Coherent mixing of 2S and 2P hydrogen atomic states due to the interaction with a metal surface

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Recently it has been demonstrated [1, 2] that the spectrum of the radiation emitted by a driven hydrogen atomic beam ($v/c = 0.01$) can change considerable if the atoms are contained in a metal slit. Our experimental results were interpreted as evidence of hydrogen $2S$ and $2P$-atomic states coherent mixing caused by $2S$-metastable hydrogen atoms passing through a slit cut a metal surface. We showed that the magnitude of this effect depends strongly on kind of metal (gold or palladium), distance from the metal surface and on surface roughness effects.

A possible explanation of the production of the $(2S - 2P)$ superposition is based on the assumption that there are electric charges on the metal surface creating the electric field E_{eff} which mixes $2S$ and $2P$ states of opposite parity. In this connection, the set of experiments had been executed in conditions, when the formation of any stray electric fields inside of atomic interferometer was completely excluded. It appeared however, that all accepted measures were unable to annihilate the observed long-distant interaction effect. Further experiments confirmed such an assumption.

One of them - the simplest one, and, at the same time, giving the opportunity of absolutely unequivocal interpretation, consists in the following. The beam (97% of atoms $1S$ and 3% of atoms $2S$) with energy $20keV$, passed successively through the flat capacitor with thansverce electric field E_q quenching, if it is necessary, $2S$-component and then through two metal slits I and II separated by a variable distance L, which could change in limits from 0 up to 15 mm. The first slit (slit I), $0.05mm$ width, played simultaneously role of a collimator. Width of the second slit (slit II) - analyzer - could be accepted equal 0,3; 0,5 or 1,0 mm., remaining constant during experiment. L_α-quanta, appearing due to the deexcitation of $2P$-atoms were registered by detector D placed behind the slit II at a constant distance.

Already from the primary experimental data (number of L_α-counts versus L), obtained with detector D, for $E_q = 0$ and for $E_q = 1000v/cm$, it was obvious, that in the presence of $2S$- component, distinct intensity oscillations of the $2P$-atoms flux were observed, i.e. the interference of this state. On contrary, in the case, when $2S$-atoms were removed from the beam ($E_q = 1000v/cm$), $2P$-intensity oscillations disappeared completely.

Such picture could arise only under following conditions: in the slit I, owing to interaction of $2S$-atoms with its metallic walls, coherent mixing of $2S$ and $2P$ states occurs, i.e. formation of the $2S - 2P$-superposition. In the second slit, under influence of similar interaction, addi-

tional coherent mixing of these states takes place, owing to that, with change of distance L, oscillations of the $2P$-component intensity are observed. We shall emphasize once again: the intensity oscillations could arise only with presence of the considered mechanism - any other reasons cannot cause them. In the described system consisting only of two, covered by gold and thorougly grounded plates with the slits for passage of the beam, the electrical fields are absent completely. Thus, the conclusion made earlier, reliably proves to be true: the interaction of the exited moving hydrogen atom with a metal surface has a specific nature and only phenomenologically can be ascribed to the action of some effective field E_{eff}.

It is necessary to note, that the results of experiments, obtained with various versions of the interferometer, have very good reproducibility, that has allowed, first of all, to determine intensity and direction of the field E_{eff} with respect to direction of the atom speed. For this purpose, instead of the slit II, the system with longitudinal (i.e. parallel or antiparallel with respect to the atom speed vector) electrical field was installed. If the electrodes, creating the field, with the slits, cut in them, were shortened and grounded, then, with change of distance L distinct oscillations of the $2P$-component intensity were observed (analogous to experiment with the slit II). With presence of a field coinciding with the speed direction, the amplitude of beets was increased, and the character of the interference curve testified coincidence of the phases of beets caused by an external field and the field E_{eff}. In case of change of a sign of a field the amplitude of beets was decreased and the mismatch of phases occured. The processing of the received data has allowed to make the conclusion, that the direction of a field E_{eff} coincides with direction of the atom speed and its intensity (for the used geometry of slits) corresponds to intensity of an electrical field equal 3,6 V/cm. If the slit II is formed by two sharp edges, the function $I_{2p}(l)$ becomes exponential and simply reduces to $exp(-2\pi/\Delta_L)$, where $\Delta_L = v/\delta$ (v - atom velocity, δ - Lamb frequency). The "Lamb wavelength" Δ_L, i.e the period of spatial oscillations of the interference curve, is huge on the atomic scale and does not involve any characteristic of the metal surface. Hence it follows that the observed effect is indeed a long range interaction, and is a universal phenomenon.

[1] Yu. L. Sokolov, *Phys. Usp.* **42** 451 (1999).
[2] B. B. Kadomtsev and M. B. Kadomtsev *Physica Scripta* **50** 243 (1994).