WP1 Ferroelectric Fast Reactive Tuner

Objective of WP1

The work package ferroelectric fast reactive tuners follows the development of a key component in the framework of the technology area #1, energy savings from RF power. To effectively operate a superconducting RF (SRF) cavity at a desired field level and to accelerate or deflect a particle beam with some given average beam current and to also stabilize the RF fields to highest level, usually RF control systems provide a large enough power overhead to compensate for any disturbance of the cavity's field amplitude and phasing.

Especially the tuning and stabilization of the Eigenmode's frequency to an exact value, often with a required sub-hertz accuracy, demands for special tuning systems. Often those are not reliable or capable enough to compensate the fast perturbations, that SRF cavities are mainly driven over-coupled to their power source, allowing more stability by a larger bandwidth, but at the cost of more invested RF power, of which mostly more than 99% are reflected and dumped in a water-cooled RF load. Detuning compensation by classic mechanical piezo based systems have proven some success in laboratory demonstration experiments [ref 1-3] but failed mostly so far to be routinely used in accelerators to rely their design on that high level of detuning control. Often these control schemes require complex algorithms with high computational effort, as the coupled mechanical-RF system is highly non-linear and thus inherent unstable in a control theory point of view.

Moreover, detuning to compensate fast transients in the RF fields by varying beam currents, e.g. due to injection processes or a variation of the temporal structure of a bunch train, would need a cavity frequency detuning in the time range beyond any capability of mechanical systems.
Therefore, in this work package we focus on developing a class of tuners, which can respond in µs or better and offer a tuning action without interfering with the mechanical system of a cavity. These fast reactive tuners rely on the fact, that ferroelectric materials change their dielectric properties when applying a high voltage. Inserting this material in an RF transmission line with proper resonant behavior can thus change its impedance and such eigenmode frequency controlled by the high voltage and at time constants mostly dictated by the switching capabilities of the HV power supply. Coupling this device thus to an RF cavity results in a fast tuning mechanism of the coupled resonator-FRT system. During the iSAS program, we will focus on developing fast reactive tuner mainly for two applications, microphonics compensation for high loaded quality factor operated SRF cavities, which are the core of any energy recovery linac, like PERLE, bERLinPro or LHeC and tuners for compensating beam-loading transients, especially for the case of LHC injection, but also future applications in the FCC context.
Both use cases significantly reduce the required RF power level while preserving the required field stability set by the accelerator demands.

• Capture the theme of each of the tasks in one phrase (similar to the “tasks” listed per WP in the original proposal, i.e. more detailed compared to the introduction for an expert audience)

• List the actions involved per sub-objective (similar to the bulleted tasks in the original proposal, also for an expert audience)

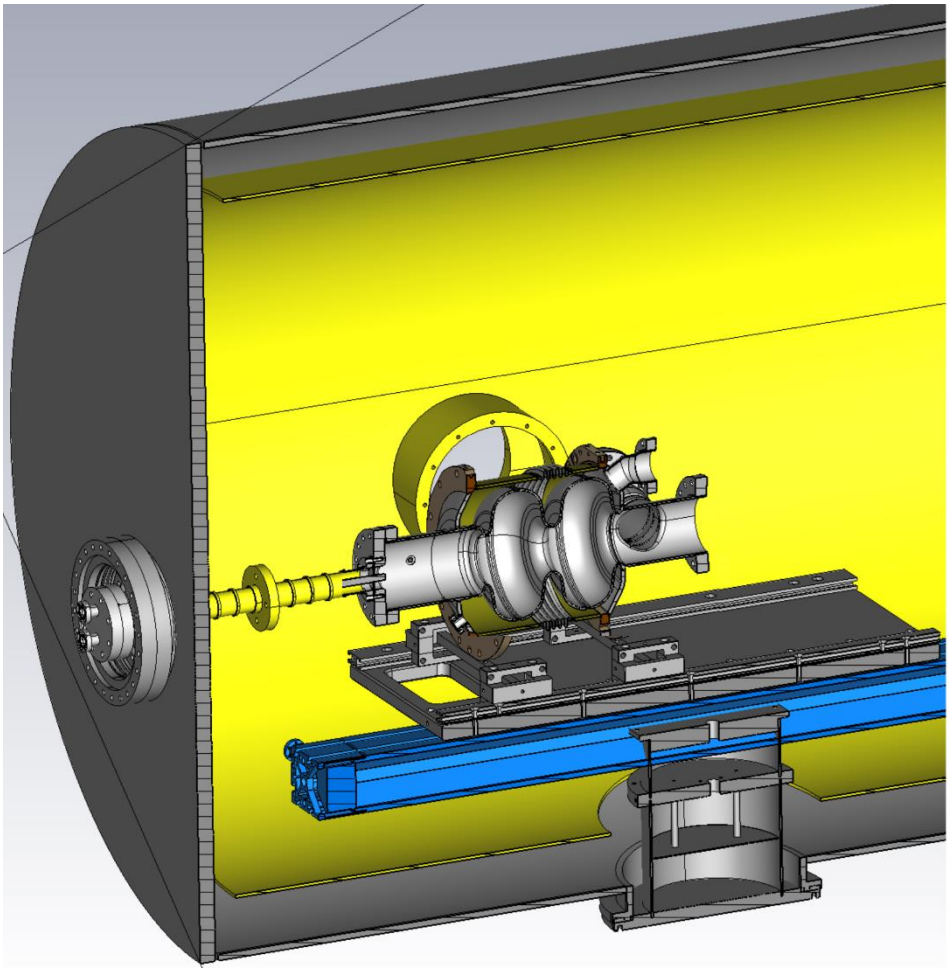

Figure 1 Example of an FE-FRT coupled via a beamtube port to a superconducting RF cavity with 1.3 GHz fundamental frequency to be tested in an horizontal test cryostat.

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