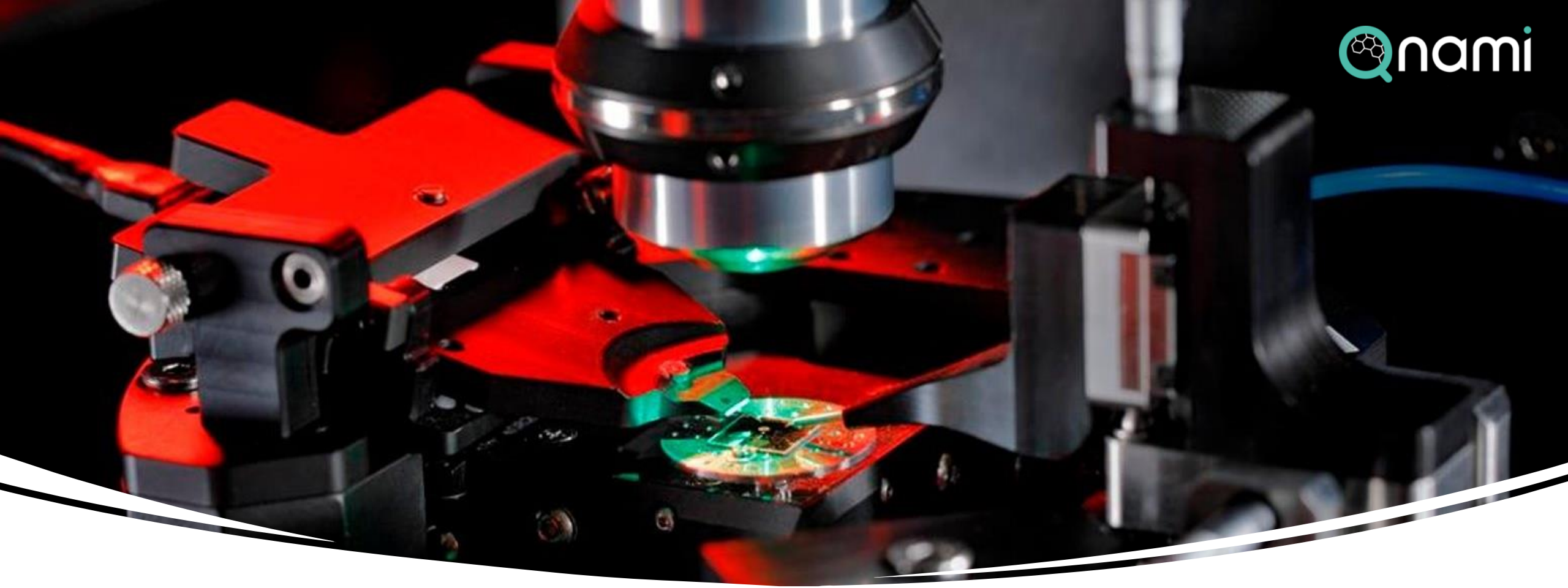


Quantum Sensing Unleashed

Innovations, Applications, and Market Expansion

Dr. Alexander Stark, CIO and Co-Founder

EPIC Technology Meeting on Industrial Quantum Photonics Technology at TOPTICA

10th-12th of October 2023

alexander.stark@qnami.ch

www.qnami.ch

Qnami leverages the culture for high precision in Switzerland

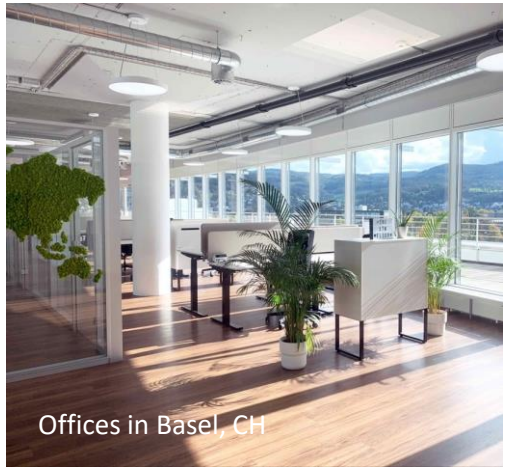
We are building a quantum platform for sensing applications. Our goal is to bring practical solutions to customers in the need for accurate measurements.

