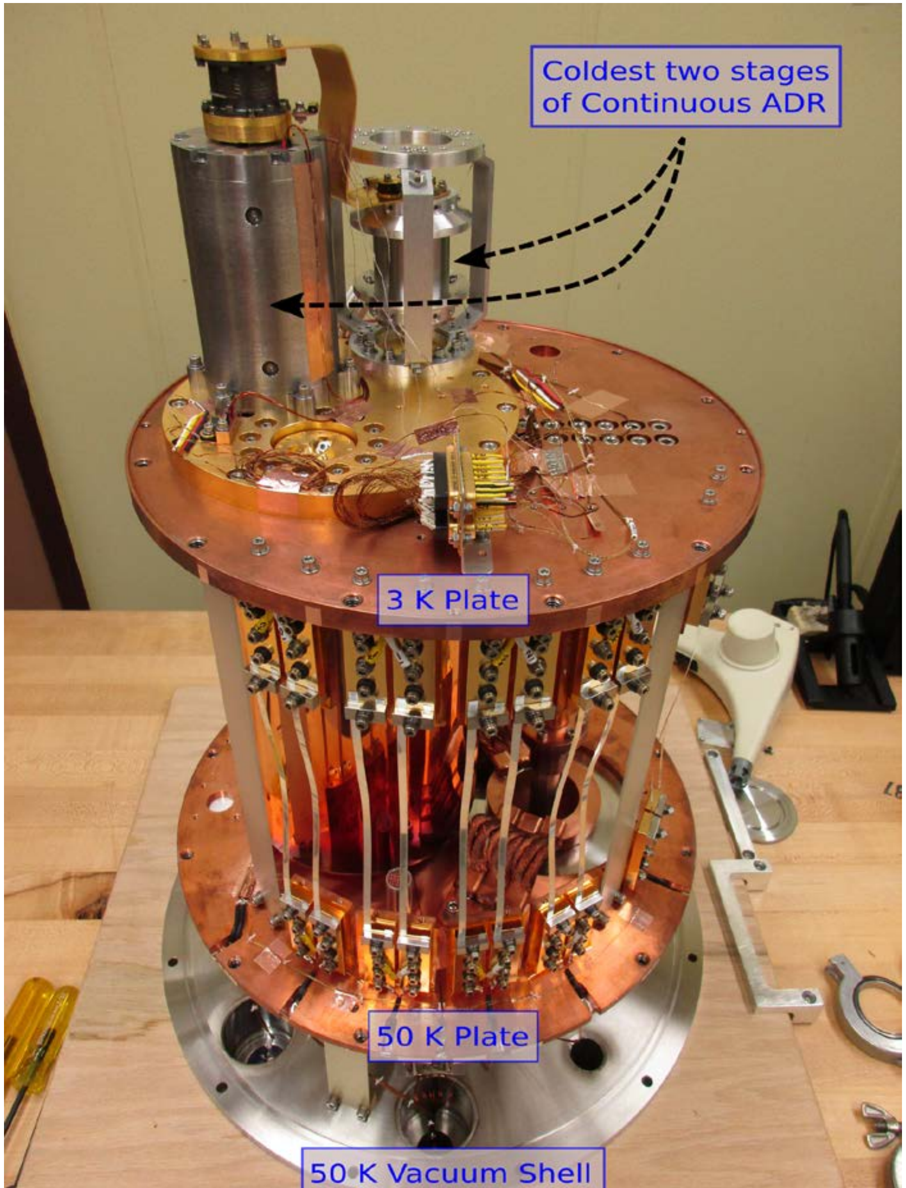
Quick-replacement high-temperature superconducting current leads for use in a research cryostat

