A DUAL-POLARIZATION InSb RECEIVER FOR 461/492 GHz

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Abstract

A dual-polarization InSb hot-electron bolometer-mixer receiver has been built for the James Clerk Maxwell Telescope, for operation at 461 and 492 GHz (the frequencies of the \( J = 4 \rightarrow 3 \) rotational transition of CO and of the \( ^3P_1 \rightarrow ^3P_0 \) transition of neutral carbon). Receiver noise temperatures of 500 K have been obtained at 461 GHz, in observing bandwidths of 3 MHz. The receiver was designed as a "common-user" or facility instrument. Here we describe those aspects of the design and construction which enabled this goal to be realized.
I INTRODUCTION

The receiver described in this paper was conceived as a "Day-1" receiver for the 15 m James Clerk Maxwell Telescope (JCMT), which is located at ~ 4000 m on the mountain of Mauna Kea, Hawaii. This combination of a large-diameter, accurately figured telescope capable of diffraction limited operation at frequencies in excess of 700 GHz, coupled with the high, dry mountain site, offers an unparallelled opportunity for observations of two emission lines — the CO J = 4 → 3 rotational transition and the CO 3P 1 → 3P 0 fine-structure transition of atomic carbon — which are thought to be amongst the most important coolants of the dense clouds of molecular hydrogen where star formation is currently taking place.

Almost all observations of these two transitions have been made with InSb receivers using either the 0.9 m telescope of the Kuiper Airborne Observatory (KAO) or at the 3 m NASA Infrared Telescope Facility (IRTF) — see, e.g., refs [1,2] — using the InSb receiver constructed at Caltech [3-5]. The beamwidths obtained with those receivers are ~ 3 arcmin and ~ 55 arcsec respectively; in contrast, the diffraction limited beam FWHM for the JCMT at this frequency is only 10 arcsec.

The fundamental principles of operation of the InSb hot-electron bolometer mixer are described in Phillips[4] and references therein. The mixer responds to signals at frequencies which differ from that of the incident local oscillator by less than the reciprocal time constant of the electron-gas in the crystal lattice: for InSb this time constant is ~ 10^-7 sec, giving a maximum intermediate frequency (I.F.) of about 2 MHz. This has two consequences: first, the mixer is intrinsically narrow-band, the instantaneous observing bandwidth being less than or comparable with the expected width of the astronomical line; second, the receiver can be sensibly operated in double sideband mode, since the two sidebands are separated only by a narrow band of perhaps 200 kHz centered on the L.O. frequency, and are substantially wider than this gap. Spectra can be measured by sweeping the frequency of the local oscillator across the band of interest, and taking data at each individual frequency point in the band. Thus, when comparing the noise temperature obtained from a receiver of this type with that from a broad-band detector, using for example Schottky-diode or SIS detectors, the narrow-band noise temperature should be multiplied by a factor of \sqrt{2N}, where N is the number of narrow-band spectral channels observed.

InSb receivers remain competitive with the current generation of Schottky receivers (which typically have SSB noise temperatures of ~ 7000 K) purely