FONDAZIONE BRUNO KESSLER

FUTURE BUILT ON KNOWLEDGE

Nanotecnologie in FBK

Prof. Gianluigi Casse
Direttore del Centro FBK-SD

Fondazione Bruno Kessler (FBK)

- **10** research centers
- over **400 researchers**
- **100 PhD students from 25 countries**
- over **200** including Thesis students, and visiting professors

- **3.600** sqm laboratories
- More than **100 EU projects** (2020)
- More than **150 projects** with companies (2016)

FBK-SD Centre Sensors and Devices

SENSORS AND DEVICES
FONDAZIONE BRUNO KESSLER

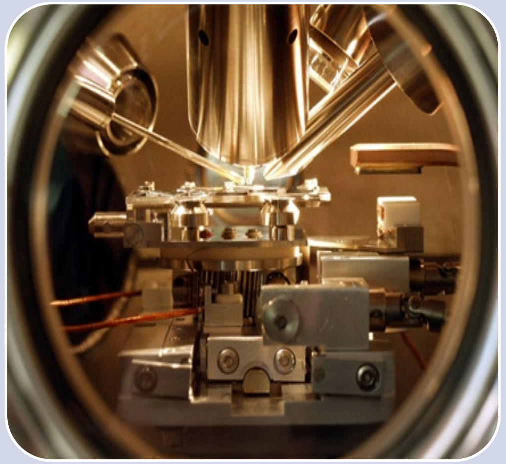
Director | Gianluigi Casse

Researchers and Technicians | 80 employees
- 56 Researchers
- 24 Technicians and admin

20 PhD

Mission

Summing a wide base of complementary competences, know-how and state of art research infrastructure to achieve outstanding results in both research and innovation fields.



Basic research:
Internal and cooperative research

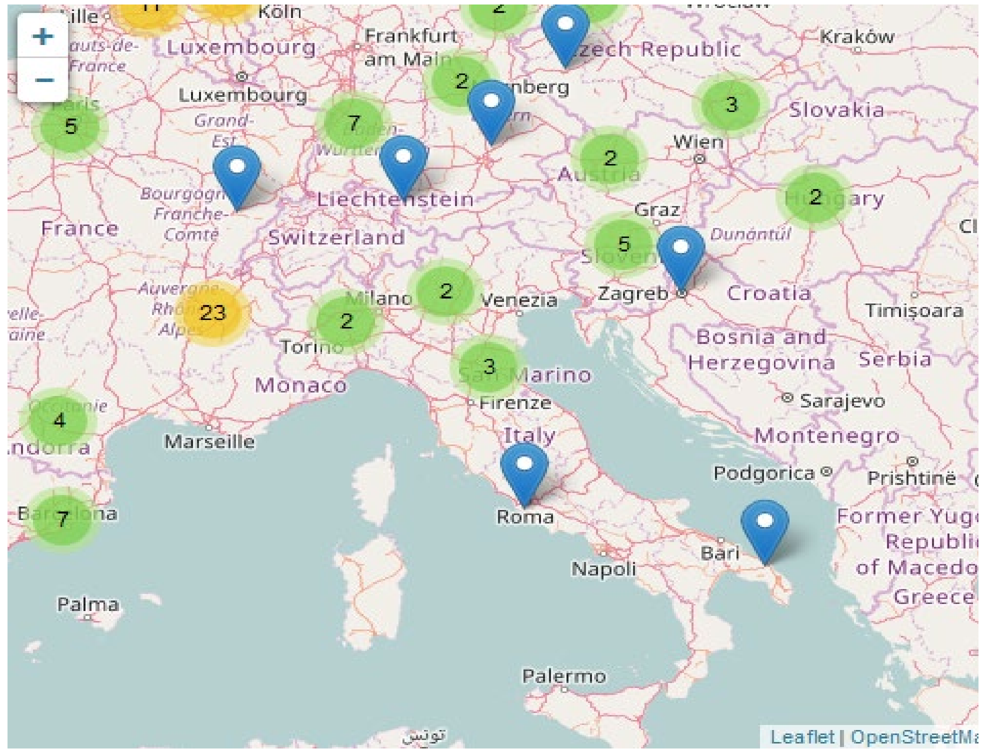
Innovation:
Companies, Start-up's
Joint laboratories

