Development of filter-like cavities for axion DM searches (RADES project)

Axions and IAXO in Spain

Zaragoza, Spain, October 27-28, 2016

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Outline

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1. Introduction
2. Different coupling patterns
3. Shaping techniques
4. Conclusions

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Introduction

General context

Radiofrequency cavities under strong magnetic field will allow for axion to photon conversion.

Needed to make exploratory search in the whole spectrum, since axion mass is unknown.

Many experiments were done at radiofrequencies without success.

Objective now is to prepare experiments at microwave frequencies.

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Objective now is to prepare experiments at microwave frequencies.

A single cavity at these frequencies will be either too small or over-moded.

Proposed solution is to used several coupled cavities with one resonant mode.

Objectives of the work

Preliminary design is available, based on taking all couplings equal.

All internal cavities have the same resonant frequency, except for the first and last cavities.

Some ideas can be investigated from coupled cavities synthesis:

- Explore different solutions with different coupling patterns.
- See if shaping techniques can be useful for this application.

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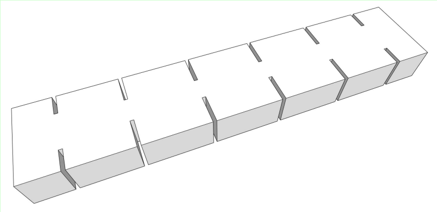

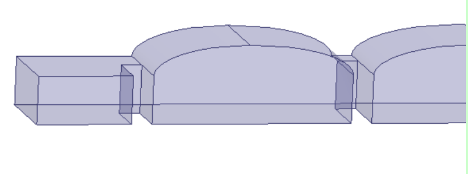

Example of shaped cavity.

Different coupling patterns

Different coupling patterns can be used to produce different types of transfer functions:

- Butterworth (maximally flat).
- Chebyshev (equal ripple).
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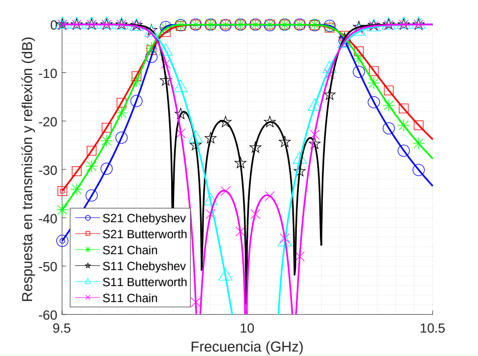

Design of direct coupled cavity filters with the same 3dB bandwidth but with three different transfer functions.

Any impact on the geometrical factor that improves coupling photon/axion?.

Are there improvements in the unloaded quality factor?.

Different coupling patterns

Power gain

Power gain can be used to assess the power dissipation in an electrical network.

Only dissipation losses are considered.

Lowest losses related to highest unloaded quality factor are for the Butterworth case.

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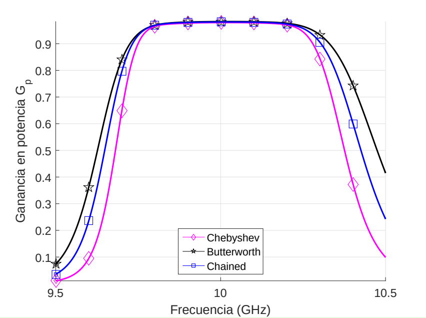

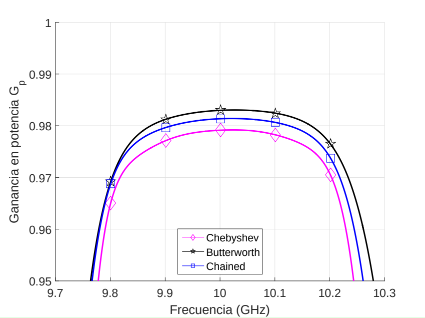

Different coupling patterns

Unloaded quality factor

With some calculations the unloaded quality factor for the three cases can be evaluated.

$$IL = \frac{4.343\, f_0}{BW\, Q_U} \sum_{r=1}^{N} g_r \tag{1}$$

Highest unloaded quality factor is for Butterworth response.

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	$\sum g_r$	BW (-3 dB)	IL (dB)	Q_U
1.- Butterworth	8.4721	509	0.075	9638.3
2.- Chebyshev	8.4942	502.7	0.0918	7993.9
3.- Chained	7.1432	509	0.0817	7460.1

Shaping techniques

General concepts

Unloaded quality factor can also be increased by applying shaping to the cavities.

Different types of shaping can be applied to a base geometry.

Important parameters for the project can be:

Unloaded quality factor, spurious free range, geometric factor for axion/photon coupling.

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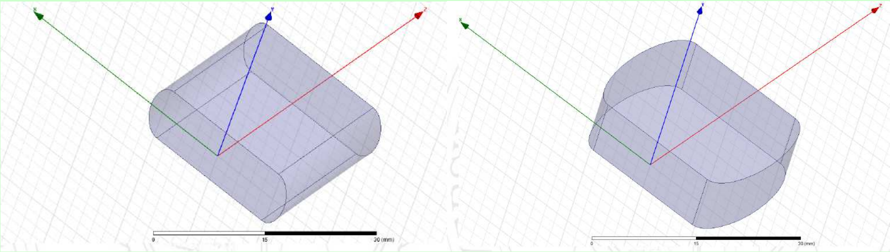

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Initial investigations

Some shaping geometries show optimum values of the shaping parameter for the unloaded quality factor and spurious free range.

