A STUDY ON A MONO-MODAL ACCELERATING CAVITY BASED ON PHOTONIC BAND-GAP CONCEPTS

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Abstract

One of the main problems with high intensity beams is the presence in accelerating cavities of higher order modes (HOMs) which might degrade the beam quality. Accelerating cavities require HOMs suppression while keeping a high quality factor (Q) fundamental mode. Both these requirements can be hardly met in closed metallic cavities (by using particular geometrical configuration). At high frequencies and for superconducting cavities these configurations become cumbersome and technically unviable. We propose a new type of a high Q mono-modal cavity based on Photonic Band Gap (PBG) concepts and operating in the microwave region. These cavities are intrinsically mono-modal and can be easily scaled to different frequencies: HOM can be efficiently suppressed without affecting the fundamental mode. Our studies on different prototypes working in the 2-20 GHz range are presented. The RF characterization (simulation and measurements) is shown as well. The chosen operating frequency is linked to our current cryogenic apparatus.

WHAT IS A PBG

A PBG system is formed by a periodic alignment of macroscopic objects, like metallic or dielectric cylinders. The structure exhibits frequency band-gaps which prevent the propagation of e.m. radiation along the periodicity directions in the structure itself. In such a system a cavity can be realized by removing rods. When the lattice contains such "defects", new modes (known as defect modes) can exist in the frequency stop-bands; they will be localized in the "cavity" decaying exponentially in all directions away from the defect site. In this way, one can get a cavity with a very high quality factor, Q, at the fundamental mode. By optimising the lattice geometry the HOMs will fall into the frequency pass bands, exhibiting very low Q's.

By using superconducting materials the fundamental mode Q can be enhanced to higher values. An alternative configuration consisting in dielectric cylinders plus superconducting plates (hybrid configuration) can be used as well. The working mode can be chosen to be a quasi-TM01 mode, where the electric field is parallel to the beam direction in the centre of the cavity (parallel to the cylinders).

15 GHZ COPPER PROTOTYPE

The cavity consists of a two-dimensional hexagonal lattice, composed of thirty-six metallic cylinders (height 4.6 mm, diameter 3 mm, lattice constant 8.58 mm), sandwiched between two Copper plates. The cylinder in the centre of the structure is missing (symmetry break). In this position a hole was created on both conducting plates allowing for the beam clearance; the hole is also used for coupling the cavity to the pick-ups for the experimental characterization. The working frequency of this structure is 14.5 GHz. Fig 1 and 2 show some views of the realized cavity.

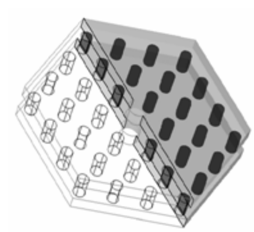

Figure 1: Schematic view of the copper PBG cavity.

Figure 2: A photo of the realized PBG; it is shown a connector used to excite and to measure the field inside the structure.

SIMULATIONS AND MEASUREMENTS

The eigenmodes and the eigenfrequencies of several PBG configurations have been studied using MWS code (3D e.m code of CST). In fig. 3, the fundamental mode E-field is shown; the mode is clearly confined inside the first circle of cylinders.

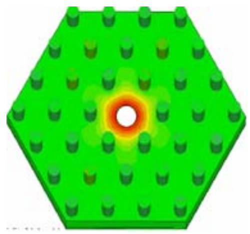

Figure 3: Copper PBG cavity. Electrical longitudinal field of the fundamental mode:.

The experimental characterization has been performed using a Network Analyzer for the measurement of the Scattering matrix. Simulations have been performed modelling the structure in the same range of frequencies (10-20GHz) of the measurements at room and low (77K) temperature. The fig. 4 shows the transmission parameter S_{21}. The agreement is very good: the fundamental mode frequencies differ for 0.6%. It shows that this mode is localized and not affected by boundary conditions.

