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Memorandum

Subject : Test of RAL/U²T photomixer at 660 GHz

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The RAL/U²T photomixer has a nominal bandwidth of 75-110 GHz (W-band), and has a WR-10 waveguide output flange. This device is described in detail elsewhere.[1,2] The RF output of the device at frequencies from 100 to 700 GHz has been measured using a Fourier-transform spectrometer at Rutherford Appleton Laboratories.[3] These measurements showed available power above 600 GHz in excess of 100 nW. A Hot-Electron Bolometer (HEB) receiver was available for making a very sensitive measurement of the RF output power of the photomixer at 660 GHz. Useful RF power is available at this frequency despite several limiting factors: the photomixer was designed for the lower frequency range, the WR-10 waveguide is severely overmoded at 660 GHz, and the photomixer is operated well above its 3 dB bandwidth. The purpose of this measurement was not to demonstrate adequate power for a direct photonic local oscillator application, but rather to measure the characteristics of the photonic signal through a low noise submillimeter receiver and backend electronics for the first time. A dual laser and photomixer system such as the one demonstrated here would have potentially useful application as a photonic calibrator system on millimeter and submillimeter telescopes. The HEB receiver used in the test belongs the Smithsonian Astrophysical Observatory and was in use as an installed receiver at the Submillimeter Telescope (SMT) operated by the Steward Observatory of the University of Arizona.[4]

Fig. 1 shows the basic setup. The receiver was double sideband with quasi-optical LO injection through a Martin-Puplett diplexer. The IF frequency was 1.8 GHz with a 600 MHZ bandwidth. A second IF conversion places the band center at 3.5 GHz. The calibrator signal is injected through the RF (sky) port of the Martin-Puplett, using a conventional 75-110 GHz pyramidal feed horn. No great effort was made to try to select an optimum feed for this test. Two lasers were used, a fixed wavelength fiber laser and a tunable external cavity laser. A fiber amplifier was also used to equalize the contributed power between the relatively low power tunable laser and the high power fiber laser. The lasers were tuned to 660 GHz by first tuning them to a very low frequency (100 MHz) and then verifying the difference frequency with a low frequency commercial photodetector and a spectrum analyzer. The tunable laser was then tuned by changing the wavelength by 5.50 nm, which is roughly 660 GHz. After a short while of fine tuning with piezo driven mirror of the tunable laser the signal appeared in the IF. The procedure was surprisingly easy. The 3.5 GHz IF signal is shown in Fig. 2. Next the signal was routed through the backend electronics and a spectrum was taken with the antenna in total power calibration mode. The injected photonic signal

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[1] ALMA memo #396, "A Photonic MM-Wave Reference and Local Oscillator Source," P. G. Huggard & B. N. Ellison (Rutherford Appleton Laboratory, Chilton), P. Shen, N. J. Gomes & P. A. Davies (University of Kent, Canterbury), W. P. Shillue, A. Vaccari, W. Grammer & J. M Payne(NRAO, Tucson), 2001-11-21

[2] P. G. Huggard, B. N. Ellison, P. Shen, N. J. Gomes, P. A. Davies. P. Shillue, A. Vaccari, J. M Payne, "Efficient Generation of Guided Millimeter-Waves by Photomixing," IEEE Photonics Technology Letters, Feb. 2002, Vol. 14, No. 2, pp. 197-199

[3] P.G. Huggard, B.N. Ellison, private communication

[4] Many thanks to Harry Fagg of Steward Observatory for use of the receiver and help with the measurement.

saturated the Acousto-Optic Spectrometer (AOS) backend and had to be reduced in strength by 20 or 30 dB in order to take a spectrum. The resulting spectrum is shown in Fig. 3.

The HEB receiver noise temperature was measured to be 600 deg K. Using this as a calibration, and measuring the IF power after injection of the photonic signal, the RF power was determined to be approximately 1 nW (before signal power reduction required for Fig. 3). It must be kept in mind that this is the signal strength actually coupled to the HEB mixer after propagation through the Martin-Puplett, and includes mismatch in the WR-10 waveguide, overmoding effects, loss and overmoding in the pyramidal feed horn, misalignment of the feed, and mismatch of the feed to the receiver RF port beam waist. It is not unlikely that 100 nW or more of power could have been measured with more effective coupling of the photomixer to the receiver. Nevertheless, as can be seen from Fig. 3, there is more than enough power available for the photonic signal to be useful as a telescope calibration tone.

