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Hydrogen Maser: Measurement of Wall Shift with a Flexible Bulb

The oscillation frequency of a hydrogen maser is shifted from its free-space transition frequency by collisions of the hydrogen atoms with the wall of the bulb used as a gas-storage reservoir. Past investigations have measured this frequency shift by operating the maser with storage bulbs of different sizes, all having the same type of wall coating. Then, since the frequency shift is inversely proportional to the mean free path of the hydrogen atom, which itself is proportional to the ratio of the bulb's volume to its surface area (at a fixed temperature), one can use the results obtained from maser operation using different sized bulbs to calculate the maser frequency shift caused by the wall. Unfortunately, difficulties in exactly duplicating the wall coatings have made it difficult to determine the wall shift with an accuracy greater than one percent.

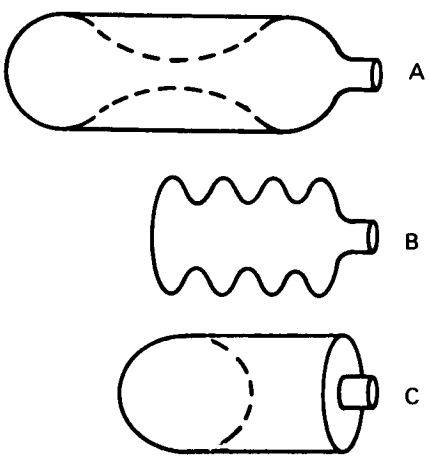

Figure 1. Three Types of Flexible Bulb

A new technique for measurement of the wall shift eliminates this problem. The storage bulb is made flexible instead of rigid, and the mean free path of the atoms is changed by squeezing the bulb. The squeezing changes the bulb's volume without changing its surface area. Thus, one needs only to measure the volumes in the different configurations to learn the change in the mean free path and so calculate the wall shift.

The configuration of the flexible bulb may be conventional (Fig. 1A), shaped like a bellows and compressed longitudinally (Fig. 1B), or cylindrical with one flexible end (Fig. 1C). So far, the most promising coating materials are polytetrafluoroethylene (PTFE), a copolymer of tetrafluoroethylene and hexafluoropropylene (FEP), and a viscous fluorocarbon with an average molecular weight corresponding to the formula $C_{21}F_{44}$. Bulbs of polyethylene surfaced with tetracosane, $C_{21}F_{44}$, FEP, or dimethyldichlorosilane have been made to oscillate in the hydrogen maser. With tetracosane, wall-shift measurements were poor because the wax cracked extensively when the bulb was squeezed; however, preliminary measurements with $C_{21}F_{44}$ were accurate within a statistical error of 5% (1.0 MHz). Measurements with FEP are now under way.

This flexible-bulb method can be extended to the measurement of wall shifts in other systems whose frequencies are perturbed by wall collisions; for example, optical-pumping experiments in which evacuated cells are used, or experiments using the "large storage box" hydrogen maser.

Current flexible-bulb measurements require the maser to be brought to atmospheric pressure for squeezing. In the future the bulb will be squeezed under vacuum (by use of a sliding O-ring seal or a bellows arrangement, for example). Measurements should then be possible which within a few hours will give results which are considerably more accurate than those obtained over several months by conventional techniques.

(continued overleaf)

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