Development and testing of the FDM readout of the TES arrays aboard the LSPE/SWIPE balloon-borne experiment

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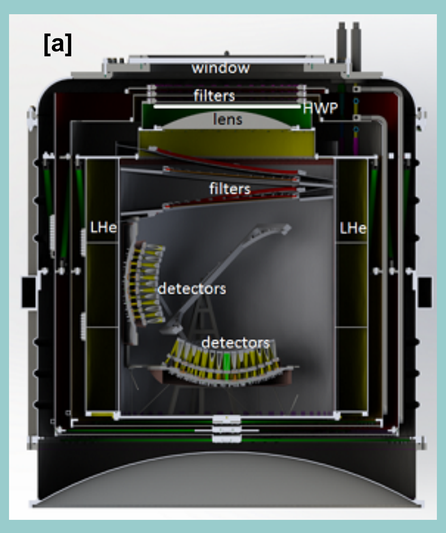
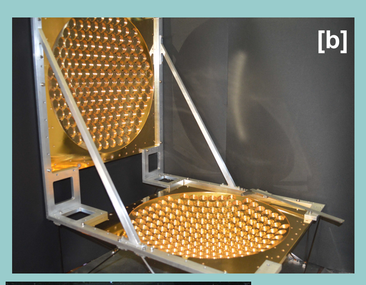
THE LSPE/SWIPE EXPERIMENT IN BRIEF

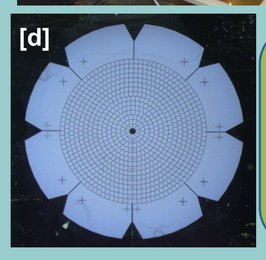
The **Large Scale Polarization Explorer**[1] (LSPE) is

- a research programme aimed at measuring the **B-mode** polarization of the Cosmic Microwave Background (CMB) at large angular scales, exploiting the reionization peak at multipoles $l < 10$.
- A sinergy of two experiments: STRIP (ground, Tenerife) and **SWIPE** (balloon, Arctic night flight).

➢ See L. Lamagna's poster (this section, Poster ID: **252-165**) [1], and [2].





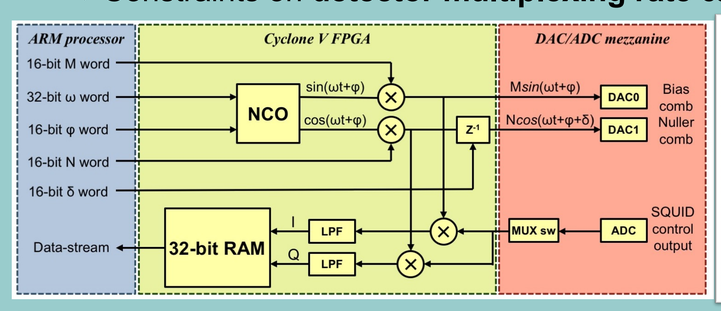


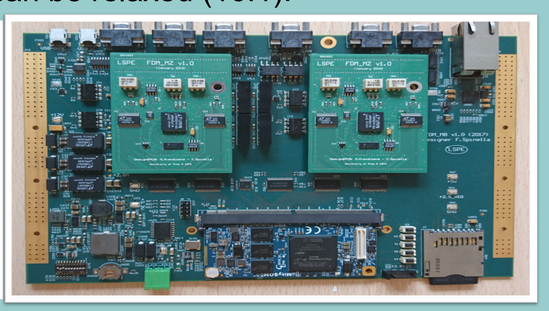
[a] The SWIPE cryostat rendering showing all the optical elements.
[b] The two curved focal plane frames.
[c] A prototype LC board in the focal plane back-plate.
[d] A Large Area TES produced at INFN-Genova. See B.Siri's poster ID-**220-400**

The **detection chain** of SWIPE is based on Large Area Absorber TES [3], suitable to terminate multi-moded waveguides [4].

- Two orthogonal focal planes (as in Fig. [a] and [b]) host 326 TES.
- TES are distributed among three frequency bands centered respectively at 140 GHz, 220 GHz and 240 GHz.
- The number of optical modes gathered by the optical system goes from 10 to about 20 per detector, going from the lowest to the highest frequency.
- TES readout: **Frequency Domain Multiplexing**, as described in, e.g., Dobbs et al. [5]. See the following block diagram referring to specific SWIPE components.

