GREAT: ready for early science aboard SOFIA

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***Abstract*— GREAT, the German REceiver for Astronomy at THz frequencies, has successfully passed its pre-shipment acceptance review conducted by DLR and NASA on December 4-5, 2008. Shipment to DAOF/Palmdale, home of the SOFIA observatory, has been released; airworthiness was stated by NASA. Since, due to schedule slips on the SOFIA project level, first science flights with GREAT were delayed to mid 2010.**

Here we present GREAT's short science flight configuration: two heterodyne channels will be operated simultaneously in the frequency ranges of 1.25-1.50 and 1.82-1.91 THz, respectively, driven by solid-state type local oscillator systems, and supported by a wide suite of back-ends. The receiver was extensively tested for about 6 month in the MPIfR labs, showing performances compliant with specifications.

This short science configuration will be available to the interested SOFIA user communities in collaboration with the GREAT PI team during SOFIA's upcoming Basic Science flights.

***Index Terms*— airborne astronomy; heterodyne receiver; high resolution spectroscopy; SOFIA**

I. Introduction

GREAT[1][2] is a highly modular principal investigator heterodyne instrument designed for use aboard the SOFIA[3] airborne observatory. The instrument is developed and funded by a consortium of four German research institutions.

Main goal of the design was to provide best possible performance within the boundaries drawn by the observatory and the airworthiness requirements.

In total four independent heterodyne channels are under development for the instrument. Two out of these can be operated simultaneously during one observing flight. The channels being developed so far target at, e.g., high-J CO-transitions, ionized carbon (at ~1.9 THz), deuterated molecular hydrogen HD (~2.7 THz), and atomic oxygen (~4.7 THz).

For the first flight configuration GREAT will be equipped with the both so called low-frequency channels L#1 and L#2. L#1 operates from 1.25 to 1.52 THz while L#2 ranges from 1.82 to 1.92 THz.

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II. System description

GREAT consists of a main structure housing an electronics rack, two cryostat mounts, two optics compartments, two LO-mounts and a calibration unit. The telescope signal is either split by polarization or by frequency (dichroic mirror) to feed two independent heterodyne receiver channels for simultaneous operation. The cryostats are liquid Nitrogen and liquid Helium cooled wet dewars providing the 4.2 K operation temperature of the mixer-devices. The hold time is well above 20 hrs, which is far more than the expected flight duration of SOFIA (< 14 hrs). The calibration unit consists of two black-body radiators, one placed in a small liquid Nitrogen cooled dewar and one at ambient temperature. Switching between the two loads and the sky is done by a remote controlled mirror.

As heterodyne mixing elements in both first flight channels and in the 2.7 THz channel HEB-mixers made by KOSMA are used[4]. They show excellent noise performance and stabilities. Currently their IF-bandwidth is limited to about 600 MHz (by the isolator), but we hope to overcome this limitation with the next generation of KOSMA mixers expected to be operational within this year. The 4.7 THz channel will be equipped with HEB-mixers developed by DLR-PF[5].

The optics[6] of each channel is placed on an optical bench, which can be reproducibly mounted to the main structures optics compartment. This, together with easily exchangeable cryostats and LO-systems makes possible to reconfigure the system even between two flights of a SOFIA flight series, e.g. to change the RF-frequency channel.

The frontend is fully remote controllable via Ethernet. A VME-type computer provides all necessary control signals. In addition the system can be operated fully manual even when the computer is switched off. Together with a partly redundant electronics system this improves reliability of the system during flight, even in case of a device or software malfunction.

GREAT uses a two-stage IF-system which can provide signals for three different backend-types. The simultaneous use of the 8-channel AAOS[7] system, two CTSs[8], and a two channel fast Fourier transform spectrometer[9] is possible. The array-AOS, with the second stage of the IF-processor provides a total bandwidth of 4 GHz at 1 MHz spectral resolution per frequency channel. The CTS can simultaneously analyze a 220 MHz wide part of the band at approx. 45 kHz resolution. The free to configure FFTS-chains offers up to 1.8 GHz instantaneous bandwidth at 255 kHz resolution each. A higher resolution mode with correspondingly lower bandwidth can easily be configured by software (750 MHz with 53 kHz). The FFTS operates with the first IF-stage only, reducing complexity at the backend-side.

