# In-house Development of Scientific Instrumentation

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Correlated Quantum Matter Group

## Who are we and what do we do?

The ***Correlated Quantum Matter group*** is jointly funded by UZH and PSI, where it is part of the Laboratory for Neutron and Muon Instrumentation (LIN).

### Research topics

- The overarching theme of our research are quantum materials governed by strong electronic correlations
- We work on discovering and understanding novel quantum states such as quantum spin liquids, skyrmion lattices, novel superconductors.
- We probe and tune properties of quantum materials to establish their functionality

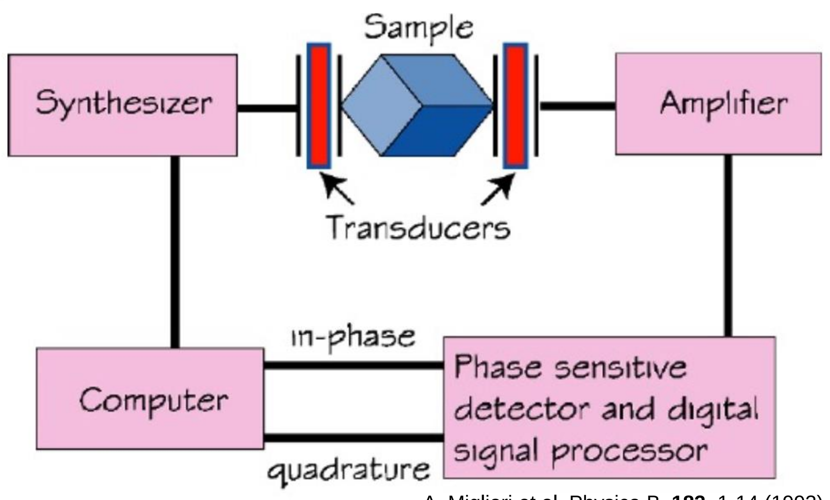
### How do we do this?

- We use large-scale facilities to perform neutron- and x-ray experiments that provide microscopic insights (2[nd] poster)
- Develop scientific instruments to probe coupling of charge, spin and lattice degrees of freedom.
- Develop ways to tune materials (e.g. with strain)
- At the same time, we actively build synergies between UZH and PSI through LIN

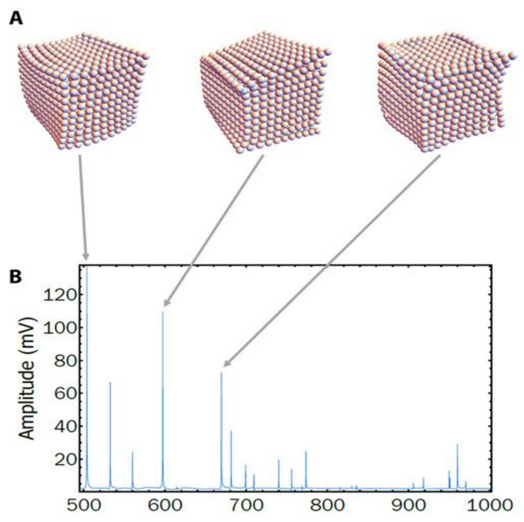
## Resonant Ultrasound Spectroscopy

### Motivation:

Resonant Ultrasound Spectroscopy (RUS) is highly sensitive to changes in the eigen vibration modes. It is able to measure **all** elastic moduli $C_{ij}$ simultaneously. Thus, all quantum phenomena, which couple to lattice can be detected. RUS is probes symmetry breaking of the lattice and can discover new phases.

