Letter of Intent

SNOWMASS202, RF Accelerator Technology

Challenges in the Building Reliable SRF Cavity Tuners for Future Higher Energy and Higher Intensity Accelerators

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Progress in HEP strongly depends on the availability of future higher energy and higher intensity accelerating machines, based on SRF technology. SRF cavities will have much narrow bandwidth and will operate in more demanding modes- higher accelerating gradient and larger repetition rate. As consequence, cavities will be deformed/detuned by stronger electromagnetic (Lorentz) forces (LFD). Data presented in the Table 1 demonstrated significant increase of the LFD for future SRF LINACs over existing one.

SRF cavity tuner is essential subsystem that allowed to bring and keep cavity in operational resonance. Tuner is the combination of the slow tuner (electro-mechanical system that compressed/stretched cavity in the range of 1-2mm) and fast tuner (piezo-electrical system, working in serious with slow tuner that capable to fast retune cavity in the range of ~10um) [1]. Role of the slow tuner is to bring cavity to operational frequency after cool-down to T=2K. Piezo tuner must compensate dynamic cavity detuning caused by LFD and microphonics [2].

There are needs for specialized R&D program to bring existing SRF cavity Tuner's technology to the new level to satisfy requirements of the future accelerators.

Tuner design must be simple for purposes of the cost reduction. At the same time there are demands for higher stiffness of the tuner to minimize LFD of the cavity/tuner system. Tuner design must allow for replacement of the active components (in case of failure) without dis-assembly of the cryomodules. Tuner must be fabrication from materials with low remnant magnetizations.

Reliability of the tuner will make significant impact on the overall down-time of the accelerator complex. Failure of the tuner could lead to necessity to turn off cavity. In some situations, non-working tuner could make significant impact on the beam dynamic of the whole accelerator complex. In large portion reliability of the tuner determined by endurance of the active components: electromechanical actuator (EMA) and piezo actuators (piezo).

Function of the (EMA) is to convert rotation (of the stepper motor) to linear motion of the tuner arms to compress/stretch cavity. EMA, deployed in the slow tuner, built form stepper motor, gear box and shaft/traveling nut system. EMA installed on the tuner inside insulated vacuum and at cryogenics temperature. Only specialized dry lubrications could be use on the bearing and gear system, that making operation of the EMA for 20 (+) years a challenging task [3,4]. Collaborations with industry required to develop new reliable EMA system based on the new ideas, new materials.

One of the most challenging quest is development of new type of piezo-electrical actuators to be deployed in high-gradient and high intensity SRF LINACs. Piezo-actuator, when operated at high amplitude and high repetition rate, will experience high power dissipation inside piezo-ceramic stack. In typical industrial applications piezo operated at room temperature and heat dissipated inside piezo-ceramic stack taking away from the piezo ceramic surface by flow of the air or specialized oil. In the SRF tuner applications piezo will operate at cryogenic temperature and inside insulated vacuum environment. Heat generated inside piezo-ceramic stack could be transfer only through the very low thermal conductivity ceramic volume to the piezo-actuator end-plates and through tuner metal fixture to LHe bath. Several experiments, conducted at INFN/DESY[5] and FNAL[3], demonstrated significant overheating of the center layers of the piezo-ceramic stack, that quickly led to piezo failure. Available on the market piezo-actuators, when will run in high dynamic operational condition required for PIP II or ILC LINACs, very likely will fail after just several hours.

Collaboration with industrial partners in development of the new reliable piezo-actuator could be proceeded in two directions. First direction is development of the piezo-actuator based on the broadly used piezo-electric ceramics. These types of piezo ceramic have low heat transfer coefficient and will required some new techniques to remove dissipated heat from the surface of the piezo stack. Second direction is development of the new type of ceramics that will have less heat dissipation and /or much higher capability to transfer heat through bulk ceramics.

Table 1. Example of the level of the LFD for RF-pulse LINACs. Important from the point of view resonance control is value of the ration LFD/HBW. For high intensity LINAC (like PIP III) specification of 25Hz repetition rate will required very high operation rate from piezo to compensate LFD.

Pulsed SRF accelarators, existing and projects	Cavity Half-bandwidth, Hz	LFD, Hz	LFD/HBW
ESS	**500**	**400**	**0.8**
XFEL	**140**	**550**	**4**
PIP III	**30**	**600**	**20**
ILC (50-60MV/m)	**55**	**2500-3600**	**40-60**

References.

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