Mark O. Kimball, Michael A. Sampson, Edgar R. Canavan, and Richard V. Letmate

NASA Goddard Space Flight Center

Cryogenic Engineering Conference 2019

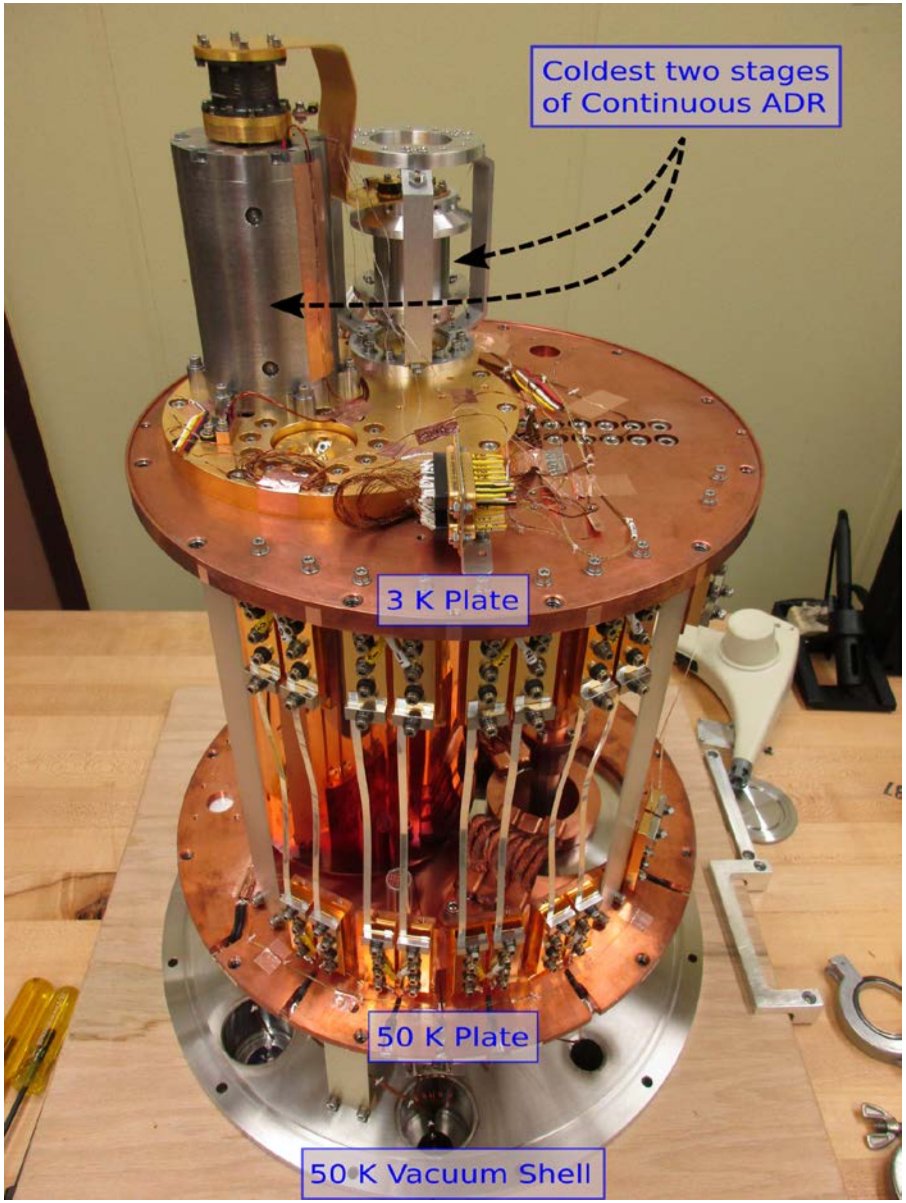
Overview of the System



A cryostat was built to contain a 4-Stage Continuous Adiabatic Demagnetization Refrigerator (CADR).