Qnami AG
Incorporation: 2017 (spin-off University of Basel)
Headquarter: Basel (CH)
Quantum Foundry: Villingen (CH)
Qnami Germany GmbH (DE, Sales)

Team: 25
>180 years of Quantum Expertise accumulated

Academic and industrial partners:

imec
elementsix DE BEERS GROUP
ETH Zürich
QUANTUM BRILLIANCE
UNI BASEL
clinatec
csem
PAUL SCHERRER INSTITUT PSI
SWITZERLAND INNOVATION PARK INNOVAARE


Offices in Basel, CH


R&D and Production Labs


Team in May 2022


Quantum Foundry in Villigen, CH


Industry level clean-room infrastructure

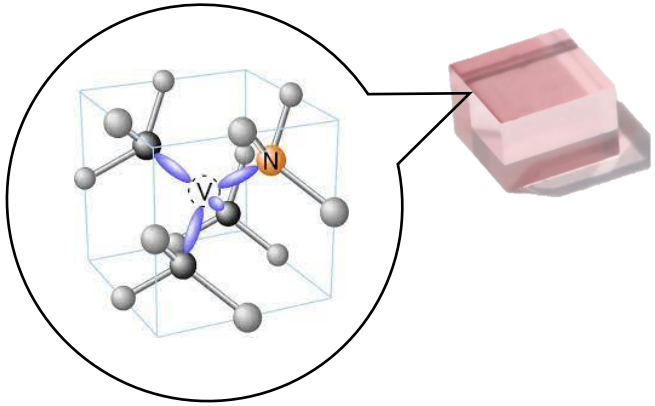
TOP 100 SWISS STARTUP AWARD 2022
venture leaders
Forbes
MIT Technology Review

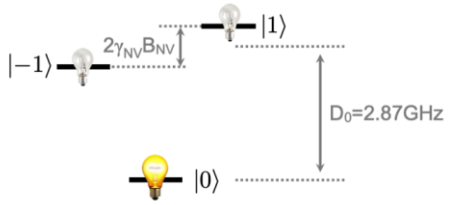
Quantum sensing using “defective diamonds”

The NV center in diamond: an atomic compass with high sensitivity under ambient conditions

Quantum system

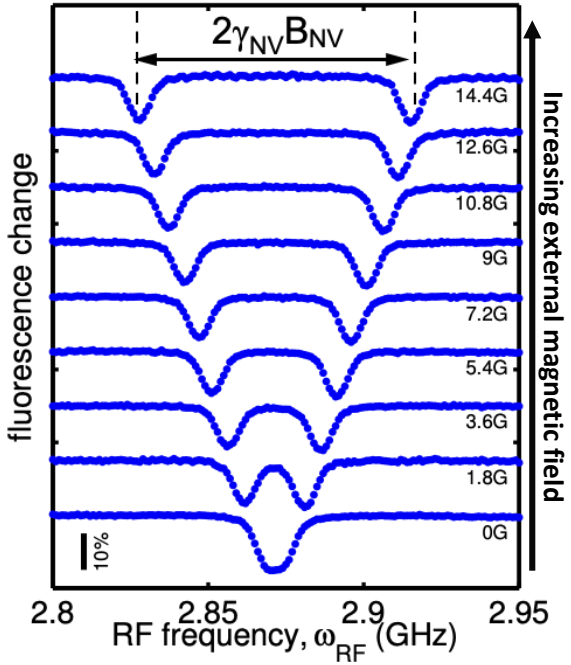
Synthetic ultra-pure diamond substrates are doped with Nitrogen atoms to form the **keystone** of our platform: the **Nitrogen-Vacancy (NV) centers**





