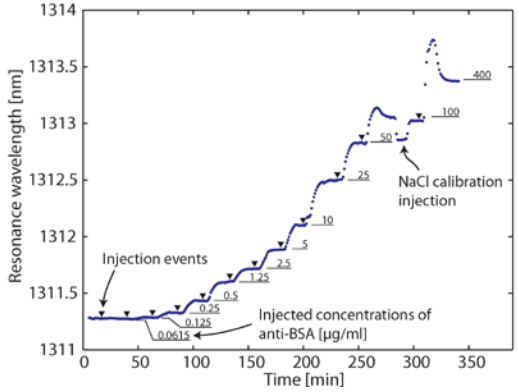
Optical Ring Resonator Biosensor Arrays

Goran Stemme, Microsystem Technology Lab, KTH









- Sensor array for multiplex label-free biosensing
- Concurrent real-time measurement of up to 6 biomarkers
- Integrated microfluidic sample handling
- Surface mass density detection limit 0.9 pg/mm^2

"A packaged optical slot-waveguide ring resonator sensor array for multiplex label-free assays in labs-on-chips". **Carlborg**, **Gylfason**, Sohlström, Stemme, W. Van der Wijngaart et al., *Lab on a Chip*, **10**, 281, (2010)

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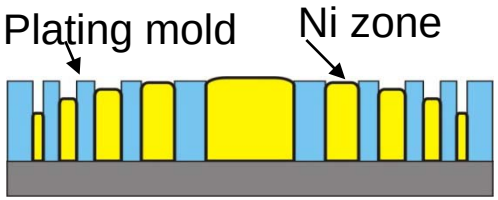
Nano Fab Lab, Stockholm Sweden

X-ray diffractive optics

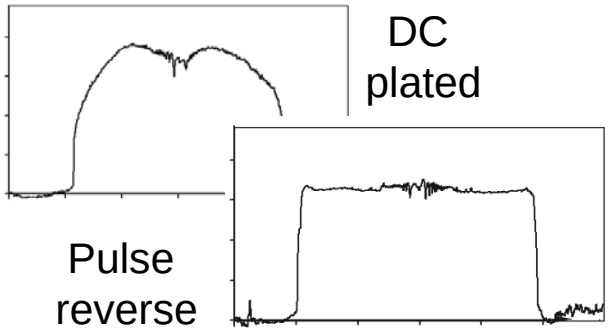
Hans Hertz, Applied Phys. KTH Albanova

M. Bertilsson et al., RSI (2007); Holmberg et al, JVST (2006); Lindblom et al, JVST (2006)

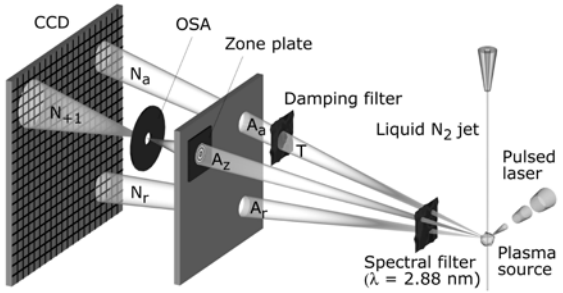
Electro-plating uniformity

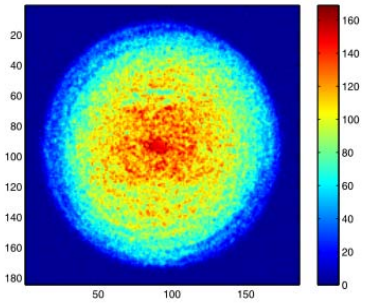


Pulse plating

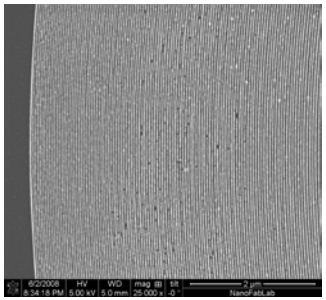


Local diffraction efficiency measurm.

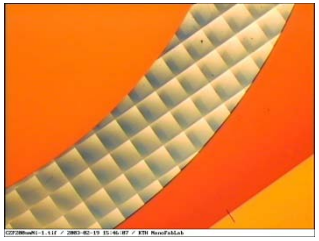




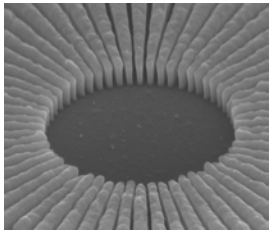
Structures



20-25 nm Ni zone plates



5 mm diam condensers



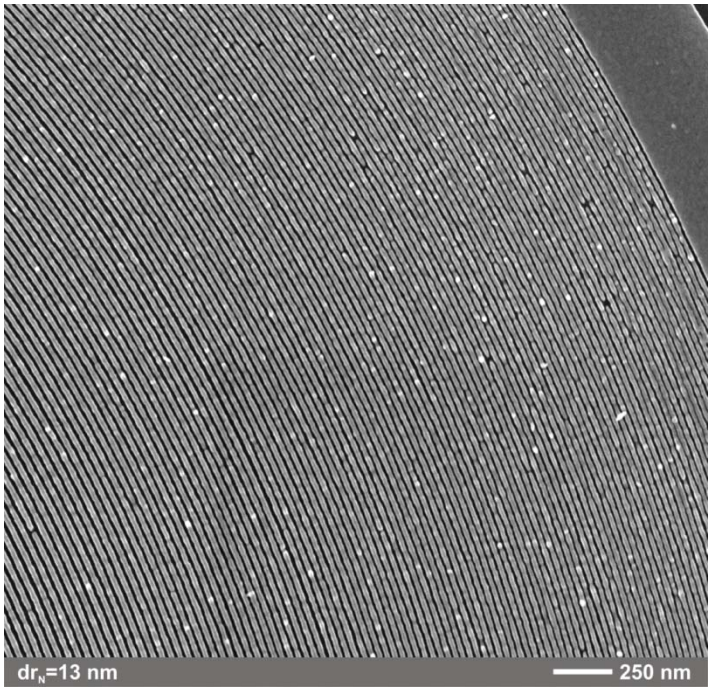
Test patterns

High Resolution EBL

Hans Hertz, Applied Phys. KTH Albanova

Reinspach et al,, JVST B (2009)

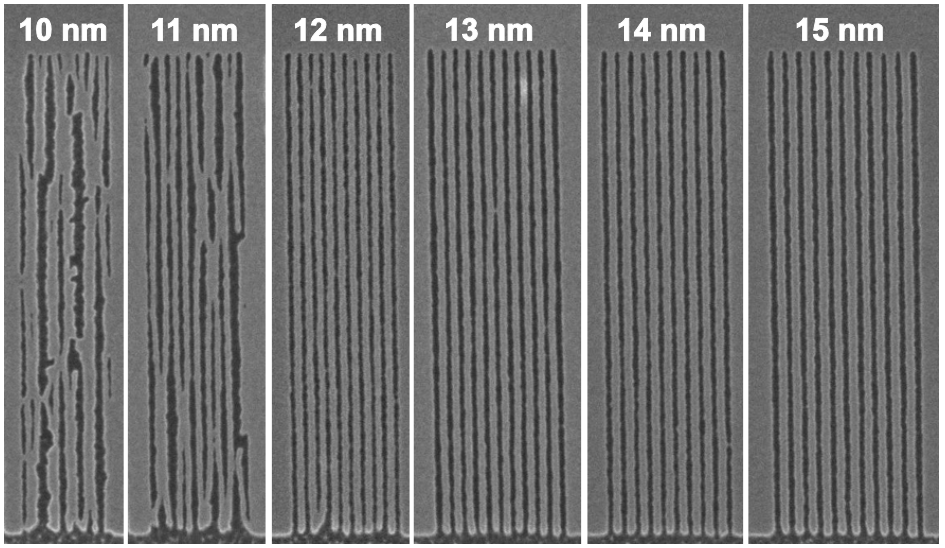
Single-write Ni ZP



Ø=19 µm
dr_N=13 nm; h=35 nm
f=100 µm @ λ=2.48 nm
Excellent uniformity
Efficiency: 2.7% (15 nm/h=55 nm zp)

