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DIFFERENTIAL EFFECT OF THE THOMAS PRECESSION OF THE RELATIVISTIC ELECTRONS

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Introduction

The Thomas precession of any body was discovered in 1927 [1,2] as a new phenomenon in the atomic physics and special theory of relativity. This phenomenon is a pure relativistic one and is the result of the noncommutativity of the composition law of the relativistic velocity vectors. The Thomas rotation formalism based on the noncommutative and non-associative groups for relativistic velocities has been studied by A.A. Unger [3]. It was also proved [4,5] that Thomas precession can be explained by using its associated grouplike structure.

The most dramatic feature of the Thomas precession was discovered by one of the authors (B.S.N.) [6,7]. In line with a direct approach, which is in complete accordance with the earlier results [8], it follows that there exists the Thomas precession effect, which is defined by the mutual orientation of two velocity vectors, one of the electron itself in the laboratory frame and another one of the laboratory frame.

For any observation angle θ there exists a local Thomas spin precession frequency $\omega(\theta)$, which is defined by equation [7,9]:

$$\omega(\theta) = \frac{eB_0}{mc}\left[a + \frac{\gamma_e + \gamma_0}{\gamma_e} \cdot \frac{1}{1 + \gamma_e\gamma_0(1 + \beta_e\beta_0 \cos\theta)}\right], \tag{1}$$

where β_e is the velocity of the electron in the laboratory frame and β_0 is the velocity of the laboratory frame itself, and γ_e and γ_0 are the corresponding Lorentz factors, $a = g/2 - 1$ is the anomalous part of the particle g-factor, and eB_0/mc is the static Larmor frequency.

From Eq. (1) it follows that the differential effect of the Thomas precession is a pure relativistic one and vanishes for $\gamma_e \to 0$. The local spin Thomas precession frequency can be approximated by the linear function of β_e. To observe this differential effect we must use electrons accelerated up to 1 MeV, and we must also increase the scale of the electronic orbit up to the macroscopic one ($\sim$ 0.1 m). In such conditions we get the opportunity to measure the local Thomas precession frequency in the different parts of the macroscopic ring orbit. This effect contradicts the Einstein relativity theory but is in line with Lorentz approach.

Device

The proposed experimental device consists of a compact storage ring of the accelerated electrons with energy 0.5 MeV ($\gamma \approx 2$). The curvature radius of the ring trajectory is equal to 92 mm. The lifetime of the electron bunch must be equal to 10 ms or more. The energy spread of the electron beam must be as small as 0.1%.

The electrons are injected into the storage ring at initial energy of 30 keV. The polarization vector of the accelerated electrons is directed along the main magnetic field of the storage ring. The induction acceleration of the electrons is accomplished via the adequate time-program of the main magnetic field.

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The local resonator coil is placed in the part of the electronic orbit at 180° with respect to the injection unit. The magnetic field of this coil is oriented along the velocity vector of the electrons and is fed by the alternative electric current at various frequency to search for the resonance frequency, at which the depolarization of the electron spin is taking place. The time variations of this frequency during the day is the goal of the observations.

To control the depolarization effect, a polarimeter with Mott scattering counter at the angle $\theta_{s.c.} = 125°$ must be used. The current of the electrons in the storage ring must be of the order of 1 μA; and the degree of the spin polarization, of the order of 80%.

The whole experimental device consists of the following parts: storage ring of electrons, source of the polarized electrons [11], injector unit, static accelerator, resonance depolarizing coil, Mott polarimeter and computer control system.

Figure 1 gives the general view of this device, which includes: 1 — vacuum chamber, 2 — liquid nitrogen chamber, 3 — liquid helium chamber, 4 — polarized electron source, 5 — static voltage supplier, 6 — distributed insulator, 7 — Roots pump, 8 — probe, 9 — quadrupole lenses, 10 — depolarizing magnetic coil, 11 — rotable target and 12 — particle counter of the Mott polarimeter.

Figure 2 gives a side view of the central part of the storage ring with 13 — two pairs of the coils, producing the main magnetic field B_Z, and 14 — quadrupole lenses.

Expected effect

The expected daily variations of the differential (local) Thomas precession is of the order of $\delta\omega_T \gtrsim 10^{-4}\,\omega_0$ with ω_0 being the electron cyclotron frequency. To get the measurement error of the order of $0.1 \cdot \delta\omega_T$, the lifetime of the electronic bunch must be 10 ms or more.