- Capable of providing > 4 µW of usable cooling at 50 mK at the coldest stage
- Uses a Sumitomo RDK-101D GM cryocooler as the ultimate heat sink at 3 K
  - Coupled to an CNA-11B air-cooled compressor
  - Air-cooled, no cooling water lines
  - 110 V power input
  - *Ultra-portable*
  - With 100 mW of heat lift at 4 K when upper stage is at 50 K, need to limit the parasitic heat to the 3 K plate!
- 10 current leads needed to run the 4 CADR stages and the superconducting heat switch between Stages 1 and 2
  - May be a dominant heat leak to the 3 K plate

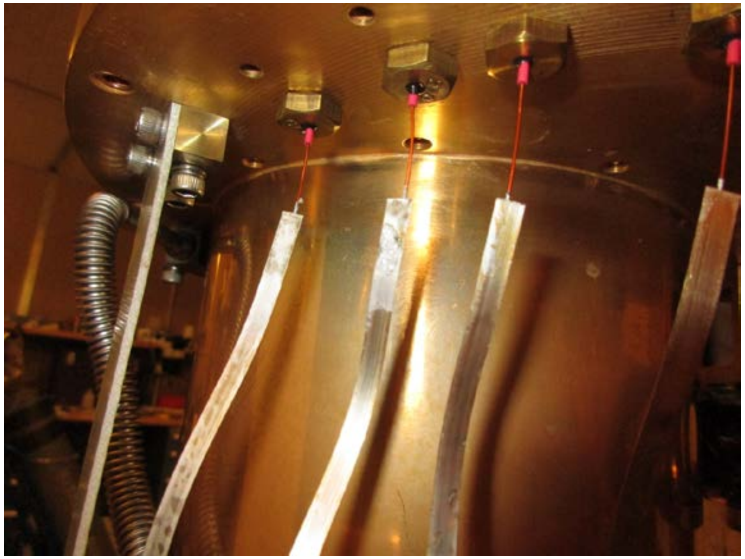
Overview of the Problem

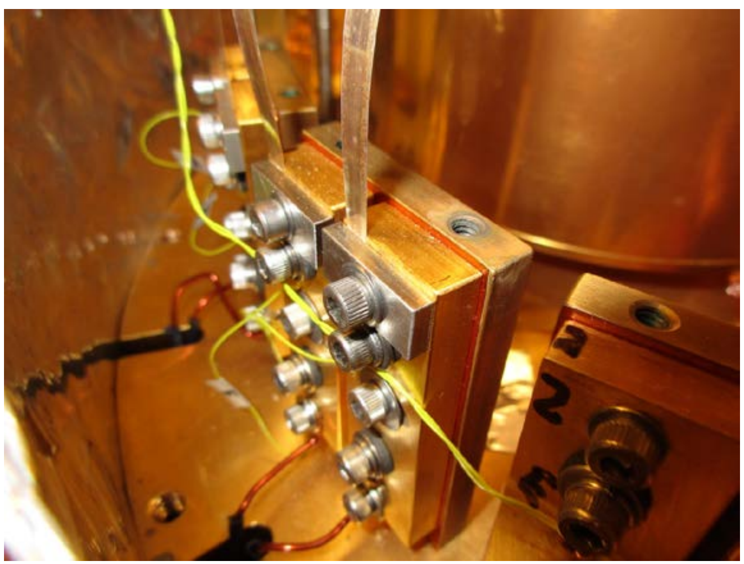


10 current leads needed to run the 4 CADR stages and the superconducting heat switch between Stages 1 and 2

- May be a dominant heat leak to the 3 K plate
    - Cannot use traditional metal wire, too thermally conductive when sized properly for the current necessary
- High-Temperature Superconducting tape an excellent solution here
    - Our current requirements far below the critical current in the tapes on hand (4 A or less)
    - Extremely low thermal conductivity from 50 to 3 K minimizes the heat leak to the 3 K Plate

How to attach HTS Leads?

