ELECTRUM LAB
KTH & RISE IN COLLABORATION

Electrum Laboratory

Complete Solutions in Nano and Microtechnology

Nils Nordell

(Director)

Electrum Laboratory

Mission

- To offer a competitive laboratory environment for micro and nano technology:
  - Processes capabilities – including cleanroom – for device fabrication
  - Facilities for characterization of materials and devices.

- To create an open environment for education, research, development and small scale production.

- To assure a cost efficient usage of expensive laboratory resources.

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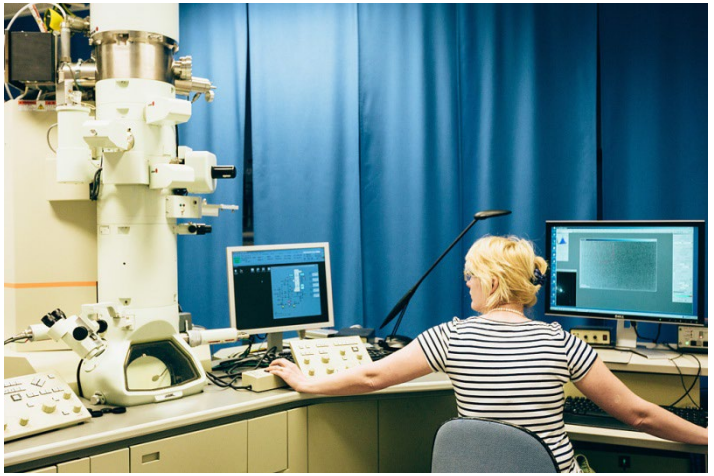
A flexible lab resource

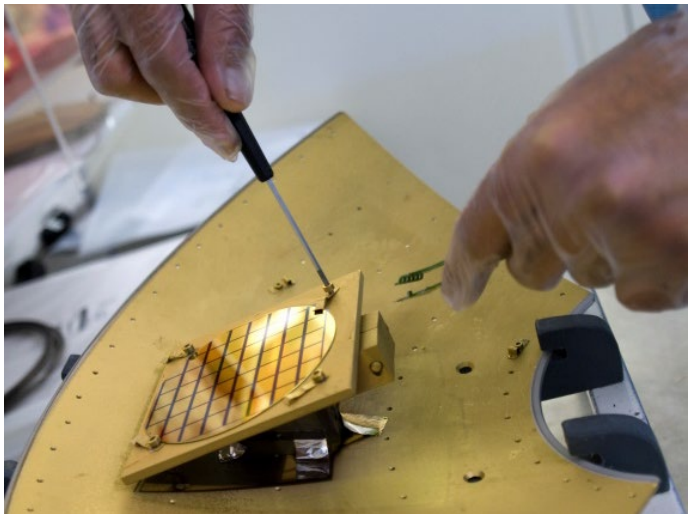
- **Research and development**
  - Inventing, designing, manufacturing of novel devices
  - Establishing novel processes and characterization techniques
  - Synthesis and characterization of new materials and structures
  - Flexibility, allowing different materials and sizes

- **Small scale production**
  - Incubator for start-up and spin-off companies
  - Access to all the lab resources
  - Possibility to rent lab space for proprietary equipment
  - Stability and repeatability maintained

- **Education**
  - Advanced undergraduate and graduate courses.
  - Life-long learning
  - Micro- and nano fabrication technologies and characterization.



Open Access Laboratory Facilities



Open for academic and commercial users, alike.

Easy access to processing and characterization tools.

Education for lab access and tool driving licenses.

Tool expert assistance or own usage of tools.

Rent of lab space

Possibilities for research collaborations.

Simple business model:
- Pay per user and use
- Myfab one-stop shop solution

Common user interface through MyfabLIMS:
- Databases of tools and users
- Booking, Logging, Invoicing

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Laboratory fees

Tool Fees (SEK/h)	LOW	MEDIUM	HIGH
A - Most simple tools: optical microscopes, wet benches etc.	125	235	350
B - Analysis and most simple processing	350	580	700
C - Conventional analysis and simple processing	580	930	1 160
D - Most advance analysis and conventional procssing	1 160	1 500	1 850
E - Most advanced processing, e.g. stepper litho and epitaxy	2 300	3 500	4 600
Cleanroom user fee			
Registered user (SEK/month)	1 550	4 800	4 800
Time in cleanroom (SEK/h)	50	165	165
Laboratory area (SEK/m^2/year)			
Cleanroom lab	8 650	17 300	17 300
Non-cleanroom labs	8 650	8 650	8 650
Support fee (SEK/h)			
Person Time	800	1 300	1 300

LOW:
Internal (KTH/RISE)
Swedish Academia (Myfab)

MEDIUM:
Micro companies
Research institutes
Collaboration partners
Long term users
International academia

HIGH:
Larger companies
Single use

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Process Lines

- Tools for industrial production

ISO 9001 certified management system

- *controlled processes and tool uptime*
- *calibrated characterization tools*

Silicon Technology

Silicon – CMOS for circuits
Silicon – Microsystems technology

Compound Semiconductors

InP & GaAs – Opto electronics and photonics
SiC – High temp. and power electronics

Post process: dicing and bonding

Characterization of materials and devices

Design and simulation

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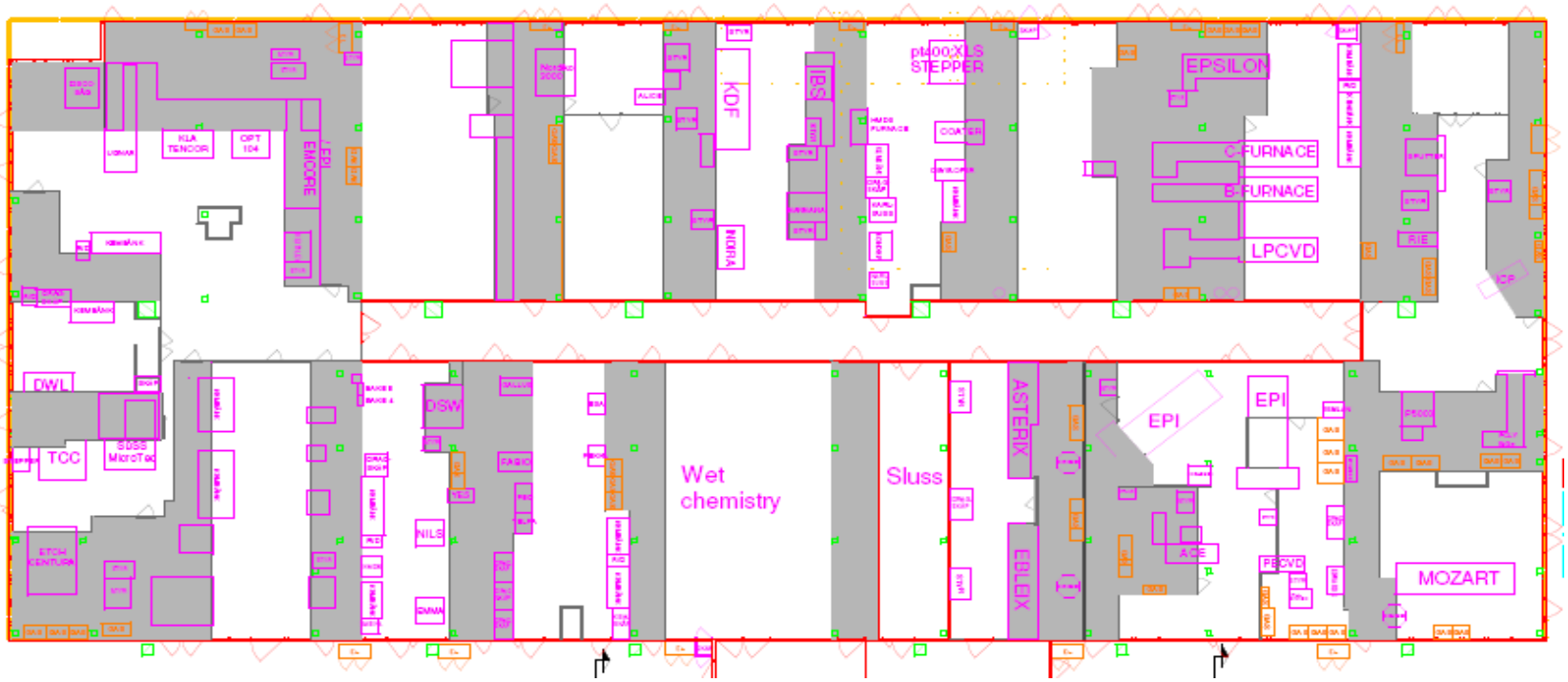
Key Figures