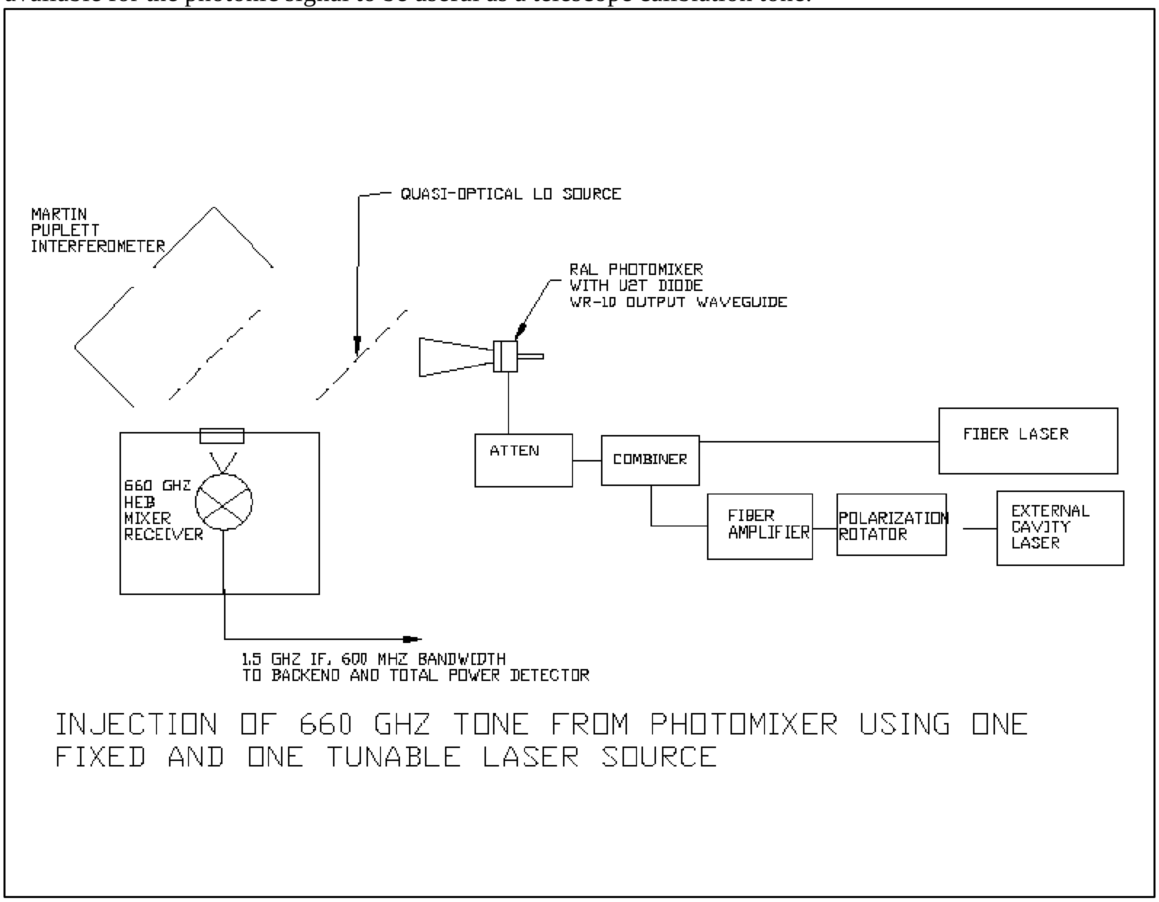

Figure 1 - Schematic of test setup for measurement of RAL/U2t photomixer at 660 GHz

