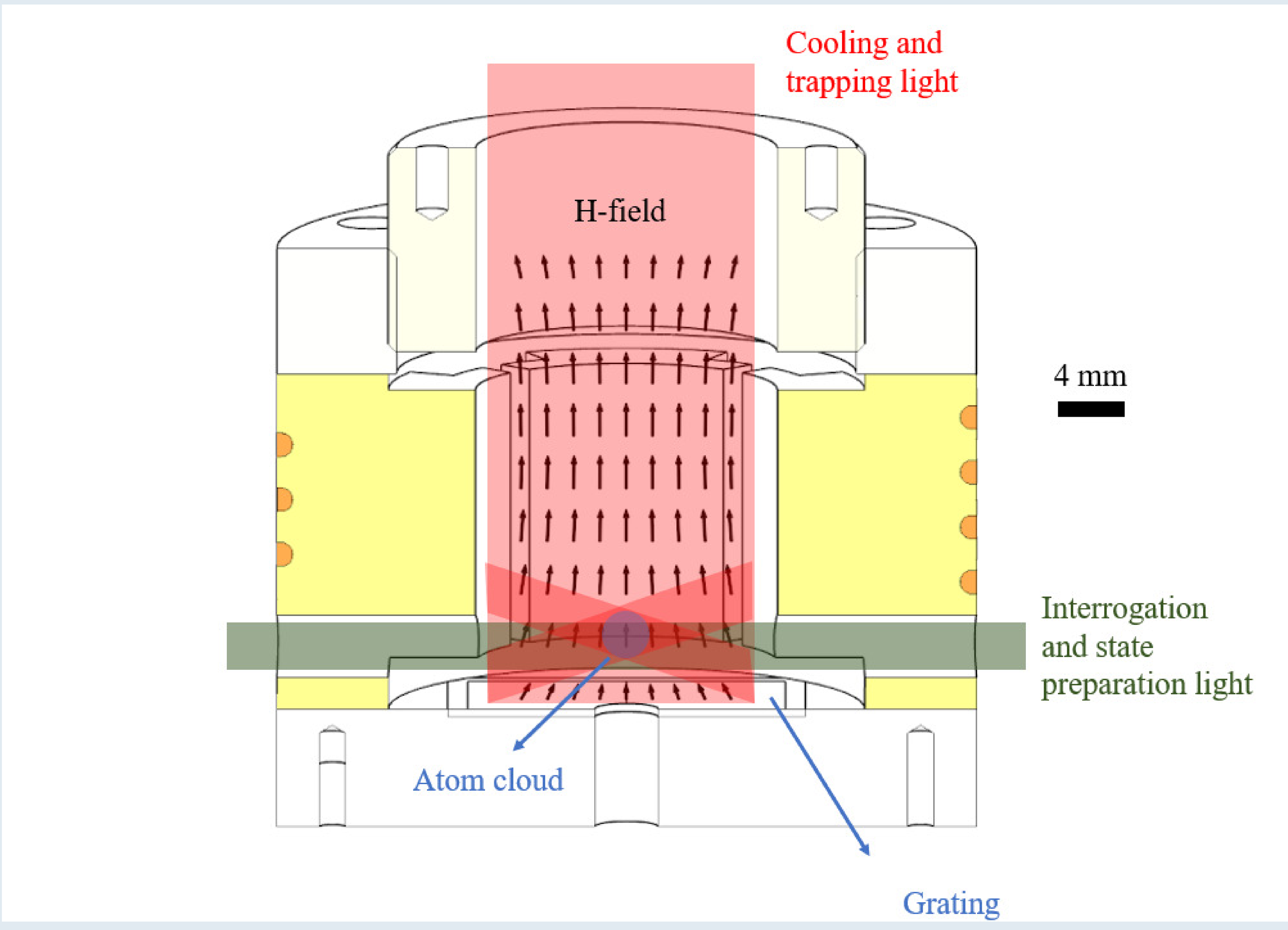

Design and Simulation of an Additive Manufactured Microwave Cavity for Compact Cold Atom Clocks

Loop-Gap electrode structures allow for small sub-wavelength size microwave cavities with high field homogeneity and uniformity. Simplified additive manufacture requires precise simulations.

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Introduction

Compact cold atom clocks are promising candidates for mobile high-stability and exact frequency references, close to primary standards' realization of the SI second.

We study a cold atom clock approach where laser-cooled atoms are produced inside the microwave cavity, using a single laser beam impinging on a diffraction grating (G-MOT) [1].

Requirements for the microwave cavity:

- Resonance at the 6.835 GHz Rb atomic reference transition
- Microwave magnetic field aligned with the cavity main axis
- Homogeneous microwave field (constant H_z) and high field uniformity (constant direction of H vector)

Loop-Gap resonators [2] can meet these goals at sub-wavelength overall size. The critical electrode dimensions (few µm precision) can be realized using additive manufacture.

