SPOKE CAVITY DEVELOPMENTS FOR THE EURISOL DRIVER

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Abstract

EURISOL is the next generation of Radioactive Ion Beam (RIB) facility which aims at the provision of high intensity beams of radioactive nuclei with variable energy, from a few keV to greater than 100 MeV per nucleon, at an intensity several orders of magnitude higher than those currently available. The driver of EURISOL has to accelerate protons at a final energy of 1 GeV and 5 mA current, but also deuterons at 200 MeV (total energy). For the intermediate energy part of the driver, a solution based on superconducting (SC) spoke cavities is under study at the IPN Orsay laboratory. In this paper are presented the experimental results on the beta 0.15 spoke cavity, as well as achievements on the power coupler and cold tuning system. A new horizontal cryostat for performing a test of a fully equipped spoke cavity is also presented.

INTRODUCTION

The feasibility study of EURISOL has been carried out within the 5th European framework program. In the EURISOL report [1] issued in December 2003, the use of 2-gaps spoke resonators was considered as a promising option for the intermediate energy part of the driver (10 MeV – 100 MeV). Since then, a R&D program has started at IPN Orsay to develop this type of resonator. This work is ongoing within the framework of the Eurisol Design Study, part of the 6th European framework program. After the fabrication and test of a 2-gap beta 0.35 spoke cavity @ 352 MHz [2] which successfully achieved an accelerating gradient of 11 MV/m (using the beta.lambda definition for the accelerating length), the low beta spoke prototype (β = 0.15) is now under development. This paper reports on the latest results obtained on the low beta cavity, as well as on the development of the spoke cavity ancillary components: the power coupler, the cold tuning system and also the horizontal cryostat to test fully equipped spoke cavities.

THE BETA 0.15 SPOKE CAVITY

The cavity geometry and RF parameters of the beta 0.15 spoke cavity developed at IPN Orsay has been detailed in [2]. In may 2005, the first cold RF test was performed on the cavity before welding its helium tank. The maximum achieved gradient was 4.8 MV/m (using the beta.lambda definition for the accelerating length), limited by a quench. The unloaded quality factor Q_O at low field was 1.2 10^9. Since then, the stainless steel helium tank has been attached to the cavity (Fig. 1). The tank was welded by TIG on the already existing stainless steel bellows copper-brazed to the niobium. A new RF test was then carried out to qualify the helium tank. Our vertical cryostat was modified from its helium bath test configuration in order to be able to test a cavity equipped with a helium tank.

Figure 1: β 0.15 spoke with its helium tank

The cavity preparation was the following: 120 µm removed from the cavity inner surface by BCP, 2 hours of high pressure rinsing by the 4 ports, assembly in the CEA Saclay class 100 clean room. The result is shown on the Figure 2. Please note that all accelerating fields are expressed using the beta.lambda definition for the accelerating length (2 times lower than using the iris-to iris length definition).

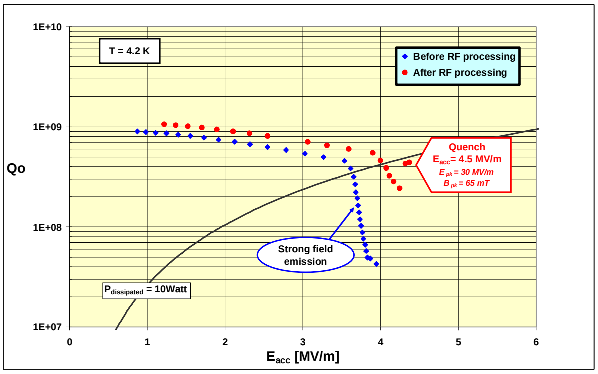

Figure 2: RF test results of the beta 0.15 spoke cavity after the helium tank welding.

The cavity exhibits a strong field emission, starting at 3.5 MV/m. After a difficult processing which took several hours, the cavity reached a maximum accelerating field of 4.5 MV/m (65 mT), limited by a quench, at almost the same field we reached before the helium tank welding. This rather low performance achievement, compared to

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the one obtained with the β 0.35 cavity, confirms the presence of a big defect on the cavity surface. An important result is that no leak was detected on the helium tank. This will allow us to use this cavity to test in a horizontal cryostat, in an accelerator configuration, the ancillary components we are developing (cold tuning system and power coupler).