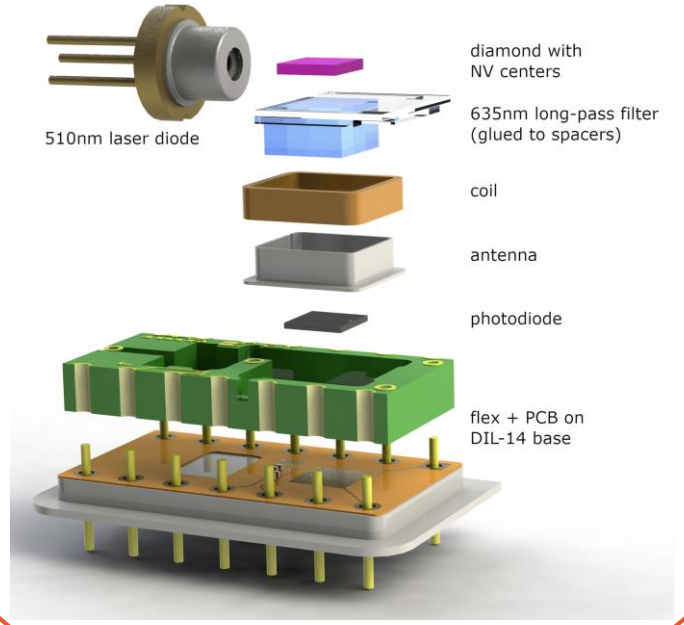
Multi-sensor

Thanks to **quantum physics**, the light emitted by NV centers depends on **external parameters** (magnetic field, temperature, etc…)



Compact technology

A quantum technology as **simple** as it gets: integrated optical and radio frequency pulses is used to drive and read the NV quantum state. Compatible with existing CMOS, photonics, electronics, detector...

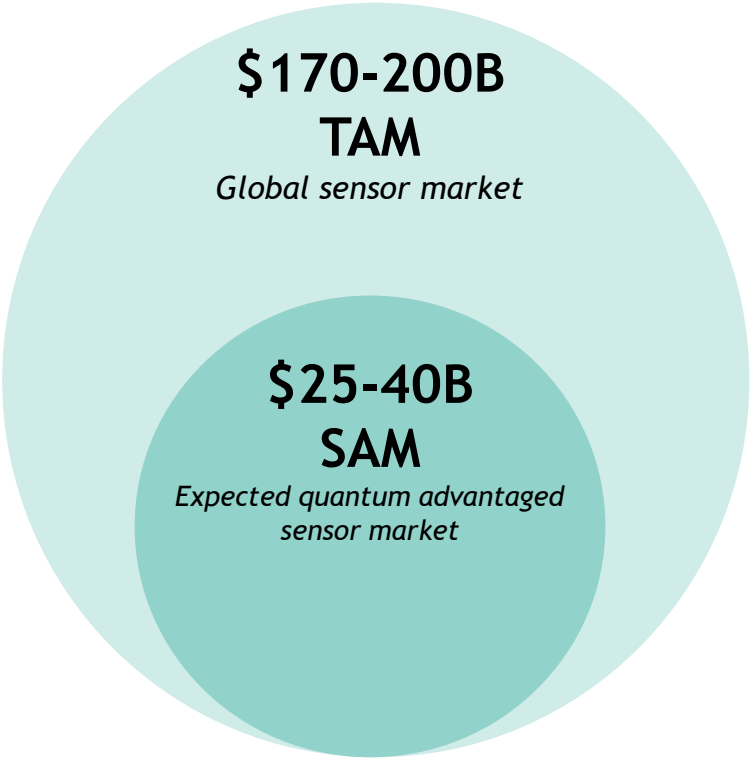


all without the need of complex calibration!

all operating under ambient conditions!

