

Quantum phase engineering for angular momentum states

S. McEndoo¹, S. Croke², J. Brophy¹ and Th. Busch¹

(1) Physics Department

University College Cork

Cork, Ireland

(2) Perimeter Institute for Theoretical Physics

Waterloo, Ontario,

N2L 2Y5, Canada

e-mail: smcendoo@phys.ucc.ie

Abstract

Superfluid vortices in Bose-Einstein Condensates have been one of the most interesting topics of research in cold atomic physics in recent years. They are represented by localised defects around which a quantised current is flowing and the associated quantum numbers can in principle be used to represent quantum bits [1]. These quantum numbers are of geometrical nature and they would allow achieving large storage times, since the lifetime of a vortex is often only determined by the topology of the external trapping potential. While the fundamental properties of vortices are well investigated, proposals for detailed state engineering are rare.

Here we will show how a vortex superposition state can be created in a controlled manner. For this we make use of a process related to Stimulated Raman Adiabatic Passage (STIRAP), which in optics is a process that uses a counterintuitive sequence of laser pulses to transfer an electron between the two ground states in a lambda system. An analogous process for the centre-of-mass states for trapped atoms, called Coherent Tunneling Adiabatic Passage (CTAP), has recently been suggested, which allows high fidelity transfer of population densities between spatially separated traps.

Applying this process to a two-dimensional vortex state takes a degree of freedom into account that has no equivalent in the optical case and we find that the non-trivial phase distribution of the vortex gets changed in a complicated but predictable way [2]. In particular we show that the

phase distribution of the final state can be adjusted by the experimenter by simply choosing the overall time the CTAP process will take.

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References

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