

USPTO PATENT FULL-TEXT AND IMAGE DATABASE

(11 of 23)

United States Patent
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Lidar droplet size monitor for in-flight measurement of aircraft engine exhaust *contrails*, droplets and aerosols

Abstract

A lidar system which utilizes optical backscatter and extinction to determine the size of particles inside the exhaust plume of an aircraft at a distance of several hundred meters behind the aircraft. The system transmits a laser beam through the exhaust plume of the aircraft, where it is reflected by the particles contained in the exhaust plume. The reflected light is detected by a receiver, where it is processed by a computer to calculate the size of the particles in the exhaust plume.

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Field of Search:

356/336,342

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Government Interests

GOVERNMENT LICENSE RIGHTS

The U.S. Government has a paid up license in this invention and the right in limited circumstances to require the patent owner to license others on reasonable terms as provided for by the terms of contract number F33657-81-C-0067 awarded by the United States Air Force.

Claims

We claim:

1. A lidar system that is aboard a flying vehicle to monitor a particle size of particles contained in an exhaust plume produced by the vehicle, said system comprising:

means for propagating a beam that travels through the exhaust plume;

means for detecting the propagated beam after the propagated beam is reflected by the particles contained in the exhaust plume; and

means coupled to said detecting means for calculating the particle size of the particles contained in the exhaust plume.

2. The system claimed in claim 1, further including means coupled to said calculating means for displaying the particle size of the particles contained in the exhaust plume.

3. The system claimed in claim 2, wherein said displaying means is a meter.

4. The system claimed in claim 1, wherein said propagating means is a laser.

5. The system claimed in claim 4, wherein said propagating means further includes:

contrail;

FIG. 2 is a block diagram of the apparatus of this invention; and

FIG. 3 is a graph of the data that is received from the apparatus of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings in detail, and more particularly to FIG. 1, the reference character 11 represents an aircraft that is flying. Aircraft 11 has affixed thereto the apparatus of this invention 12. The apparatus of this invention 12 determines the average particle size between two points P1 and P2 in an aircraft engine exhaust, C. Apparatus 12 transmits a beam B, of laser light to the exhaust plume, C. Point P1 is located at an arbitrary point in the region where beam B passes through exhaust plume C and point P2 is located inside exhaust plume C at a distance from aircraft 11 further than point P1. The beam of laser light B is then reflected back from the exhaust plume C and is collected by a receiver hereinafter described, that is contained within apparatus 12.

FIG. 2 is a block diagram of the apparatus of this invention 12. Apparatus 12 comprises a laser transmitter 13; a lens 14; a window W1; a receiver 15; a lens 16; a window W2 and a computer 17. Laser transmitter 13, transmits a beam of light that propagates through lens 14 and window W1. Laser transmitter 30 has a wavelength chosen in the range between 0.2 and 25.0 micrometers. The wavelength is optimized for the particular application. The aforementioned beam of light travels out to exhaust plume C (described in the description of FIG. 1), where it is reflected by the particles in the exhaust plume. The reflected light passes through window W2, and lens 16. The reflected light is now detected by receiver 15. Receiver 15 transmits the reflected light to computer 17. Computer 17 process the detected light by utilizing a method disclosed by James Klett in Applied Optics, Jan. 15, 1981, p. 211, which is herein incorporated by reference to determine the droplet size. James Klett's method will be described in the description of FIG. 3.

FIG. 3 is a graph of the signal transmitted by receiver 15 to computer 17 vs. the range of particles P1 and P2 from airplane 11. The signal transmitted by receiver 15 consists of a range resolved radar return, S. The signal strength of the signal S, is dependent upon the distance between apparatus 12 as well as the types of material that beam B (FIG. 1) passes through. Signal S, will be attenuated if beam B contacts any particles.

Three signals are illustrated in FIG. 3, S1, S2, and S3. The signals S1, S2, and S3 all become strong at P1, an arbitrary point in the region where beam B passes through exhaust plume C. Point P2 is located at an arbitrary point inside exhaust plume C at a distance from aircraft 11 further than point P1. If exhaust plume C is strongly attenuating, the signal would look like S3, i.e., there is little signal returned from P2. If exhaust plume C is weakly attenuating, the signal would look like S1, i.e., there is strong signal returned from P2. When exhaust plume C is moderately attenuating, the signal would look like S1, i.e., there is a moderate strength signal returned from P2.

The degree of attenuation of signal S, depends on the size of the particles in exhaust plume C. Computer 17 uses a method developed by James Klett in Applied Optics, Jan. 15, 1981, p. 211, which is incorporated by reference to determine the droplet size. It is based on measuring the optical extinction of the light beam (how much of the light beam is removed for each unit of distance traveled inside the plume) and the optical backscatter of the light beam (how much of the light is backscattered for each unit of distance traveled inside the plume).

The ratio of the optical extinction to the optical backscatter will uniquely determine the droplet size,

when the basic droplet characteristics are known (type of material, rough range of sizes to be expected).

Computer 17 digitizes the return signal, determines the above parameters, and assigns a droplet size to the particles in exhaust plume C, based upon that determination.

Computer 17 transmits the determined particle sizes to display 18. The pilot views display 18 and notes the determined particle size to change the mixture of fuel being burned by the aircraft engines to reduce pollution and make the engines more efficient. Display 18 may be a needle type panel meter which points to the droplet size, or any similar device known to one skilled in the art.

