NEWSLETTER

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IST AUSTRIA
Institute of Science and Technology

Foreword

Moore's law demands that we revolutionize what we mean by information technology: we can't just keep adding more transistors—we need to reconsider the materials we use. Nowhere is this more apparent than in quantum computing, where new states of matter will help quantum mechanics take center stage. I design unique experiments on high-temperature superconductors, quantum spin liquids, and topological materials to understand quantum materials at the most fundamental level.

My research focuses on "strongly-correlated" materials, such as superconductors and quantum spin liquids, where interactions between electrons give rise to technologically-useful properties. These materials defy our usual descriptions of electrons in solids, and continually challenge our experimental methods. I use strong magnetic fields—thousands of times stronger than the magnets on your fridge—to understand and manipulate strongly-correlated materials. Magnetic fields are particularly powerful because they are non-disruptive, reversible, and can even induce the formation of new, exotic states of matter.

Before joining IST Austria, I was a postdoc at the Max Planck Institute for Chemical Physics of Solids in Dresden, Germany, where I learned how to craft micron-sized structures out of materials using ion-beam ablation—think of a nano-sandblaster. Before that, I was a researcher at the National High Magnetic Field Laboratory (NHMFL) in Los Alamos, New Mexico, USA – home of the world's largest nondestructive (100 tesla!) magnet. There, I learned how to adapt a broad set of experimental techniques to extreme measurement environments. Tackling the complexities of tomorrow's materials requires the experimental know-how and theoretical insights that can be found among the excellent researchers at IST Austria, and I'm excited to be among them!

Kimberly Modic | Assistant Professor at IST Austria since January 2020

IST Austria evaluation – A positive trajectory

Recently, the third evaluation report of IST Austria was published. The report states: "Clearly, IST Austria is following a positive trajectory to meet the goals which have been assigned to it by the Austrian government and the state of Lower Austria."

The international review panel of six reviewers—two Nobel laureates and a Turing awardee among them—left no doubt that to achieve the ambitious long-term goal of becoming an international leader in basic research, a long-term commitment from the government and the state of Lower Austria is essential. The report recommends IST Austria should keep growing at the present pace, by about five professors per year, to reach the milestones of 90 professors by 2026 and 150 by 2036. To achieve this growth, the report asks the politicians to provide long-term stability for the future. Another important recommendation is to run a combined master-PhD program which enables bachelor students to earn a master's degree on the way to their PhD.

Pioneers at the intersection of sciences

The NOMIS Fellowship Program was launched at IST Austria in collaboration with the NOMIS Foundation, enabling top scientists to establish themselves as leaders at the intersection of scientific disciplines.

One of the founding principles of IST Austria is interdisciplinarity. Although interdisciplinary research is challenging, it also offers enormous potential for understanding the driving forces of our planet, society, and health. The new fellowship tailored to train postdoctoral scientists in interdisciplinary research, and in creating this opportunity, IST Austria and the NOMIS Foundation are paving the way for future "thought leaders." Each year, two fellows will gain access to world-class research facilities and the resources to explore high-risk research concepts. The fellowships also foster institutional and international exchange by allowing the inclusion of outstanding external mentors from various disciplines.

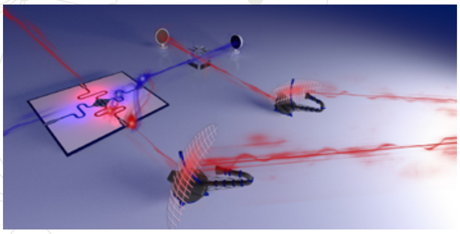
Thomas Henzinger elected to two prestigious American academies

Thomas Henzinger, computer scientist and president of IST Austria, has been selected to join the US National Academy of Sciences (NAS) and the American Academy of Arts and Sciences.

Thomas Henzinger on the honor of joining these groups: "I am humbled to be chosen by my peers to become a member of both of these prestigious academies. Achieving excellence in science is always a collaborative effort. This is why I also want to thank all of my students and collaborators throughout the years."

