A matter wave interferometer with the K_2 molecule

Christian Lisdat, Kirsten Jaspers, Matthias Frank, Horst Knöckel, and Eberhard Tiemann

Institut für Quantenoptik, SFB 407 Universität Hannover
Welfengarten 1, D-30167 Hannover, Germany
Tel +49-511-7623306, Fax +49-511-7622211
E-mail: tiemann@iqo.uni-hannover.de, Website: http://www.iqo.uni-hannover.de

Matter wave interferometers offer the possibility of high precision metrology, measurements of small internal couplings or the influence of rotations and topological phases. Usually these experiments make use of the internal degrees of freedom of the particles, in particular their electronic states. We will widen this scope by using the K_2 molecule with its rotational and vibrational levels, which should be, for example, sensitive to weak influences like collisions with other particles. Such effects by collisions on atomic and molecular matter waves were already observed and can be interpreted as an index of refraction [1].
The interferometer applied is a typical Ramsey-Bordé setup [2], which makes use of the transition between the ground state X $^1\Sigma_g^+$ and the long living electronically excited state b $^3\Pi_u$. This transition is observable due to coupling of the states b and A $^1\Sigma_u^+$.
We present systematic investigations to characterize the interferometer and compare our mea-

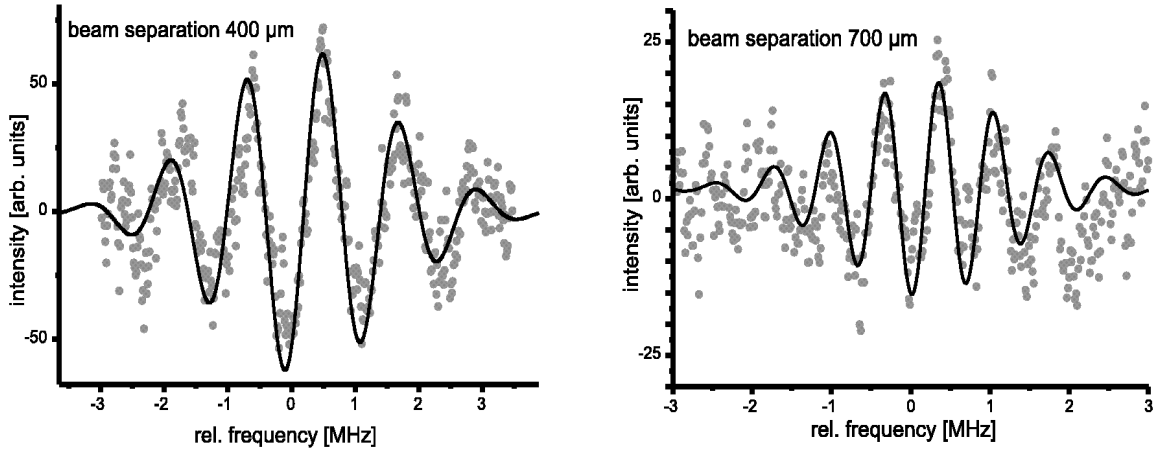

Figure 1: Interference fringes with the transition b $^3\Pi(0_u^+)$ v'=27, J'=26 ← X $^1\Sigma_u^+$ v="0, J"=25

surements with numerical simulations (Fig. 1). Here, experimental traces with substracted incoherent background for two dark zone lenghts D are shown. The solid curve is a simulation with adjusted amplitude and phase.
The possibilities of studying the influence of cold collisions between K_2 molecules and potassium atoms within the molecular beam will be discussed by estimating phase shifts induced in the interference signal and the status of experiments concerning this topic will be presented: In a supersonic beam relative velocities between the collision partners below 20 m/s can be achieved. Deflecting the atoms out of the beam will switch on and off atom-molecule collisions.

Additionally, the influence by collisions can be varied through excitation of atoms to Rydberg states.
Finally we present an interferometer setup connecting vibrational levels in the ground state by STIRAP [3] and show experimental results of investigations about the capability of STIRAP as beamsplitter in a complex system with hyperfine structure.

