SAL
SILICON AUSTRIA LABS

SUB-WAVELENGTH OPTICS FOR MINIATURIZED SENSING AND IMAGING APPLICATIONS

EPIC Technology Meeting on Photonics for Miniaturized Optics:
From Components to Use-cases at Sony DADC
18-19 September 2024

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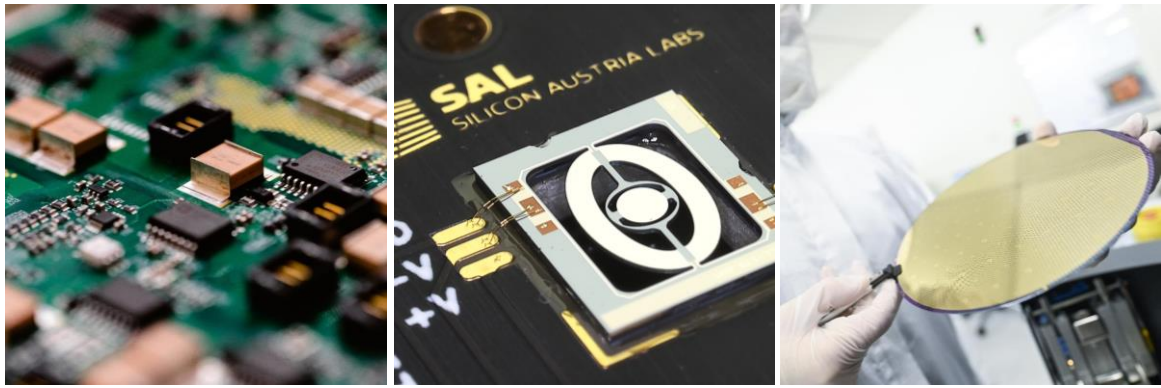
Bundesministerium
Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie
FFG
Das Land Steiermark
SFG
ZUKUNFTSFONDS STEIERMARK
LAND KÄRNTEN
ober österreich
Member of UAR INNOVATION NETWORK

SILICON AUSTRIA LABS

What do we do?

Silicon Austria Labs (SAL), established in 2018, is a European **R&D center** with a focus on the development of efficient and trustworthy technologies in the field of **electronic systems.**

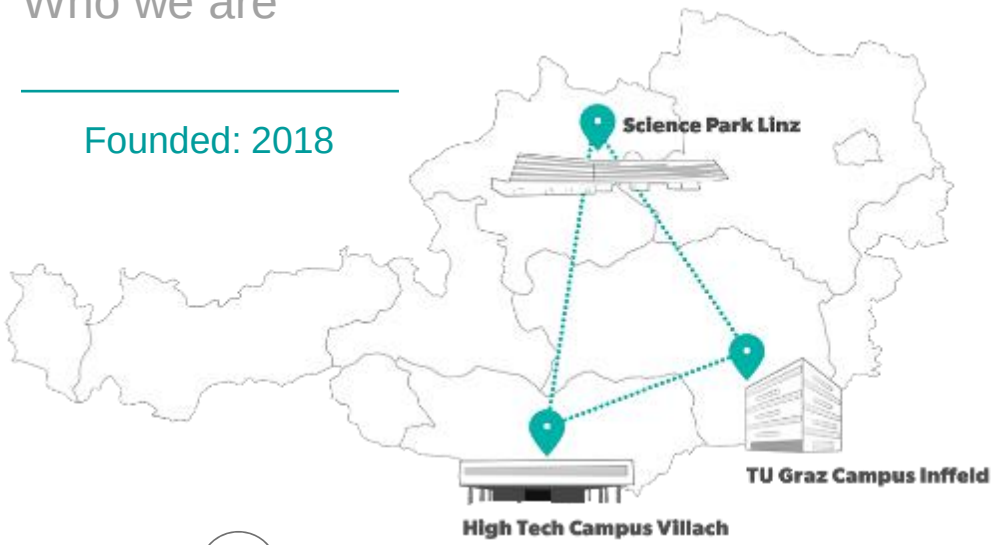
- Industry-oriented research
- R&D services
- Well-equipped research infrastructures
- Customized opportunities for cooperation



KEY FACTS*

Who we are

Founded: 2018



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LOCATIONS

- Graz (HQ)
- Villach
- Linz

> 90

PARTNER NETWORK

- From Industry & Research

> 300

EXPERTS

- Experienced team
- 40 nations
- Multidisciplinary

184

PUBLICATIONS

SAL SILICON AUSTRIA LABS

5

SHAREHOLDER

- 50,1 % Republic of Austria (BMK)
- 24,95 % FEEI
- 10 % Styria (SFG)
- 10 % State of Carinthia
- 4,95 % Upper Austria (UAR)

45 Mio. €

PROJECT VOLUME

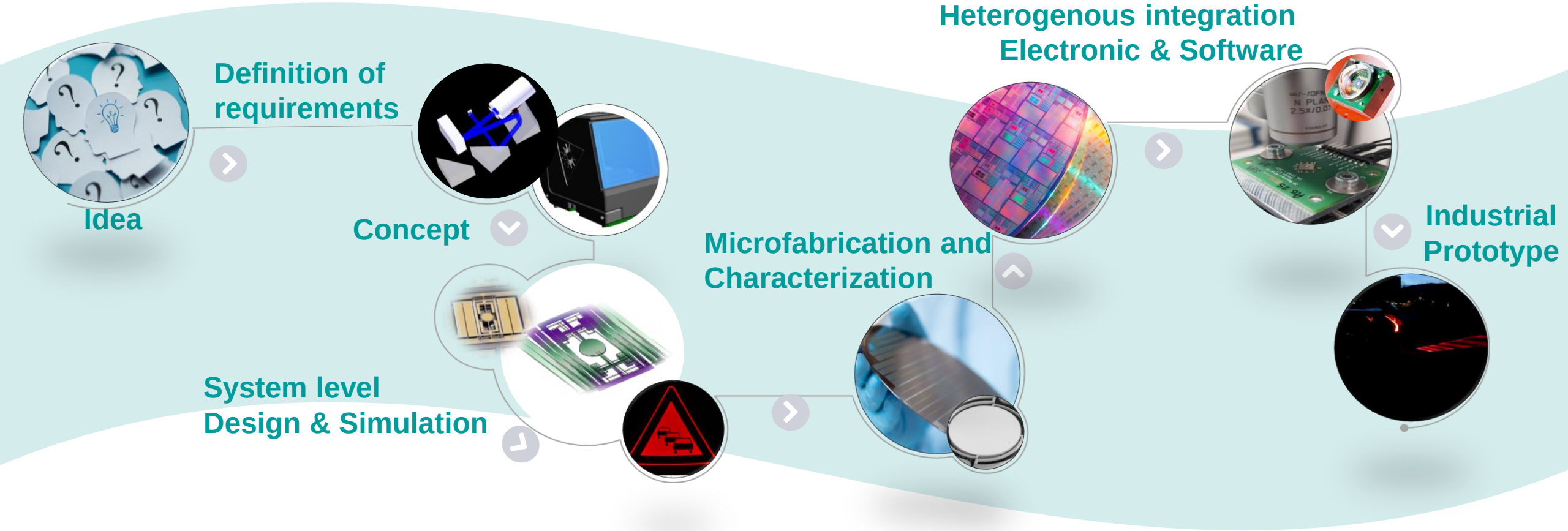
- Total volume for research projects

*2023

SAL UNIQUE SELLING PROPOSITION
FROM IDEA TO PRODUCT

Enabling quick and reliable technology implementation through a full stack of competencies:

an example for a MOEMS scanning micromirror for smart road lighting



SAL Divisions

SENSOR SYSTEMS

POWER ELECTRONICS

INTELLIGENT WIRELESS SYSTEMS

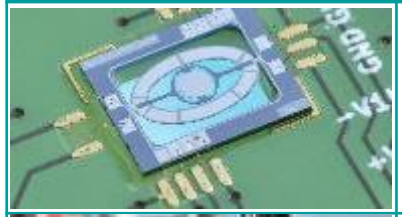
MICRO-SYSTEMS

EMBEDDED SYSTEMS

MICROSYSTEMS

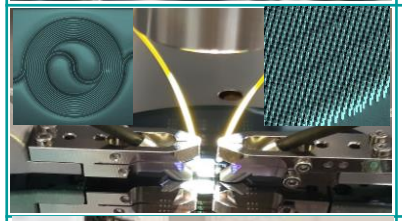
The Microsystems Research Division is dedicated to pioneering advancements beyond current technological standards in novel micro-electro-mechanical systems (MEMS), MOEMS, integrated photonics, and integrated magnetics by synergizing advanced materials and fabrication technologies. Through close collaboration with industrial and scientific partners, SAL endeavors to innovative at every stage, from initial design and proof-of-concept to the development of product prototypes.

