Matter-Waves lensing in Dynamic Wave-Guides

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Mattewaves are promising candidates for the realization of extremely sensitive sensors. Some of the most sensitive and precise measurements to date of gravity[1], inertia[2], and rotation[3] are based on matter-wave interferometry with free-falling atomic clouds. A critical requirement to achieve very high sensitivities is the long interrogation time, which consequently leads to experimental apparatus up to a hundred meters tall or the requirement for experiments to be performed in microgravity in space[4—7]. To tackle this problem, the gravitational acceleration must be cancelled, e.g. by manipulating atomic waves in time-changeable traps and waveguides [8].
We have recently demonstrated smooth and controllable matter-wave guides by transporting Bose-Einstein condensates (BECs) over macroscopic distances without any heating or decohering their internal quantum states [9]. A neutral-atom accelerator ring was utilized to bring BECs to very high speeds (up to 16 times their sound velocity) and transport them in a magnetic matter-wave guide for 15 centimetres whilst fully preserving their internal coherence. We then use a magnetogravitational matter-wave lens to collimate and focus matterwaves in ring-shaped time-averaged adiabatic potentials. This “Delta-kick cooling” sequence of Bose-Einstein condensates reduces their expansion energies by a factor of 46 down to 800 pK. Compared to the state-of-the-art experiments, requiring zero gravity or large free-flight distances, the ring-shaped atomtronic circuit has a diameter of less than one millimetre and exhibits a high level of control, providing an important step toward atomtronic quantum sensors and the investigation of very low energy effects in ultra-cold atoms.

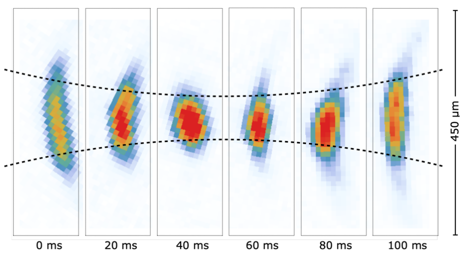

Figure: The focus of a BEC in a matter wave guide based on Time-Averaged Adiabatic Potentials

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10. Saurabh Pandey et al. *Atomtronic Matter-Wave Lensing* Phys. Rev. Let. **126 17** (2021)

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