Society and industry:
Service
and
education

FBK-SD is a KET EU Centre

Heterogeneous integration of different advanced technologies (silicon, NEMS and MEMS, functional coating, photonics, nano-electronics, bio-surfaces)

FBK is a KETs Technology Centre for Small-Medium Industry by the EU



- ➢ <u>Micro and Nano electronics</u>
- ➢ <u>Nanotechnology</u>
- ➢ <u>Photonics</u>
- ➢ Industrial biotechnology
- ➢ Advanced materials
- ➢ Advanced manufacturing

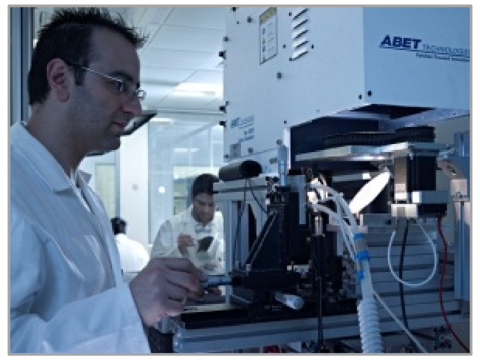
Research Fields and technology platforms

- Micro and nano devices
- Sensors
- Radiation Detectors
- Imagers and digital imagers
- MEMS/NEMS for Bio and RF
- Innovative Materials for devices
- Quantum Technologies

- Pilot CMOS line
- Microelectronics (ASICs design)
- Superconductive circuits
- Integrated Photonics
- Hetero-integration
- Nanofab
- Bio surface functionalization
- Mechatronic

Micro-Nanotechnology Facilities

Micro/nanofabrication Facility



6” Microfabrication Area

Clean Room Detectors

500 m^2; Class 10/100 0,8 um CMOS pilot line: Ion Implantation, Oxidation, Diffusion, RIE, Deep RIE (silicon and oxide), Lithography (stepper 0.35 um and mask aligner), metal sputtering, optical profilometry

Clean Room MEMS

200 m^2 Class 100/1000 diffusion, lithography (mask aligner), wafer bonding, electroplating, Si bulk micromachining, metal evaporation, RIE, mechanical and optical profilometry,

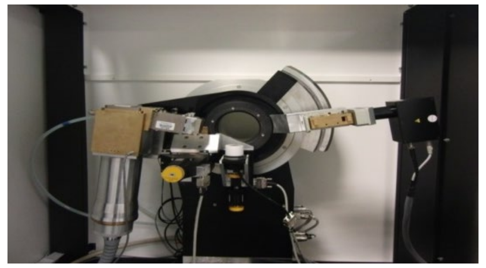
Testing Area

200 m^2 manual parametric testing, automatic parametric/functional testing, optical testing (spectral responsivity, quantum efficiency), solar cells efficiency characterization, gas and pressure sensors test benches

Integration Area

50 m^2 clean room Class 1000 Microassembly station; screen printing, bonding (ball & wedge bonder), Shear-Pull Tester, reflow oven, CNC micro-mill