Cold development: ZEP in hex acet

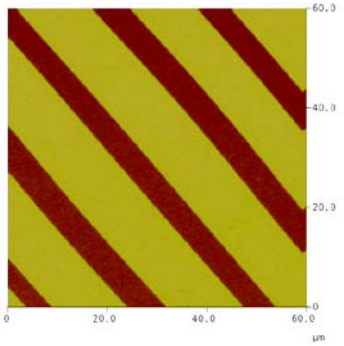
Good Mold stability



Ferroelectric domain engineering for novel optical applications

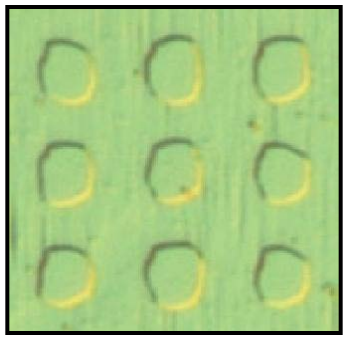
Fredrik Laurell, Applied Physics, KTH Albanova

Micro- and nano-meter ferroelectric domains electrically polled 1 mm bulk ferroelectric crystal



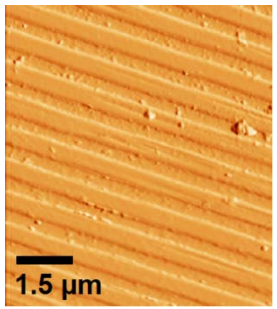
Frequency conversion

Λ= 20 µm



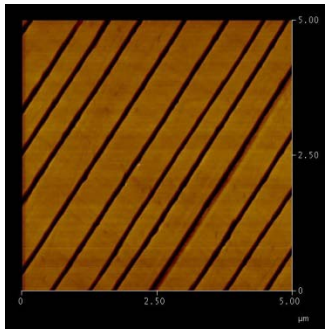
2D nonlinear photonic crystal

Λ= 6.09 µm x 6 µm



Electrically addressable Bragg reflectors

Λ= 800 nm



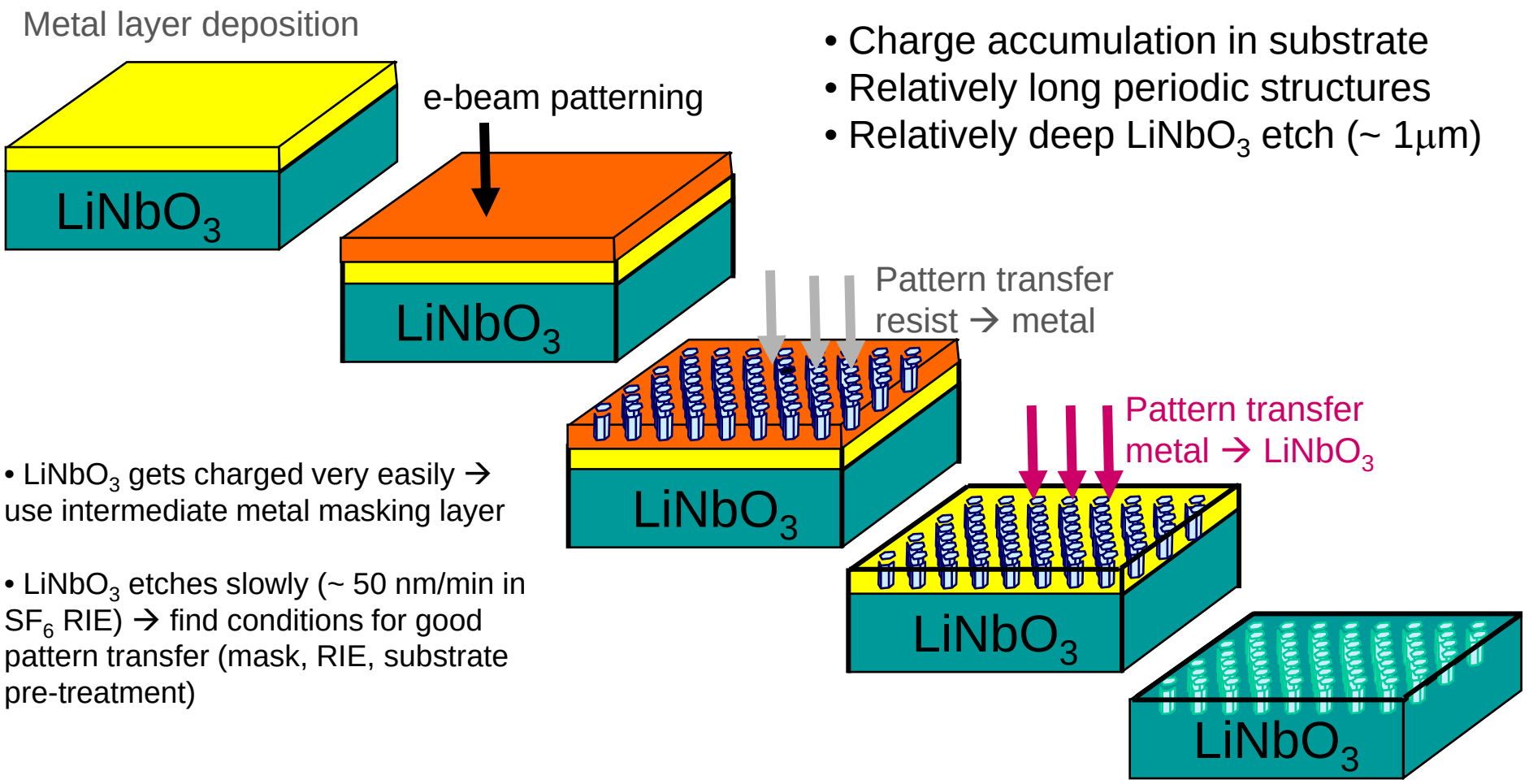
Self-assembled nanostructures

Λ= 500 nm

C.Canalias et al. Appl. Phys. Lett. 86,181105 (2005)

Nonlinear photonic crystals

Fredrik Laurell, Applied Physics, KTH



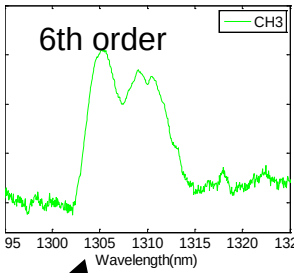
- Charge accumulation in substrate
- Relatively long periodic structures
- Relatively deep $LiNbO_3$ etch (~ 1μm)

- $LiNbO_3$ gets charged very easily → use intermediate metal masking layer

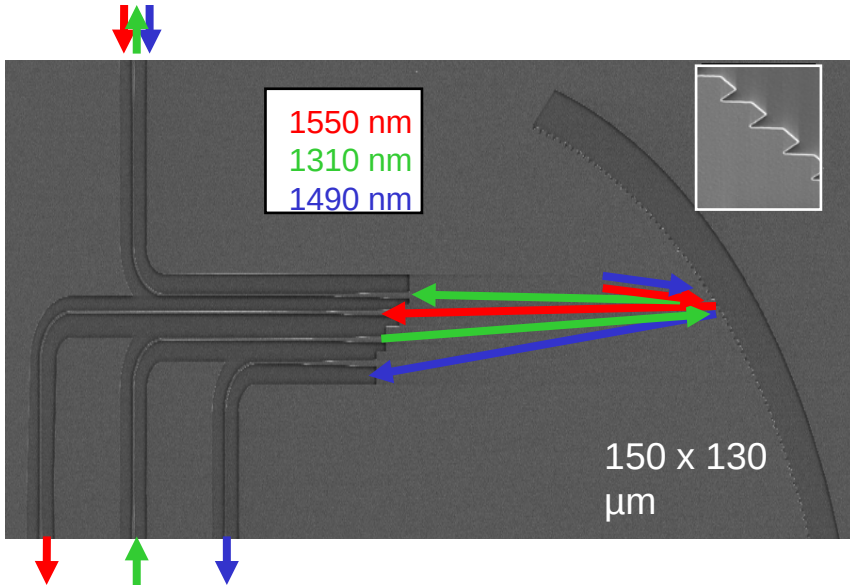
- $LiNbO_3$ etches slowly (~ 50 nm/min in SF_6 RIE) → find conditions for good pattern transfer (mask, RIE, substrate pre-treatment)

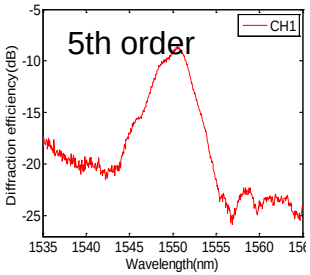
SOI cross-order Echelle-grating triplexer

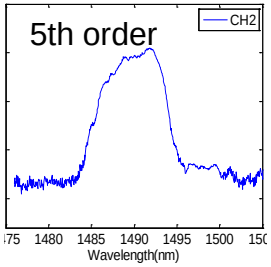
Lech Wosinski, FMI, KTH Kista



Different diffraction orders to cover large spectral range and keep the device compact.