In operation since 1987

1 300 m^2 clean room lab
Class 100 - 10 000 (particles/ft^3)
1 200 m^2 other labs

Yearly turn around: 55 MSEK

No. users: c:a 250
No. dependent of lab: > 600

Total investment value: > 800 MSEK
No. registered tools: 220
Average tool lifetime: 15 years
Re-investment: 15 MSEK/yr

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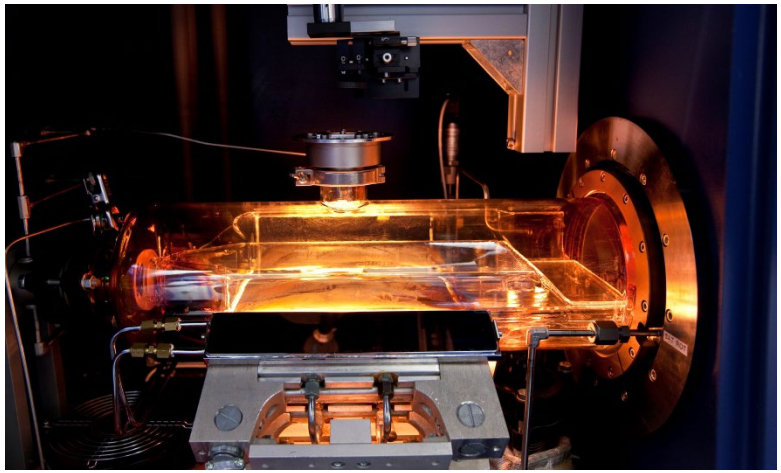
Profile Technologies

Material synthesis



- Vapor phase epitaxy of semiconductor materials
- Pulsed laser ablation of advanced oxides
- Atomic Layer Deposition of complex materials
- Wet chemistry and ink-jet printing of graphene

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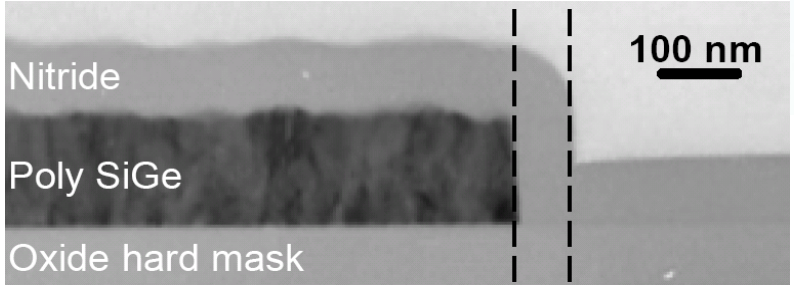
Stepper Lithography



- i-line and g-line steppers
- Wafer sizes up to 200 mm
- Resolution down to 0.5 µm (i-line)
- Alignment accuracy: 60 nm (i-line)
- Throughput: up to 80 wafers/h

- Sidewall Transfer Lithography: Allows line widths down to 10 nm

Precision etch technologies

- Centura and P5000 etchers (Applied Materials)
- End point detection
- Wafer sizes up to 200 mm
- Chambers for etching of
  - Conventional Si structures
  - Deep Si structures
  - Metals
  - Dielectrics

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Material characterization

High resolution scanning electron microscopy
- environmental microscopy
- focused ion beam
- chemical analysis

High resolution transmission electron microscopy
- with chemical analysis

Atomic Force Microscopy

X-ray diffraction

Electric, optic and magnetic characterization

Application Examples

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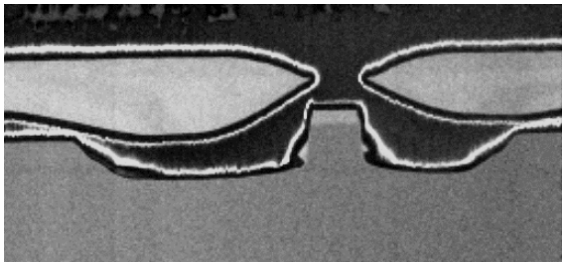
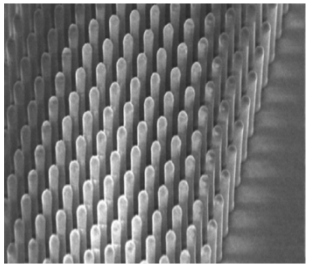
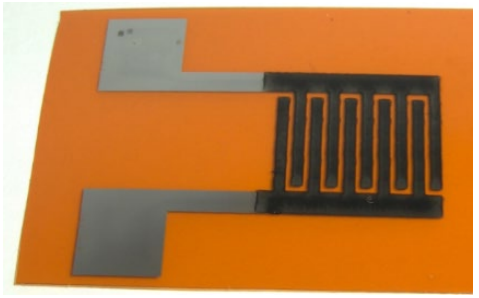
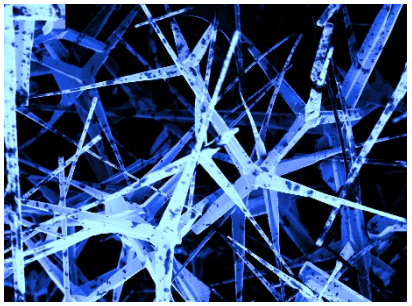
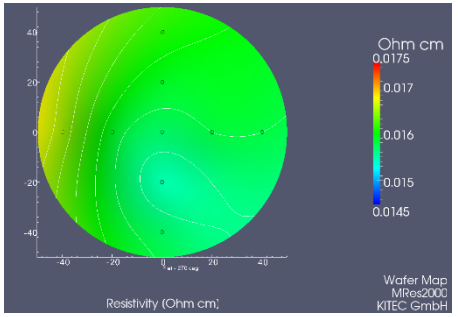
Material physics

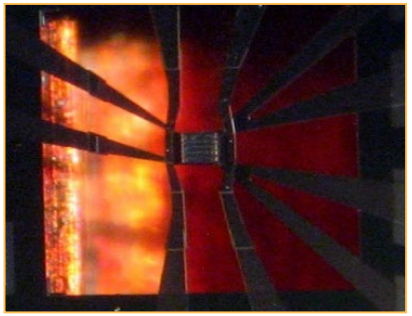












- Advanced crystal growth studies
- Photonic crystals
- Graphene micro super capacitors by ink jet printing
- Zink oxide for sensing in forensic and medtech applications
- Highly uniform and defect free SiC substrates
- Novel characterization techniques

