Reply to Comment on ‘Species-selective lattice launch for precision atom interferometry’

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REPLY

Reply to Comment on 'Species-selective lattice launch for precision atom interferometry'

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In our paper [1], we based the calculation of $\lambda_{\text{tune-out}}$ of ^{39}K on reference [2] and more specifically on the tabulated values in version 1.0, which reports the lifetimes as $\tau_{D1} = \tau_{D2} = 26.37(5)$ ns. This led to $\lambda_{\text{tune-out}} = 768.959$ nm. Assuming the corrected values (table 1) in a more recent version of [2] (v1.02) or the ones in the original paper [3], we find the $\lambda_{\text{tune-out}} = 768.9691(20)$ nm, which is the same result as Cronin *et al* [4] and explain the discrepancy of 9.4 nm. As suggested, we use in this reply a more accurate formula of the dipole potential accounting for the contribution of the off-resonant terms:

$$U_{\text{dip}}(\vec{r}) = -\frac{\pi c^2}{2}\left[\frac{\Gamma_1}{\omega_{D_1}^3}\left(\frac{1}{\omega_{D_1}-\omega_L}+\frac{1}{\omega_{D_1}+\omega_L}\right)+\frac{2\Gamma_2}{\omega_{D_2}^3}\left(\frac{1}{\omega_{D_2}-\omega_L}+\frac{1}{\omega_{D_2}+\omega_L}\right)\right]I(\vec{r})$$

with the D_1, D_2 atomic transition lines ω_{D_1}, ω_{D_2}, the laser frequency ω_L and the speed of light c. This expression yields a small correction of 1.7 pm as pointed out by Cronin *et al* [4]. Contributions of core electrons and other atomic excitations to the residual static polarizability of alkalis can lead to further small corrections (less than 1 pm). We choose not to include them in this reply for the sake of simplicity. The interested reader is referred to table 5.5 in [5] for the considered isotopes.

We recalculate the tune-out wavelengths in table 1 with updated and referenced D lines data and give uncertainties throughout.

In order to verify that the results of our proposal remain valid despite the change in the numerical values of $\lambda_{\text{tune-out}}$, we recalculate the acceleration sequence that we introduced in our proposal. The new potential expression led to the need to choose a new couple of integers ($N1 = 2028$ and $N2 = 982$) for the momentum kicks of the two species (to initially minimize the differential velocity to 77 μm s^{-1}). The required detuning, following equation (8) in our paper, is of 4.99 pm instead of 2.9 pm previously. This leads to a slightly larger value of the depth of the parasitic lattice for Rb (5.38 nK instead of 3.12 nK). Figure 1 illustrates the main result of our paper with these new parameters. As the reader can appreciate, no changes are to be reported. In the Rb isotope case, the effect of the parasitic lattice leads to a velocity offset of about 1 μm s^{-1} consistent with the results of our papers ($P = 4$ W in figure 8). All conclusions drawn in our proposal remain, therefore, unaffected after the corrections proposed in the comment.

Table 1. Updated table 1 of [1], with the lifetime of the atomic excited level τ and the line transition frequency ω_0. $\lambda_{\text{tune-out}}$ is calculated according to the dipole potential expression U_{dip} stated above. The different lifetimes of K isotopes reflect different measurements and not an isotopic shift.

Isotopes	τ_{D_1}(ns)	τ_{D_2}(ns)	$\omega_0^{D_1}/2\pi$(THz)	$\omega_0^{D_2}/2\pi$(THz)	$\lambda_{\text{tune-out}}$(nm)	References
Cs	34.750(70)	30.462(46)	335.116048807(41)	351.72571850(11)	880.1549(338)	[6–8]
^{85}Rb	27.679(27)	26.2348(77)	377.107385690(46)	384.230406373(14)	790.0273(47)	[9]
^{87}Rb	27.679(27)	26.2348(47)	377.107463380(11)	384.2304844685(62)	790.0272(47)	[10]
^{39}K	26.72(5)	26.37(5)	389.286058716(62)	391.01617003(12)	768.9708(28)	[3, 11]
^{40}K	26.79(7)	26.45(7)	389.286184353(73)	391.016296050(88)	768.9702(39)	[11, 12]
^{41}K	26.79(7)	26.45(7)	389.286294205(62)	391.01640621(12)	768.9700(39)	[11, 12]
Na	16.299(21)	16.254(22)	508.3331958(13)	508.8487162(13)	589.55650(35)	[13]
^{6}Li	27.102(9)	27.102(9)	446.789635(20)	446.799685(20)	670.987388(31)	[14, 15]