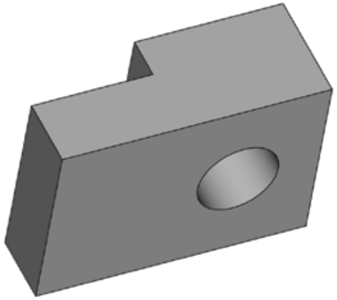




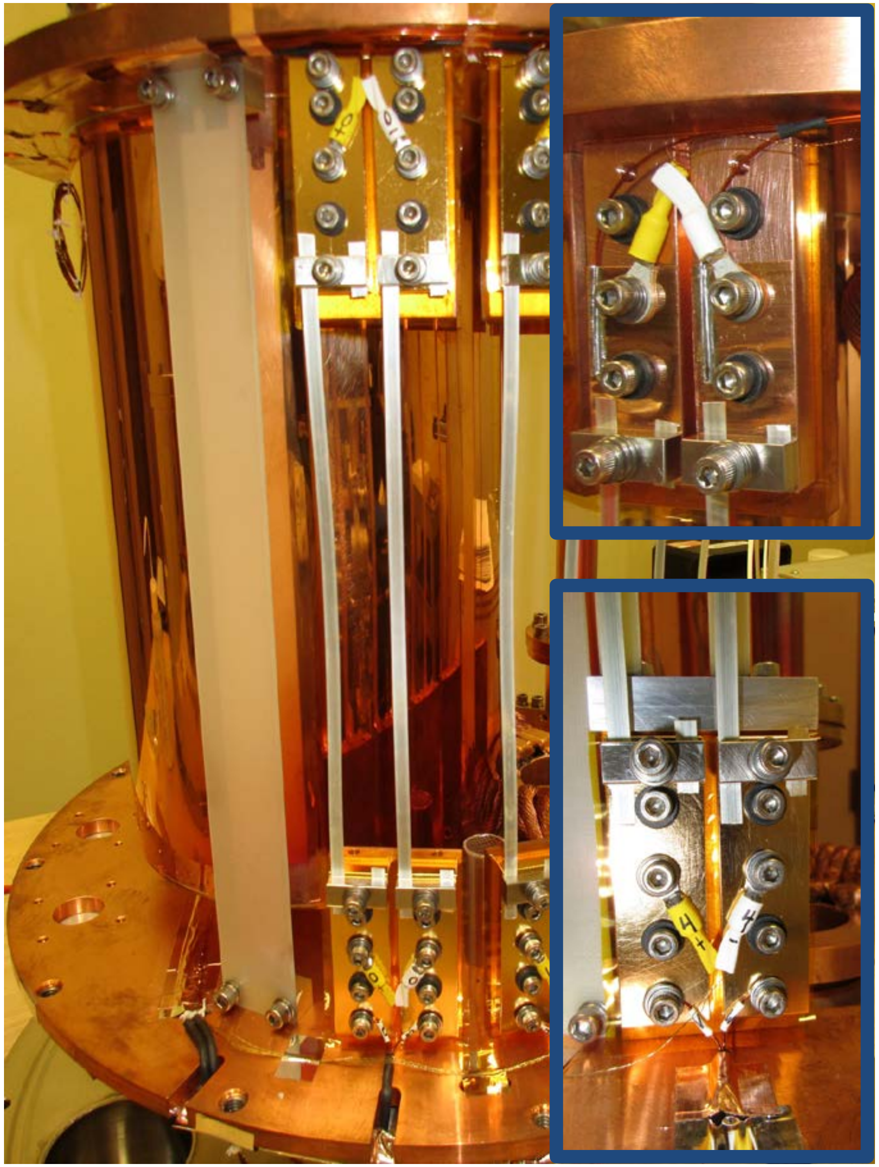
- Solder directly to the HTS tapes
  - Concern damaging the superconducting layer rendering a section of the tape normal
  - Not simple to replace a tape that is damaged for some reason
- Clamp the tape to conducting blocks
  - Concern damaging the tape via some mechanical strain or cracking the superconducting layer
  - May be easy to replace a tape if needed.