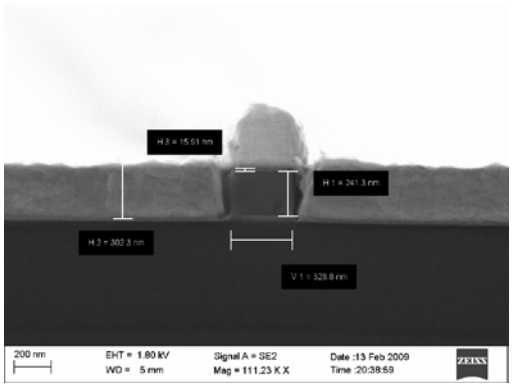
RESULTS:

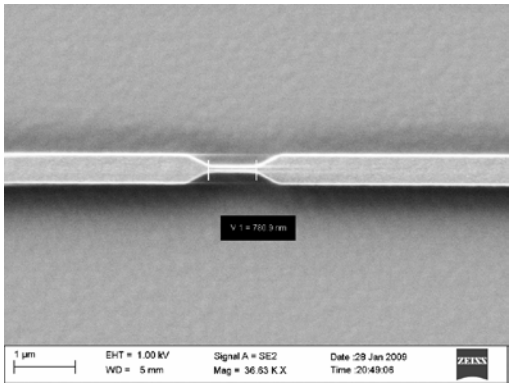
- crosstalk < 20dB
- loss per channel ≈ 11dB

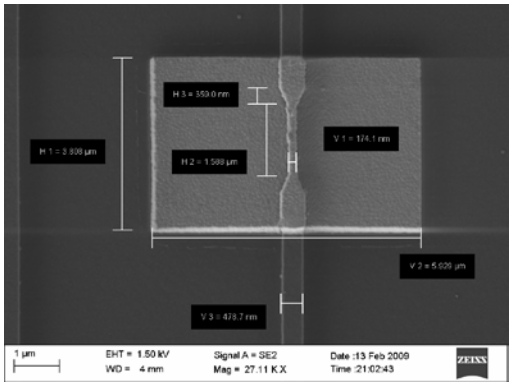
"Experimental demonstration of a cross-order echelle grating triplexer based on an amorphous silicon nanowire platform", N. Zhu, J. Song, L. Wosinski, S. He and L. Thylen, Optics Letters, Vol. 34, 383-385 (2009).

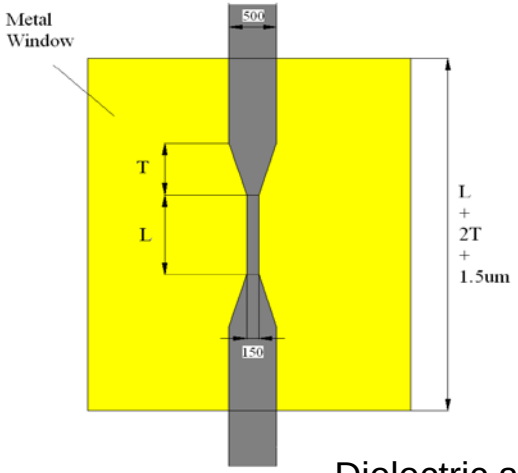
Plasmonic slot waveguides for photonics

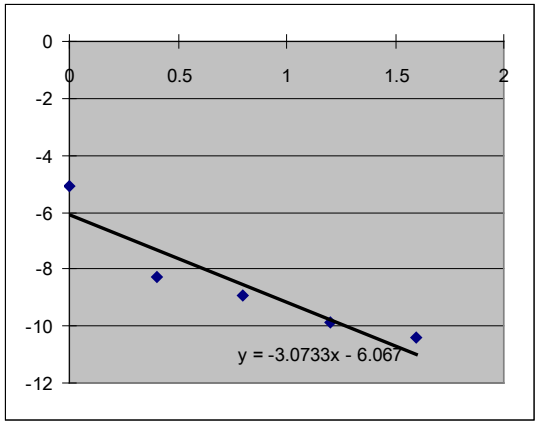
Lech Wosinski, FMI, KTH Kista











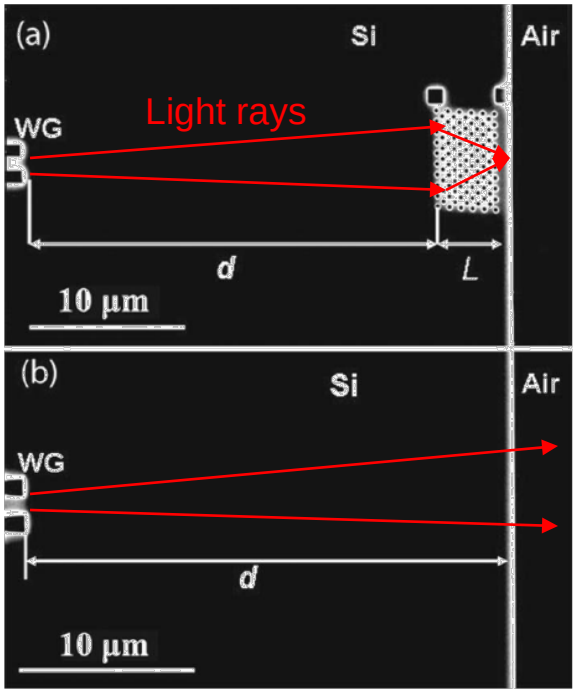
RESULTS:

- Propagation loss = 3.0733 dB/µm
- Loss of coupling between 500nm Si waveguide to 500nm Si wg with metal = 2.1 dB/facet
- Loss of taper/350nm = 0.4 dB/taper

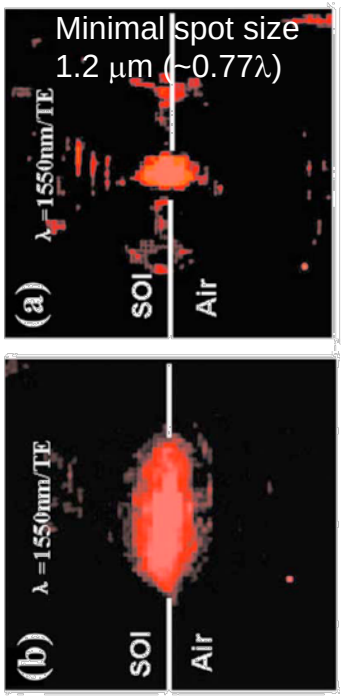
Dielectric and plasmonic slot waveguides for photonic integration
B.Jaskorzynska, Y. Song, N. Zhu, Z. Wang, M. Qiu and L. Wosinski , ICTON 2009,Procs of the IEEE.

Focusing light by negative refraction

Min Qiu, Photonics, KTH



Light focused



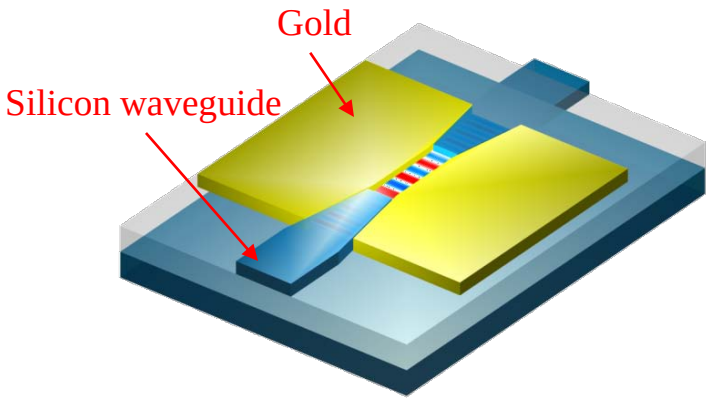
Light spot size at the device edge

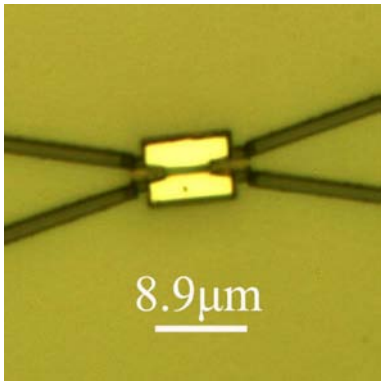
- Near infra-red light focused demonstrated by a two-dimensional silicon photonic crystal flat lens
- Photonic crystal slab fabricated on a silicon-on-insulator substrate by focused-ion-beam direct milling
- Sub-wavelength focusing observed

