A compact CW-THz spectrometer for applications to gas phase identification and quantification of multiple species.

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***Abstract*—A CW-THz spectrometer using photomixing has been constructed using two external cavity diode lasers and a tapered semiconductor optical amplifier. One diode laser is stabilized to atomic transition of Rubidium and the second is stabilized with a terahertz beatnote separation by means of a low contrast Fabry-Perot interferometer. The line intensity and self broadening coefficient of carbonyl sulphide was determined to validate the spectrometer performance.**

***Index Terms*— millimeter wave frequency conversion, millimeter wave spectroscopy, semiconductor lasers**

I. Introduction

THE use of monochromatic continuous wave terahertz (THz) sources can allow gas phase concentration measurements to be made in subjects heavily contaminated by aerosols and particles [1,2]. The species selectivity and hence discrimination may be optimized employing a source with a spectral purity similar to the Doppler width of molecules of interest. Photomixing or optical heterodyning offers a purity in the order of 3 MHz, compared to the Doppler FWHM of 1.6 MHz (at 1 THz) of OCS for example. Existing photomixing sources are generally limited to laboratory studies due to the size and complexity of the lasers and frequency stabilization required. This frequency range is particularly suited to the measurement of small polar molecules many of which present an interest as atmospheric pollutants. The development of a CW-THz spectrometer suitable for use outside of a laboratory environment is required if this waveband is to demonstrate its advantages for pollution monitoring, high selectivity and reliable measurements in the presence of aerosols.

II. Instrument Architecture

An optical beatnote at the required terahertz frequency is generated by mixing two identical External Cavity Diode Lasers (ECDL) operating at 780 nm. The power available from each laser is 50mW, in order to increase the optical power incident on the photomixer a tapered semiconductor optical amplifier (Toptica, BoosTA) was used to simultaneously amplify the emission of both lasers providing powers up to 1 W. The photomixers used where fabricated at the Institut d'Electronique de microelectronique et de nanotechnologie at Lille using GaAs-LTG yielding charge carrier lifetimes in the order of 300 fs [3]. Broadband spiral antenna allow single devices to cover the frequency range from 0.3 to 3 THz. The highly divergent THz radiation is collected by a semi-hemispherical silicon lens before being collimated by a metallic parabolic mirror. The collimated THz beam passes through the sample chamber before being focused onto the detection element of a Silicon bolometer by a second parabolic mirror.

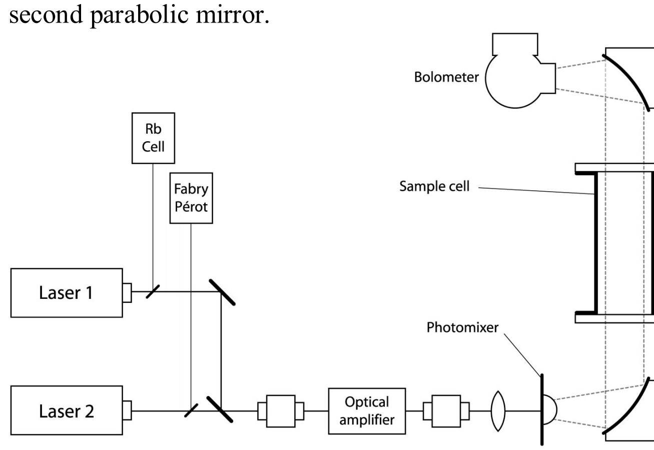

Fig 1. CW-THz spectrometer consisting of two ECDLs an optical amplifier, and a photomixer. The THz radiation is collimated, propagated through a sample cell before being detection by a bolometer.

In order to achieve the required spectral purity a laser frequency stabilization scheme is implemented. The use of commercially available components and relatively a simple stabilization scheme should ensure that this system is suitable for deployment in environments such as industrial sites previously inaccessible to such instruments. The first ECDL is stabilized to a saturated absorption of Rubidium by means of gas cell with associated normalization electronics (CoSy, TEM Messtechnik). Frequency correction signals are generated (LaseLock, TEM Messtechnik) and applied to the laser [4]. The spectral purity expected from this system is in the order of 1 MHz.

