Quantum Sensors & Single Photon Techniques for Mass Spectrometry

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SuperMaMa

The Vision of EU FET Open SuperMaMa

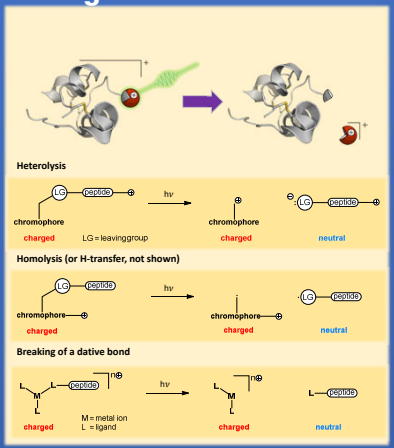
Quantum Tools for Mass Spectrometry and Molecular Analysis

- Superconducting nanowire detectors (**SNWDs**) have been established and optimized for photophysics.
  SuperMaMa explores superconducting nanowires for **biomolecule detection**.
- Common detectors in mass spectrometry require beam velocities > 20'000 m/s a challenge for many biomolecules.
  SuperMaMa explores a quantum detector technology that shall accept particles at **low energy**.
- Detectors in mass spectrometry are designed to detect ions.
  SuperMaMa aims to extend the detection range to **neutral** and yet **mass-selected molecular beams**.
- In physical chemistry, photoionization of proteins in the gas phase has been a grand challenge.
  SuperMaMa explores how to neutralize or ionize them by **single/few-photon cleavage**.
- Standard mass spectrometers and particle detectors are insensitive to internal molecular properties.
  SuperMaMa explores the possibilities of quantum detectors to access **internal molecular energy**.
- Most superconducting nanowire photodetectors are single or few-pixel devices.
  SuperMaMa works towards a mm-sized **128-pixel superconducting nanowire camera**.
- State-of-the-art nanowire sensors keep all readout electronics at ambient conditions.
  SuperMaMa develops a scalable concept based on integrated **cryogenic electronics**.

Expected benefits for complementary communities

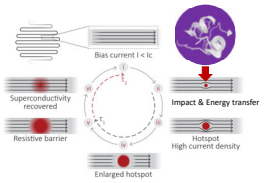
The SuperMaMa techniques shall also support the communities in:
quantum photonics and communication, aerosol physics, life sciences, particle physics, astronomy and the foundations of physics.

Single Photon Charge Control of Proteins

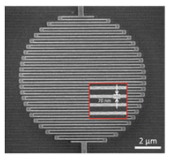


The Quantum Detector (SNWD), Single Quantum

The Hotspot Model



NbTiN Detector Realization

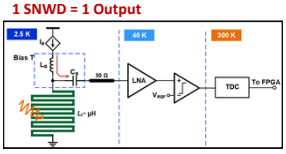


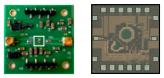
High sensitivity ion detector layout:

- Pixel area : 20 x 20 µm²
- Meander width : 100 nm
- Wire height : 10-12 nm
- Bias Current : 6-12 µA

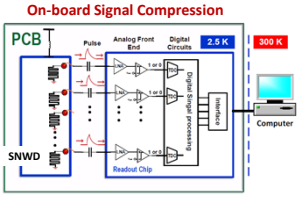
Cryogenic Integrated Electronics, EPFL

1 SNWD = 1 Output





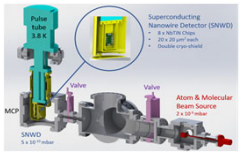
On-board Signal Compression

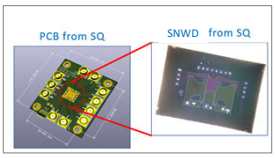


SNWD readout using Low Noise Cryogenic Amplifiers

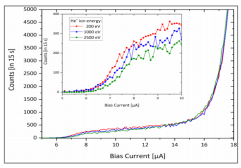
Detection of Ions, UNIVIE

SNWD Tests with Ions

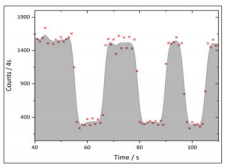




Discriminating Single Ions from Single Photons



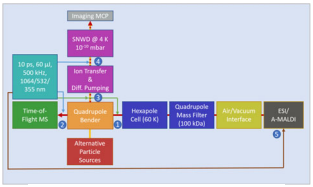
Bias Current has TWO thresholds



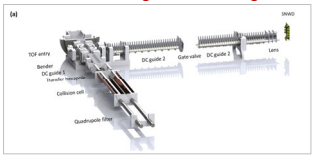
Periodic Magnetic Deflection

Mass Spectrometer Integration, MSVISION & UNIVIE

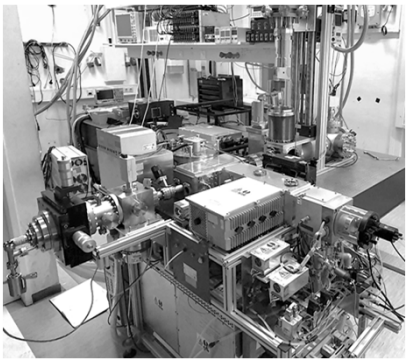
SuperMaMa: Overall Experimental Layout



Mass Filtering and Ion Guiding



SuperMaMa: Real-World Implementation



Our Background References

1. J. Schätti, M. Kriegleder, M. Debiossac, M. Kerschbaum, P. Geyer, M. Mayor, M. Arndt, and V. Köhler, *Neutralization of insulin by photocleavage under high vacuum*, **Chem. Commun., 55, 12507 (2019).**
2. M Debiossac, J. Schätti, M. Kriegleder, P. Geyer, A. Shayeghi, M. Mayor, M. Arndt, and V. Köhler, *Tailored photocleavable peptides: fragmentation and neutralization pathways in high vacuum,* **Phys. Chem. Chem. Phys. 20, 11412 (2018)**
3. M. Marksteiner, A. Divochiy, M. Sclafani, P. Haslinger, H. Ulbricht, A. Korneev, A. Semenov, G. Gol'tsman, M. Arndt, *A superconducting NbN detector for neutral nanoparticles*, **Nanotechnology 20**, 455501 (2009).
4. M. Sclafani, M. Markseiner, F.M. Keir, A. Divochiy, A. Korneev, A. Semenov, G. Gol'tsman, M. Arndt, *Sensitivity of a superconducting nanowire detector for single ions at low energy*, **Nanotechnology 23**, 065501 (2012).
5. Mehrpoo, M., Sebastiano, F., Charbon, E., & Babaie, M. *A Cryogenic CMOS Parametric Amplifier.* **IEEE Solid State Circuits Letters,** 3(1), 5-8 (2020.)
6. E. Charbon, *Cryo-CMOS Electronics for Quantum Computing Applications,* **ESSDERC 2019** - 49th European Solid-State Device Research Conference **(2019).**
7. M. Mehrpoo, F. Sebastiano, E. Charbon, M. Babaie, *A Cryogenic CMOS Parametric Amplifier,* **IEEE Solid-State Circuits Letters** (Early Access) **(2019)**.

Acknowledgement, disclaimer & How to find us

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2. All information on this website reflects the views of the SuperMaMa Consortium. The European Commission - Research Executive Agency is not responsible for any use that may be made of the information it contains.

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