

In order to guide certain mobile craft such as aircraft or certain missiles, or even boats, a knowledge is required of their relative velocity with respect to the ambient fluid. Aircraft will be the subject of what follows, it being understood that what will then be stated will also be valid, fluid type excepted, for other types of craft be they flying or travelling over the ground, over the water or under the water.

It is known, in an aircraft, to determine this relative velocity from signals provided by four probes:

- a static pressure probe whose sensitive surface is arranged parallel to the airflow streamlines, at a spot where neither low pressures nor high pressures occur,

- a total pressure probe, whose sensitive surface is generally placed at the front of the aircraft, at least substantially perpendicular to its longitudinal axis,

- two clinometric probes, for example of the wind vane type, which give respectively the angle of incidence and the angle of sideslip of the aircraft. It is recalled that the angle of incidence is the angle which the velocity vector relative to the wind makes with the chord of the wing of the aircraft, that is to say with the line which joins the forwardmost point and the rearmost point of the wing in a vertical section parallel to the plane of symmetry of the aircraft. Knowledge of the angle of incidence is vital since it enables the risks of stalling to be foreseen; as regards the angle of sideslip, this is the angle which the velocity vector relative to the wind makes with the longitudinal axis of the aircraft.

These four probes, which form as many protuberances on the exterior wall of the aircraft, have various disadvantages. They raise problems of mechanical resistance to bad weather conditions, of correct operation in all weathers and in particular in icy weather; they render the aircraft more easily detectable by radar, this being a drawback for military aircraft; they require, as a function of the angle of incidence,

corrections of the measurements made by the pressure probes; they create turbulence.

It is also known, through the document EP-A-9533, to produce Doppler effect laser anemometers which emit a laser beam modulated by an oscillator and which compare the modulation of the reflected signal with that of the oscillator in order to deduce therefrom the velocity of the particles which caused the reflection. With this type of anemometer the measurement volume consists of that portion of the emitted beam in which the particles which caused the reflection lie; it is therefore impossible to make a point measurement, that is to say within a small volume situated a predetermined distance from the anemometer.

The purpose of the present invention is to avoid, or at least reduce these disadvantages.

This is achieved by producing devices for measuring with the aid of fringe-effect laser anemometers such as is used, on fixed supports, in enclosed spaces, for measuring airflows, choosing from among these anemometers those most able to be loaded aboard and adapting these anemometers to the particular conditions of measurement in free space.

According to the invention a device aboard a mobile craft for obtaining signals representative of the relative velocity of the craft with respect to an ambient fluid is characterised in that it includes n , where n is a positive integer, fringe-effect laser diode anemometers, in that each anemometer includes an optical filter whose pass band is centred on the emission frequency of the laser diode, in that this filter is arranged in the optical path between the measurement volume of the relevant anemometer and its photodetector and in that the signals are provided by the photodetectors of the n anemometers, for at least two distinct directions of the n measurement axes relating to the n anemometers, for the purpose of determining at least two components of the velocity.

The present invention will be better understood

and other characteristics will emerge with the aid of the description below and of the figures relating thereto, which represent:

5 - Figures 1 and 2, two views of an anemometer usable in a device according to the invention,

 - Figure 3, a view of the measurement volume of the anemometer according to Figures 1 and 2,

 - Figures 4 to 7, views relating to three devices according to the invention.

10 In the various figures the corresponding elements are designated with the same labels.

 Figure 1 is a diagrammatic view of a laser diode anemometer with, in series at an optical level, an emitter source consisting for [sic] a power laser diode,
15 1, a collimating lens, 2, an optical beam splitter with semi-reflective mirrors, 3, a sending lens, 4, a receiving lens, 5, an interference filter 6, an iris 7 and a photodetector 8. This anemometer is described in French Patent Application 2 637 085 of 28 June 1989; it was
20 developed by the Franco-German Research Institute of Saint-Louis (France); for its use within the context of the invention it has, in particular, been modified by adjoining elements 6 and 7 whose role will be explained below.

25 The operation of the anemometer according to Figure 1 is as follows.

 The laser diode 1 emits monochromatic radiation. From this radiation the collimating lens 2 forms a light beam which it directs onto the entrance of the beam
30 splitter 3. The beam splitter divides the incoming beam into two beams, A and B, which it conveys to the sending lens 4. This sending lens makes the two beams converge towards a zone M, called the measurement volume, where interference fringes are produced. These fringes appear
35 in Figure 3 which is a highly magnified diagrammatic view of this measurement volume in the vertical plane passing through the diode and substantially the middle of the volume M; this volume, which varies as a function of the transverse dimensions accorded to the beams A and B and

as a function of the angle Q made by the beams when they cross, is of the order of a few hundred microns in length and of the order of a few tens of microns in thickness and in width. The alternately bright and dark fringes, which are created in the volume M , are parallel to the plane bisecting the two beams. The distance s separating the middle of two consecutive fringes is equal to the wavelength of the radiation from the diode 1, divided by twice the sine of the angle $Q/2$. The dust particles entrained by the flow of air in the volume M , scatter a light whose intensity varies, owing to the fringes, periodically with a frequency, f , proportionately to their velocity V or, more precisely, as a linear function of the component U of their velocity V in the direction XX perpendicular to the plane of the fringes; this direction constitutes what is generally called the measurement axis of the anemometer; the relation which links U , f and s can be written:

$$U = f.s \text{ (apart from the sign)}$$

Part of the light thus scattered by the particles which have passed through the volume M passes successively through the sending lens 4 and the receiving lens 5 in order to converge towards the photodetector 8, passing via the interference filter 6 and the iris 7. This light, whose luminous intensity is modulated, produces modulation of the electrical output signal from the photodetector 8 so that straightforward measurement of the frequency of modulation of this electrical signal allows determination of the component U of the velocity vector.

