Q 38: Poster: Quantum Optics and Photonics I

Time: Tuesday 16:15–18:15 Location: Orangerie

Q 38.1 Tue 16:15 Orangerie

Mean-Field Dynamics of a Homogeneous Photon Bose-Einstein Condensate — Enrico Stein and •Axel Pelster — Physics Department and Research Center OPTIMAS, Technical University of Kaiserslautern, Erwin-Schrödinger Straße 46, 67663 Kaiserslautern, Germany

We show, that a Bose-Einstein condensate of photons [1,2] can be described consistently on the mean-field level by using an open-dissipative Gross-Pitaevski approach as it is widely used in the community of exciton-polariton condensates [3,4]. In our context this means to set up a pair of coupled mean-field equations, one for the coherent condensate wave function and one for the diffusion of temperature in the dye solution. With this mean-field approach at hand we perform a linear stability analysis for a homogeneous photonic BEC. At first, we determine the steady state, from which we deduce a photon-photon interaction strength agreeing with the experimental value [2,4]. Afterwards, we analyze small deviations from the BEC steady state, yielding both the Bogoliubov spectrum and its damping. In particular, we show that the Goldstone theorem turns out to be valid even for such an open-dissipative photonic system. Finally, we note that our mean-field modelling yields for experimenal realistic parameters a stable BEC steady state as both pumping and dissipation are included.

[1] J. Klaers et al., Nature **468**, 545 (2010)

[2] J. Klaers et al., Appl. Phys. B **105**, 17 (2011)

[3] M. Wouters and I. Carusotto, Phys. Rev. Lett. **99**, 140402 (2007)

[4] D. Dung et al., Nature Photonics **11**, 565 (2017)

Q 38.2 Tue 16:15 Orangerie

The Space Atom Laser - An isotropic source for ultra-cold atoms in microgravity — •Matthias Meister, Albert Roura, Wolfgang P. Schleich, and The QUANTUS Team — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology ($\mathrm{IQ}^{\mathrm{ST}}$), Universität Ulm, D-89069 Ulm

Atom laser experiments based on magnetically trapped Bose-Einstein condensates (BECs) performed on ground allow to create an accelerated, directed beam of atoms due to gravity. In microgravity, on the other hand, the dominant force acting on the outcoupled atoms is the repulsive interaction between the particles resulting in a slowly expanding three-dimensional shell. Remarkably, this outcoupled shell possesses a fairly isotropic distribution in position and momentum even when the initial BEC was trapped in an elongated, anisotropic trap.

We present a realistic protocol that allows the generation of such an unusual arrangement of atoms in microgravity by applying radio frequency outcoupling methods to a magnetically trapped BEC. In order to pave the way for its experimental implementation in NASA's Cold Atom Laboratory on the ISS, we have thoroughly studied this process numerically including experimental imperfections like fluctuating particle numbers or instabilities of the magnetic trap.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number 50WM1556.

Q 38.3 Tue 16:15 Orangerie

Calorimetry and Coherence of a Photon Bose-Einstein Condensate — •Erik Busley[1], Julian Schmitt[2], Tobias Damm[1], David Dung[1], Fahri Öztürk[1], Christian Kurtscheid[1], Jan Klärs[3], Frank Vewinger[1], and Martin Weitz[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, D-53115 Bonn — [2]Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, CB3 0HE Cambridge, United Kingdom — [3]Faculty of Science and Technology, University of Twente, De Horst 2, 7522LW Enschede, Netherlands

We have in earlier work experimentally realized Bose-Einstein condensation of photons. The condensate is generated in a dye-filled optical microcavity which provides a photon dispersion equivalent to harmonically trapped massive bosons. Thermalization of the photon gas is achieved by subsequent absorption and emission cycles in the dye molecules which fulfill the Kennard-Stepanov relation.

Here we report on recent results regarding the caloric properties of the photon condensate. The specific heat shows a cusp singularity at the phase transition similar to liquid helium. Also, the internal energy per particle shows the expected behavior for a phase transition. More recently, we have investigated the first-order coherence of the photon gas below and above condensation threshold. Tunable Michelson and Mach-Zehnder interferometers are used to split up and recombine the cavity emission to obtain temporal and spatial coherence. The interferometrically measured coherence times range from picoseconds below criticality to microseconds above the condensation threshold.

