Towards Cold Atom Experiments in Chinese Space Station

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Introduction

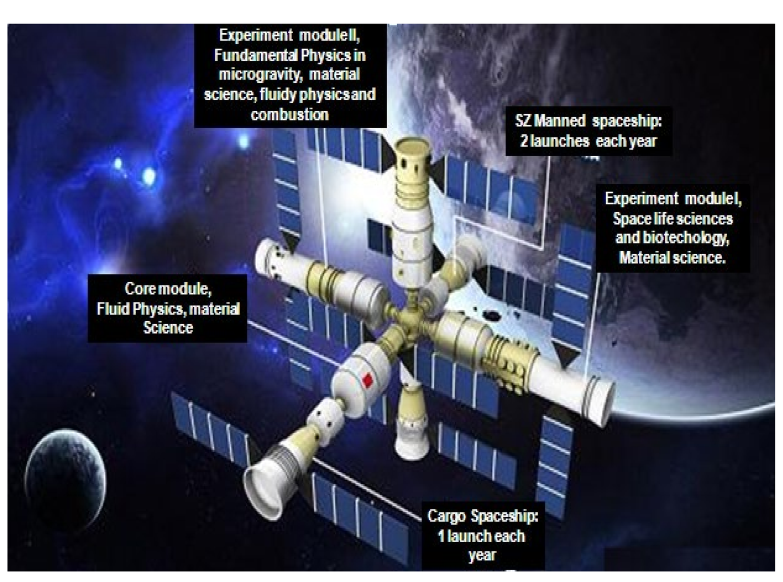
Chinese space station is due to launch in 2021, and the science module II is due to launch in 2022 with an Cold Atom Physics Rack (CAPR). The purpose for the cold atom physics rack is to achieve picokelvins ultra low temperature and implement four challenging experiments based on CAPR in first three years, and about 10 experiments is planned in next seven years, the mission for the experiments is focused on quantum simulation.

There are three advantages for the quantum gas in space: (1) ultralow temperature: 10^{-12} K（pK）,three order lower than on the earth (nK), (2) longer observation time (20s) , three order longer than on the earth (20ms)， (3) space uniform, no gravity gradient potential.

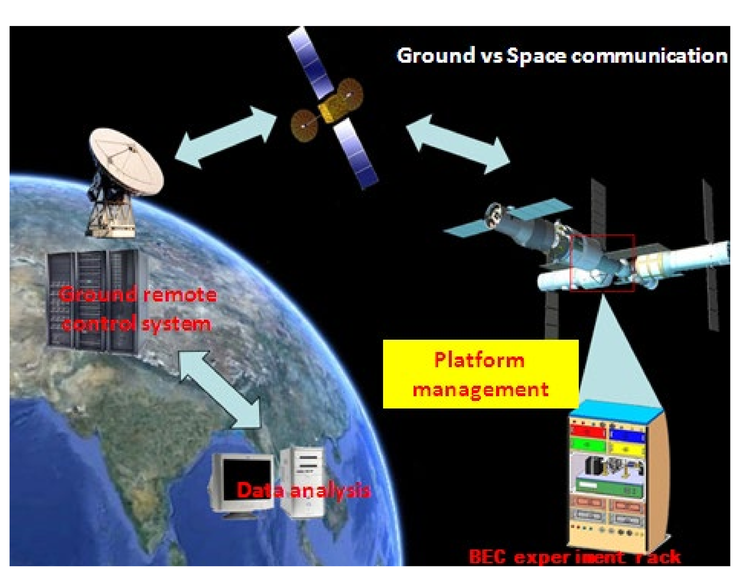
Four fundamental physics experiments based on quantum gas will be implemented in the Chinese space station in first three years:.
(1) Quantum Magnetism, (2) Exotic material; (3) Acoustic black hole; (4) Effimov effect.

