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Deliverable 5.5

Multipixel FPA demonstrator composed of miniaturized 2SB receivers operating near 1mm

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Dissemination Level

Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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COVID-19 affects the Deliverable D5.5, to which the Art.51 applies as follows:

An FPA demonstrator operating near 1mm wavelength with 7 tightly packed sky pixels and composed of wide-band low-noise 2SB SIS mixers has been developed. The cryostat and the cold optics have been built and all necessary commercial components have been purchased. Because of the COVID-19 pandemic the fabrication of the cryostat was delayed by 6 months. System integration just started in December 2019 and only first vacuum and cooling tests could be carried out. Work will continue in 2021 in order to achieve a fully functional 7-pixels prototype receiver. Tests at the IRAM 30 m telescope are scheduled for end of 2021. A report describing the system design and fabrication as well as integration and very first system tests is delivered.

1 Executive Summary

A tightly packed reception module of 7 pixels operating near 1 mm wavelength and composed of wide-band low-noise 2SB SIS mixers has been developed within AETHER. The goal within AETHRA was the development, fabrication, and testing of a focal plane array receiver demonstrator based on this reception module as well as its employment at IRAM's 30 m telescope.

The work focused mainly on the design of the cryostat for the 7-pixels receiver demonstrator. The receiver employs a closed-cycle cryogenic system with three stages at respectively 77 K, 15 K, and 4 K. An internal cold load located on the 15 K stage is used for the calibration of the receiver. The signal and calibration windows are integrated into the cover of the cryostat whereas all other interfaces are disposed on its base plate. The mechanical drawings of the cryostat have been prepared and the cryostat has been fabricated.

In order to achieve a good coupling of the receiver to the telescope the designed optics consists of two parts: warm optics in front of the cryostat common to all pixels and individual cold optics maximizing the coupling to each feedhorn. The cold optics consists of rows of double-faced mirrors and has been integrated together with the 7-pixels mixer-amplifier assembly and support structures into a 4 K module which has been fabricated. The warm optics consists of focusing and plane mirrors which are arranged on a plate in front of the cryostat. A rotating mirror in front of the signal input window of the cryostat allows switching between signal and calibration paths.

For the output of the IF signals from the cold amplifiers to the base plate custom-made stainless steel semi-rigid coaxial cables have been purchased. The LO signal is transmitted from the input on the base plate to the reception module by a custom-made gold plated stainless steel waveguide. Multiple temperature sensors and associated control devices for controlling the temperatures of the cold head as well as the temperature stages of the cryostat have been acquired. Finally, all wiring of the cryostat has been prepared.

For the warm IF chains an integrated approach has been investigated. For this purpose different components have been ordered and evaluated. Finally, a prototype warm IF chain has been fabricated and tested.

After delivery of the cryostat it has been assembled and first vacuum and cooling tests have been carried out.

2 Focal plane array receiver demonstrator

2.1 Cryostat

A cryostat for the 7-pixels receiver demonstrator has been designed and fabricated. The cryostat features three temperature stages at respectively 77 K, 15 K, and 4 K, each connected to the respective stage of a closed-cycle cryogenic system by flexible copper straps. The stages are stacked successively with decreasing temperature on the base plate at 300 K using thermal insulating epoxy spacers. All vacuum feedthroughs for the LO input, the IF outputs, and different connectors for the

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receiver control are disposed on the base plate forming the interface to the outside. Two windows are integrated into the cover of the cryostat. The first passes the beam to the reception part of the receiver mounted on the uppermost 4 K stage and the other serves for directing the beam to the internal calibration load located on the cover of the 15 K stage.

All mechanical drawings of the cryostat have been prepared by IRAM's design office and the cryostat has been fabricated by SATIL, Chambery.

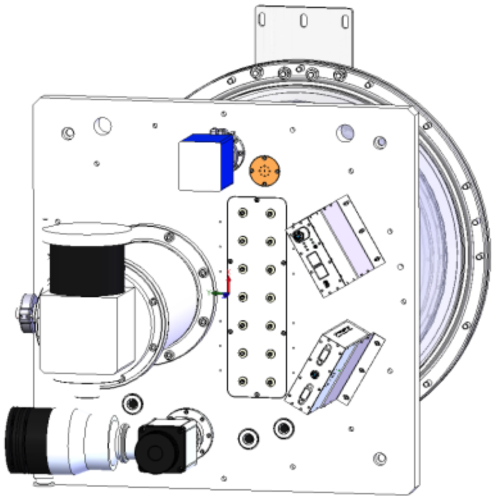

Fig. 2.1-1: Cryostat of the 7-pixels prototype with three temperature stages at 4 K, 15 K, and 77 K, respectively (left) and its base plate with all interfaces (right).

2.2 4 K module

The 4 K module forms the reception part of the receiver and is disposed on the 4 K stage. It consists of the 7-pixels mixer-amplifier assembly with LO distribution coupler developed and fabricated within AETHER as well as individual reflective optics, and support structures.