Concluding remarks

As was shown in [7], the average value of the Thomas precessiong frequency is equal to

$$\omega_{av} = \frac{eB_0}{mc}\left(g + \frac{1}{\gamma_e}\right) = \frac{g}{2} \cdot \frac{eB_0}{mc} - \omega_c(\gamma_e - 2)\,, \qquad (2)$$

does not contain any information of the translational movement of the laboratory system. This result is in complete aggrerment with results of the $(g-2)$ experiment for electrons [10].

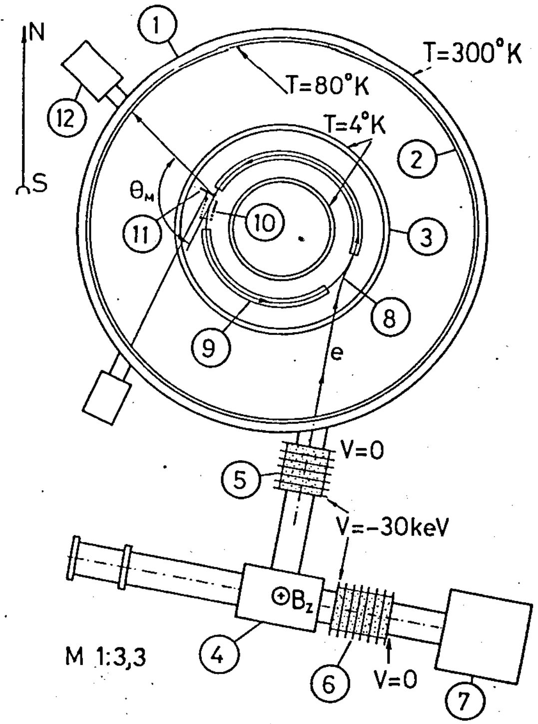

Fig. 1. General view of the experimental setup designed for observation of the differential effect of the Thomas precession of the relativistic electrons.

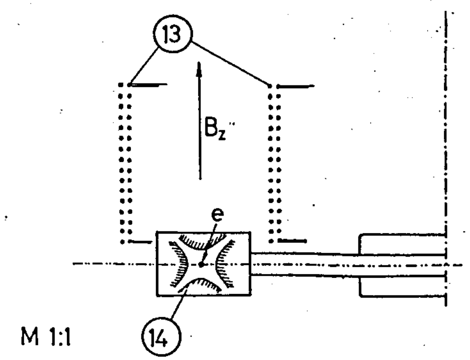

Fig. 2. Side view of the central part of the storage ring.

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Дифференциальный эффект прецессии Томаса релятивистских электронов

Показано существование эффекта прецессии Томаса, который зависит от взаимной ориентации двух векторов скорости: одного для электрона в лабораторной системе координат и другого для лабораторной системы координат. Указанный эффект можно наблюдать при помощи экспериментальной установки, которая представляет собой макроскопическую модель кольцевых траекторий электрона в атоме. Такая макроскопическая модель обеспечивает адекватные условия для экспериментального исследования этого дифференциального чисто релятивистского эффекта, который определяется двумя главными особенностями установки: 1) электроны имеют релятивистскую скорость ($\gamma \approx 2$), а не малые скорости в природных атомах ($\gamma - 1 \approx 0.1$), и 2) макроскопический масштаб траекторий электронов с радиусом орбиты электронов порядка 10 см.

Описанное в данной работе устройство, предназначено для экспериментального доказательства существования указанного дифференциального эффекта прецессии Томаса. Даны технические параметры экспериментальной модели. Существенной частью ее является источник поляризованных электронов.

Работа выполнена в Лаборатории сверхвысоких энергий ОИЯИ.

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Differential Effect of the Thomas Precession of the Relativistic Electrons

It is shown that there exists the effect of the Thomas precession which depends on the mutual orientation of two velocity vectors: one of the electron in the laboratory frame, and another one of the laboratory frame. This effect can be observed in the experimental device which represents a macroscopic model of the electron ring trajectories in the atom. Such model offers the most adequate conditions for an experimental investigation of this differential pure relativistic effect defined by two main features of this device: 1) relativistic velocity of the electrons ($\gamma \approx 2$), instead of low velocity in the natural atoms ($\gamma - 1 \approx 0.1$), and 2) macroscopic scale of the electron trajectories with electron orbit radius of the order of 10 cm.

The device designed for experimental proof of this differential effect of the Thomas precession is described. The technical parameters of this experimental model are given. The essential part of the model is the spin polarized electron source.

The investigation has been performed at the Laboratory of Particle Physics, JINR.

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