Current Status of the Antarctic Submillimeter Telescope and Remote Observatory

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ABSTRACT

The Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) is a 1.7-m diameter offset Gregorian instrument operating year-round at the NSF Amundsen-Scott South Pole Station. During the Austral winter of 2002, there were five submillimeter heterodyne receivers mounted on its optical table: 1) a 230 GHz SIS receiver, 2) a 450-495 GHz SIS quasi-optical receiver, 3) a 450-495 GHz SIS waveguide receiver, 4) a 800-820 GHz fixed-tuned SIS waveguide receiver and 5) a 2x2 804-810 GHz fixed-tuned SIS array receiver (PoleSTAR). Observations were conducted at 230 GHz, 460-490 GHz and 810 GHz towards Galactic Center region and Magellanic Clouds. After an upgrade of PoleSTAR and a successful installation of a 1.5 THz heterodyne receiver (TREND) during the last Austral summer, AST/RO is currently able to measure the sky at wavelengths from 1.3 mm to 200 μm.

AST/RO could be used in future as an observational test bed for additional prototype Terahertz instruments. Observing time on AST/RO is available on a proposal basis (see *http://cfa-www.harvard.edu/~adair/AST_RO*).

I. Introduction

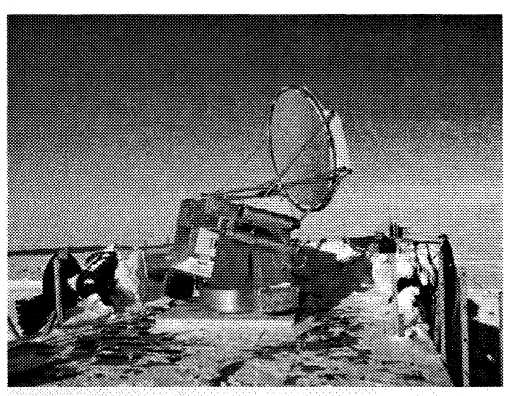

Fig. 1. The Antarctic Submillimeter Telescope and Remote Observatory atop its building at the South Pole in 2002 February.

The Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) is a 1.7-m diameter offset Gregorian telescope with optics designed for wavelengths between 3 mm and 200 μm. It is the first submillimeter-wave telescope to operate year-round on the Antarctic plateau and is open to the astronomical community on a proposal basis. The South Pole is the best ground-based observatory site for the millimeter, submillimeter, and far-infrared, due to its extremely cold, dry conditions. Since AST/RO became operational in January 1995 at the United States National Science Foundation Amundsen-Scott South Pole Station, over 800,000 raw spectra have been obtained, including maps of the Magellanic Clouds, Carina molecular clouds, and the Galactic Center region in the 230 GHz line of CO (2-1), 492 GHz line of C I, 461 GHz line of CO (4-3) and 807 GHz line of CO (7-6). Figure 1 is a photograph of AST/RO, which located on the roof of a dedicated support building about 1 km from the Geographic South Pole. In this paper we report the current status of AST/RO.

II. The AST/RO Optics and Calibration System

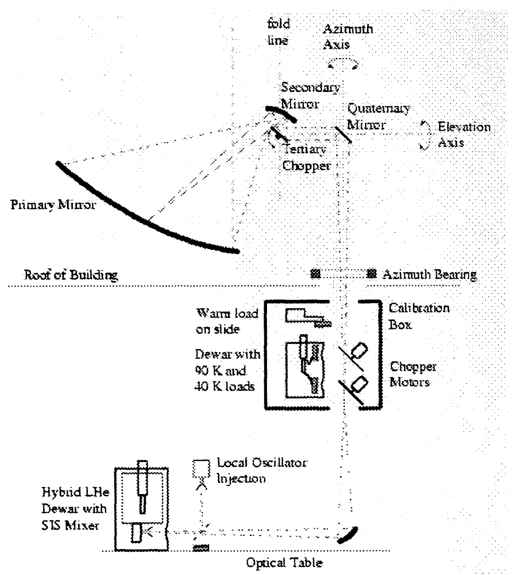

Fig. 2. Schematic of the AST/RO optical system.