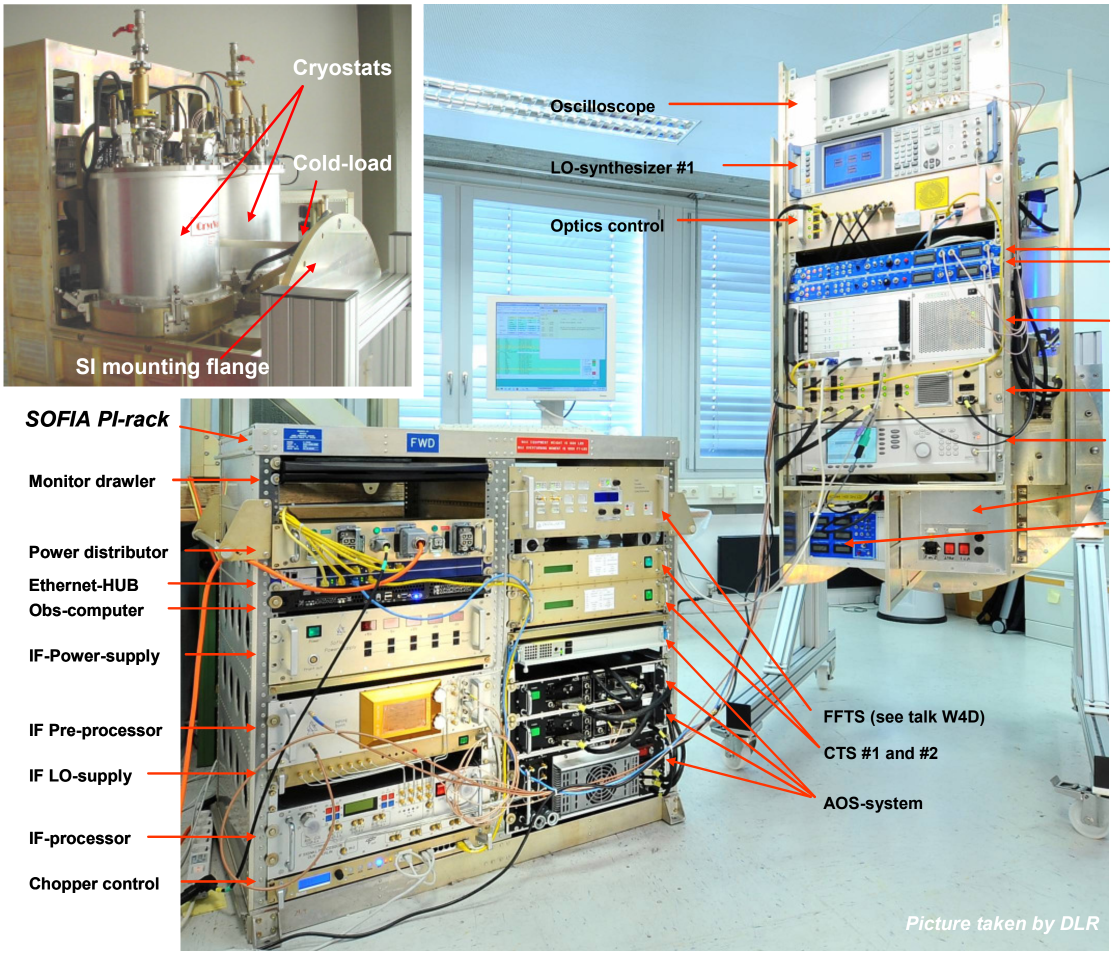

Fig. 1. GREAT in its early science flight configuration, equipped with channels L#1 and the L#2. All components are flight hardware including the airworthy wiring.

Table 1. GREAT performance data as measured during the lab-tests.

Channel	LO-coverage (using VDI solid-state chains)	spectr. Allan-variance minimum time	DSB noise-temperature	beam-shape
L#1: 1.4 THz	**Chain 1:** 1.25 – 1.40 THz (with a gap at 1.28 THz) **Chain 2:** 1.42 – 1.52 THz	>100 s TP Allan times are in the order of >30 s.	< 1800K (measured with wrong leveling of the IF)	expected waist-position and opening angle
L#2: 1.9 THz	1.81 – 1.905THz (with a gap at 1.88 THz)	>90 s TP Allan times are in the order of >15 s.	< 1300K best measured value at 1821GHz was 1150K.	expected waist-position and opening angle

III. Performance

During extensive AIV tests prior to the pre-shipment review both low-frequency channels have been characterized in detail. All minor problems that appear when operating new technologies for the first time were addressed and solved. Table 1 summarizes the basic performance numbers.

IV. Conclusion

GREAT meets all design requirements and is ready for shipment. All auxiliary equipment, as the transportation cart and shipping boxes, is ready to go. Ongoing development is concentrated to improve the IF-bandwidth of the both low-frequency HEB channels and to complete the mid-frequency channel at 2.7 THz within this year.

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