A $170B+ sensor market in urgent need of higher accuracy and sensitivity

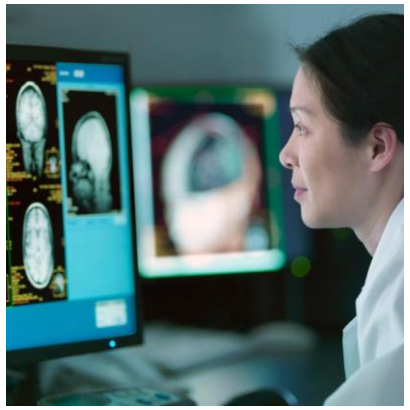
Current applications of sensors require a leap in their performance to unlock the next generation of devices and enhance our understanding and interaction with the world



Market by 2030

Source: Boston Consulting Group 2023
Making Sense of Quantum Sensing

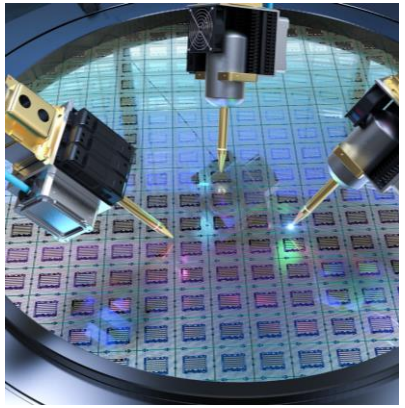
Scientific Instrumentation
(Horiba, Bruker, Oxford Instr)



Bioimaging
(Siemens, Ricoh, Megin)

Diagnostics
(AstraZeneca, Roche, Abbvie)

Navigation
(Honeywell, Lockheed)

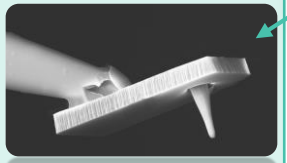


Semiconductor
(KLA, TEL, Nova)

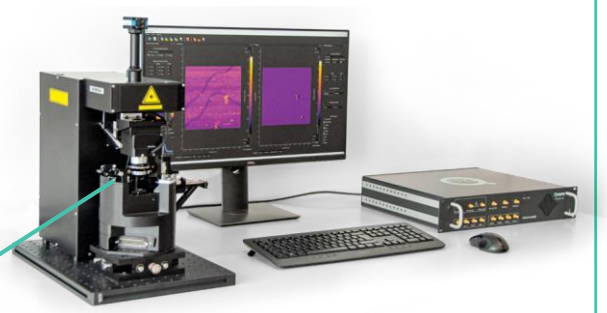
Defense
(Lockheed, Thales)

Qnami Product Portfolio

Quantilever MX
(diamond scanning probe)



ProteusQ™ (2020)



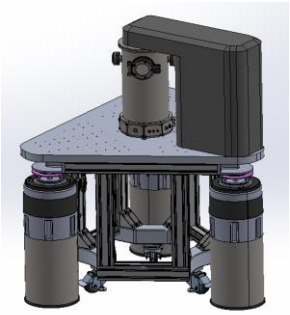
Scanning NV Microscope

scientific | semiconductor

Inspection of new materials & semiconductor chips

User value: short loop in design & process development of new materials and electronic chips through better diagnostics.

ProteusQ-LT (2023)



Cryogenic scanning NV microscope

scientific | quantum

Inspection of superconducting materials and quantum computing chips

User value: unlocking new research areas in physics that can only be measured at cryogenic temperatures.

Quantum Foundry (2019)