The interference filter 6 is an optical filter with narrow pass band centred on the frequency of the emission line of the diode 1; its role is to rid the light delivered to the photodetector 8 as far as possible of anything not originating from the diode 1 and more particularly of sunlight; without the filter 6 the photodetector 8 would be easily saturated, which would render any measurement impossible.

It should be noted that the laser diode

anemometers, devices according to the invention, which are described with the aid of Figures 4 to 7, have been produced with a laser diode whose emission line was at 0.82 microns but that a study is under way to produce laser diodes at 1.4 and 1.9 microns; such diodes will have the advantage of having an emission line situated in a gap in the sun's spectrum and hence of making it possible, in association with the filter 6, for the photodetector 8 to receive virtually no sunlight since the pass band of the filter will be situated entirely within this gap. It should also be noted that the pass band of the filter 6 may be chosen to be all the narrower the more stable the frequency of the emission line of the diode 1; thus temperature stabilisation of the diode 1 permits the use of a filter with very narrow band, ± 1 nanometre, that is to say a filter which is very effective against spurious light.

The role of the iris 7 is to rid the light received by the photodetector 8 of radiations which did not originate from the measurement volume since they are offset too far with respect to the optical axis ZZ of the anemometer.

Figure 2 represents the anemometer according to Figure 1, seen end-on, that is to say from a point on the optical axis ZZ situated beyond the measurement volume M. In this figure has been represented only the measurement axis XX, the measurement volume M, the perimeters of the sending lens 4 and receiving lens 5 and the light beams A and B made to converge, by the sending lens 4, towards the measurement volume M after they reach it by passing from one side to the other of the receiving lens 5.

It was seen, when describing Figure 3, that the anemometer according to Figures 1 and 2 allowed determination of the component of the relative velocity vector along the axis XX. For the piloting of an aircraft it is necessary to have the component of the relative velocity vector in the vertical plane passing through the longitudinal axis of the aircraft. Now, with an aircraft, the relative velocity vector is situated within a cone, known

a priori, given by the constructor of the aircraft; it is therefore possible, with two anemometers, whose measurement axes are correctly arranged in the vertical longitudinal plane of the aircraft, to determine the component of the velocity vector in this plane by projecting this vector onto these two axes; this arrangement must be such that the velocity vector is always situated within the same angle included between the two measurement axes, so that there is no ambiguity in its determination given that the projections onto the measurement axes are known in amplitude but not in sign; since the maximum deflection of the relative velocity vector does not, in general, exceed 90 degrees under flight conditions, it is possible to arrange the two measurement axes at 45 degrees, on either side of the longitudinal axis of the aircraft, in order to obtain the desired projections.

Since measurements of the velocity vector is achieved by averaging over the values given by the anemometer, there is no need to determine the two above-mentioned projections relating to the same particle; it is therefore possible to segregate the measurement volumes of the two anemometers by always leaving them in the same airstreams. Such an embodiment is depicted in Figure 4; this figure shows two anemometers identical to the anemometer according to Figures 1 and 2, in an end-on view like that of Figure 2 where the references relating to these two anemometers are those of Figure 2 followed by a 1 and a 2 respectively. The two anemometers of Figure 4 are arranged one above the other and are turned through -45° and $+45^\circ$ about their longitudinal axis corresponding to the axis ZZ of Figure 1; of course, different values may be chosen for these angles but, keeping in mind, as was explained earlier, the maximum deflection of the relative velocity vector.

Another possibility for determining the relative velocity is to use a single anemometer like that of Figures 1 and 2, but making its beam splitter, 3, turn or oscillate about the axis ZZ; the maximum values obtained

for the relative velocity correspond to particles whose paths are parallel to the measurement axis XX and the minimum values to particles whose paths are virtually perpendicular to the axis XX. Such an embodiment is represented in Figure 5.

The device according to Figure 5 differs from the anemometer according to Figures 1 and 2 only by the adjoining of a rotating plate 30 driven by a motor 31 and coupled to an angle sensor 32 intended to deliver a phase reference signal in order to allow processing of the signal delivered by the photodetector 8. The rotating plate supports the beam splitter 3 and drives it in rotation about the axis ZZ. In the case where the motor drives the splitter under oscillation, the oscillations may be pendular, that is to say be progressive like a clock pendulum or may be effected abruptly with stoppages of predetermined duration around the two extreme positions; in the latter case the measurements are made only during stoppages. In the case of complete revolutions or progressive oscillations the measurements are made with the splitter in motion.