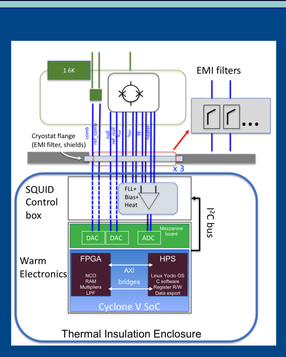
► Target B-mode sensitivity can be reached with a reduced number of detectors.
⇒ **Compliant with the power budged** of an Arctic winter balloon flight relying on batteries.
⇒ Constraints on **detector multiplexing rate** can be relaxed (16:1).

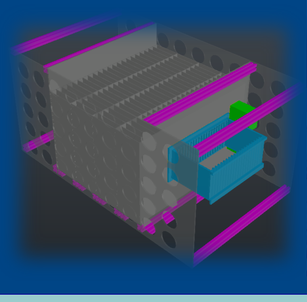


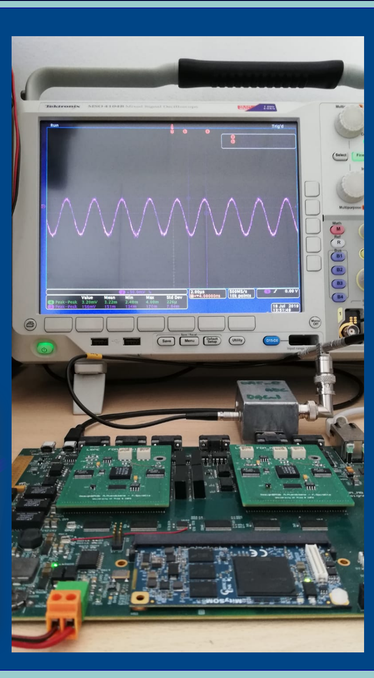


FREQUENCY DOMAIN MULTIPLEXING - WARM

➢ The warm section for the SWIPE readout electronics features a custom board whose core is an Altera Cyclone V SoC including an FPGA with 110K logic elements and a dual core ARM9 processor. Tone generation (200 kHz to 1.6 MHz), demodulation and nulling at SQUID input are managed by this subsystem (×**12 boards**). See, e.g. [6].
➢ It exploits mezzanine plug-ins for 16-bit DACs & ADCs (LT).
➢ It uses **Gbit interface** for data communication and **CAN & I²C interfaces** towards the SQUID control.
➢ Crate (cyan in the rendering) with *ad hoc* board thermal sinks.

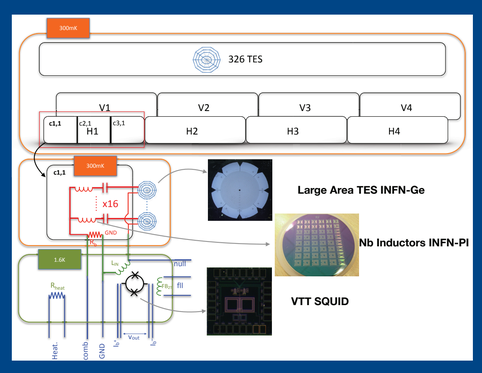




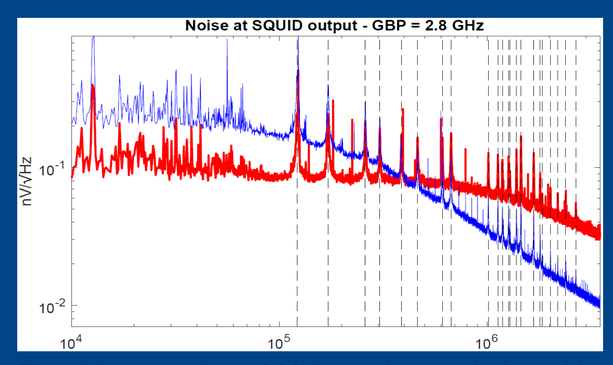


FREQUENCY DOMAIN MULTIPLEXING - COLD

The **cold electronics** components are hosted on 8 boomerang-shaped PCBs to be mounted on the back of each quarter of the 2 focal planes. Each PCB hosts 3 readout chains of 18 channels, composed by a C0G/NP0 SMD capacitor and a superconducting inductor in series with each TES. Each chain is readout by a **6-series array SQUID** by VTT.



