Aberrations of Bragg beam splitters – 3D simulations

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Atomic beam splitters are a central component of matter wave interferometers, which provide the opportunity of high-precision rotation and acceleration sensing. Potential applications range from fundamental physics to inertial navigation. In the QUANTUS (quantum gases under microgravity) free-fall experiments atom interferometry is the central method as well [1].

Beam splitters are used to prepare a coherent superposition of atomic wave packets in momentum space by transferring photon momentum from a laser field. Clearly, the aim of such devices is to cover a wide momentum range with unit response. Equivalent to optical systems all matter wave devices require accurate specifications and ubiquitous imperfections need to be quantified.

We focus on the response and aberrations of an atomic beam splitter in quasi Bragg configuration, viz. considering losses into higher diffraction orders, in three dimensions.
In particular, we characterize the non-ideal behavior due to spatial variations of the laser beam profiles and wave front curvatures, regarding realistic Gaussian laser beams instead of ideal plane waves. In addition, different temporal envelopes of the laser beams will be considered.
We present results of numerical and analytical studies of the velocity dependence of the complex reflectivity of the beam splitter. Especially for secant hyperbolic pulse shapes, we developed an analytical Demkov-Kunike model. Finally our theoretical results are confirmed by experimental data [2].

Figure 1 shows the effect of different aberrations to the beam splitter response.

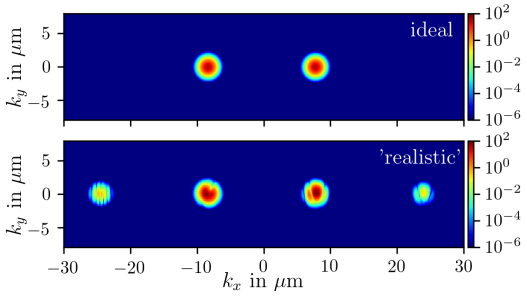

Figure 1: The column integrated density in momentum space after applying a beam splitter pulse, ideally (top) splitting the whole population into two parts of equal size, shows imperfections for 'realistic' beam splitters (bottom).

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References

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