Q 38.4 Tue 16:15 Orangerie

Reservoir-induced collapse and revival of photon-BEC oscillations — Bastian Havers[1], •Tim Lappe[1], and Johann Kroha[1,2] — [1]Physikalisches Institut and Bethe Center for Theoretical Physics, Universität Bonn, Nussallee 12, 53115 Bonn, Germany — [2]Center for Correlated Matter, Zhejiang University, Hangzhou, Zhejiang 310058, China

Bose-Einstein condensation of light was first realized in 2010 by filling a photon gas into a dye-filled optical microcavity and subsequently thermalizing it at room temperature. Recently, mirror delamination has enabled the creation of double-well potentials for the photons, such that Rabi or Josephson oscillations can be observed. For short reabsorption times of the photons by the dye, these undergo a collapse and revival. We describe this effect in terms of the non-Markovian dynamics of the bath of dye-molecule excitations. To study the nonequilibrium dynamics, we use the Keldysh technique in a path-integral formulation. The dye molecule excitations are modeled by a miniband of bosonic excitations, which is a good approximation for the realistic case of low excitation density. We take into account cavity losses as well as nonradiative decay and transverse dephasing in the dye. We find a crossover from a regime of normal Josephson oscillations to collapse-and-revival dynamics, depending on system parameters like the cavity cutoff and the photon-dye coupling. This illuminates the physically important processes that are responsible for collapse and revival in the system.

Q 38.5 Tue 16:15 Orangerie

Kinetic theory of non-thermal fixed points in a Bose gas — •Aleksandr Mikheev, Christian-Marcel Schmied, Isara Chantesana, and Thomas Gasenzer — Kirchhoff-Institut für Physik, INF 227, 69120 Heidelberg, Germany

We outline a kinetic theory of non-thermal fixed points for the example of a dilute Bose gas. We study universal dynamics after a cooling quench, focusing on situations where the time evolution represents a pure rescaling of spatial correlations, with time defining the scale parameter. Possible universal dynamics is identified by means of a scaling analysis of the kinetic equation describing the interactions of (quasi)particle field modes. The non-equilibrium initial condition set by the quench induces a redistribution of particles in momentum space. This can take the form of a wave-turbulent flux or more general evolution in which the momentum distribution shifts in a self-similar manner, signaling the critically slowed approach of a non-thermal fixed point. The approach of the fixed point is tied to collective scattering between highly occupied long-wavelength modes which require a description in terms of a non-perturbative kinetic theory. We obtain a possible finite-size interpretation of wave-turbulent scaling recently measured by Navon et al. [N. Navon, A. L. Gaunt, R. P. Smith, and Z. Hadzibabic, *Nature 539, 72 (2016)*].

Q 38.6 Tue 16:15 Orangerie

Melting of Mott Lobes of Bosons in an Optical Lattice — •Martin Bonkhoff, Oliver Thomas, Axel Pelster, Herwig Ott, and Sebastian Eggert — Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger Straße 46, 67663 Kaiserslautern, Germany

We investigate the finite-temperature properties of harmonically confined bosons in a 3d cubic optical lattice. At first we solve numerically exact the underlying Bose-Hubbard model in mean-field approximation, where we take into account the harmonic trapping confinement via the local density approximation. With this we obtain the quantum phase diagram as well as the particle and the entropy density, which reveal that the Mott lobes melt due to a delicate interplay of thermal fluctuations [1] and particle hopping. Finally, we compare the theoretical calculations for the resulting particle density with experimental measurements, which were obtained with a scanning electron microscope [2].