Cold Atom Physics Rack (CAPR) in Chinese Space Station

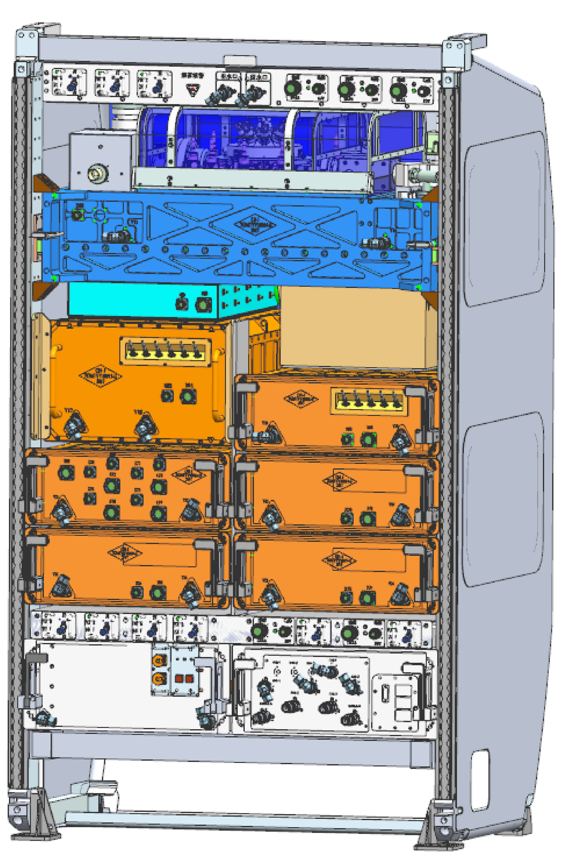
Using the space environment conditions provided by the manned space station, as well as the ability of astronauts to operate, maintain and replace in orbit, and based on the constraints of external mechanical, electrical, thermal, information, measurement and control resources, Cold Atom Physics Rack (CAPR) is developed to support the research of space ultra cold atomic physics， it consists of five parts：
（1）Physics module；（2） Laser and optics module；（3）Electronics module；（4）Remote control module; (5) Rack support module.



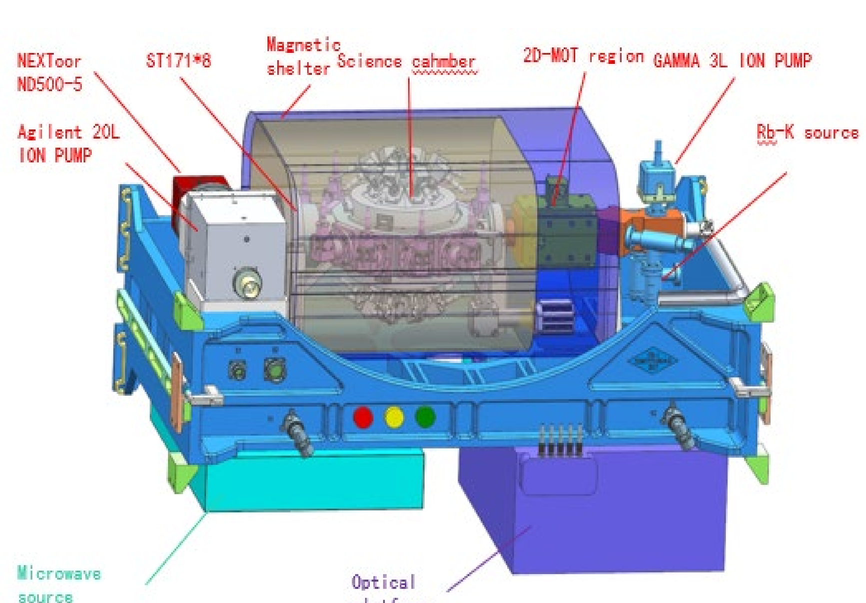
CAPR will be assembled in Science module II in Chinese Space Station which will be launched in 2022.



Link from CAPR in space and Ground control station



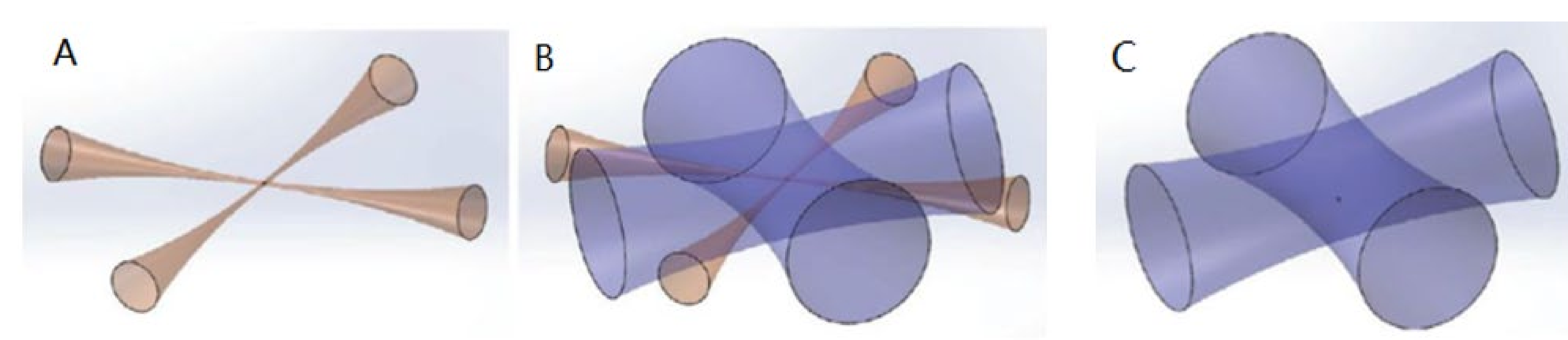
Five units in CAPR:（1）Physics module;（2） Laser and optics module;（3）Electronics module;（4）Remote control module; (5) Rack support module



