A tunable, high power source for GUSTO's local oscillator at 4.74 THz

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***Abstract*—The Galactic/Extra Ultra long Duration Balloon Spectroscopic-Stratospheric Terahertz Observatory (GUSTO), is a NASA balloon-borne project and is scheduled for launch in late 2022. The balloon will carry a spectroscopic telescope that will detect three brightest emission lines from interstellar medium. GUSTO measurements will shed light on the life-cycle of the gases in the Milky Way and Large Magellanic Cloud (LMC). In this talk, we will discuss the details of a quantum cascade laser used in the local oscillator for detecting the oxygen line at 4.74 THz.**

***Keywords*—THz QCL, GUSTO, OI line**

I. Introduction

Terahertz (THz) radiation is loosely defined by the frequency range of 0.5 to 10 THz (1 THz = 10^{12} cycles per second). The THz spectral range has found unique applications in astronomy owing to a vast amount of THz radiation from the interstellar medium (ISM), the matter between stars consisting of low-density gases and dust in planetary atmospheres [1]. The nitrogen line [NII] at 1.4 THz, the carbon line [CII] at 1.9 THz, and the oxygen line [OI] at 4.7 THz are among the brightest emission lines in ISM. [OI] line is rich with information about star formation as it mostly probes warm natural gas heated by massive newborn stars [1]. This spectral line has been inaccessible until recently due to the lack of local oscillators (LOs) in THz frequencies. The invention of THz quantum cascade laser (QCL) [2] made it possible to perform heterodyne observation on this line, and even map it within the Milky Way galaxy. Following up on the STO-2 successful flight, which demonstrated the feasibility of a balloon borne terahertz telescope, GUSTO will be launched in late 2022. GUSTO will survey 124 square degrees of the Milky Way and all of the Large Magellanic Cloud (LMC) in three important interstellar lines with higher angular and velocity resolution compared to previous measurements. The required performance metrics for the local oscillator at 4.7 THz were calculated by researchers at SRON and the University of Arizona to ensure the proper performance of HEB receiver array and phase grating integrated with the optical set-up. By considering the optical loss due to the non-Gaussian beam pattern of THz QCLs, phase grating, and the available cooling power, the overall performance metrics were calculated and listed in Table I. The continuous frequency tunability is essential for detection of large Doppler shift for mapping in the Milky Way. The low cooling power in GUSTO (3.5 W at 60 K) is mainly due to the limits on weight and heat exchange with environment for sterling coolers in balloon borne projects (GUSTO). This higher operating temperature with lower cooling power posts additional challenges in the LO development as compared to previous missions. In this talk, the development of a unidirectional antenna coupled third order distributed feedback grating (UADFB) [3] at 4.744 THz to overcome these limitations is discussed.

TABLE I
GUSTO minimum requirements for the local oscillator at 4.74 THz

performance metric	requirements
nominal frequencies (GHz)	4740.0, 4741.6, 4743.6, and 4749.2
c.w. output power	>1.6 mW at 55 K in single lobe
tunability	1.5 GHz at nominal frequencies
heat dissipation	< 2.7 W at 55 K, < 3.5W at 60 K

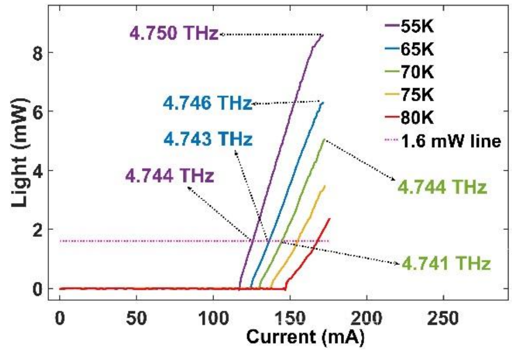

Fig. 1. Light-Current with measured frequencies indicated in the inset.

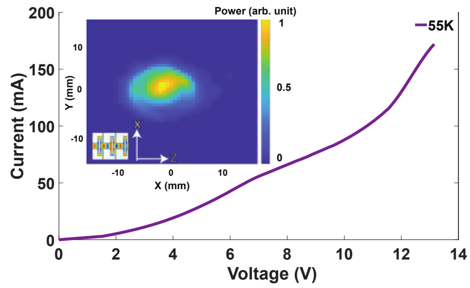

Fig. 2. Measured Voltage-Current and beam pattern as inset.

II. Results

The light-current-spectrum results for a flight ready device are shown in Fig. 1. A combination of red sift in lasing frequency with temperature and blue shift with electrical bias (Stark shift) in in one of the UADFB devices could cover the entire frequency band required by GUSTO. The large tuning with electrical bias is inherent in intersubband lasers However, larger tuning with injection requires high dynamic range, high power, and a robust single mode operation offered in the UADFB platform. Because of near perfect phase matching for this device, a tight single lobe beam is achieved. The measured beam pattern without any collimating optics is shown in Fig 2.

References

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