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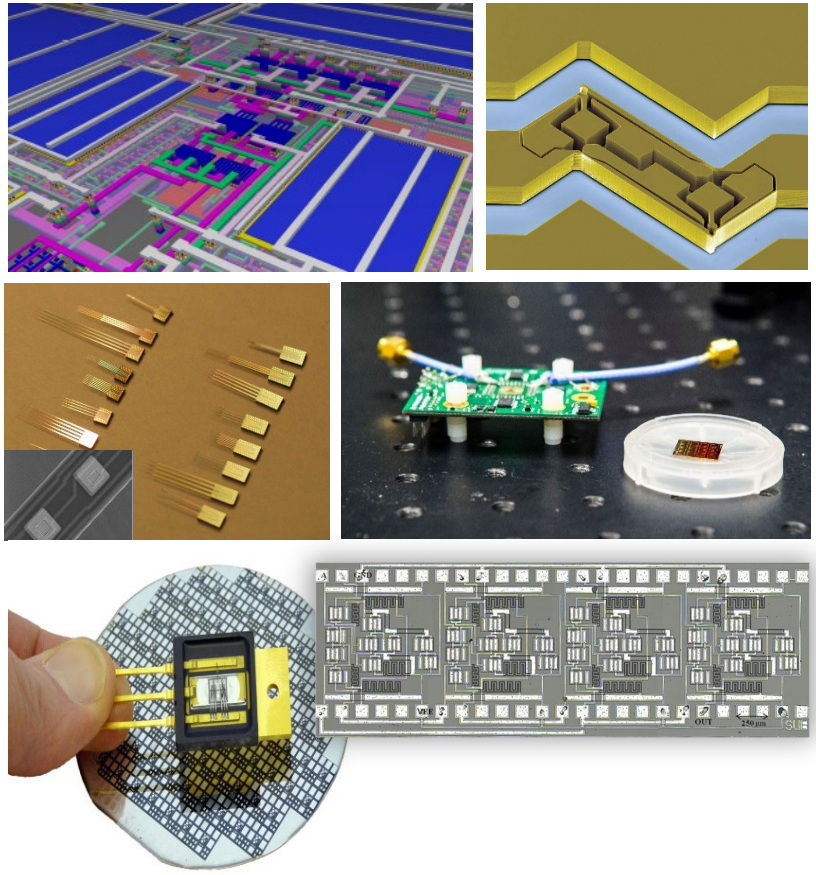
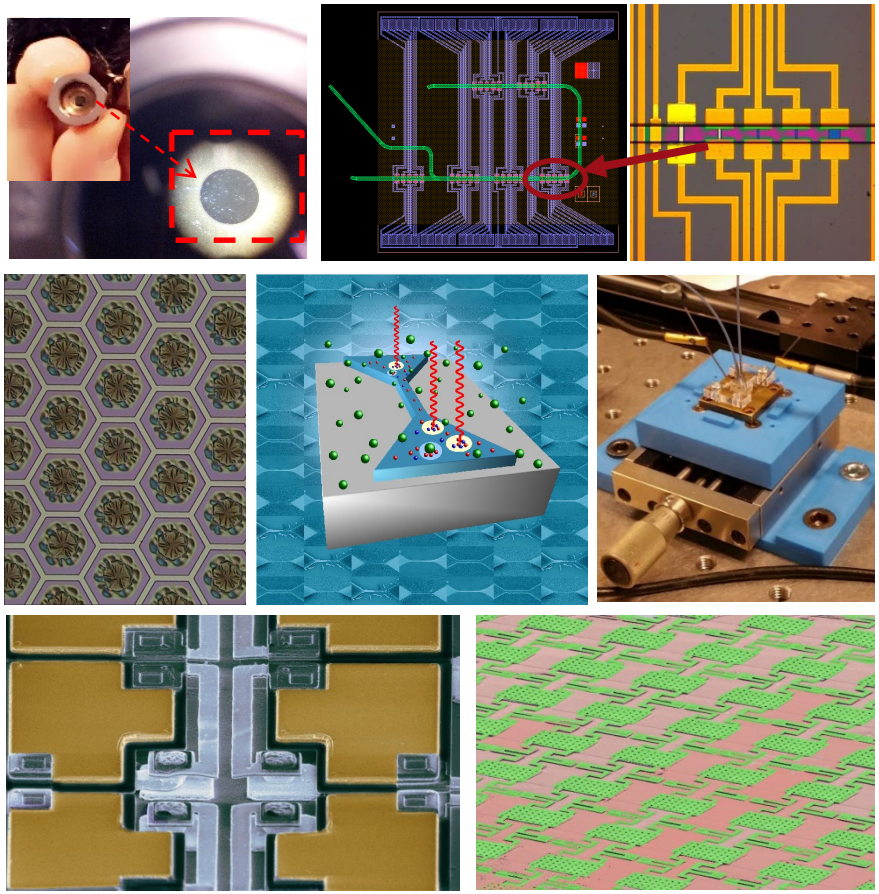
Integrated micro and nano devices



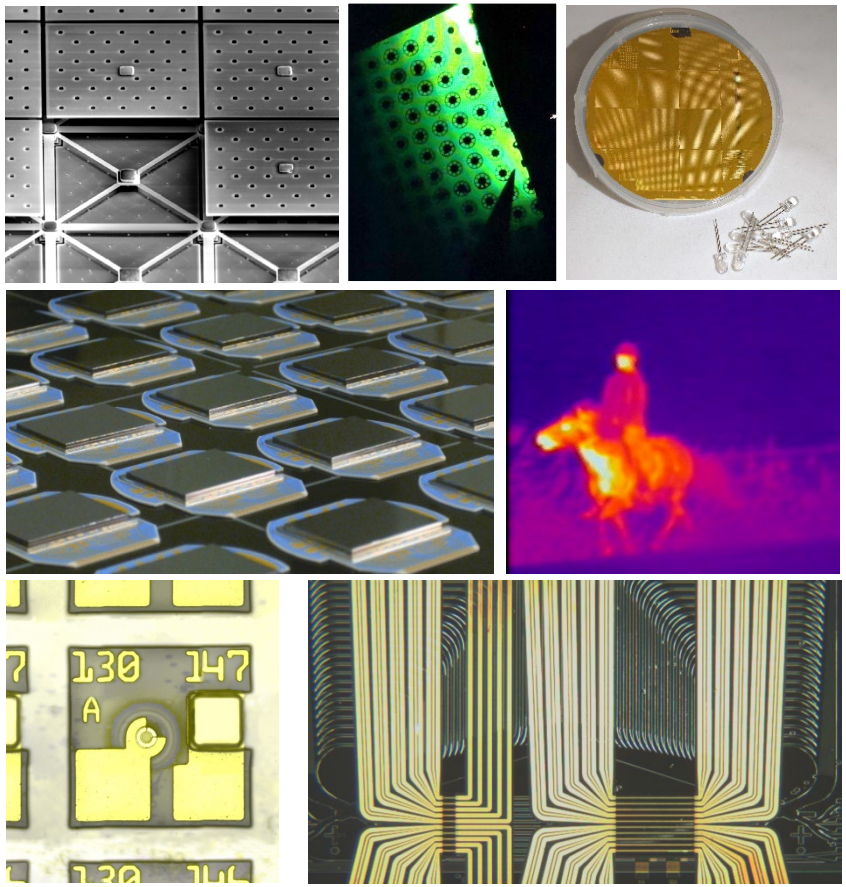
- Monolithic 3D Integration for silicon / silicon-germanium radio frequency integrated circuits
- High frequency micro mechanical switch for telecom
- Micro needles with multiple contacts for brain studies
- Quantum well electro-absorption modulators for Free-space optical communication
- Silicon carbide discrete power devices and integrated circuits for high power and high temperature applications
- Device design and characterization

Sensors



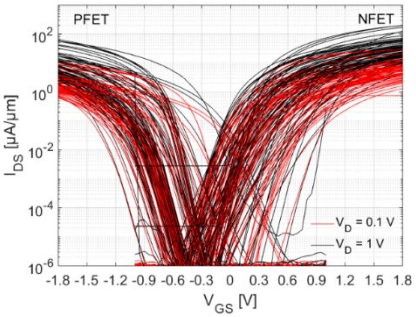
- Silicon carbide high pressure & high temp. sensors for automotive industry
- Micro fluidic chip for protein bio sensing
- Ferromagnetic filter for detection of electron spin polarization
- Silicon nano wires for protein detection
- Infrared detector – uncooled bolometer array for night vision systems in cars
- High impedance surface array for automotive radar

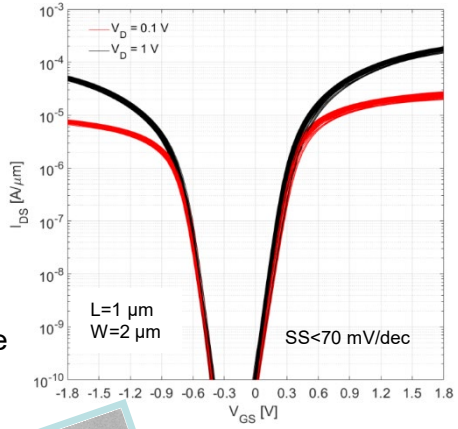
Optical systems



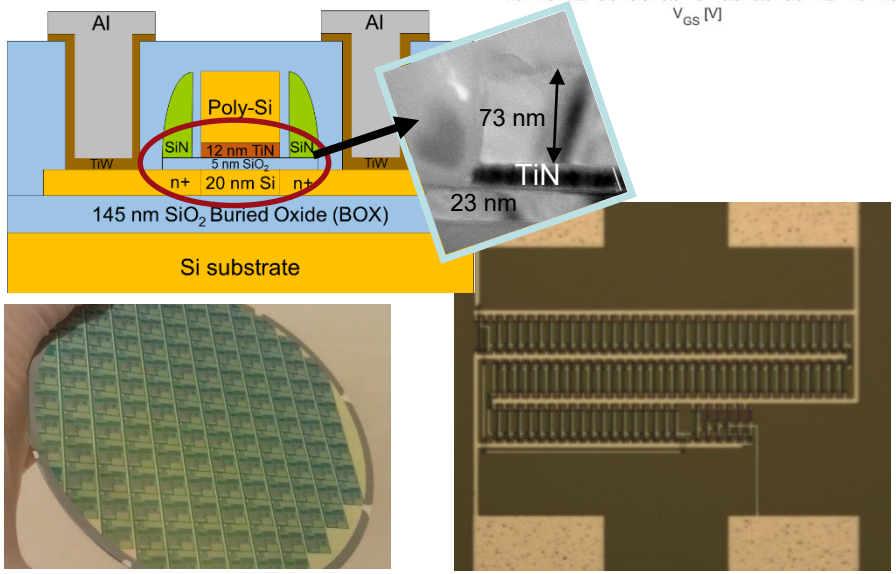
- Micro mirrors for light beam control
- Green LED with transparent graphene electrode
- Volume production of sensor arrays for IR cameras
- Vertical cavity surface emitting lasers for optical communication.
- Photonic integrated circuits for telecom