NAS is a society of distinguished scholars that is charged with providing independent, objective advice to the United States on matters related to science and technology. The American Academy of Arts and Sciences honors exceptional scholars, leaders, artists, and innovators, and engages them in sharing knowledge and addressing challenges facing the world.

Research Highlights



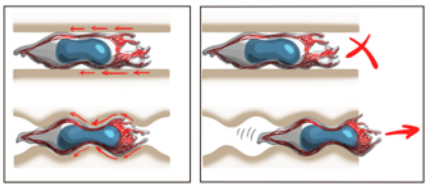
IST Austria scientists demonstrate quantum radar prototype

Physicists at IST Austria have invented a new radar prototype that utilizes quantum entanglement as a method of object detection. This successful integration of quantum mechanics into our everyday devices could significantly impact the biomedical and security industries. The study has been published in the journal *Science Advances*.

Quantum entanglement is a physical phenomenon where two particles remain interconnected and share physical traits regardless of how far apart they are from one another. Scientists from the research group of Johannes Fink along with collaborators Stefano Pirandola from the Massachusetts Institute of Technology (MIT) and the University of York, UK, and David Vitali from the University of Camerino, Italy, have demonstrated a new type of detection technology called "microwave quantum illumination" that utilizes entangled microwave photons as a method of detection. The prototype, also known as a "quantum radar", is able to detect objects in noisy thermal environments where classical radar systems often fail. The technology has potential applications for ultra-low power biomedical imaging and security scanners.

Lead author and, at the time of the research project, IST Austria postdoc Shabir Barzanjeh on the prototype's performance: "The main message behind our research is that 'quantum radar' or 'quantum microwave illumination' is not only possible in theory but also in practice. When benchmarked against classical low-power detectors in the same conditions we already see, at very low-signal photon numbers, that quantum-enhanced detection can be superior."

Throughout history, basic science has been one of the key drivers of innovation, paradigm shift, and technological breakthrough. While still a proof of concept, the group's research has effectively demonstrated a new method of detection that, in some cases, may already be superior to classical radar.

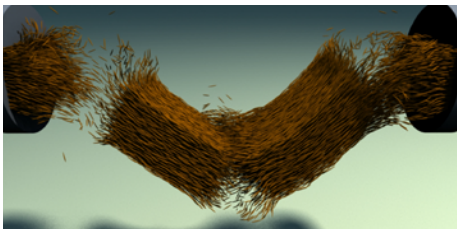


"Off-road" mode enables mobile cells to move freely

Cancer cells and leukocytes are able to move through tissue and organs quickly. It is not fully understood how these mobile cells manage to travel and survive far away from their place of origin. In a *Nature* study, the group of Michael Sixt and their collaborators in France presented a general biomechanical principle of cell migration that allows cells to move freely, especially in rough terrain.

The scientists engineered cell-sized "microfluidic" channels with various wall geometries: from completely smooth to rough textures. They then let the cells migrate through these channels and observed that the integrin-deprived cells were unable to move forward when the walls were smooth and parallel. "The cells were 'running in place'—just like a car tire would spin on icy grounds," says Anne Reversat, first author and former IST Austria postdoc. "However, when the walls were textured with bumps, the cells could efficiently migrate without integrins. Cells that still carried their integrins could migrate equally well in both rough textured and smooth channels."

Upon closer experimental and theoretical examination, the team discovered the unifying mechanical theme that underlies both modes of locomotion: Actin—the filamentous building material of the cell's cytoskeleton—flows from the front of the cell to the tail end. This "retrograde actin flow" is the force within the cell that, once coupled to the environment, drives the cell body forward. Actin can couple not only through integrins; it can also couple without any transmembrane receptors. "The retrograde flow generates intracellular shear forces that push against the channel walls whenever there is a bump. If the walls are parallel, or the bumps are too far apart, this does not work. Another way to see this is that the cell propels itself by changing its shape over time. After all, leukocytes are amoeboid cells—'amoibos' being the Greek word for 'changing'. As the fine structure of tissues is geometrically very complex, amoeboid cells can always rely on this mode of locomotion. This makes them enormously adaptable. Essentially, they can go everywhere."