AST/RO is a full steerable, offset Gregorian telescope with a tertiary chopper mirror at the exit pupil and a four-mirror Coudé arrangement. Figure 2 is a schematic of the optical design. The primary mirror is an offset section of a paraboloid made of carbon fiber and epoxy with a vacuum-sputtered aluminum surface. It has a surface roughness of 6 μm and an rms figure of about 9 μm (Stark 1995, 1997). The secondary mirror is a section of a prolate spheroid. The tertiary and quaternary mirrors are flat.

The calibration system is suspended underneath the azimuth structure above the receiver table, as seen in Fig. 2. Three blackbody calibration loads can be viewed by the receivers: a load at the receiver room ambient temperature and two loads cooled by closed cycle refrigerator to 40 and 90 K. The ambient temperature load is mounted on a linear actuator and can be moved to block the beam from the sky. The cooled loads are in a Dewar to the side of the beam coming into the Coudé room and are switched into the beam by flat chopper mirrors (Stark 1997).

III. The AST/RO Submillimeter-wave Receivers

During the 2002/2003 Austral summer season, we upgraded PoleSTAR and replaced the 450-495 GHz SIS quasi-optical receiver (165-250 K DSB, Engargiola, Zmuidzinas, & Lo 1994) with a 1.5 THz heterodyne HEB receiver (TREND). Figure 3 shows the AST/RO receivers mounted on optical table.

- ***230 GHz SIS receiver (Kooi et al 1992)***

The 230 GHz SIS receiver has a full height rectangular waveguide mixer with two tuning elements: E-plane tuner and backshort. The mixer, which uses a small size 0.25 μm^2 Nb/AlOx/Nb SIS tunnel junction with ωRC ~1.7 at 230 GHz and a wideband integrated IF matching network, is able to work in a frequency range of 225-255 GHz with the current local oscillator (LO). The LO power is injected to the junction via a 12 μm thick Mylar beamsplitter. Since the upgrade in 2001, this receiver has been working stably for CO (2-1) observations, with a typical DSB receiver noise temperature of 80 K. A novel Millitech 230 GHz multiplier, which is a combination of an X-band power amplifier and an 18^{th}-order harmonic generator with signal input from a frequency synthesizer, has been successfully used as an alternative LO source for CO, ^{13}CO and C^{18}O (2-1) observations. With this ultra-compact LO unit, no high frequency phase-lock control loop is necessary.

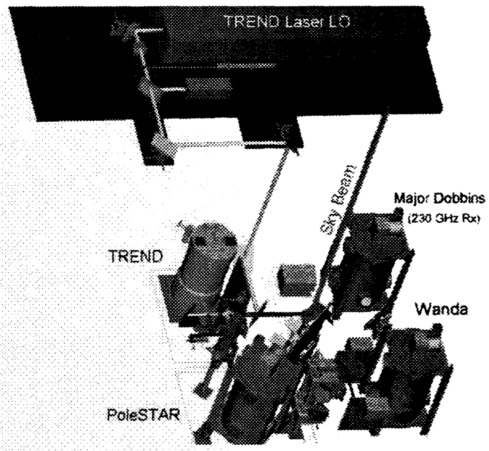

Fig. 3. A 3-d view of current AST/RO receiver room configurations with 1.5 THz HEB receiver TREND and its laser local oscillator installed, looking downwards to the Coudé focus. (Created: Dathon Golish, modified: Kecheng Xiao)

- ***450-495 GHz/800-820 GHz dual channel SIS receiver (Wanda) (Walker et al. 1992, Honinggh et al. 1997)***

