High-power broad-band room-temperature 2.46-2.70 THz LO sources to enable high-spectral resolution mapping of HD and [NII]

Jose V. Siles[1], Jonathan H. Kawamura[1], Robert H. Lin[1], Choonsup Lee[1], Imran Mehdi[1], Paul F. Goldsmith[1] and Jorge Pineda[1].

Understanding the structure and dynamics of ionized gas in star forming regions is critical for exploring the effect of radiative feedback of massive stars into the interstellar medium. Stellar feedback is a key driver of galaxy evolution, and the ionized gas is an important tracer of these processes. A particularly powerful probe of the ionized gas is the far-infrared fine-structure lines of ionized nitrogen. These lines are not hindered by dust extinction and can readily propagate through the plane of the Galaxy. The intensity ratio of the [NII] 122 µm (2.46 THz) and 205 µm (1.46 THz) lines is a key diagnostic of the electron density of the gas, and therefore can be used in the position-position-velocity space to determine the 3D distribution of ionized gas densities in star forming regions. This information is crucial for understanding the process of star formation and the effect that stellar feedback has in the regulation of star formation in galaxies. However, high-spectral resolution observations of the [NII] 122 µm have not been yet performed due to the lack of powerful local oscillator sources and the difficulty of performing observations at SOFIA flight altitudes. Future balloon-borne and space-born platforms (e.g. OST) will require high-power LO sources able to enable array receivers in the 2.5 THZ range. These LO sources need to be able to operate at room-temperature and be efficient in order to minimize the dc power consumption. Broadband operation between 2.46 THZ and 2.7 THz is required to cover the important HD 1-0 line. HD is considered the best tracer of the gas mass in protoplanetary disks, which is currently not well-constrained.

Current state-of-the-art room-temperature 2.5-2.7 THz sources (JPL) produce only 3-14 µW in the 2.5 THz frequency range [1], with powers levels under 3 µW at the [NII] and HD frequencies. The 2.7 THz receiver of GREAT on board SOFIA features a LO source with output power levels <3.5 µW in this frequency range [2] (Virginia Diodes), barely enough to pump a single Hot-Electron-Bolometer (HEB) based receiver unless the source is cryogenically cooled. None of these sources provide enough LO power to enable observation of the [NII] 122 µm line, and they are far from being able to allow array receivers in this frequency range.

In order to overcome this issue, we planned to update one of the x3x3x3 2.7 THz Schottky diode based frequency multiplied LO chains reported in [1] with (i) new high-performance 300 GHz and 900 GHz tripler designs based on the successful JPL on-chip power-combined topology used in the THz sources presented in [3], and (ii) a novel biasable 2.4-2.7 THz tripler design to replace the former unbiased 2.5 THz tripler design used in [1]. The goal is to provide output power levels in excess of 30 µW to enable high-spectral resolution mapping of HD and [NII], similar to the power levels of the recently demonstrated JPL 16-pixel 1.9 THz source and the 4-pixel 1.9 THz source successfully flown on-board the Stratospheric Terahertz Observatory for [CII] mapping. Preliminary results with only the new 900 GHz tripler stage added are shown in Fig. 1. A factor of four improvement in power (up to 20 µW) is already achieved together with a considerable increase in bandwidth. The injected power at W-band has not been increased so the improvement is completely due to the higher performance of the new multiplier designs. In the conference, we will present these new designs and further tests showing the additional improvement once the rest of stages are updated with these new designs.

A new compact architecture design, significantly smaller than the one in [1] will also be presented together with a preliminary design of a 16-pixel LO source at 2,7 THz.

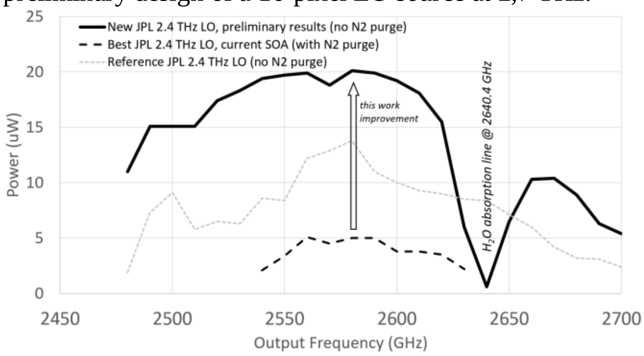

Fig. 1. Preliminary room-temperature performance of the new JPL 246-2.7 THz LO source (solid line) consisting of the reference JPL 2.4 THz LO source (dashed line) updated with on-chip power-combined frequency triplers. Current state-of-the-art results from [2], under N2 purge to remove the impact of the water absorption line, are also plotted (dotted line).

[1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109.

The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

References

[1] C. A. Duran, et al., "4GREAT: A Multiband Extension of GREAT from 490 GHz to 2.7 THz," *28th International Symposium on Space THz Technology*, March 2017.

[2] A. Maestrini, et al., "Design and characterization of a room temperature all-solid-state electronic source tunable from 2.48 to 2.75 THz", *IEEE Trans. on THz Science and Technology*, Vol. 2, No. 2, pp. 177-185, March 2012.

[3] J. V. Siles, et al., "A New Generation of Room Temperature Frequency Multiplied Sources With up to 10× Higher Output Power in the 160 GHz – 1.6 THz Range," *IEEE Trans. on THz Science and Technology*, Vol. 8, No. 6, pp. 596-604, November 2018.

NOTES: