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Two-colour photoassociation spectroscopy in ultracold ensembles of ^{40}Ca near the ^{3}P$_1$ - ^{1}S$_0$ asymptote

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Compared to the intensively investigated two valence electron systems strontium and ytterbium, calcium offers by far the narrowest ^{1}S$_0$ - ^{3}P$_1$ intercombination line with a natural linewidth of 375 Hz at a wavelength of 657 nm. Using this transition for spectroscopy allows for highly precise measurements and might enable the application of optical Feshbach resonances with low atomic losses.

We have measured the three most weakly bound ground state vibrational levels in the $X^1\Sigma_g^+$ potential of ^{40}Ca$_2$, using two-colour photoassociation. We previously measured [1] molecular states corrected for quadratic magnetic shifts [2] in the a$^3\Sigma_u^+$, $c^3\Pi_g$ exited state potential that served as intermediate levels. Cold ensembles of about 10^5 calcium atoms trapped in a crossed dipole trap at temperatures of approximately 1 μK have been interrogated in both Raman and Autler-Townes configuration. The field free binding energies have been derived with kHz accuracy benefiting from offset-locked tunable lasers with few Hertz linewidth and from a detailed lineshape analysis.

The interaction potential at large internuclear separations for these weakly bound levels is dominated by the long-range coefficients C_6, C_8 which have been derived using a full quantum computation including variation of the inner potential range [3]. Based on the three ground state binding energies measured so far we obtain a preliminary value for the s-wave scattering length $a = 308(10)a_0$.

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[1] M. Kahmann et al., Photoassociation spectroscopy of 40Ca measured with kilohertz accuracy near the 3P1+1S0 asymptote and its Zeeman effect. Phys. Rev. A, 89:023413 (2014)

[2] E. Tiemann et al., Nonlinear Zeeman effect in photoassociation spectra of 40Ca near the 3P1 + 1S0 asymptote. Phys. Rev. A, 92:023419 (2015)

[3] O. Allard et al., Experimental study of the Ca2 1S + 1S asymptote. Eur. Phys. J. D, 26:155–164 (2003)

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