RESEARCH TOPICS



Piezoelectric Microsystem Technologies pioneers innovative MEMS solutions for miniaturized sensors, transducers, and acoustic wave resonators, establishing full stack development platforms for novel piezo MEMS systems.

Magnetic Microsystem Technologies focuses on the development and integration of magnets, sensors and spintronic devices into microsystems and their applications for magnetic position and orientation sensing.

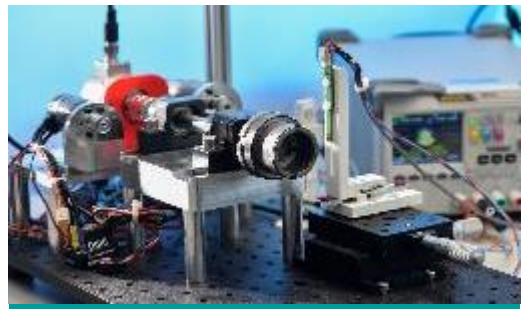


Integrated Photonics Technologies specializes in advancing meta-optics and integrated photonic solutions tailored for compact, multifunctional sensors applicable across automotive, consumer electronics, communication sectors.

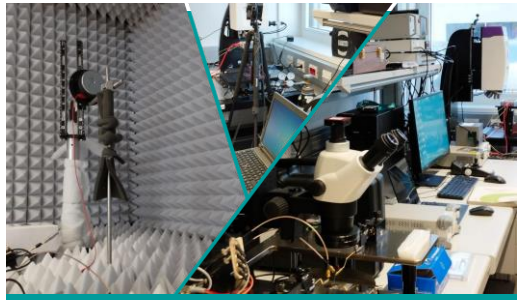
Thin-film Technologies specializes in solutions catering to the development, fabrication, and characterization of cutting-edge thin film technologies applied across piezo-electrics, photonics, magnetics, and electronics applications.

INFRASTRUCTURE

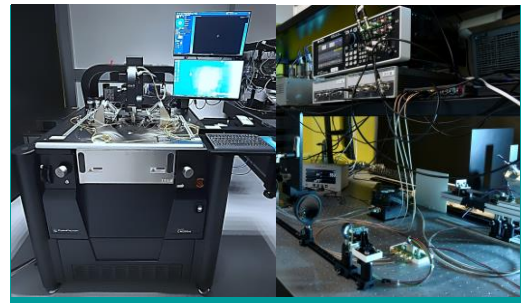
THIN FILM CLUSTER



MAGNETICS LAB



ACOUSTICS LAB



PHOTONICS LAB

SAL MicroFab
MICRO NANO FABRICATION CENTER

SAL SILICON AUSTRIA LABS

- To bridge the gap between R&D and high-volume manufacturing (HVM) with advanced prototyping, small series production and process transfer to industrial level
- To cooperate with global players on cutting-edge electronic based system applications
- To create synergy between scientific and industrial partners
- To become a key step in the idea to product competence

2016 | 2018 | 2020 | 2022 | 2023 | 2024 | 2026 | 2028 | 2030

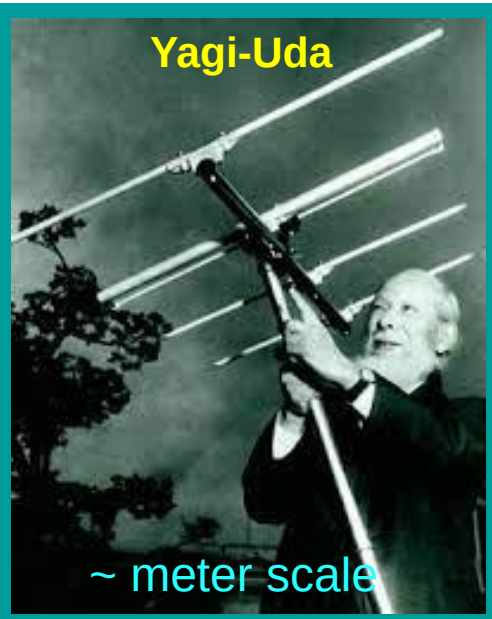
SAL MicroFab Cleanroom I

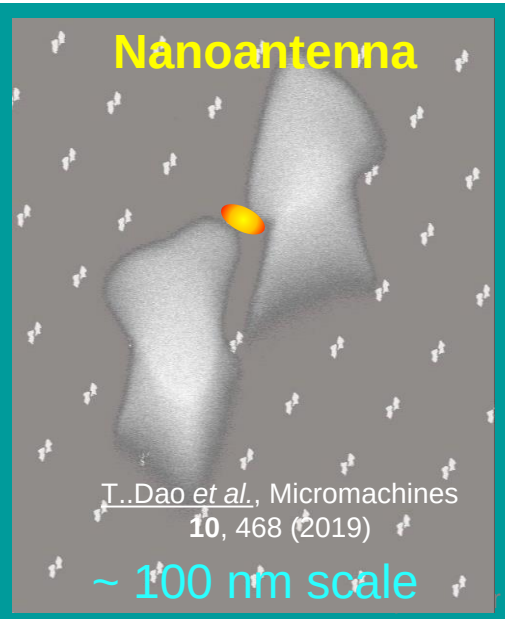
- 300 m² ISO 5
- Up to 8-inch process capability
- Micro and nano fabrication: M(O)EMS, RF filters, integrated photonics
- Characterization equipment

SAL MicroFab NEW Cleanroom II

- 1100 m2 ISO 4 / 5
- Focus on small series production
- Semi-automated – Technology transfer to HVM
- Front-end and Back-end (More than Moore)
- MEMS, PIC, Heterogeneous integration, ...

