Development of a 71-116GHz RF module for the EMIR receiver upgrade

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Abstract— **The Eight MIxers Receiver (EMIR) was installed at IRAM 30-m Pico Veleta Telescope (Andalusia, Spain) in 2009. It is composed of four cryogenic dual polarization side band separating SIS receiver modules covering frequencies from 71 GHz to 365 GHz (and delivering 4-12 GHz IF channels). Outside the EMIR cryostat, some switchable dichroic filters can be inserted in the optical path to allow dual band observations of the same point of the sky.**

In December 2015, the 3 mm band, which covered initially 84-116 GHz, was upgraded to cover the full 3mm atmospheric transmission window which can be observed at Pico Veleta, i.e. the 71-116 GHz band. Excellent performances are obtained with this new 3mm receiver, which covers ~ 50% of bandwidth with noise temperature of almost 30 K in the full band. This work also demonstrates the possibility of covering two ALMA bands simultaneously (ALMA band 2 + band 3 ~ 68-116 GHz) with a single receiver.

INTRODUCTION

The Eight MIxersReceiver (EMIR) has been installed at IRAM 30-m Pico Veleta Telescope in 2009. It has been initially developed to make single band and dual band observations for frequencies covering from ~84GHz to 365GHz. Since it installation, several upgrades have been performed on this receiver to improve it performances. The later one, which has been made at the end of 2015, has consisted in enlarging the frequency coverage of EMIR in the 3mm atmospheric window (shown in Fig. 1), by replacing the 84-116 GHz RF and optical module by a new one allowing to cover the 71-116 GHz band.

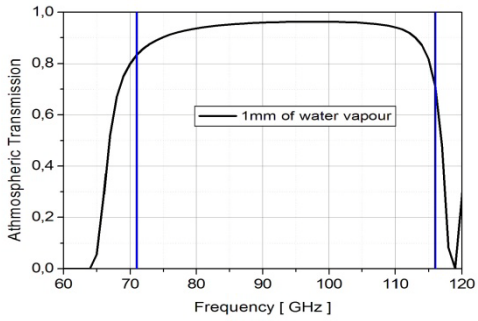

Fig.1: Transmission of the atmosphere in the 3mm band.

EMIR RECEIVER SPECIFICATIONS

The EMIR [1] receiver (see Fig. 2)is composed of four cryogenic dual polarization SIS modules covering the 3mm band, the 2mm band, the 1.3mm band and the 0.8mm band. The specifications of the different modules are the following:

-Band 1 (3 mm): 71-116 GHz (since dec-2015; 84-116 GHz before)
-Band 2 (2 mm): 127-179 GHz
-Band 3 (1.3 mm): 200-276 GHz
-Band 4 (0.8 mm): 276-365 GHz
-Technology: side band separating SIS receivers, delivering 4 x 4-12 GHz IF channels per receiver module

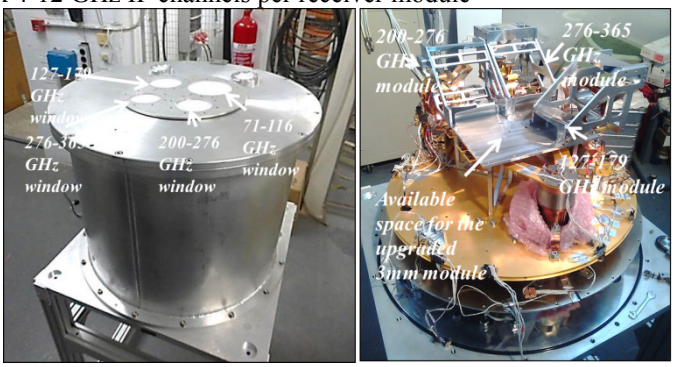

Fig.2: External (left) and internal (right) views of the EMIR receiver cryostat.

At room temperature, a set of three dichroic filters, provided by QMC [2], are mounted on a translating frame in front of the cryostat windows. These filterscan be inserted in the optical path to allow simultaneous observations of the same point of the skywith two different frequency bands. The available band combinations are:

- Band 1 (3 mm) + band 2 (2 mm)
- Band 1 (3 mm) + band 3 (1.3 mm)
- Band 2 (2 mm) + band 4 (0.8 mm)

OPTICAL MODULE DESIGN

The EMIR upgraded optical module is presented in Fig 3. It is composed of a pair of focusing mirrors (an elliptical mirror plus a parabolic mirror) which ensure a proper frequency independent illumination of the sub-reflector. Inside the cryostat, those mirrors are cooled at 15 K. Some epoxy supports allow to thermally disconnect those mirrors form the

other parts of the module (SIS mixers, feed horn, Ortho Mode Transducer, cryogenic IF isolators and low noise amplifiers …) which operate at 4 K.

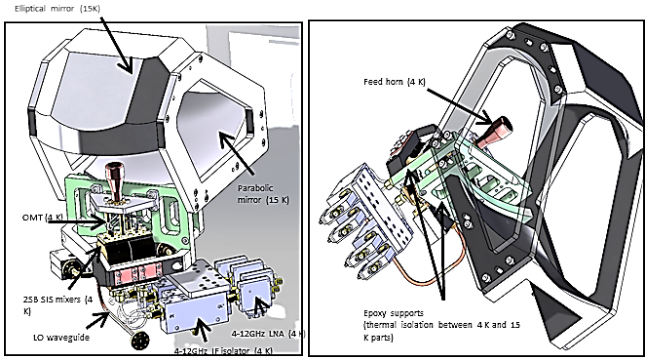

Fig 3: Mechanical 3D drawings of the 71-116GHz optics + RF module.