Analytical facility



D-SIMS Dynamic Secondary Ion Mass Spectrometry

ToF-SMS Time of Flight Secondary Ion Mass Spectrometry

XPS X-Ray Photoelectron Spectroscopy

SEM-EDX-EBSD Scanning Electron Microscopy

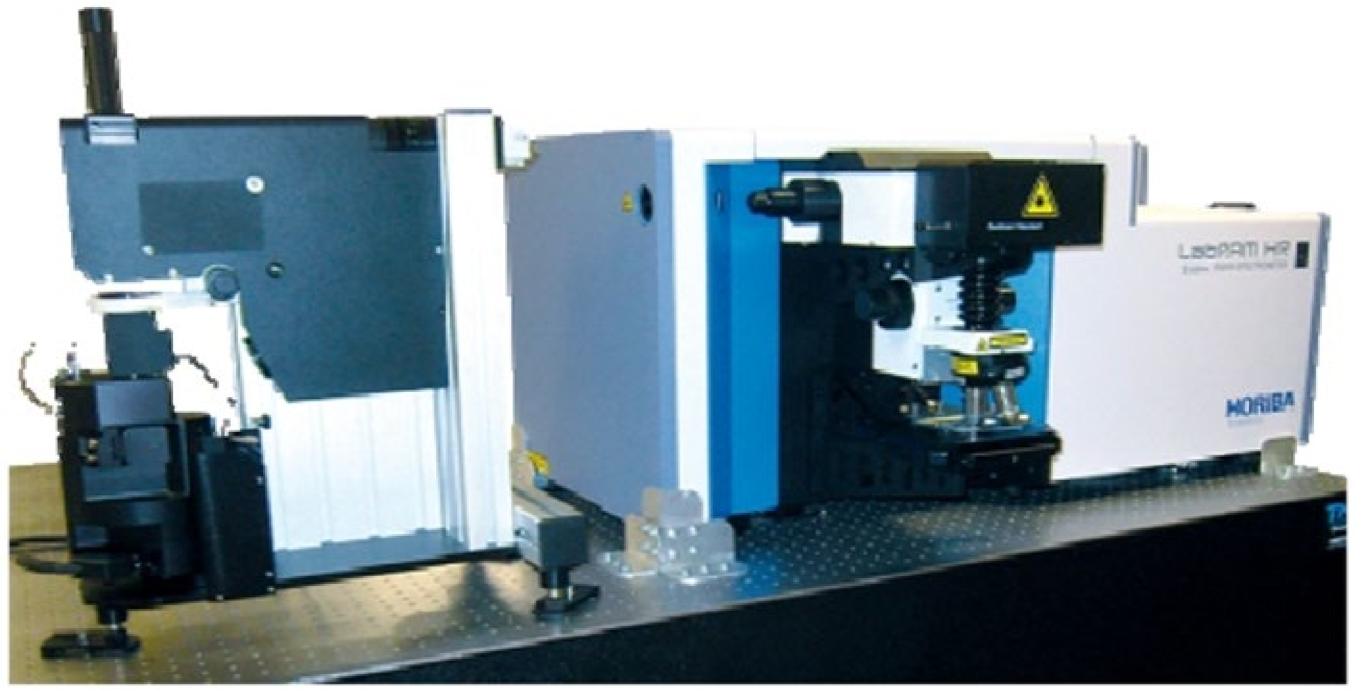
AFM Atomic Force Microscopy

XRD/XRF X-ray Diffraction / X ray Fluorescence

AFM/Raman Spectroscopy

FIB/SEM Focused Ion Beam

LabRAM HR Evolution Nano Horiba



- HR spectrometer for Raman and PL
- Confocal microscope coupled to the spectrometer
- SPM microscope placed in a chamber with controlled atmosphere
- Simultaneous decoupled use of spectrometer and SPM

Raman & PL spectroscopy

- Raman/PL spectra
- 1D/2D/3D Raman/PL spectral map

Components

- Lasers: 355 / 532 / 633 / 785 nm;
- Power laser control 100%-0.05%;
- Optical filters to block the laser line;
- Gratings: 600 / 1200 / 1800 / 2400 gr/mm;
- Laser polarization rotator (λ/2 filter) and polarization analyzer;
- High quality, full frame CCD detector;
- Modulo EasyNav^{TM};
- Microscope objectives: 5x, 20X, 50X, 100X visible ligth;
  40X, 60X H_2O immersion;
  74X, 80% T, NA 0.66, 200-5000 nm.

Performances

- Spectrometer: working range 200 nm – 2000 nm,
  resolution <= 1 cm^{-1} in 300 nm-1000 nm;
- Confocal Raman PL spectra in 300 nm – 1500 nm;
- Raman S/AS below 10 cm^{-1} with G/R/IR; below 200 cm^{-1} with UV;
- Motorized xyz stage, minimum xy step 10 nm, z <100 nm.