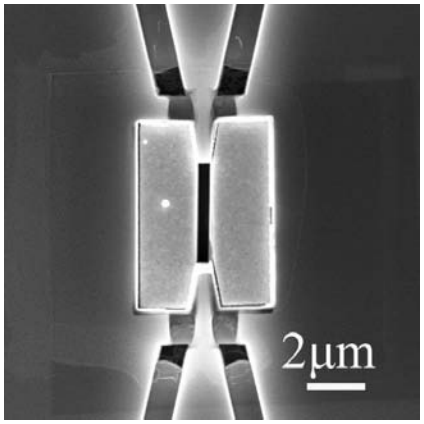
Direct characterization of focusing light by negative refraction in a photonic crystal flat lens
J. Tian, M. Yan, M. Qiu, C. G. Ribbing, Y.-Z. Liu, D.-Z. Zhang, and Z.-Y. Li, Appl. Phys. Lett. **93**, 191114 (2008)

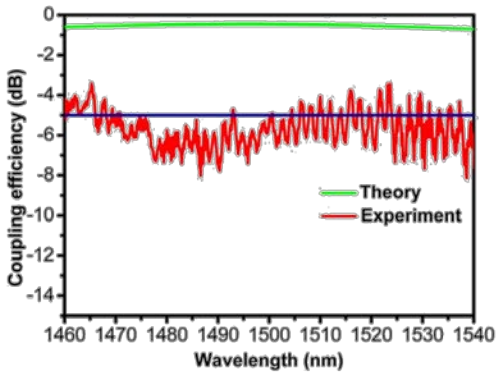
Broadband plasmonic waveguide coupler

Min Qiu, Photonics, KTH









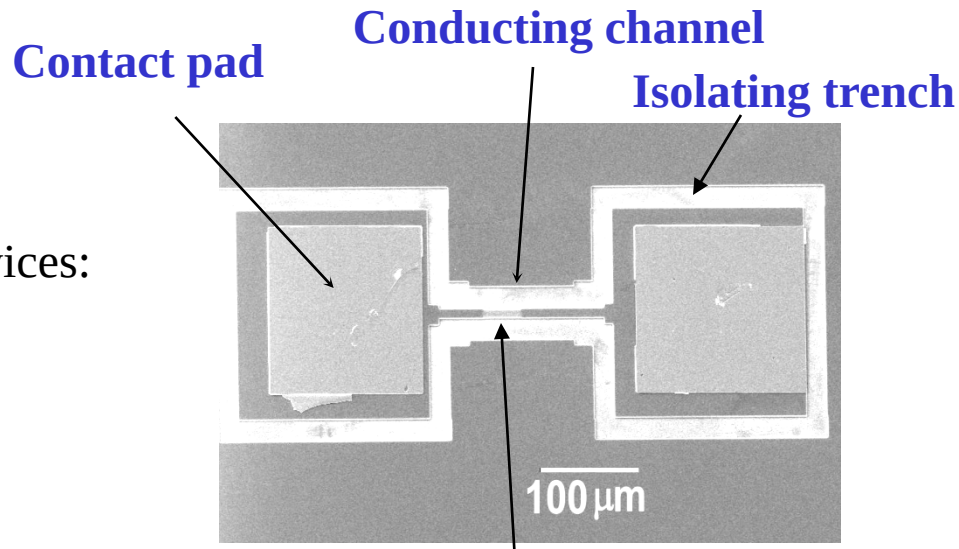
- Plasmonic coupler is composed of a tapered silicon strip waveguide and a subwavelength metal gap waveguide
- 35% coupling efficiency per facet demonstrated
- A crucial step for hybrid integration of plasmonic components with conventional dielectric components

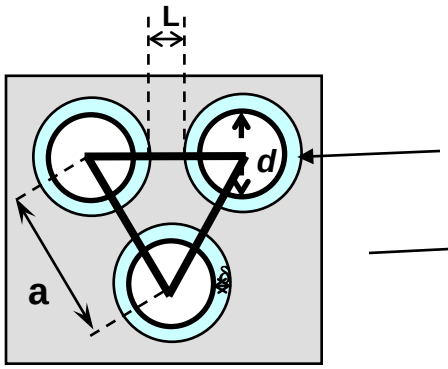
Broadband high-efficiency surface-plasmon-polariton coupler with silicon-metal interface
J. Tian, S. Yu, W. Yan, and M. Qiu, Appl. Phys. Lett. **95**, 013504 (2009)

Carrier Transport in 2D-Photonic Crystals

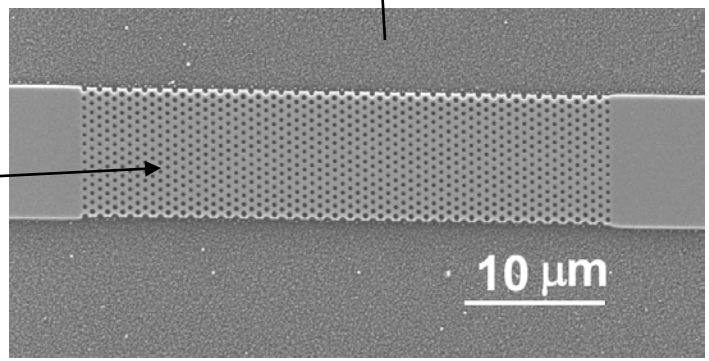
Srinivasan Anand, MAP, KTH Kista

- InP active material, 2D photonic crystal
- Electrically addressed Photonic crystal devices:
- Electrical contact schemes
- Pattern dependent electrical properties





