channel distorting potentials were the same.

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g_J Factor of an Ion: Determination of $g_J(^4\mathrm{He}^+, 1^2S_{1/2})/g_J(^4\mathrm{He}, 2^3S_1)$

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A measurement of the g_J factor of the hydrogenlike ion $^4\mathrm{He}^+$ in its $1^2S_{1/2}$ ground state has been made using an optical pumping technique. This represents the first precision measurement of the g_J factor of a simple atomic ion. The result is $g_J(^4\mathrm{He}^+, 1^2S_{1/2})/g(e^-) = 1 - 70.87(30)\times 10^{-6}$. This value agrees with theory and provides confirmation of the Breit term $\frac{1}{3}(Z\alpha)^2$ to within 0.5%.

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Measurements on hydrogen and hydrogenlike systems serve well as a test of physical theories. The theory for the interaction of these simple one-electron systems with an external magnetic field can be tested by making precision measurements of their g_J values. Earlier measurements[1] of the g_J values of hydrogen and deuterium have confirmed the mass-dependent terms of this theory[2] to within an accuracy of three parts in 10^{11}. The Z dependence of the theory can be examined by measuring the g_J value of the helium ion (He^+). We report an initial result for the ratio of the g_J value of this one-electron ion to that of the helium atom in the 2^3S_1 metastable state (He*). To our knowledge this represents the first precision measurement of the g_J value of a simple atomic ion.

Our measurements have been conducted in 50-ml cylindrical Pyrex cells containing a few mg of $^{87}\mathrm{Rb}$ metal and purified $^4\mathrm{He}$ at pressures ranging from 1 to 2 Torr. Optical pumping[3] of rubidium provides the primary polarization source and also serves to monitor Zeeman resonances in other species.[4] A weak, pulsed, electrodeless rf discharge, typically with pulse width of 50 μs and repetition rate of 240 Hz, produces He^+ ions in their $^2S_{1/2}$ ground state as well as He* and e^-, which are then polarized through exchange- and/or state-selective destructive collisions with the optically pumped Rb. We have successfully observed Zeeman resonances in all the species: Rb, He^+, He*, and e^-. Thus, we can determine the g factor of He^+ relative to that of either Rb, He*, or e^-. The He^+, He*, and e^- resonances are all resolved in our 100-G magnetic field and have respective linewidths of 800, 400, and 5000

Hz, while the Rb resonance has a linewidth of 450 Hz. Since Rb has a g factor about four times smaller than the other species, our best resolution is obtained for the ratio $g_J(\mathrm{He}^+)/g_J(\mathrm{He}^*)$. In comparison to our earlier determination[5] of $g_J(\mathrm{He}^*)/g_J(\mathrm{Rb})$, production and detection of He^+ requires not only a lower pressure but also a more intense discharge than for He*.

At an applied magnetic field of 100 G, the He^+ and He* resonances are separated by about 30 parts per million (ppm), and a digital sweep of both resonances is shown in Fig. 1. The e^- resonance, lying about 41 ppm higher in frequency than the He* resonance, is too weak and broad to be observed unless the rf field were much stronger than that used to obtain Fig. 1. The signal strength S under conditions of comparable rf saturation is such that $S(\mathrm{He}^*):S(\mathrm{He}^+)$ is approximately 10:1. Although the differences in the detection processes and their cross sections have not been examined, we have used the broadening of the Rb resonance by the discharge to estimate that the electron density in the weak discharge is $\sim 1.5 \times 10^9/\mathrm{cm}^3$ and the He* density is $\sim 1.5\times 10^{10}/\mathrm{cm}^3$. This supports a density ratio of 10/1 for $n(\mathrm{He}^+)/n(\mathrm{He}^+)$ in our pulsed discharge, rather than the larger value of 100:1 given by Pinard and Leduc[6] in their continuous discharge, and is consistent with our observed signal strengths.

A computer-controlled data acquisition system sequentially samples the He^+ and He* resonance line shapes. For each resonance, data points are taken at fifteen frequencies spread over about four linewidths. The line-shape parameters are then determined with a nonlinear least-squares routine to fit the data with a Lorentzian line shape that has been modified to include a sloping baseline. The ratio of g_J factors, $g_J(\mathrm{He}^+)/g_J(\mathrm{He}^*)$, is obtained directly from the frequency ratio of the fitted resonance centers. The signal-to-noise ratio of the He^+ signal is adequate to permit determination of this ratio to at least 0.1 ppm for a 15-min data run. However, at present our precision is limited to about 0.3 ppm by a systematic effect associated with a small asymmetry of the He* resonance. This asymmetry results in a shift of the He* resonance frequency as the discharge intensity is varied. This is a characteristic common to all cells, even those in which the helium pressure is greater than 5 Torr where a He^+ signal is not observed. An extrapolation of the values of $g_J(\mathrm{He}^+)/g_J(\mathrm{He}^*)$ versus He* resonance linewidth is used to suppress this effect. In the low-pressure cells required to observe He^+ resonances, we have found a smaller slope for this extrapolation procedure than in the higher-pressure cells[5] used in our determination of the ratio $g_J(\mathrm{He}^*)/g_J(\mathrm{Rb})$. To within the present uncertainty of 0.3 ppm, no systematic effect is observed for other experimental parameters such as the Rb pumping light intensity and polarization, the homogeneity of the applied magnetic field, the helium pressure in the cell, or the rf power driving the Zeeman resonances.