Efficient animation for visual artists

Animating the movement of complex deformable materials and objects consisting of large numbers of irregular-shaped bodies may now be easier thanks to a new technique developed by computational scientists at IST Austria. The study was published in the journal *Computer Graphics Forum* as part of the annual 2020 Eurographics conference.

In the world of computer animation, efficiency is key. One problem confronting many visual artists and animators is the ability to animate complex materials that can bend, flex and exhibit both plastic and elastic-like properties when placed under physical stress. These materials are known as elastoplastic materials. Scientists from the group of Chris Wojtan have shown that simulating the behavior of elastoplastic materials can be made more efficient by applying a specialized technique that uses previously established models in a new way.

In developing their method, the group looked at established techniques for modeling elastoplastic materials that exhibit isotropic behavior (i.e., the same physical behavior in all directions). They then applied these techniques to more complicated materials that exhibit anisotropic behavior (i.e., non-uniform physical behaviors in different directions). By reusing and swapping different isotropic models and applying them across various scenarios, the group was able to create an effective simulation method for anisotropic elastoplastic material behavior using previously established and efficient isotropic techniques.

"While the current research literature is full of established methods that effectively simulate isotropic elastoplastic material behavior, our method is the first time in computer animation that anisotropic elastoplastic materials have been animated by reusing isotropic models," says Chris Wojtan. Camille Schreck, lead author and IST Austria postdoc, adds: "Visual artists and animators are typically ill-equipped when animating these types of materials. It will be interesting to see where this research is used and built upon in the future."

Funding

The foundation of scientific excellence

Only a diversity of funding sources guarantees that research is independent research. IST Austria builds on that premise. The sources include public funding from Austria and the European Union, as well as private funding from foundations and donors. With this, the Institute can support its professors in their research and help them conduct excellent basic research.

In 2020, the Institute has passed the milestone of 100 FWF funded projects and fellowships, and is proud to announce the two newest ERC grantees on campus.

The European Research Council (ERC) awarded Julian Fischer and Scott Waitukaitis two grants to do fundamental research into the physical mechanisms that lead to tribocharging and to investigate largely unexplored aspects of multiscale PDEs. Both grants are part of the ERC's 'Starting Grant' initiative designed to support future research that has the potential to contribute to major scientific breakthroughs.

Improving the science of both these areas not only has ramifications for the deeper understanding of the role of randomness in multiscale PDEs, but also could impact new technologies like triboelectric nanogenerators.

The Werner Siemens Foundation funds the research of Maria Ibáñez with several million Euros. The goal of the foundation is to support innovative projects and young talents in the natural sciences and technical fields. Maria Ibáñez is a physicist specialized in nanomaterials. With her research group, she develops novel functional nanomaterials using precisely designed nanocrystals as building blocks and investigates their properties as a function of their finely tunable nano-features.

Starting in September 2020, the funding will span eight years and supports the Ibañez Group in looking for high-efficiency, cost-effective thermoelectric materials for wide use in generators and cooling devices.

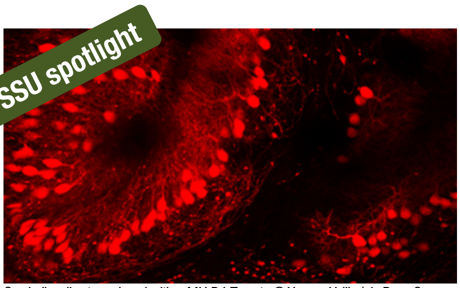
All of the achieved funds enable independent research and, being highly selective in their choice of projects, scientists, and institutions. They also provide a seal of excellence for the science done at IST Austria.

More information about Maria Ibáñez can be found on her group website!

More information about ERC's 'Starting Grant' can be found on the news website!