SUB-WAVELENGTH OPTICS – ENGINEERING LIGHT AT SUB-WAVELENGTH SCALES

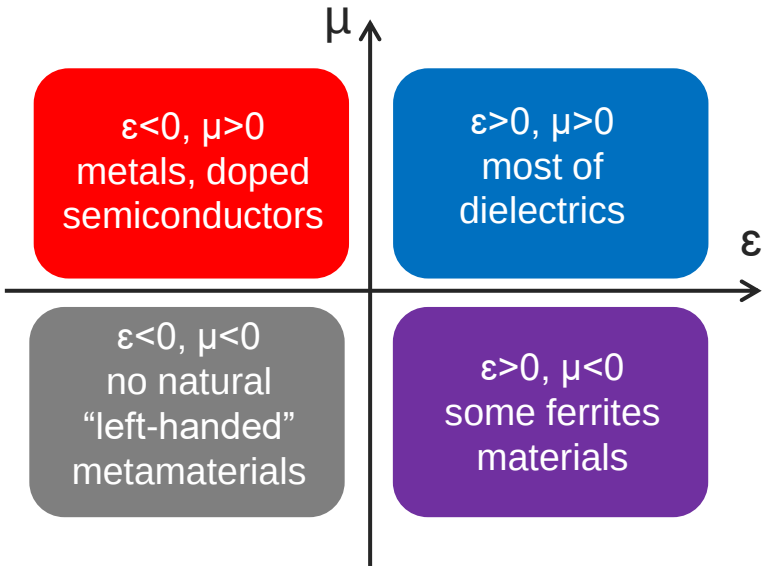


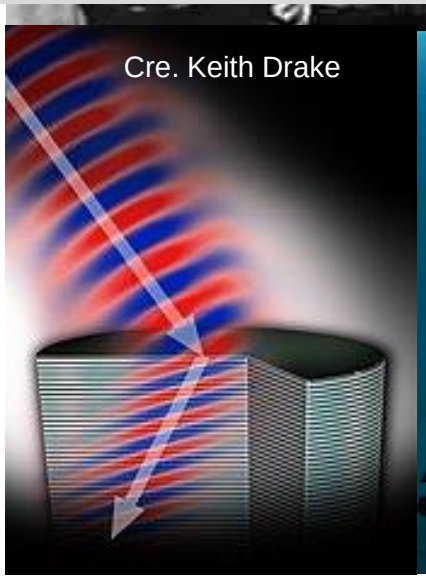


T..Dao *et al.*, Micromachines **10**, 468 (2019)

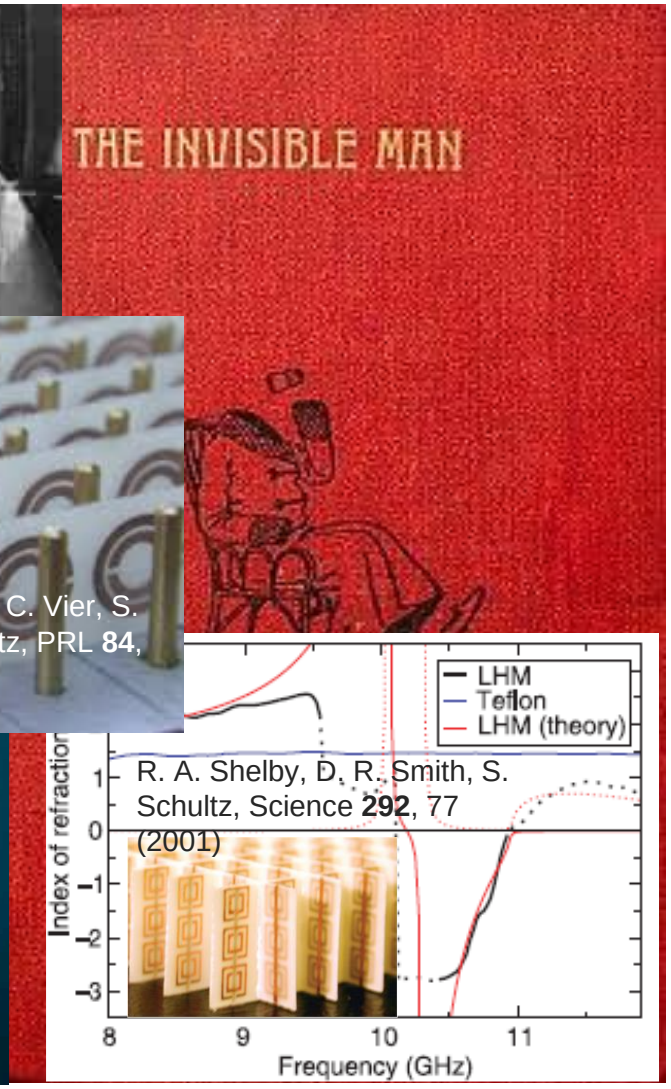
METAMATERIALS

- "Left-handed" metamaterials: *Negative* permeability and permittivity → doppler effect, Cherenkov radiation and Snell's law are inverted.
- Proposed by V. G. Veselago (1967); developed by D. R. Smith, W. J. Padilla, S. Schultz (2000); J. B. Pendry; V. Shalaev, ….
- Materials: Metals, hybrid metal-dielectric structures, all dielectrics (Mie)
- Applications: ultrahigh-resolution imaging systems, polarization optics, invisible and cloaking devices, ….






D. R. Smith, Willie J. Padilla, D. C. Vier, S. C. Nemat-Nasser, and S. Schultz, PRL **84**, 4184 (2000)

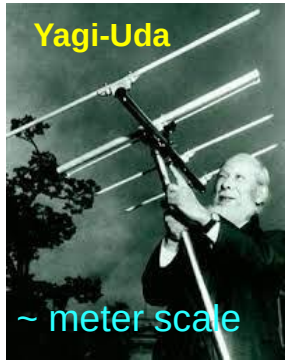


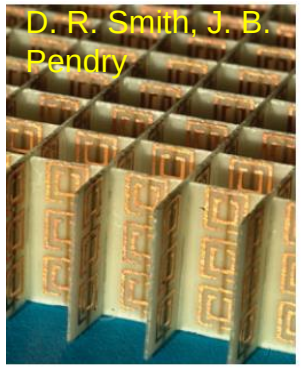
R. A. Shelby, D. R. Smith, S. Schultz, Science **292**, 77 (2001)

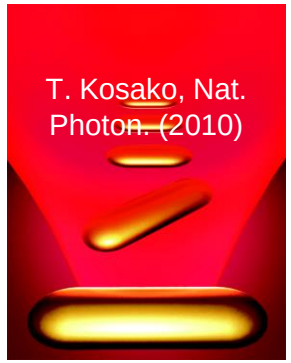
SUB-WAVELENGTH OPTICS

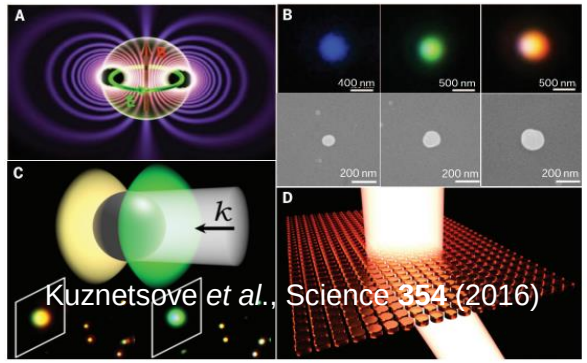
SAL SILICON AUSTRIA LABS

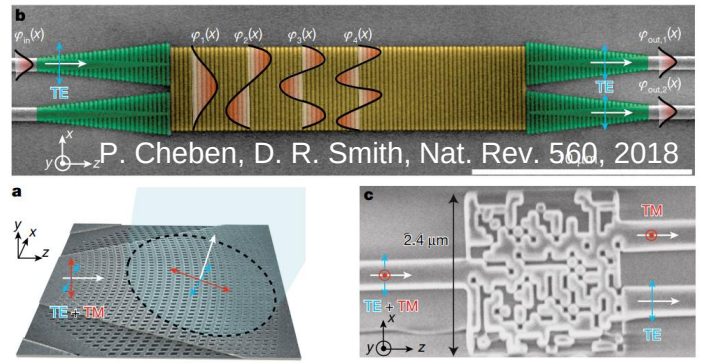
Antennas | Metamaterials | Plasmonics | PhCs | Dielectric metasurfaces | Integrated photonics

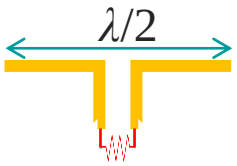












Radio | Micro | Optical frequency range

- **Engineering light at subwavelength scales**
  - Near field, far field, super resolution, spectroscopy
  - Polarization, resonance controls
  - Transmission, reflection, absorption, phase
  - Wavefront control, beam shaping, cloaking
  - Beyond classical limit (quantum)

- **Driven by**
  - New concept, theory
  - Functional materials
  - Fabrication, integration
  - Simulation engines
  - Deep learning