CMOS line for heterogeneous integration



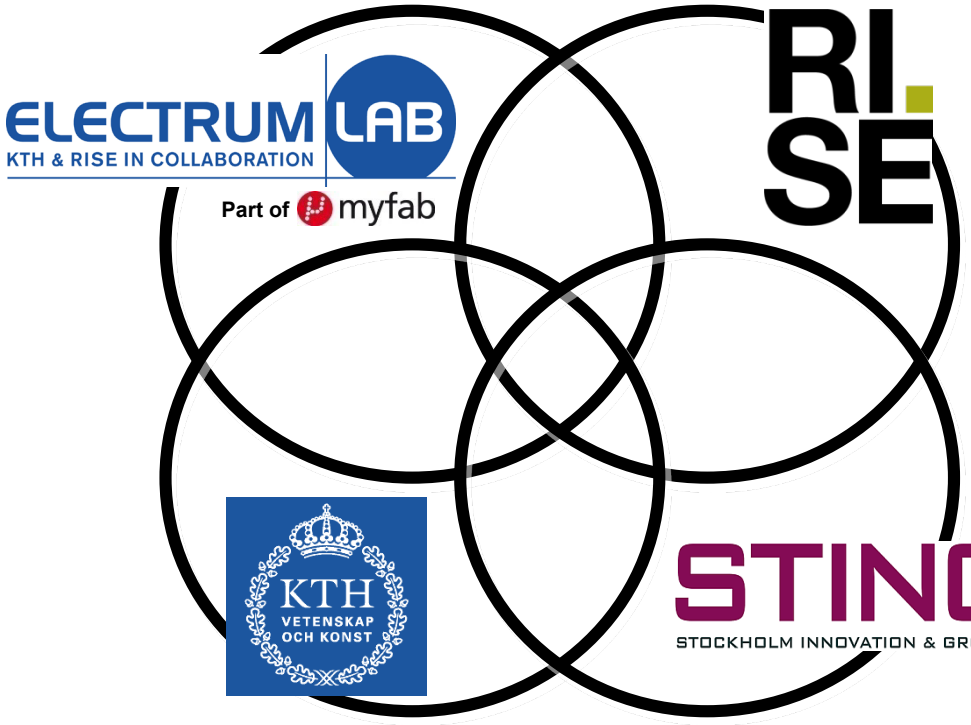


Transistor characteristics before and after process optimization



- CMOS circuits for integration:
  - Non-conventional devices: chemical sensors, biosensors, energy harvester, optical components…
  - Evaluation of new materials and designs
- A reproducible and predictable CMOS line
  - 100 mm wafers, 5 nm SiO_2 gate, 3 GHz operation
- Conservative design rules
  - i-line stepper: 0,5 µm resolution, 50 nm alignment
  - Active/metal: 2 µm, contact holes: 1x1 μm^2
- Simple circuits designs achieved:
  - Ring oscillator, inverter, frequency divider…
- Cadence Virtuoso design environment
- Available for collaboration projects

The Electrum Innovation System: Fosters Companies:



silex MICROSYSTEMS

ascilion
Pain-free glucose measurements

IRnova

ascatron

SCINT-X
STRUCTURED SCINTILLATORS

NanOsc

Kiselkarbid i Stockholm

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Incubator

Access to the whole lab:
- Processes
- Characterization
- Network of researchers and entrepreneurs

Proprietary lab area for rent:
- For own tools

Access to partners: Myfab and ISSP
- Backup processes
- Profile processes

Production incubator: RISE
- Technology transfer
- Technology and product development projects
- Foundry services

Business incubator: STING & KTH innovation
- Startup
- Business lab
- Business accelerator

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Incubator support
- Research into innovation

Ideas from research and development:
- In house - KTH or RISE - or external
- From researcher to entrepreneur: STING & KTH Innovation

Lab access:
- Flexibility - new ideas explored and developed
- Processing and characterization in existing tools
- Transparent price model

Facility support:
- Full support from the facility
- Authority permits, chemical handling, infrastructure, etc.

Personnel resources:
- Training
- Processing & Characterization
- Network of people

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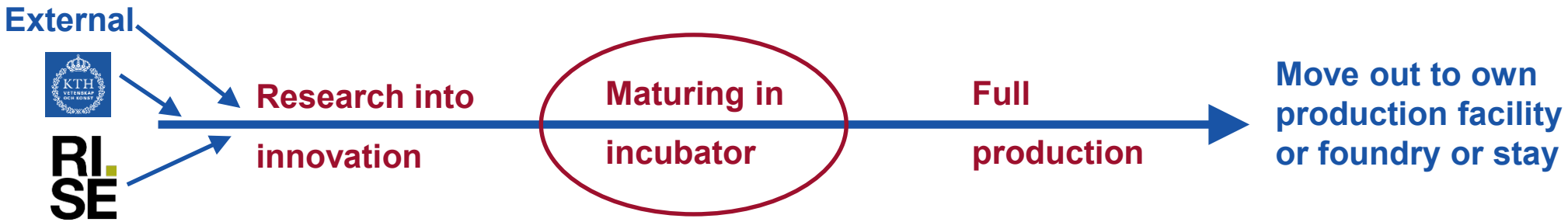
Incubator support
- Developing in incubator

Maturing technology:
- Manufacturability: RISE production incubator
- Market penetration: STING & KTH Innovation

Lab access:
- Refining processes
- Process stability for yield
- Access to partners: Backup & Profile processes
- Lab area for rent - proprietary & shared tools
- ➢ **Organize lab to always have empty space**

Facility support:
- Specification and installation of proprietary tools

Personnel resources:
- "Foundry services" in processing & characterization
- Company contributes to the “network of people”



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Incubator support
- Ready to fly

Full production:
- Mature technology and sales organization

Lab access:
- Need stable processes and control of costs
- ISO 9001 certified management system
- Lab area for rent - proprietary & shared tools

Facility support:
- Company contributes, e.g., to safety arrangements

Personnel resources:
- Recruiting people in the lab environment

Moving out or stay?:
- Expensive to stay for high volumes
- Cost efficient to stay for low volumes in shared tools

➢ **Moving out creates a financial setback for the lab but frees space for next company to grow**

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Success stories

In total:
> 130 M€ turnover
> 500 employees

Established at own fabs:

Silex Microsystems
World's leading pure-play MEMS foundry
988 MSEK turnover and 292 employees (2020)

II-VI Järfälla (former Syntune)
Optoelectronics for telecommunication
302 MSEK turnover and 167 employees (2020)

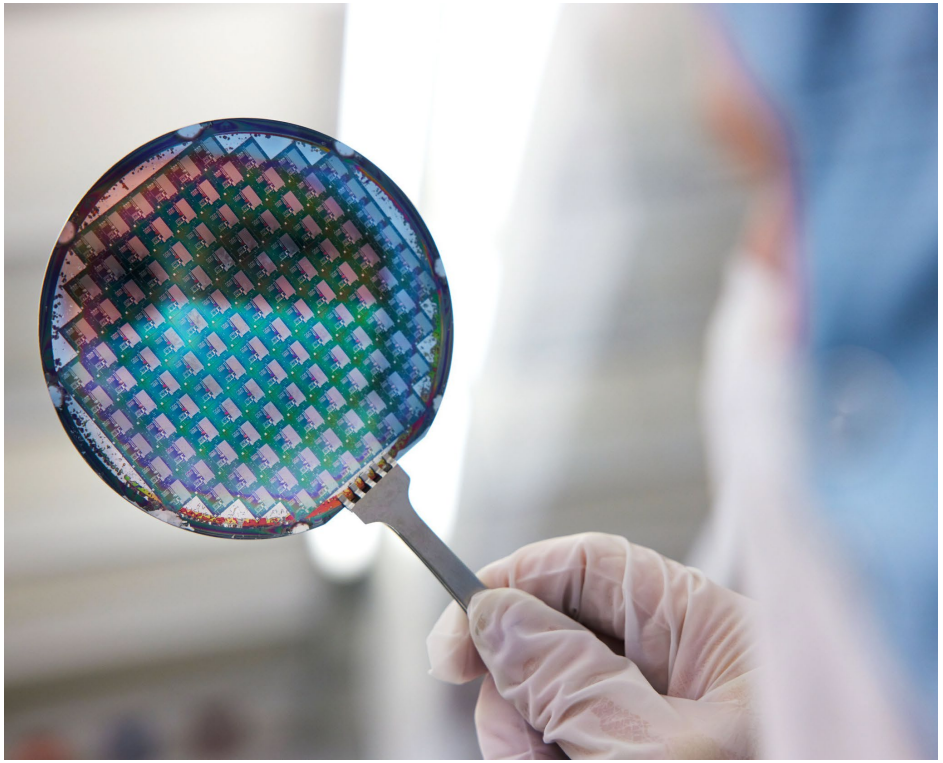
Development / Production at Electrum Lab:

IR-Nova
Imaging IR photodetectors and modules
58 MSEK turnover and 28 employees (2020)

On Semiconductor (former TranSiC)
Silicon Carbide based power devices
29 MSEK turnover and 13 employees (2019)

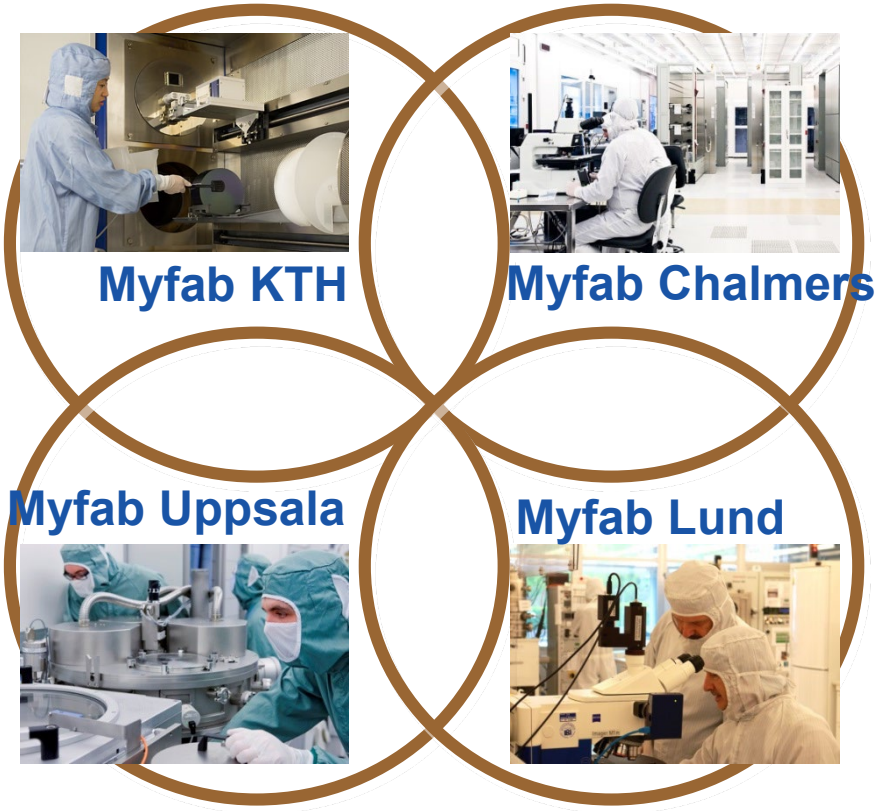
II-VI Kista (former Ascatron)
Pure play foundry for silicon carbide epitaxy and processing
15 MSEK turnover and 13 employees (2019)

KISAB - Kiselkarbid i Stockholm
Defect free silicon carbide substrates
9 MSEK turnover and 9 employees (2020)



And several other companies are using the lab services…

myfab Swedish Nano and Microfabrication Infrastructure



Realize your nano visions

- A distributed cleanroom facility
- Access to all processes and tools in the network
- Backup for standard processes
- Unique profile processes at each lab
- Supporting academia and industry
- Common marketing activities

Supported by

- Swedish Research Council (Vetenskapsrådet)
- The participating universities:
  - KTH
  - Uppsala University
  - Chalmers
  - Lund University

CAMART^2 - Excellence Centre of Advanced MAterial Research and Technology Transfer

- A Horizon 2020 Widespread project

Partners

- Institute of Solid State Physics, University of Latvia
- KTH Royal Institute of Technology
- RISE Research Institutes of Sweden

Goal

- To enhance the innovation capabilities of ISSP UL
- Commercialization of research results at ISSP UL
- Synergy with industrial partners
- Strengthen nanotechnology and materials physics in the Baltic Sea region.

Implementation

- Business Plan: Science, Innovation, Education, Infrastructure, Outreach, Organization.
- Funding: 15 MEUR + 16 MEUR infrastructure (2017-2023)

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Electrum Laboratory invites you!

KTH and RISE in collaboration offer:

Processes – from separate process steps to full device process sequences.

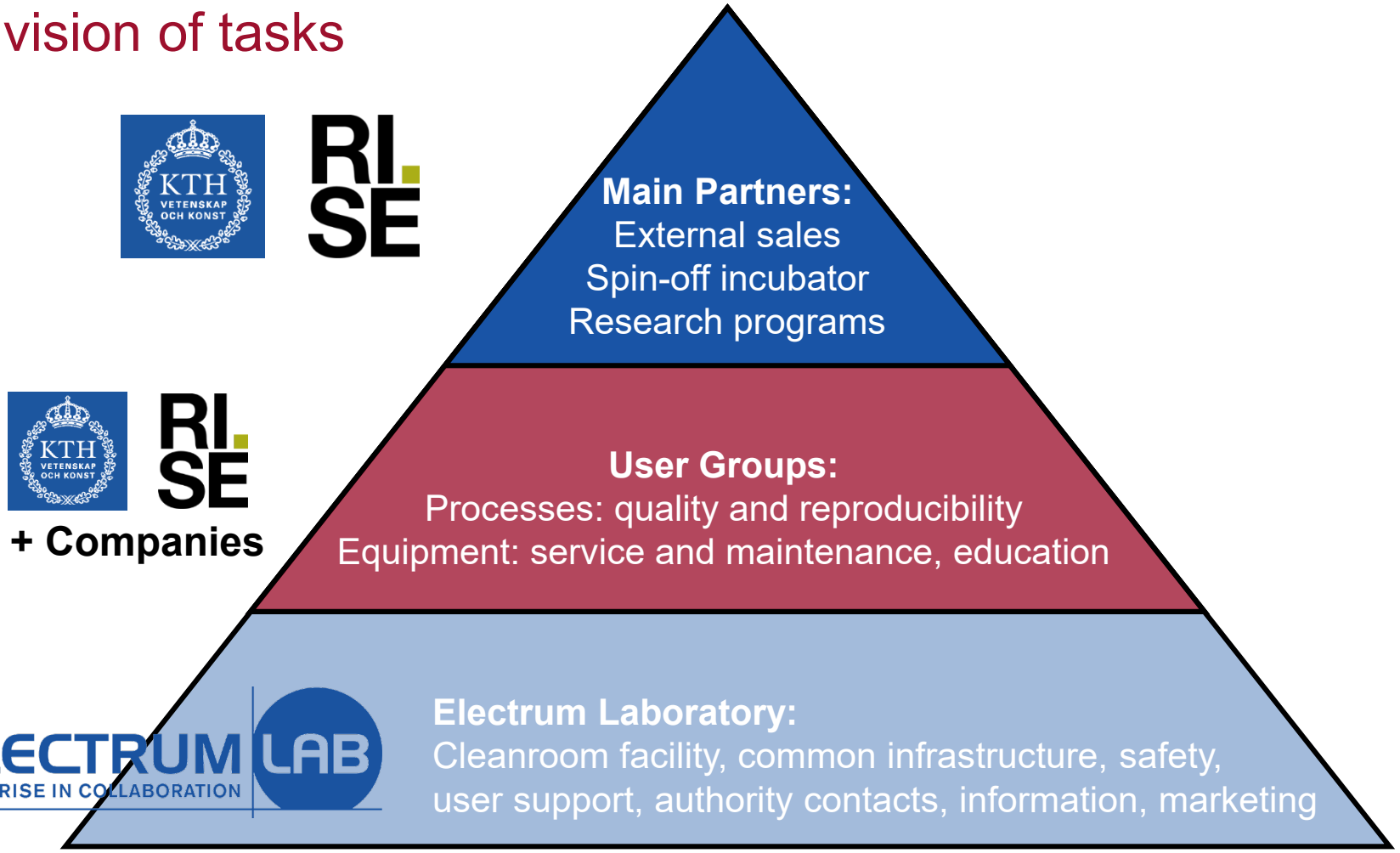
Characterization – from single measurements to integrated analysis for deep understanding of complex structures

- Process and characterization services are provided by our skilled experts
- Commissioned research and development projects
- Prototyping and small scale production
- Access to our tools for your own personnel
- Cleanroom area and labs to rent
- Education in process technology, characterization and cleanroom infrastructure.
- Access to the lab resources at our collaboration partners within the Myfab network and at ISSP.


Thanks for
your attention!