First Attempt to Generate a Clamp Joint

- Older cryostat used a combination of solder joints and clamp joints
- Near 4 K, HTS tapes were soldered directly to LTS leads.
  - Often worked, sometimes not
- A mid-temperature stage installed so the tapes did not need to traverse a wide range in temperature
  - Required twice as many tapes cut
  - Blocks used to clamp the tapes had a portion relieved (~ 1.5 mm) to allow the tapes to be sit flush on the gold-coated contact blocks



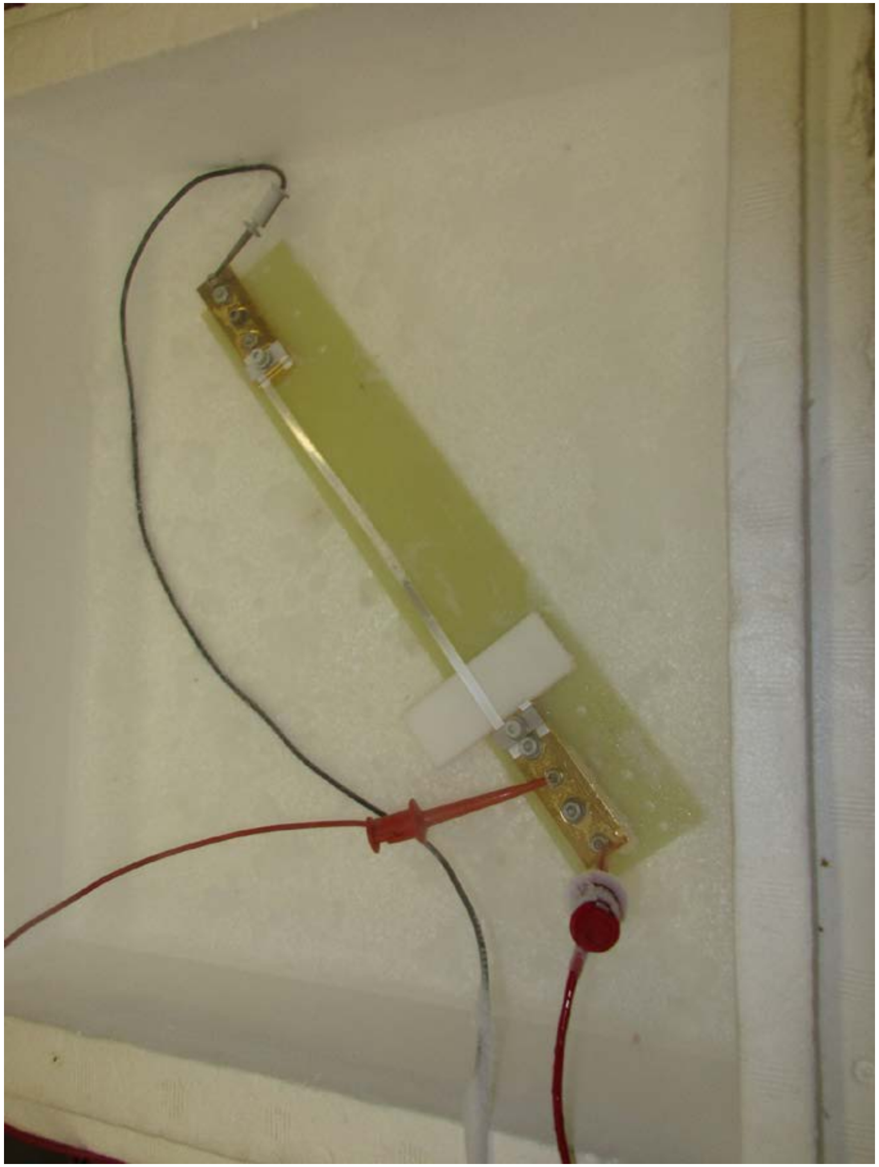
Implementation in New Cryostat



In the new cryostat, it was decided to try spanning 50 to 3 K using a single tape per circuit leg