Depleted region Width δ

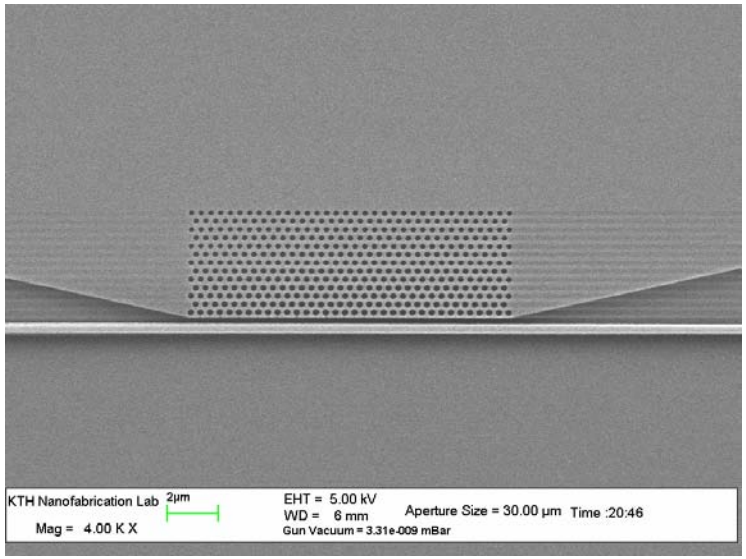


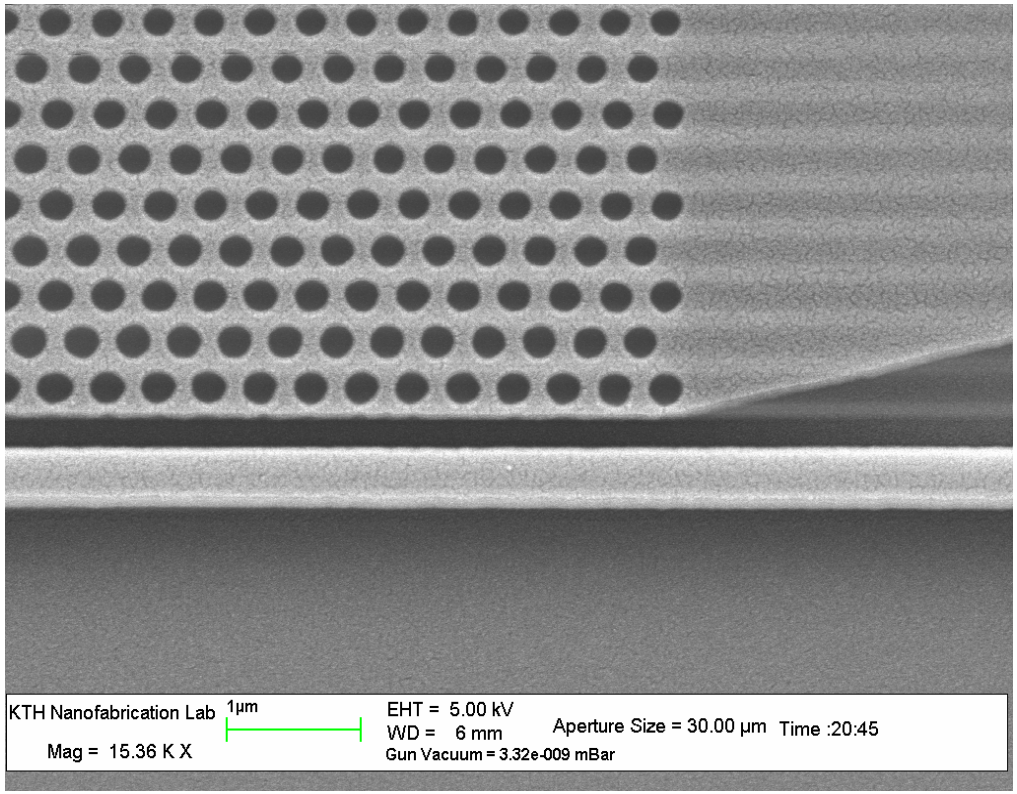
A.Berrier, M. Mulot, G. Malm, M. Östling and S. Anand, Proc. SPIE Optics and Photonics'06

Surface-mode cavity in 2D photonic crystal slabs

Min Qiu, MAP , KTH Kista

- PECVD growth of amorphous silicon on silica structure
- E-beam lithography
- ICP etching
- Application for high Q optical filter





Ziyang Zhang, Matteo Dainese, Lech Wosinski, and Min Qiu, Accepted Appl. Phys. Lett. 2006