[1] F. Gerbier, Phys. Rev. Lett. **99**, 120405 (2007)
[2] B. Santra and H. Ott, J. Phys. B **48**, 122001 (2015)

Q 38.7 Tue 16:15 Orangerie

Quantum field mapping of dissipative quantum systems — •Etienne Wamba, Axel Pelster, and James Anglin — Technische Universität Kaiserslautern, 67663, Kaiserslautern, Germany

We consider an arbitrary D-dimensional quantum gas that interacts with a bath. In an attempt to recover the Lindblad master equation and generalize the Caldeira-Leggett model, we describe the entire-system dynamics as that of a quantum gas that is made of two species of particles, using a single Hamiltonian. We exactly map into each other, the quantum fields of different evolutions of the set, and for some specific types of coupling between them, we try to solve the evolution of the quantum fields of the systems.

Q 38.8 Tue 16:15 Orangerie

Self organisation of a BEC in two crossed cavities across an atomic resonance — •Davide Dreon, Andrea Morales, Philip Zupancic, Xiangliang Li, Tobias Donner, and Tilman Esslinger — ETH, Zürich, Switzerland

The interaction of a Bose-Einstein condensate (BEC) with the electromagnetic field of an optical cavity is known to exhibit a superradiant phase transition to a self-organized phase. In our experiment, a ^{87}Rb BEC is placed at the mode crossing of two optical cavities. The BEC is illuminated with a 'pump' laser beam whose detuning from the D_2 atomic line determines the interaction regime. We recently explored different red detunings, where the system reduces its potential energy spontaneously forming an attractive lattice in the cavity mode. Here, we have observed a supersolid phase [1,2] and a phase with intertwined order [3]. In contrast, in the blue detuned case the energy of the atoms is increased by the presence of an optical lattice and therefore spontaneous superradiant scattering in the cavity should be inhibited.

I will report on our most recent experimental results on the blue side of the atomic resonance, where we observe, surprisingly, that self-organization is still possible. We measure the phase diagram of the system and explain our findings with simple energy arguments. In addition to the steady state regime typical of red detunings, dynamical instabilities leading to limit cycles of the cavity field amplitude or chaotic behaviors are expected [4].

[1] Nature, 543, 87-90 (2017), [2] arXiv:1704.05803 (to appear in Science), [3] arXiv:1711.07988, [4] PRL 115, 163601 (2015)

Q 38.9 Tue 16:15 Orangerie

Coupled order parameters with ultracold atoms in two crossed cavities — •Philip Zupancic[1], Andrea Morales[1], Julian Léonard[1,2], Xiangliang Li[1], Davide Dreon[1], Tilman Esslinger[1], and Tobias Donner[1] — [1]Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

The concept of intertwined order describes the simultaneous existence of independent order parameters and can therefore allow materials to feature multiple properties. Examples include multiferroic materials that have coexisting ferroelectric and ferromagnetic orders leading to enhanced functionalities, and materials that are superconducting at high temperatures due to intertwining between charge- and spin-order.

I will report on our recent experimental realization of an intertwined ordered phase in a quantum gas where we can control the interaction between the atoms at the microscopic level. Our system is realized by a BEC that can transit into self-organized phases with the modes of two crossed optical cavities.

For vanishing inter-order coupling we realize a supersolid phase of matter by symmetry enhancement of the composite order parameter to a $U(1)$ symmetry. Here we observe the simultaneous existence of a Higgs and Goldstone mode. Increasing the inter-order coupling, this symmetry breaks down to a $\mathbb{Z}_2 \times \mathbb{Z}_2$, and we observe the emergence of an extended intertwined phase arising from the coupling of the individual order parameters. This coupling enables us to increase or decrease the critical point of one order by controlling the other.

Q 38.10 Tue 16:15 Orangerie

Superfluidity and Vortex interactions in 2D Bose mixtures — •Volker Karle — Institut für Theoretische Physik, Universität Heidelberg, D-69120 Heidelberg

Two-component Bose mixtures in low dimensions are at the center of the current interest in Bose droplets. We theoretically consider a two-component bosonic gas in two dimensions at low temperatures with zero-range repulsive interaction. While mapping the classical binary liquid to an Ising-like model provides corrections to the mean-field densities, in 2D another phenomenon appears: The non-dissipative drag, also called Andreev-Bashkin effect, leads to a modification of the usual BKT-transition for the coexistence phase where both components exhibit superfluid behavior at the same time. We study the renormalization of the densities at finite temperatures using standard RG-methods.

