SMAC – Miniature Atomic Clock, Route to further Miniaturization

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The first prototype of the Swiss Miniature Atomic Clock (Swiss–MAC) was presented by CSEM in 2012. This paper describes the improvements made on the prototype development during 2013 and presents some of CSEM concepts opening the way to further miniaturize the atomic clock for real handheld devices applications.

The field of compact atomic clocks started a scientific and technological revolution with the year 2000: atomic clock technology based on MEMS components manufacturing now shows the promise of having miniature (< 1 cm^3) and low-power (< 100 mW) atomic clocks (MACs). The Swiss–MAC was designed to target such state of the art specifications.

Departing from the detailed design presented in 2011, the Swiss–MAC has stepwise been manufactured and assembled in 2012 and 2013. The current prototype (shown in Figure 1) integrates most of the desired functionalities [1], except the vacuum encapsulation of the physics package and the integrated temperature regulation of the atomic vapor cell.

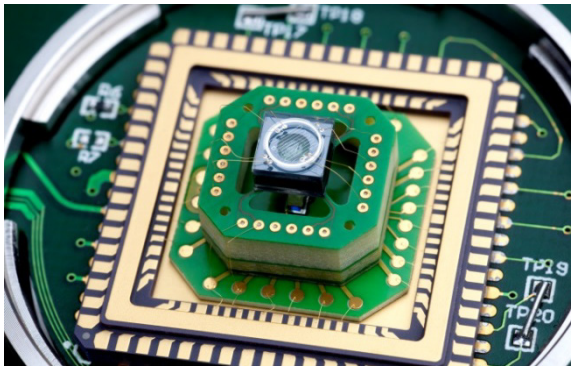

Figure 1: The Swiss Miniature Atomic Clock (Swiss–MAC) physics package with stacked PCB layers in a commercial ceramic package.

The core physics package, as designed and presented in 2012, is realized by a stacking of standard functionalized PCB layers. It has a dimension of 11 x 11 x 8.5 mm^3, including the functionalized atomic vapor cell with a dimension of 26 mm^3. The cell, fabricated at wafer level (Figure 2), can be wirebonded (Figure 3) or surrounded by a flex circuit for electrical connection (heater, Tsensor and C-coils).

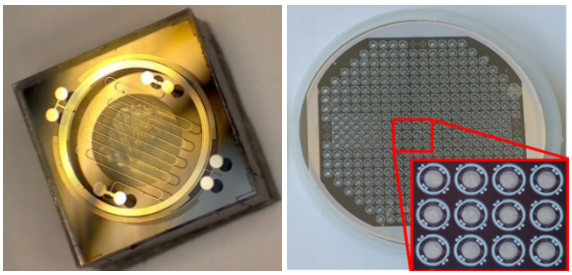

Figure 2: Functionalized 4 x 4 x 1.6 mm^3 atomic MEMS cell after dicing (left) and 4 inch wafer of approximately 280 cells (right).

The Swiss–MAC prototype is controlled by means of a LabVIEW® interface communicating with an MSP430 microcontroller. The latter drives the 3rd generation of a dedicated proprietary and unique ASIC, with built-in RF lock loop and laser lock loop [2], and with integrated laser bias current source, three temperature sensors, and additional current sources (laser + cell heating currents and magnetic field current).

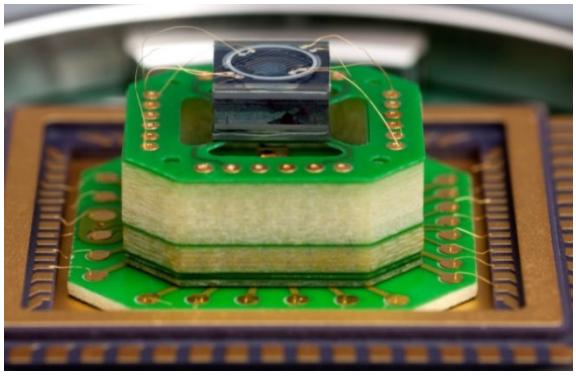

Figure 3: Picture of the physics package with stacked PCB layers and wire bonded functionalized atomic vapor cell.

The Swiss–MAC prototype is currently in its integration and final test phase. The main lock loops could already be closed and preliminary performances show frequency stability very close to the required telecom specifications. The complete prototype is to be fully characterized by the end of 2013.

CSEM engineers are working on ways for further miniaturization of the Swiss–MAC prototype with the goal of showing its potential for integration in future portable devices and also in future wristwatches. The main challenges to be faced are related to the thickness of the physics package and to the power consumption of the prototype. Building blocks of the conceptual design are illustrated in Figure 4. First components are to be fabricated and tested in 2013 in order to start the realization of such a prototype in the following years.

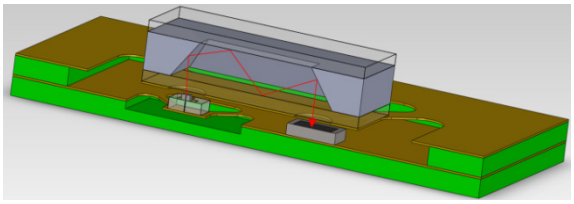

Figure 4: Conceptual design of a miniature atomic clock showing the feasibility of a very thin physics package for handheld applications.

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[1] J. Haesler, *et al.*, "The integrated Swiss Miniature Atomic Clock", Joint UFFC, EFTF and PFM Symposium, Prague, July 2013

[2] J. Haesler, *et al.*, "Driving an extra small atomic resonator with low-power integrated RF frequency and laser locked loops", IFCS-EFTF, San Francisco (USA), May 2011