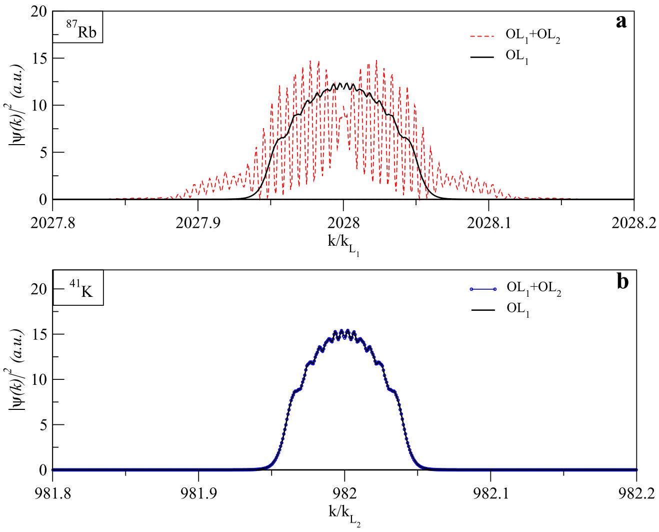

Figure 1. View of the central momentum class of the accelerated Bose–Einstein condensates. These results are obtained for very close ramping sequences to the ones of figure 5 of our proposal [1], slightly adapted to realize the new number of momentum kicks mentioned in the text.

References

[1] Chamakhi R *et al* 2015 Species-selective lattice launch for precision atom interferometry *New J. Phys.* **17** 123002

[2] Tiecke T 2010 Properties of potassium (http://tobiastiecke.nl/archive/PotassiumProperties.pdf)

[3] Wang H, Gould P L and Stwalley W C 1997 Long-range interaction of the ^{39}K(4s) + ^{39}K(4p) asymptote by photoassociative spectroscopy *J. Chem. Phys.* **106** 7899

[4] Cronin A D and Trubko R 2016 Comment on 'Species-selective lattice launch for precision atom interferometry' *New J. Phys.* **18** 118001

[5] Gregoire M D 2016 Static polarizability measurements and inertial sensing with nanograting atom interferometry *PhD Thesis* University of Arizona

[6] Steck D A 1998 Cesium D line data v2.1.4 (http://steck.us/alkalidata/cesiumnumbers.pdf)

[7] Young L *et al* 1994 Precision lifetime measurements of cs $6p^2p_{1/2}$ and $6p^2p_{3/2}$ levels by single-photon counting *Phys. Rev.* A **50** 2174

[8] Patterson B M *et al* 2015 Lifetime measurement of the cesium $6P_{3/2}$ level using ultrafast pump–probe laser pulses *Phys. Rev.* A **91** 012506

[9] Steck D A 2008 Rubidium 85 D line data v2.1.6 (http://steck.us/alkalidata/rubidium85numbers.pdf)

[10] Steck D A 2001 Rubidium 87 D line data v2.1.5 (http://steck.us/alkalidata/rubidium87numbers.pdf)

[11] Falke S *et al* 2006 Transition frequencies of the D lines of ^{39}K, ^{40}K, and ^{41}K measured with a femtosecond laser frequency comb *Phys. Rev.* A **74** 032503

[12] Volz U and Schmoranzer H 1996 Precision lifetime measurements on alkali atoms and on helium by beam-gas-laser spectroscopy *Phys. Scr.* T **65** 48

[13] Volz U *et al* 1996 Precision lifetime measurements on NaI $3p^2P_{1/2}$ and $3p^2p_{3/2}$ by beam-gas-laser spectroscopy *Phys. Rev. Lett.* **76** 2862

[14] Scherf W *et al* 1996 Re-measurement of the transition frequencies, fine structure splitting and isotope shift of the resonance lines of lithium, sodium and potassium *Z. Phys.* D **36** 31

[15] McAlexander W I, Abraham E R I and Hulet R G 1996 Radiative lifetime of the 2*p* state of lithium *Phys. Rev.* A **54** R5