SMAC3P–Assembly and Functional Tests of a Flat Form Factor Miniature Atomic Clock

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The preliminary building blocks of a miniature atomic clock (MAC) physics package (PP) with a height of less than 5 mm were presented in the past years. CSEM presents in this paper the manufacturing and functional testing of the main MAC constituents.

It has been shown previously that a height of less than 5 mm for the physics package is requested in order to integrate a MAC in portable devices. Such a flat packaging is made possible by a planar arrangement of the individual components (cell, laser, and detector) with an optical connection by a planar multimode waveguide (patent pending).

The atomic vapor cell (Figure 1) is the core component of the MAC. Loading it with rubidium is obtained by a proprietary process based on RbN_3 solution dispensing and UV-decomposition. The cell lifetime and intrinsic frequency drift could be drastically improved thanks to protective coatings.

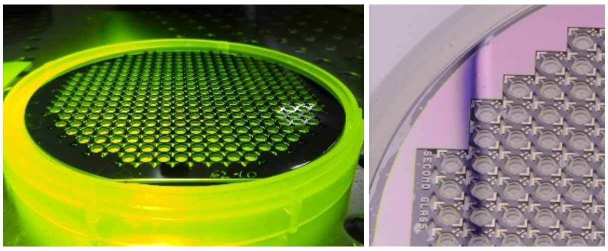

Figure 1: Wafer of 332 cavities (left) and functionalized cells (right).

Light coupling from the laser to the atomic cell and to the photodetector is realized by a planar waveguide (11 × 14 mm) with three in- and out-coupling diffraction gratings (Figure 2). The fabrication process has been optimized in order to fulfill the requested yield and overall light transmission efficiency.

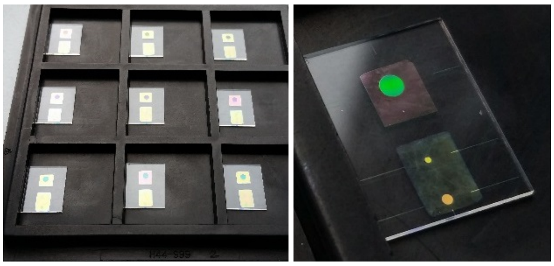

Figure 2: Planar waveguides with three diffractive gratings each.

The different MAC components are packaged thanks to low temperature co-fired ceramics (LTCC) fabricated at CSEM Brazil, offering smart assembly solutions, 3D electrical routing, low thermal conductivity and vacuum compatibility. The LTCC cavity is obtained by co-firing more than 20 LTCC tapes with a final top waviness lower than 20 µm (Figure 3).

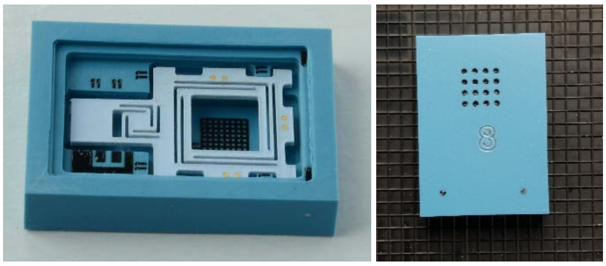

Figure 3: (Left) LTCC cavity (blue) and thermal holder (white); (right) Bottom of LTCC cavity with ball grid array (BGA) pads.

Vacuum encapsulation of the physics package remains one of the biggest challenges to be solved for the MAC to meet the low-power (minimal thermal losses) requirements. Different sealing approaches have been evaluated and preliminary vacuum encapsulation tests are ongoing (Figure 4).

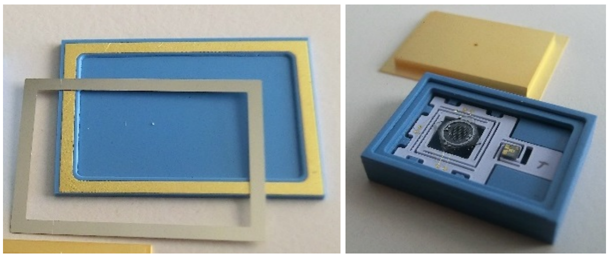

Figure 4: Sealing test samples (left); LTCC cavity and cap (right).

Driving the atomic clock is realized by a newly designed ASIC (Figure 5), offering highly improved frequency lock-in and temperature sensing capabilities, which are currently being tested and validated with representative MAC prototypes.

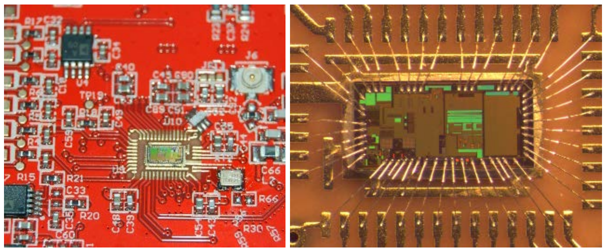

Figure 5: Test PCB (left) and ASIC micrograph (right).

Functional testing of the MAC will be made on a test PCB platform equipped with a dedicated MAC PP socket (Figure 6). Driving the PCB and the ASIC is realized by a micro-controller with a LabVIEW® interface.

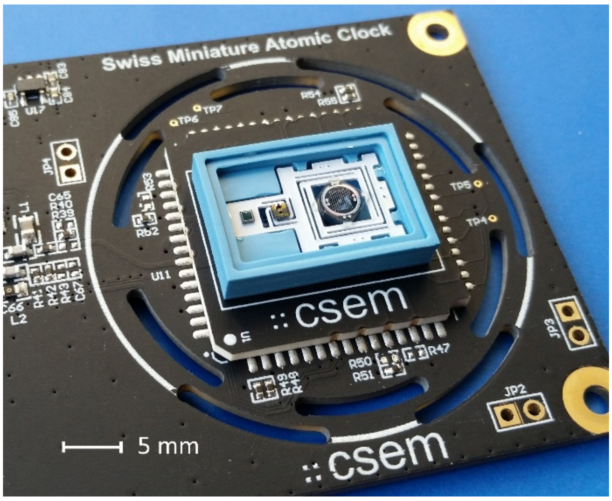

Figure 6: Test PCB platform with a dedicated socket for the MAC PP.

Parallel and complementary developments for a ceramic based MAC prototype are being conducted in collaboration with the European Space Agency (ESA) and VTT in Finland.