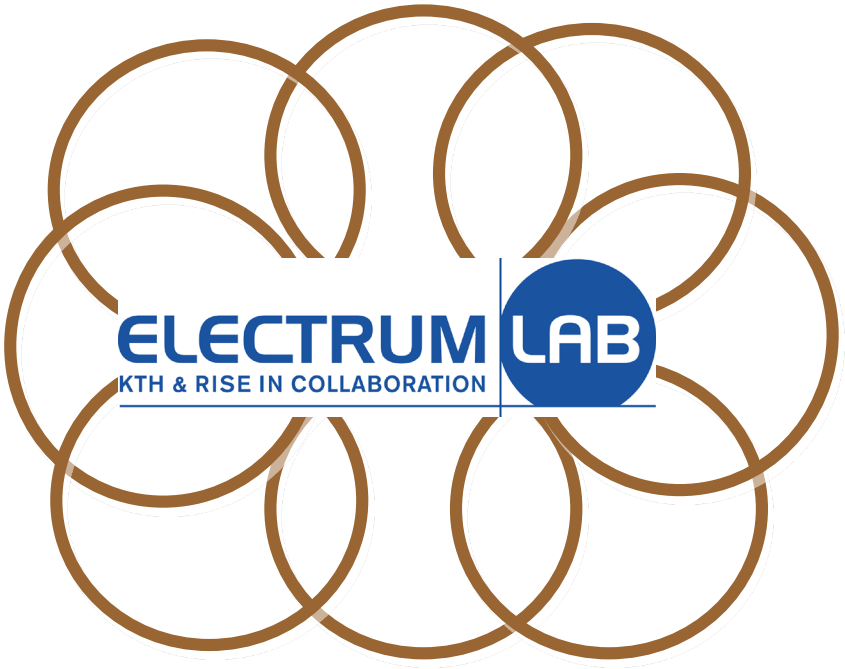
Electrum Lab organization

- Division of tasks



Electrum Lab organization

- Involving the user groups



Lab Director has a coordinating role.

Major user groups are represented in the Management team and Task forces handling:

- Lab organization and rules
- Quality management
- Lab safety
- Tool investments
- Facility planning
- Cross contamination and tool rules
- Fee system

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Electrum Lab for Education

Courses with lab exercises at Electrum:

EK2360 – Hands-On Microelectromechanical Systems Engineering 7,5 hp (MSc)
25 participants

EK2350 – Microsystem Technology 7.5 hp (MSc)
46 participants

FEK3250 – Microsystem Technology for PhD Students 8.0 hp (PhD)
4 participants

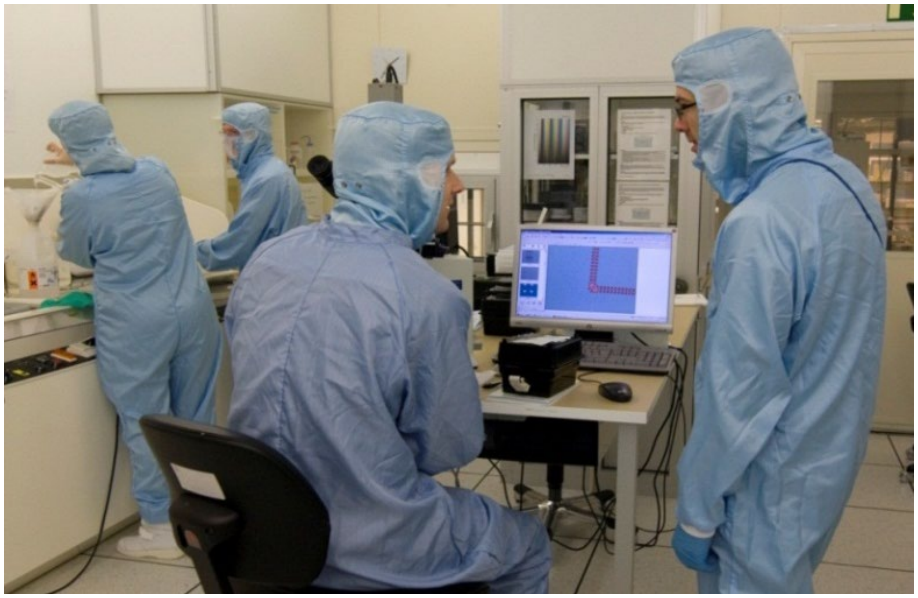
FEK3360 – Advanced Hands-on MEMS Course 10.0 hp (PhD)
8 participants

FEK3300 – Applied Micro- and Nanofabrication 15.0 hp (PhD)
2 participants

IH2659 – Nanofabrication Technologies 7.5 hp (Master & PhD)
40 participants

IH2652 – Methods and Instruments of Analysis 7,5 hp

SK2822 – Compound semiconductors and Photonic Devices 7.5 hp



In addition around 60 Masters and PhD students work in the lab on a yearly basis

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Challenges in innovation and growth

Technical: To defeat nature

- Nanotechnology is demanding and every detail must work
- Management must understand the R&D realities
- Time could be more important than money

Financial: Building trust for the project

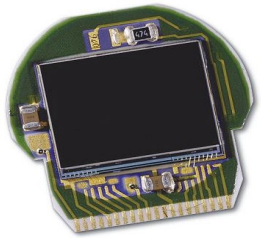
- Deep-tech need long-term financing
- The idea needs to mature - ”there is always money for good ideas”
- Working for free for some time - your own investment may attract others
- Financing is highly cyclical and may disappear quickly in a recession.

Market: Develop technology in concordance with needs

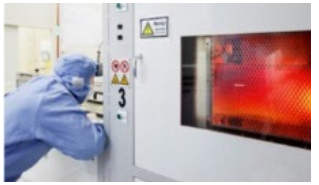
- Early contacts with the market - help to develop the right thing
- Be open to adopt the technical solution to another application

Team: A well formulated common goal

- Sort out the personal driving forces early

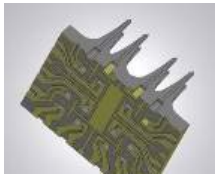


IR nova



Ascatron / II-VI Kista

TranSiC / ON Semi



Ascilion

Spinn-Y

Tool Investments and responsibility

Tool investments funded by:

- Research grants - private and governmental
- User groups - some open for general use
- Electrum Lab - user fees or grants

Tool and process responsibility:

- On the user groups
- Handle maintenance, service, consumables, process control etc.
- Not always the owner of the tool
- Encouraged to sell tool time
- May be canceled at any time
- ➢ ***Certify access to key processes***

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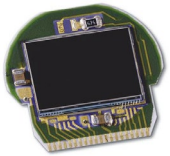
Incubator companies



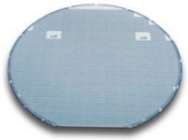
IR-Nova (2003)
Imaging IR detectors with high detectivity and resolution

TranSiC (2005) **- Fairchild** (2011) - **On Semiconductor** (2016)
High power transistors in silicon carbide

Ascatron AB (2011) **- II-VI Kista** (2021)
Pure play foundry for silicon carbide epitaxy and processing

KISAB - Kiselkarbid i Stockholm AB (2017)
Defect free silicon carbide substrates

Bright Day Graphene (2017)
Development of sustainable energy solution



Nanosized AB (2018)
Nanoparticle size determination for semiconductor industry

TeraSi AB (2020)
MEMS based terahertz devices

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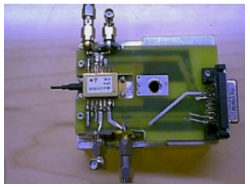
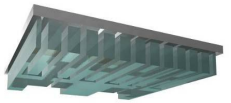
More start-ups

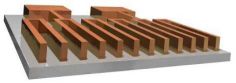
- **Altitun AB (1997)**
  - *Optoelectronics for telecommunication*



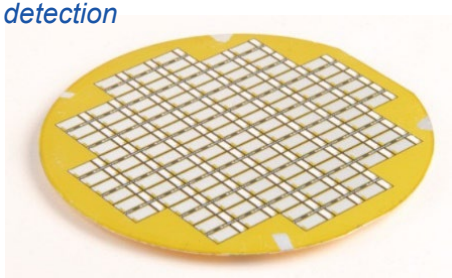
- **Optillion AB (1999)**
  - *Optoelectronics for telecommunication*
- **Silex Microsystems AB (2000)**
  - *Micromechanic devices for opto and bio applications*
- **Comlase NT AB (2001/2003)**
  - *Pump lasers and coating technologies*
- **Advanced Microwave Device Solutions AB (2001)**
  - *High power/high frequncy transistors in silicon carbide*
- **PhoXtal Communications AB (2002)**
  - *Optoelectronics for telecommunication*



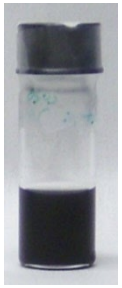
- **Replisaurus Technologies AB (2002)**
  - *Electrochemical Pattern replication*