Cavities are optimized to keep unchanged the resonant frequency.

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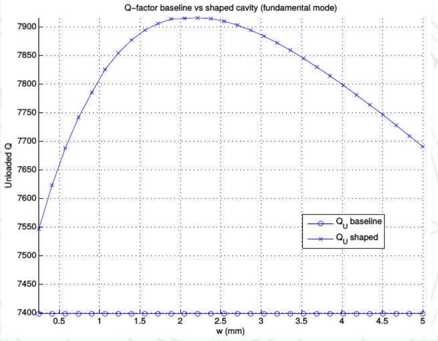

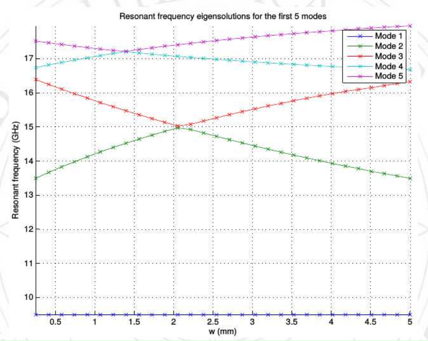

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Filter design with shaping

Shaping is applied to coupled cavities.

Shaping parameter is 2.5 mm in this example.

Structure is compared with a baseline filter using rectangular cavities.

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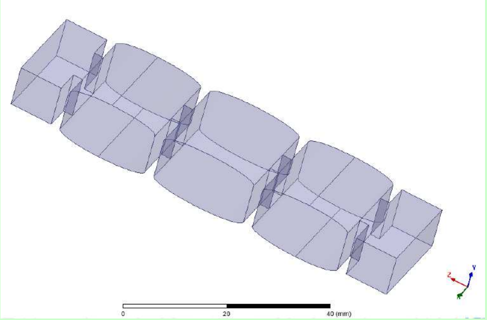

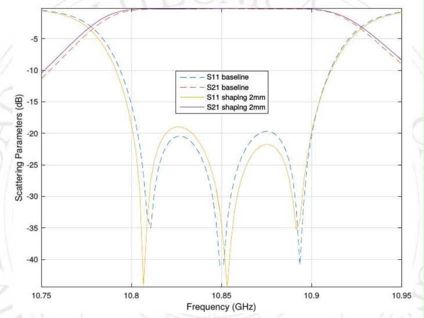

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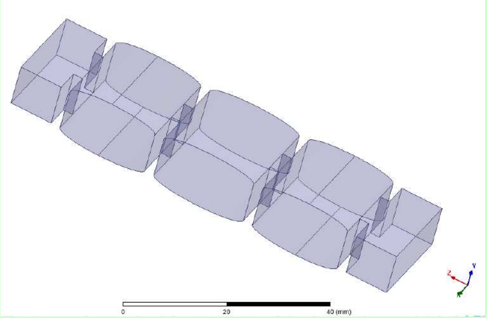

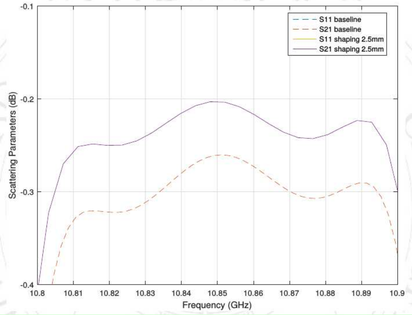

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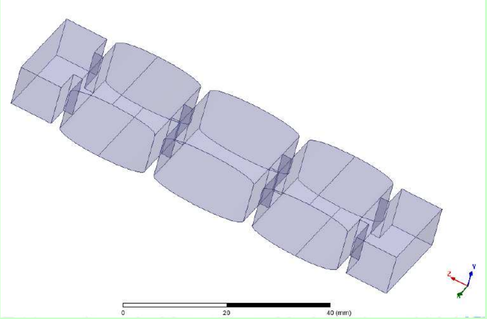

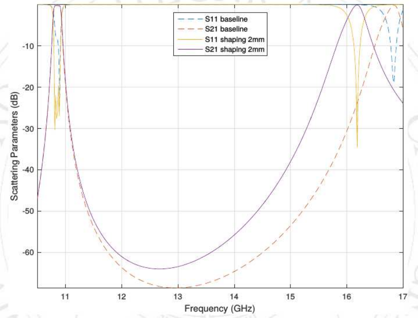

Conclusions

- To search for Axions at high frequencies we propose to use coupled cavities. This increases the space of the experiment avoiding at the same time over-moded cavities.
- A first design is now being manufactured to carry out first experiments.
- This design is based on selecting all couplings equal, and all internal cavities with the same resonant frequency.
- Two research lines concerning the design of coupled cavities will be followed in the future.
  1. The design of coupled cavities using different coupling patterns.
  2. The design of cavities incorporating shaping techniques.
- These new designs may have impact in the unloaded quality factor of the device and in the spurious free range.
- Very important to investigate how these factors will impact the geometric factor describing the axion/photon coupling.