AlbaNova FYSIK ASTRONOMI BIOTEKNIK

KTH VETENSKAP OCH KONST

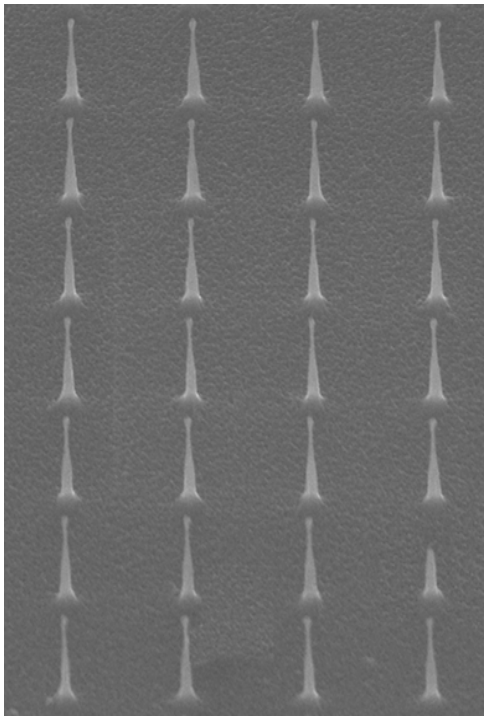
UNIVERSITET STOCKHOLMS

Nano Fab Lab, Stockholm Sweden

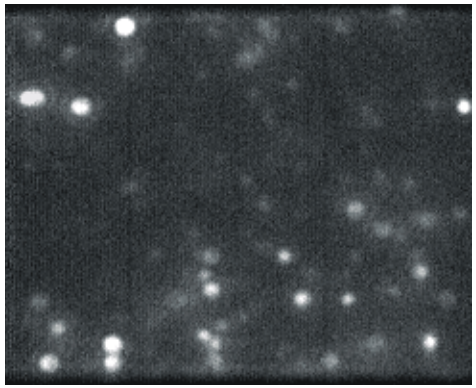
Silicon quantum dots

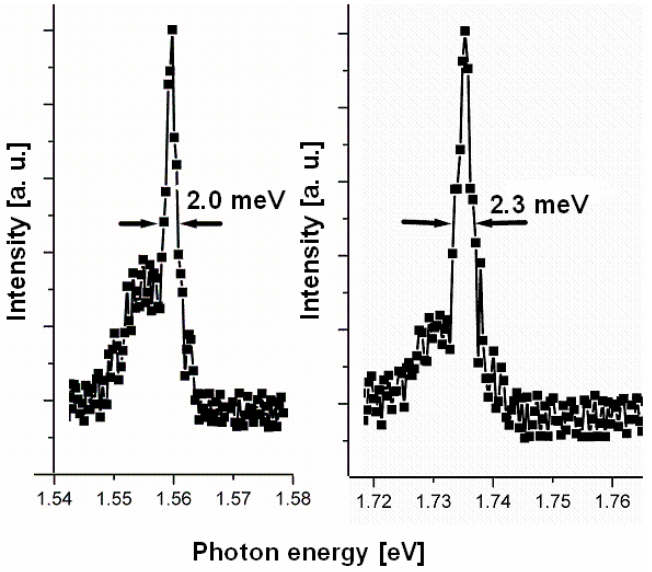
J. Linnros, MAP, KTH Kista

- E-beam lithography
- Size reduction by oxidation
- Removal of oxide

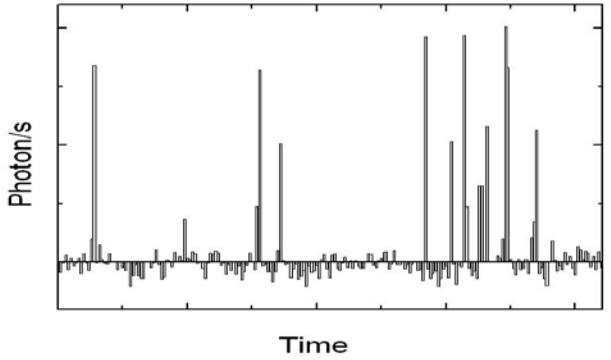


Sharp Photo Luminesence emmision lines





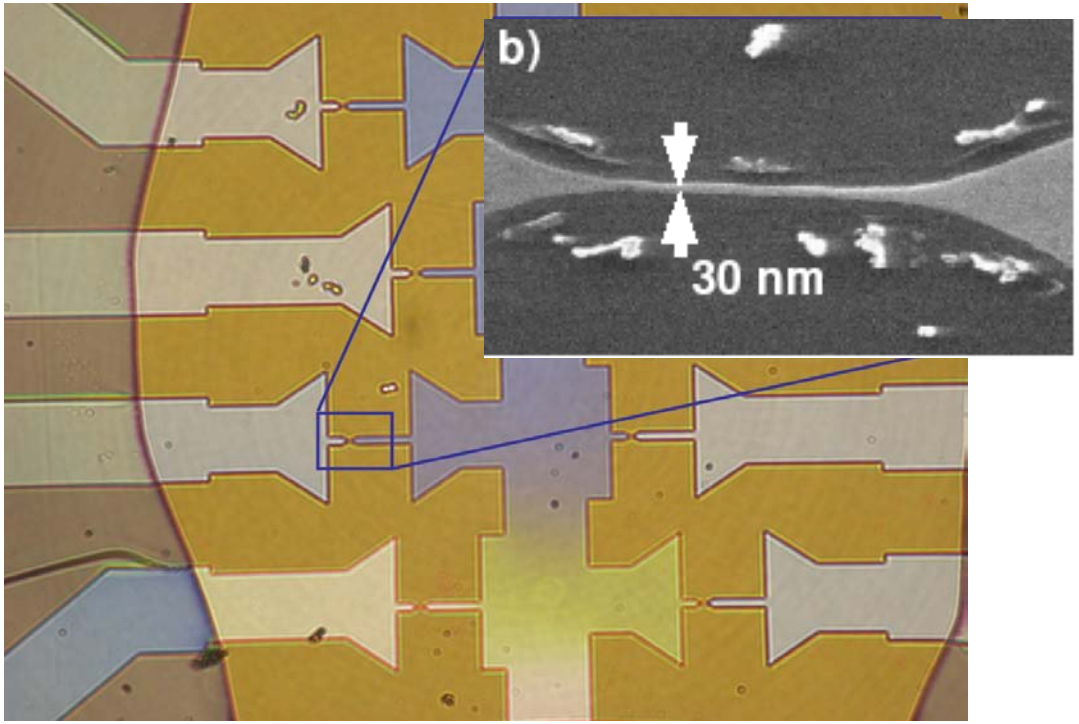
On/Off Blinking

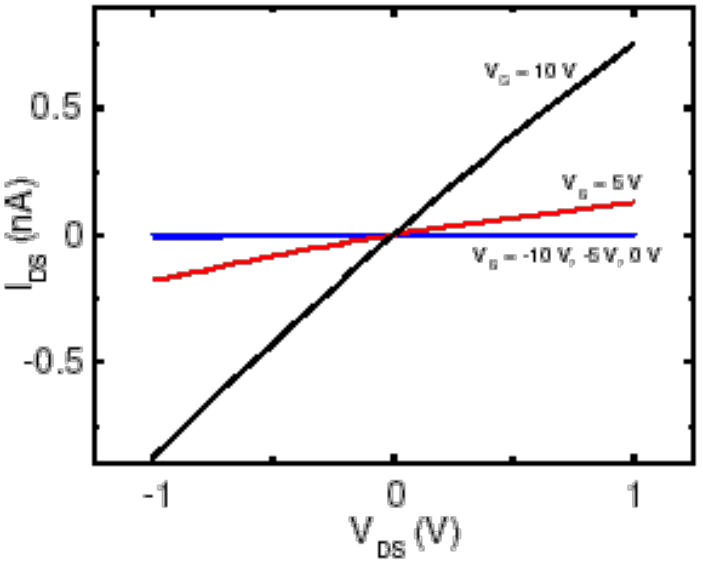


Sychugov et al. PRL 94, 087405 (2005), Sychugov et al. PRB 71, 115331 (2005)

Silicon nanowires

J. Linnros, MAP, KTH Kista





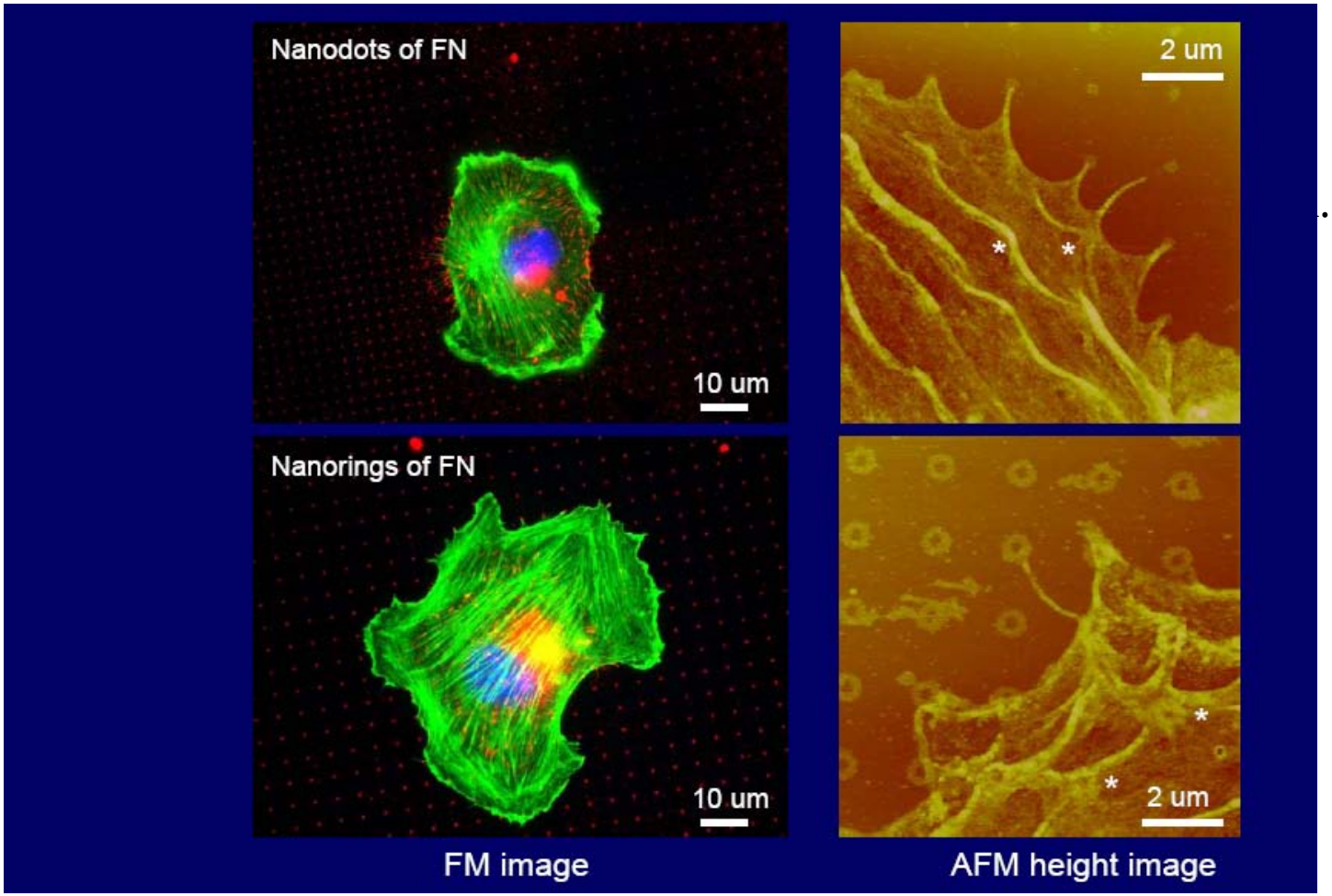
Transistor characteristics

- Chip, SOI technology
- Electron beam lithography
- Size-reduction by
- electrochemical etching

Juhasz et al., NanoLett 5, 275 (2005)

Nano-Patterned Protein templates for cell growth studies

David Haviland, Applied Physics, KTH Albanova

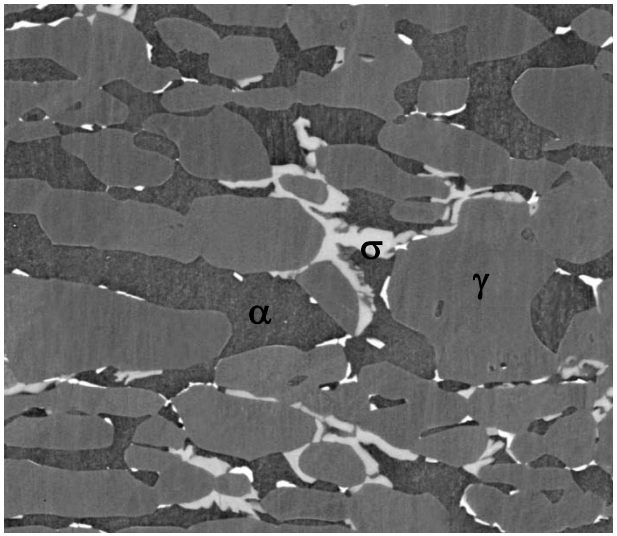


Modulation of Cell Adhesion Complexes by Surface Protein Patterns, D. Pesen and D. B. Haviland, ACS Appl. Mater. Interfaces, 1, 543-548 (2009). (featured article on cover)

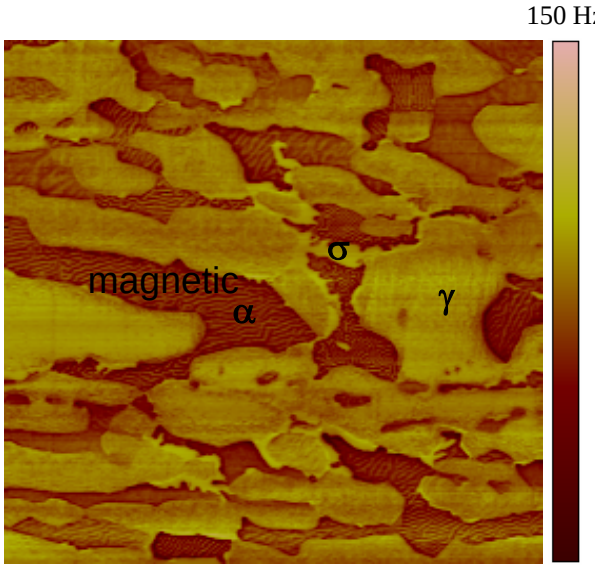
Characterization of relative nobility of phases in duplex stainless steel

