New instrumentation to monitor the air we breathe

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Summary: Air pollution is the biggest environmental concern worldwide, having an adverse effect on human health, ecosystems and the economy. Nitrogen dioxide is a major air pollutant, mainly emitted by road traffic vehicles and in particular by diesel vehicles. This work involves the development of a new analytical instrument to accurately quantify nitrogen dioxide levels in the air we breathe.

What are the effects of air pollution?
- Exposure to air pollution is unavoidable
- Sources include transport, domestic heating and industrial processes
- Adverse effects on human health (Figure 1), ecosystems and economy
- Causes 3 million premature deaths a year worldwide³
- Particulate matter, ozone and nitrogen dioxide are most problematic

Monitoring air pollution is therefore vital
- Air quality monitoring is vital to establish:
  - Which areas are affected
  - Whether pollutants are within legislative limits
  - Whether measures to improve air pollution and/or mitigate its effects are effective
- Defra’s network of AURN air monitoring stations across the UK record a range of pollutants (Figure 2)

Nitrogen dioxide
- Nitrogen oxides (NOₓ) = nitric oxide (NO) + nitrogen dioxide (NO₂)
- Acts as a precursor for ozone (O₃)
- Major source = vehicle exhausts
  - 5 – 10 % emitted directly as NO₂ (primary)
  - Exception: diesel vehicles = NO₂/NOₓ up to 70 % in emissions²

Figure 1 From car exhaust to the human body: health impacts of air pollution (Adapted from European Environment Agency, Air Quality Report 2013)

Figure 2 a) Concentrations of NO₂ recorded at the AURN site on the University of Leicester campus from 01/01/2016 – 31/12/2016; b) Photo and location of the AURN measuring station at the University of Leicester

What’s special about our new instrument?
- Broadband LED light is directed into a cavity formed by two ultra-reflective mirrors
- Multiple reflections of the light increase the effective path length of light from 1 m (physical path length) to ~ 3 km
- This allows detection of atmospheric trace gases at low ambient concentrations
- This technique is highly selective, i.e. it can specifically target NO₂
- The new time-tagged detector technology enables:
  - Greater information content of light signal
  - Simple calibration procedure, eliminating use of calibration gases

Applying the new instrument
- Ability to record NO₂ absorption spectrum
- LED and cavity outputs recorded simultaneously
- Real-time measurement applications

NO₂ measurement methods – pros and cons
- Passive diffusion tubes
- Chemiluminescence (standard for NO₂)
- Absorption spectroscopy
- Broadband Cavity Enhanced Absorption Spectroscopy (BBCEAS)
- Cavity methods
- Compact instrumentation
- Assumess measurement is solely from NO₂ (450 nm)³

Figure 3 a) Developmental instrument on optical desk; b) Simplified schematic of new “time-tagged photon detection” instrument; c) Data analysis showing LED reference and cavity output recorded simultaneously; d) Data analysis of broxyn calibration performed using new time-tagged detector

References
2. Cardwell et al., Atmospheric Environment, 2011
3. Ball et al., Chemical Physics Letters, 2004
4. Kebabian et al., Environmental Science & Technology, 2004
5. The Telegraph api.com/products/TEGRA.aspx

Abbreviations
AURN = Automatic Urban and Rural Network
BBCEAS = Broadband Cavity Enhanced Absorption Spectroscopy
CAPS = Cavity Attenuated Phase Shift Spectroscopy
DPM = Department for Environment, Food & Rural Affairs
LED = Light Emitting Diode
NO₂ = parts per billion per volume
PM = Particulate Matter
ppbv = parts per billion by volume

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