Development of High-Power Multi-Pixel LO Sources at 1.47 THz and 1.9 THz for Astrophysics: Present and Future

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Abstract— **Two high-power room-temperature 4-pixel frequency multiplied local oscillator sources at 1.47 THz and 1.9 THz have been recently developed at the Jet Propulsion Laboratory (JPL) to enable multi-pixel heterodyne terahertz spectroscopy for astrophysics. Initial tests show output power levels per pixel in the 5-70 μW range, enough to drive Hot Electron Bolometer (HEB) based receivers. These sources are the baseline for the Stratospheric Terahertz Observatory (STO-2) balloon, to be launched from Antarctica by the end of 2015. The LO power of each pixel can be independently controlled using the dc bias of the last stage multipliers. Using dc bias in the last multiplier stage (beyond 1.4 THz) was challenging from a fabrication point of view, but it improves the circuit matching and the results show a considerable increase in the performance of the LO source (up to a factor of two in some cases). These 4-pixel modules will be the basis for a 16 pixel LO system currently under development. Novel designs with superior power handling capabilities have also been demonstrated and will be introduced to increase the performance and compactness of these multi-pixel sources.**

I. INTRODUCTION

There are many key tracers of the interstellar medium and the process of star formation in the submillimeter region of the spectrum. Many of these, including CII, NII, CO, and H_2O have been successfully observed with the Herschel HIFI instrument, which was a single-pixel system. The goal now is to develop and demonstrate focal plane arrays that can perform high resolution mapping of extended sources in a reasonable observation time frame. This will provide a major enhancement of capability for high spectral resolution imaging of submillimeter lines with STO-2 (NII at 1.47 THz and CII at 1.9 THz) and future suborbital and space platforms.

II. MULTI-PIXEL MULTIPLIED SOURCE ARCHITECTURE

The 4-pixel 1.47 THz frequency multiplied LO source (see Fig. 1) consists of a W-band (WR-10) 2-way waveguide splitter followed by W-band isolators with an approximate 1 dB insertion loss, two 150-170 GHz doublers with 25-30% conversion efficiencies, two WR-5 2-way waveguide splitters, a 490 GHz tripler module featuring four individuals tripler chips with a conversion efficiency of around 5-8%, and four 1.47 THz frequency tripler blocks. All frequency multipliers are dc bias controlled, which allows to independently adjust the LO power per pixel to match the requirements of each specific HEB mixer chip. The LO chain is driven by a Ku-band synthesizer and a Millitech AMC-10-0000N active sextupler followed by a Quinstar 79-85 GHz amplifier providing around 300-400 mW total power (150-200 mW power at the input of each 160 GHz doubler).

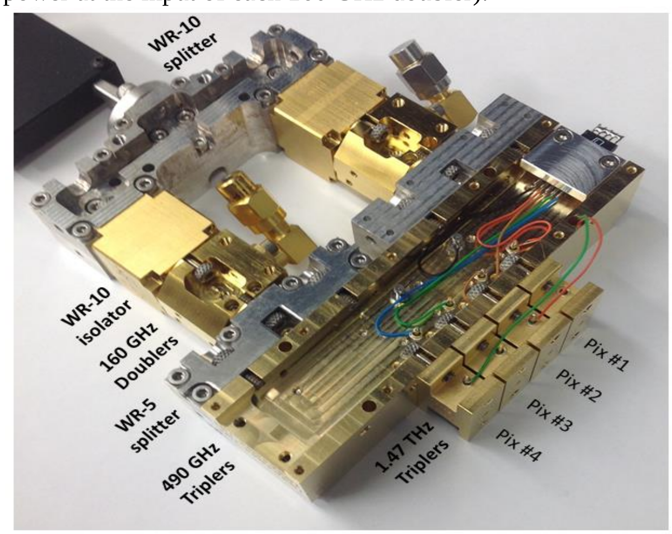

Fig. 1 Photo of the JPL 4-pixel 1.47 THz frequency multiplied LO source.

The 4-pixel 1.9 THz frequency multiplied LO source [1] (see Fig. 2) consists of a X3X2X3X3 configuration driven with a Ka-band synthesizer and two Ka-band high-power amplifiers followed by WR-28 2-way splitters to generate four independent outputs. Each amplifier produces around 1 W each resulting in ~120 mW power at the input of each of the 110 GHz triplers. The last split-waveguide block features both the 650 GHz tripler and a 1.9 THz tripler. The conversion efficiencies of the frequency multiplied stages are: ~25-30% for 110 GHz tripler stage, ~20-25% for the 210 GHz doubler stage, ~4-6% for the 630 GHz tripler stage and ~2% for the 1.9 THz tripler stage.

