Measurement of the $E2$ transition probability in Ca and metrological applications

N. Beverini, F. Sorrentino , and E. Maccioni

Physics Department, University of Pisa
via Buonarroti 2, 56127, Pisa, Italy
Tel +39-050844288, Fax +39-050844333
E-mail: fiodor@df.unipi.it

We present here an experimental determination of the Einstein A_{ki} coefficient for the E2 quadrupole line in Calcium.

The forbidden transitions between the ground state and the metastable levels of Calcium and Magnesium have a large metrological interest for frequency standards working in the visible and near-infrared regions.

Much work has been done on the Calcium $^1S_0 \rightarrow {}^3P_1$ intercombination line at 657 nm, and some works are in progress on the corresponding $^1S_0 \rightarrow {}^3P_1$ transition in magnesium at 457.1 nm. The $^1D_2$ metastable level in Calcium can be excited either through an electrical quadrupole ($E2$) absorption at 457.5 nm, or through a dipole-allowed two-photon absorption at 915 nm. The two-photon transition appears particularly interesting for metrological applications, because of its intrinsic Doppler-free properties.

An experiment is now in progress in order to observe the two-photon transition on a cooled sample of Calcium atoms. As the lifetime of the $^1D_2$ level is dominated by the $^1D_2 \rightarrow {}^3P_1$ decay, the occurrence of the transition can be detected by observing the subsequent fluorescence emission at 657 nm. The radiation at 915 nm has been produced by developing a homemade CW tunable Ti:Sa laser, which can operate single-mode at the wavelength of 915 nm. More than 400 mW are available.

As a first step, we have measured the quadrupole transition probability on an absorption cell. The experimental values available in literature for the $E2$ transition rate are affected by a large error (20 %), and the theoretical estimations are not univocal [1]. About 100 μW of radiation at 457.5 nm were generated by frequency duplication of the Ti:Sa output on a $KNbO_3$ crystal. An absorption cell 40 cm long has been specially designed in order to work at a calcium vapor pressure of some 10^{14} (that is 550-600 °C). At this density the Doppler broadened absorption is of the order of some %. The effective density in the cell was calibrated by observing the absorption on the $^1S_0 \rightarrow {}^3P_1$ intercombination line at 657 nm; the source for the radiation at 657 nm was a diode laser in external cavity.

We compared the integral absorption of the two lines. To measure the integrated absorption we contemporarily scanned the two lasers across the lines, and fitted the recorded profiles assuming a pure Doppler line broadening. In fact the ratio between Doppler and homogeneous line-width is about one thousand. We took into account the three most abundant isotopes of Ca (^{40}Ca, ^{44}Ca and ^{42}Ca) and the values of the isotope shifts given in literature. Our measurements

were made in the linear absorption regime, i.e. we checked that saturation effects were absent. We measured the ratio between the two transition rates as 53.8 ± 0.8. Considering the most accurate experimental estimation available in literature [2] for the transition rate at 657 nm, this gives a value of 55 ± 3 sec^{-1} for the $E2$ transition rate.

[1] K. Fukuda, K. Ueda, *J. Phys. Chem.* **86** 676 (1982).

[2] R. Drozdovski, M. Ignaciuk, J. Kwela, J. Heldt, *Z. Phys. D* **41** 125 (1997).