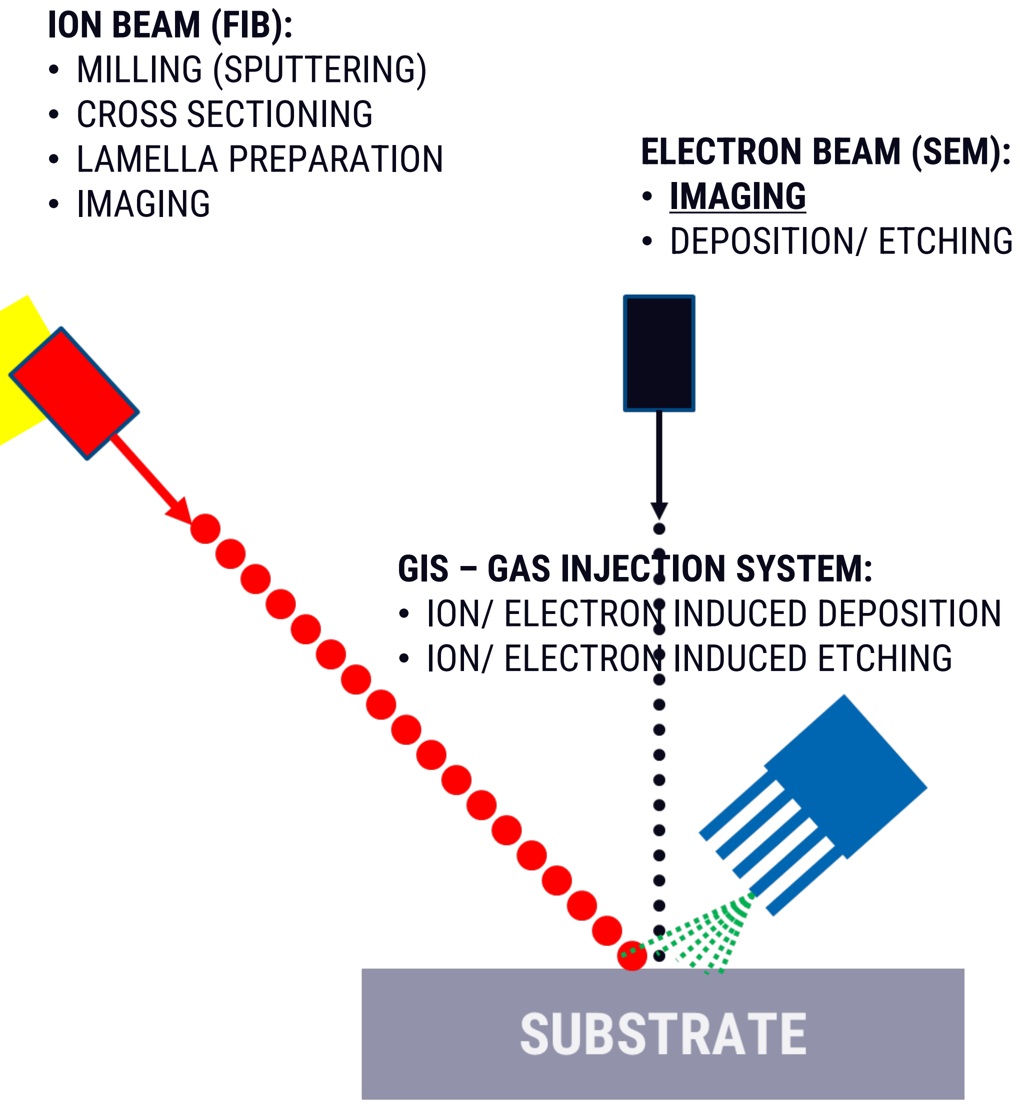
FIB Raith

FIB COLUMN

LIQUID METAL ALLOY ION SOURCE
Si^{++}; Au^{++}; Au^{+}
Ge^{+} or Ge^{++}

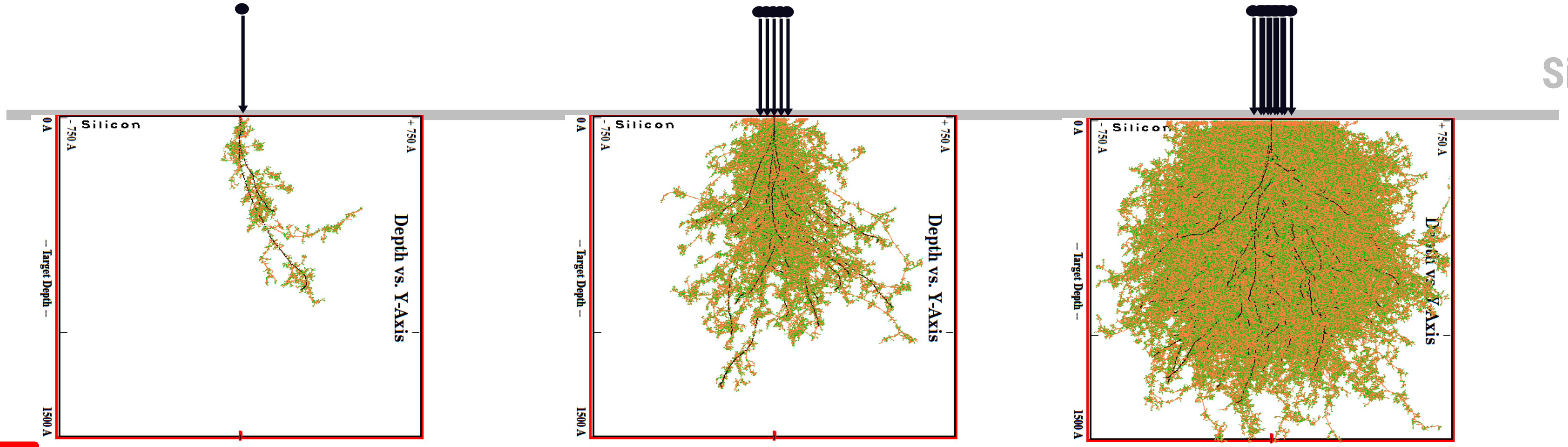
ION ENERGY (ACC. VOLTAGE: 2 -35 kV):
2 -35 keV for SINGLE CHARGED ions;
4 –70 keV for DOUBLE CHARGED ions.
LMAIS ION BEAM INTENSITY:
Si^{++}: min. 1.5 pA; max. 475 pA
Ge^{+}: min. 1.3 pA; max. …
Ge: min. 1.9 pA; max. 420 pA
Au^{+}: min. 4.1 pA; max. 2,000 pA
Au^{++}: min. 1.7 pA; max. 420 pA
PATTERN GENERATOR: 20 bit/ 50 MHz
MINIMUM DWELL TIME: 20 ns
MINIMUM STEP SIZE: 0.2 nm on 200 µm WF

LASER INTERFEROMETER TABLE
EXCELLENT STITCHING AND BLIND NAVIGATION
SMALL SAMPLES preferred
TILT 0-90°ON 1.5x1.5 cm2