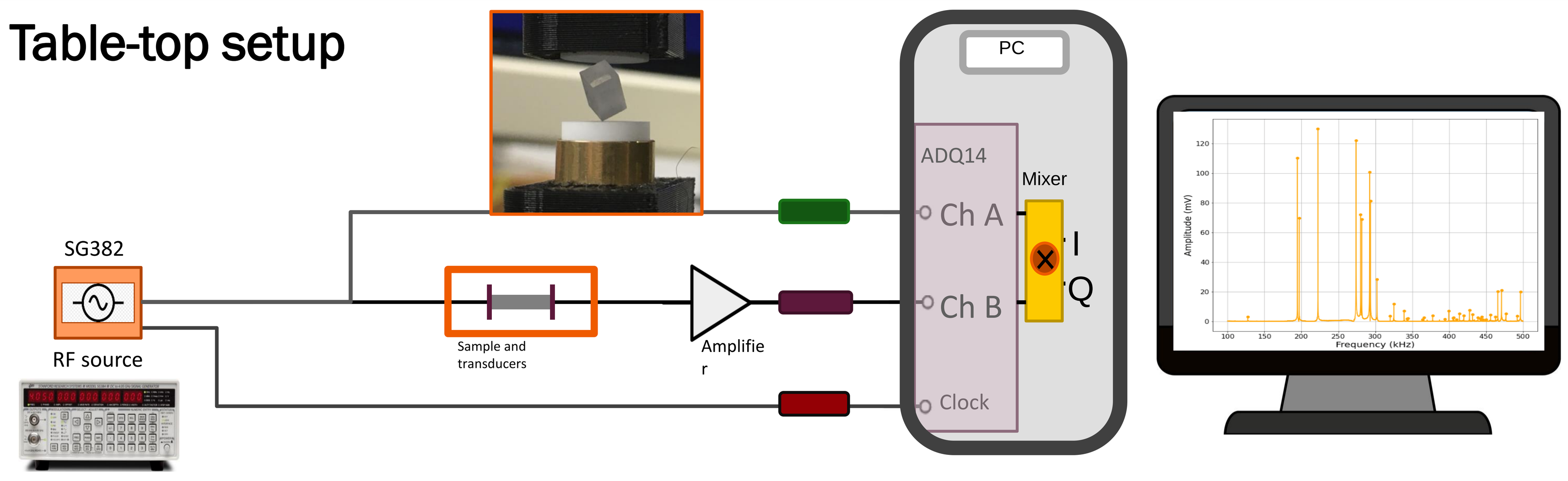



A. Migliori et al, Physica B .183, 1-14 (1993)

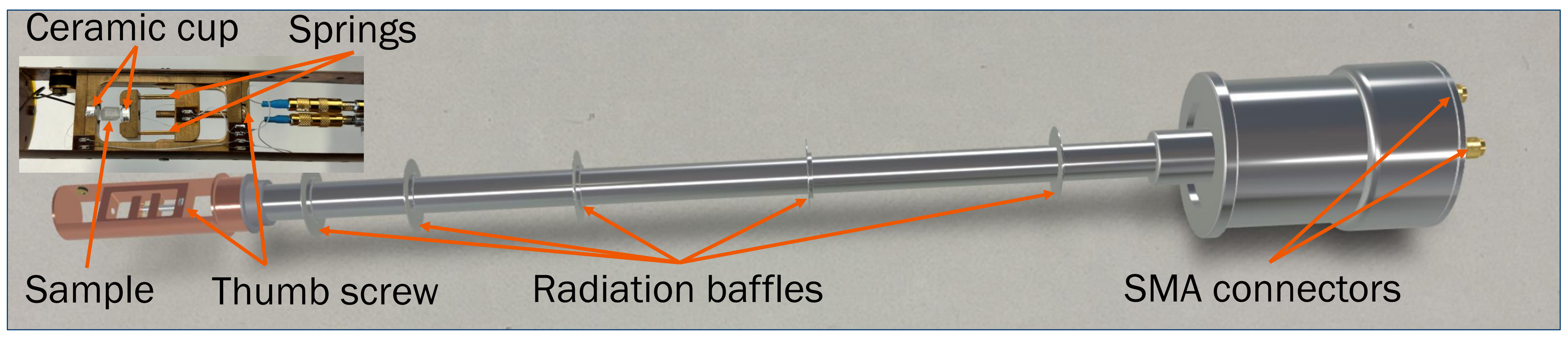



S. Ghosh et al, Science advance. 6, 10 (2020)

### Table-top setup



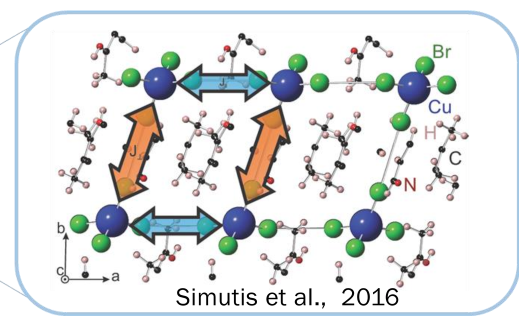

### Sample stick for PPMS:

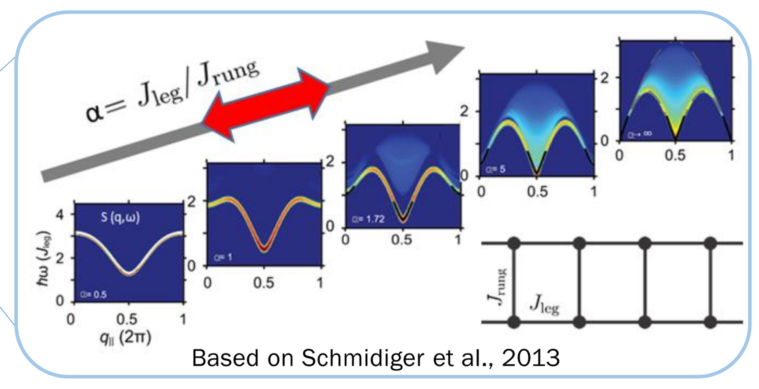



## Nuclear Magnetic Resonance under strain

### Motivation: Quantum Properties "On Demand"

- Emergent properties of quantum matter ultimately depend on the **overlap of the electronic wavefunctions** between different atoms
