Experimental and numerical study of the microwave field distribution in a compact magnetron-type microwave cavity

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Compact microwave resonator cavities are widely used in compact atomic frequency standards (atomic clocks) to apply a well-defined microwave field to the atoms that provide the stable reference transition for the clock. The geometry and homogeneity of the microwave magnetic field over the volume occupied by the atoms inside the cavity – is crucial for the clock performance, and in particular for the realization of vapor-cell clocks based on pulsed optical pumping (POP) [1]. We have previously developed a compact magnetron-type microwave cavity[2] for Rb atomic clocks based on continuous-wave double-resonance (DR) interrogation, and this cavity is also of interest for the realization of a compact POP clock.

Here we present a measurement of the microwave magnetic field distribution inside this cavity[2], using an imaging technique[3]. A CCD camera is used to record spatially-resolved images of Rabi oscillations in the ^{87}Rb ground-state, from which the microwave field distribution inside the cavity is obtained (integrated along the symmetry axis z of the cavity). An amplitude variation of < 20% is found for the B_z microwave field component distribution, with a slight asymmetry attributed to the precise practical realization of the cavity.

The general electromagnetic approach treats the cavity as filled with a perfectly homogeneous dielectric, bounded by perfect conductor conditions where only separate TM or TE solutions may exist. In practice this assumption is violated due to the presence of the Rb cell inside the cavity, openings for the optical pumping, and the power coupling mechanism. A numerical study was used to qualitatively and quantitatively determine the resulting inhomogeneities of the microwave field. The obtained results show good agreement with the imaging results. The presented studies are relevant for assessing clock performance limitations arising from the cavity studied, and give design guidelines for future improved cavities of similar type.

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