OPTICAL RESONANCE CELL WITH MEANS FOR REGULATING INTERNAL VAPOR PRESSURE

This application is a continuation of Ser. No. 796,236, filed Feb. 3, 1969, now abandoned.

The present invention relates to optical resonance cells which can be used, for example, in atomic clocks or optically pumped magnetometers.

At the present time, cells are available which are capable of operation only at very low optimal temperatures. In other words, these cells can operate only with an optimum density of a saturating alkaline metal vapor; if this density is too low in the cell, too few atoms are involved in the phenomenon of optical pumping and resonance, and the resonance signal disappears. Conversely, if the vapor density is too high, there is too high a degree of absorption of the pumping light wave, due to the fact that, because of the relaxation phenomenon, the atoms of a vapor are never all oriented, and the output signal reaching the optical detector is too weak.

The optimum temperature of operation of a resonance cell is for example 35° C in the case of caesium vapor and 45° C in the case of rubidium vapor. The regulation of the temperature of such cells, at ambient temperatures which may be higher than these temperature levels, requires the use of thermoelectric devices (such as frigatrons) which take a relatively large amount of power.

One solution has been considered with a view to avoiding the need for the use of such devices. A specific compound of carbon and alkaline metal is used which enables a suitable alkali vapor pressure to be achieved by the heating of said compound to a temperature in the order of 250° C or more. However, this approach has the drawback that part of the resonance cell has to be heated to 250° C, and this may be detrimental in so far as the stability of the system which comprises the cell, is concerned, due to convection currents which develop inside the cell.

It is an object of the invention to overcome these drawbacks of the earlier proposed systems and to provide a resonance cell the control of whose temperature is a straight-forward matter in all normal conditions of operation, this without excessive power consumption, the desired result being achieved by operation of the system at a relatively high temperature although the optimum vapor density is maintained.

According to the invention, a specific property of absorption of atoms of the alkali vapor is exploited. This property is exhibited for example by a layer of substance, such as paraffin, deposited upon the walls of the cell, which layer has already been used in certain known cells with a purpose similar to that for which a filler gas is used, that is to say in order to prevent disorientation of the vapor atoms as a consequence of direct collision with the cell walls (the mean free trajectory of the vapor atoms being greater than the cell dimensions). This property is again exhibited by the glass of the wall itself, if a filler gas is being used.

According to the invention, there is provided an optical resonance cell comprising an envelope having transparent walls; a bulb containing an alkali metal and communicating with said envelope; first means for decelerating the alkali vapor flow between said bulb and said walls; and second means for absorbing on said walls a predetermined number of alkali atoms of said vapor flow.

For a better understanding of the invention and to show how the same may be carried into effect, reference will be made to the drawings accompanying the ensuing description and in which:

FIG. 1 illustrates an optical resonance cell in accordance with the invention; and

FIG. 2 is an explanatory graph.

The cell according to the invention, illustrated in FIG. 1, comprises an envelope 1 of any desired shape, the walls of which are covered with a fine layer or film 2 of a substance which, on the one hand, prevents any disorientation of the vapor atoms as a consequence of collision with the walls, and, on the other hand, has a certain capacity for absorption of said atoms. This layer will be, for example, of paraffin.

The cell likewise comprises an exhaust stem 3 and a bulb communicating with the cell and containing alkaline metal 5, the vapor of which is to be optically pumped. In accordance with the invention, the bulb 4 is connected to the envelope 1 through a tube 6 having a neck 7 of very small diameter.

The layer 2 should be sufficiently thin to enable the envelope to retain its transparency to the pumping light. The operation of the cell is based upon a specific property of the paraffin layer 2, namely that it absorbs per second, a certain number of atoms of the alkaline vapor, which number is a function of the temperature and of the number of atoms in the envelope.

In known cells, in which a paraffin layer is employed in order to prevent disorientation of the vapor atoms by collision with the cell walls, this absorption has no effect from the point of view of the vapor pressure within the envelope, since the reserve of alkaline metal at all times compensates the atoms lost by absorption by the paraffin and necessary to establish the saturation vapor pressure at the envelope temperature, which temperature will have to keep an optimum value of, for example, **C in the case of caesium** and 45° C in the case of rubidium. In contradistinction to that, in the case of the invention the flow of gas atoms supplied by the alkaline metal reserve contained in the bulb 4 is limited, is order to enable the cell to operate at a higher temperature, while at the same time maintaining the optimum vapor pressure, for example $P_{45°}$, i.e. the pressure corresponding to the saturation pressure at 45° in the case of rubidium. The operation of the cell in accordance with the invention can be explained in the following manner:

Let it be assumed that it is desired to operate the cell at a temperature θ, the envelope 1 and the bulb 4 thus being brought to this temperature while maintaining within the envelope the optimum vapor pressure P_{45}°, assuming that the alkaline metal is rubidium. In the bulb, the vapor pressure is $P_{\circ}$ above P_{45}, if θ is higher than 45° C. At the temperature θ, the paraffin layer 2 absorbs n_a atoms per second for a number n of rubidium atoms in the envelope corresponding to a vapor pressure of P_{45}. In addition, because of the pressure difference between the bulb and the envelope, there is supplied through the neck 7, to the envelope, a stream of n_e atoms per second. Thus, equilibrium, and therefore the optimum pressure P_{45}°, is maintained inside the cell, even if the latter is brought to a temperature θ, if $n_a = n_e$.

By way of example, considering a neck 7 of radius r, the number n_e of rubidium atoms, supplied per second to the envelope, is given by:

$$n_\theta = \sqrt{\frac{\pi}{2}} \frac{N}{\sqrt{R.T.M.}} \cdot r^2 \, \Delta \rho$$

where $\Delta\rho$ is the difference $P_\theta - P_{45°}$ in pressure between the bulb 7 and the envelope 1, N is the Avogadro factor, R the gas constant, T the absolute temperature $\theta + 273.15$ of the vapor, and M the atomic mass of the vapor.

In the M K S A system this gives

$$n_e = 1.5 \times 10^{21} \, r^2 \, \Delta \rho.$$

Also, it is possible to determine experimentally the absorption characteristic of the paraffin layer 2 as a function of the temperature θ of the cell. FIG. 2, shows by way of example curves which respectively illustrate the variations in n_a and n_e for a given paraffin layer and a given diameter of the neck 7, the rubidium vapor pressure in the envelope being $P_{45°}$. The transition point at around 77° C, for n_a, corresponds to the melting point of the particular paraffin. There are three points for which $n_a = n_e$

Two stable points, one at around 45° and the other at around 80°, and an unstable point at 77°.

Preferably, an operating temperature no higher than the melting temperature of the paraffin will be used, because absorption then becomes very fast and this means that a substan-