



UNIVERSITY
OF INNSBRUCK

Dr. Helmut Ritsch, Professor

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To
Mrs. Karpova
Physical and Mathematical Sciences
St. Petersburg University
St Petersburg 199034
Russia

Letter of reference on the Dissertation *Quantum Optics with ultracold quantum gases* submitted by Igor Mekhov

Dear Madam or Sir,

With pleasure I am forwarding you my report to support acceptance of the Dissertation of Igor Mekhov, *Quantum optics of ultracold quantum gases: open systems beyond dissipation* to obtain the degree of *Doctor of Physical and Mathematical Sciences* at the Saint Petersburg State University with speciality 1.3.6. Optics.

Igor Mekhov spent a very fruitful period of several years from 2007-2010 as a junior researcher in my research group on theoretical Quantum Physics at the University of Innsbruck before leaving to join top international research institutions as Harvard and Oxford university. With his excellent broad expertise and research experience in quantum optics, quantum measurement and ultra-cold gases he is now one of the outstanding young theoreticians in ultra-cold quantum gas cavity QED.

In this theses the candidates presents an impressive and well chosen selection of new and important physical results, that he together with his group have obtained during the past decade. His thesis starts with a short but concise and to the point introduction to the field, clearly highlighting its general foundations and the special aim and goals of his own work. On the long run he targets a complete quantum mechanical description of the complex interacting dynamics of ultra-cold gases and light fields in optical resonators. In the first chapters he demonstrates that in a open quantum system the output carries ample information on the quantum statistical properties of the total system, which thus can be measured precisely and with minimal perturbation on the dynamics in real time. Under favourable conditions and with clever geometric setups almost the whole particle statistics can be retrieved from measurements on the output light. In this context he certainly was amongst the first to fully realise and utilise that such quantum measurements on the fields in a strongly coupled system induce an inevitable but controllable back action on the atomic part.

In the following chapters he demonstrates that, most interestingly, this back-action can be well controlled via the precise form of the measurement. Actually by a clever choice of field and measurement geometry, he shows that, surprisingly, not only atomic densities but also atomic coherence can be influenced and partly controlled via proper measurement projections. As a particular highlight, if one uses

the information obtained in real time for feedback on the system and measurement devices, even phase transition in the system can be steered and directly observed.

In the final chapter then he presents a first line of results towards the long term goal of a complete description and applications of the full atom-photon quantum dynamics. Here one carefully has to distinguish truly unique quantum effects from semi-classical interference effects. This is very vital to understand in detail for harnessing the full power of quantum physics in future atom based quantum simulators or for applied quantum optimisations in cavity based ultra-cold quantum gas optimisers.

His work over the years, overall, has lead to an impressive collection of original publications in the worlds leading refereed scientific journals, with significant impact on the current and future developments in this field.

In summary, with the new physics discovered and presented in this thesis, Igor Mekhov proves to be an careful theorist and a group leader on an outstanding scientific level, who produced many creative, novel contributions of great relevance at the forefront of Quantum Optics research. Hence I unconditionally support the candidate to obtain the degree of *Doctor of Physical and Mathematical Sciences* at St Petersburg university.

Sincerely,

A handwritten signature in blue ink, appearing to be 'H. Ritsch', written in a cursive style.

Dr. Helmut Ritsch, Professor