SUB-WAVELENGTH OPTICS

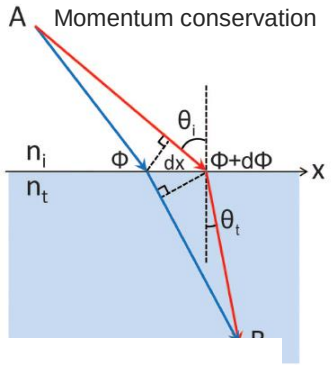
- **Metasurfaces: Ultrathin metamaterials** (F. Capasso, E. Hasman, V. Shalaev, …)
- Resonance, polarization, phase, propagation, transmission reflection, refraction, absorption, …

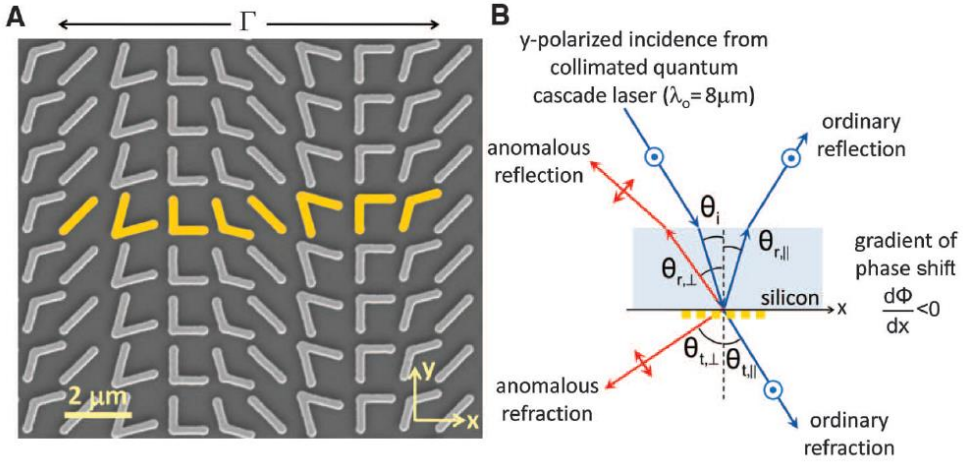
Generalized Snell's law for refraction

$$\sin(\theta_t)\, n_t - \sin(\theta_i)\, n_i = \frac{\lambda_0}{2\pi}\frac{d\Phi}{dx}$$

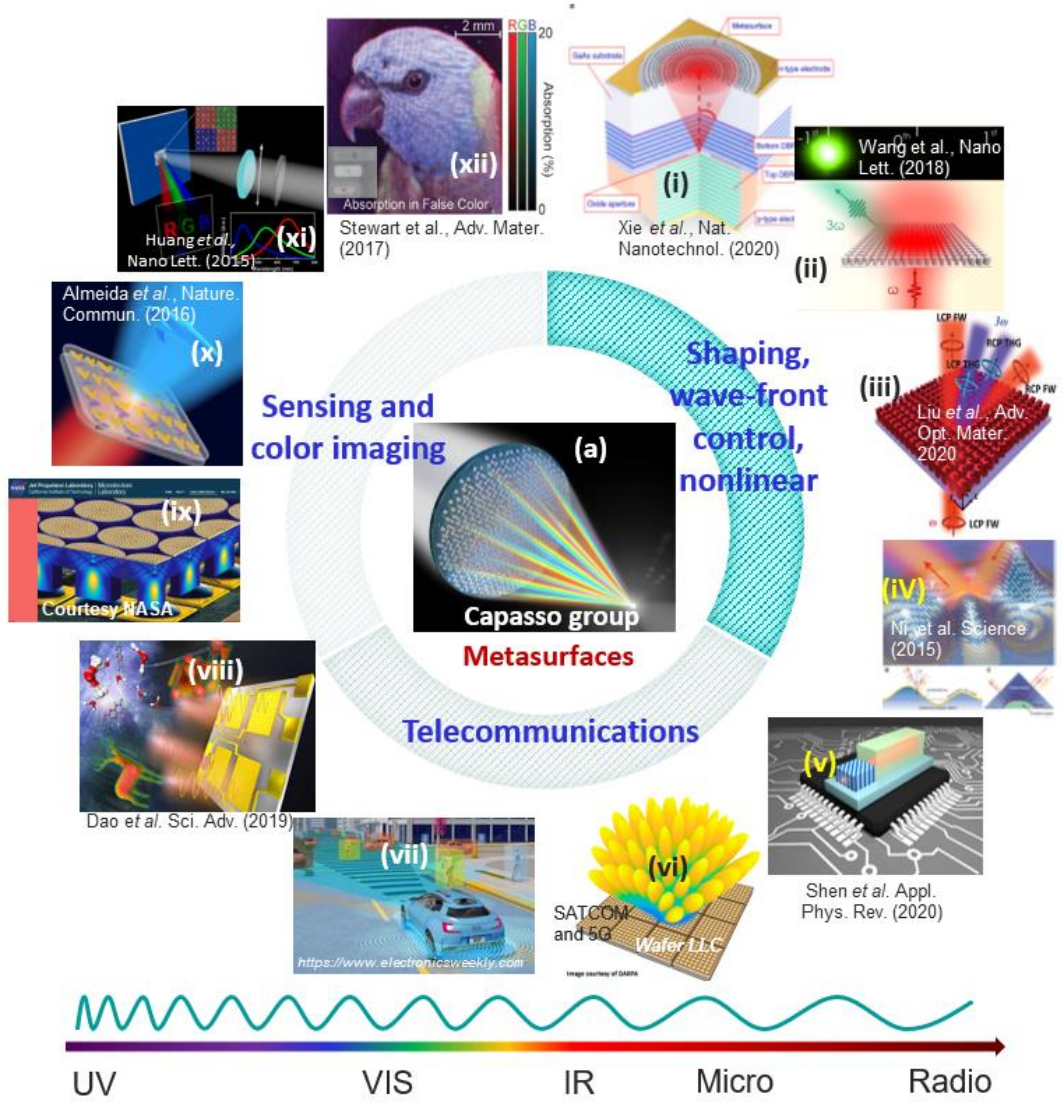
Generalized Snell's law for reflection

$$\sin(\theta_r) - \sin(\theta_i) = \frac{\lambda_0}{2\pi n_i}\frac{d\Phi}{dx}$$



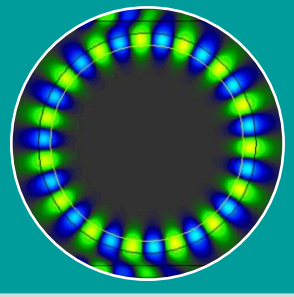
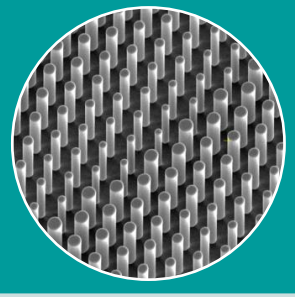
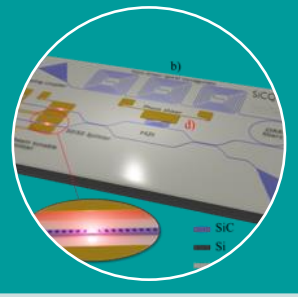


N. Yu, F. Capasso, Z. Gaburro et al., Science **334**, 333 (2011)



WHAT WE ARE DOING

- Addressing critical challenges in subwavelength MetaOptics and Photonics Integrared Circuits (PICs) for diverse applications by leveraging emerging technologies & unique materials.