Q 38.11 Tue 16:15 Orangerie

Variable potentials for thermalized light and coupled condensates — •David Dung[1], Christian Kurtscheid[1], Julian Schmitt[2], Tobias Damm[1], Frank Vewinger[1], Jan Klärs[3], and Martin Weitz[1] — [1]Institut für Angewandte Physik, Universität Bonn — [2]present address: Department of Physics, University of Cambridge, United Kingdom — [3]present address: Faculty of Science and Technology, University of Twente, The Netherlands

Cold atoms in lattice potentials are an attractive platform to simulate phenomena known from solid state theory, as the Mott-insulator transition. In contrast, the field of photonics usually deals with non-equilibrium physics. Recent advances towards photonic equilibrium physics include polariton lattice experiments, as well as the demonstration of a photon condensate in a dye-filled microcavity. Here we report the creation of variable micropotentials for light using thermo-optic imprinting within a supermirror microcavity filled with a dye-polymer solution. The long photon lifetime allows for the thermalization of photons in microsites. Within the generated trapping potentials, photons by repeated absorption-emission cycles thermalize to the temperature of the dye solution, and in a single microsite we observe a photon Bose-Einstein microcondensate. Effective interactions between the otherwise nearly non-interacting photons are observed due to thermooptic effects, and in a double-well system tunnel coupling between sites is demonstrated, as well as the hybridization of eigenstates. Prospects of the findings include photonic lattices in which cooling alone can produce entangled manybody states.

Q 38.12 Tue 16:15 Orangerie

Weakly interacting Bose gases far from thermal equilibrium — •Lingna Wu, André Eckardt, and Alexander Schnell — Max Planck Institut für Physik komplexer Systeme

For the ideal gas a simple description of this open system is given by the Born-Markov approximation. Within this framework, the bath induces quantum jumps between energy eigenstates. Taking into account temperature-dependent dissipation for the interacting gas is challenging. Already on the level of a simple mean field approximation, it requires the diagonalization of the mean field Hamiltonian in every step of the time integration. We propose and test a scheme to circumvent this problem by treating the system-bath coupling semi-classically. This allows for simulating true non-equilibrium steady states, for example by coupling the system to two baths with different temperature T. We treat both systems with particle number conservation and systems with particle pump and loss. In the latter case we apply our model to find predictions for exciton polariton experiments.

Q 38.13 Tue 16:15 Orangerie

Geometric Phase for Gaussian Unitaries — •Stephan Kleinert, Wolfgang P. Schleich, and the QUANTUS Team — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm, D-89069 Ulm

In the presence of a time-dependent Hamiltonian, a quantum state accumulates, apart from a dynamical phase, a geometric phase which solely depends on the topology of the projective Hilbert space.

We investigate the geometric phase acquired by an arbitrary quantum state (pure and mixed states) in the presence of a general quadratic Hamiltonian. To address this problem, we use the powerful tool of Gaussian unitaries providing a simple interpretation in Wigner phase space. In this context, we further introduce the notion of geometric phase in symplectic continuous-variable phase space.

As an example, our general formalism is applied to motional states in light-pulse atom interferometers [1].

The QUANTUS project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economics and Energy (BMWi) under grant number 50WM1556.

[1] S. Kleinert, et al., *Representation-free description of light-pulse atom interferometry including non-inertial effects*, Physics Reports **605**, 1 (2015).

Q 38.14 Tue 16:15 Orangerie

Diffractive Guiding of Matter Waves — •Moritz Carmesin[1], Maxim A. Efremov[1], Dror Weisman[2], Ady Arie[2], and Wolfgang P. Schleich[1,3] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ$^{\text{ST}}$), Universität Ulm, 89069 Ulm, Germany — [2]Department of Physical Electronics, Faculty of Engineering, Tel-Aviv University, Tel-Aviv 69978, Israel — [3]Hagler Institute for Advanced Study, Institute for Quantum Science and Engineering (IQSE), and Texas A&M AgriLife Research, Texas A&M University, College Station, TX 77843-4242, USA

A matter wave freely propagating behind a single slit narrows before it expands. This effect, known as diffractive focusing [1, 2], originates exclusively from the modulation of the wave's amplitude, rather than from the phase modulation due to a lens.