Rb-K Quantum gas mixture system for experiments in space

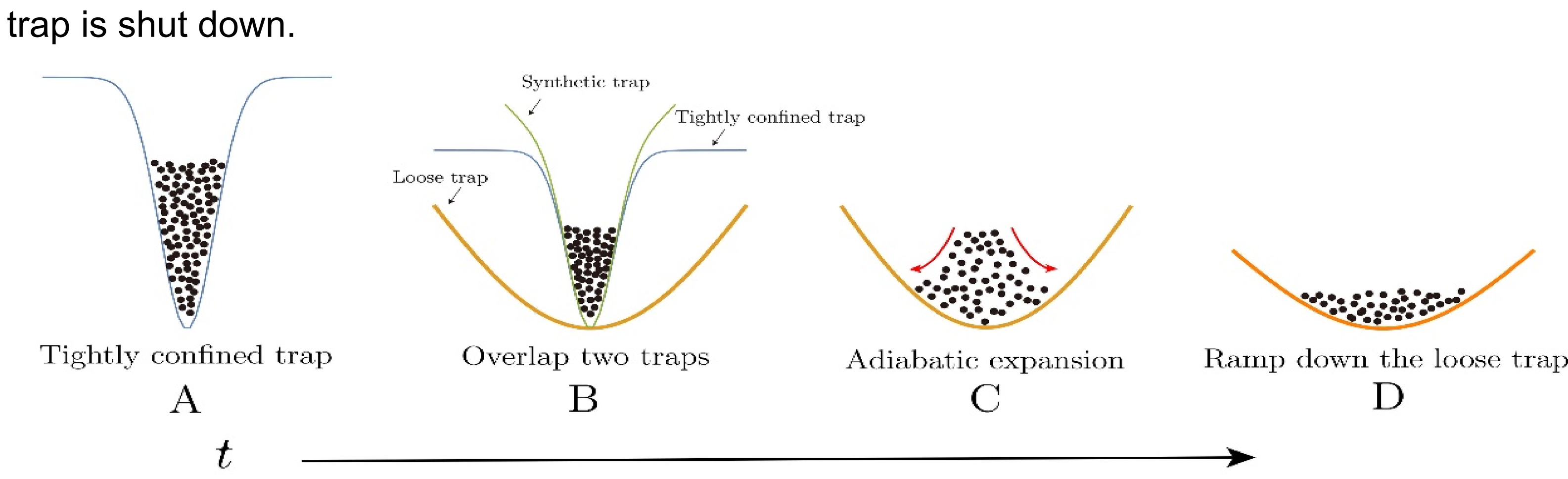
Cooling atoms to 100pK by an all-optical trap with the Two Stage Cooling (TSC) scheme

To reach temperatures in the picokelvin regime within an acceptable time, the CAPR (Cold Atom Physics Rack) system intended for the Chinese Space Station (expected to be launched in 2022) has adopted an all-optical trap with the Two Stage Cooling (TSC) scheme， which was proposed by Peking University team [1,2] in 2013. In the first stage of this technique, two crossed laser beams with a narrow waist and high power are used to form an optical trap for runaway evaporation cooling. Then, in the second stage, atoms with low enough temperatures are loaded into the optical trap formed by a crossed laser beam with a wide beam diameter and weak power to conduct controllable decompression cooling to finally reach a temperature below 100 pK.



(a)

Proposed set-up of the multi-beam dipole trap and the two-stage approach to picokelvin temperatures in microgravity. The dark dots represent the atomic ensembles. (a) A: Evaporative cooling in a very narrow crossed-beam dipole trap for 5 s. B: Overlapping the thin trap with a wider and weaker one. C: Decompression in the combined trap for 10 s. In the end, the narrow trap is shut down.