Ion Dose makes the difference for applications: sputtering yield and milled depth

70 keV Ge$^+$ on Si - collision cascade (SRIM simulations)



Si SURFACE

ION INDUCED (NANO-) STRUCTURES:

- ripples, hillocks, terraces…
- nanovoid
- self-assembly

ION DOSE

$$\varphi = \int_0^t J_{ion} dt$$

$$z(t) = \int_0^t \frac{J_{ion} Y}{\rho} dt$$

MILLED DEPTH

$$z(\varphi) = \frac{Y\varphi}{\rho}$$

ρ = Atomic Density,
Y = Ion Species, Energy and Angle

INCREASING ION DOSE

SINGLE ION IMPLANTATION;

- single vacancy-complexes.

1-100 ions per spot

ION IMPLANTATION:

- composition change
- defect creation
- amorphization

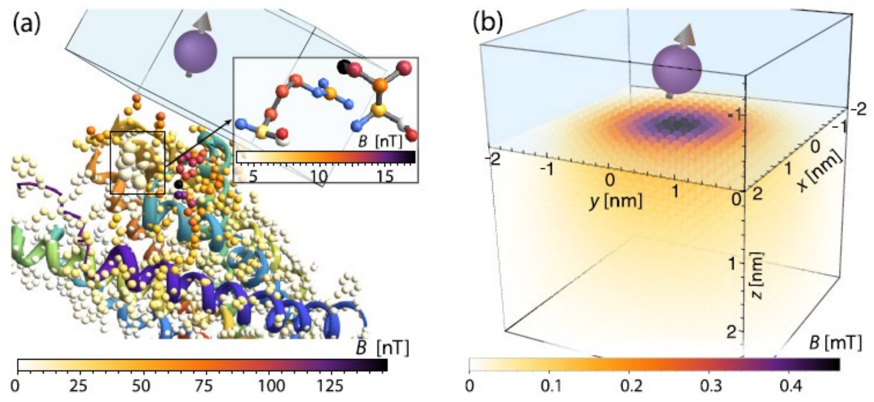
1E13-1E16 ions/ cm^2

ION MILLING:

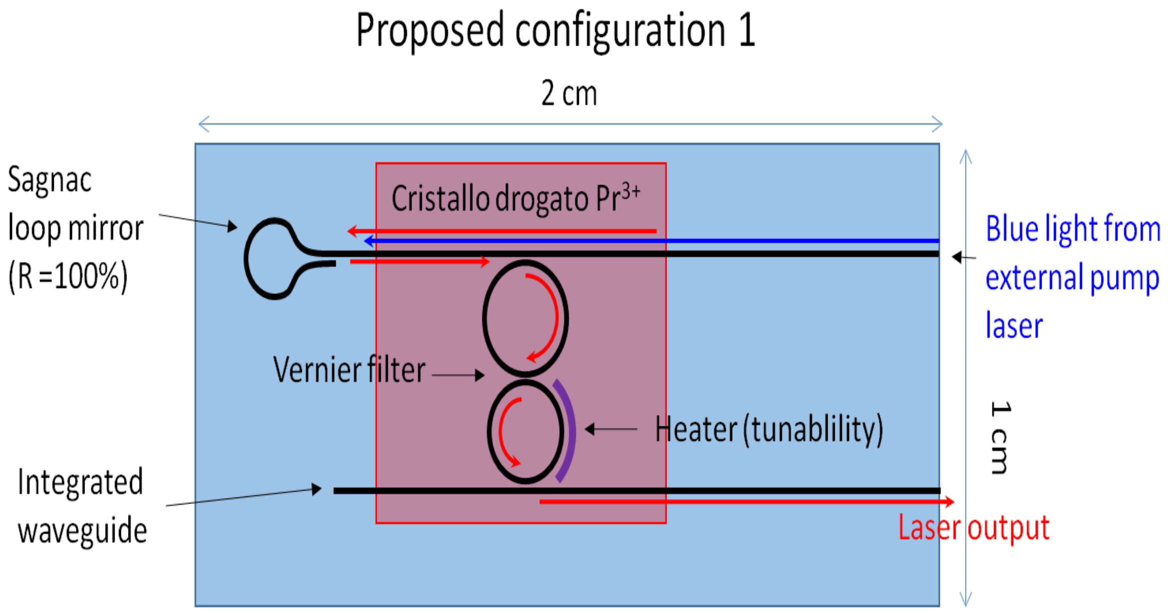
- sputtering
- patterning.

6E15 - … ions/ cm^2

Examples in Quantum Technologies



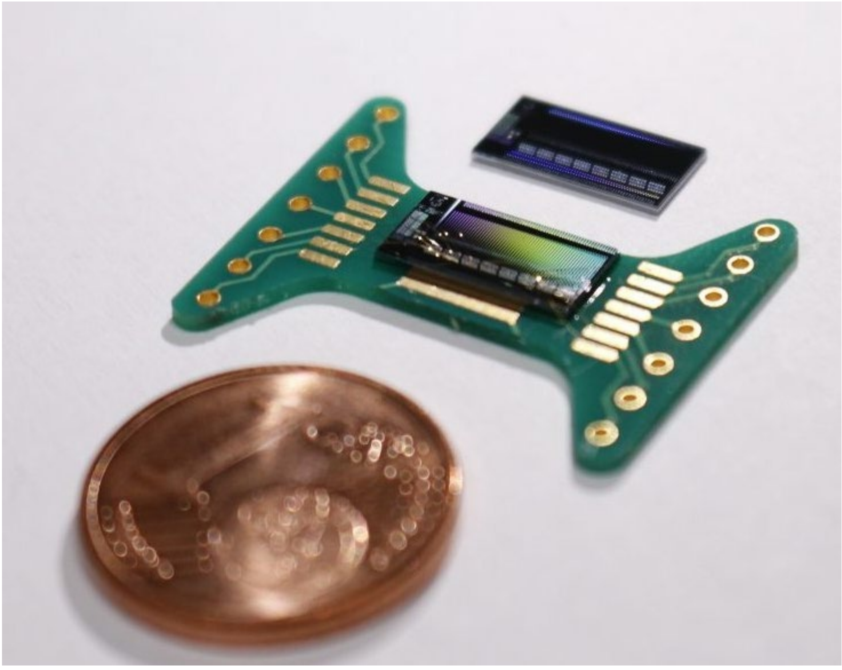
NV centres to detect the individual position of nuclear spins to reconstruct the structure of a protein accommodated on a bulk diamond sensor. In this domain, the frequency resolution of NMR instruments is too low. NV polarization leakage due to entanglements to specific nuclear spins under magnetic field gradients allows for the reconstruction of nuclear spin positions with unprecedented resolution.