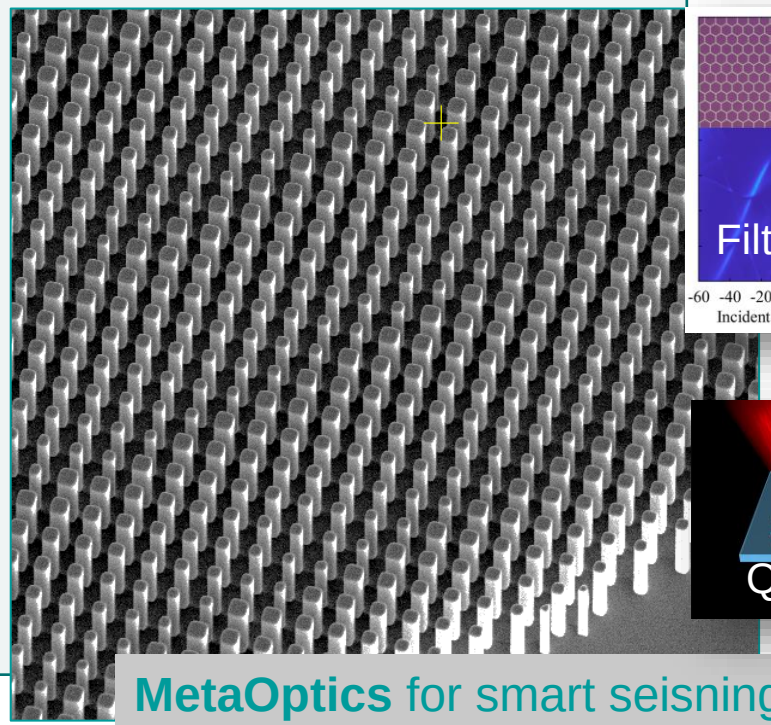
New concepts, new physics, new materials	*Technology development (design and fabrication)*	*Demonstration & use cases*
Integrated photonics	**Metaoptics/photonic MEMS**	**Quantum photonics**
		
On-chip OPA, LiDAR	Wafer-level (meta) optics	Quantum sources
PIC for sensing	3D sensing, imaging	Integrated Q-PICs
MIR PIC integrated QCL&QCD	Nonlinear metasurfaces	Nonlinear Q-PICs
Quantum PIC	Reconfigurable photonics	QKD PIC

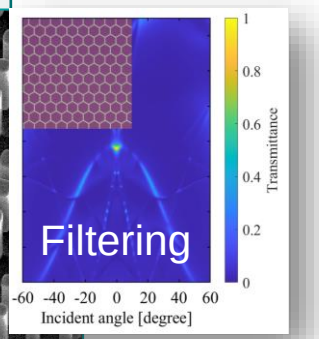
Transitioning from laboratory innovation to industry

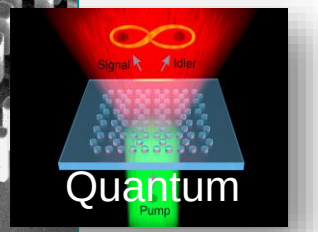
WHAT WE ARE DOING

Addressing critical challenges in subwavelength **MetaO**ptics and **P**hotonics **I**ntegrared **C**ircuits (PICs) for diverse applications by leveraging emerging technologies & unique materials.

MetaOptics

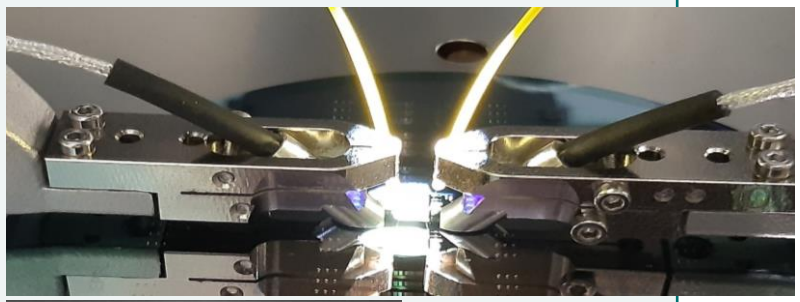


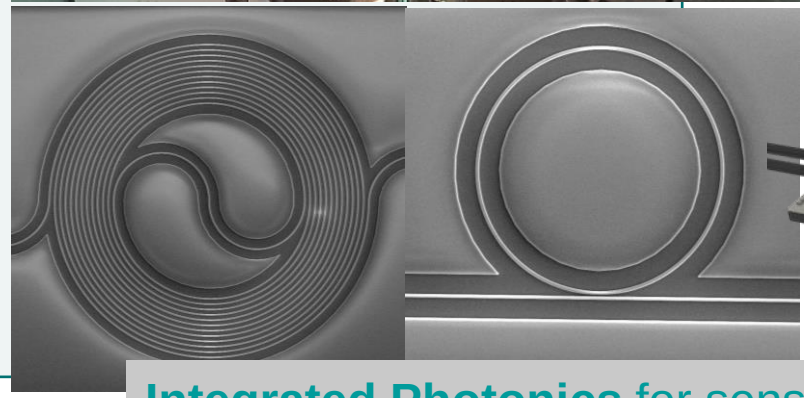




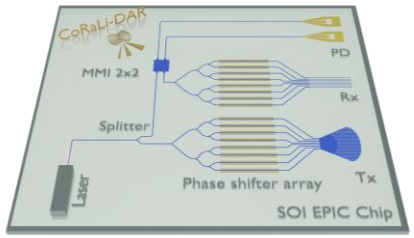
MetaOptics for smart seisning and imaging devices: camera, sensor, AR, VR and quantum applications.