The cold section of the FDM, with the stages at different temperatures.

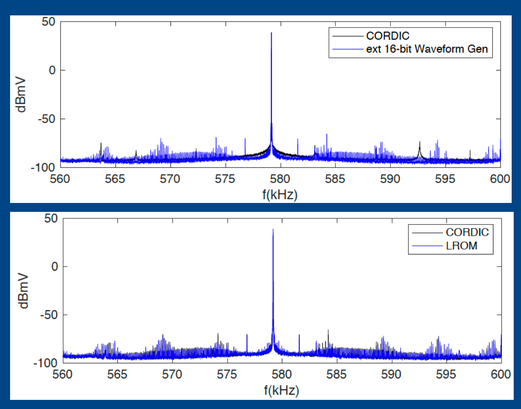


The Johnson noise of 22 1Ω resistors windowed by the cold LC filters, observed through the band of the a Magnicon XXF-1 electronics (in OL, and FLL)

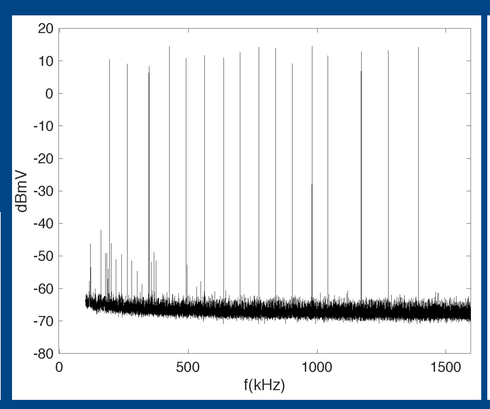
LATEST RESULTS and PERSPECTIVES

⇒Warm electronics: functional tests

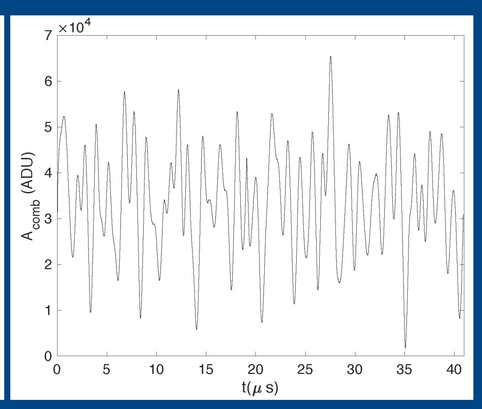
Single tone generation with different algorithms and comparison with the purity of an external generator.



Comb generation in the SWIPE readout frequency range, with a representative spacing of ~70 kHz.

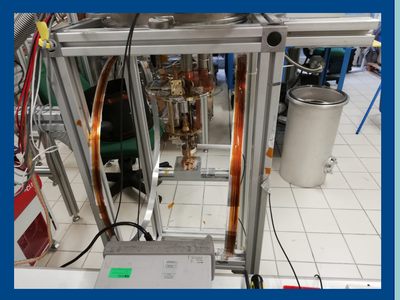


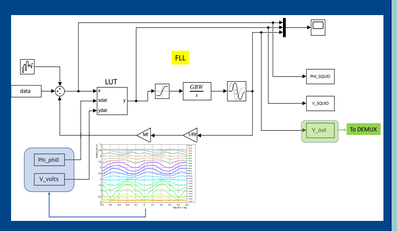
Generation of the 16-tone buffered time-stream by means of multi-channel (4x) NCOs.



⇒Future Works

➢ COLD, lab test cryostat: assembly of end-to-end detection chain representative of SWIPE conditions (connectors, cables, shieldings).
➢ COLD, lab test cryostat: sensitivity of the detection chain to slowly varying magnetic fields (picture on the right, pair of Helmholtz coils to produce typ. 20 μT, from few to hundreds Hz).
➢ WARM: complete the characterization of the comb (spurious signals, signal dynamics, etc.).
➢ WARM: implement the demodulation scheme and test on the full chain.
➢ End-to-end noise modelling.





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