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Review Article

Detection of biological warfare agents using ultra violet-laser induced fluorescence LIDAR

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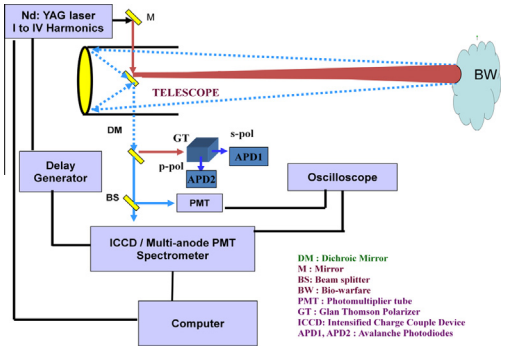
HIGHLIGHTS

- System has application in early warning against biological warfare attack.
- Review highlights the threat of biological warfare agents, their types, and detection using UV-LIF LIDAR.
- LIF signal of *Bacillus globigii* cloud at distance up to 5 km is presented with MAPMT and ICCD detectors.
- Overview of current research in internationally available working UV-LIF LIDAR systems are also mentioned briefly.
- This review will be very useful for graduate and under graduate students in understanding of Standoff UV-LIF LIDAR system.

GRAPHICAL ABSTRACT

UV-LIF LIDAR system.



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ABSTRACT

This review has been written to highlight the threat of biological warfare agents, their types and detection. Bacterial biological agent *Bacillus anthracis* (bacteria causing the disease anthrax) which is most likely to be employed in biological warfare is being discussed in detail. Standoff detection of biological warfare agents in aerosol form using Ultra violet-Laser Induced Fluorescence (UV-LIF) spectroscopy method has been studied. Range-resolved detection and identification of biological aerosols by both nano-second and non-linear femto-second LIDAR is also discussed. Calculated received fluorescence signal for a cloud of typical biological agent *Bacillus globigii* (Simulants of *B. anthracis*) at a location of ~5.0 km at different concentrations in presence of solar background radiation has been described. Overview of current research efforts in internationally available working UV-LIF LIDAR systems are also mentioned briefly.

Introduction

In today's world there is increasing awareness to vulnerabilities to biological attack not only to military assets but civilian targets as well. The defense against the use of biological agents is a national security and homeland defense objective. Use of biological agents as a means for defeating enemies has persisted through the centuries [1]. Following scientific breakthroughs such as the understanding of the germ theory of disease by Koch in the late 19th century, bio-weapons found increased emphasis, with numerous nation-state programs existing throughout the 20th century [2,3], and some into the 21st [4]. There is a long historic record of use of bio-

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logical warfare (BW) agents. During World War-I anthrax agent was used against human beings and animals by Germans, followed by large scale field trials by Japanese against war prisoners and Chinese population during World War II. Biological program took back seat after Biological and Toxin Weapon Convention (BTWC) in 1972. But biological agents regained their importance after the bioterrorist attack of anthrax powder on October 4, 2001. United States experienced its most severe bio-attack when a perpetrator mailed anthrax spores to the news media and the Congress, resulting in 22 casualties, including five deaths [5]. Although US postal service was used for that attack but in future the bioterrorist attack can happen through aerosol route also. So there is a need to develop a system to provide early warning of a remote biological warfare attack so that protective measures can be taken before getting exposed to infectious and lethal doses of the aerosol cloud.

Biological agents as weapon

Biological agents (BAs) are naturally occurring or engineered bacteria, viruses, fungi, rickettsiae and biological toxins. The use of BAs as weapon is a serious threat because of several reasons [6].

(a) BAs have the ability to multiply in the human body and significantly increase their effect in contrast to their chemical counterparts.
(b) BAs are highly virulent and toxic; they have an incubation period (their effects are not seen even days after dissemination) and some can be transmitted from person to person.
(c) Biological agents can be grown in facilities that are inexpensive to construct because all that is involved is growing organisms that are found in nature in a lot of cases. Therefore biological agents have often being described as poor man's bomb. BAs can be grown in facilities that resemble pharmaceutical, food or medical production sites that provides no detectable sign that such agents are being produced. In the absence of adequate detection system there is time lag between infection and appearance of symptoms, which gives the perpetrators a chance to escape.
(d) BAs have remarkably low dose for infection (the quantity of agents that is required to create desired results) in comparison to other types of agents. The approximate mass in milligrams (mg) of a biological agent needed to achieve the desired results in comparison to toxins and chemical warfare agents is shown in Fig. 1.

A vast difference in effectiveness between biological agents (microbial agents, e.g., bacteria and viruses) and chemical agents can be easily seen. As it is evident from the figure, some biological agents are as much as fourteen billion times dangerous in comparison to chemical agents. It can also be noted from Fig. 1 that if a terrorist chooses to use a toxin agent (in order to get relatively rapid effects in a tactical situation), a much greater mass of the toxin agent will have to be employed than if biological agents were being used under similar dissemination conditions. Though it is difficult to guess bioagents that can be used in biological warfare yet their selection may be based on the following criteria [7–9].

1. Lethality.
2. Ease of production in large quantities.
3. Stability in aerosol form.
4. Ease of dissemination.
5. Contagiousness.
6. Ability to impact public health, causing panic and social disruption.
7. Unavailability of treatment or vaccine.

Based on above criteria, biological agents, which are considered of great concern, are summarized in the Table 1 below:

The bio-agent can be dispersed by various ways. Three major ways have been identified for their dissemination [10,11].

1. By vector (i.e. insects).
2. Contaminating water or food supply.
3. Distributing as bio-aerosol particles.

Although well known insects normally transmit virulent diseases for instance, fleas transmit plague and mosquitoes transmit yellow fever but the difficulty of dealing with large number of insects and their unpredictability once released make significant biological attacks with insects unlikely.

Diseases and deaths from contaminated water and food are also well known in nature. For example typhoid is transmitted by contaminated water and botulism commonly comes from eating improperly canned food. One of most effective method for a biological attack is to dispense the bioagents as aerosol particles in the air, with depending on air movement to reach the target for large distance. Bioagents then float in the air until they are inhaled. Aerosol attack has following major advantages:

(1) The bio agents are dispersed in the air and driven by the wind can drift over large areas. During the sunny day, because of warm air lifts, disseminated aerosols may travel over a wide area but at kilometric altitude.
(2) Many diseases are more virulent when spread by the aerosol route.

Description of biological agents

Lederberg and Primmerman [2,10] have discussed that bioagents fall into five categories:

Bacterial agents, viral agents, rickettsiae, fungi and biological toxins.

Bacterial-agents

Bacteria are small, single-celled organisms, most of which can be grown on solid or liquid culture media. Diseases caused by bacterial agents are Anthrax, Tularemia, cholera, Diphtheria, plague and Typhoid fever.

Viral agents

Viruses are the simplest type of microorganisms. They consist of protein coat containing genetic material, either DNA or RNA. Viruses lack a system for their own metabolism; they require living hosts (cells of an infected organism) for their replication. Diseases caused by viral agents are Smallpox, Yellow fever, Dengue fever and Ebola.

Rickettsiae

Rickettsiae are obligate intracellular bacteria that are intermediate in size between most bacteria and viruses and possess certain characteristics common to both bacteria and viruses. Diseases caused by rickettsiae are – Q-fever, Endemic typhus and Rocky Mountain spotted fever.