PIC

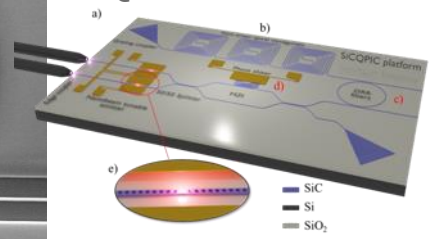




LiDAR



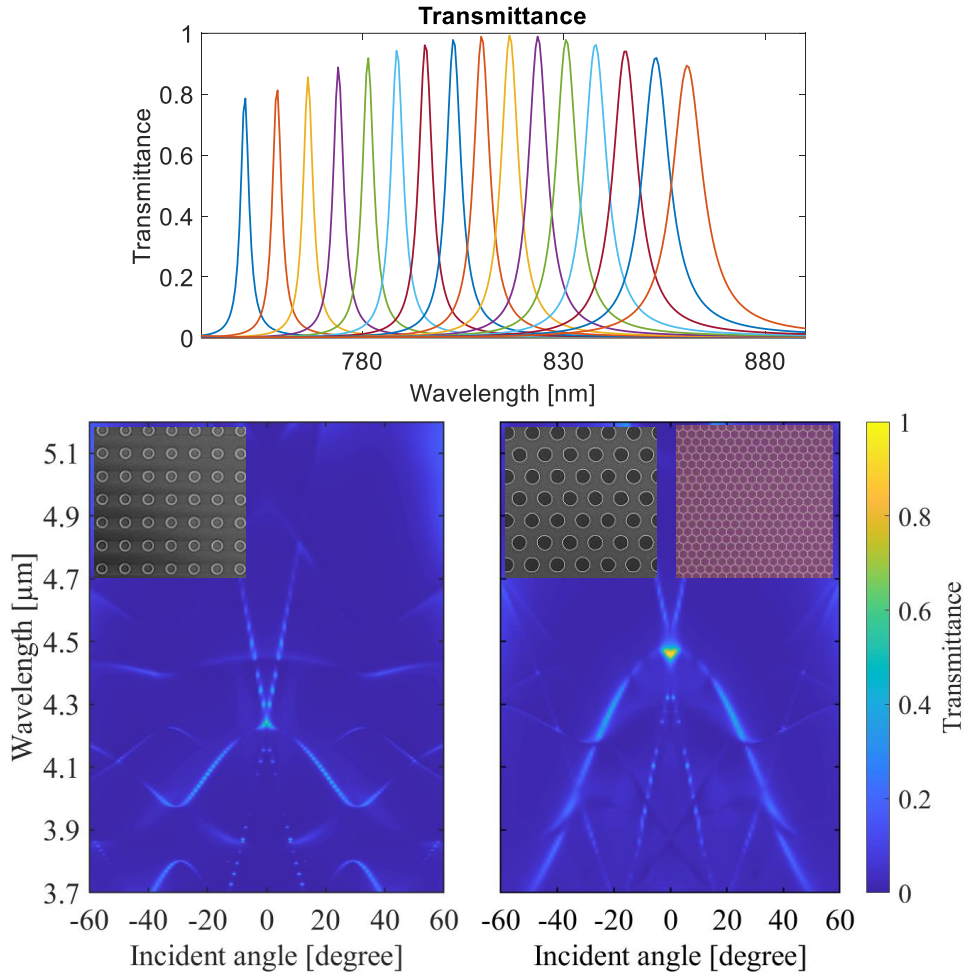
Quantum



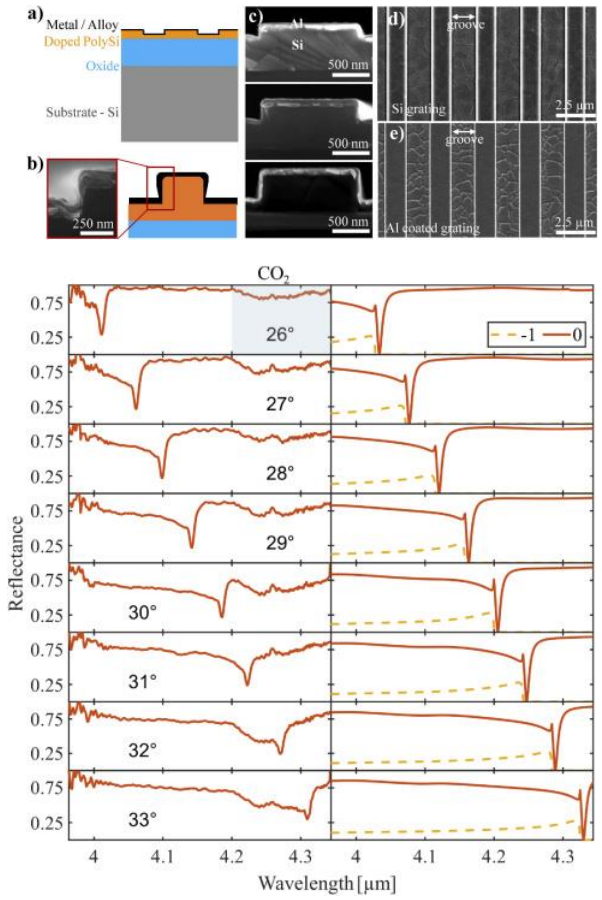
Integrated Photonics for sensing, programable photonics, LiDAR, quantum communication.

META-OPTICS FILTERS

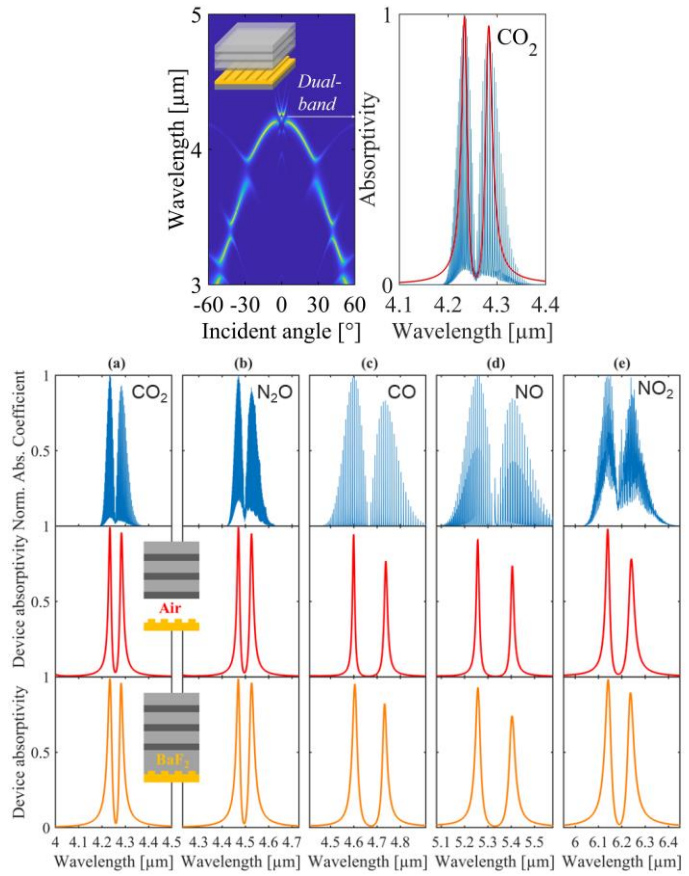
Multispectral imaging



Spectroscopic sensing



J. Spettel, Opt. Mater. Express **11**, 1058 (2021)

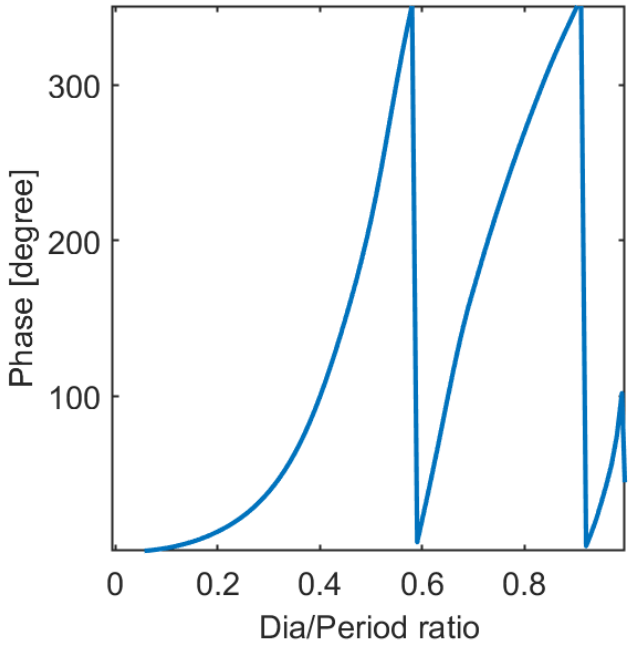


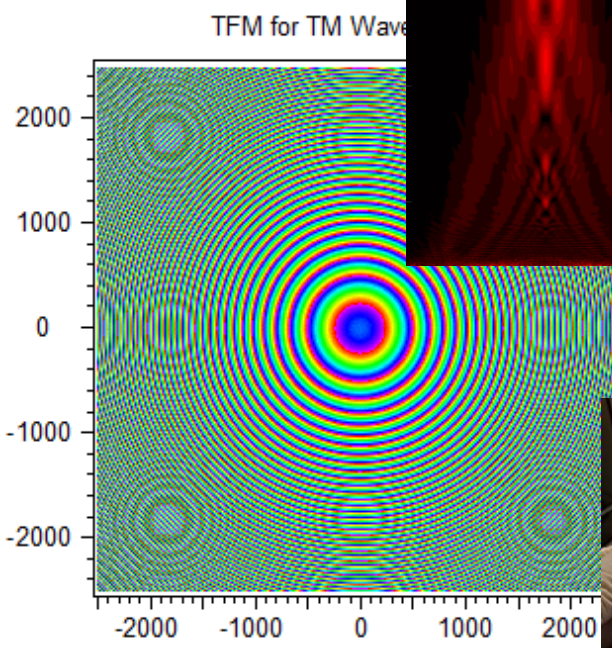
T. Dao et al. OSA Continuum **4**, 1827 (2021)