- Create clamp blocks with no relief cut
  - Use a short section of tape mirrored about the screw used to clamp block to allow even pressure across tape
- LTS leads attached to the 3 K plate current block via low-resistance solder joint
- Current leads from outside the Dewar terminate on the 50 K current block via a screw
- This worked great… ***until it didn't***
  - 10 μΩ or less resistance per clamped joint
  - Something caused the tapes to go normal -> no pattern to which tape would remain normal after a cooldown

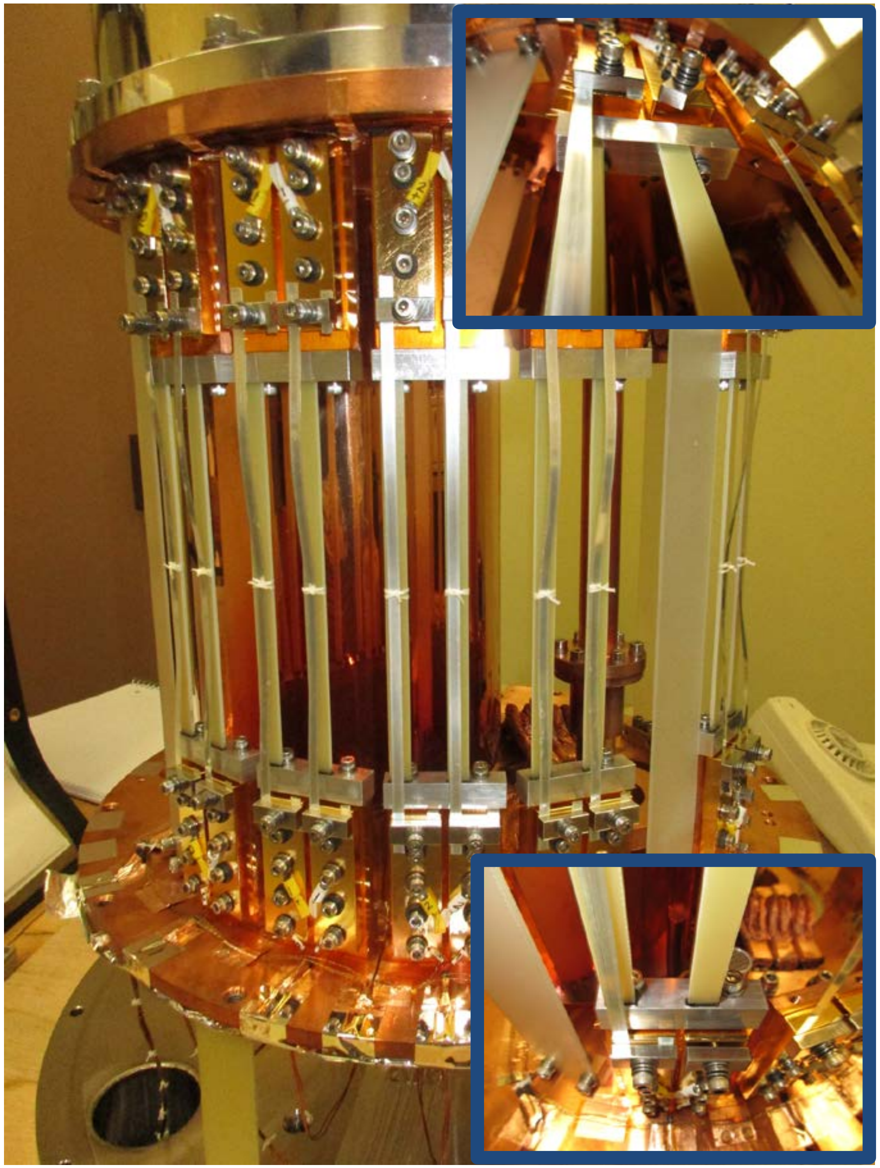
Test of Individual Tape



There was a fear that a rapid pumpout of the Dewar flexed the HTS tapes and broke the YBCO layer