RF MODULE DESIGN

The upgraded 3mm RF module is composed of:

- a corrugated feed horn with circular waveguide output coupled to an Ortho Mode Transducer (OMT) which diplexes the two linear orthogonal polarizations of the receiver;
- two side band separating SIS mixers [3] with integrated IF couplers delivering four 4-12 GHz IF channels;
- A local oscillator waveguide splitter that distributes the LO power to the two polarizations;
- 4 cryogenic isolators and 4 cryogenic low noise amplifiers connected to the SIS mixers outputs

Some pictures of the assembled RF module are presented in Fig. 4.

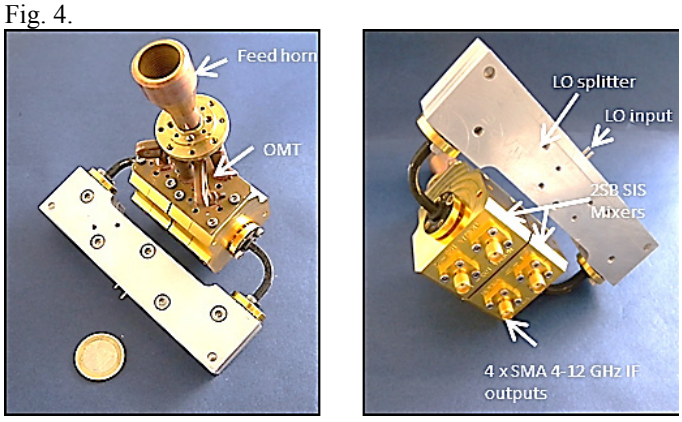

Fig.4: Views of the assembled 71-116GHz RF module.

INSTALLATION AT 30-M TELESCOPE, AND TESTS

Before it installation at the IRAM 30-m, the 71-116 GHz module has been first tested into a dedicated test cryostat. The integrated (in the 4-12GHz IF band) noise temperatures, the noise temperatures in the IF band and the image band rejection of the module have been characterized.Fig.5 shows the excellent noise performances reached by this module (~30K of noise temperature in the full 71-116GHz band)

The optical performances (co and cross-polarization patterns, co-alignment on the sky between the two polarizations) have also been measured.

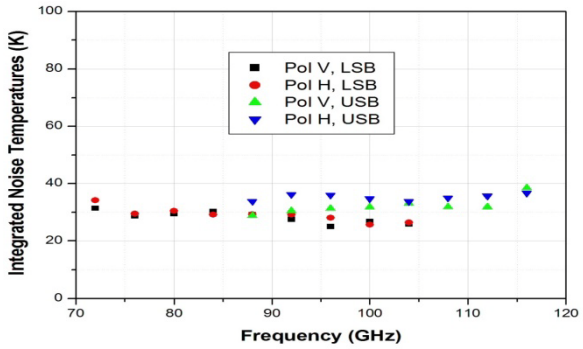

Fig.5: Integrated noise temperatures of the 71-116GHz RF module (including the OMT).

After these laboratory tests, the "old" 84-116GHz module has been replaced by this new module at the IRAM 30-m, into the EMIR cryostat. A picture of the 71-116 GHz module once installed into the receiver is presented Fig. 6.

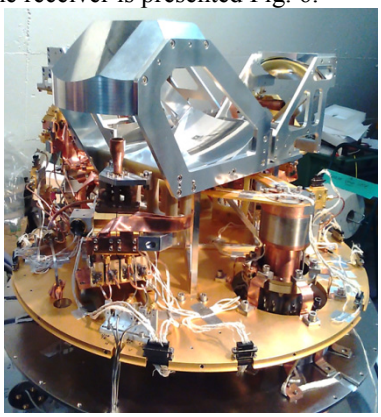

Fig.6 : Integration of the 3mmupgraded module into the EMIR receiver.

CONCLUSIONS

The 71-116GHz EMIR module was successfullyinstalled at Pico Veleta in December 2015. State of the art performances are obtained in the whole very wide frequency range (~ 50% of bandwidth) of this receiver, which demonstrates the possibility of covering two ALMA bands in the same time (ALMA band 2 + band 3) with a single receiver. This new EMIR 3mm module is now widely used by astronomers: in particular, the astronomical observations which are made in the new part of the band covered (71-84GHz) represent now ~ 10% of the observing time at Pico Veleta.

ACKNOWLEDGMENT

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REFERENCES

[1] M. Carter, B. Lazareff et al., "The EMIR Multi-band mm-Wave Receiver for the IRAM 30m Telescope", Astronomy &Astrophysics, vol. 538, pp. 13, 2012

[2] QMC Instruments

[3] D. Maier et al., "Fully integrated sideband-separating SIS mixers for the NOEMA receivers"in Proc. 25thISSTT, Moscow, Russia, 2014