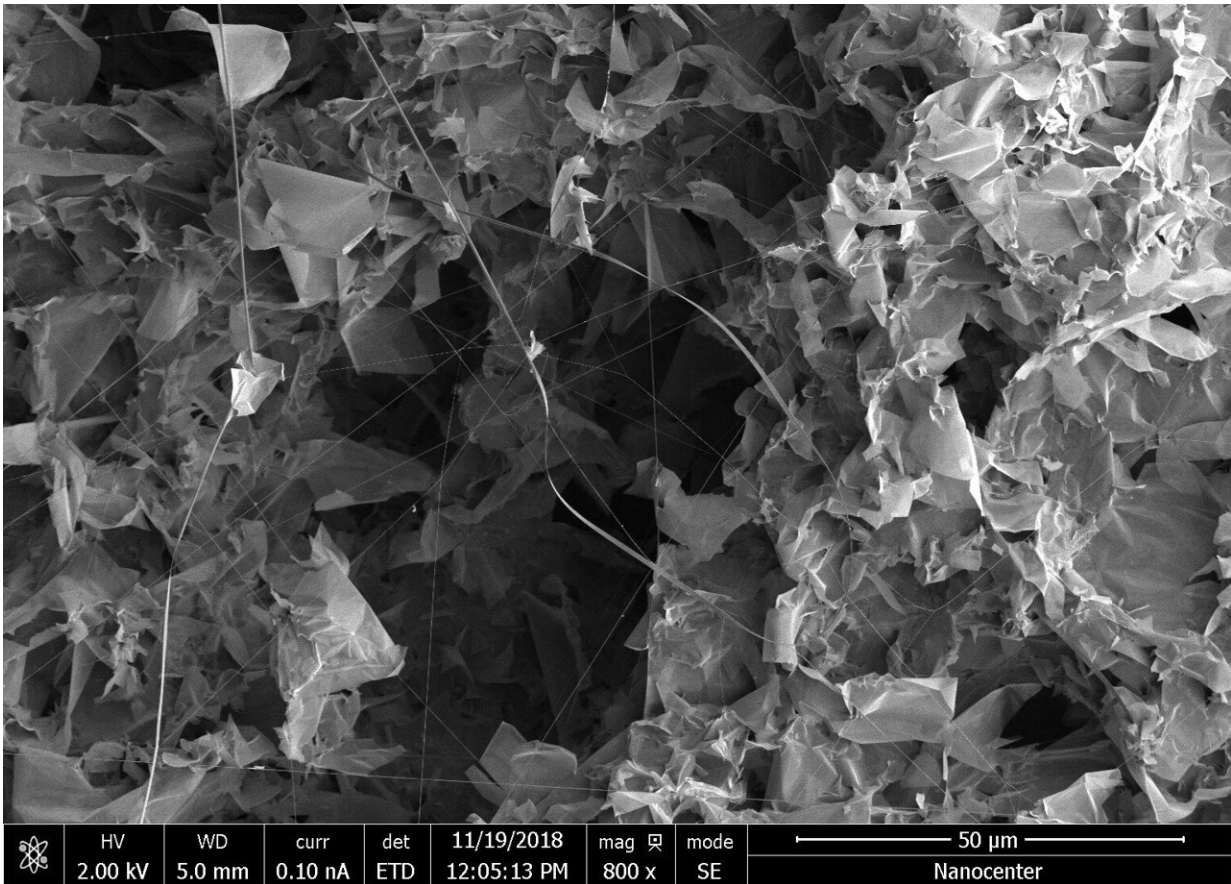


Real-life 'quantum molycircuits' using exotic nanotubes

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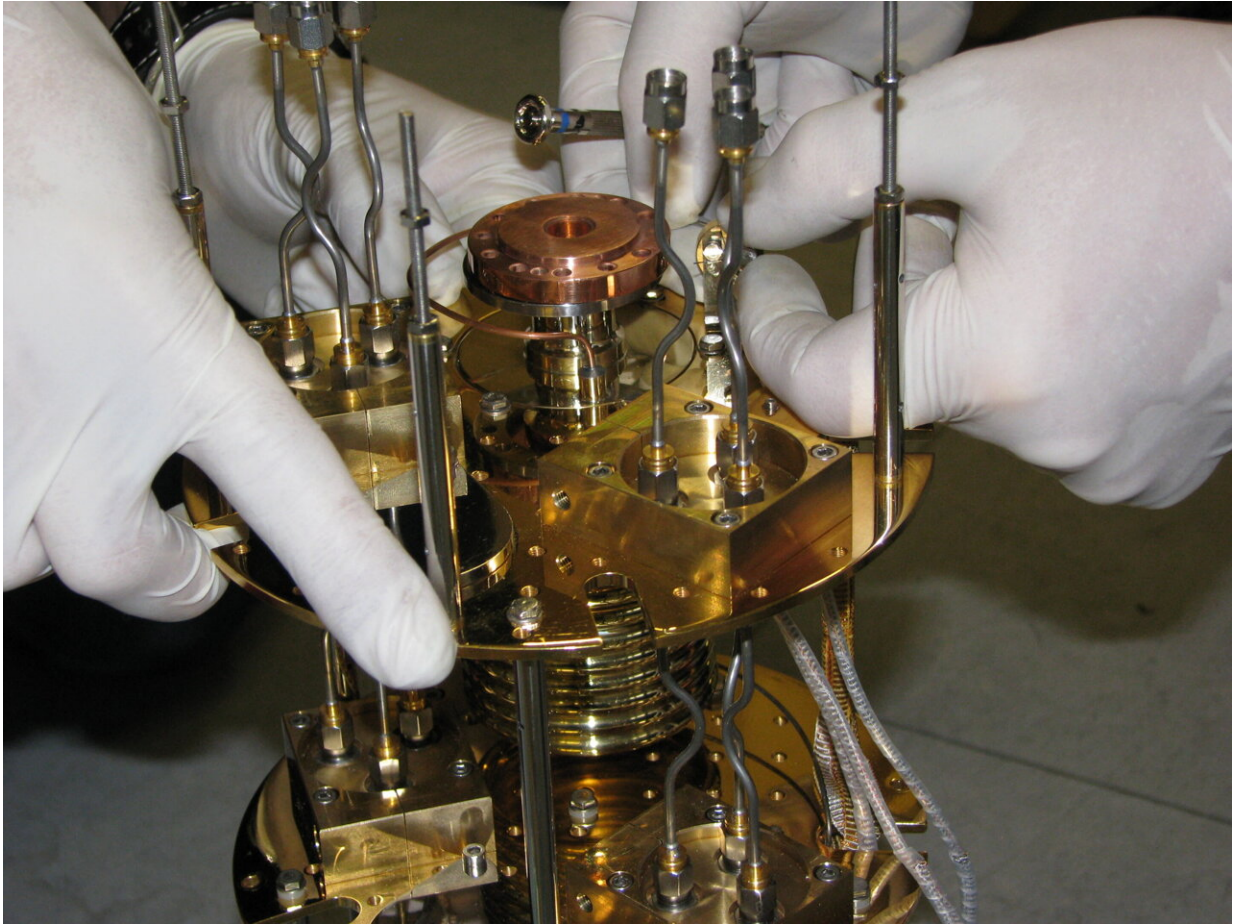
Electron microscope image of as-grown MoS₂ nanomaterial, with flakes, ribbons, and nanotubes. Credit: Dr. Luka Pirker, IJS Ljubljana

Molybdenum disulfide MoS₂ is a groundbreaking material for

electronics applications. As a two-dimensional layer similar to graphene, it is an excellent semiconductor, and can even become intrinsically superconducting under the right conditions. It's not particularly surprising that science fiction authors have already been speculating about molycircs, fictional computer circuits built from MoS_2 , for years—and that physicists and engineers are directing huge research efforts at this material.

Researchers at the University of Regensburg, have many years of expertise with diverse quantum materials—in particular also with carbon nanotubes, tube-like macromolecules made from carbon atoms alone.

"It was an obvious next step to now focus on MoS_2 and its fascinating properties," said Dr. Andreas K. Hüttel, head of the research group Nanotube Electronics and Nanomechanics in Regensburg. In cooperation with Prof. Dr. Maja Remškar, Jožef Stefan Institut Ljubljana, a specialist in the crystalline growth of [molybdenum disulfide](#) nanomaterials, his research group started working on [quantum devices](#) based on MoS_2 nanotubes.