- Built a simple fixture to mount a HTS tape that appeared normal even though both ends were below 60 K
- Submerging the fixture with tape attached allowed a measurement of resistance
- *Tape proved to be intact and superconducting at 77 K*
  - *Fourth lead not shown in the image to the left. We constructed a probe that could touch the tape in various locations to identify where a break occurs if one exists*

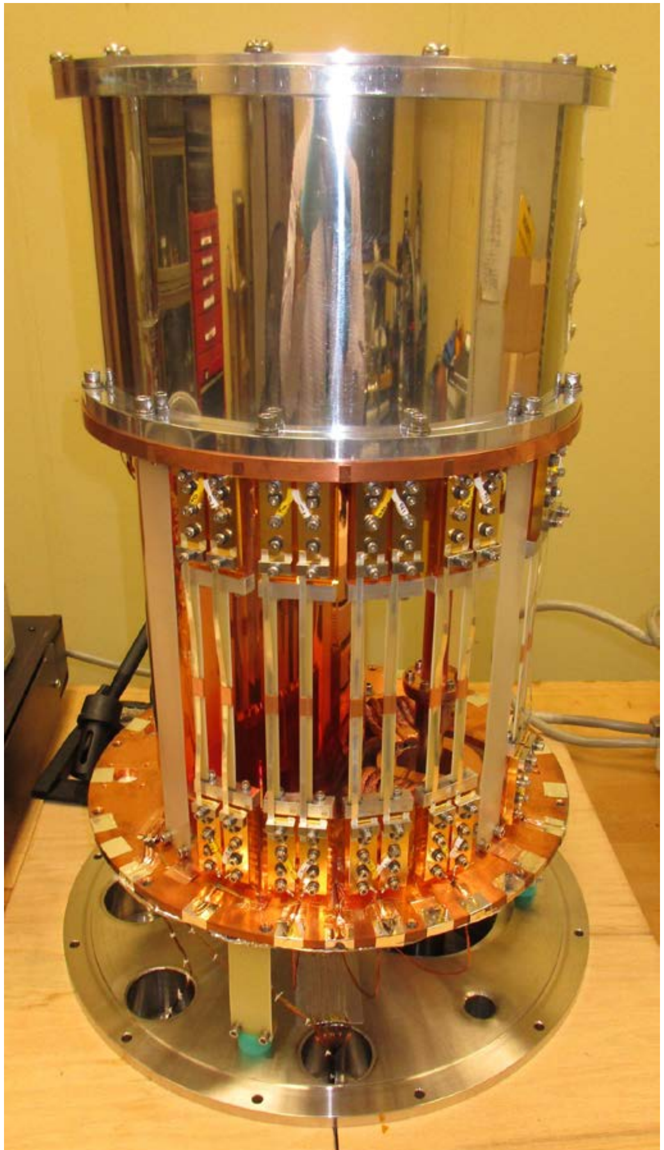
Install Strongbacks Behind Tapes



Strongbacks made from G10 installed behind each tape

- Provide structural support
- Provide a “black” structure near tapes to absorb some 50 K radiation and higher temp radiation if it exists
- G10 slats epoxied into an aluminum block at the 50 K side and float in a slot on the 4 K side

Final Configuration and Conclusion



- Ten 4 mm-wide YBCO HTS Tapes installed in a Dewar to run a 4-Stage CADR
- Behind each tape is a strongback made form G10
    - Strongbacks epoxied on the 50 K end, allowed to float on the 4 K end
    - Copper tape adheres tapes to strongback half-way down the run; replaced the original idea of using lacing cord to anchor the tapes
- Ten HTS Tapes contribute 1.77 mW to 3 K plate (assumes the G10 does not make contact at 3 K)
- Since installed system run 8 times -> all 10 tapes performed as expected!