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Editorial: Open quantum systems in quantum technologies

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Editorial on the Research Topic
Open quantum systems in quantum technologies

Quantum technologies are increasingly developed as engineered platforms where imperfect isolation, continuous monitoring, and control hardware are intrinsic features rather than small corrections. In this context, open quantum systems (OQS) provide the natural framework to describe how devices behave in realistic conditions, and to transform dissipation, measurement back-action, and noise from limitations into design elements. This Research Topic, "Open Quantum Systems in Quantum Technologies", brings together contributions that illustrate this shift - from the operational meaning of measurement, to practical cooling protocols, to scalable simulation formalisms, and data-driven inference tools.

A first perspective is offered by *Joint observables induced by indirect measurements in cavity QED* by Raikisto and Luoma, which addresses how effective observables emerge when a system is monitored indirectly through an ancillary channel. In a cavity-QED setting where the output light is continuously measured, the authors show that the induced observables can be tuned by the detection scheme (e.g., homodyne versus heterodyne) and by the initial cavity state, including regimes where otherwise incompatible observables become jointly measurable in an unsharp form. Beyond foundational interest, these results inform measurement design for stabilization and feedback in monitored quantum devices.

Control in the presence of dissipation is exemplified by *Cooling strongly self-organized particles using adiabatic demagnetization* by Jäger. For polarizable particles coupled to a lossy cavity mode, the article analyzes a two-step protocol: strong driving first cools the particles into a self-organized configuration, followed by an adiabatic ramp-down of the drive that transfers energy and reduces kinetic motion toward the recoil scale. The work highlights the practical trade-off between suppressing heating and maintaining approximate adiabaticity, and illustrates how structured light-matter dissipation can be used as a resource for preparing low-energy states.

At the algorithmic level, the Review *Spatio-temporal tensor-network approaches to out-of-equilibrium dynamics bridging open and closed systems* by Cerezo-Roquebrún et al. synthesizes recent progress in representing non-equilibrium dynamics - open or closed - through spatiotemporal tensor networks. By connecting influence functionals, process tensors, and transfer-matrix viewpoints, the review clarifies when such objects are compressible and where complexity barriers arise, while pointing to emerging strategies to extend classical simulation capabilities for quantum devices operating far from equilibrium.

Finally, *An introduction to Bayesian simulation-based inference for quantum machine learning with examples* by Nikoloska and Simeone highlights the growing importance of principled, likelihood-free inference methods for calibrating simulators and quantifying uncertainty. Using parameterized quantum circuits as illustrative simulators, the authors discuss Bayesian simulation-based inference workflows that remain applicable when explicit likelihoods are unavailable, a setting increasingly common in noisy quantum experiments and learning pipelines.

Together, these articles emphasize complementary aspects of the OQS agenda for quantum technologies: measurement as an operational, designable interface; dissipation-enabled control and cooling; scalable simulation formalisms that bridge open and closed dynamics; and inference frameworks that connect models to data with uncertainty quantification. As quantum platforms scale, progress will increasingly depend on integrating these elements - linking measurement and feedback to robust control, leveraging efficient representations to guide computation, and using statistical inference to validate and refine device-level models.

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