TOWARDS GAMMA-RAY COHERENT EMISSION IN ULTRACOLD ^{135m}Cs

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To date, the realisation of a gamma-ray laser has been hindered due to the difficulty in accumulating a sufficient number of emitters (i.e. excited nuclei) and the unsustainability of single-pass amplification. In order to circumvent these limitations, we propose the use of ^{135m}Cs isomers (see Figure 1) in a Bose-Einstein condensate (BEC) as a solution for realising a coherent gamma-ray source [1]. This would solve the problem of requiring a large accumulation of emitters, and it would effectively reduce the emission linewidth due to suppressed Doppler effects in ultracold temperatures. A single-burst gamma-ray source based on the proposed mechanism will be the precursor of gamma lasers, opening new avenues in fundamental research and technology, with relevant impact in fields such as medicine, security and industry.

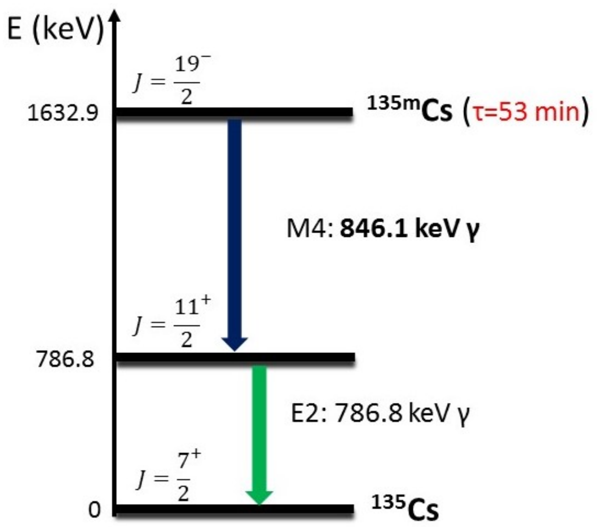

Figure 1: Nuclear de-excitation scheme of the ^{135m}Cs isomer.

The proposed technique takes advantage of the coherence of ^{135m}Cs, in a BEC, achieving collective de-excitation of the isomers well below the densities required by the Dicke super-radiance. In contrast to the latter theory, where the emission of the first photon from the inverted sample creates the dipole-dipole interactions and subsequently the coherence in the system, the coherence of the potential emitters has been already established thanks to the spatial coherence of the BEC. In this condition, an instability in the system can lead to a collective de-excitation of the isomers hence generating a coherent gamma-ray field at 846 keV [1].

A complete system for laser cooling and trapping atoms has been installed at the Accelerator Laboratory [2] of University of Jyväskylä. ^{135m}Cs will be produced by proton bombardment of a Uranium target and then routed towards the laser cooling chamber.

[1] L. Marmugi, P. M. Walker, F. Renzoni, arXiv 1608.03468 (2016).
[2] I.D. Moore et al., Nucl. Instrum and Meth. B 317 (2013) 208