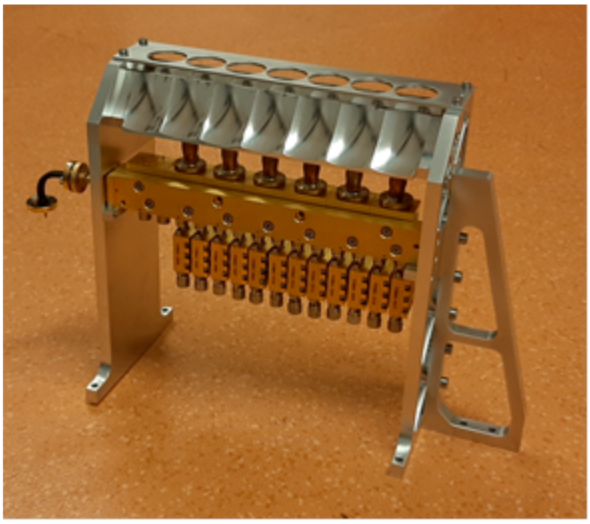

Fig. 2.2-1: 4 K module.

Individual reflective optics has been designed in order to maximize the beam coupling by reimaging the telescope aperture onto the feedhorn apertures. It consists of an array of double-faced mirrors each exhibiting a flat surface on one side and a parabola on its other side. This individual optics is suitable for larger focal plane arrays by stacking the rows of mirrors on top of each other. In this case, one face of the double-faced mirror serves for one row of pixels, and its other face reflects the beam of a neighbouring row of pixels. The chosen feed horn spacing of 25 mm results in an angular beam spacing on the sky of approximately 23 arc seconds, corresponding to ~2 HPBW (Half Power Beam Width). This value is a good compromise in order to achieve a closely packed RF module but also keep enough space between pixels to be able to insert individual optics. In order to improve the circularity of the beam shapes a row of circular apertures has been added to the individual optics.

The individual optics and support structures of the 4 K module have been fabricated by IRAM's workshop and the module has been assembled.

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2.3 Warm optics and calibration

The design of the warm optics consisting of a pair of focusing mirrors and plane mirrors has been completed. All mirrors are arranged on a plate in front of the cryostat at room temperature. The pair of focusing mirrors forms a Gaussian beam telescope thus ensuring a frequency independent coupling to the telescope. A rotating plane mirror in front of the signal input window of the cryostat allows switching between signal and calibration paths. It is mounted on a rotary table so that it can be set to three different positions. In the first position the receiver beam is coupled to the telescope, in the second position the beam is coupled to the internal cold load, and in the third position a load at ambient temperature is presented in front of the window.

2.4 Chassis

A chassis based on Bosch profiles has been designed. The chassis serves as support structure for the cryostat both for lab tests and the installation at the telescope. Besides the cryostat, it receives the plate with the warm optics and houses all electronics modules.

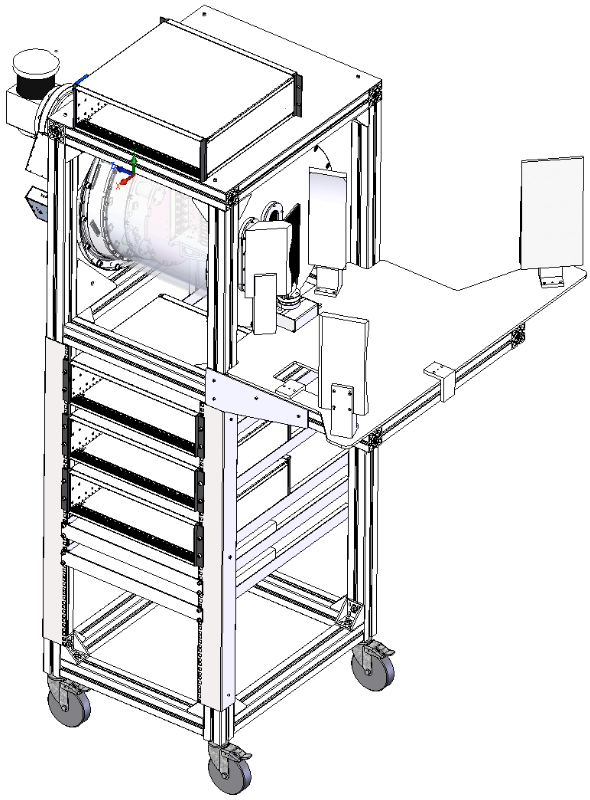

Fig. 2.4-1: Chassis with receiver and warm optics.

2.5 Warm IF chain

Conventional warm IF chains are based on connectorized components and thus are relatively big. Because of the high number of IF outputs and the limited space at the base plate of the receiver an integrated approach has been investigated. Different components have been ordered and evaluated.

