

Supplementary Table 1

$\Delta\omega_z/2\pi$ (Hz)	$n = 1$	$n = 2$	$n = 3$	$n = 4$
$m = 0$	0	-217	-434	-651
$m = 1$	-9	-226	-443	
$m = 2$	-18	-235		
$m = 3$	-27			

Frequency shifts in Hz for a transition transferring an atom from the ground band to the fourth band, starting with n and m atoms in each of these bands. The shifts are measured relative to an initial state with one atom in the ground band and none in the excited band.