Atom interferometers and atomic clocks use the coupling of internal and center-of-mass degrees of freedom of composite systems, such as atoms, to electromagnetic fields. Unifying both concepts leads to quantum-clock interferometry, which makes use of the relativistic coupling between internal and center-of-mass degrees of freedom encoded in the mass defect. In this contribution, we derive such a coupling based on quantum field theory.

In many quantum-field-theoretical treatments of atoms, the description is often limited to point particles denying access to the internal structure and thus the mass defect. In contrast, in field-theoretical bound-state calculations the center-of-mass degrees of freedom, most relevant for atom interferometry, are usually neglected. We now combine both approaches to describe atoms as composite particles formed by two elementary fermions and derive an effective quantum field theory for an interacting ensemble of charged, composite particles. This way, the coupling between internal and center-of-mass degrees of freedom encoded in the mass defect naturally arises. Moreover, our field theory is of cobosonic (composite boson) nature rather than purely bosonic, first-order relativistic corrections are contained consistently for the energy of one coboson and the scattering of two cobosons, and the light-matter interaction is given in multipolar form.

To this end, we discuss potential consequences of our results for currently planned matter-wave and quantum-clock-interferometry setups, implemented e.g. in very-long-baseline dark-matter and gravitational-wave detectors.

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