50 mK ADR Cryogen free Cooler for the Cryogenic Spectrometer on the IXO. Engineering Model Single Shot to Continuous.

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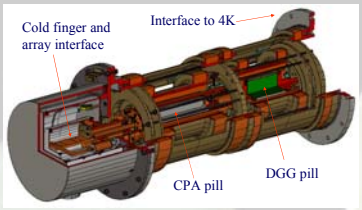
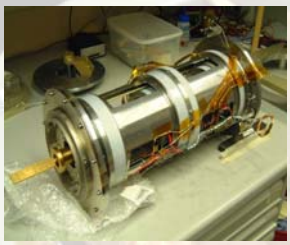
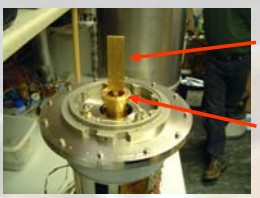
Flight level engineering model double adiabatic demagnetisation refrigerator (dADR)

25 mK base temperature from 4 K with only 2 stages of cooling





- Developed by Mullard Space Science Laboratory (MSSL), and Astrium under ESA contract
- Single-shot *flight-like (TRL 4+)* dADR providing cooling at 1K (DGG), and >25 mK (CPA)
  - Designed to be pre-cooled by closed-cycle cooler (specifically Planck 4K JT)
  - Long hold-time (20h –30h depending on the heat switches) and operation from 4K, leads to relatively high mass (30kg)
    - 50% of the mass is in the magnets. Magnets are extreme low current (2.4 Amps for 3 Tesla and contain an active magnetic shield).
  - Radiation hardness **proven**
  - Launch vibration survivability **proven**
  - ADR sequencing and control stability (to LSB few tens of μK), **proven**
  - Minimum temperature 25 mK, **proven**
  - Containment of ADR stray magnetic field to <0.06 μT @ 0.5 m from ADR. **proven**
  - Complete system thermal model validation, **proven**



dADR mounted on the 4K stage of the ground test cryostat. Cooling to 4 K provided by a pulse tube cooler

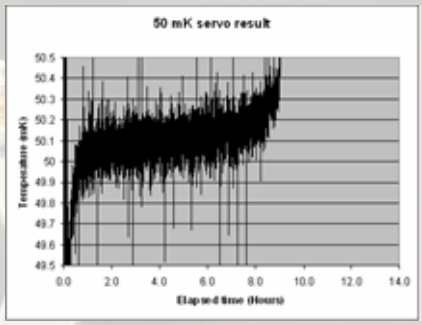
The Cooling parts (CPA and DGG) of the dADR

System on the vibration table prior to vibration qualification

Performance

50 mK hold time with 1μW heat load measured to be 8 hours with a 4 K bath temperature.

Hold time dominated by low temperature heat switch used.



Improvements to current system for IXO

- Temperature stability to 8 μK (limit of present readout electronics)
- New heat switches will be installed in March 2009. This will increase hold time to 20 hours (@1 μW heat load) and 60 hours (no additional heat load)
- Bath temperature of 2.5 K and not 4 K proposed for IXO
  - Reduced bath temperature will enable the ADR size to be reduced by ~ factor 2.

ADR for the IXO cryogenic spectrometer

Prior to IXO the XEUS payload accommodation study, performed by EADS Astrium, has shown that the current dADR can be used to cool the TES detectors for the cryogenic spectrometer using current 4 K cooler technology (i.e. the Planck 4 K JT)

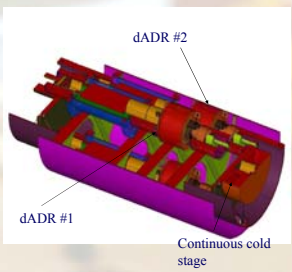
(Astrium presentation at the ESA Space cryogenic workshop 2007)

The cryogenic spectrometerI with the MSSL/Astrium dADR as presented in the XEUS payload accommodation study.

Conversion of the flight dADR to a Continuous ADR

A continuous ADR can be constructed from two dADRs running in tandem connected to a common detector cold stage. While one dADR is cold the other is recycling. This system has the advantage that it comprises of smaller versions of our vibration qualified dADR and thus will need minimal development to achieve flight level construction.

A continuous ADR leads to a cooler significantly reduced in mass compared to a single shot system. The mass reduction is dependant on how fast the ADR can be re-cycled as the cold ADR only needs to be sized for this length of time.



3D cut away design view of the MSSL continuous ADR.

Magnet design	Performed (minimum re-cycle time = 10 minutes)
Pill design	Smaller version of the dADR
Pill suspension	
System	Smaller version of the dADR
Cooler interfaxce	4.5 K or less
Mass	~5 Kg or less
Redunadancy	50% redundant (inclusion of third dADR makes a fully redundant cooler)
Continuous stage	Designs currently under test