A low contrast Fabry Perot interferometer (iScan, TEM

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Messtechnik) is used to stabilize the second ECDL. Unlike many Fabry Perot systems that can only provide information at the resonant frequency the advantage of this low contrast interferometer is that it is capable of providing a stabilization signal at any frequency. Hence this laser can frequency scanned by means of the cavity grating peizo with an active frequency correction being provided by the interferometer. To verify the correct operation and stabilization of the lasers a microwave beatnote was measured using a fast photodiode and a spectrum analyzer, fig 2. The spectral purity of the beatnote was determined to be 3 MHz at –3 dB.

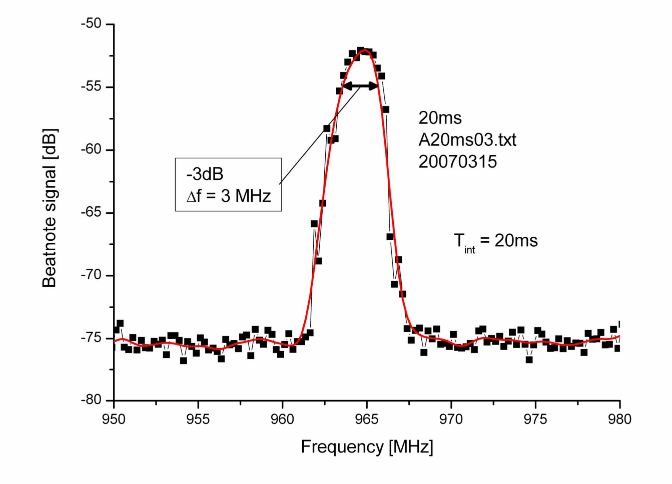

Fig 2. Beatnote measurement with an integration time of 20 ms.

III. Gas Phase Spectroscopy

To establish the utility of this spectrometer for gas phase subjects the line intensity and self-broadening coefficient of carbonyl sulphide (OCS) were determined and compared with values obtained by a similar spectrometer using Ti:Sa lasers [5].

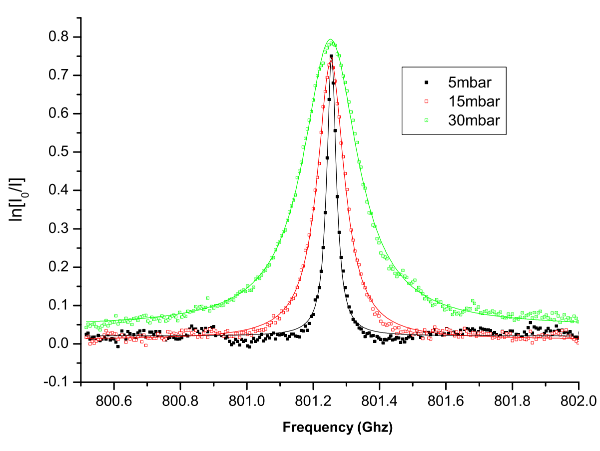

Fig 3. Typical spectra of OCS. Transition at 802.8 GHz (J=65→66) and T = 293 K.

Three transitions were measured, 619.2 GHz (J=50→51), 717.6 GHz (J=58→59) and 802.8 GHz (J=65→66), at pressures in the range 5 mbar to 50 mbar. Each measurement was normalized by data recorded under equivalent conditions with the sample cell empty. The optical density of the sample was determined and fitted using a Lorenztian function as the collisional broadening is greater than the Doppler width and the instrument spectral purity. Typical data are presented in fig 3. The line intensity was determined by examining the line strength as a function of the pressure, table 1. In a similar fashion the self-broadening coefficient was determined using the half width half maximum, table 2.

Frequency [GHz]	Line strength [$MHz.bar^{-1}.cm^{-1}$]	
	ECDL	Ti:Sa
619.2	947(5)	1000(30)
717.6	630(10)	608(8)
802.8	352(3)	365(6)

Table 1. Line strength of OCS measured by phomixing spectrometer using ECDL and Ti:Sa lasers.

Frequency [GHz]	Self-broadening [$MHz.mbar^{-1}$]	
	ECDL	Ti:Sa
619.2	3.88(2)	4.00(15)
717.6	3.26(2)	3.15(4)
802.8	3.30(2)	3.06(3)

Table 2. Self-broadening coefficient of OCS measured by phomixing spectrometer using ECDL and Ti:Sa lasers.

The values obtained by the different spectrometers are in reasonable agreement demonstrating the suitability of this CW-THz source for high resolution spectroscopy of gas phase species.

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