Development of Remote Gas Sensing SO_2 Camera & UAV

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1st place in the technical paper competition

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Introduction

Sulphur Dioxide is an important gas for geologists and environmentalists. Volcanic SO_2 flux has been correlated with eruptions, and SO_2 is a prominent greenhouse gas that contributes to global warming. The SO_2 camera is essentially a 2D remote gas sensor; that is, an imaging system capable of real-time detection and concentration of SO_2. With such a device, SO_2 can be detected and measured simply by aiming the camera system at a plume, such as one from an active volcano or industrial stack.

The system uses readily available components and can be manufactured at a significantly lower cost than similar (and very rare) systems currently available. As opposed to simply logging data for analysis at a later time, the device will show - in real-time - a false-colour image correlating to the concentration of the gas observed, overlaid onto a picture taken with visible light of the object being studied. The result is an overlay of the gas concentration onto the actual picture of the area being analyzed.

The device will be small, portable, and utilize a USB interface for convenient, quick setup and operation.

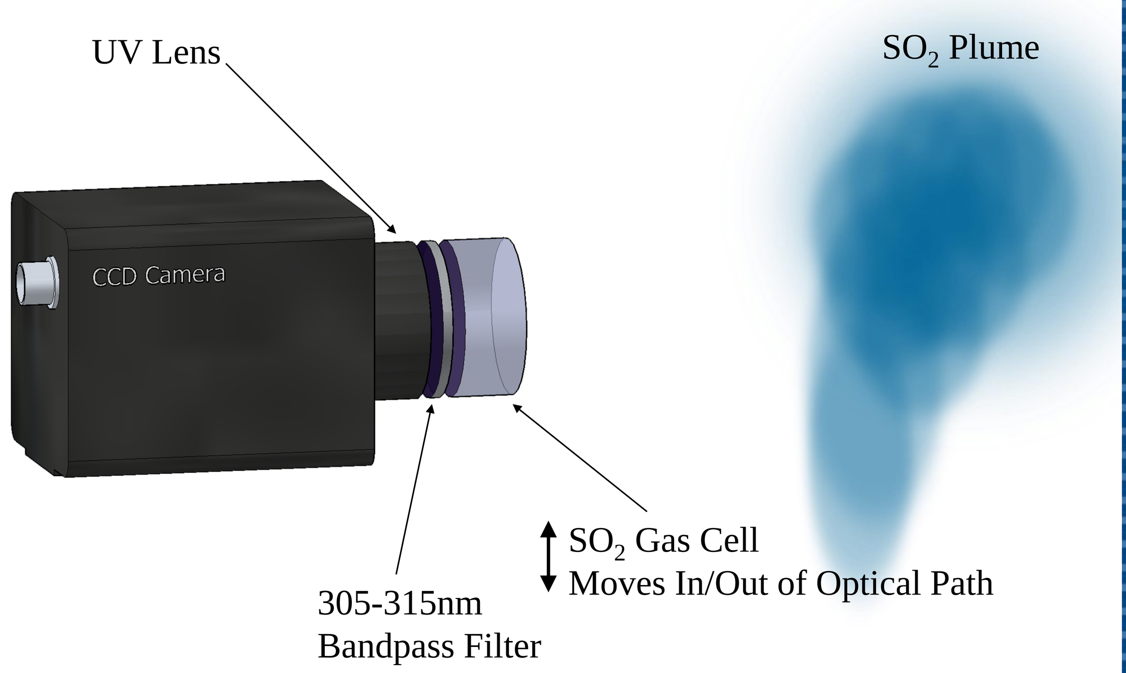
Aim

Being a highly portable system, the SO_2 camera is designed to be small enough to be carried by an Unmanned Aerial Vehicle (UAV). This unique advantage not only allows for fast, real-time SO_2 concentrations to be acquired, but also the ability to obtain such information from an aerial perspective.

One such application for this is the monitoring and profiling of a volcanic plume. Geologists have studied the emission of SO_2 from volcanoes using older remote sensors that will give a concentration reading at a single point, but they require a more extensive profile. The 2-dimensional nature of this imaging system overcomes this limitation.

Mounting the system in a mobile unit – the UAV – allows for a complete 360 degree profile of the SO_2 gas plume to be obtained. This information has previously been impossible to gather, not to mention extremely hard to obtain.

SO_2 Camera Overview



The SO_2 camera is based upon a gas correlation method to isolate the SO2 signature in a video frame.

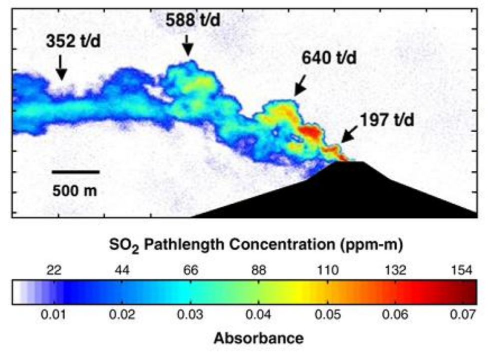
SO_2 gas, like every gas, has a unique absorption spectrum. In the 300 nm range, its profile is very distinct with strong absorption, and many peaks and valleys.

A band-pass filter is placed in front of the camera to isolate the incoming light to this unique wavelength range, approximately 305 – 315 nm.

A video frame is captured and stored, and a gas cell filled with a known concentration of SO_2 is placed in front of the optical path, and another frame is captured.

The SO_2 gas cell acts like a highly selective filter, absorbing any incoming wavelengths of SO_2 when it is in the optical path. The two images can then be correlated to each other (subtracted) and the difference represents the SO_2 concentration in the atmosphere.