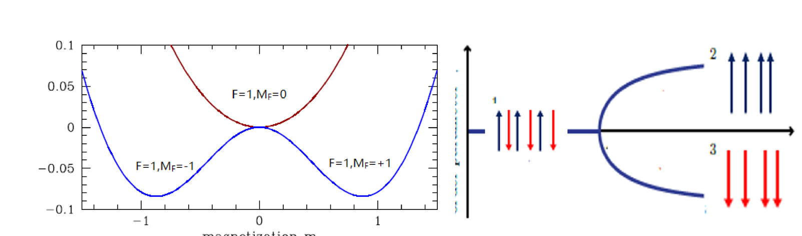


(b)

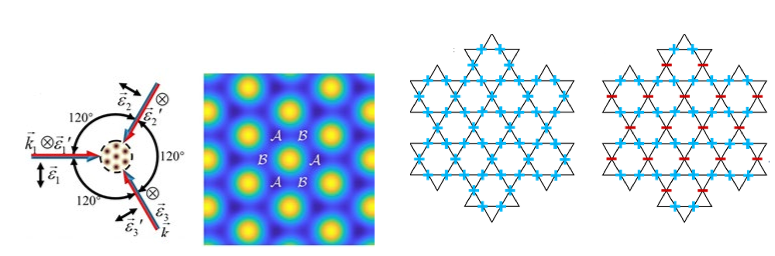
(b) Corresponding trap potential relating (a), A: tightly confined trap potential from beginning of trap loading atoms corresponding (a)-A, B: the trap potential for two traps overlapped, corresponding to (a)-B, C: The atoms expand in the second trap potential, corresponding to (a)-C, D: the atoms adiabatically expand in the low trap potential, corresponding to (a)-C.

Four experiments in Rack (CAPR) for the first period

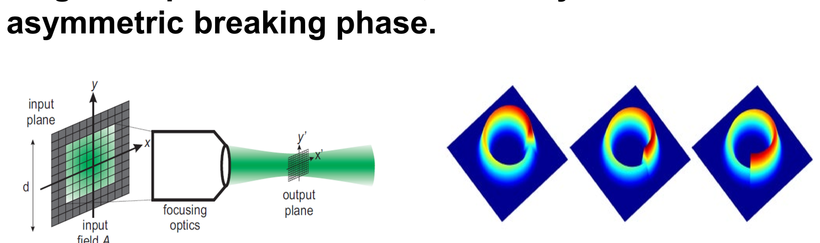
In the first three years, four fundamental physics experiments based on quantum gas will be implemented in the Chinese space station: (1) Quantum Magnetism, (2) Exotic material; (3) Acoustic black hole; (4) Effimov effect. The four experiments will be implemented based on 100pK ultra low temperature.



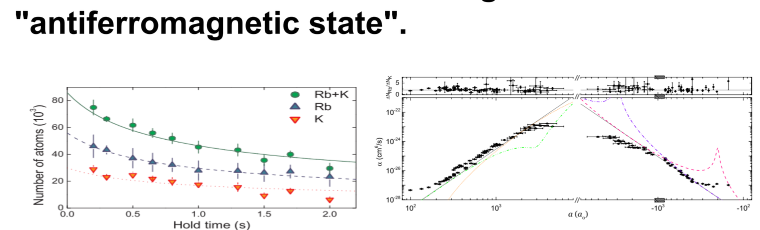
(1) Quantum Magnetism experiment is aim to build up mange In the experiment, rubidium atoms are prepared in paramagnetic state, and then ferromagnetic state is realized by adding transverse sudden change magnetic field. This is a quantum magnetic phase transition, from symmetric state to asymmetric breaking phase.



(2)) Exotic material experiment is to construct the magnetic model of Kagome lattice by using the honeycomb optical lattice with staggered well depth. In the magnetic model, the atomic density dipole is used to simulate the spin, so as to realize the phase transition from "ferromagnetic state" to "antiferromagnetic state".



(3) Acoustic black hole experiment is to build an BEC acoustic black hole. The quasi-static Hawking radiation of BEC acoustic black hole will be observed by using ring quantum fluid.



(4) Efimov effect experiment is to build Bose Fermi mixture. In this experiment, the Efimov resonance spectrum of rubidium potassium mixture (especially 87rb-40k mixture) will be observed.

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