A list of awards, honors, and distinctions can be found on the Award page!

SSU spotlight



Cerebellar slice transduced with a AAV-DJ-Tomato © Yvonne Vallis / de Bono Group

Viruses as tools for better understanding biological phenomena

When we think about viruses, we immediately think of diseases—especially these days. However, viruses have been widely used as tools to induce exogenous protein expression in living cells and organisms in basic research and as vaccine vectors in applied research. Why are viruses so useful in this regard?

Viruses are among the smallest organisms we know of and are dependent on a host organism to complete their life cycle; in particular, they cannot replicate on their own. Thus, their very small genomes (some viruses have as little as 2 genes compared to the 20,000 humans have) are highly adapted to successfully infect their host cells.

The knowledge of virus-host interactions and virus's biology that has been accumulated in the past decades now allows scientists to safely manipulate viruses in order to use them as research tools. Certain characteristics of different viruses make them ideal for delivering genes in a specific context. For example, neuroscientists use the rabies virus to map brain connections, as this virus is highly adapted to infect the nervous system. Lentivirus, on the other hand, can be manipulated to infect a broad range of cell types and, due to its ability to integrate into the host genome, can induce long-term effects. Because of this, cell biologists use lentivirus widely to induce the expression of specific genes, usually tagged with a fluorescent protein, to study protein function, localization, and interaction with the wider protein network of the cell.

Theoretical knowledge and hands-on skills are both necessary to make effective use of the particular advantages of different viruses. This expertise is not generally found within the research groups on campus, thus in 2017, the Life Science Facility began planning for expanded services to support virus work. In June 2019, Virus Services (VS) was established to aid experimental biologists in the development of molecular tools for working with living cells and tissues.

VS has been fully operational since January 2020, and is currently focused on the development and production of different viral systems for gene delivery, including molecular cloning. An expansion of services (e.g. the generation of stable cell lines) is planned for the future.

VS Logo with commonly used virus vectors: Lentivirus, Rabies virus and Adenovirus

The Life Science Facility is one of eight Scientific Service Units (SSUs) currently established at IST Austria. Its excellently trained staff supports experimental biologists in their research work. Its media and cleaning kitchen, as well as fish, plant, and mass spectrometry facilities consistently supply reliable and high-quality experimental resources so scientists can focus on their scientific questions. For information, visit the SSU website.

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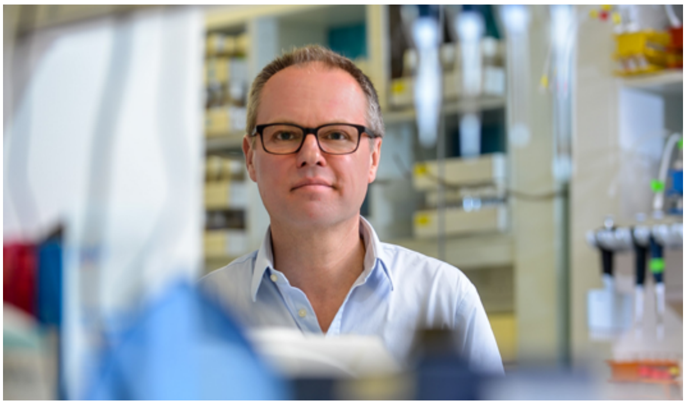
Summer Science Camps 2020

Every year, IST Austria offers a wide range of events and other opportunities to reach out to people interested in science and to communicate the importance and role of science for society. During the summer months, the focus shifts towards our youngest scientists. With extensive COVID-19 precautions, IST Austria's highly anticipated science camps took place on campus.

Starting in late August, the "Sommercampus" held a full week of research activities for primary school children. During the "Talentesommer", teenaged scientists got their chance and designed their own research laboratory. During both camps, the kids get to experience science in a fun and new way.

Keep an eye out for next year's registration period with our events website!



IST Lecture by Gero Miesenböck on October 7

On October 7, Gero Miesenböck will give an IST Lecture on "Mechanisms for balancing sleep need and sleep ". Gero Miesenböck is an Austrian neurophysiologist known as the founder of optogenetics.