- Insulating limit: control of the antiferromagnetic exchange energy.
- Metallic limit: **small changes in Fermi surfaces** can lead to **dramatic modifications of quantum phases**

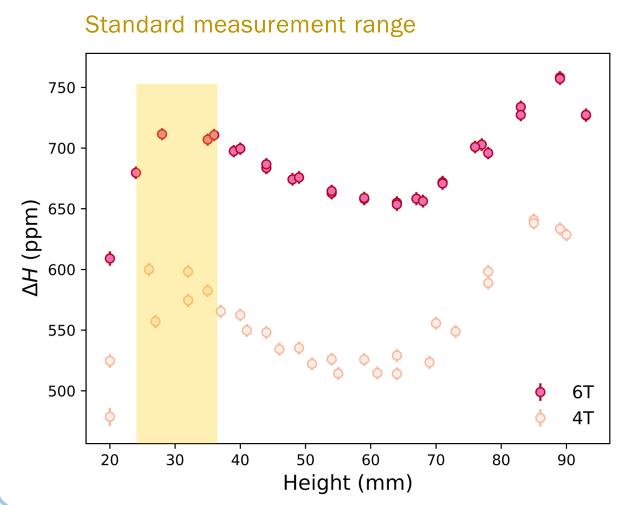




### Tools: Uniaxial Pressure Cells

- Enables selective tuning of model parameters
- Currently, rapidly expanding area of research
- home-build and commercially available

For this project, we implemented **an NMR setup** for use in a **PPMS** around the **Razorbill FC 100** uniaxial pressure cell.