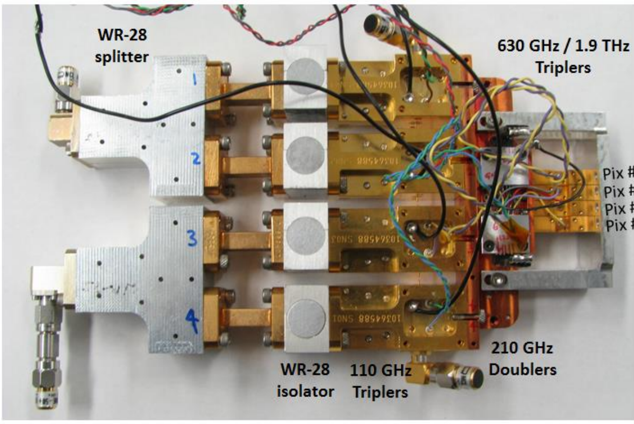

Fig. 2 Photo of the JPL 4-pixel 1.9 THz frequency multiplied LO source.

III. Results

A. *Measurements of the 4-pixel modules*

The output power per pixel for both the 1.47 THz source and the 1.9 THz source is measured using a circular to WR-10 1-inch waveguide transition and a PM4 Erickson power meter. The output power is not corrected for the transition loss. The results are presented in Fig. 3. For these tests, the dc bias lines of the multipliers in each multiplication stage were tied together, so no independent tuning per pixel was considered. The 1.47 THz triplers and the 1.9 THz triplers used in these specific tests were biasless. All the pixels, except for one pixel of the 1.9 THz source (due to a degraded 1.9 THz tripler chip), provide around 5-70 µW, which is enough to drive the HEB mixers.

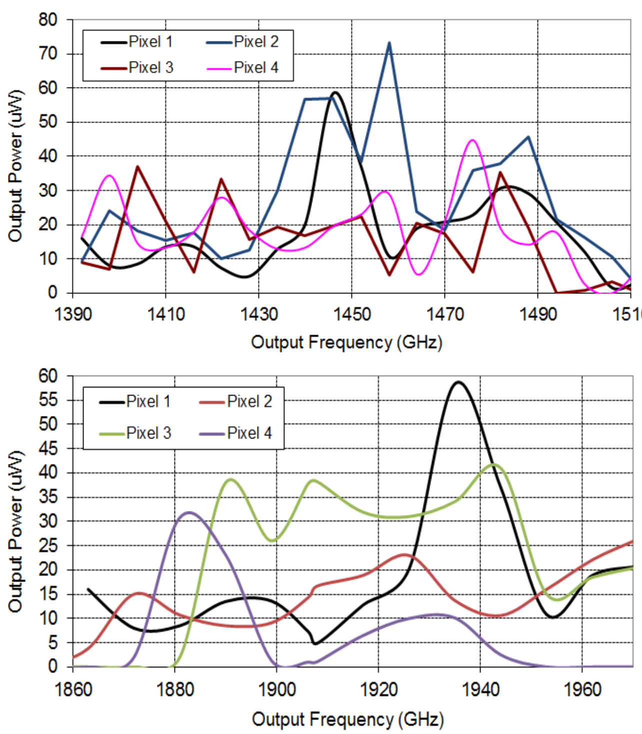

Fig. 3 Initial results of the 4-pixel sources for STO-2: Output power per pixel as a function of output frequency for both the 1.47 THz LO source (top) and the 1.9 THz LO source (bottom).

B. *Importance of using dc bias in the last stage*

Even though biasless last stage triplers were used for the initial tests shown in Fig. 3, the blocks were designed to be compatible with both biasless and biasable devices. Using biasable frequency multipliers in the last multiplier stage of these LO sources not only makes it possible to accurately control the output power per pixel, but also to compensate for fabrication variations and to increase the performance of the devices. To demonstrate this, the same design has been fabricated biasless and biasable for both the 1.47 THz tripler stage and the 1.9 THz tripler stage. These designs are shown in Fig. 4 (top) for the 1.47 THz case. It can be seen in Fig. 4 (bottom) that using dc bias can improve considerably the output power per pixel of these frequency multiplied LO sources. In particular, the output power at 1.47 THz increases from ~15 µW to ~ 30 µW. This is the first time a direct comparison between same designs (biasless and biasable) is provided above 1.4 THz.

A similar comparison at 1.9 THz will be provided in the final paper, as well as frequency sweeps using the biasable option for the last stage multiplier for both the 1.47 THz and the 1.9 THz 4-pixel LO sources.

