A cryogenic solid state LO source at 1.9THz

Nicolas Reyes[1], Rolf Güsten[2], Urs Graf [3], Christophe Risacher [2], Oliver Ricken[2]
[1]*Universidad de Chile, Santiago, Chile*
[2]*Max Planck Institut für Radioastronomie, 53121, Bonn, Germany*
[3]*Universität zu Köln, 50923, Köln, Germany*
*Contact: nireyes@uchile.cl

Abstract— The Low Frequency Array instrument at SOFIA is a heterodyne array designed to observe in the complete range between 1.9 and 2.5 THz. It is a 14 pixel instrument, working in a dual polarization configuration. To provide enough LO power for the 14 HEB mixers a cryogenic solid state LO source is used. It consists of two identical set of millimeter wave amplification and multiplication chains, one per polarization. The frequency coverage is limited to 1.830 to 2.070 GHz, centered on one of the main scientific target of the instrument, the CII at 158mm. We present an overview of the design of this LO source and present the experimental results obtained.

INTRODUCTION

The Low Frequency Array instrument at SOFIA is a heterodyne array designed to observe in the complete range between 1.9 and 2.5 THz. It is a 14 pixel instrument, working in a dual polarization configuration. The instrument is operative since 2015[1] and have produced valuable scientific data [2]. To provide enough Local Oscillator (LO) power for the 14 HEB mixers a cryogenic solid state source is used. It consists of two identical set of millimeter wave amplification and multiplication chains, one per polarization. The solid state sources were produced at Virginia Diodes inc. [3] and are constantly improved for better performance. Their current frequency coverage is 1.830 to 2.070 GHz, centered on one of the main scientific target of the instrument, the CII emission line at 158mm. Current operational modes allows for separated tuning of the two sources, to have each polarization working at a different frequency. In this work we present an overview of the LO system as installed during the commissioning flights of the instrument.

LO MULTIPLICATION CHAINS

The LO solid state chains from VDI use novel technologies, such as diamond substrates for thermal management, in-phase combining networks, and power amplification at 30 GHz. They achieve a peak output power of 30 mW at ambient temperature. To further increase the output power, the last two passive triplers are cooled to 80 K, effectively doubling the output power to about 60 mW.

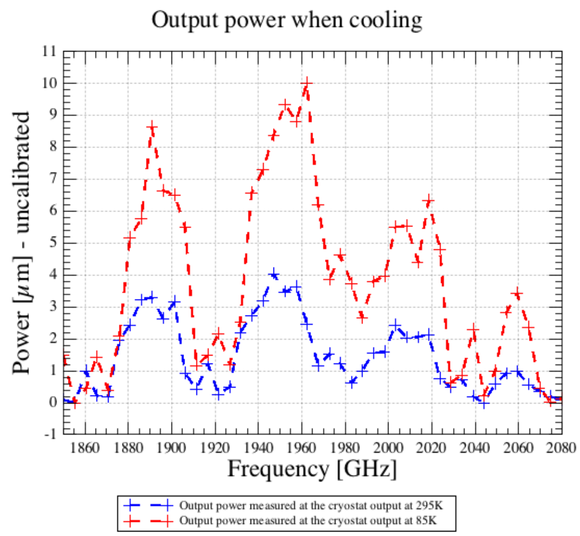

Fig. 1 Measured power at ambient temperature (blue) and at 85 K (red). Power scale is not calibrated and includes the coupling efficiency of the detector horn, vaccum window losses and free space propagation.

LO SYSTEM

The two solid-state chains are integrated with the control electronics, power supplies, and cooling machine in to a compact module. Triplers are cooled to 80 K by a Stirling cooler based on a moving magnet. It provides 2 W of cooling power at 80 K. The cold tip from the cooler is thermally connected to the triplers via flexible copper straps. To thermally isolate the triplers from the room temperature components, two 1” stainless steel WR-5 waveguides are used. The waveguides were copper plated (thanks to NRAO) to reduce the losses to only 0.5dB. The small LO cryostat optical window is a 1-mm-thick high resistivity Silicon window coated on both sides with Parylene. The window is optimized for 1.9 THz, reaching a transmission above 88%. The solid state multiplier chains need a reference signal in the 13 GHz range. The characteristics of the reference signal are critical, as the phase and AM noises of the signals contribute to the total system performance. Several synthesizer modules were tested. When comparing the overall receiver performance, the best results are achieved with a YIG synthetizer from VDI. In that configuration the receiver sensitivity compares to lab-bench synthesizers. Using other models, such as VCO-based synthesizers, the receiver noise temperature can degrade by up to 20%.

