GENERAL RELATIVISTIC FRAMEWORK FOR ATOMIC INTERFEROMETRY

Christian J. BORDÉ
Laboratoire de Gravitation et Cosmologie Relativistes, UPMC, URA 769, Paris and Laboratoire de Physique des Lasers, UPN, URA 282, Villetaneuse, France

A. KARASIEWICZ and Ph. TOURRENC
Laboratoire de Gravitation et Cosmologie Relativistes, UPMC, URA 769, Paris, France

ABSTRACT

We give covariant equations for a two-level spin 1/2 atom interacting with laser fields in a gravitational background. Some gravitational effects of interest for atomic interferometry are derived, including spin-gravitation effects. A possible application to gravitational wave detection is outlined.

1. Introduction

Following neutron interferometry, the recent advent of atomic interferometry[1-4] has opened new potentialities to probe space-time with massive particles. A new aspect is the possibility to excite the internal degrees of freedom of the atom so that different values of the effective mass and of the spin may be used. Prototypes, using laser beams for the atomic beam splitters, have been demonstrated to exhibit tremendous sensitivity to inertial and constant gravitational fields[3,4]. It is therefore of great interest to investigate relativistic effects in these devices associated either with large atomic velocities or with more general gravitational fields. Only the motion of the center of mass of the atoms needs to be treated relativistically and independently of the internal degrees of freedom. The atom mass spectrum is assumed to be known in its rest frame. This means that, to each internal energy level of the atom of given total angular momentum, we may associate an equivalent elementary particle with the same mass and spin and therefore a Lorentz spinor field.

In a second quantization approach, these atomic fields can be quantized with either bosonic or fermionic commutation rules. Then the atom in state "A" appears as the quantum associated with the field ψ_A. This point of view, introduced twelve years ago in the Minkowskian case, leads to a "Feynman-like" diagrammatic representation of interaction processes in atomic spectroscopy[5]. Of course, in low energy experiments, interaction processes conserve the number of atoms. In the interaction representation, an interaction Lagrangian corresponding to the electric dipole interaction can be written and used to derive the Hamiltonian density in the