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Application of time-tagged photon imaging for trace gas measurement using cavity enhanced absorption spectroscopy

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Optical spectroscopy is a powerful tool for the measurement of atmospheric gases and changes to atmospheric composition. For example, global measurements of ozone (and other species) are updated daily from satellite observations using essentially the same spectroscopic principles. The strength of spectroscopic methods at visible, UV or IR wavelengths lies in (i) their selectivity, which makes it possible to target individual compounds unambiguously, and (ii) their sensitivity, which makes them is capable of accurately determining mixing ratios in the range 10e-9 to 10e-12.

We describe the application of a microchannel plate-based time-tagged photon imaging detector to broadband cavity enhanced absorption spectroscopy (BBCEAS). BBCEAS is technique which utilizes a high finesse cavity with a broad band light source for determination of atmospheric absorption over a range of wavelengths, to provide very high accuracy trace gas measurements. The detector tags each detected photon with a three-dimensional x,y,t coordinate which is used to identify the wavelength of each photon along the spectrometer dispersion axis (x coordinate) and simultaneously record its source, either from the cavity or reference signal from the light source (y co-ordinate). The time coordinate, t, identifies the photon arrival time. Phase shift and attenuation as a function of wavelength, for both cavity output and the light source, are determined by time-histogramming the imaged spectra.

Time-tagged photon imaging offers a unique advantage for a multi-wavelength frequency domain BBCEAS since it provides direct access to mirror reflectivity and thus photon path length, a key quantity that cannot be measured directly by conventional BBCEAS instruments. This combination of technologies provides an instrument whose calibration is a simple procedure not requiring technical input or specialist gases, and capable of automation.

We present data which demonstrate the applicability of time-tagged photon imaging to BBCEAS and preliminary results illustrating trace gas measurement accuracy.

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