In a simplified picture, two $J = 1$ levels are coupled in a STIRAP zone via a $J' = 0$ level.

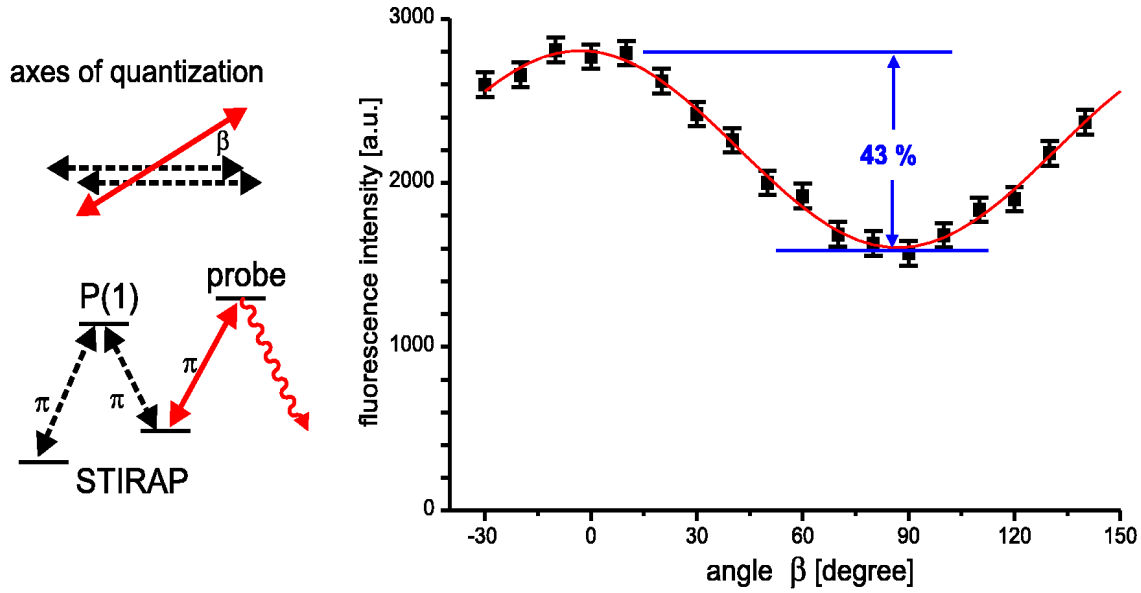

Figure 2: Coherent preparation of population in magnetic sublevels m by STIRAP probed by tilting quantization axes of STIRAP and probe lasers with respect to each other.

Using linearly polarized light, $m_J = 0$ is populated only. In a frame of observation rotated by 90°, the population is coherently spread over $m_J = \pm 1$, while the population of $m_J = 0$ is zero. Probing in this frame with π–light will therefore induce no fluorescence on a P(1) transition with $J' = 0$.
Fig. 2 shows the dependence of fluorencence of such a probe transition on the angle β between the axes of quantization of STIRAP preparation and probe beams. Since the manifold of m–levels is increased by the presence of hyperfine structure, the situation is not as simple as described above. By the existence of several m_F–levels in the excited intermediate state of the STIRAP process, a larger set of magnetic sublevels is populated. Additionally, energetically nearly degenerate Λ–systems exist for different total angular momenta F. Both effects lead to non vanishing fluorescence for $\beta = 90°$. Nevertheless, the system shows the capability as interferometer setup.

[1] M. Chapman, C. Eckstrom, T. Hammond, R. Rubenstein, J. Schmiedmayer, S. Wehinger. D. Pritchard, Phys. Rev. Lett. **74**, 4783 (1995)

[2] Ch. J. Bordé, N. Courtier, F. du Burck, A. N. Goncharov, M. Gorlicki, Phys. Lett. A **188**, 187 (1994)

[3] U. Gaubatz, P. Rudecki, S. Schiemann, and K. Bergmann, J. Chem. Phys. **92**, 5363 (1990)