By placing several single slits in a row, we can exploit their narrowing feature in order to guide a wave, i. e. to transfer a maximal amount of intensity to a point at a given distance from the source of the wave. This novel kind of wave guide based on diffraction is useful in situations where the conventional guiding based on reflection is not easily applicable.

This work is supported by the German-Israeli Cooperation (DIP) of DFG.

[1] Case, W. B., Sadurni, E., Schleich, W. P., Optics Express **20**, 27253 (2012)

[2] Weisman, D. et al. PRL **118** 154301 (2017)

Q 38.15 Tue 16:15 Orangerie

Impact of interactions on BEC interferometry — •Christian Ufrecht, Albert Roura, Wolfgang P. Schleich, and the QUANTUS team — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ$^{\text{ST}}$), Universität Ulm, D-89069 Ulm

In recent years, light-pulse atom interferometry with macroscopic arm separation and Bose-Einstein condensates as highly coherent atom sources has attracted a lot of attention. However, interactions between the atoms, which are often disregarded in the theoretical description, can lead to significant effects such as mean-field phase shifts or phase diffusion.

To better understand these phenomena, we discuss the problem in second quantization, where the inclusion of interactions is straightforward. Based on a clear separation of the atomic clouds along different paths in position or momentum space, we propose a method that leads to a path-dependent description involving a transformation to the rest frame for each individual path. In this picture phase contributions predicted by the non-interacting theory and effects generated by the interaction separate most clearly. As an application of this method we discuss how two-mode squeezing between momentum states driven by atomic interactions can be exploited to overcome the shot-noise limit.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number 50WM1556 (QUANTUS IV).

Q 38.16 Tue 16:15 Orangerie

Wigner representation of Bose-Einstein condensates in the Thomas-Fermi limit — •Jan Teske and Reinhold Walser — Technische Universität Darmstadt

In 2017, the MAIUS sounding rocket created the first Bose-Einstein condensate in space and realised a matter-wave interferometer [1]. In general, atom interferometers serve as high precision sensors for accelerations, gravity and gravity gradients with a wide range of scientific and technological applications.

Simulating cold quantum gases is mostly done with classical mean fields or with ray tracing simulations in phase space. It is therefore necessary to have simple approximation schemes for interacting BECs in the Thomas-Fermi limit in phase space. In the present contribution, we compare analytical approximation for the Thomas-Fermi Wigner functions with a full Gross-Pitaevskii mean field simulation.

[1] http://www.dlr.de/dlr/desktopdefault.aspx/tabid-10081/151_read-20337/

Q 38.17 Tue 16:15 Orangerie

Interplay between AC-Stark shift and two-photon light shift in Raman diffraction — •Eric P. Glasbrenner[1], Alexander Friedrich[1], Wolfgang P. Schleich[1], Ernst M. Rasel[2], and Enno Giese[3] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ$^{\text{ST}}$), Universität Ulm, D-89069 Ulm — [2]Institut für Quantenoptik, Leibniz Universität Hannover, D-30167 Hannover — [3]Department of Physics, University of Ottawa, K1N6N5 Ottawa

Light-pulse atom interferometry has become a standard tool for the realization of high precision experiments and in quantum sensing applications as well as tests of fundamental physics. Nowadays such interferometers rely on either Raman or Bragg diffraction, realized via a retro-reflective setup with two counter-propagating lasers. However setups of this kind lead to a light shift contribution to the interferometer phase due to the off-resonant two-photon transitions. The AC-Stark shift on the other hand arises naturally as the atoms interact with two counter-propagating Raman beams. Usually, this AC-Stark shift is only considered as an energy shift of the initial atomic levels [PRA 78 043615 (2008)] without any contribution to dynamical effects such as the light shift. However, in our presentation we show this point of view is wrong and find the explicit modifications to the light shift due to the AC-Stark effect and analyze its consequences. The QUANTUS project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number 50WM1556.

