Towards the implementation of the strontium lattice clock design

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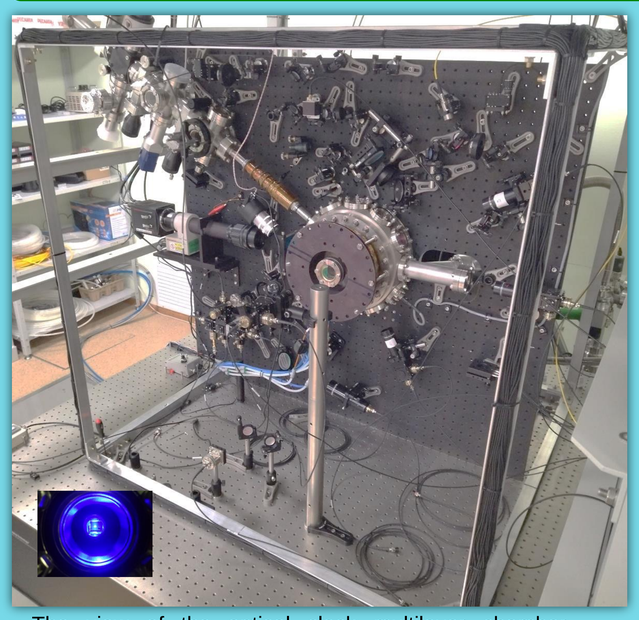
Introduction

1. We have built strontium lattice clock systems with cryogenic chamber: the design of the new vacuum system is multilayer chamber with main chamber, heat shield and internal cryogenic chamber

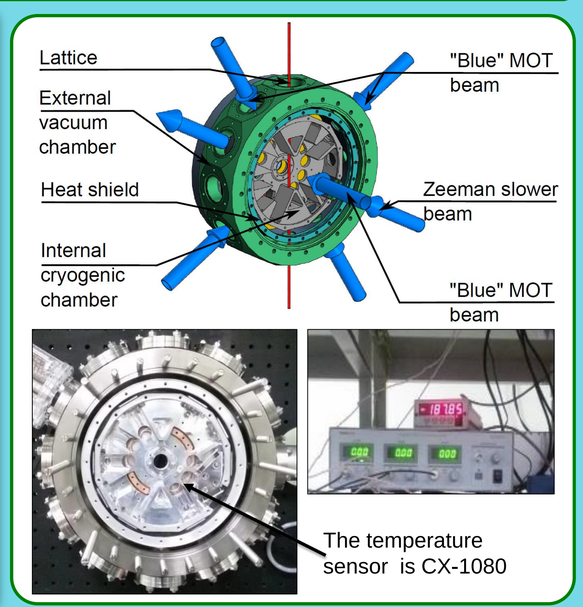
2. We have built multichannel laser systems with interference filter as separator of the wavelengths. The first beatnotes of the appropriate channels in multichannel systems: «clock» and secondary cooling were obtained.

3. Thermal narrow atomic sources (ovens) had have built also. The narrow beam divergence atomic oven for Sr and Yb optical clocks developed as import elements replacement program.

The internal chamber with cryogenic cooling



The view of the optical clock multilayer chamber. Special suspension of the AL-10 Cryomech cryogenic cooler (14W@80K) has been developed.



The chamber consists of external «big» chamber, thermal aluminum shield and cryo «internal» chamber. Min achieved temperature of the internal chamber is -187°C

The narrow-line multichannel optical stabilization system

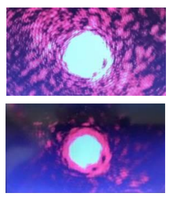
1.The two dual channel system have been built. The cavities of both systems have finesse F ≈ 60000

2.Reducing the weight and size characteristics of the frequency stabilization systems group

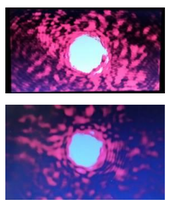
3. The simplifying of the tuning and the cost reducing of the stabilization systems by combining of the optical parts of the stabilization systems of the several laser sources

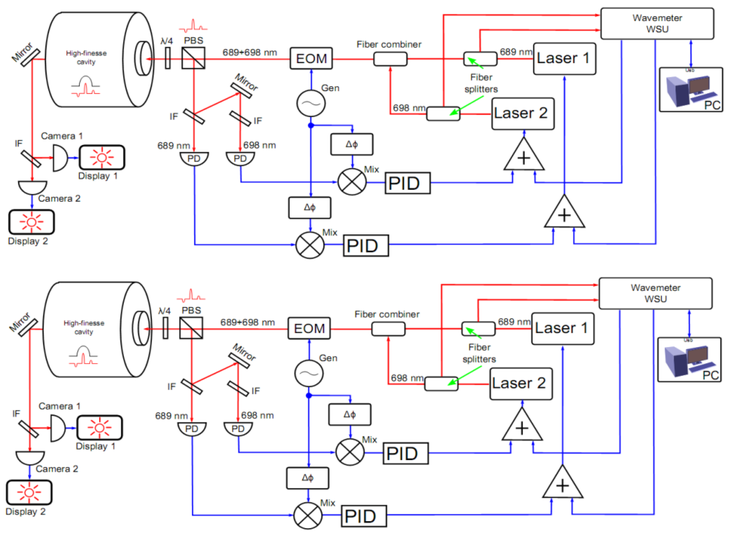
4. Evaluation of the systems by comparison with each other