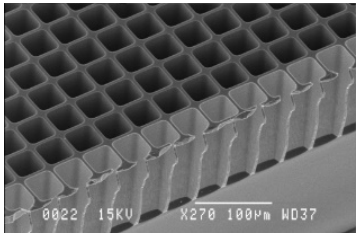
- **Scint-X AB (2006)**
  - *Imaging x-ray detector with high sensitivity and resolution*
- **Micro Delta T (2007)**
  - *Nanostructured surfaces for enhanced heat transfer*
- **NanOsc AB (2007)**
  - *Oscillators for telecommunication and other applications*
- **Nocilis Materials AB (2011)**
  - *Epitaxy of advanced Si-Ge-Sn-C alloys and energy harvesting*
- **Spinn-Y AB (2011)**
  - *Spin filter for electron spin polarization detection*



- **Epiclarus AB (2012)**
  - *Epitaxial growth of III-V materials*
- **Ascilion AB (2012)**
  - *Pain-free glucose measurements*
- **Neosense AB (2014)**
  - *Sensor for real-time measurement of blood oxygenation*



- **Aninkco AB (2015)**
  - *Graphene based inks for printed electronics*
- **NanoPro AB (2018)**
  - *Consultancy and fabrication of semiconductor devices*
- **Gatty Instruments AB (2018)**
  - *MEMS based gas sensors*



ELECTRUM LAB
KTH & RISE IN COLLABORATION

Contact for more information:
thomas.swahn@chalmers.se
+46 73 074 46 76

Learn more at:

www.myfab.se

Myfab National Access offers **free** access to Myfab:

- Usage of equipment for fabrication and analysis
- Training services from on-site staff
- Scientific support in realizing “nano visions”
- Standard material (to some extent)

Myfab National Access is open for

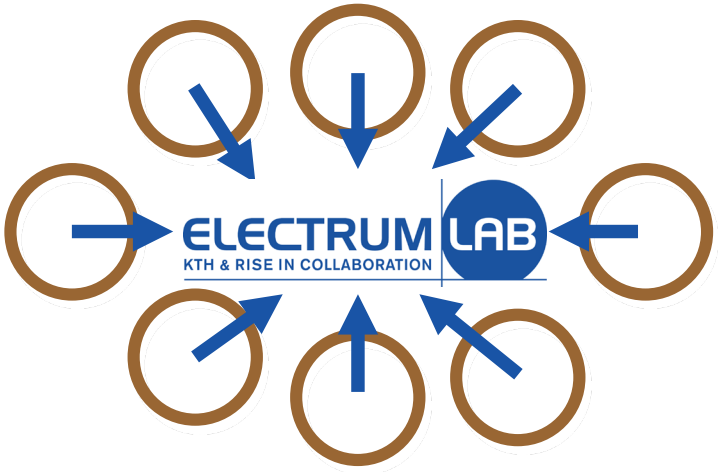
- Swedish academic or SME users with no previous cleanroom experience.

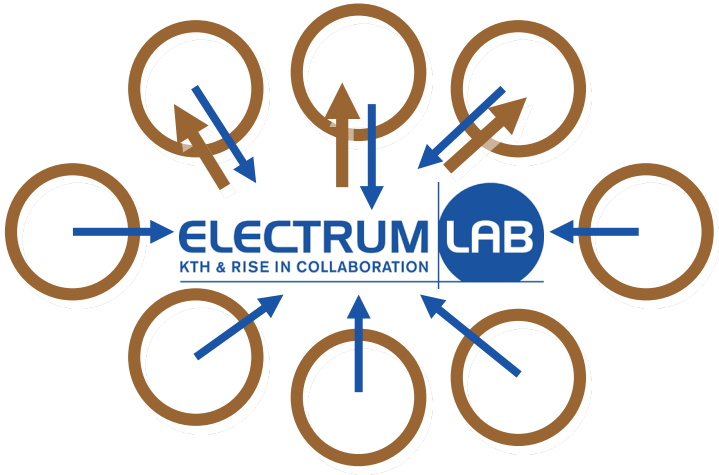
Myfab National Access will

- Promote the Myfab laboratories
- Lower the barrier to realize novel ideas in micro and nanofabrication
- Stimulate the creation of new activities and relations.

Economic control

- Charges and reimbursement





Lab fees are paid to Electrum lab for basic infrastructure, premises, coordination etc.

Fees based on:

- Registered users
- Hours in cleanroom
- Lab area (for tool responsible)

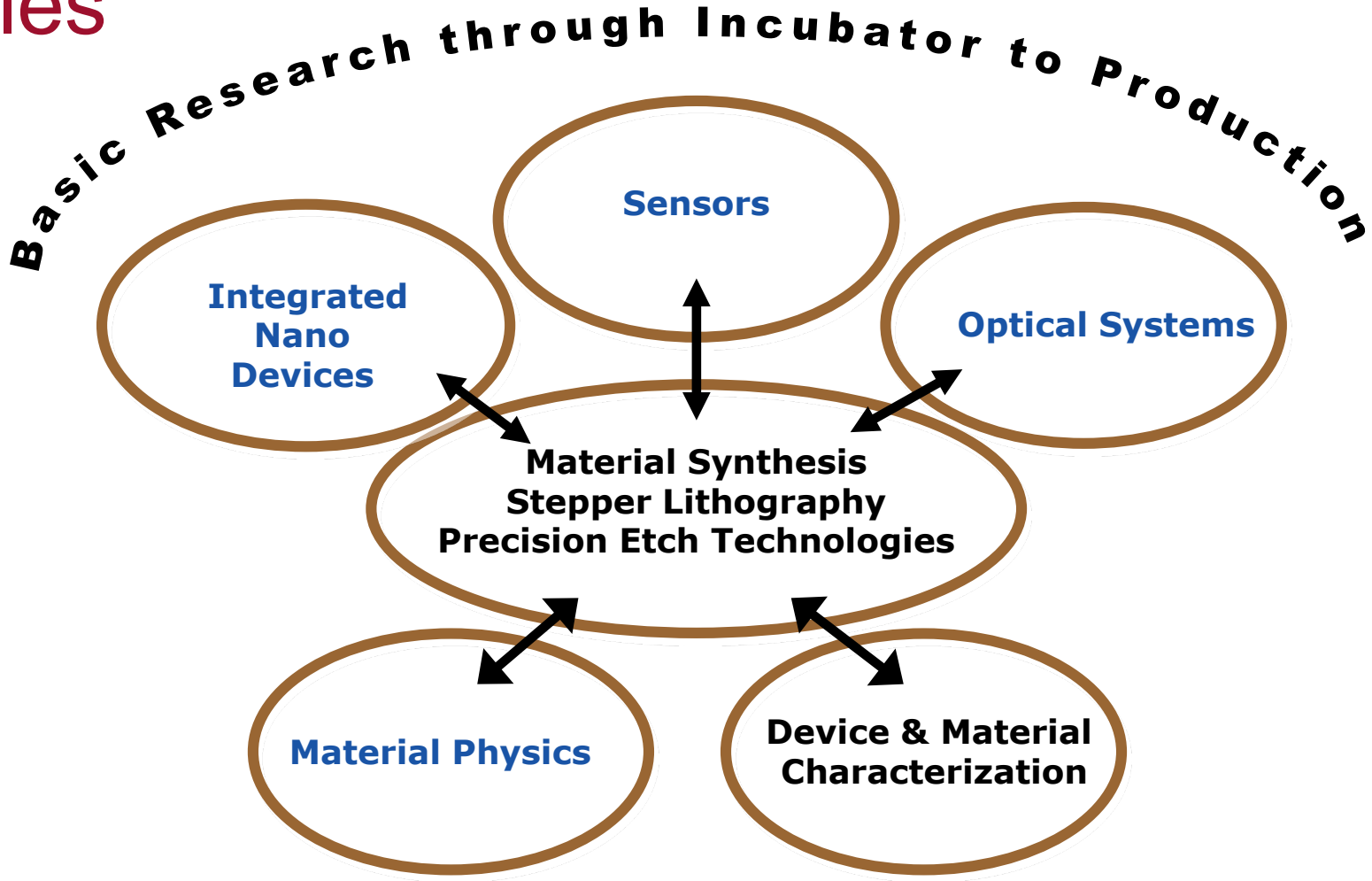
Tool fees are paid to Electrum lab and reimbursed to tool responsible groups for consumables, maintenance, lab area, etc.