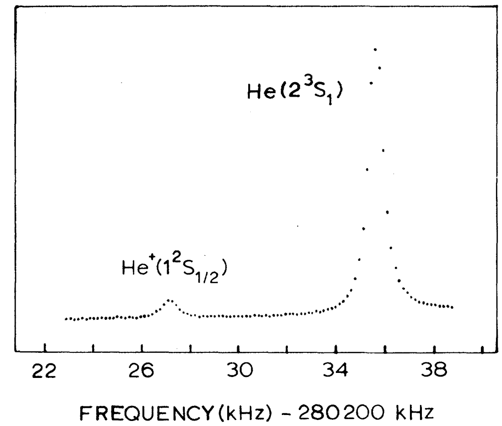

FIG. 1. Zeeman resonances of $\mathrm{He}^+(1^2S_{1/2})$ and $\mathrm{He}(2^3S_1)$ in a 100-G magnetic field. Their respective linewidths are about 0.8 and 0.4 kHz, while their separation is 8.37 kHz (30 ppm).

Our initial experimental result is

$$g_J(^4\mathrm{He}^+, 1^2S_{1/2})/g_J(^4\mathrm{He}, 2^3S_1) = 1 - 29.95(30)\times 10^{-6}.$$

With use of the previously determined ratios[5,7] $g_J(\mathrm{He}^*)/g_J(\mathrm{Rb})$ and $g_J(\mathrm{Rb})/g(e^-)$ yields an experimental value with respect to the free electron:

$$g_J(^4\mathrm{He}^+, 1^2S_{1/2})/g(e^-) = 1 - 70.87(30)\times 10^{-6}.$$

The theoretical value[2] for this ratio is

$$g_J(\mathrm{He}^+)/g(e^-) = 1 - \tfrac{1}{3}(Z\alpha)^2 + (\alpha/4\pi)(Z\alpha)^2 + (m/2M)(Z\alpha)^2 + \dots$$
$$= 1 - (71.002 - 0.124 - 0.015 + \dots)\times 10^{-6} = 1 - 70.863\times 10^{-6}.$$

Thus, our present result confirms the Breit term $\tfrac{1}{3}(Z\alpha)^2$ to within 0.5%.

In summary, our work on He^+ is the first use of an ion for precision g_J-factor comparisons. It offers the most promising opportunity to test the Z dependence of the g_J-factor theory for a hydrogenlike system. Using our current apparatus, we hope to improve the precision of our value to a few parts in 10^8 so that we will be able to criticize the radiative correction term $(\alpha/4\pi)(Z\alpha)^2$ to about 10%.

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Demonstration of Resistive Inhibition of Fast Electrons from Laser-Produced Plasmas in Low-Density Gold Targets

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A numerical model is used to show that the range of suprathermal electrons from laser-produced plasmas can be significantly reduced by the electric field needed to drive a return current of cold electrons. Direct experimental evidence of a reduction of preheat by at least a factor of 3 is presented for targets containing a low-density gold layer.

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It is now well established that when high-intensity light is incident on solid targets, a considerable fraction of the laser energy is converted into suprathermal electrons with a temperature T_H much greater than that of the thermal plasma.[1-3] Some of the energy of these electrons heats the target to comparatively large depths. Experiments with 1.06-μm lasers on layered targets containing K fluors[4] have measured the range of these suprathermal electrons and found that the range was consistent with the hard x-ray measurement of temperature and the Bethe-Bloch formula[5] for energy loss with scattering included. Preheat would have to be minimized for an ablative compression, and the use of a vacuum gap[6] might be one way of optimizing a *target* to prevent preheat. In this Letter we demonstrate an alternative target design for reducing the preheat range by including a high-resistivity, low–volume-density material within the target. The effect is explained simply; it is confirmed by a numerical simulation and by direct experimental measurements.

Consider a laser beam incident on a semi-infinite plane target. A fraction of the absorbed laser power is converted into suprathermal electrons flowing into the target carrying a current density j_H, which is typically 10^{10} A cm^{-2}.[4] The very-high-energy deposition rapidly ionizes the target which becomes a high–electron-density ($N_e \sim 10^{23}$ cm^{-3}), low–electron-temperature ($T_e \sim 200$ eV) plasma of resistivity η. Because such a plasma has a very small skin depth for the time scale of the laser pulse, a return current j_c must flow so that

$$j_H + j_c = 0.$$

The resistive electric field, $E = \eta j_c = -\eta j_H$, decelerates the suprathermal electrons, converting a part of their energy into Ohmic heating, ηj_c^2. If the collisional range of the suprathermal electrons is r_a (mass per area) and the target density is ρ then in the absence of electric field inhibition the suprathermal electrons will go a distance r_a/ρ, and the electrostatic potential a distance r_a/ρ into the target will be $\sim \eta j_H r_a/\rho$. However if $\eta j_H r_a/\rho \gtrsim kT_H/e$ the resistive electric field will appreciably impede the suprathermal electrons. The potential within the target is estimated in Table I for solid-density gold and for gold at 1% of its solid density (0.2 g cm^{-3}), with $j_H = 10^{10}$ A cm^{-2} for 100 ps as suggested by experi-