Sr1 TEM00: 689, 698 nm

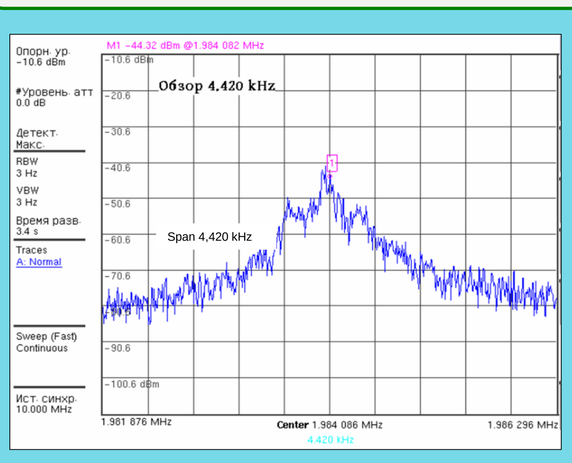


Sr2 TEM00: 689, 698 nm

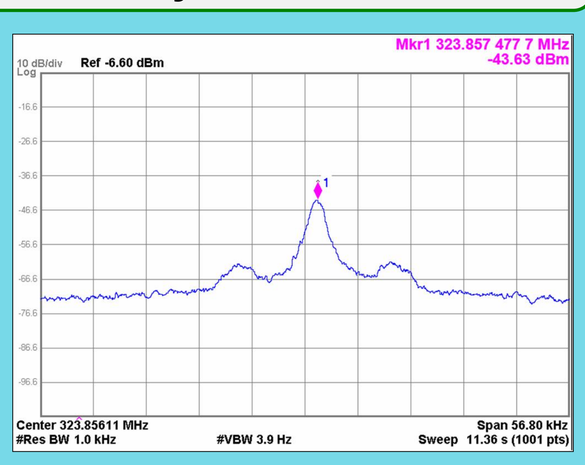




Evaluation of the systems by comparison of the clock channels of the each multi channel system



Beatnotes spectrum of two clock systems: horizontal (~47 cm) and small vertical (~10 cm) (span 4.4 kHz, 440 Hz per div.).



Beatnotes of the clock channels of the multichannel laser stabilization systems (span 56.8 kHz, 5,6 kHz per div.).

The narrow beam divergence atomic oven

Aims:

1.Reducing the weight and size characteristics of the atomic oven

2. The maintainability improving

3. Simplification of the manufacturing technology, elimination of “thin” spots of the previous developments

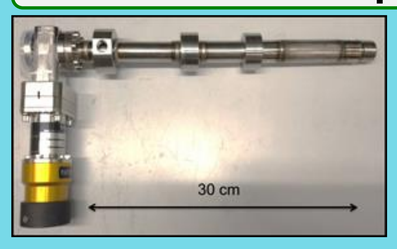
Solution: The principle of the universality (item 1) + the “matryoshka” principle (item 2, 3): (Altshuller G.S., 1973):

1. the object performs several different functions, eliminating the need for other objects

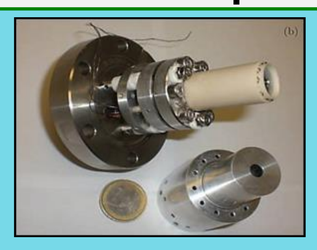
2. one object is placed inside another, which, in turn, is inside a third, etc.

3. one object passes through cavities in another object.

The atomic oven previous development



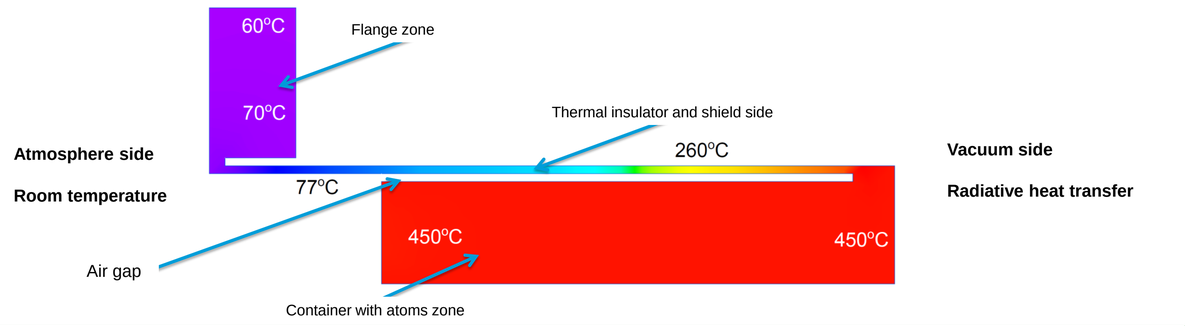
Type of the heater: replaceable
The heater position: outside of the vac. volume
Operating temperature: 400-600°C.
Power consumption: 110-130 W.
Max oper. temperature: up to 600°C.
The reparability: without devacuumization
Characteristic length: ~30 cm.
Flange: CF16



