BODE: A SHORT-RANGE FLUORESCENCE LIDAR

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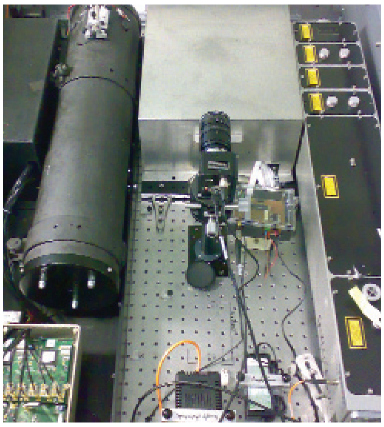
THE PROJECT

The Preparatory Action for Security Research (PASR) initiative from the EU invited proposals for research projects in areas that included the development of improved techniques for the detection of dispersed biological agent material. A consortium led by Cilas of France proposed investigating the development of a short-range fluorescence lidar for the detection and discrimination of biological aerosols at stand-off distances of a few hundred metres. The proposal was successful and became the Biological Optical Detection Equipment (BODE) project. In total there were nine participating organisations with Biral (UK) responsible for the lidar receiver and data acquisition systems, DLR (Germany) the laser system, Cilas (France) the integration and software, FOI (Sweden) the system trials and CEB (France) the data analysis. Other members of the consortium provided support and advice based on their experience in related fields.


BODE LIDAR

Objectives

It was first established, in agreement with the sponsors, that the governing objective was to extend the technology of fluorescence lidar to give the best possible discrimination between deliberately generated biological material and the particulate background of the atmosphere. At the same time as pushing the boundaries of fluorescence lidar technology it was also important to design a practical system that could be demonstrated in field trials. The principles of the system design were established by agreement between the consortium members with the detailed design of the components and other aspects of the project being the delegated responsibility of the individual organisation.

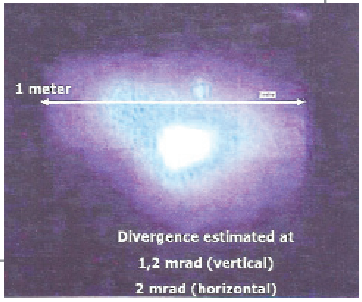
Design Principles

It was first agreed that the system would include two laser excitation wavelengths. The reasoning behind this was that agent material is likely to include a number of components that give their optimum fluorescence in response to different UV wavelengths. This response is quite well established and so it was felt that it would be possible to use the ratio of the responses to different excitation wavelengths to differentiate material that was potentially an artificially generated threat aerosol, from the natural biological material that is always present in the atmosphere. It was also predicted to be of value in differentiating non-biological material, that may also fluoresce, from the biological target.

It was also agreed that the receiving optics would need to include spectral resolution of the fluorescence response. This is needed to take advantage of the dual excitation wavelengths as the differences in fluorescence response can only be effectively measured by the relative response of different parts of the emission spectrum. Indeed variations in spectral response from a single excitation wavelength can often deliver effective differentiation. Because the luminescence that can be collected from a distant cloud of aerosol is very small the spectral resolution that can be achieved without compromising accuracy is limited. It is therefore vital to design the spectroscopy system to deliver the best resolution in the parts of the spectrum where the fluorescence has the highest intensity and where the potential for differentiation between the target material and interferents is greatest.

The Laser

The laser system was designed and built by DLR of Germany. It is based on a commercial Nd-YAG solid-state laser delivering up to 200mW per pulse at a repetition rate of 10 Hz. The fundamental frequency of 1064nm is converted into the target frequencies by the use of frequency multiplication and Optical Parametric Oscillators (OPOs). The latter are used to sequentially combine signal and idler frequencies and this, together with frequency multiplication using non-linear crystals, enables the target wavelengths to be generated. The converted wavelengths are, of course, of a much lower power than the fundamental frequency. The design enabled the target power of 10mW per pulse to be achieved.



