Compact 1.9 THz Multi-Pixel Local Oscillator Chain

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***Abstract* — Single-pixel heterodyne receivers are severely limited in their capability to map large areas on the sky. We report on the development of THz multi-pixel local oscillator sources that ought to enable THz array receivers of the future. We demonstrate a prototype 16-pixel chain at 1.9 THz. Output power in excess of >10 microwatts has been demonstrated per pixel from this compact chain.**

Index Terms — THz multipliers, frequency multipliers, LO technology, multi-pixel receivers

I. INTRODUCTION

The details of the evolution of molecular clouds and the formation of the next generation of stars out of the dust and gas in the dense regions of the interstellar medium (ISM) remain mysterious. Velocity information, which can only be provided by high spectral resolution receivers, is required to assess the role of turbulence and gravity in determining the kinematics of the ISM and its evolution into new stars.

The interstellar medium is composed of multiple phases, distinguished by whether matter is ionic, atomic, or molecular, and the temperature and density of the matter. The 1.9 THz fine structure line of the CII gas is one of the brightest tracers of the different phases of the ISM [1]. The [CII] line is the main cooling line in the ISM that is heated by newly formed starts and is therefore a tracer of star formation. To date only single pixel receivers have been utilized to make these measurements. However, only limited areas can be mapped and thus a comprehensive understanding of ISM dynamics is still missing. A multi-pixel heterodyne receiver is ideally suited for measuring the velocity resolved spectra of [CII] as well as other tracer gases in the ISM and would be needed for future space missions. We have been working on developing such a subsystem and will outline the progress to-date along with prospects for the future.

II. MULTI-PIXEL THZ SOURCES

There are a number of solid-state approaches for generating THz radiation including photomixers [2], Resonant Tunneling Diodes (RTDs) [3] and Heterostructure Barrier Varactors (HBVs) [4]. However, for the THz range, Schottky diode based frequency multipliers have been the most popular due to compactness, relatively low dc power consumption, acceptable performance at room-temperature (with possibility of improvement upon cooling), high-fractional bandwidth (15-20% typical), frequency agility and tunability, temperature stability, and spectral purity. Recent progress in multiplier sources has been described in more detail elsewhere [5]. In recently developed competitive approaches such as Indium Phosphide based MMICs, output power levels of approximately 50 mW in the 200 GHz range[6], 7 mW in the 400 GHz range, 2-3 mW in the 600 GHz[7] range and ~1 mW at 850 GHz [8] have been demonstrated using power combining techniques. Beyond 1 THz, devices such as Quantum Cascade Lasers (QCL) are quickly progressing and offer attractive power levels but require cryogenic cooling. Moreover, due to poor beam quality, the useful output power is drastically reduced as reported in [9]. QCLs have other disadvantages such as the need for frequency locking and limited bandwidth.

Availability of high power amplifiers, both at W-band as well as Ka-band utilizing GaN technology [10] have now made it possible to have compact modules that can provide power in the range of 1-3W in the 90-110 GHz range. Advanced Schottky diode fabrication technology, along with better thermal design and utilization of on chip power combining topologies, have enabled Schottky multiplier chips that can efficiently handle the increased input power. Accurate device models, more precise control of waveguide dimensions during CNC machining, and better circuits have increased efficiency and reliability of assembly providing for next generation of multiplied sources.

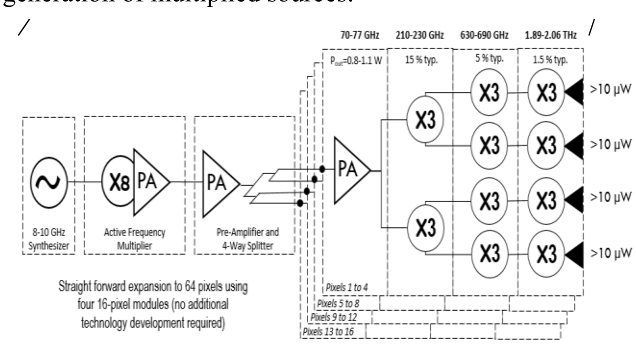

Figure 1: W-band GaN power amplifiers make it possible to design 1.9 THz sources with only 3 multiplier stages. The large input power from the amplifiers is effectively handled by designing on-chip power dividing and power combining topologies.

Two distinct approaches can be adopted for developing multi-pixel receivers and specifically the LO needed for such systems. In the first approach, a single-pixel high-power source is constructed that puts out enough power to pump the desired number of mixers. In such an approach a device such as a Fourier grating is used to multiplex the LO signal. The second approach is to build a multi-pixel LO source where there is a one-to-one correspondence between the mixer elements and the LO elements. This is the approach that has been adopted here. This approach offers a number of advantages as it does not stress any single anode with high temperature and provides some cushion from single point failures. Moreover, it allows for optimizing power for each pixel, which is critical for attaining optimum sensitivity.

Scheme for a compact 16-pixel source is shown in Fig. 1. This is based on utilizing GaN amplifiers working in the 70-77 GHz range with >1 W of output power. Such amplifiers are now available and make it possible to design multi-pixel chains. The first stage tripler is a single chip that can divide the power and multiply it. Either a dual-chip or quad-chip topology can be utilized. A quad-chip realization is shown in Fig. 2. This particular chip can handle close to 3 W of input power and can produce around 500 mW at the desired frequency range.