Q 38.18 Tue 16:15 Orangerie

Optimal focusing of free matter waves — •Patrick B. Boegel[1], Maxim A. Efremov[1], and Wolfgang P. Schleich[1,2] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ$^{\text{ST}}$), Universität Ulm, D-89069 Ulm — [2]Institute for Quantum Science and Engineering (IQSE), Department of Physics and Astronomy, Texas A&M University, College Station, TX 77843

A common way to control the position and the size of maximal focusing of a matter-wave is to use a lens, which imprints a position-dependent phase on the initial wave. However, even quantum mechanics allows focusing even without [1,2] a lens, that is when the initial wave function is a real-valued one. Hence, the optimal focusing relies on a smart choice of this initial wave function [3].

Here we find the optimal real-valued wave function of a free particle for the case of two dimensions and study the role of anti-centrifugel forces [4] in matter-wave focusing.

[1] Case, W.B.; Sadurni, E.; Schleich, W.P., Optics Express 20, 27253 (2012)

[2] Weisman D. et al. Phys. Rev. Lett. **118**, 154301 (2017)

[3] Vogel, K. et al., Chem. Phys. **375**, 133-143 (2010)

[4] Białynicki-Birula I., et al., Phys. Rev. Lett. **89**, 060404 (2002)

Q 38.19 Tue 16:15 Orangerie

Electron beam splitter in microwave fields — Robert Zimmermann, Philipp Weber, •Michael Seidling, and Peter Hommelhoff — Lehrstuhl für Laserphysik (FAU), Staudtstraße 1, 91058, Erlangen, Germany

We report on the development of an electron beam splitter based on free electrons manipulated by microwave electric fields applied to micro-structured chips. The working principle is of a Paul trap: a microwave potential applied to electrodes causes an oscillating electric field by which electrons can be guided in a pseudopotential [1]. The transverse confinement naturally provides discretized motional quantum states that govern the motion. Based on the initial designs of guides [2-4], we have developed an electron beam splitter, which is predicted to split coherently. We show ongoing efforts to demonstrate coherent splitting: electron optics are integrated into the setup to overlap both output beams and make interference stripes visible. To establish phase control over the electron and the microwave, a laser triggered SEM is used as a pulsed electron source. The future goal is to show interaction-free measurements [5] with free electrons, which would pave the way for the development of the quantum electron microscope [6].

[1] W. Paul, Rev. Mod. Phys. 62, 531 (1990) [2] J. Hoffrogge, et al.; Phys. Rev. Lett. 106, 193001 (2011) [3] J. Hoffrogge and P. Hommelhoff; New J. Phys. 13, 095012 (2011) [4] J. Hammer, et al.; Phys. Rev. Lett. 114, 254801 (2015) [5] P. Kwiat, et al.; Phys. Rev. Lett. 74, 4763 (1995) [6] W. P. Putnam and M. F. Yanik; Phys. Rev. A 80, 040902(R) (2009)

Q 38.20 Tue 16:15 Orangerie

Qualification of a lasersystem for atom interferometry

with Potassium — •Julien Kluge[1], Julia Pahl[1], Aline N. Dinkelaker[1], Christoph Grzeschik[1], Markus Krutzik[1], Achim Peters[1,2], and The QUANTUS Team[1,3,4,5,6,7] — [1]HU Berlin — [2]FBH Berlin — [3]U Bremen — [4]LU Hannover — [5]JGU Mainz — [6]U Ulm — [7]TU Darmstadt

The QUANTUS-2 experiment is a testbed for dual-species atom interferometry in microgravity with potassium and rubidium inside a drop tower. While the rubidium system is already running and performing in atom-chip based BEC experiments, the potassium subsystem is coming towards its final assembly and integration.

In this poster, we present the controling mechanisms for the potassium laser system. This includes the software for the hardware communication to regulate multiple experimental parameters and handling of incoming and outgoing data streams. One main feature is a verification of an automated frequency stabilization using atomic spectroscopy for the DFB diode lasers and a evolutionary algorithm-based optimization of TEC feedback parameters.

Furthermore we show verification and qualification tests done on a miniaturized drop tower as well as results gathered in the recent campaigns.

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