Figures 6 and 7 correspond to another on-board measurement device, for obtaining signals representing the relative velocity, with respect to the air, of an aircraft. This device consists of a double anemometer which is distinguished from that according to Figures 1 and 2 by a beam splitter 3' with four exit beams A, B, A', B', by two measurement volumes, M and M', by two irises 7 and 7' and by two photodetectors 8 and 8'. The four beams are represented, in Figure 7, in the exit plane of the splitter 3; this figure shows that, in the exit plane of the splitter 3, the beam pair A'B' is offset by 90° with respect to the pair AB and that, moreover, its middle is offset downwards with respect to the middle of the pair AB, which means that the measurement volumes M and M' corresponding to the beams AB and A'B' respectively are distinct and that some light originating from these measurement volumes can be focused onto the two neighbouring photodetectors without there

being interference between the radiation originating from the two measurement volumes M and M'. It should be noted that, bearing in mind the position of the beams A'B' at 90 degrees from that of the beams AB, the measurement axes, not represented in Figure 6 but corresponding to the axis XX of Figure 1, are vertical as in Figure 1 for the volume M and perpendicular to the plane of the figure for the volume M'. The device according to Figures 6 and 7 has been produced with an angle of 90 degrees between the two measurement axes. In the case where the maximum deflection of the relative velocity vector is less than 90 degrees, this angle between the measurement axes can be reduced down to the value of this maximum deflection on condition however, as is moreover the case for the other devices, that the longitudinal axis of the aircraft is parallel to the bisector of this angle. It should be noted that the photodetectors 8, 8' which are separated in Figure 6 are, in fact, in the embodiment having served as an example, carried by the same support.

The present invention is not limited to the examples described below [sic]; it applies in particular to the case where the co-ordinates of the velocity vector are desired in space rather than in a plane, this requiring at least three anemometers in the case where the measurement axes are fixed and at least two anemometers in the case where they are revolving or oscillating; in the case of three fixed measurement axes, the device will be able to consist, for example, of the devices according to Figures 4 or 6 and 7 associated with an anemometer according to Figures 1 and 2 with the measurement volumes close to one another and, for example, an angle of 90 degrees between these two assemblies. It is also possible to associate, for example, an anemometer according to Figures 1 and 2 with a device according to Figure 5 with, for example, an angle of 90 degrees between them and with their measurement volumes close to one another.

Similarly, the make-up of devices according to the invention can be different from that of the devices

described hereinbefore; thus, the beam splitter or splitters which, in the embodiments which were in question, were made of mirrors, may also be made with the aid of optical fibres.

5 It is also possible not to use an iris and to arrange the light filters between the sending lenses and the receiving lenses.

10 Associated with an electronic circuit for processing the signals delivered by its photodetector or photodetectors, the device according to the invention constitutes an apparatus for measuring the relative velocity of the craft on board which it is placed.



CLAIMS

1. Device aboard a mobile craft for obtaining signals representative of the relative velocity of the craft with respect to an ambient fluid, characterised in
5 that it includes n , where n is a positive integer, fringe-effect laser diode (1) anemometers, in that each anemometer includes an optical filter (6) whose pass band is centred on the emission frequency of the laser diode (1), in that this filter is arranged in the optical path
10 between the measurement volume (M , M_1 , M_2 , M') of the relevant anemometer and its photodetector (8, 8') and in that the signals are provided by the photodetectors of the n anemometers, for at least two distinct directions (X_1X_1 , X_2X_2) of the n measurement axes relating to the n
15 anemometers, for the purpose of determining at least two components of the velocity.
2. Device according to Claim 1, characterised in that it includes two anemometers whose respective measurement volumes (M_1 , M_2) are close to one another and
20 whose respective measurement axes (X_1X_1 , X_2X_2) make an angle.
3. Device according to Claim 1, characterised in that it includes an anemometer with a beam splitter (3) mounted on a rotary support (30) in such a way that the
25 measurement volume (M) revolves on itself.
4. Device according to Claim 3, characterised in that the rotary support (30) drives the splitter (3) in a continuous rotational motion.
5. Device according to Claim 3, characterised in
30 that the rotary support (30) drives the splitter (3) in an oscillatory motion.
6. Device according to Claim 5, characterised in that the oscillatory motion is of pendular type.
7. Device according to Claim 5, characterised in
35 that the oscillatory motion takes place with abrupt passage between two extreme positions and stoppages of predetermined value in each extreme position.
8. Device according to Claim 1, in which n is at least equal to 2, characterised in that two of the



n anemometers form a double anemometer with common laser diode (1), followed optically by a beam splitter (3') with four exit beams and by two distinct photodetectors (8, 8').

- 5 9. Device according to any one of the preceding claims, characterised in that the anemometers include an iris (7, 7') arranged in the optical path between their measurement volume (M, M') and their photodetector (8, 8').
- 10 10. Apparatus for measuring the relative velocity of a mobile craft, characterised in that it includes a device according to one of the preceding claims.