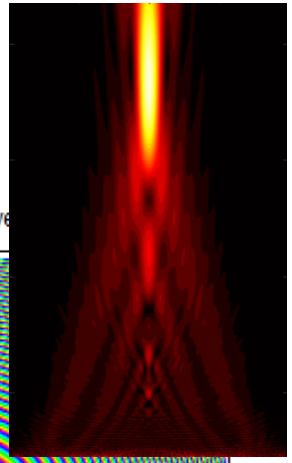
MIR METAOPTICS FOR IMAGING & SENSING

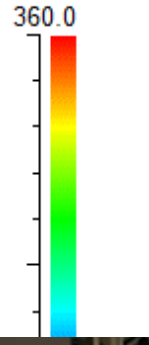
Metalenses for IR imaging

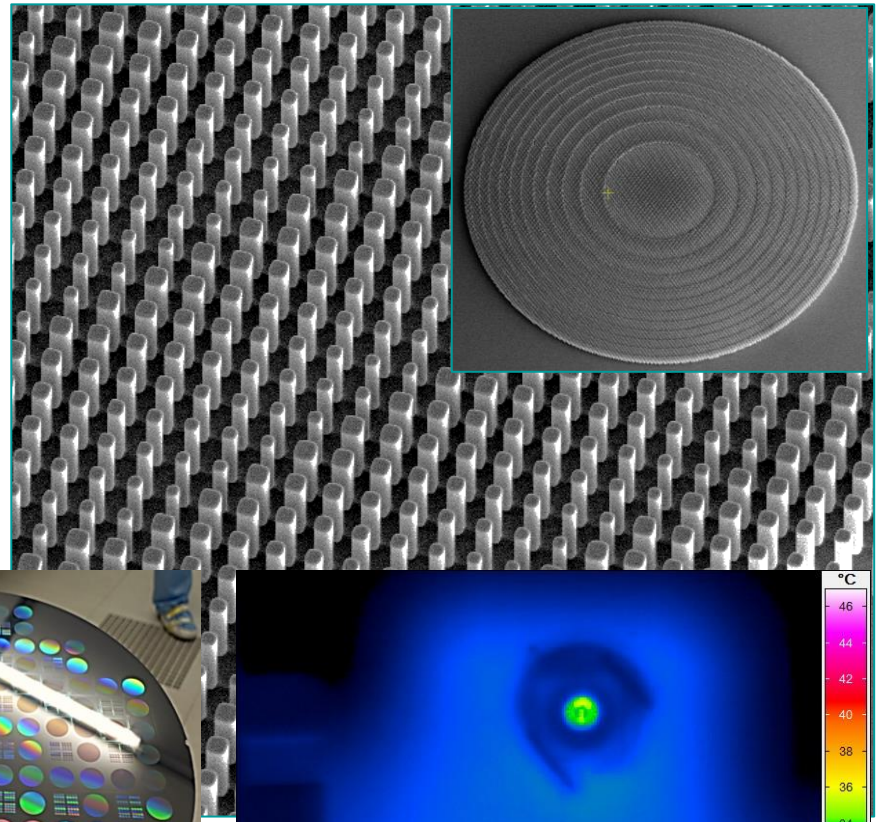
Achromatic & polarization insensitive lenses











HOW TO WORK TOGETHER

Partners	Research institutions/ universities	Tools and materials supplier	Industries/ manufactures	End-users
SAL	➢ Co-develop technologies from concept to prototyping ➢ Provide reliable fabrication processes ➢ Foster collaboration with other RTOs, industry, and end-users for technology maturation ➢ Explore funding opportunities: national, EU, and bilateral proposals	➢ Collaborate to develop devices from concept to prototyping ➢ Offer complementary fabrication processes compatible with tools and materials ➢ Engage with RTOs, industry, and end-users for technology maturation ➢ Explore funding opportunities: national, EU, and bilateral proposals	➢ Partner to co-develop devices from concept to prototyping ➢ Offer complementary fabrication processes and provide feedback to improve performance and yield ➢ Collaborate with RTOs and end-users for technology maturation ➢ Explore funding opportunities: national, EU, and bilateral proposals	➢ Define device requirements and provide input throughout concept and prototyping ➢ Offer critical feedback to optimize and align solutions with market needs ➢ Collaborate with RTOs, industry, and manufacturers to drive technology maturation ➢ Explore funding opportunities: national, EU, and bilateral proposals

HOW TO WORK TOGETHER

SAL Cooperative Research

Purpose:
- Easy, accessible co-financing for R&D projects with SAL
- Long term R&D cooperations (>1year)

Organisational Framework:
- Project Evaluation by SAL
- SAL General Contract Terms
- SAL Project Agreement
- IP-rules are in line with the European State Aid Law

Advantages:
- 50% co-financing by SAL
- Bi/multilateral cooperation possible
- No application process necessary

Contract Research

Purpose:
- Technology Concepts
- Test & Measurements
- Feasibility Studies
- Proof of Concept Studies
- (Rapid) Prototyping

Organisational Framework:
- Quote – Order Process

Advantages:
- Fast project start
- No further contractual framework necessary
- Fixed price
- Clearly defined deliverables

R&D Services

Design and **simulation**, **characterizations**, **measurements** and **testing** up to **manufacturing** in the field of micro- and nanotechnology.

