Laboratory based terahertz spectroscopy for ice desorption studies of the interstellar medium

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During the process of star formation in the interstellar medium (ISM), gas molecules, such as H_2O, CO or CO_2, become trapped on the surface of dust particles (grains) and form ice layers. Within this medium, complex molecules are created by chemical reactions (e.g. HCOOH or CH_3OH). The molecules thus formed are subsequently released (desorbed) though predominantly thermal and non-thermal processes. Non-thermal desorption[1] is due to ionization of the ice by cosmic rays, UV photon absorption, collision between dust particles and chemical reactions on surface (recombination). Studying the chemistry of desorbed species via laboratory-based experiments, and which emulate the physical processes of desorption, provides valuable additional astrophysical information which potentially supports and corroborates astronomical observations and increases our understanding of the desorption mechanisms. This, in turn, increases our knowledge of star formation and star forming regions. However, the majority of ice desorption experiments use absorption spectrum analysis (reflection-absorption infrared spectroscopy); an experimental technique which does not entirely reflect the astronomical observational method, e.g. as used by the Atacama Large Millimetre and submillimetre Array (ALMA) which predominantly observes molecular species in emission. To provide a more direct comparison with observational astronomy performed via ALMA, and to independently study interstellar chemistry, we are developing a sensitive laboratory-based high-spectral-resolution terahertz spectrometer that will allow us to directly observe the spectral emission signatures of molecular species under representative environmental conditions, i.e. those found within the interstellar medium (ultra-high vacuum - $<10^{-7}$mbar and low ambient temperature – 10 K).

As a first step towards the creation of a dedicated facility, we have modified a terahertz spectrometer originally conceived for Earth atmospheric observation. The core of the instrument is a heterodyne radiometer comprising a sub-harmonically pumped image rejection Schottky diode mixer[2] (SHIRM), a local oscillator, and a high-speed digital spectrometer[3], and which we have interfaced with a low pressure 1m gas cell. Combined together, these components provide a highly sensitive single-sideband detection system operating in the region of [320 GHz – 360 GHz] and partially mirroring the spectral range of ALMA band [275 GHz – 373 GHz]. Molecular species are viewed through the cell by the radiometer against a cold (77K) background target and a spectral resolution of 1 MHz, with an instantaneous bandwidth of 4 GHz/sideband, allows spectral profiles to be characterized. We describe the instrument concept and construction, and present preliminary spectral measurements.

References

1. H. J. Faser, M. P. Collings, and M. R. S. McCoustra; Review of scientific Instrument, 73, 5 (May 2002), 263-269.
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3. Spectrometer developed and provided by Star Dundee, Ltd., http://www.star-dundee.com