COLD TUNING SYSTEM

The cold tuning system (CTS) is an important cavity component which allows to adjust in-situ the cavity frequency after the cool-down, and which is also used to compensate from slow drifts of the cavity frequency during operation.

The spoke cavities CTS is an adaptation of the CTS we have developed for the elliptical 700 MHz 5-cell cavities [3]. Its design is based on the system developed by the CEA for Soleil cavities. The CTS consists in a mechanical system (fig. 3) driven by a cold stepping motor operating under vacuum and a moto-reductor. The motor drives a ball screw, linked to a double lever arm mechanism which can act on four rods attached to the cavity. The design was optimized to obtain high rigidity, lowest possible weight and cost. The system includes also the possibility to use piezoelectric actuators for the fast compensation of frequency shifts.

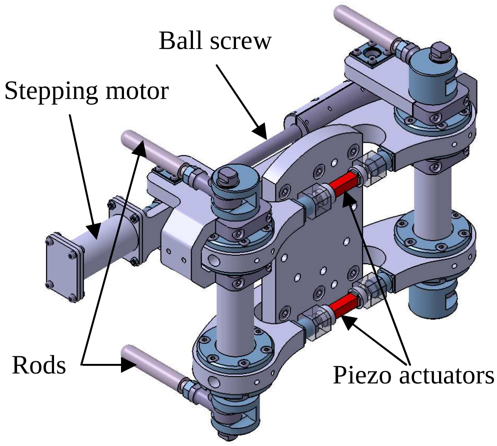

Figure 3: The cold tuning system for spoke cavities.

The theoretical resolution of the system is 1.95 nm per micro-step, giving a frequency resolution of 1.95 Hz. Another important requirement is the CTS mechanical rigidity that should be much higher than the cavity rigidity in order to keep all the longitudinal displacement available for the cavity deformation. The β 0.15 spoke cavity axial rigidity was estimated at 6 kN/mm. Calculations performed with CATIA give a CTS rigidity estimation of 162 kN/mm. This high value allows 96 % of the CTS longitudinal displacement to be effectively seen by the cavity.

One usual drawback of a CTS acting in the axial direction is a reduction of the real-estate gradients due to the need of longitudinal space to physically place the CTS. The spoke cavity CTS has been designed in order to be able to place 2 CTS in front of each other (fig. 4), saving space between 2 adjacent cavities.

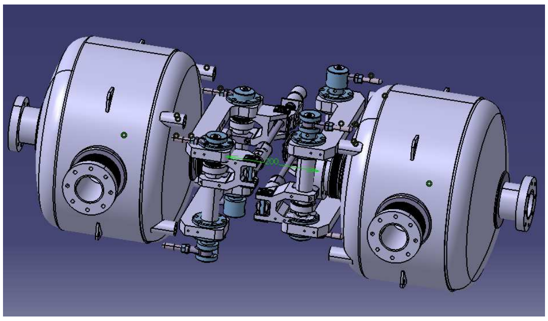

Figure 4: Adjacent mounting of the spoke CTS.

All mechanical pieces have been fabricated and assembled. The stepping motor and the ball screw have just been received. A first test on the cavity at warm temperature will be performed in October. The first cold test in our horizontal cryostat (without the piezo at first) is scheduled for the very beginning of 2007.

POWER COUPLER

A 352 MHz capacitive power coupler has been developed for our 2-gap spoke cavities to be mounted on the 56mm diameter port. The geometry is coaxial, at 50 Ω, using a warm disk ceramic window. The coupler is designed to be able to transfer 20 kW of RF power to the cavity. Two pipes located on the window outer diameter give us the possibility to water-cool the ceramic (fig. 5).

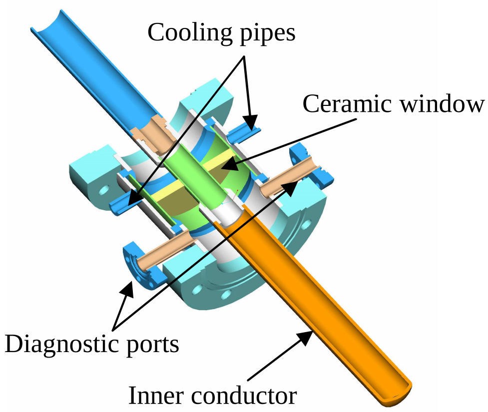

Figure 5: Power coupler for 2-gap spoke cavities

Several window geometries were studied [4]: cylindrical, disk (with and without chokes), travelling wave…For each geometry, the HFSS software was used to calculate the RF parameters, the surface field on the ceramics, the bandwidth, and the RF losses. Finally, the design based on a disk ceramic without choke was chosen because it was the best compromise between good RF performances and simplicity, leading to a reliable and cost-effective design. The computed S_{11} parameter is shown on Fig. 6: a value of – 57 dB is obtained at the nominal frequency. The coupler exhibits a very large bandwidth, allowing having standard fabrication tolerances.