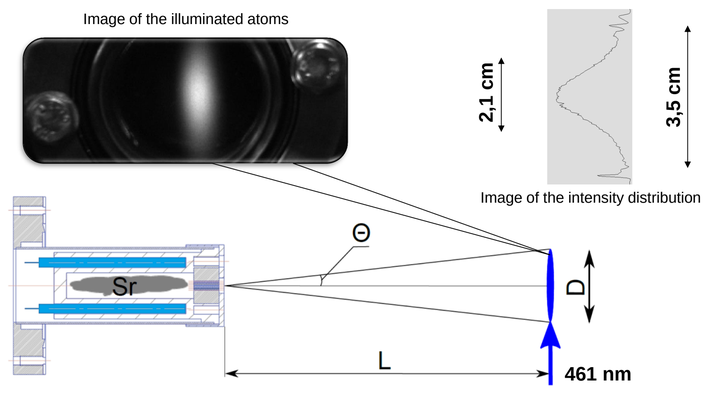
Type of the heater: replaceable
The heater position: inside of the vac. volume
Operating temperature: 430°C.
Power consumption: 25-30 W.
Max oper. temperature: up to 550°C.
The reparability: with devacuumization
Characteristic length: ~8 cm. [6]
Flange: CF35

Type of the heater: replaceable
The heater position: inside of the vac. volume
Operating temperature: 430°C.
Power consumption: 25-30 W.
Max oper. temperature: up to 600°C.
The reparability: without devacuumization
Characteristic length: ~8 cm.
Flange: CF35

Simulation of the temperature distribution

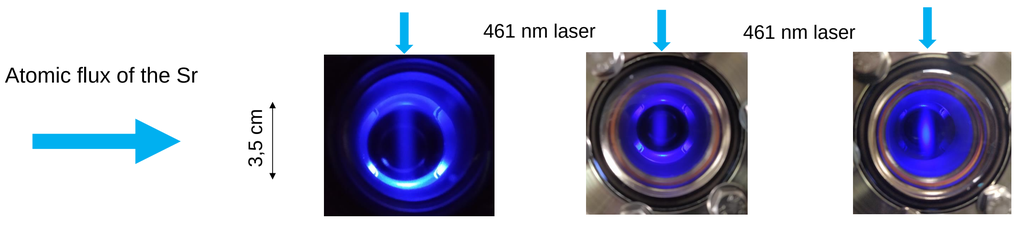


Investigation of the atomic oven beam divergence



$$\Theta = arctan\left(\frac{D}{2L}\right)$$

where
D – the size of the beam by factor of 1/e, cm,
L – distance from the edge of the atomic oven to coverage zone, cm,
Θ – the divergence angle by half maximum level.



View of the illuminated atoms->	Configuration №1	Configuration №2	Configuration №3
The distance from the edge of the atomic oven to observation zone, L, cm	160	50	33
Min diameter of the vacuum system/tube, D, cm	3,5	1,8	3,5
Divergence angle, α, deg	n/a	n/a	1,82

Conclusions

1. During of the strontium lattice clock experiments the multilayer chamber with thermal radiation shield and internal cryogenic temperature has been developed. The min temperatures which could be achieved below -187°C.
2. The multichannel laser stabilization system with high-finesse cavity was suggested and realized. The separation of the wavelength is realized with interference filter. The beatnotes of the two multi-channel systems have been implemented. The new type of the autorecovering of the systems with radiofrequency modulation feedback is suggested and realized.
3. The compacted source of strontium atoms, developed during a laser cooling experiment also. The elements of the implemented design are made of stainless steel, even thermal insulator. The design of the atomic source does not contain heating elements inside the vacuum system. The neediness for complete depressurization of the vacuum system during changing of the heating elements was eliminated. final divergence of the new atomic oven beam did not exceed 30-31 mrad.

References and publications

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[5] M. G. Gurov, Patent RU 2786601, 29.06.2022.
[6] M. Schioppo, N. Poli, M. Prevedelli et al., Rev. Sci. Instrum. 83, 103101 (2012).
[7] M. G. Gurov Patent RU 2786601, 29.06.2022.
[8] Patent US 2021/0345475 A1, Date of Patent: Nov. 4, 2021.
[9] Patent US 3,667,066, Date of Patent: May. 30, 1972.
[10] M. G. Gurov, Patent RU 2811394, 07.11.2023.

Thank you for watching