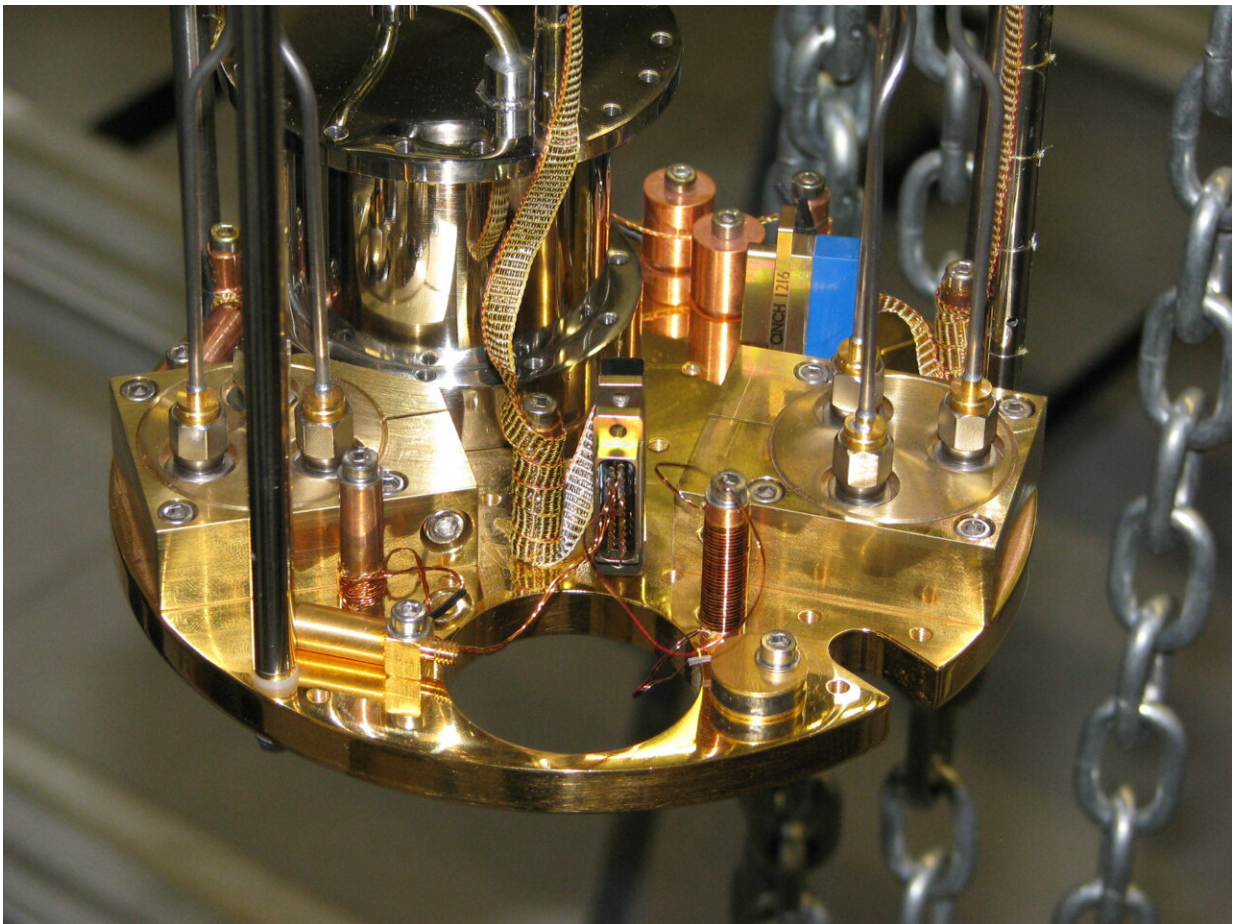
Low temperature setup during initial assembly. Credit: Dr. Andreas K. Hüttel, Univ. Regensburg

"It turns out that MoS_2 makes quantum confinement, i.e., discrete electronic states as you would need for qubits and quantum computers, very difficult to reach with flat flakes on a chip. That is exactly why we are interested in these exotic nanotubes. The tubes can be grown clean and straight, with diameters down to 20nm—and will then automatically give you the small structure sizes that you need."

