

Matter wave gyroscopes at the quantum limit and Gauss sums | 3GS

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PhD:

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Abstract:

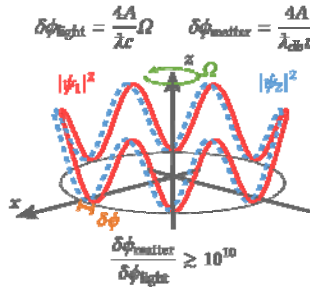


Fig. 1 Matter wave Sagnac gyroscope vs rinalaser avroscope.

Since the first observation of a Bose-Einstein condensate (BEC) in 1995, BECs have become a versatile tool in the investigation of many quantum phenomena. In particular, interferometers based on matter waves enable high-precision measurements of electromagnetic and gravitational fields, accelerations and rotations as well as tests of the weak equivalence principle. These BEC-based devices can principally attain much higher sensitivities than laser-based interferometers of the same size. This advantage is due to the fact that the de-Broglie wavelength of a BEC is much smaller than the wavelength of light in a laser-based interferometer (see Fig. 1). Moreover, the sensitivity of a BEC interferometer is determined by the enclosed space-time area, that is the enclosed area and the velocity of the atoms. Therefore, gravity imposes a fundamental limit for experiments performed on earth due to the limited interrogation times available for a BEC inside a typical setup. Fortunately, ring geometries as well as microgravity forms offer a way to circumvent this problem. can be used to realize Raman- or Bragg based pulse interferometers and gyroscopes for the precision measurement of rotations and accelerations. In our work we aim at finding the sensitivity-limits of these type of devices by considering the following aspects:

- i. Sensitivity limiting effects due to parasitic diffraction phases of realistic Raman-/Bragg splitters using a combined analytic and numerical approach applicable to ring- as well as free space interferometers [1, 2, 3, 4, 5].
- ii. Influence of the BEC dynamics of the matter-wave along the interferometer axis in between light pulses by an effective Gross-Pitaevsky equation (GPE) [4].
- iii. The limitations of an effective GPE description of interferometry due to the induced quantum potential from the confined quantum motion in the radial direction.
- iv. Design of novel pulse schemes and interferometer geometries to measure accelerations, rotations and the interaction with external potentials [1, 5].
- v. Application of number theoretical tools to enhance the sensitivity of a matter wave Sagnac gyroscope via an approximation of the Gross-Pitaevsky propagator in a suitable weak nonlinearity regime by a Gauss sum.

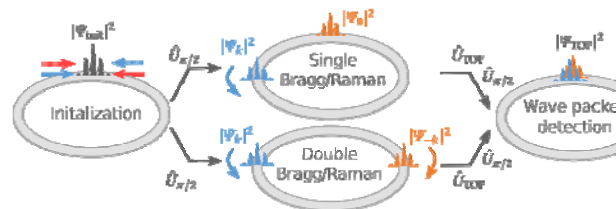


Fig. 2 Raman- or Bragg pulse based interferometry in ring geometry

Recent results:

- 1) Novel analytical and numerical description of the two-photon light shift in atomic Bragg diffraction [3, 4].
- 2) Asymptotic analytic results for the explicit interdependence of AC-Stark shift and two-photon light shift in Raman- and Bragg diffraction as well as a full numerical characterization of this effect in the relevant parameter regimes. Application of these results to the suppression of these parasitic phase shifts in Raman- and Bragg type beam splitters. [4, 5]

Publications:

- [1] **Composite-Light-Pulse Technique for High-Precision Atom Interferometry**, P. Berg, E. Giese, W. P. Schleich et al. PRL **114** 063002 (2015)
- [2] **Double Bragg interferometry**, H. Ahlers, E. Giese, E. M. Rasel, W. P. Schleich et al. PRL **116**, 173601 (2016)
- [3] **Light shifts in atomic Bragg diffraction**, E. Giese, A. Friedrich, S. Abend, E. M. Rasel, W. P. Schleich PRA **94** 063619 (2016)
- [4] **Phase contributions in atomic Bragg diffraction due to retro-reflective geometries**, A. Friedrich, E.

3) Proposal for a new class of generalized matter wave interferometers based on branch dependent Bragg- or Raman pulses with applications to facilitating an interferometer with a hard wall mirror, quantum clocks and gravitational decoherence. [6]

Giese, E. M. Rasel, W. P. Schleich (in prep., 2017)
[5] Interplay of two-photon light shift and AC-Stark shift in Raman diffraction, A. Friedrich, E. Glasbrenner, W. P. Schleich, (in prep., 2017)
[6] Mimicking a hard wall mirror in light-pulse atom interferometers, E. Giese, A. Friedrich, W. P. Schleich (in prep., 2017)

Further Collaborators:

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