The cavity is quasi mono-modal (Q=1700 @ 77K). An higher mode appears around 20GHz, which is propagating and depends on the boundary conditions as it is shown by the disagreement between simulation and measure. It has a very low Q value.

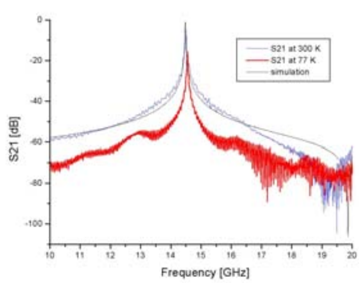

Figure 4: Comparison between experimental (low and room temperature) and simulation data of S21 parameter.

SHUNT IMPEDANCE MEASUREMENT

The cavity shunt impedance was measured by means of a perturbative method based on the Slater perturbation theorem [6] giving a value of 100.9 MW/m at room temperature and for Q=1200. The value is higher than for a standard pill box cavity which has all the HOM.

A HYBRID CONFIGURATION

A hybrid (Sapphire cylinders + superconducting plates) cavity has been designed and constructed at 15 GHz to be tested at low temperature (7K) (in Fig. 5 it is shown a structure with Copper plates). First tests at room temperature show the mono-modal behaviour even if the field is not so well confined as in the metallic case (the E field reaches the 3rd rod circle). The S21 parameter measurement is reported in fig. 6 compared with the simulation. There are still some problems with the coupling pickups.

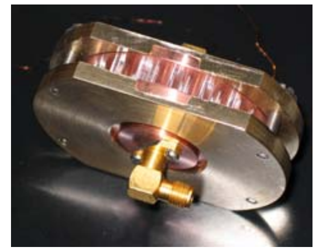

Figure 5: The hybrid PBG: dielectric cylinders on copper plates. Here it is shown a connector and the external clamping system.

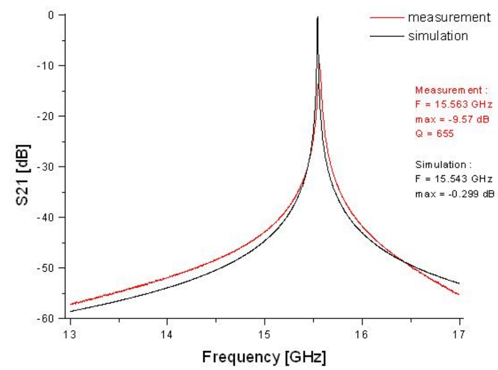

Figure 6: Hybrid cavity S21 parameter: comparison between experimental (room temperature) and simulations

CONCLUSION AND FUTURE WORK

A completely Nb cavity has been designed and it is under construction using new techniques at 15GHz and at 6GHz.

Studies on coupled cavities are in progress to analyse also the feeding system. In the fig. 7 a possible configuration is shown with two accelerating cavity and aside coupling cavity for the RF feeding system.

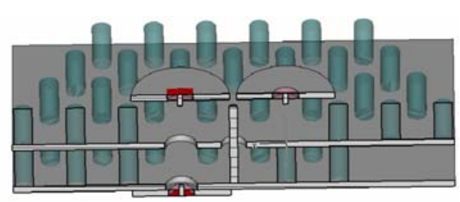

Figure 7: A study on a possible way to realize a coupled PBG cavity (MWS figure)

The three modes of the coupled structure are reported in fig. 8 as resulting from the simulation performed with MWS code. The frequency distance between the modes depends on the coupling factor.

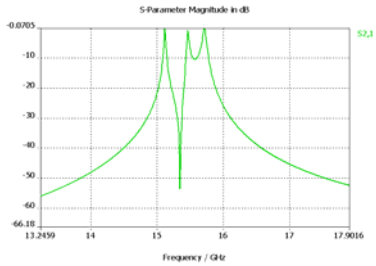

Figure 8: The results of the coupled PBG simulation.

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