This event will take place on the IST Austria campus in the Raiffeisen Lecture Hall with a limited seating capacity of 100 participants, and it will additionally be offered online via Zoom. Please note that due to the limited seating capacity in the Raiffeisen Lecture Hall, registration is on a first-come-first-served basis.

For more information about the IST Lecture visit the event website.

COLLOQUIUM SPEAKERS

PAST SPEAKERS: Andrea Liu, University of Pennsylvania (May 4) | Markus Arndt, University of Vienna (Jun 8) | Rich Sutton, University of Alberta and Deepmind (Jul 13) | Anna-Liisa Laine, University of Zurich (Sep 7)

FUTURE SPEAKERS: Andrea Cavalleri, Max Planck Institute for the Structure and Dynamics of Matter (Oct 5) | Michael J. Shelley, Flatiron Institute, Simons Foundation (Nov 9) | Tom Mitchell, Carnegie Mellon University (Nov 16) | Amir Yacoby, Harvard University (Nov 23) | Thierry Giamarchi, University of Geneva (Nov 30) | Maria Chudnovsky, Princeton University (Dec 7) | Elchanan Mossel, Massachusetts Institute of Technology (Dec 14)

SELECTED RECENT PUBLICATIONS

Geher GP, Titkos T, Virosztek D. 2020. Isometric study of Wasserstein spaces - the real line. Transactions of the American Mathematical Society. 373(8), 5855–5883.

Pitrik J, Virosztek D. 2020. Quantum Hellinger distances revisited. Letters in Mathematical Physics. 110(8), 2039–2052.

Shehu Y, Dong Q-L, Liu L-L, Yao J-C. 2020. New strong convergence method for the sum of two maximal monotone operators. Optimization and Engineering.

Gulden T, Berg E, Rudner MS, Lindner N. 2020. Exponentially long lifetime of universal quasi-steady states in topological Floquet pumps. SciPost Physics. 9.

Diringer AA, Gulden T. Robustness of the Floquet many-body localized phase in the presence of a smooth and a non-smooth drive. arXiv:2007.14879.

Vegter G, Wintraecken M. Refutation of a claim made by Fejes Tóth on the accuracy of surface meshes. Studia Scientiarum Mathematicarum Hungarica. 57(2), 193–199.

Avvakumov S. 2020. Topological methods in geometry and discrete mathematics, IST Austria, 119p.

Grah R. 2020. Gene regulation across scales – how biophysical constraints shape evolution, IST Austria, 310p.

Laukoter S, Pauler F, Beattie RJ, Amberg N, Hansen AH, Streicher C, Penz T, Bock C, Hippenmeyer S. Cell-type specificity of genomic imprinting in cerebral cortex. Neuron. 107(9), 1–20.

Sixt MK, Huttenlocher A. 2020. Zena Werb (1945-2020): Cell biology in context. The Journal of cell biology. 219(8).

Corominas-Murtra B, Scheele CLGJ, Kishi K, Ellenbroek SIJ, Simons BD, Van Rheenen J, Hannezo EB. 2020. Stem cell lineage survival as a noisy competition for niche access. Proceedings of the National Academy of Sciences of the United States of America. 117(29), 16969–16975.

Yu X, Liu J, Li J, Luo Z, Zuo Y, Xing C, Llorca J, Nasiou D, Arbiol J, Pan K, Kleinhanns T, Xie Y, Cabot A. 2020. Phosphorous incorporation in Pd2Sn alloys for electrocatalytic ethanol oxidation. Nano Energy. 77(11).

Montesinos López JC, Abuzeineh A, Kopf A, Juanes Garcia A, Ötvös K, Petrásek J, Sixt MK, Benková E. 2020. Phytohormone cytokinin guides microtubule dynamics during cell progression from proliferative to differentiated stage. The Embo Journal.

A full list of publications from IST Austria can be found in the IST Austria Research Explorer.

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