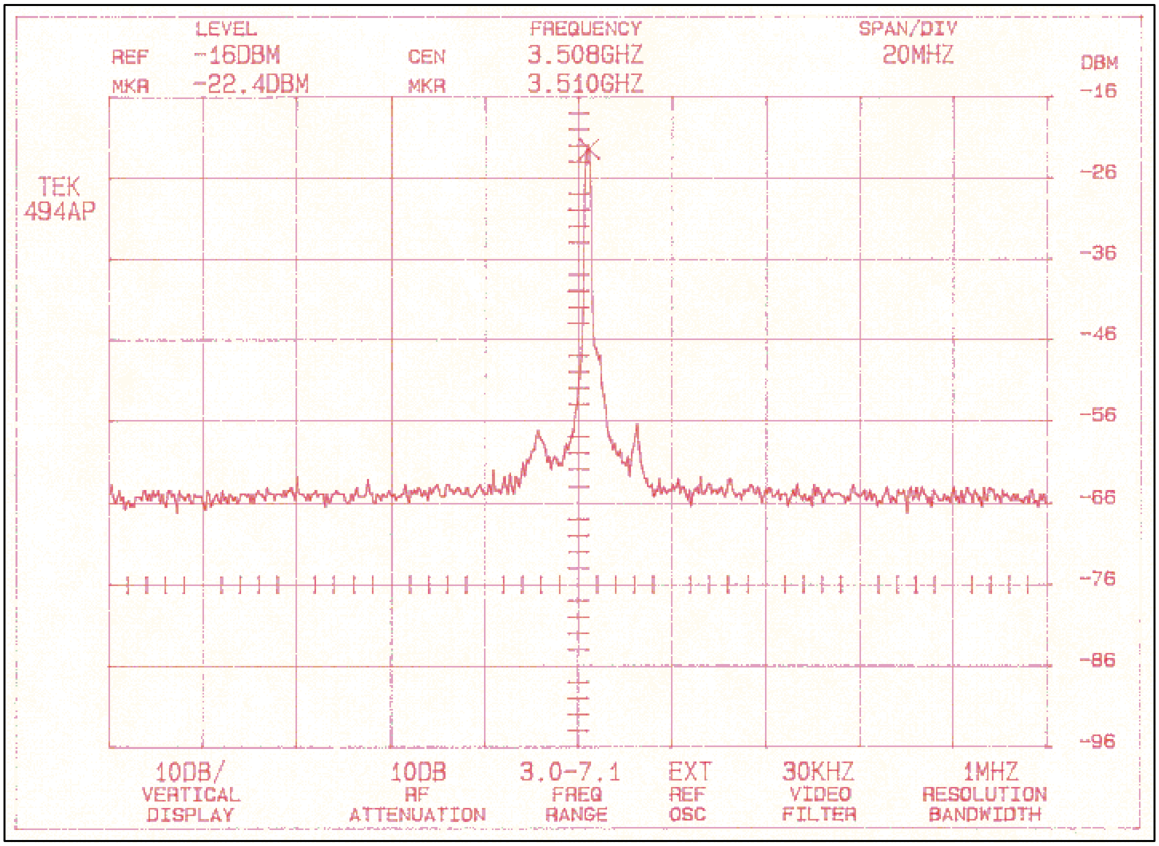

Figure 2 - Spectrum of 3.5 GHZ IF of Hot Electron Bolometer Receiver with Injected Photonic Signal at 660 GHz

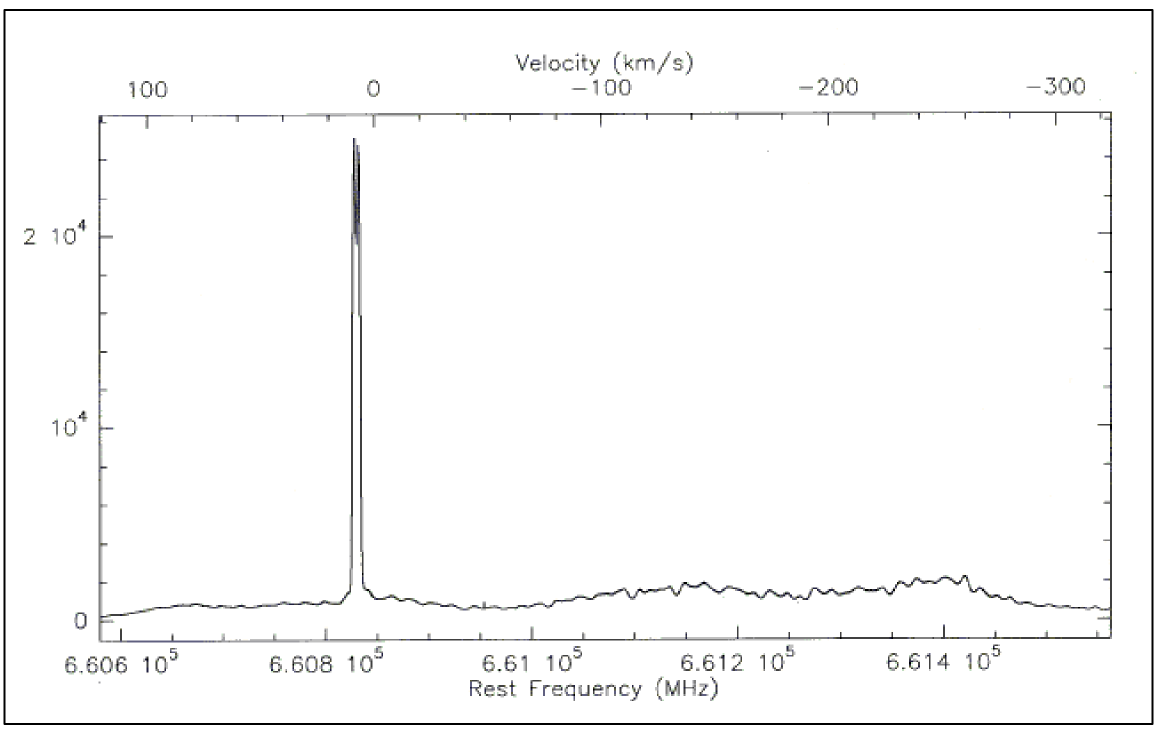

Figure 3 - Spectrum of Photonic signal taken in Astronomical Total Power Calibration mode through Acousto-Optic Spectrometer Backend