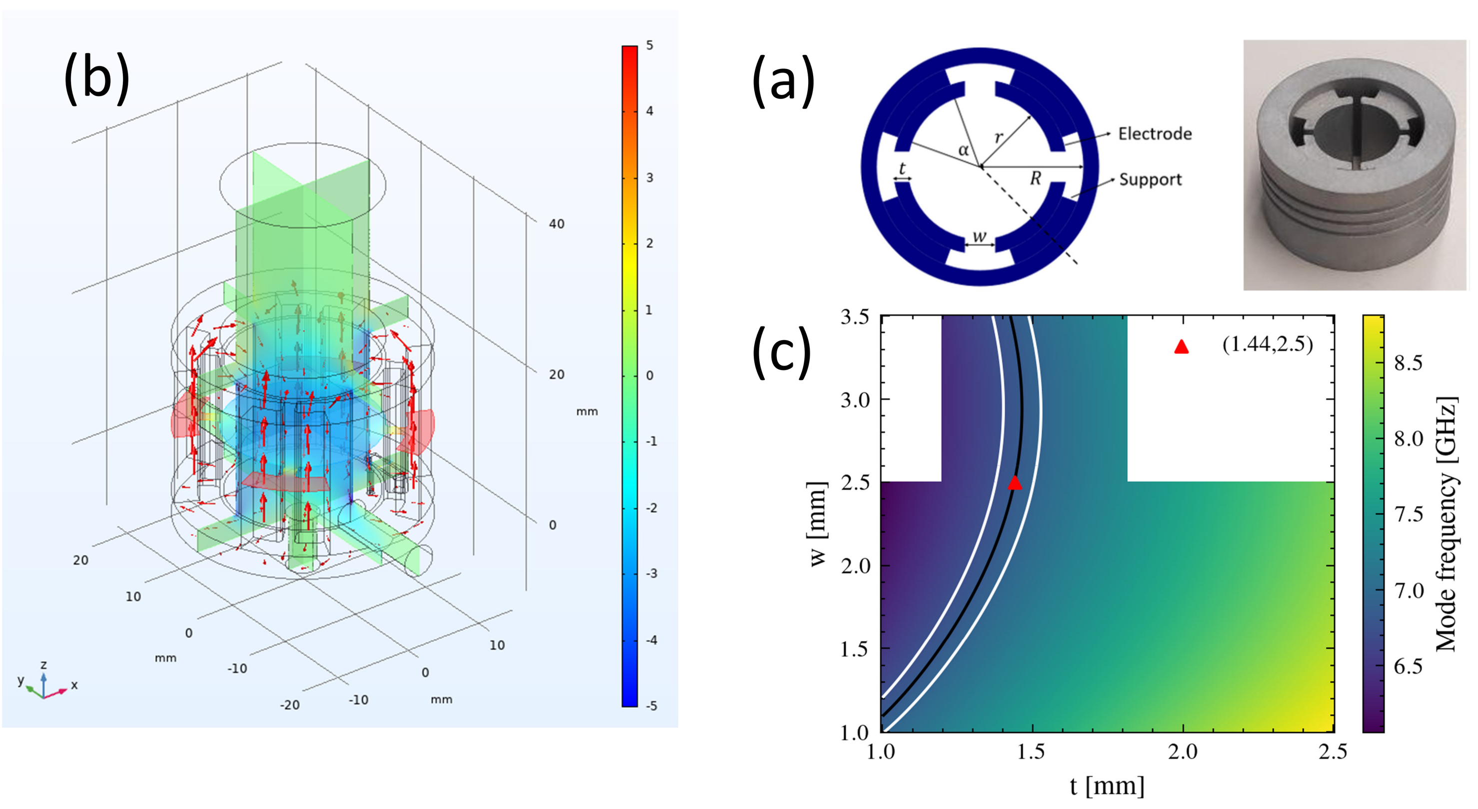

Figure 1: (a) general loop-gap geometry. (b) 3D magnetic field simulation. (c) frequency study as function of *t* and *w*.

Methodology

The general loop-gap geometry and additive manufactured cavity body are shown in Figure 1a.

The main critical parameters defining the resonance frequency are the electrode thickness *t* and gap width *w* that can be well controlled by additive manufacture of the cavity body.

Eigenmode analysis (Fig. 1b) and parametric study of the cavity's simulated S11 resonance frequency as function of *t* and *w* (Fig. 1c) allows to determine the optimum cavity geometry for the cold atom clock application. [3]

Few µm electrode manufacturing precision and alignment is achieved.

Results

The measured S11 spectrum for the additive manufactured cavity corresponds well to the simulations (Fig. 2a). A linewidth of ≈ 20 MHz and Q-factor of 360 are achieved, at the 6.835 GHz frequency.