The second stage tripler is based on the dual-chip architecture and can produce 20-25 mW of output power. The compact 16-pixel chain is shown in Fig. 3. This chain, and in particular the last stage that includes a built-in horn, was machined by developing a meticulous process for achieving mechanical tolerance of less than a few microns. Spacing between the horns is 2.5 mm but can be varied according to the optical design of the receiver. Typical measured results from the 1.9 THz source are shown in Fig. 4. These measurements are all at room temperature and can be further improved if the multiplier chain can be cooled to moderate temperatures such as 120-150K.

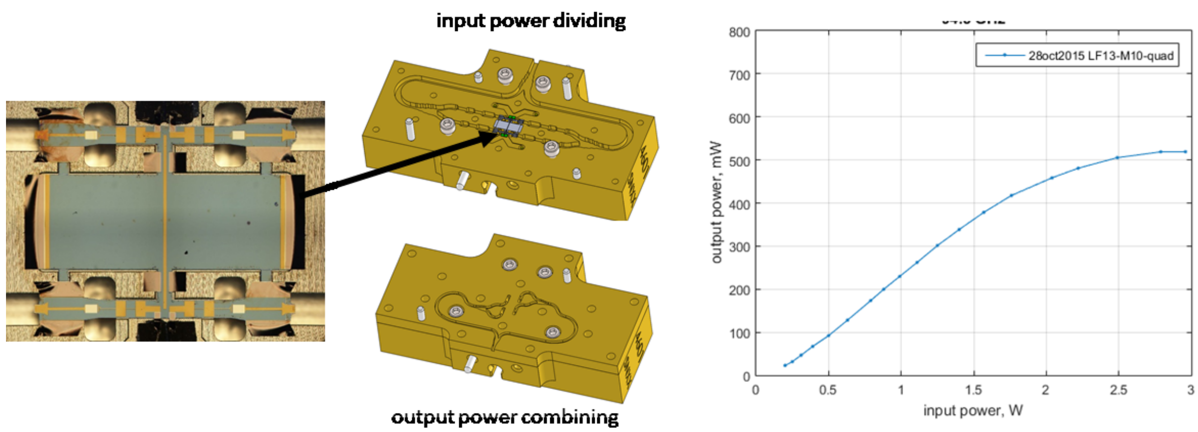

Figure 2: A quad-chip first stage tripler has been designed, fabricated and tested. The chip is mounted in an E-split waveguide block and tested at room temperature.

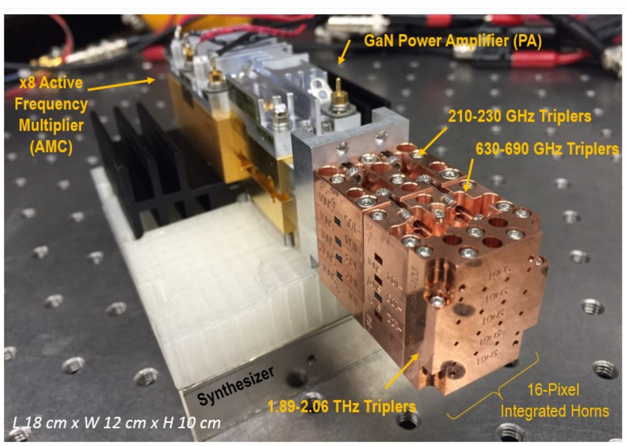

Figure 3: A compact 16-pixel LO chain has been built with diagonal horns at the output. This can directly couple power to the hot electron bolometer based mixers.

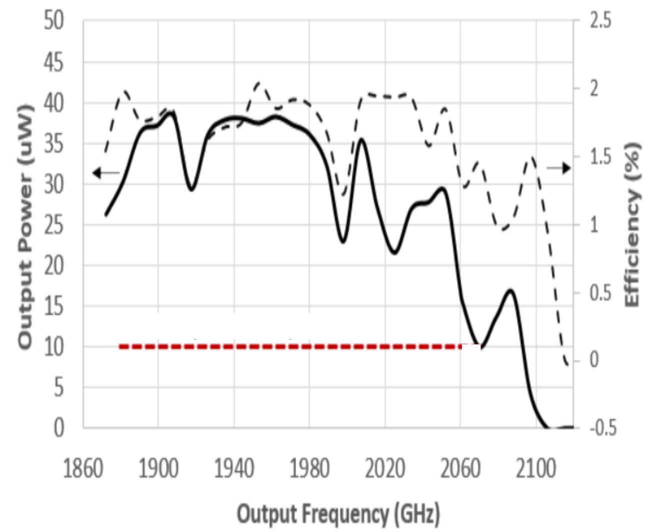

Figure 4: Nominal power requirement of 10 microwatts is demonstrated across a wide frequency range. This power level is sufficient to pump hot electron bolometer mixers.

III. Summary

Recent advances in solid-state power amplifiers and precision machining capability has made it possible to design and implement multi-pixel LO sources. A 16-pixel LO chain working at 1.9 THz has been described. Output power close to 40 microwatts per pixel has been recorded from this chain at room temperature. This LO chain enables multi-pixel receivers for future space applications.

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