Yu. L. Sokolov and V. P. Yakovlev. *Measurement of the Lamb shift in the hydrogen atom.* Measurement of the Lamb shift in the hydrogen atom is one of the most important tests of quantum electrodynamics. Although measurements of δ have been made for more than a quarter-century, beginning with the classical Ref. 1, it should perhaps be acknowledged that progress in improvement of accuracy has been very modest. We now have the following experimental and theoretical values of δ [MHz]:

$$\delta_{exp} = 1057.862 \pm 0.020\ ^{2}, \quad \delta_{theor} = 1057.912 \pm 0.011\ ^{4},$$
$$\delta_{exp} = 1057.845 \pm 0.009\ ^{3}, \quad \delta_{theor} = 1057.864 \pm 0.014\ ^{5}.$$

As we see, these values are scattered outside the random error limits, and accuracy does not exceed 0.01 MHz. This evidently precludes speaking of the existence of disagreement (or agreement) between the theoretical and experimental values. The accuracy with which δ is measured must be improved.

This paper reports measurement of the Lamb shift on a "Pamir" system with the aid of an atomic interferometer, which makes it possible to observe the stationary interference pattern of two phase-shifted 2p (or 2s) components of the hydrogen atom.[6] The interferometer consists of two plane-parallel capacitors with a longitudinal electric field that are separated by a variable gap l. An atom in the metastable 2s state (components with the total angular momentum $F=1$ were first removed from the beam) in flight through this system at velocity v is subject to the action of the nonadiabatic fields in each capacitor, and this results in mixing of the states $(2s_{1/2}, F=0)$, $(2p_{1/2}, F=1)$ and $(2p_{3/2}, F=1)$. The dependence of the escape probability of 2p atoms after traveling through the interferometer on the length l [or on the proper time of flight $T=(l/v)\sqrt{1-(v^2/c^2)}$] is determined by the free evolution of the 2s and 2p states in the gap between the capacitors, where there is no field. The difference between the probabilities for two opposite field values in the second capacitor is simplest in form:[7,8]

$$F(T) = \exp\left(-\frac{T}{2\tau}\right)[A\cos(2\pi\nu T+\varphi)+B\cos(2\pi\nu_1 T+\varphi_1)];$$

here τ is the lifetime of the 2p state, ν is the frequency of the transition $(2s_{1/2}, F=0)-(2p_{1/2}, F=1)$, and ν_1 is the fine-splitting frequency. The parameters A, B, φ_1, and φ_2 are determined by the action of the field in the capacitors and do not depend on l.

Using least squares, the theoretical $F(T)$ curve was fitted to the experimental points by adjustment of the parameters, including ν/v, which contains the transition frequency of interest to us. When the velocity of the atoms remained constant, reduction of the initial data enabled us to find ν/v with accuracy no worse than 5 ppm. With velocity drift, the interference curve deforms, does not agree with the $F(T)$ relation, and therefore cannot be processed.

Stabilization and measurement of the velocity constitute the most difficult part of the experiment and impose the basic limitations of the method. A beam of neutral atoms was produced by charge transfer from ~20-keV protons, which were passed through an analyzing magnet, to molecular hydrogen. Strict collimation conditions ensured high velocity uniformity of the atoms entering the interferometer ($\Delta v/v \approx 2\cdot 10^{-6}$). The velocity was determined from the experimentally established decay length $l_0 = v\tau$ of the 2p atoms and the theoretically calculated lifetime of the $2p_{1/2}$ state, $\tau = 1.596185\cdot 10^{-9}$ sec.[7,8] The error in τ is estimated to be of the order of magnitude of a few ppm.

The procedure used to exclude systematic errors consisted of repeated modification of the apparatus and comparison of the resulting interference curves. The resolution of the apparatus, both with respect to velocity and frequency ν, was determined by minor variation of the proton velocity. The sensitivity threshold is within the limits of the accidental errors of measurement of ν.

Over two hundred $F(T)$ measurements were made with interferometers of three different modifications. The values found for ν on reduction of data meeting the constant-velocity selection criterion (42 cases) form a compact group with an average value

$$\nu = 909.9014 \pm 0.0019^{9}$$

(the error was assumed equal to one standard deviation). The corresponding value of the Lamb shift is

$$\delta = 1057.8594 \pm 0.0019.$$

These data are encouraging from the standpoint of further accuracy improvement. The statistics must be improved significantly. It is also necessary to calculate the lifetime of the 2p state more accurately.

The theoretical value of δ can apparently be improved as well.[9,10,11] Therefore improvement of measurement accuracy is extremely important, since comparison with theory will make it possible to draw several fundamentally important inferences pertaining, among other things, to the dimensions of the proton.

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