This dual channel receiver was built by Steward Observatory Radio Astronomy Laboratory (SORAL), University of Arizona, in 1996. The "Wanda" 450-495 GHz SIS mixer (Caltech) has a double tuning structure of E-plane tuner and backshort, while the "Wanda" 810 GHz mixer (U. Koln) is fixed-tuned. The two mixers have been built into a single dewar and are used in a two channel configuration. Two phase-locked RPG-made LO chains (77 GHz-Gunn ×2×3 and 135 GHz-Gunn ×2×3) provide LO power for both channels via 45° Mylar beamsplitters. A wire-grid polarizer splits the RF signals and allows simultaneous measurement of the atomic carbon [C I] $^3P_1$-$^3P_0$ and [C I] $^3P_2$-$^3P_1$ lines or the CO (4-3) and the CO (7-6) molecular rotation lines. The DSB uncorrected receiver noise temperatures are 250K and 1100 K. An extensive survey towards the Galactic Center region was carried out using this receiver during the 2001 and 2002 Austral winter seasons (Martin et al. 2003).

- ***800-820 GHz 2 x 2 array SIS receiver (PoleSTAR) (Groppi et al. 2000)***

This SORAL-built 4-channel receiver has been installed on AST/RO since November-December 2000. It has a unique optical system with a pair of parabolic mirrors and two flats, to reimage AST/RO's focal plane onto a compact 2x2 array of lenses located in the array cryostat and to efficiently inject local oscillator power into each mixer. A quasi-optical LO power divider is used to split the focused LO beam into 4 equal parts. A JPL-supplied LO unit which comprises a 100 GHz Gunn oscillator, a 100 GHz power amplifier and a ×2×2×2 doubler chain, together with a simple Mylar beamsplitter are now used to pump the array.

The SIS mixers used in PoleSTAR were made by KOSMA (Honinggh et al. 1997). Each mixer uses a Potter horn with a circular-to-½ height rectangular waveguide transition to couple radiation to a Nb SIS junction. The junctions achieve low noise performance through the use of an on-substrate Al tuning structure and a fixed waveguide backshort. The mixers have embedded magnets to suppress the Josephson effect. After a recent upgrade, three mixers are on the sky with receiver temperatures less than 600 K, including all losses in the system.

- ***1.5 THz heterodyne HEB receiver (TREND) (Gerecht et al. 1999, Yngvesson et al. 2001)***

During the 2002/2003 Austral summer season, TREND was successfully installed and initialized on AST/RO. The TREND optics, dewar and its laser LO can be seen in Figure 3. TREND is a single-pixel THz receiver and its LO frequency can be changed by choosing different pumping gases in the submm laser LO. Details of the TREND receiver will be described elsewhere in these proceedings.

- ***Acousto-Optical Spectrometers (AOSs) on AST/RO***

Two low-resolution spectrometers (LRSs) with a bandwidth of 1 GHz (bandpass 1.6-2.6 GHz), one high-resolution AOS (HRS) with a 60 MHz bandwidth (bandpass 60-120 MHz) (Schieder et al 1989).

An array AOS having four low-resolution spectrometer channels with a bandwidth of 1 GHz (bandpass 1.6-2.6 GHz) for the PoleSTAR array (Horn et al. 1999).

IV. Cryostat

The cryostats on AST/RO (except for TREND) were constructed by Precision Cryogenics and are based on the successful CSO hybrid design. They use a CTI model 350 coldhead to cool the outer and inner radiation shields to ~77 and ~14 K, respectively and a 4 liter liquid helium reservoir to maintain the mixers at their ~ 4 K operating temperature. In the single pixel AST/RO receivers, 30.5 mm diameter, Teflon coated, crystalline quartz windows are used at 300 and 77 K. Zytex is used as the IR filter on the 12 K radiation shield. Holding times of ~ 5 days can be achieved. With the array receiver PoleSTAR, an additional layer of Zytex has been substituted for the 50-mil quartz windows at 77 K. This past Austral summer, we replaced the original Zotefoam vacuum window with a lower-loss crystalline quartz window which has an IR-reflective coating. With all 4 mixers and amplifiers operating in the cryostat, the measured LHe hold time is ~ 4 days.

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