Jinshan Pan, Surface &Corrosion Science, KTH

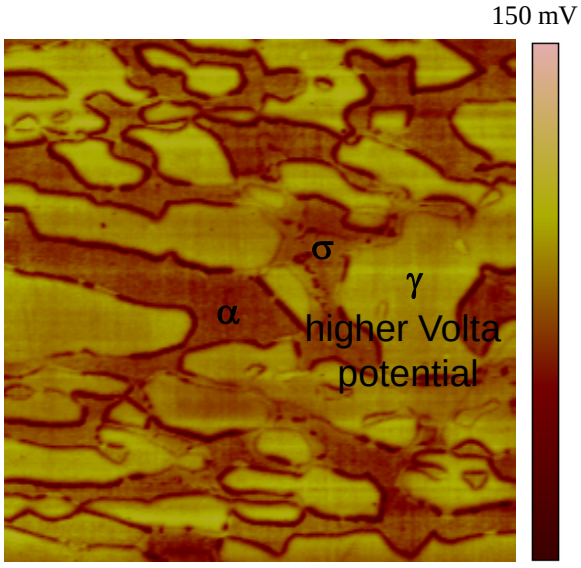
Duplex stainless steel 2205, heat treated, contains ferrite (α), austenite (γ) and sigma (σ) phases



BSE-SEM (σ bright phase)



MFM (α magnetic pattern)

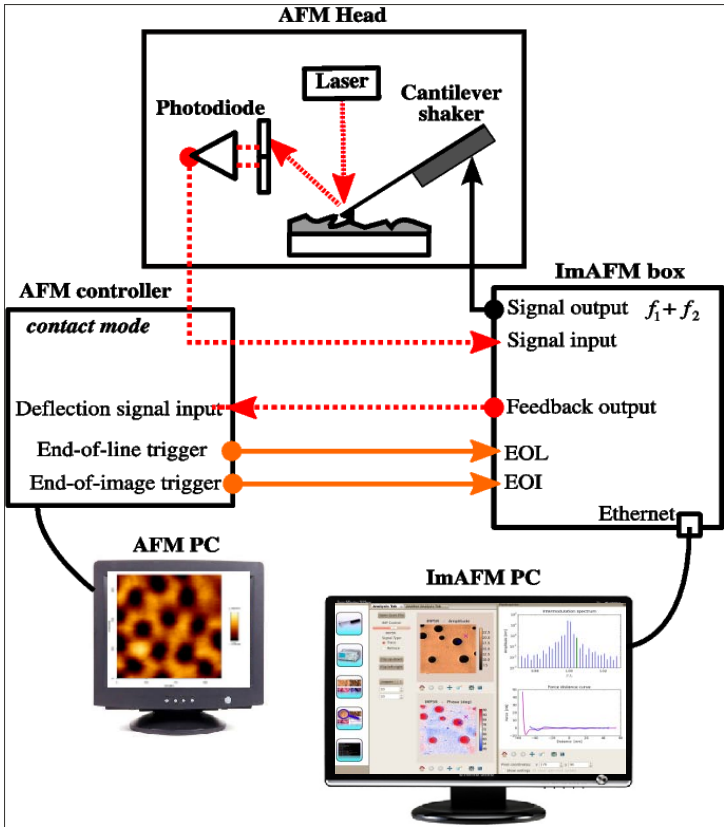


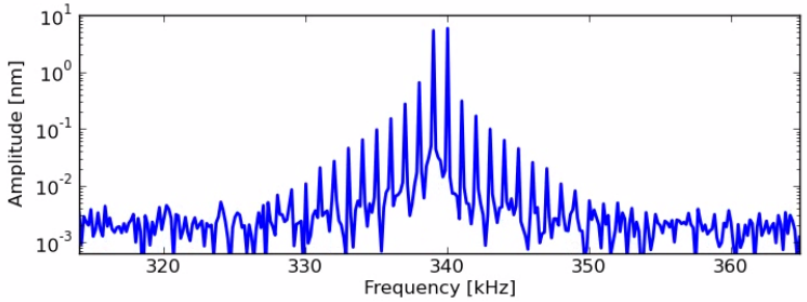
SKPFM (γ higher Volta potential)

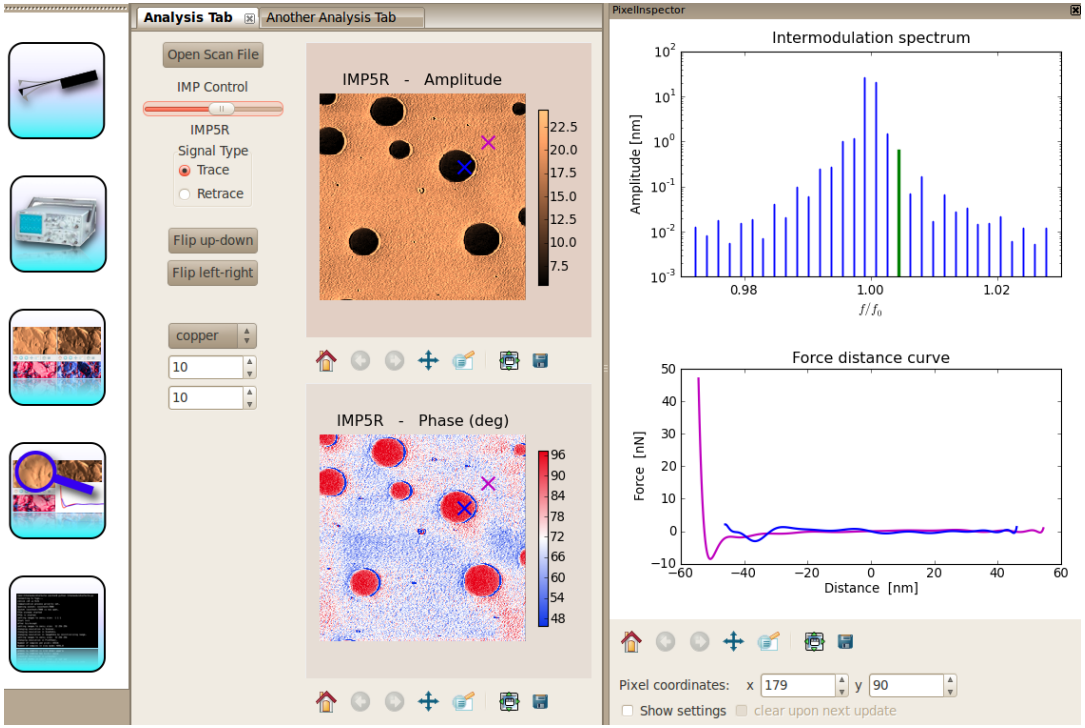
Characterization of phases in duplex stainless steel by magnetic force microscopy scanning Kelvin probe force microscopy
N. Sathirachinda, R. Gubner, J. Pan, U. Kivisäkk, *Electrochem. Solid-State Lett.*, **11**, C42-C45 (2008)

