DESIGN OF 650 MHz TUNER FOR PIP-II PROJECT
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Abstract
The Proton Improvement Plan (PIP) II project at Fermilab is a proton driver linac which will use five different cavity geometries including a 650 MHz 5-cell elliptical cavities that will operate in RF-pulse mode. Detuning of these cavities by Lorentz Forces will be large and strongly depend of the stiffness of the cavity’s tuner. First prototype tuner built and tested warm [1,2]. Measured stiffness of the prototype tuner was below 30kN/mm instead of expected from simulation 70kN/mm [2]. Significant effort has been invested into understanding discrepancy between simulation and experimental data that led to newest tuner design. Updated “dressed cavity-helium vessel-tuner” model provided consistent results between ANSYS simulations and experiment results. Modified tuner design and analysis in limitations for overall “cavity/tuner system” stiffness will be presented.

INTRODUCTION
The 650 MHz cavity will have a half-bandwidth (HBW) of 30Hz and will operate in RF-pulse mode. The cavity’s resonance frequency needs to be controlled to the level of 20 Hz (peak). As seen from Fig. 1, the cavity’s Lorentz Force detuning strongly depends on the tuner stiffness [3]. Cavity tuner stiffness is one of the key parameters that needs to be addressed during tuner design.

The first prototype was built and tested [2]. Based on the ANSYS simulations the tuner stiffness was expected to be 60kN/mm [1]. Measurements revealed that prototype stiffness is only 25-30kN. This will increase Lorentz Force Detuning (LFD) coefficient to ~1.4 times bringing the value of the parameter LFD/HBW to ~15-20.

Figure 1: LFD coefficient vs. tuner stiffness.

To keep stiffness of tuner higher, instead of flexible (as at Saclay-1 tuner) we are using solid arms (connection from tuner frame to the Helium Vessel. The same solution that was used in the design of the LCLS II 1.3GHz tuner [5]. Solid arms connections to the He vessel for double-lever tuner required “sliding” element between tuner arm and main lever (Fig. 3). ANSYS simulation indicated and...
detailed measurements confirmed that the major contribution of the overall tuner stiffness reduction came from cartridge with 4 piezo-capsules and the “sliding” joint between main lever and tuner’s arm (Fig. 4).

Figure 3: Kinematics scheme of the double lever tuner. Left end of the main lever required “sliding connection” for operation of the double lever scheme.

Calculations based on the updated ANSYS model provided stiffness of the prototype tuner mounted on the cavity’s mock-up stand. Considering the effects of gravity force (Fig. 5) provided results of 32kN/mm that is very close to experimental results [2].

Figure 4: Displacement of the piezo tuner components with forces applied to the tuner.

Figure 5: ANSYS model of the tuner, mounted on the test stand. Gravity forces considered during calculations of the stiffness Top & Bottom tuner arms.

Figure 6: New vs Modified Tuner Design.
MODIFIED TUNER DESIGN

Figure 6 shows the major modifications from the prototype to new tuner design. Analysis of the prototype tuner led to the decision to modify fast tuner design and interface between left arm and main tuner arm.

Instead of a 4 piezo-actuator cartridge, we decided to use a design similar to LCLS II 1.3GHz tuner where the piezo-capsule is installed between main arms and cavity interface ring [5]. Because of the limited space, piezo-actuators were installed into designated packets machined into the main tuner arms. New 650MHz tuner adopted from LCLS II 1.3GHz tuner several design solutions, like ceramics balls, piezo-adjustment screws, safety rods (Fig. 7). ANSYS simulation helped to conduct optimization studies by varying dimensions of the different components of the tuner. Calculated stiffness of the slow tuner frame (insert A, Fig. 7), with electromechanical actuator, was ~140kN/mm. Calculated stiffness of the dressed cavity/tuner system that included piezo-capsules (with stiffness ~100kN/m [6]) and Nb-Ti cavity-tuner transition ring (Fig. 8) decreased to the level of the 42kN/mm. As one of the proposals we considered slow tuner frame design with stiffness up to 600kN/mm. Disadvantage of the 600kN/mm design that it will require significant modification of the dressed cavity He vessel design and will be difficult to assemble. As soon as piezo and transition ring introduced into calculations, stiffness of the system dropped to just 55kN/mm.

Simulations illustrated that slow tuner frame is not a limited factor for the stiffness of dressed cavity/tuner system. Stiffness could be increased only with significant modification of the dressed cavity design that included He vessel and transition ring, and using piezo-actuators with much larger cross-section (and stiffness).

CONCLUSION

The expected stiffness of the updated cavity/tuner system will be close to 42kN/mm. At least two major tasks need to be accomplished to reach stiffness of the dressed cavity/tuner system to the level of 60-70kN/mm: redesign of the dressed cavity system (He vessel and cavity-tuner interface) and develop new reliable piezo-actuator with larger cross-section/high stiffness.

REFERENCES