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Max Planck Institute for Solid State Research

Matter wave gyroscopes at the quantum limit and Gauss sums| 3GS	**Start Date:** September 1st 2014

PhD: Enno Giese (Ulm, 1.9.2014 - 30.11.2015) Alexander Friedrich (Ulm, 1.12.2015 - today)	**PIs:** Prof. Wolfgang P. Schleich (Ulm) Prof. Helmut Maier (Ulm)

Abstract:

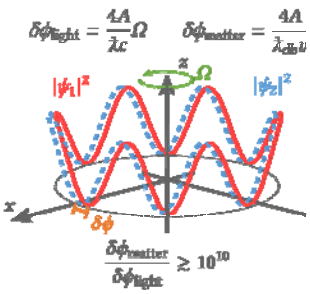

Fig. 1 Matter wave Sagnac gyroscope vs ringlaser gyroscope.

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 platforms offer a way to circumvent this problem. Both can be used to realize Raman- or Bragg based light 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 week nonlinearity regime by a Gauss sum.

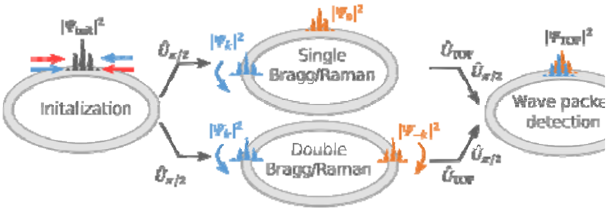

Fig. 2 Raman- or Bragg pulse based interferometry in ring geome-

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: QUANTUS Collaboration, Gerhard Birkl (TU Darmstadt), Malcom Boshier (Los Alamos National Lab, NM), Frank Narducci (Naval Air Systems Command, Baltimore, MD), DataVortex Technologies (Austin, TX)	