### Field homogeneity (PPMS)



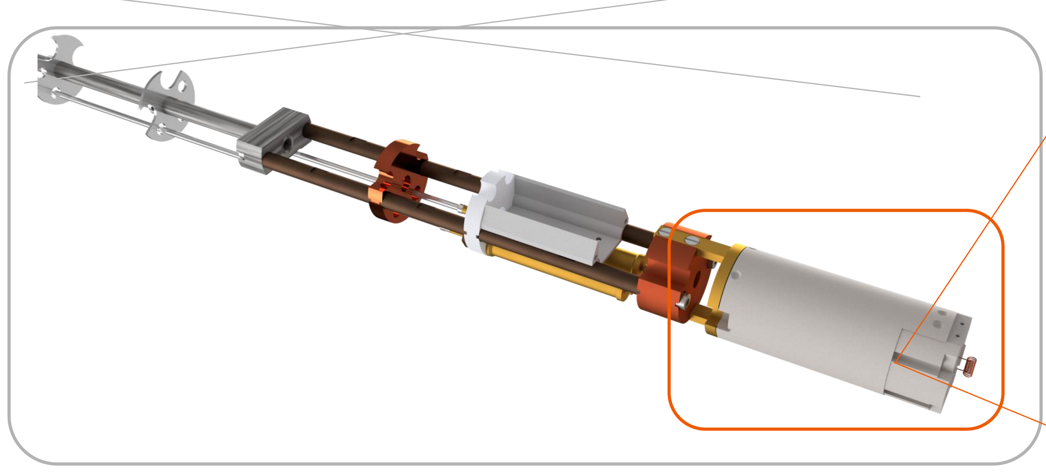

$$\Delta H = \frac{H_{eff} - H_{set}}{H_{set}}$$

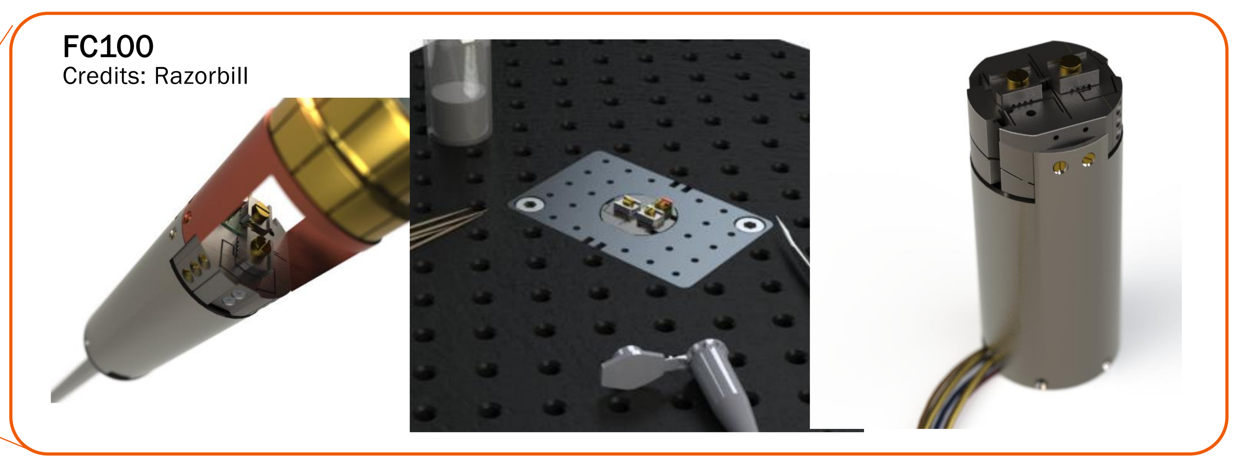
*Concern:*
The field could be too inhomogeneous for NMR.

*Result:*
The typical solid state NMR frequency shift is $\Delta\nu > 0.1\%$, and the NMR signal are generally broad. Therefore, with relatively small fluctuations (< 100 ppm), we expect the homogeneity of PPMS to be sufficient for the vast majority of our experiments.

### Strained NMR – specially designed for PPMS

Final design produced. First NMR tests are ongoing.






* For most of metals and superconductors, e.g., Al, Si, YBCO, $MgB_2$

** For cross sections of 0.10 mm² and a force of 100 N.

### Outlook and strategy

Strain tuning has become increasingly relevant for studying condensed matter systems in recent years. This progress in uniaxial pressure experiments was made possible through major technical breakthroughs, and increasingly powerful instruments. It is being generalized for X-ray diffraction, muon spin rotation ($\mu$SR) and neutron scattering.

Many innovative devices were developed at or within a close collaboration with PSI. Due to its inherent sensitivity to spin dynamics, NMR is an ideal probe to estimate the response of the underlying Hamiltonian to strain ahead of large-scale facility experiments for which beamtime access is competitive.

Consequently, we believe that the new NMR setup, combined with large scale facilities, will open new, unique opportunities for UZH, PSI and the partner universities. Moreover, the development of RUS described above is complementary.

### Proof of concept: $^{27}$Al NMR

The first test were performed at PSI in a Quantum Design PPMS, at 5K and 3.62T, corresponding to a Larmor frequency $\omega_L$= 40.225 MHz.