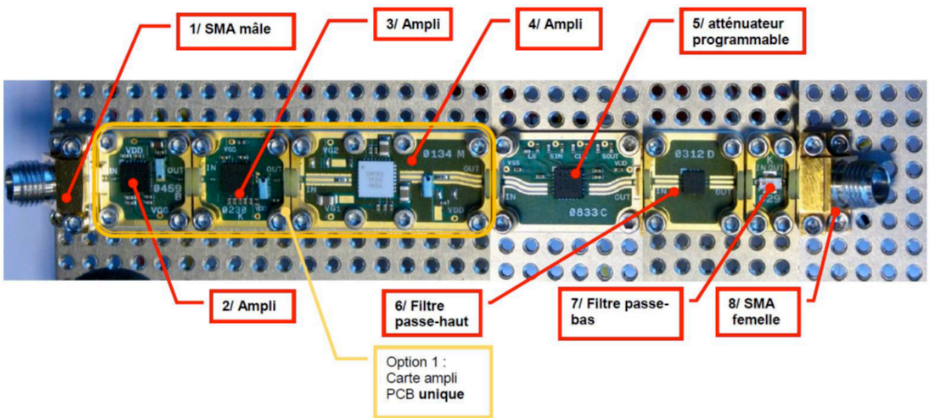

Fig. 2.5-1: Prototype of warm IF chain.

Finally, a prototype integrated warm IF chain based on Xmicrowave components has been developed and tested. For the 4-12 GHz IF band the achieved gain was around 45 dB and noise temperatures

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between 270 and 400 K could be measured. Since tests at the telescope have to be carried out with a limited IF band due to the lack of suitable backends and IF transport scheme, the warm IF chains of the EMIR instrument will be used. During lab tests the complete IF band will be characterized by employing existing warm IF chains with integrated YIG filters for sweeping through the IF band. Nevertheless, the possibility of integrated warm IF chains will be further investigated for future multipixel receivers.

2.6 RF test bench

In order to be able to characterize the receiver with respect to its noise and image rejection performances, a dedicated rf test bench has been designed and assembled. Various software routines using python and C++ have been developed to control the receiver itself as well as the different components of the test bench.

2.7 Integration and tests

The cryostat has been delivered end of November. In a first step it has been assembled, in order to verify if all parts fit together. After this test proved successful, vacuum tests have been carried out with different levels of integration. First all apertures were covered by suitable caps. In a second step all caps have been replaced by the final components: windows, waveguide and SMA feedthroughs for the LO input and the IF outputs, respectively, and different connectors. After a few leakage tests and corrective actions, a pressure around 10^{-6} mbar could be reached. So system integration could start. The 4 K module was disposed on the 4 K plate. Custom-made stainless steel semi-rigid cables for the IF outputs and a custom-made stainless-steel gold-plated waveguide for the LO input were installed. Temperature sensors were mounted on the different cold stages and the wiring of all components was placed. Finally, the various components were connected to the three cold stages by thermal shunts consisting of flexible copper straps. First cooling tests showed that a temperature around 5 K could be reached for the components on the 4 K stage. These tests have been performed without powering the receiver components, so that under real conditions a higher temperature is to be expected. Since this would prevent the mixers from working correctly, the cooling scheme of the cryostat has to be improved by adding more thermal shunts or even changing the cold head to one with more cooling power. Integration and testing of the receiver will continue during 2021 and a test at the 30 m telescope is planned for the end of the year.

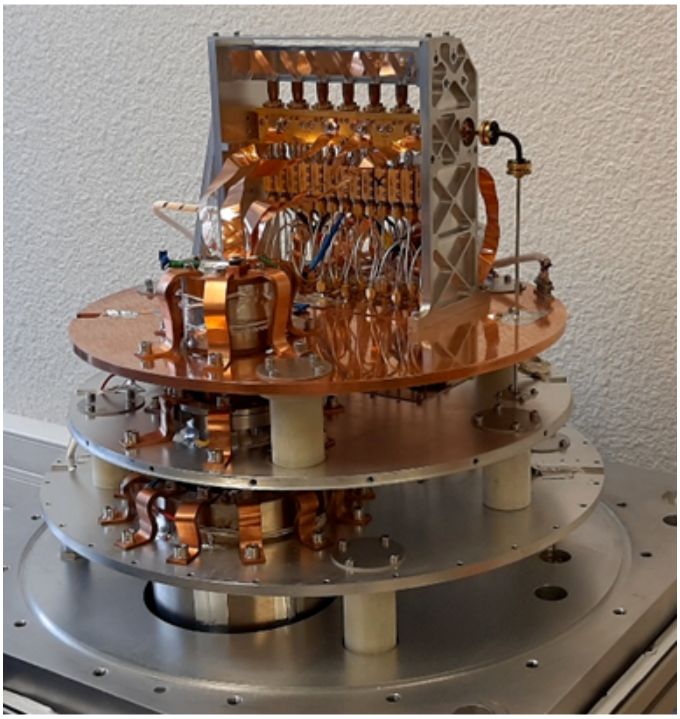

Fig. 2.7-1: Integration of the cryostat of the 7-pixels prototype receiver.

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