Application of quantum cascade lasers in atmospheric monitoring

**INTRODUCTION**

One of the main applications of quantum cascade lasers (QCL) is in spectroscopy and particularly in trace gas measurements. Such measurements are used in a number of areas ranging from air quality, industrial or pollutant control to the monitoring of greenhouse gases responsible for global warming. Until now, all QCL-based measurements have been taken along folded absorption paths using low-pressure multiple-pass cells. Since these measurements involve sampling at a single point, the data are, in many cases, only locally representative and therefore not suitable for modelling applications. The major goal of this project is the development of new QCL-based spectroscopy techniques for monitoring atmospheric trace-gases and atmospheric parameters such as temperature and turbulence over extended optical paths in the open atmosphere. Open-path measurements, in contrast to point measurements, supply space-averaged data suitable for model applications and do not show sampling alterations.

Open path setup. Path distance ranges from tens of meters to several kilometres in our experiments

RESEARCH OBJECTIVES

Open-path trace gas measurements

A major task of the project is to develop new methods for open-path measurements of trace gases. Despite their low concentration (ppt to parts of percent), trace gases play an important role in atmospheric chemistry and physics, industrial and pollution control. So far we have successfully measured ozone, CO₂, water vapour, and ammonia in the open atmosphere over optical paths of up to 6 km. An example of an ozone measurement taken over a 440 m optical path is shown in the figure below.

Comparison between ozone measurements taken with QCL open-path system and UV photometric ozone monitors.

Increasing the number of detectable species, including major greenhouse gases such as CH₄ and N₂O or fire products like CO, HCL and HCN, is an important objective of the team.

Open-path measurements of atmospheric temperature

Atmospheric temperature is a basic meteorological parameter. Temperature measurements for meteorological purposes are usually taken at fixed points by contact sensors. Due to the high spatial variability of atmospheric temperature, such measurements are not suitable as input data for weather forecasting numerical models. Space-averaged temperature data with the same spatial resolution as the model grid-scales can be obtained with the open-path QCL method developed within the project. The method uses the different temperature dependence of two closely spaced water lines. Such data are more representative and better suited for meteorological modeling applications.
The ratio of the logarithms of the absorbance of two water lines versus air temperature measured over 3000 m.

Fast laser tuning

One of the key results of the project that have made open-path measurements possible is the successful elimination of the line-shape distortion caused by atmospheric turbulence. This was achieved by using fast wavelength tuning. Since the tuning rates are of the order of hundreds of ns the atmosphere can be considered “frozen” and the turbulence-induced line-shape distortion can be neglected. The wavelength tuning exploits the thermal chirp during a long excitation pulse (intrapulse tuning). So far we have achieved tuning ranges of up to 1 cm^{-1} for tuning times of 300 ns.

APPLICATION PERSPECTIVES

The research results are expected to find application in the design of a reliable automatic instrument for atmospheric open-path measurements. The device will allow fast, accurate measurements of water vapour, pollutant and greenhouse gases, as well as, averaged in space over an extended path, measurements of atmospheric temperature. The instrument can find applications in a number of areas such as: air quality, industrial or pollutant control, fire detection, monitoring of greenhouse gases, and meteorology.

Prof. Hubert van den Bergh (EPF Lausanne)
Dr. Valentin Simeonov  (EPF Lausanne)
http://lpas.epfl.ch

Fore more information on this and other projects in the NCCR Quantum Photonics please visit our web site:  http://nccr-qp.epfl.ch

April 2007