Laser Beam Profile

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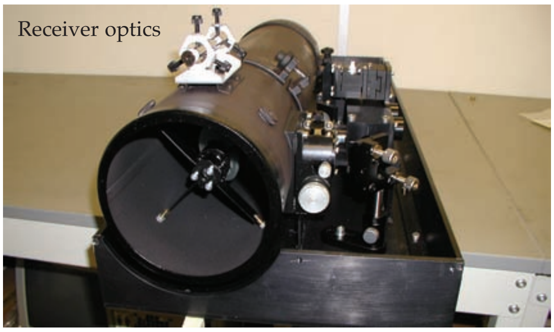
The Receiver Optics

The system The requirement for the receiver optics design was to:

- Collect as much of the light returning from the laser pulses directed at the target cloud as possible.
- Separate the elastically scattered light at the excitation frequency from any fluorescence.
- Divide the collected fluorescence into a number of spectral bands and measure the intensity in each band.

The light is collected by a Newtonian telescope with a 150mm aperture. The focussed light is reflected out the telescope body, through a spatial filter and into the optical processing system.

The elastically-scattered light is separated from the fluorescence by dichroic mirrors that are specific to the excitation wavelengths. These remove a very narrow frequency band but, because both must be in the same optical train, when excitation is by the shorter wavelength, the frequency band around the longer excitation wavelength is removed from the fluorescence response. This is corrected by interpolation between the value at either side of the band removed.


Receiver optics

The spectral resolution of the fluorescence is achieved by the use of two, four-element photomultiplier tubes (PMTs). Each of the elements is fitted with a filter that is designed to pass only a specific part of the spectrum. This technique, rather than a conventional spectrometer, was chosen so that a finer resolution could be achieved where the target fluorescence was highest and a much wider band where the fluorescence was likely to be of lower intensity.

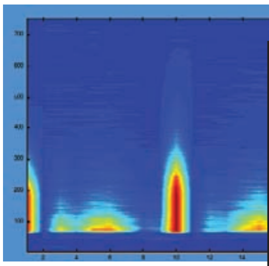
Data Acquisition

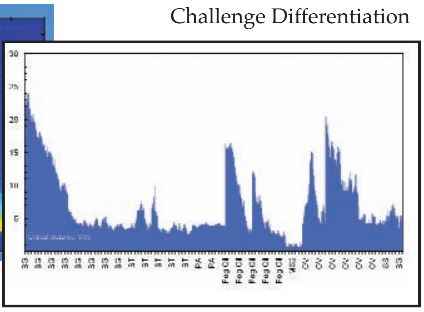
The major requirement of the data acquisition electronics was to achieve the best possible temporal resolution of the data, as this has a direct relationship to the spatial resolution achievable. The target was to be able to pinpoint the position and depth of a cloud within 2 metres. The acquisition electronics developed for the project in fact achieved better than 1 metre.

Field Trials

The integrated system was shipped to the FOI trial ground in Sweden for field trials. Most were carried out in an elongated enclosure with open ends protected by an air curtain. This enabled the control and monitoring of the generated aerosol.

The system was used to detect a range of simulants for biological agent material together with some limited examples of potential interferents. The system not only proved capable of detecting the simulants and, generally, differentiating them from interferents but also proved quite effective in differentiating between the simulants used.


Challenge response


Challenge Differentiation

Material	Bacteria	MS2	Ovabumin
Bacteria	0.85	0.00	0.00
MS2	0.00	1.00	0.00
Ovalbumin	0.13	0.00	0.75
Fog Oil	0.00	0.00	0.00
Signal Smoke	0.47	0.00	0.00

Classification and Interferent Rejection

CONCLUSIONS

This project proved highly successful, particularly as the system was assembled from components developed separately, with the integration only completed just before the beginning of the trials. Many lessons were learned from the project and further developments could produce a system that was much more compact with a lower power requirement while still delivering good detection and discrimination at longer ranges.

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