Slow velocity-tunable metastable argon beam for matter-wave experiments

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By pushing metastable argon atoms (Ar*, $^3P_2$) out of a magneto-optical trap (MOT) with a 10 Hz-pulsed laser (λ_{laser} = 811.5 nm) one is able to produce clouds of atoms tuned in velocities ranging from 10 m.s^{-1} up to 150 m.s^{-1} with a percentage error on the velocity measurement below 1%. This slow beam is spin- polarized (m_F=+2) and the velocity spread (typ. 3 %) is governed by the number of absorbed photons in the presence of the magnetic field of the MOT [1]. As a consequence, the entire mechanism for adjustable velocities depends on a non trivial combination of Doppler effect and magnetic field intensity giving rise to a non standard Brownian velocity dispersion. Post-treatments of the time-of-flight distribution enable us to look at narrower velocity dispersion (*e.g.* 1 %) than the experimental one. This original configuration provides a probe of cold atoms dedicated to the study of various atomic physics experiments. We report two examples in this abstract.

First, a periodic set of alternated electromagnets (spatial period Λ = 7.14 mm) whose low currents of I_{max} = 10 A simultaneously pulsed in time generates a pulsed magnetic field up to 2000 Gauss over a broad velocity range, similar to so-called *co-moving* potentials. An atom in such a potential looks for a frequency component v in the spectrum of the potential which coincides during a specific time window with its group velocity u such that $u = v\Lambda$. This gives rise to deceleration and/or acceleration processes. A classical point-like treatment (see Fig. 1, left) is in good agreement with the experiment for atoms at 50 m.s^{-1} although a semi-classical model would fit as well. Nevertheless pure quantum behaviors are expected at lower velocity (*i.e.* below 25 m.s^{-1}) [2, 3].

The second study reports the interaction between argon atoms and a 100 nm-pitch SiN_4-nanograting. Incident wave packets coherently covering two slits in the example below produce an interference pattern observed in the Fraunhofer regime whose envelop contains the van der Waals elastic part (see Fig. 1, right). This shows the remarkable contribution of the atom-surface interaction (Casimir-Polder) which represents more than a majority of the whole signal for atomic velocities below 100 m.s^{-1} *i.e.* relatively to the standard diffraction pattern ; *sinc*(x) (see narrower curve in Fig. 1).

Keywords: Matter-wave, slow atomic beam, co-moving field, nanograting, Casimir-Polder.

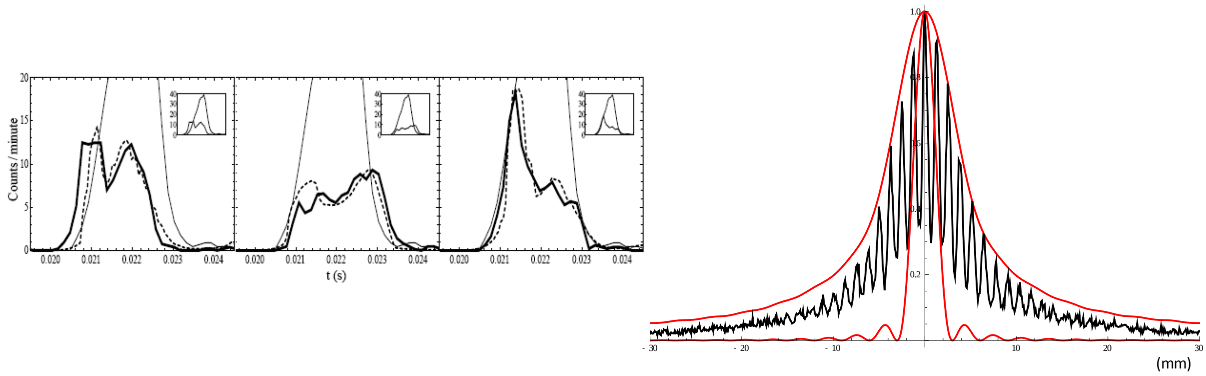

Fig. 1: (Left) Enlarged picture of time-of-flight for atoms at a mean velocity v = 52 m.s^{-1}. The thin black line is the reference without magnetic field. Three curves (thick black lines) have been recorded relative to three different pulse starting times giving different arrival times (acceleration and/or deceleration). Theoretical curves are dotted. (Right) Atomic diffraction with transmission nanograting for atoms at velocity of 38 m.s^{-1}. Envelop is fitted with basic van der Waals calculation. The narrower curve is the expected diffraction pattern without atom – surface interaction.

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