This algorithm is implemented in the LabVIEW software responsible for acquiring the video frames. After the calculations are complete (< 1 second) the false-colour representation of the gas concentration is compiled and displayed.

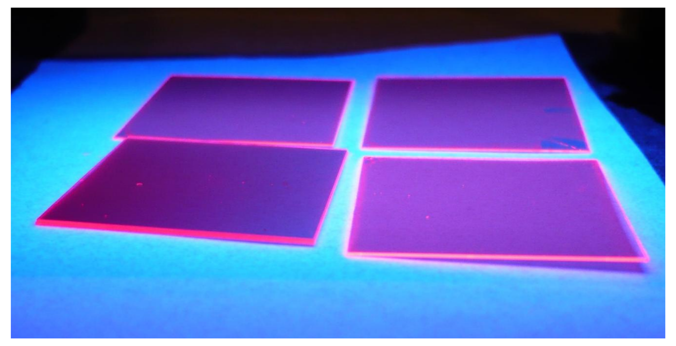


A visible picture of a volcano in Chile is shown above left, followed by a false-colour representation of SO_2 concentration on the right. This image exemplifies the result that will be obtained in real-time from the SO_2 camera.
Image source: "Development of an ultra-violet digital camera for volcanic SO_2 imaging" by G.J.S. Bluth, J.M. Shannon, I.M. Watson, A.J. Prata, and V.J. Realmuto.

Research & Results

▪Developing an Inexpensive UV-sensitive (300 nm) Camera

- Lumogen, a fluorescent dye, can be used to enhance sensitivity of existing monochrome visible cameras to UV light.
- Thermal evaporation methods are being explored for appropriate deposition of this crucial layer.



Lumogen-coated glass slides are shown fluorescing under ultraviolet illumination. The 300 nm UV light needed for the detection of SO_2 can be converted to visible light that regular CCD cameras are sensitive to.

▪Correcting for aberrations in software

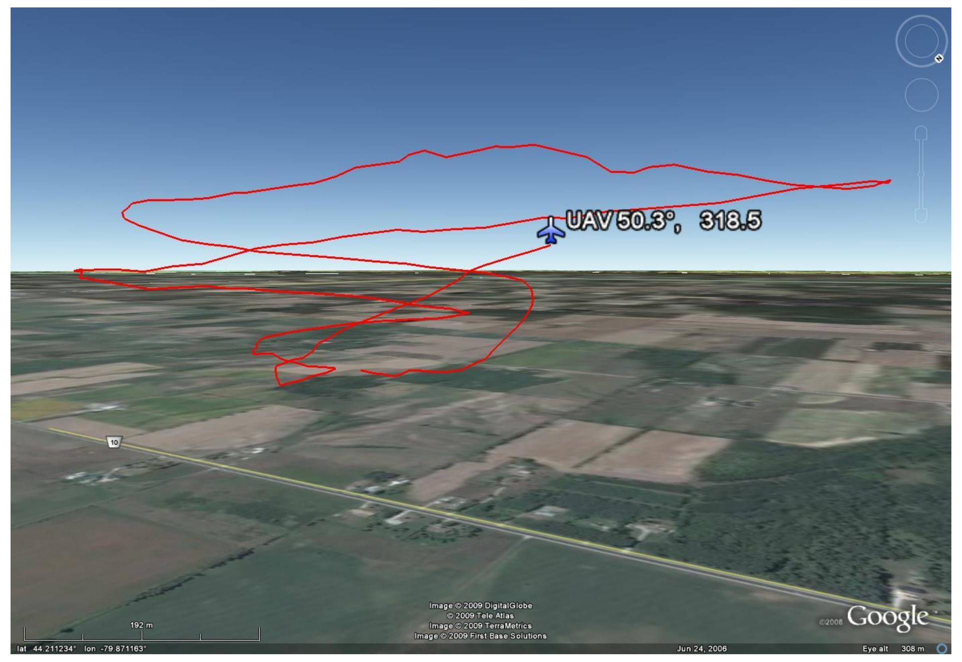
- Every pixel's intensity value is known. Applying a uniform light source can allow for a calibration 'mask' to be saved which will normalize the CCD, accounting for inconsistencies.

▪LabVIEW Computer Interface

- Powerful software capable of complex, real-time image processing for creation of false-colour concentration maps within seconds.

▪UAV - Fully Autonomous

- Aerial platform capable of flying pre-programmed flight patterns with real-time rerouting capability.
- Full telemetry system with LabVIEW and Google Earth moving-map software on the ground.



The base station for the UAV is able to track the flight in real-time using Google Earth. Commands can be sent to the UAV to alter course etc. as well as obtain SO_2 measurements while in flight.

UAV

The Unmanned Aerial Vehicle in Niagara College's Anechoic chamber. The uplink and downlink are on separate frequency bands to minimize potential interference. Designed to be a portable, low-cost scientific instrumentation platform. The electric motor allows for vibration and exhaust free operation to avoid any chance of damage or contamination of the payload. The onboard computer is compatible with the majority of scientific instruments.

Conclusion

Portability and a robust, easy to use interface makes the SO_2 camera a valuable scientific instrument for monitoring SO_2 sources. Combined with the UAV, the complete system is capable of conducting complete surveys of large geological features, such as active volcanoes or other SO_2 vents.

The 2D nature of the system eliminates problems encountered by older instruments – such as taking long periods of time to scan an area. The acquired image also lets scientists analyse an SO_2 plume in its entirety; and not just a small section of it.

Acknowledgements

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