Quantum Diamond Foundry

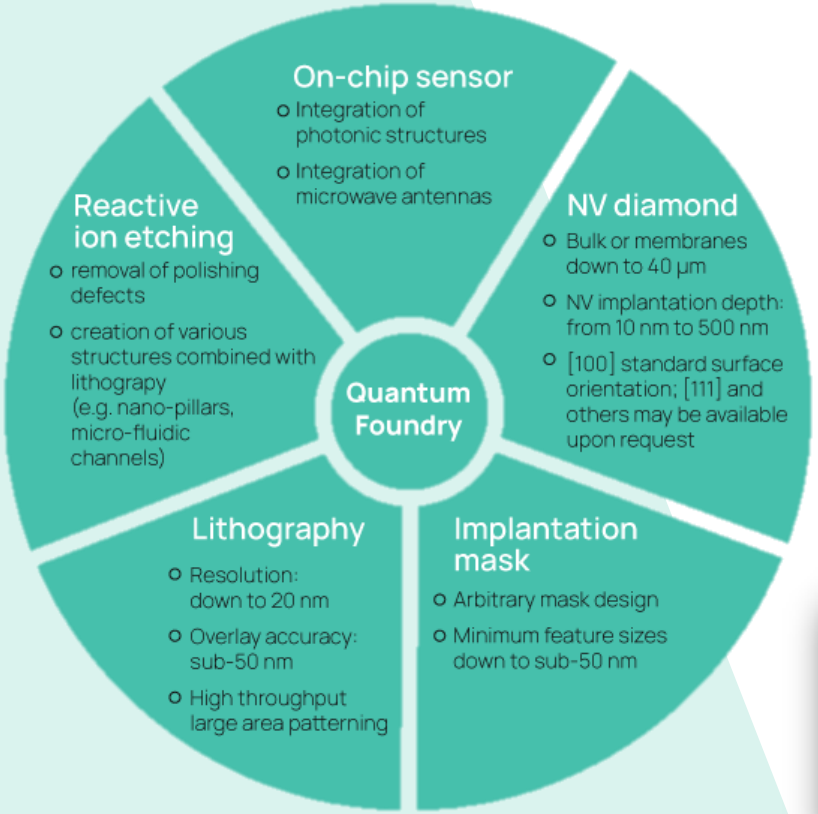
healthcare | quantum
scientific | defense

Design and manufacturing of quantum diamond chips

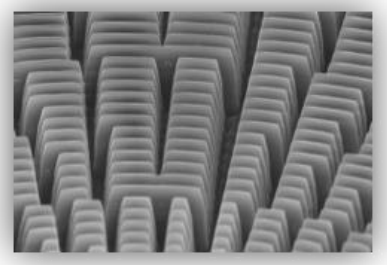
User value: access to state-of the-art expertise tailored to quantum applications.

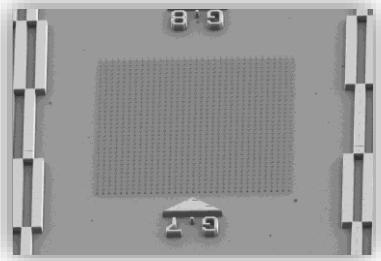
The Quantum Foundry represents the first step towards building a diamond-based quantum platform

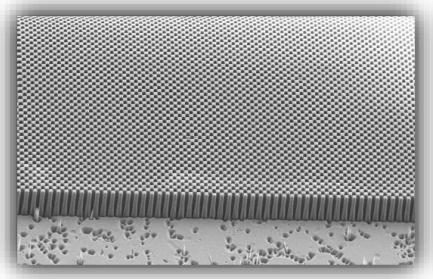
We offer to you: Design and fabrication of diamond quantum devices with a unique skillset

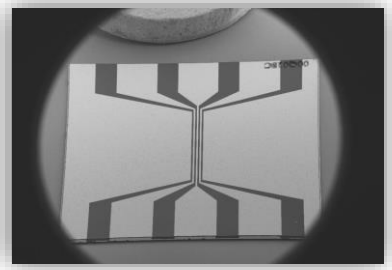


	Academia	Quantum industry
Customer profile	Leading research group	Start-ups, large group building quantum sensing pilots
Offer	Co-Design & fabrication/integration services	
User value	Access to advanced quantum diamond chips; Out-sourcing design and fabrication of custom quantum diamond chips	
Customer value	Fast time to result no CAPEX or FTE investment in manufacturing	Rapid prototype validation De-risk later scaling









