Program: The First Billion Years: A Technical Development Program for Spectral Line Observations

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Brief summary of progress to date

The goal of this project is technological development for a CO intensity mapping program whose ultimate target is the Epoch of Reionization. Phase I is now fully funded through awards from KISS, NSF and JPL R&TD as well as contributions from Stanford and Miami. This phase involves building a 19-pixel receiver (the CO Mapping Array, or COMAP) and commissioning it on a 10m telescope at OVRO before observing for two years using a broadband digital backend in order to detect CO emission from galaxies at the peak of cosmic star formation around redshifts of z=3.

The specific areas funded by KISS include

- *Simulations:* Simulations of the CO signal and analysis pipeline
- *Ka-Band MMIC Development:* Assist JPL with MMIC design and testing
- *Ka-band Module Development:* Test front-end modules
- *Telescope Commissioning:* Commission telescope for Pathfinder receiver
- *Feeds & OMTs:* Design and fabricate feeds and OMTs for receiver
- *Cryostat:* Design and fabricate receiver cryostat

In our previous report, we described progress in all of these areas and also reported that NSF and MRI funding had been secured for the project. Since then, NSF funding has taken over from KISS in the areas of simulations, Ka-band MMIC development and telescope commissioning. KISS funding continues for the Ka-band module development, feeds & OMTs and the cryostat, and we describe progress in these areas below.

Ka-band module development

As described previously, the Ka-band low-noise amplifier (LNA) modules that were designed and built using KISS and JPL R&TD funds were originally optimized for the 30-34 GHz band. Since then, we have doubled the bandwidth, to 26-34 GHz, and have developed a new LNA design for this band. The LNA modules are in the process of having their amplifier chips replaced with this new design and are being tested. So far, about 20 modules have been reworked and initial tests are promising (Fig. 1). Over the course of the next 8 weeks, these modules will be tested and re-worked as needed to produce 19 modules with noise temperature less than 16 K in the 26-34 GHz band.

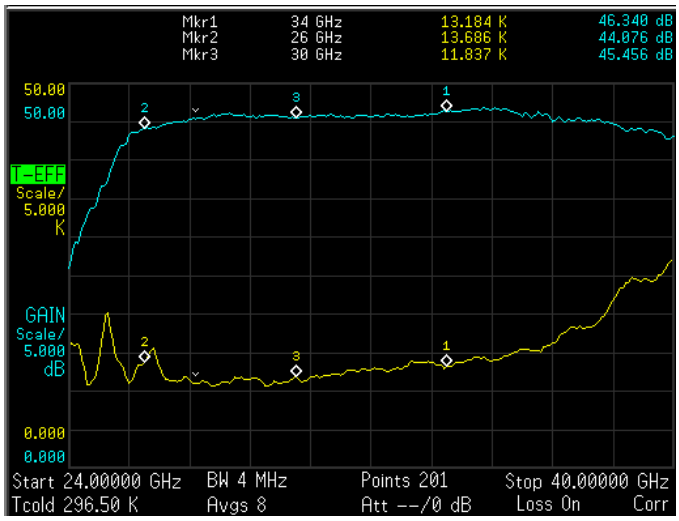

Figure 1: COMAP LNA module noise and gain

Feeds & OMTs

The feedhorn design has been completed by James Lamb. It is a corrugated horn, with a 56 mm aperture and 250 mm length. Fig. 2 (left) shows a cut-away drawing of the horn, which comes in two parts, for ease of machining. The horns are currently awaiting fabrication at the OVRO machine shop.

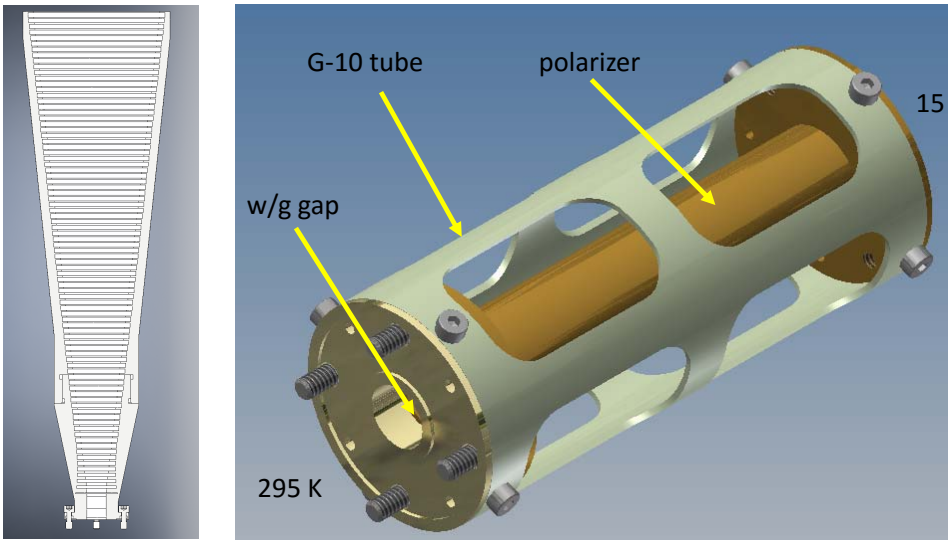

Figure 2: COMAP corrugated feedhorn (left) and circular polarizer (right)

New polarizers have been designed by James Lamb and are currently being machined at the OVRO machine shop. Fig. 2 (right) shows the polarizer design, which consists of a circular waveguide with two sets of internal fins at 45 degrees to each other. The waveguide is surrounded by a G10 support tube which allows the waveguide to incorporate an air-gap for thermal isolation.

Cryostat

The cryostat design has been finalized and it is currently being machined, with delivery expected by the end of March 2017.

Status of Collaborations (Campus/JPL/External)

Weekly telecons are held to discuss receiver fabrication and two other telecons discuss the simulations/analysis pipeline and the modeling of the CO signal, alternating each week between these two topics. The second COMAP collaboration meeting was held at OVRO on January 10/11 2017, followed by a working meeting between COMAP and FIRE collaborators at Caltech on January 13, 2017 and another meeting at Caltech to continue discussion on CO modeling on January 17, 2017. The third COMAP collaboration meeting is planned for June 2017, hosted by the University of Oslo. Tzu-Ching Chang has joined the collaboration as the JPL KISS lead. The first workshop on Opportunities and Challenges in Intensity Mapping was held at Stanford in March 2016. The second workshop will be held in Baltimore, over June 12-14 2017.

Papers / Technical Reports to date

- Li et al. 2016, 817, 169

Presentations / Conferences to date

- Cleary, K., “The CO Mapping Array Pathfinder”, AAS, 2016
- Cleary, K, “The CO Mapping Array Pathfinder”, Workshop on Opportunities and Challenges in Intensity Mapping, Stanford, March 21-23, 2016
- Li, T., “Cross-correlating CO Intensity Maps and Galaxy Surveys”, Workshop on Opportunities and Challenges in Intensity Mapping, Stanford, March 21-23, 2016
- Samoska, L., Cryogenic Low Noise MMIC Amplifiers for U-Band (40-60 GHz), European Microwave Conference, 2016

Undergraduate students, graduate students and postdocs who have worked on the project

At Caltech, graduate student Ryan Monroe is providing his spectrometer FPGA code and advises on CASPER hardware.
At Stanford, graduate student Matt Sieth has worked on COMAP and an undergraduate student, Kelley Stifter, worked on the RF signal routing;
At JPL, postdoc, Brandon Hensley, is working on CO signal modeling.