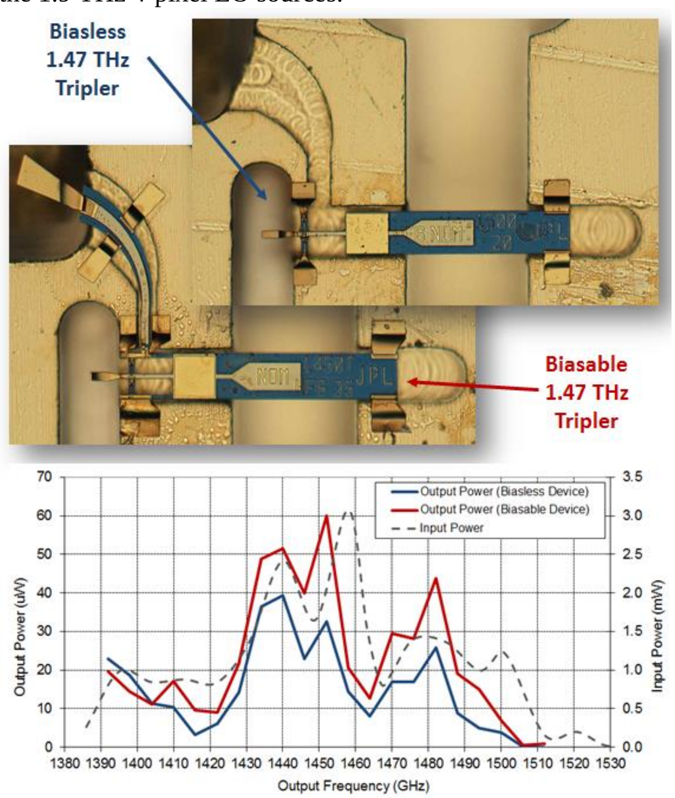

Fig. 4 Photo of the 1.47 THz frequency tripler device: biasable (top left) and biasless (top right). Output power vs. output frequency of one of the pixels of the 1.47 THz LO source using the biasless 1.47 THz tripler –blue line- and the bias able 1.47 THz tripler –red line- (bottom).

IV. Future Plans and Conclusions

At the time of abstract submission, both 4-pixel sources have been initially tested. However, we are still working in identifying the best devices to maximize the bandwidth and output power per pixel. Most of the pixels meet already the requirements for STO-2. Only one of the pixels of the 1.9 THz chain (pixel 4) is low due to a degraded 1.9 THz tripler device that we will replace soon. The 1.9 THz LO sub-system has been already successfully used in the simultaneous pumping of two HEB NbN mixers. The final stage bias will increase the stability of the receiver by controlling the output power of each pixel though a feedback loop with the HEB mixer currents controlled by the NI-DAQ.

These LO modules will be the basis for the construction of larger array configurations (8 to 16 pixel) for future suborbital missions such as the Galactic/Extra-Galactic Ultra-Long Duration Balloon Spectroscopic/Stratospheric THZ Observatory (GUSTO) (see Fig 4). For larger number of pixels sources we will need to use more efficient multiplying structures in order to increase compactness, reduce the overall power consumption and reduce assembly and test complexity (by decreasing the number of chips).

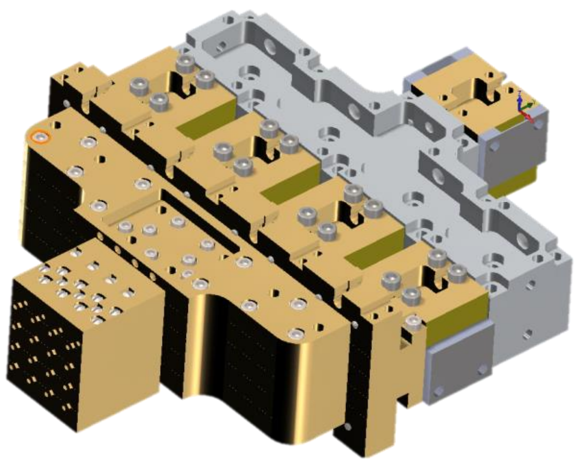

Fig. 4 Possible configuration for a 16-pixel 1.9 THz LO subsystem using vertically stacked thin metal plates.

For example, we have recently demonstrated frequency doublers in the 200 GHz range able to handle more than 500 mW input power with state-of-the-art efficiency (~25%) (see Fig. 5), as well as on-chip power combined structures able to increase the power handling capabilities of a single chip by a factor of four in the 550 GHz range. These results will be discussed, as well as how the inclusion of these new devices will simplify the build of 16-pixel sources in these frequency ranges.

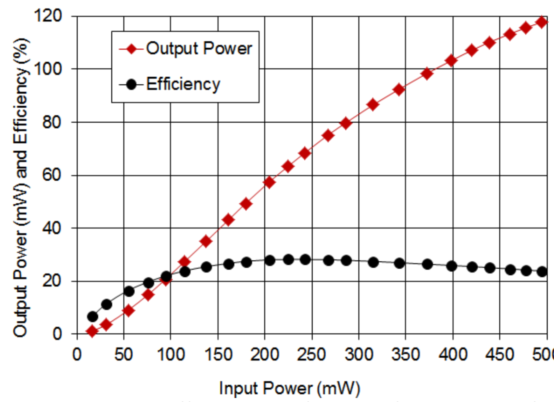

Fig. 5 Output power and efficiency as a function of input power of a high-power single-chip 190 GHz doubler recently demonstrated at JPL.

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REFERENCES

[1] J. V. Siles, I. Mehdi, C. Lee, R. Lin, J. Kawamura, E. Schlecht, P. Bruneau, and P. Goldsmith, “A multi-pixel room-temperature local oscillator subsystem for array receivers at 1.9 THz,” in *Proc. SPIE, Ground-based and Airborne Instrumentation for Astronomy V*, 2014,.