ONE METHOD OF SEARCHING FOR QUARKS

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As already indicated [1], one can attempt to search for the only stable quarks with "fractional" elementary charge either by direct use of Millikan's method or by one of its modifications.

The presence in the macroscopic test body of one or two quarks with charge equal to e/3 makes it impossible to compensate for the fractional charge by adding or subtracting electrons to this body, and such a body will always remain charged. According to known estimates [1], the number of quarks has a lower limit of $10^{-19}$. In Millikan's experiments [2] the drops carrying several electron charges consisted of $10^{13}$ atoms. It is desirable therefore, in experiments aimed at searching for quarks, to increase the mass of the body by 4 - 5 orders of magnitude compared with Millikan's mass. An increase in the mass of the test body leads to many strictly experimental difficulties. The weight of such a body cannot be balanced by an electrostatic force acting on an excess charge equal to that of several electrons, for this calls for a field intensity at which strong field emission takes place. The use of a large excess charge of more than 100 electrons is not desirable, for then the requirements become quite stringent with regards to the linearity of the dynamic scale of the instrument that registers the displacement of the body, such as to be able to detect the presence of an additional charge equal to e/3. It is therefore desirable to "suspend" the test body in a parallel-plate capacitor without direct mechanical contact. This can be done either by using servomechanism and adding a ferromagnet to the test body [3], or by using a suspension based on strong magnetic field gradients and adding a diamagnet to the body [4]. In either case the test body is in a three-dimensional potential well. The oscillation amplitude due to the excess charge ~e/3 of a spherical test body suspended in the field of a parallel-plate capacitor whose field intensity E varies with a frequency equal to the natural frequency of the body in the potential well is

$$a_q \simeq \frac{e E_0}{18 \pi r \eta \omega_0}, \tag{1}$$

if such an oscillator has a mechanical $Q \gtrsim 2$. In formula (1) $E_0$ is the amplitude of the field intensity, $\eta$ the viscosity of air, r the radius of the body, and $\omega_0$ the natural frequency of the body oscillations in the field direction.

$$Q = \frac{2 \rho r^2 \omega_0^2}{9\eta} \tag{2}$$

where $\rho$ is the density of the body. For $r \geq 1 \times 10^{-2}$ cm and atmospheric pressure we get $Q \geq 6$ if $\omega_0 = 30$ rad/sec.

If $E_0 = 30$ cgs esu, $r = 1 \times 10^{-2}$ cm, and $\omega_0 = 30$ rad/sec, then $a_q = 4 \times 10^{-6}$ cm. The amplitude of such an oscillation can be readily measured with radio-optical amplification methods (for example, using the so-called "knife in slot" method [5]). In addition to the force due to the excess charge, the test body (conductor or dielectric) experiences a force $F_{inh}$ due to the inhomogeneity of the field, and acquires an oscillation amplitude

$$a_{inh} \simeq \frac{3\ E_0^2\ \Delta d}{16\ \pi\ L^2\ \rho\ \omega_0^2}\ , \tag{3}$$

where L is the linear dimension of the parallel-plate capacitor, and $\Delta d$ the possible inaccuracy in the size of the gap d along L. Expression (3), derived for a conducting body, is valid if $Q \gtrsim 2$. For a dielectric test body, the order of magnitude of $a_{inh}$ will be approximately the same. For $L = 10$ cm, $\rho = 2$ g/cm$^3$, $\omega_0 = 30$ rad/sec, $E_0 = 30$ cgs esu, and $\Delta d = 10^{-3}$ cm we get $a_{inh} \simeq 3 \times 10^{-7}$ cm, i.e., much smaller than $a_q$ for the same parameters. In addition, it must be recognized that when the field E is sinusoidal, it is easy to filter out $a_{inh}$ from the recording instrument, since $F_{inh}$ has a frequency double that of the field. In addition to the force $F_{inh}$, the test body is acted upon by thermal fluctuations, the relative role of which increases with increasing mass of the test body. It is easy to calculate the signal-to -noise ratio by using synchronous detection:

$$\frac{a_q^2}{a_{fl}^2} = \frac{e^2\ E_0^2\ \tau}{216\ \pi\ \kappa\ T\ r\ \eta}\ , \tag{4}$$

where $\tau$ is the separation time, $\kappa$ Boltzmann's constant, and T the temperature. For the values of $E_0$, r, and $\eta$ given above and for T = 300°K we obtain in accord with (4) $\tau \simeq 0.5$ sec if $(a_q/a_{inh})^2 = 1$.

Thus, for a reliable detection of a single quark the time required will not exceed several seconds. During that time it is necessary that the magnitude of the test-body charge remain constant (if the Millikan calibration method is used). The estimates obtained apparently point to the possibility of using trial bodies with masses three orders of magnitude larger than proposed in another modification of Millikan's method [6], thus increasing the probability of observing the quarks.

We present some preliminary results, obtained in a setup in which the test body was a graphite pellet with mass $m \simeq 1.5 \times 10^{-5}$ g suspended in a strong inhomogeneous magnetic field ($H \simeq 2 \times 10^4$ Oe, $\partial H/\partial z \simeq 10^6$ Oe/cm) produced near the edge of magnet pole pieces (for details of the procedure see [4]). In the gap between the pole pieces of the electromagnet (the gap length was 6 mm) was placed a parallel-plate capacitor ($L = 10$ cm, $d = 3$ mm, $\Delta d < 1 \times 10^{-3}$ cm), with the plates perpendicular to the magnetic flux lines. The pellet had $Q \simeq 5$ in the direction of the flux lines and a natural oscillation frequency $\omega_0 \simeq 36$ rad/sec. When the pellet was displaced along the flux lines, the intensity of a narrow light beam was modulated. Demodulation and registration of the motion were with the aid of a photoresistance and a simple electronic circuit, which could measure particle oscillation amplitudes on the order of $\sim 1 \times 10^{-7}$ cm with $\tau = 10$ sec. The constant force acting on the pellet, due to the light pressure, did not exceed $1 \times 10^{-9}$ dyne and therefore could not affect the measurement results. The charge of the pellet was measured with the aid of low-intensity x-rays. Preliminary measurements have shown that it is possible to produce a charge on the order of a hundred electrons on such a pellet. The fluctuations of the charge apparently determine the possibility of employing the described procedure in the search for quarks.

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## CONCERNING INDUCED MANDEL'SHTAM-BRILLOUIN SCATTERING

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Several recent papers (cf., e.g., [1-4]) have dealt with theoretical and experimental aspects of induced Mandel'shtam-Brillouin scattering (IMBS). We shall show below that the elastic oscillations generated in IMBS are not ordinary sound waves, but anomalous waves of reduced propagation velocity and with beam velocity making a certain angle with the front. This phenomenon is similar in nature to that considered in [5]. It has apparently already been experimentally observed in the form of a shift of the Stokes line [4].

Let a plane light wave with constant energy flux density $I_0$ be incident along the z axis on a lens of focal distance $\ell$. The energy flux dI which travels towards the focus from a solid angle element $d\Omega$ is equal to

$$dI(p) = I_0 \ell^2 p^3 \, d\Omega, \tag{1}$$

where $p = \cos^{-1}\vartheta$ and $\vartheta$ is the angle between the direction of the light ray and the z axis. (The refraction of the light rays on the boundary of the investigated substance is disregarded for simplicity, inasmuch as it leads only to a numerical correction of no fundamental significance.)

The wavelength of the hypersound responsible for the IMBS is smaller by many orders of magnitude than the dimensions of the focal spot. Therefore in the first approximation it is sufficient to consider the propagation of elastic oscillations in an infinite homogeneous