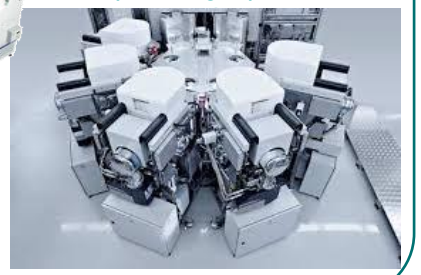
Funded Research

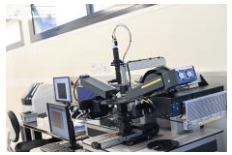
METAOPTICS FABRICATION

SAL's fabrication capabilities

PE-CVD

Multi-chamber sputtering, optical





2P-3D printer QuantumX

Nanoimprint EVG7300

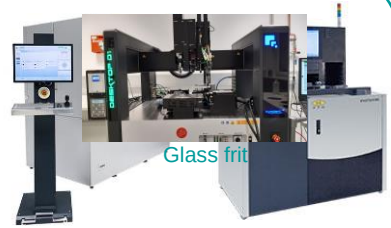
EBL EBPG5200 Plus

Two ICP etchers

HF vapour SPTS uEtch

IBE Veeco

Plasma Asher Diener Nano 6



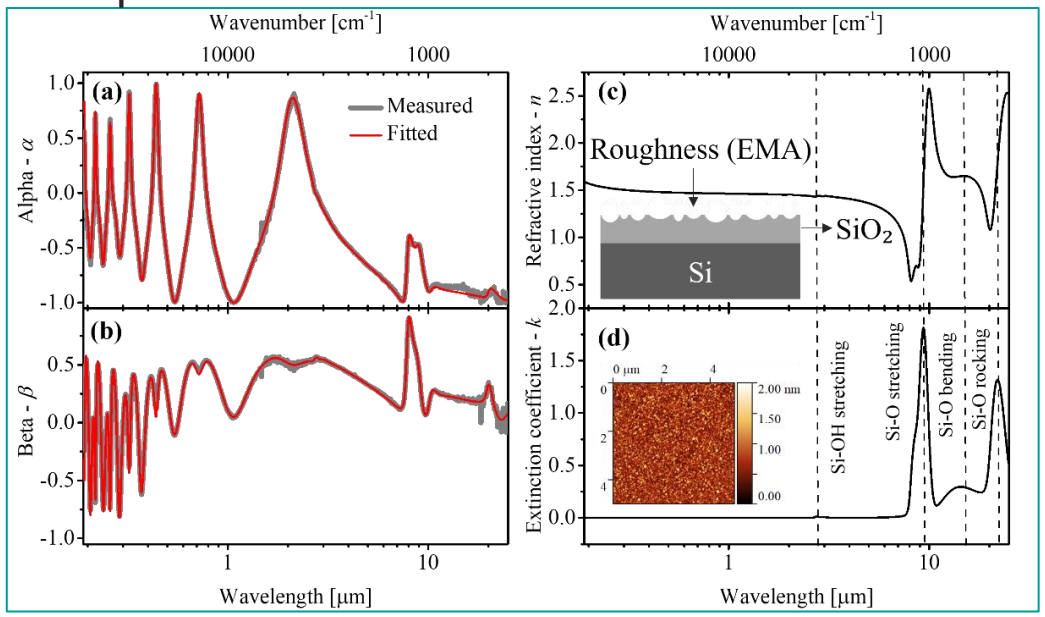
Glass frit

Wafer Aligner EVG Smart View NT

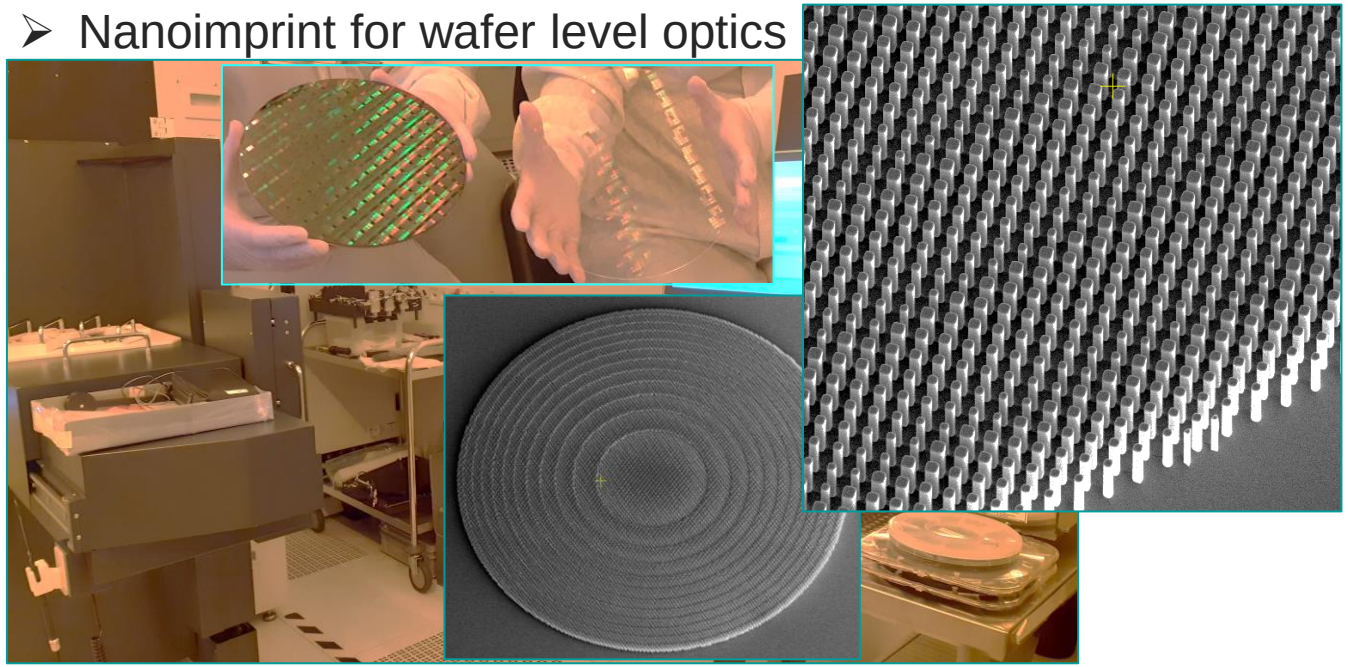
Wafer Bonder EVG 520

Functional thin films deposition ***Characterization*** ***Nano lithography*** ***Etching (wet, dry, iso- and anisotropic)*** ***Wafer-bonding, layer transfer***

➢ Optical thin film fabrication and characterization



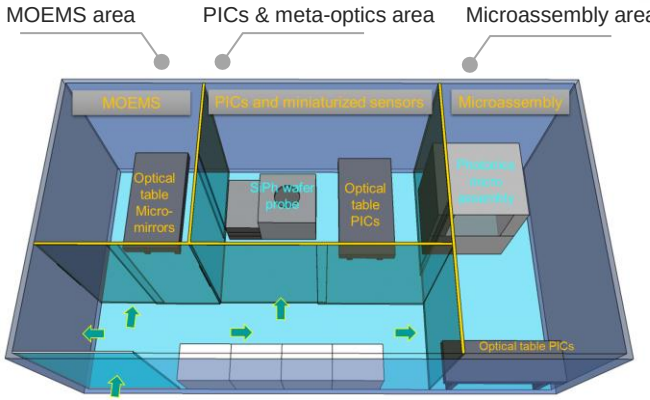
➢ Nanoimprint for wafer level optics



CHARACTERIZATIONS

SAL SILICON AUSTRIA LABS

Lab infrastructure	MOEMS characterization	Integrated photonics & Metaoptics	3D-photonics microassembly



- 50-m2-ISO7 cleanroom environment
- Temperature and humility control
- Laser safety protection

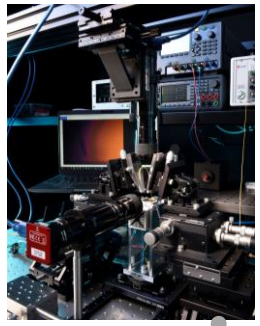
With PHOS & PMT

MOEMS characterization test bench

Nextron enviromental control system & microprobe chamber

Digital Oscilloscope

12''-wafer automated photonic probe

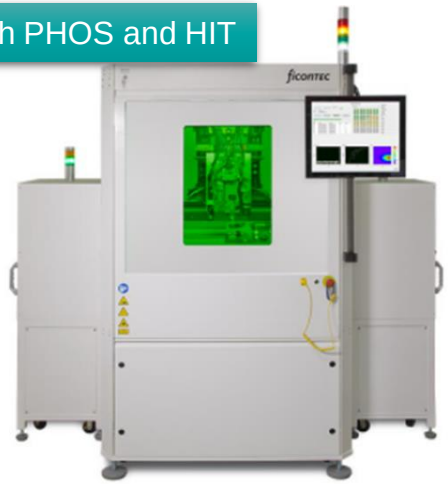


Die-level PIC test bench

Optical Spectrum Analyzer (600 – 1750 nm, ±20 pm)

C-band tunable laser (1500 – 1630 nm, ±3 pm)

With PHOS and HIT



3D Photonic Assembly system

1. Optical MEMS (MOEMS) characterizations, test benches
2. PICs, metaoptics and miniaturized sensors characterizations, test benches
3. 3D photonic micro-assembly

1. System-level test bench for MOEMS
2. Demonstrators: Micro-projectors, micro-LiDAR, smart-lighting
3. Reliability test of MEMS & MOEMS
4. Developing solutions for MOEMS device testing and demonstration

1. Automated wafer probe for integrated photonics (**PIC**) characterization
2. Wafer-level optics characterization
3. System-level PIC-based sensor test bench (NIR, MIR)
4. Lab-based environmental monitoring

1. 3D Micro-assembly machine for assembly of microoptical components.
2. In-place curing and active alignment system.
3. Flipchip module and laser soldering.
4. High precision motion with sub-µm resolution.

OUTLOOKS

- **Metaoptics**
  - Engineers light at the sub-wavelength scale
  - Enhances functionalities, optical integration, and miniaturization
- **Progress**
  - Significant advancements over the past decade
  - Driven by breakthroughs in materials science, fabrication, and computational methods like deep learning
- **Current focus**
  - Shift from an emerging field to a promising photonic technology
  - Emphasis on technology maturation to meet growing application demands
  - In Europe, the sector is expanding, necessitating robust collaboration among RTOs, SMEs, industries, and end-users
- **SAL**
  - Dedicated to advancing metaoptics from design to fabrication and prototyping
  - Collaboration with partners and the broader community to drive progress → Advancing metaoptics toward becoming a mature technology

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THANK YOU!