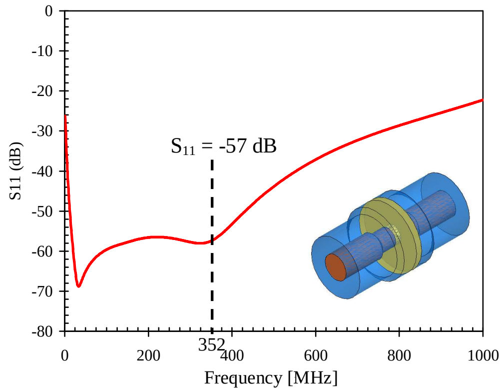

Figure 6: Calculated window reflection parameter

Two ceramic windows prototypes have been ordered to the SCT Company. They will be characterized at low power (measurement of RF parameters) before the antenna welding. The two complete power coupler prototypes will be ready in the beginning of 2007, and a first test @ 10 kW is scheduled for spring 2007.

HORIZONTAL CRYOSTAT FOR FULLY EQUIPPED SPOKE CAVITIES TESTS

In order to be able to test fully equipped spoke cavities (i.e. cavity equipped with their helium tank, power coupler and cold tuning system), a horizontal cryostat is under construction at IPN Orsay (Fig. 7). The vacuum vessel is a refurbishment of a CEA Saclay cryomodule used for the MACSE accelerator.

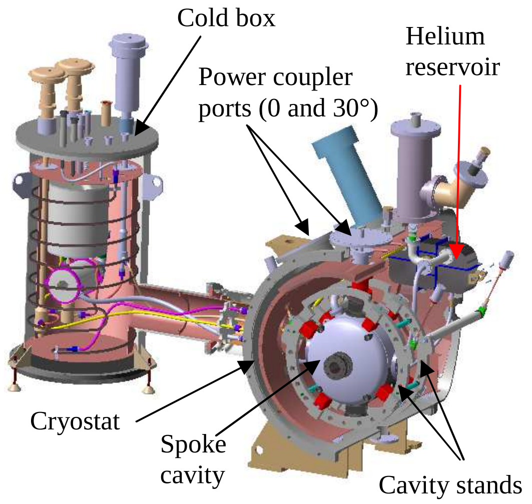

Fig 7: Inside view of the cryostat and cold box

The cryostat is 1.5 meter long, about 1 m diameter and could host single spoke cavities of various β. The vacuum vessel was modified to be well adapted to the spoke cavity geometry. A cold box, placed sideways close to the cryostat provides the cryogenics fluids to the cryostat for a 4.2 K tests and could be further upgraded to a 2K operation. The cavity has two possible positions in the cryostat: the spoke bar placed horizontally (power coupler vertical) or with a 30° angle with respect to the horizontal plane (coupler angled by 30° from the vertical plane). This versatility gives us the possibility to study and overcome any cooling problem that might occur due to bubbling effect around the spoke bar when this one is placed horizontally. The mechanical modifications of the vacuum tank are achieved, the mechanical pieces are fabricated and the assembly of the cryostat and the cold box has just started. A first cryogenic test at low power, with the spoke cavity equipped with its cold tuning system is scheduled before the end of 2006. A cavity test with its power coupler operating at 10 kW is foreseen for summer 2007.

OUTLOOKS

The work in progress at the IPN Orsay laboratory will allow performing a test in summer 2007 of a spoke cavity in an accelerator configuration, i.e. equipped with its helium tank, RF power coupler and cold tuning system. The good performances previously obtained on the β 0.35 cavity confirmed the potential of this type of resonators. The beam dynamic study group of the EURISOL Design Study has just achieved a new reference layout for the driver, based on triple spoke cavities for the 60 to 140 MeV section of the driver. Based on our experience on single spoke developments and their associated components, we have just started a new program aiming at the fabrication and test of a triple spoke cavity for the EURISOL driver.

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