SMAC 2P—Towards a Flat Form Factor Miniature Atomic Clock

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CSEM's Swiss miniature atomic clock (SMAC) prototypes have successfully being assembled but suffer from excessive thermal losses. CSEM's engineers are thus working on improved thermal efficiency (thermal design and improved vacuum levels). In order to open the way to the integration of MACs in portable devices, CSEM is presenting the first building blocks of a MAC physics package with a height of less than 5 mm.

The design, the fabrication, the assembly and the preliminary vacuum encapsulation of CSEM's Swiss-MAC have been reported for the past years.

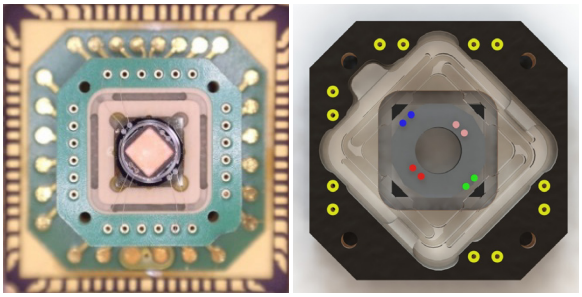

Figure 1: Physics package of the Swiss-MAC (right); Design of a thermally optimized atomic vapor cell holder (left) [less than 5 cm^3].

A full Swiss-MAC has been successfully assembled and encapsulated with which first Coherent Population Trapping (CPT) clock signals have been measured. Further physics packages are currently being assembled in order to continue the characterization process and to assess the assembly reliability. The initial Swiss-MAC prototype suffers from excessive thermal losses. Thereofore, CSEM is currently working on developing smart solutions for improved thermal efficiency, especially for the atomic vapor cell holder [1], as illustrated in Figure 1. In addition, decreasing the overall size of the Swiss-MAC, especially its height, is currently at the center of CSEM's development activities related to miniature atomic clocks. It has been shown that a height of less than 5 mm for the MAC physics package is requested in order to be integrated in portable devices like GNSS receivers, mobile phones, tablets or even watches.

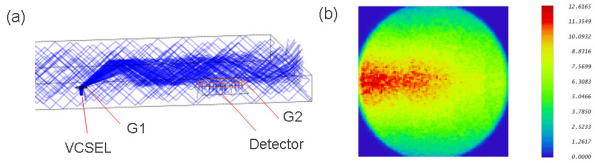

Figure 2: Optical simulations of CSEM's patent pending planar waveguide approach with gratings for a flat form factor MAC.

Such a flat packaging is made possible by planar arrangement of the individual components (cell, laser and detectors) next to each other's as opposed to stacking them. In this configuration, the optical connection is achieved via a planar multimode waveguide structure with gratings (G1 and G2) for input and output light coupling. Optical simulations (Figure 2), prototype manufacturing and first lab proof of principle showed to be very promising. This waveguide structure relies on a patent pending technology developed by CSEM.

This new physics package needs to provide means of integrating the waveguide approach as well as to provide smart assembly solutions, high flexibility in terms of electrical routing, low thermal conductivity and to be vacuum compatible. Low temperature co-fired ceramics (LTCC) showed to be the material of choice. Thanks to CSEM Brazil's LTCC production line in Belo Horizonte, preliminary manufacturing of LTCC cavities and holders was realized according to the flat form factor design developed for the SMAC. By means of an appropriate optimization of the manufacturing processes and by means of a methodical LTCC tapes selection, the LTCC team confirmed the feasibility of the atomic clock physics package in ceramics.

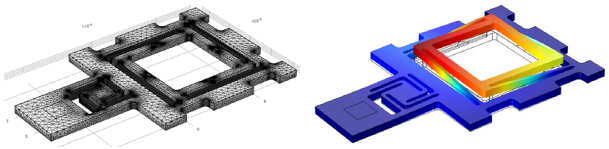

Figure 3: Mechanical simulations of the LTCC based atomic clock.

The detailed design of the LTCC based flat form factor SMAC has thus been engineered. Mechanical simulations (Figure 3) showed to be compliant with the request of a height of less than 5 mm, still providing enough stiffness.

The first LTCC fabrication batches were recently finalized as illustrated in Figure 4. Their characterization is ongoing and first assembly tests are expected in a near future.

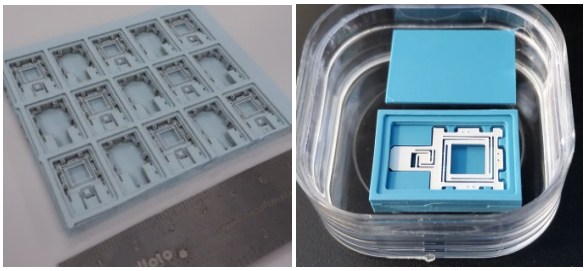

Figure 4: LTCC batch fabrication of the main LTCC physics package building blocks (cavity, holder and cap).

Thanks to the development presented in this paper and to very promising results for extended life-time atomic vapor cells at CSEM, the full prototype of a flat form factor SMAC is expected in the coming two years. Parallel and complementary developments for a ceramic based SMAC prototype are being conducted in collaboration with the European Space Agency (ESA) and VTT in Finland.

CSEM would like to thank the Swiss Confederation, the Canton of Neuchâtel, the Canton of Basel-Landschaft and the Cantons of Central Switzerland for their financial support as well as CSEM Brazil for the collaboration.

[1] L. Zulliger, “Thermal and Structural Optimization in a Miniature Atomic Clock”, Projet de Master, EPFL-CSEM, 2015