Fig. 2b shows the H_z amplitude and phase over the extension of the cold atom cloud (gray shaded area).

Measured Ramsey fringes of the reference clock transition (Fig. 2c) show a width of 49 Hz, resulting in a clock stability of $\approx 4\times10^{-11}\ \tau^{-1/2}$.

From measured Rabi oscillations (Fig. 2d) we deduce a variation (std deviation) of H_z on the order of 6% over the volume of the cold atom cloud. [3]

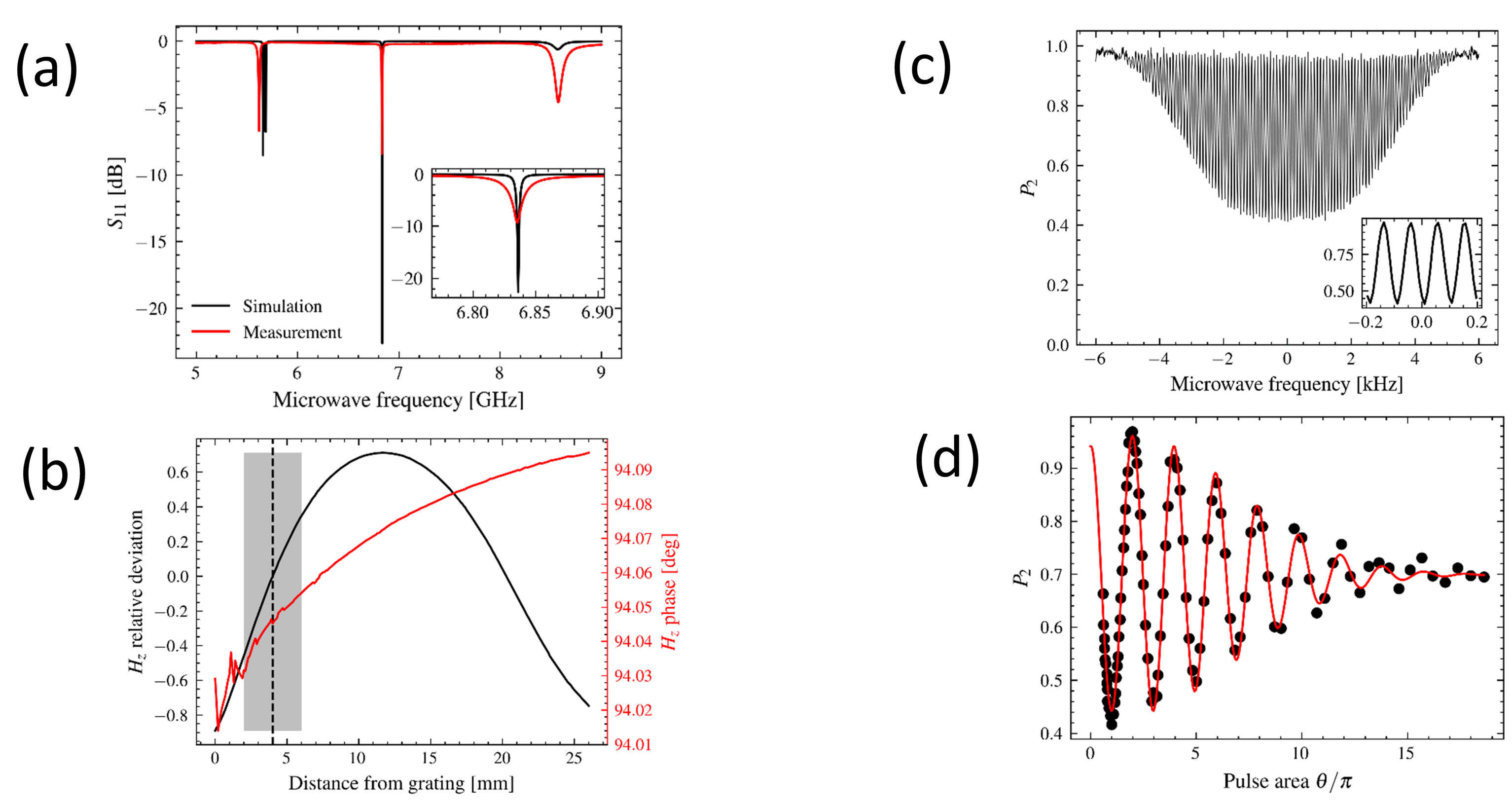

Figure 2: (a) simulated and measured S11 spectrum.
(b) field amplitude and phase. (c) clock signal Ramsey fringes.
(d) measured Rabi oscillations.

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This work was partly supported by the European Space Agency (ESA). The views expressed in this document are those of the authors and cannot be taken to reflect the official opinion of the European Space Agency.