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Workshop proposal for Pauli Center:
"FIXNET – *Fixed-Point Optimization in Tensor Networks for Quantum Matter*"

Organizers: Juraj Hasik (UZH), Anna Francuz (Uni Vienna), Bart Andrews (ETH), Laurens Vanderstraeten (Université libre de Bruxelles), Jannes Nys (ETH)
Desired date: Q4 2025 with the specific date to be selected based on the ongoing poll on the availability of the main research groups.

Scientific background and program description

Understanding strongly correlated quantum matter is a fundamental challenge in modern physics, with implications ranging from high-temperature superconductivity, topological quantum computing, to the design of novel quantum materials. This challenge and its inherent exponential complexity drive the development of novel advanced computational approaches. Tensor networks, in particular infinite Projected Entangled Pair States (iPEPS) [1], have quickly emerged as a new and powerful tool for capturing the essential physics of such systems in two dimensions.

Recent advances in optimization of iPEPS by automatic differentiation (AD) [2] have significantly enhanced their precision and greatly simplified their software implementation for simulations of both ground and excited states of quantum lattice models. Together, these improvements enabled the introduction of high-quality and flexible open-source libraries, substantially lowering the barrier to entry and opening the path to more widespread adoption of iPEPS. However, simulations of new exotic phases and their dynamics, in particular (but not limited to) Dirac spin liquids or Fractional Chern Insulators demand further algorithmic innovations.

This workshop will bring together experts in strongly correlated lattice models, tensor networks, and high-performance computing to explore recent breakthroughs and outstanding challenges in iPEPS simulations and software implementation. Topics will include advanced optimization techniques like implicit differentiation for iPEPS fixed points [3], new approaches to excited state simulations [4, 5], and iPEPS open-source software standardization. A key focus will be on developing methods that enable scalable simulations with large symmetric (block-sparse) tensors on heterogeneous computer architectures. The workshop will be open and the introductory talks together with the tutorials will provide an opportunity for interested undergraduate and graduate students to learn about the state-of-the-art tensor network methods.

Invited speakers: Jutho Haegeman (Gent), Marek Rams (Krakow), Tao Xiang (CAS, Beijing), Philippe Corboz (UvA), Miles Stoudenmire (Flatiron), Philipp Schmoll (FU Berlin), Johnnie Gray (Caltech), Naoki Kawashima (University of Tokyo)

Given the focused nature of the topic, to maximize the impact of the workshop we aim to invite key leading researchers, both from Europe and overseas. However, we are mindful to keep CO_2 emissions to a minimum and so the majority of the participants will be from Europe and the local area.

Expected participants: Paul Brehmer (Uni Vienna), Lukas Devos (Flatiron), Erik Weerda (FU Berlin), Yi Xu (Rice), Boris Ponsioen (Fermioniq), Jan Naumann (FU Berlin), Hao Chen (UZH), Hai-Jun Liao (CAS, Beijing), Wei-Lin Tu (Seoul), Olivier Gauthe (Flatiron), Wen-Tao Xu (TU Munich), Jakob Unfried (TU Munich), Andreas Läuchli (PSI), Attila Szabo (UZH), Natalia Chepiga (TU Delft)

Schedule

Below, we give a tentative schedule for the workshop. The program will consist of invited and contributed talks expected to introduce fixed-point methods, leading tensor network software libraries, and their recent state-of-the-art applications. Participants are encouraged to bring posters, which will be displayed in the coffee break area throughout the workshop. In the breakout sessions, the participants will be split into the working groups, each group addressing a specific topic related to future directions in software development and applications, with a short round of reporting following the session.

	Morning	Afternoon
1st day	Welcome + talks	talks
2nd day	talks	talks + breakout session
3rd day	talks + tutorials	talks + breakout session

We plan three coffee breaks per day. A workshop dinner for all the participants will take place on the 2nd day.

Budget

We expect 25-35 participants. We intend to use spaces of UZH Physik-Institut to host the talks, tutorials, and breakout sessions. The lunches will take place in Mensa at Campus Irchel. We aim to cover accommodation and local costs for invited participants (except local). All participants are expected to cover their travel costs. To provide this level of hospitality we are kindly requesting 14K CHF funding from the Pauli center, we have secured a contribution from Neupert's group and are applying for further funding from SNSF Scientific Exchanges grant facility. If resources permit, we intend to contribute to local costs for interested graduates and PhDs without their own financial support.

	Unit cost per person	Workshop (number of persons)
Coffee breaks (all)	90 (9x10)	3150 (35)
Workshop dinner (all)	80	2800 (35)
Lunches (all)	45 (3x15)	1575 (35)
Accommodation (invited only)	720 (4 nights x 180)	5760 (8)
Local costs (invited only)	320 (4 days x 80)	2560 (8)
Totals (regular/invited)	**215 / 1255**	**15845**

References

[1] F. Verstraete, J. I. Cirac, "Renormalization algorithms for Quantum-Many Body Systems in two and higher dimensions", arXiv:cond-mat/0407066

[2] Hai-Jun Liao, Jin-Guo Liu, Lei Wang, and Tao Xiang, "Differentiable Programming Tensor Networks", Phys. Rev. X 9, 031041 (2019)

[3] Anna Francuz, Norbert Schuch, Bram Vanhecke, "Stable and efficient differentiation of tensor network algorithms", arXiv:2311.11894

[4] Wei-Lin Tu, Laurens Vanderstraeten, Norbert Schuch, Hyun-Yong Lee, Naoki Kawashima, Ji-Yao Chen, "Generating function for projected entangled-pair states" PRX Quantum 5, 010335 (2024);

[5] Boris Ponsioen, Juraj Hasik, and Philippe Corboz, "Improved summations of n-point correlation functions of projected entangled-pair states, Phys. Rev. B 108, 195111 (2023)