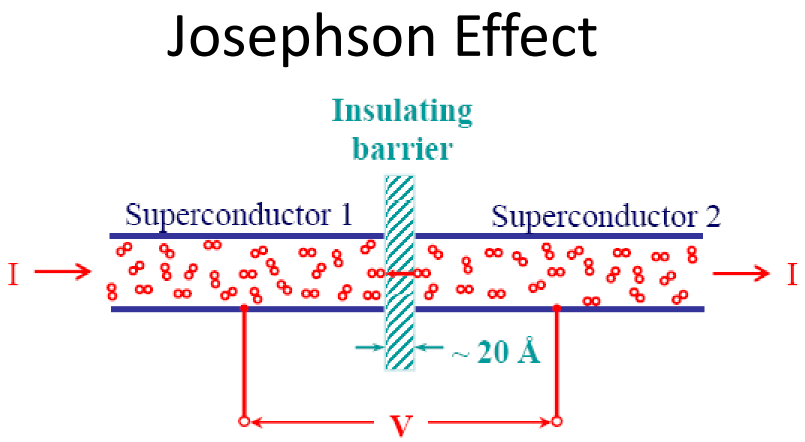
Optical pumped laser (GaN), stabilised laser emission at 698nm, linewidth ~ 1kHz, power > 0.1 mW

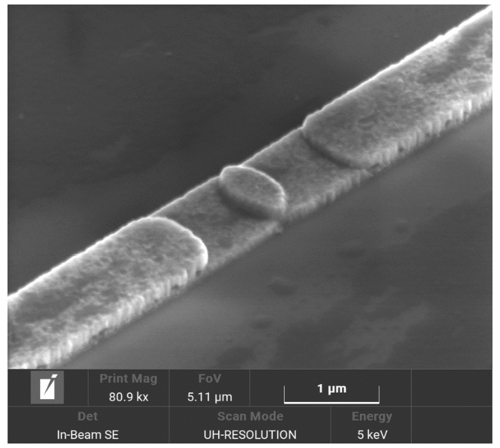
Metrology and clock distribution

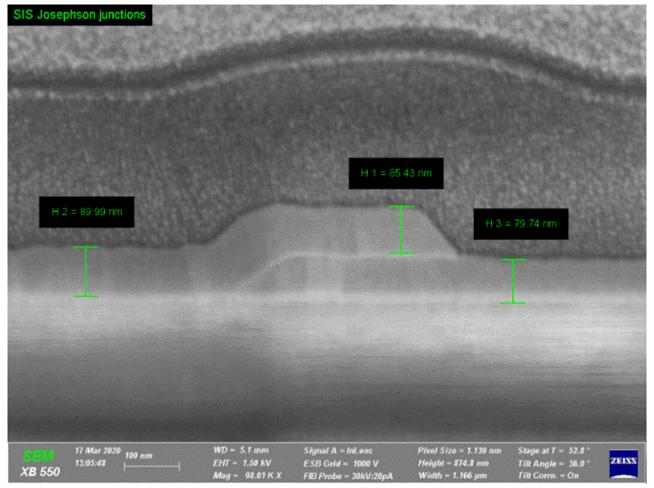
- Ultra narrow linewidth solid state laser for the Sr-atomic clock
- Space-compliant on-silicon systems
- Quantum sensors and components (Josephson junctions, nanowires, colour centre based quantum magnetometry).



Chip-scale quantum photonic-electronic integrated platform, fully interfaced to a classical computer. This reconfigurable photonic-qubit device will be a testbed for a quantum simulator to address both Artificial Intelligence (Quantum Machine Learning) and Physics (Heisenberg-Spin Systems) tasks.







Precision metrology
Superconducting digital computing
Superconducting quantum computing
SQUID-based Parametric Amplifiers for ultrasensitive detection at the quantum & subquantum limit
SQUID multiplexing for large scale arrays of TES (Transition Edge Sensors) or Magnetic Calorimeters.
Basic Research with circuit-QED

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Thanks!