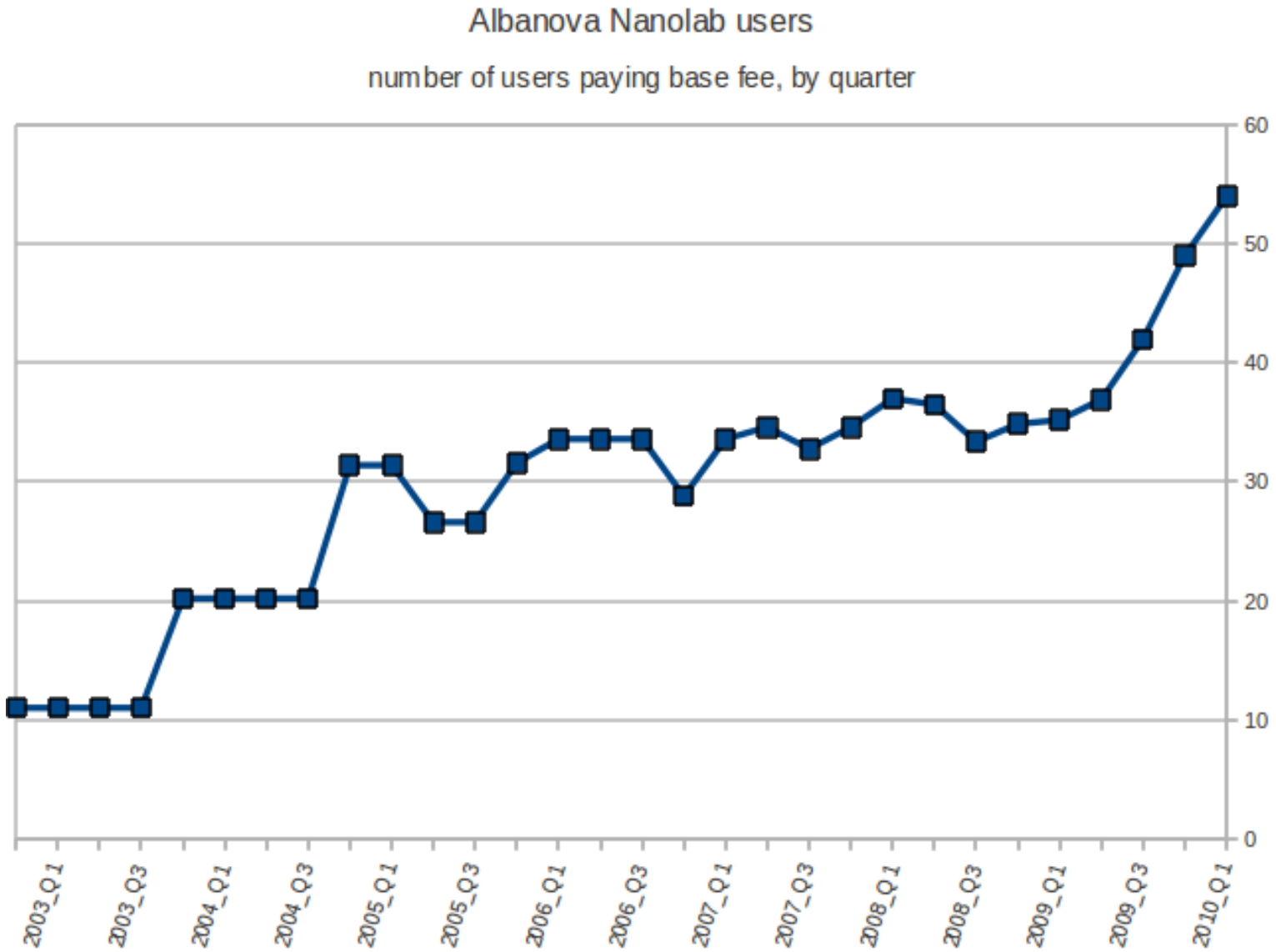
Intermodulation Atomic Force Microscopy

David Haviland, Applied Physics, KTH Albanova







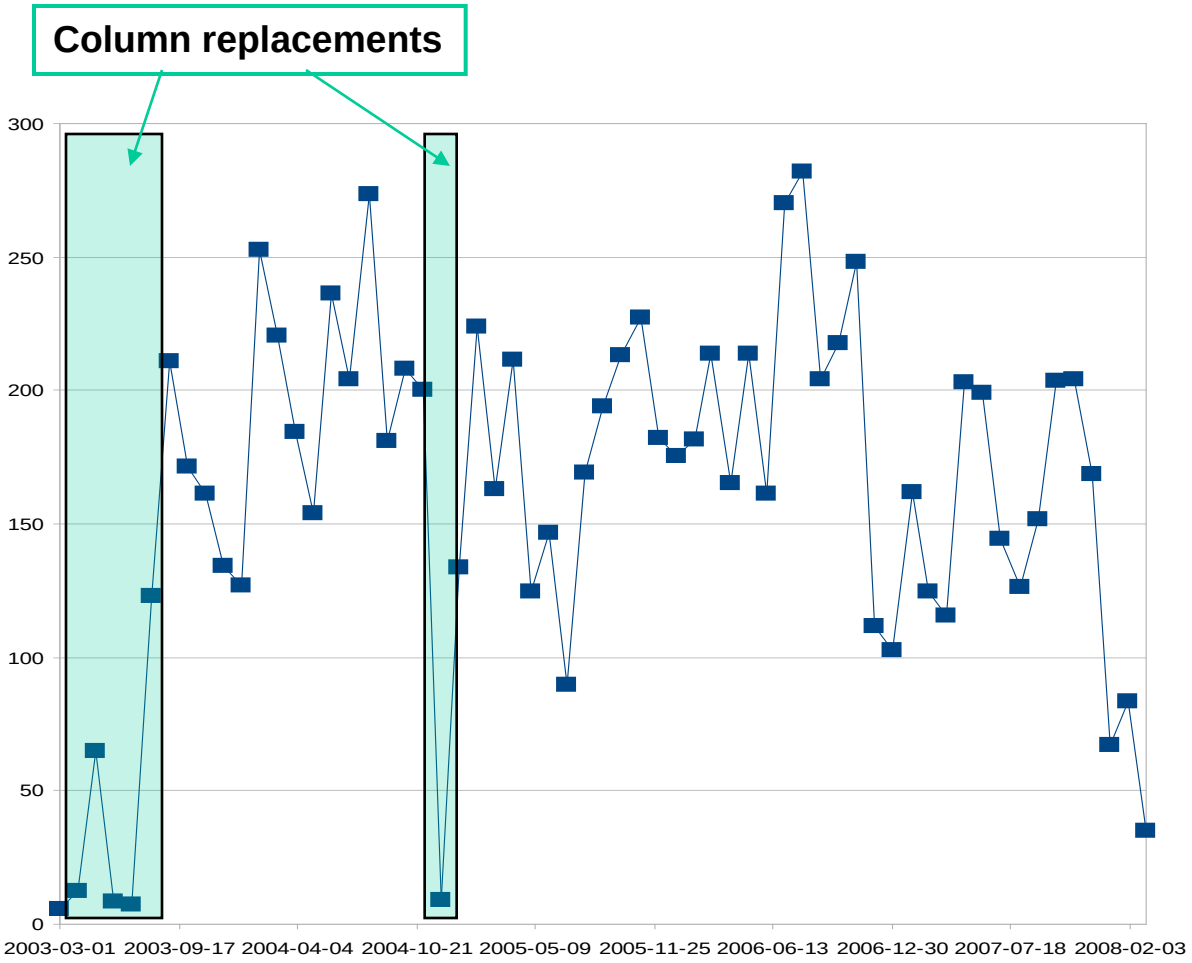

Albanova Nanolab users
number of users paying base fee, by quarter
60
50
40
30
20
10
0
2003_Q1
2003_Q3
2004_Q1
2004_Q3
2005_Q1
2005_Q3
2006_Q1
2006_Q3
2007_Q1
2007_Q3
2008_Q1
2008_Q3
2009_Q1
2009_Q3
2010_Q1

Productivity as of April 2008

See Appendix 1 of Activity report

- PhD thesis - 21 completed, 24 in progress
- Master thesis - 8
- Post Docs – 6
- Companies - 4

E-beam usage:


Column replacements
% of 40 hour week
300
250
200
150
100
50
0
2003-03-01
2003-09-17
2004-04-04
2004-10-21
2005-05-09
2005-11-25
2006-06-13
2006-12-30
2007-07-18
2008-02-03

Low cost, minimal bureaucracy

2010 Budget

Total Costs	-3.2 M SEK
Subsidies (KTH Aphys, SU phys)	+1.1 M SEK
User fees	+2.1 M SEK

User fees: 54 paying base fee (2010_Q2)

- base fee 6250 SEK per user per quarter year
- time charge on e-beam, SEM/FIB, mask align, AFM

Low cost structure because we are slim: 1 FTE technician salary, everyone helps with maintenance, education, weekly user meetings.

Access Example: E-beam Lithography

- Internal (Inst. pays subsidy)
  - 6250 SEK /quarter base fee
  - 275 SEK/hr machine time
    - ½ price after 6pm, free midnight to 7am
- External (Inst. does not pay subsidy)
  - 6250 SEK/quarter base fee
  - 600 SEK/hr machine time
    - ½ price after 6pm, free midnight to 7am

Outlook

- Can accommodate 2 systems, ca 10 users with current space
- Need to increase technical staff
- Develop SPM – more users from Chemistry
- Part of Aphys Labs (Laser, Bio-Image, Cell growth)
- Incubator for small companies
  - Xcilium
  - Intermodulation Products