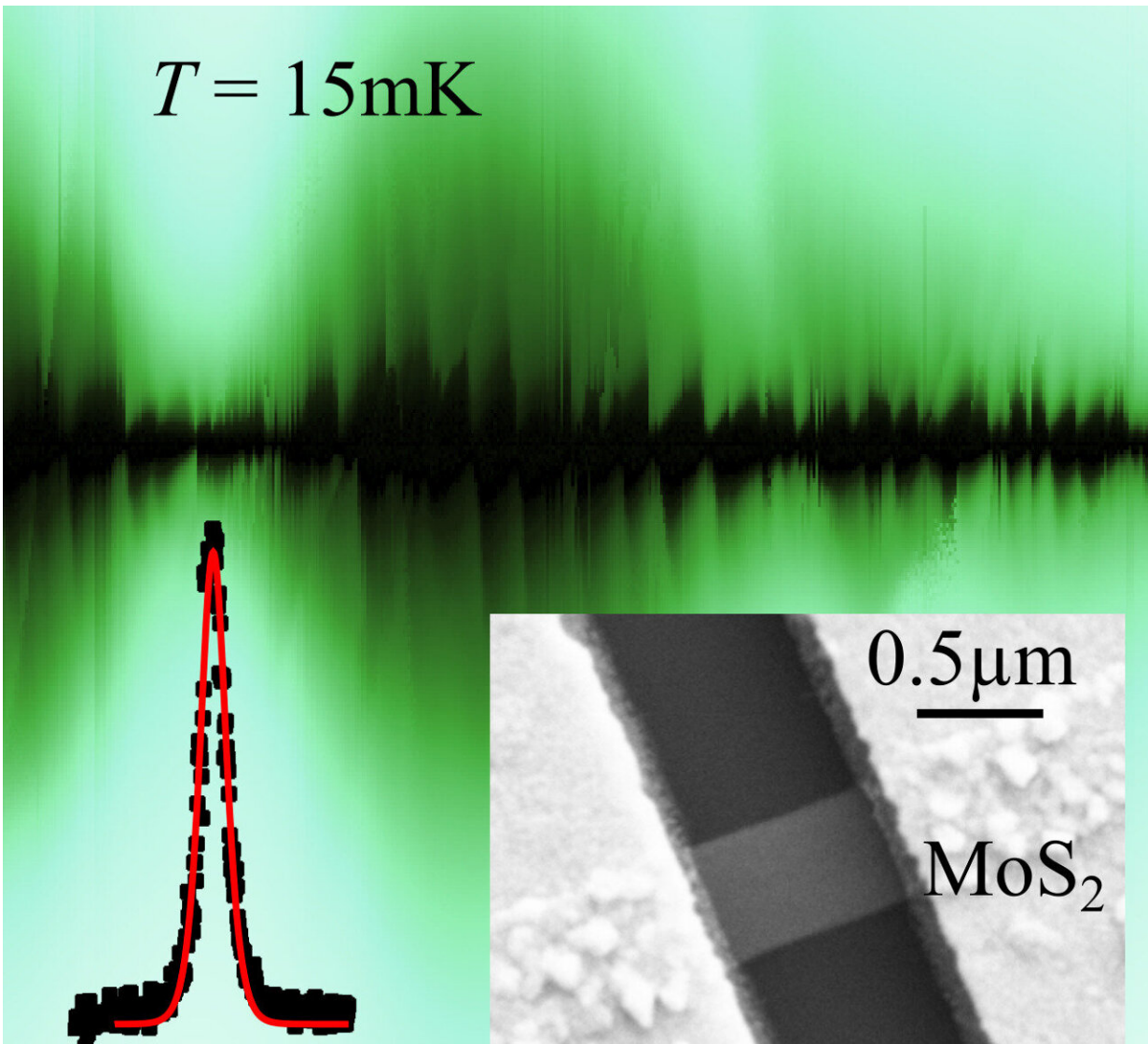
The initial challenge was to make good metallic contacts. Useful metals with low contact resistances tend to react with the MoS_2 surface and

destroy its [crystal structure](#), a difficulty that affects also "flat" MoS₂ and is one of the main reasons why not many complex circuits exist there yet.

For nanotubes, with small surface areas, this difficulty used to be even more pressing. "Now finally we obtain devices which remain electrically transparent even in the low temperature range typically needed for quantum computation, and which leave the molybdenum disulfide intact," said Dr. Hüttel.



Ultra low temperature cryostat stage with thermometers and wiring. Credit: Dr. Andreas K. Hüttel, Univ. Regensburg



Credit: Dr. Andreas K. Hüttel, Univ. Regensburg

And that's not all—the structure sizes immediately came into play. "So far, for practical reasons we used rather large nanotubes and nanoribbons. Still, we can show that in our low temperature setup, at temperatures below 0.1K as are used in many quantum computing approaches, current passes through discrete quantum states in our

chip—and that is a big step towards controllable charge, spin, or even valley qubits in MoS₂."

The research is published in the journal *Advanced Materials*.

More information: Robin T. K. Schock et al, Non-Destructive Low-Temperature Contacts to MoS₂ Nanoribbon and Nanotube Quantum Dots, *Advanced Materials* (2023). [DOI: 10.1002/adma.202209333](https://doi.org/10.1002/adma.202209333)

Provided by University of Regensburg

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