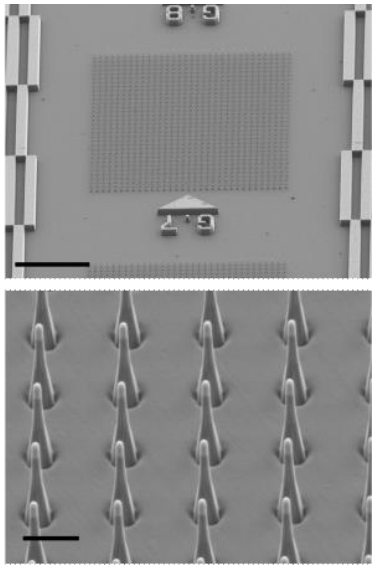
30+ customers worldwide

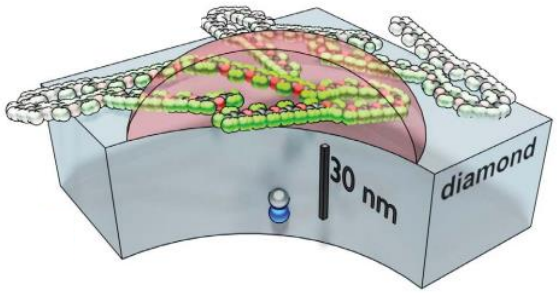
Application: quantum sensing of molecules (NMR) at the diamond surface using shallow NV centers

HARVARD UNIVERSITY

Specifications of the foundry service:

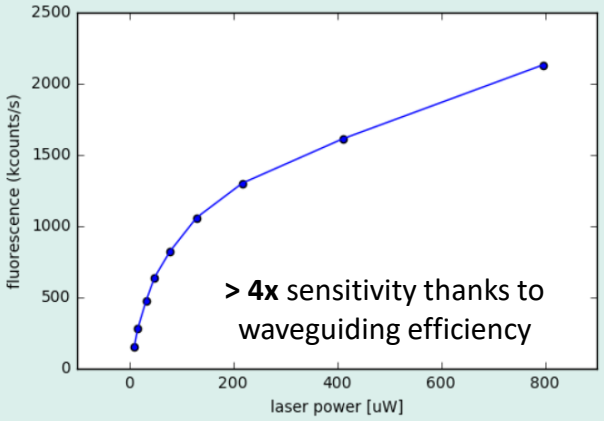
- Quantum grade, [111]-oriented base material.
- Single NV center creation at a depth of ~10 nm
- State-of-the-art design and fabrication of nanopillar arrays with embedded NV centers
- Quality control of optical and spin properties leveraging Qnami's expertise

