Further information

Video with Aris Lafranca
https://youtu.be/UhcM43AK-7s

Poggio Lab
https://poggiolab.unibas.ch

Tiny drums as sensors
Aris Lafranca receives the prize for best master's thesis

This year's prize for the best master's thesis in nanosciences at the University of Basel goes to Aris Lafranca. As part of the winning master's thesis at the Department of Physics, the young nanoscientist from Ticino investigated a hybrid resonator in greater detail. Made of hexagonal boron nitride and a silicon nitride membrane, the resonator could potentially be used to measure forces, masses or acceleration, as well as for biomedical applications. Aris' investigations sought to better characterize the system, and to monitor and control the influence of temperature.

Combination of positive properties

Aris already began investigating a tiny mechanical hybrid resonator during his first project work in the master's program. These resonators consist of hexagonal flakes of boron nitride (hBN) suspended above holes in a silicon nitride membrane (Si_3N_4) like the skin of a drum. Together, the hexagonal boron nitride and the silicon nitride membrane form a unit that brings together the different properties of these two 2D nanomaterials.

Aris Lafranca completed the work for his award-winning master's thesis in Martino Poggio's team at the Department of Physics.

When the tiny resonator is excited, the boron nitride layer – which is just a few atomic layers thick – begins to vibrate. Due to the special properties of the materials, as well as the resonator's special construction, the resonator can be caused to vibrate not only by mechanical excitation but also by light, for example. Like in a drum, the resonator amplifies the signal such that it could potentially be used as a component in sensor applications.

The researchers "read" the vibrations using light: A laser beam is divided into two beams, one of which strikes the vibrating drum. When the two lasers meet again, they form interference patterns that vary in response to changes in the resonator's vibration.

Decisive improvements

For his master's thesis, Aris investigated and characterized this two-dimensional hybrid resonator further using an improved experimental setup that includes a Michelson interferometer. He was able to extend the setup in order to boost the signal-to-noise ratio and reduce temperature fluctuations. Thanks to these extensions, Aris can now control the sample temperature precisely – which is a fundamental prerequisite for his analyses. He also wrote a Python code that controls sample temperature automatically, and he demonstrated that his measurements show good agreement with theoretical simulations.

Simulations and measurements confirm that the hBN drum has a negative coefficient of thermal expansion. “Contrary to what we know about most other materials, boron nitride contracts in response to a temperature increase,” explains Aris. “Since the boron nitride flakes and the silicon nitride membrane form a unit, this contraction leads to increased mechanical stress for the resonator at higher ambient temperatures.” This additional stress affects the boron nitride’s frequency and mode of vibration, while the frequency and mode of the silicon nitride membrane remain largely unchanged.

As the experimental setup now allows precise temperature regulation, it is possible to configure the mechanical stress inside the hBN drum – allowing researchers to study interactions with the silicon nitride membrane.

Further research on the topic

For Aris, completing his master’s thesis is far from the end of his interest in hybrid resonators. Since December 2023, he has continued his work as a doctoral student in the team led by Argovia Professor Martino Poggio. He initially took over the production of the tiny hBN drums, a process that had been developed – and carried out so far – by former SNI doctoral student Dr. David Jaeger as part of his doctoral thesis. In the future, Aris will attempt to couple multiple hBN drums, investigate different thicknesses of hBN membrane and test other samples.

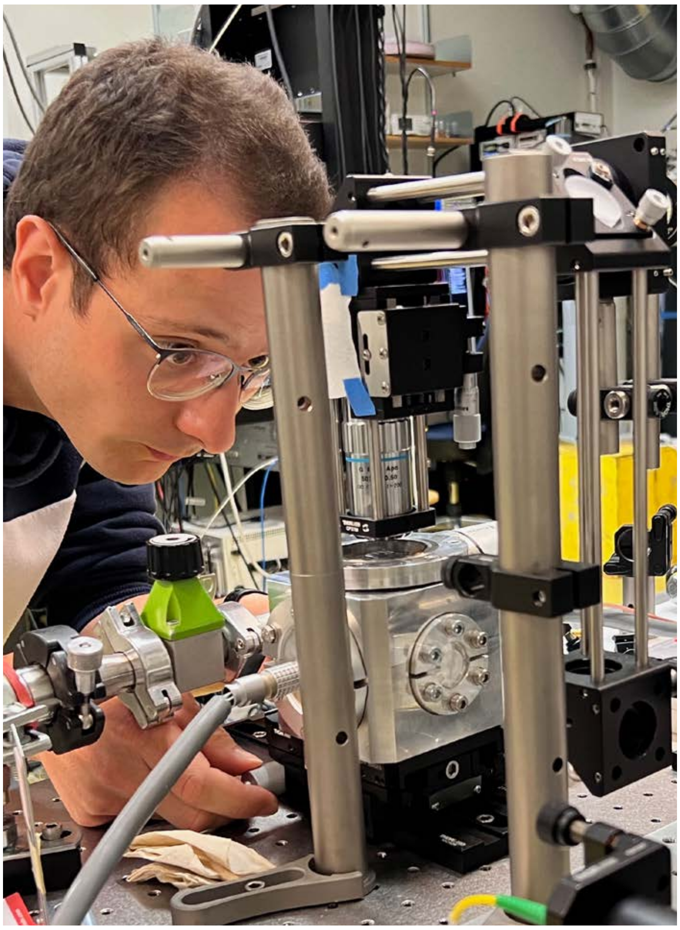
“It’s a lot of fun planning experiments of this kind, beginning to take measurements, and then using the results as the basis for solving problems and amending the plan accordingly,” says Aris when asked what he finds particularly fascinating about his work. The positive team spirit was another factor in his decision to carry on where he had left off during his master’s degree in nanosciences.

An early decision

Aris had already decided to study nanosciences back in his school days, when he learned about the interdisciplinary degree program in nanosciences at the University of Basel during “OrientaTI”, a student information event hosted by Università della Svizzera italiana (USI) for cantonal schools in Ticino. “For me, the combination of biology, physics and chemistry was the decisive factor,” he recalls.

Things weren’t always easy when he started out at Basel – as well as the technical challenges, he also had to get used to the language. “The sense of community among the students helped me a lot, though, and it wasn’t long before German was no longer a problem,” he says.

As well as the positive atmosphere among students, he particularly enjoyed topics from the worlds of physics and chemistry during his studies – and, with the hybrid resonators, the first project in his master’s degree led him to a topic that fascinated him and will keep him busy over the years ahead.



Aris Lafranca uses a Michelson interferometer to investigate and characterize the two-dimensional hybrid resonator.

> “Aris’ thesis is without a doubt the best and most expertly executed master’ thesis I have read here in Basel. I am very pleased that he has decided to continue working in experimental physics as a PhD student in my group.”

Prof. Martino Poggio, Department of Physics, University of Basel