Fees based on:

- Used tool time

Fees are differentiated: Academic / Micro companies & Institutes / Large companies

Profiles

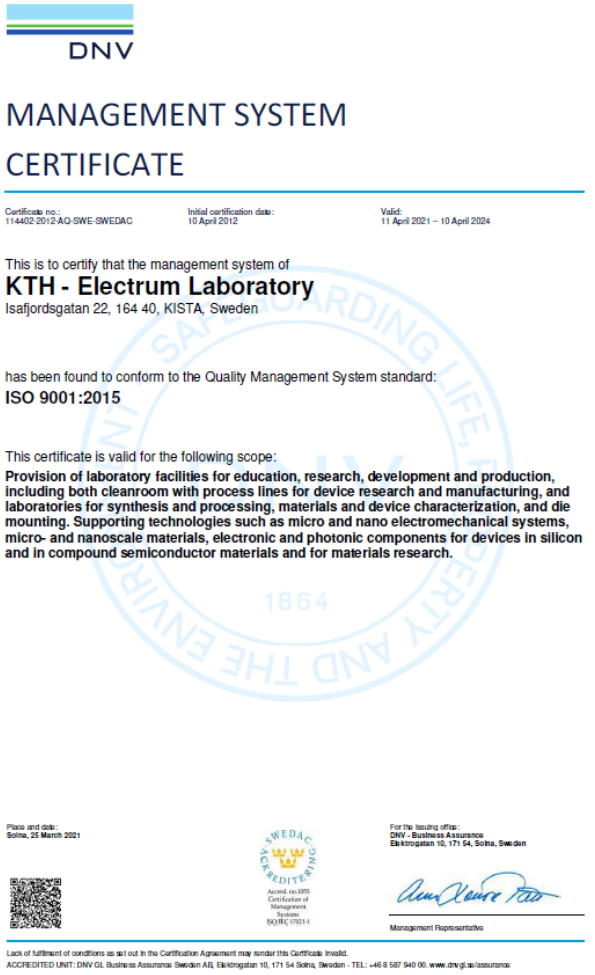

Basic Research through Incubator to Production
Sensors
Integrated Nano Devices
Optical Systems
Material Synthesis
Stepper Lithography
Precision Etch Technologies
Material Physics
Device & Material Characterization

ISO 9001:2015 certified management system

Defines:

- Overall organization and roles
- Work routines and safety
- Information flow and meetings
- Tool maintenance and uptime
- Process, monitoring and reproducibility
- Characterization tool calibration
- Education of personnel and lab users
- Customer handling
- Yearly user poll
- Yearly audits and continuous follow-up

As part of KTH, also certified according to the environmental management standard ISO14001:2015



DNV

MANAGEMENT SYSTEM CERTIFICATE

Certificate no.: 114402-2012-AQ-SWE-SWEDAC
Initial certification date: 10 April 2012
Valid: 11 April 2021 – 10 April 2024

This is to certify that the management system of
KTH - Electrum Laboratory
Isafjordsgatan 22, 164 40, KISTA, Sweden

has been found to conform to the Quality Management System standard:
ISO 9001:2015

This certificate is valid for the following scope:
Provision of laboratory facilities for education, research, development and production, including both cleanroom with process lines for device research and manufacturing, and laboratories for synthesis and processing, materials and device characterization, and die mounting. Supporting technologies such as micro and nano electromechanical systems, micro- and nanoscale materials, electronic and photonic components for devices in silicon and in compound semiconductor materials and for materials research.

Place and date: Solna, 25 March 2021
For the issuing office: DNV - Business Assurance Elektrogatan 10, 171 54, Solna, Sweden
Management Representative

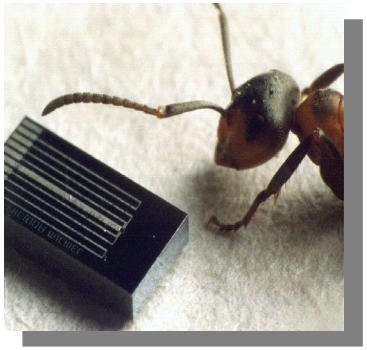
Lack of fulfilment of conditions as set out in the Certification Agreement may render this Certificate invalid.
ACCREDITED UNIT: DNV GL Business Assurance Sweden AB, Elektrogatan 10, 171 54 Solna, Sweden - TEL: +46 8 587 940 00. www.dnvgl.se/assurance

ELECTRUM LAB
KTH & RISE IN COLLABORATION

From research to company: Silex

Originated as a MEMS PhD project at KTH...

1994
KTH, RISE



Microphone for turbulence research

1996
KTH, RISE, RADI

Miniaturised sensor for blood pressure measurements

1997
RADI, RISE

Clinical blood pressure measurements

2000
RADI, Silex, RISE

Production

2004
Silex

MEMS fab

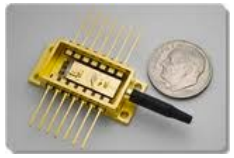
... Silex has developed to the world's leading "pure-play" MEMS foundry. In 2020:

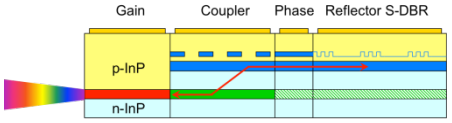
- turnover 94 MEUR
- 290 employees

From research to company: Altitun

Advanced telecom laser research...

1987
RISE





Laser research for Swedish Telecom and Ericsson

1997
RISE, KTH, Altitun

Tunable telecom laser modules

ALTITUN

2000
Sold to ADC 872 MUSD

Production established in own fab, closed 2003.

2003
Syntune AB formed

Knowledge transfer and a foundry bought from Svedice in 2008.

2008
Ignis

2011
Finisar

2019
II-VI Jarfalla

Acquisitions by international companies

II-VI

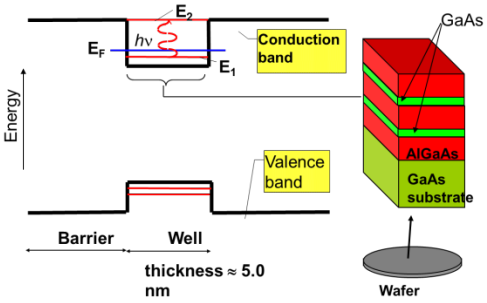
... has generated

- a great fortune for the owners
- revenue for the tax-payers
- employment for 160 persons
- turnover 28 MEUR (2020)

From research to company: IRnova

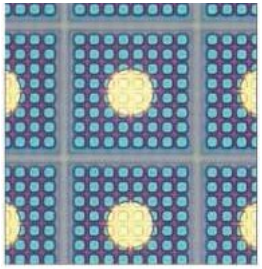
Quantum Well Infrared Photodetector (QWIP) structures developed...

1986
RISE



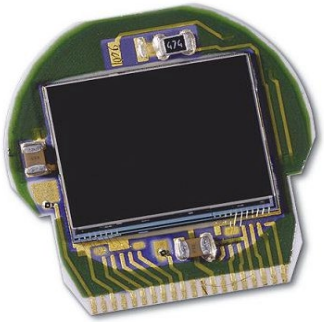
Quantum well structures formed by novel crystal growth technique

1991
RISE



Patent - grating for increased IR efficiency.

1997
RISE



Product launched - QWIP detector with read out circuit

2007
IRnova

Integrated modules with Stirling cooler

2012
IRnova

SF_6 gas detector

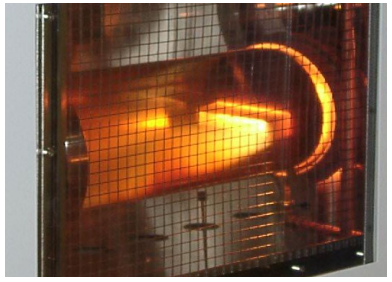
... into imaging IR detectors and modules at IRnova.
In 2020:

- turnover 5.5 MEUR
- 28 employees

From research to company: Ascatron

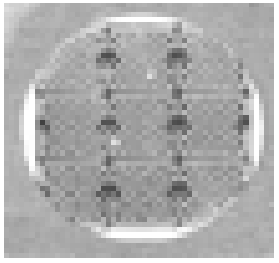
Silicon Carbide – SiC
in early 1990's immature
for electronics...

1992
ABB RISE KTH



A joint research and development program for power devices - SiC epitaxy and processing

1999
RISE



Demonstration of 4.5 kV PiN diode.

2011
Ascatron

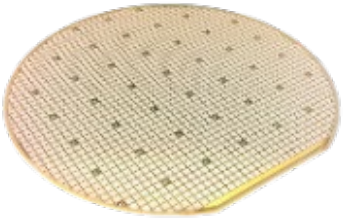
ascatron

Ascatron spin-out. Offers epitaxy and process services to global customers.

2016
Ascatron

Production of SiC epitaxial material on 150 mm substrates

2012
Ascatron



3DSiC® JBS diode volume fabrication

2020
II-VI Kista

II-VI

... has been developed for advanced high power applications. In 2019:

- turnover 1.5 MEUR
- 13 employees