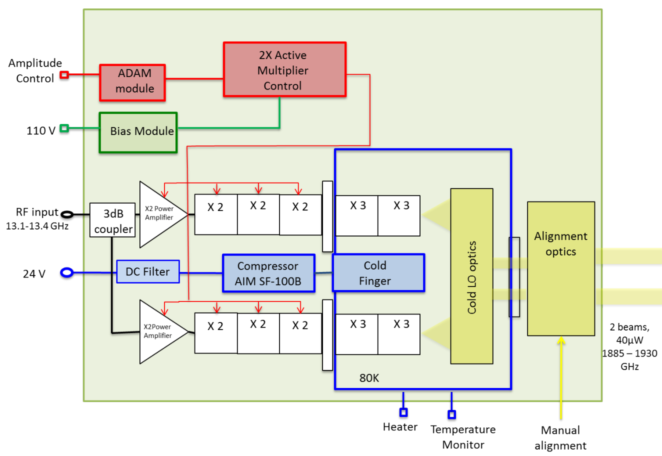

Fig. 2 Electrical diagram of the system. Multiplication factor of the chains is 144. The two LO sources use different optical paths to avoid crosstalk and spurious generation.

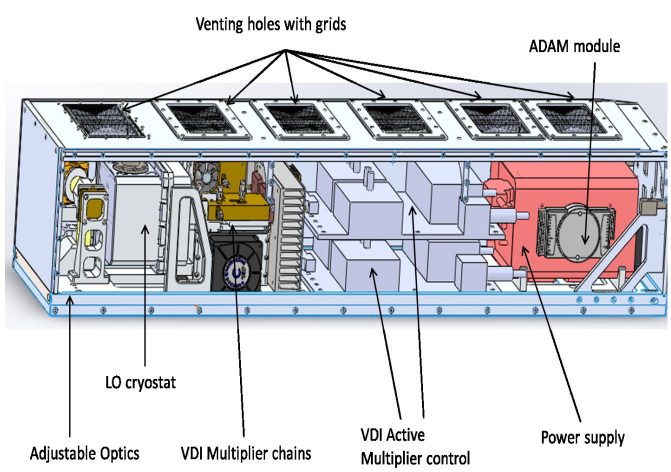

Fig. 3 CAD schematic of the produced system. Thermal management of the power amplifiers and Stirling cooler is critical. Current design optimize the air-flow on the limited space available.

OPTICAL PATH

In the first optical design, the outputs for both chains had orthogonal polarizations and were combined through a coupling grid for a common propagation, and then they were separated again by another grid to be coupled to each HEB array. However this scheme generated unacceptable levels of spurious. A revised optical design was implemented providing separate optical paths for both LO beams. An optic adjustment stage allows directing the beams to the phase gratings where the 7 beams per polarization are generated. The Fourier phase grating design details can be found in []. It is designed to operate at a center frequency of 1.9 THz with about 10% usable bandwidth. Every output beam contains about 12.8% of the incident power, i.e. 90% efficiency. The phase grating was fabricated by direct milling at U.Köln. Figure 4 shows laboratory measurements of the output beams, It was noticed during measurements that alignment of the structure is critical to achieve the required performance.

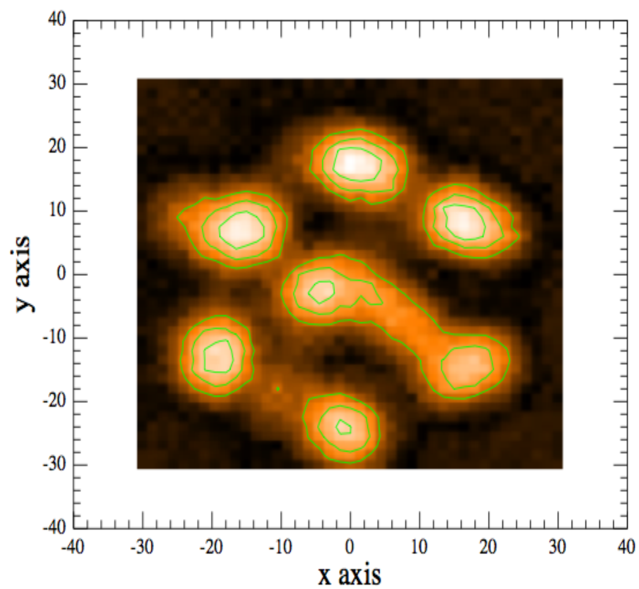

Fig. 3 Measured beam pattern of the 7 LO signal beams. Alignment of the system is critical to obtain equal power beams.

CONCLUSIONS

The LO unit is currently on use at the LFA instrument on board of SOFIA. The LO chains have been replaced to take advantage of the latest improvements on output power achieved by this technology. This article presents an overview of the design of this 1.9THz source.

REFERENCES

[1] C. Risacher, et al. "The upGREAT 1.9THz multi-pixel high resolution spectrometer for the SOFIA observatory", Astronomy and Astrophysics, Volume 595, November 2016

[2] C. Risacher, et al. "First Supra-THz Heterodyne Array Receivers for Astronomy With the SOFIA Observatory", IEEE Transaction on Terahertz Science and Technology. Vol. 6, N°2, March 2016.

[3] https://www.vadiodes.com, accessed: June 2017.

[4] U. U. Graf and S. Heyminck, "Fourier gratings as submillimeter beam splitters," *IEEE Trans. Antennas Propag.*, vol. 49, no. 4, pp. 542–546, Apr. 2001.