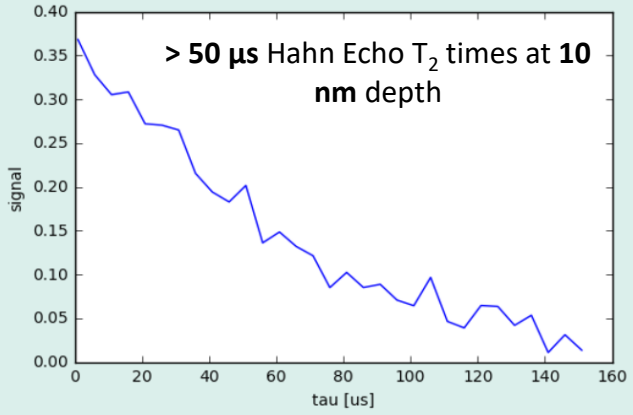




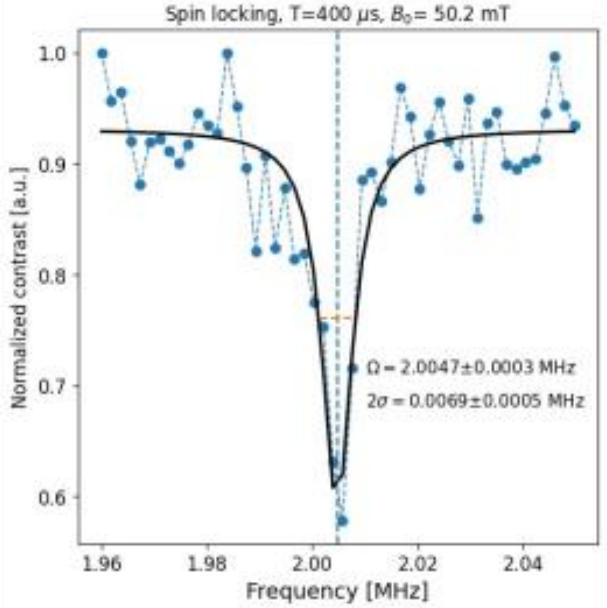
N. Aslam et.al., Science, 357, 6346 (2017)

Base optical and spin properties





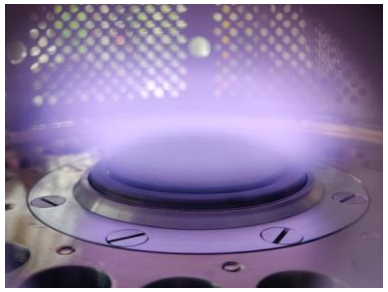
Detection of ^{19}F atoms at the diamond surface using spin-locking techniques



Days of measurements turn into hours

Solidifying the value chain to deploy the full potential of the technology

A call for a stronger ecosystem and partnerships

Diamond wafer	Quantum wafer	Nanofabrication	Device/Sensor	System	Application
					
CVD/HPHT growth Thinning Polishing	Controlled doping Density & depth Quantum coherence	Lithography Plasma etching Surface functionalizaton	Multi-layer integration Wire connectivity Photonic connectivity Heat management Low level SW language	High level SW language System architecture System integration Norm/Certification	Application management Workflow integration

Needs:
- Larger area wafers (from <1” to >4”)
- Higher precision and standardization on quantum properties
- Lower cost per mm3

Need:
- Expansion of front- and back-end infrastructure (support/co-creation of pilot lines)

Needs:
- 515-532 nm VCSELs (>1W)
- Expertise in certification
- Application-specific expertise of integrators

All of this also needs **investment**!
- Qnami Series B open and focuses on climbing up the value chain and expand our capabilities to deliver highly sensitive sensors
- Financing of co-developments with partners across the entire value chain (e.g. grants)

What comes next: deployment of diamond as a sensor platform

Next generation of integrated quantum sensors will unlock new value pools in healthcare and navigation

Heart and Brain Monitoring

- Non-invasive, non-contact detection of neuronal and/or heart muscle activity
- High-spatial and high-frequency resolution provides decisive diagnostics information
- Point of care operations expands market potential

Picture by way of illustration

Navigation

- World Magnetic Model (WMM) is the standard model for navigation, attitude, and heading referencing systems
- GPS jammer used in war in Europe highlights need for alternative positioning systems
- Geological survey for oil & gas exploration or mining prospecting

Picture by way of illustration

The desired path towards the creation of new products:
Partnership with integrators – Qnami provides the sensor platform adapted to specific needs

Qnami

the quantum wave

Thank you!

Open position right now: Semiconductor Business Manager, Industrialization Engineer, Test and Assembly Engineer

Join the #quantumwave

Qnami AG I www.qnami.ch

NV Centers with right to win vs. other quantum technologies for key physical properties

Physical Properties \ Technologies	NV Centers	Cold Atomic Clouds	Atomic Vapors	Photonics	Superconducting Circuits
Magnetic field	✓	✓ Cryogenics required	✓ Controlled environment required	✓ Unable to be miniaturized	✓ Cryogenics required
Electric field	✓	-	✓ Controlled environment required	✓ Unable to be miniaturized	-
Time & Frequency		-	✓ Controlled environment required	-	-
Temperature/Pressure	✓	-	-	-	-
Acceleration		✓ Cryogenics required	-	-	-
Rotation	✓	✓ Cryogenics required	✓ Controlled environment required	-	-

https://www.bcg.com/publications/2023/making-sense-of-quantum-sensing