Design of a High Gradient S-Band, Traveling Wave Accelerating Structure

Elettra Sincrotrone Trieste

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ABSTRACT

FERMI is the seeded FEL user facility at the Elettra laboratory in Trieste, operating in the VUV to EUV and soft X-rays spectral range; the radiation produced by the seeded FEL is characterized by several desirable properties, such as wavelength stability, low temporal jitter and longitudinal coherence.

In this poster we will present the design of an S-band, high gradient 89 cells accelerating structure. We will briefly summarize the results of the RF analysis performed on the regular cell. Both surface fields and RF parameters have been evaluated and optimized. A parametric analysis has also been set up to verify the mechanical tolerances to be used during production processes.

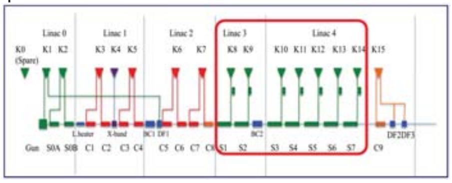
At the end, an ANSYS multi-physics environment has been used to get the thermal profile and the subsequent detuning along the accelerating structure. A prototype will validate the simulations.

FERMI Operation Highlights

FERMI is a free electron laser equipped with special beamlines that can be used by national and international users in order to carry out various types of experiments of considerable scientific value. The high quality of sources and beamlines have produced significant results, both scientific and technological.

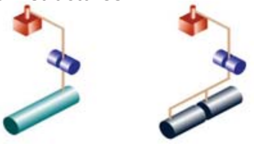
LINAC Upgrade

The high-energy part of the linac is equipped with seven Backward Traveling Wave (BTW) structures for high gradient operation designed for a repetition rate of 10 Hz and a LINAC full energy up to 1.55 GeV.



They suffer from increased breakdown activity at 25-26 MV/m and 50 Hz repetition rate and show localized damages due to the high fields.

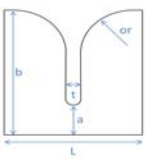
In order to improve reliability and operability at higher energy and full repetition rate, we intend to replace the 7 structures.



New accelerating structures for operation up to **30 MV/m (at 50 Hz)** and **low wakefield** contribution must be designed. In order to achieve such a critical result the actual structures will be split into two. This upgrade will increase the LINAC energy to nearly 1.8 GeV.

High frequency simulations

High frequency simulations were performed on the regular cell in order to lower surface peak field and optimize the RF parameters.



Geometric Parameter		
L	33.332	mm
A	10	mm
b	41.2986	mm
t	2.5	mm
or	13	mm

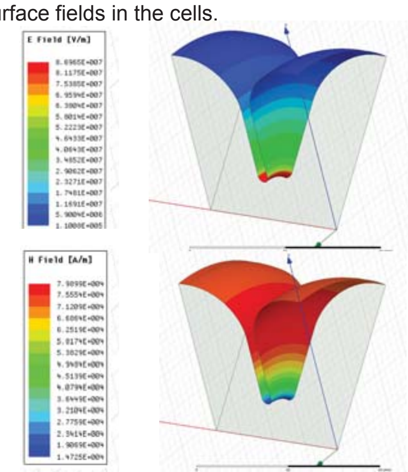
Sensitivity analysis

It's crucial to know how the cell dimensions affect the resonant frequency, so the frequency has been simulated versus each variation of the dimensions. Proper tolerances have been chosen according to this parametric simulation.

Geom. Parameters	Δf_0 [KHz/μm]
b – Outer Radius	-78.99
or – Outer Bending Radius	+27.11
t – Disk Thickness	+5.65
a – Inner Radius	+16.02
L – Cell Length	-8.02

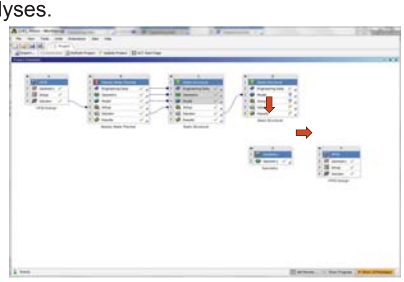
Electrical and magnetic fields

An average gradient of 30 MV/m leads to an input power of nearly 65 MW over 700ns. The following pictures show the electric and magnetic surface fields in the cells.



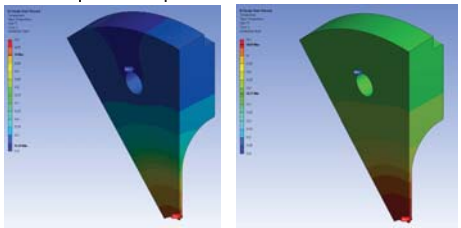
Coupled analyses

The ANSNew accelerating structures for operation up to **30 MV/m (at 50 Hz)** and **low wakefield** contribution must be designed. In order to achieve such a critical result the actual structures will be split into two. This upgrade will increase the LINAC energy to nearly 1.8 GeV. YS workbench environment allowed to make easier the coupled analyses.



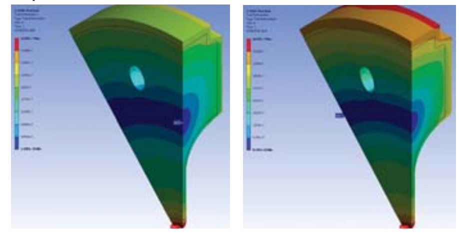
Thermal analyses

A water flow of 30 l/min at 33 C will cool the section by means of 8 cooling channels with a diameter of 8 mm. The fluid speed is 1.2 m/s. The following pictures show the first and the last cell temperature profile.



Structural analyses

The temperature field obtained as results from thermal analysis has been used for the structural analysis. The next picture shows the displacements on the first and last cells.



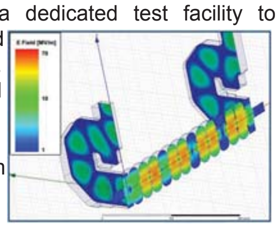
Cells detuning

Deformed geometries of cell 1, cell 45 and cell 89 have been then used for evaluating the detuning along the structure due to the thermal deformations.

	T_{min} [°C]	T_{max} [°C]	Frequency [MHz]	Detuning [KHz]
Undeformed cell	33.00	33.00	2997.9854	
1st cell deformed	33.43	34.00	2997.9849	-0.5
45th cell deformed	33.60	34.00	2997.9865	+1.1
89th cell deformed	33.77	34.07	2997.9872	+1.8

Construction drawings

A short prototype (10 cells) has been designed in collaboration with PSI (Paul Scherrer Institut) and is now under construction. It will be high power tested in a dedicated test facility to validate the RF and mechanical design. This prototype will prove the reliability of operation at a gradient of 30MV/m



Outlook

The presented calculation will lead to the fabrication of a short (0.5 m) prototype of an accelerating structure in collaboration with the Paul Scherrer Institut. The prototype will be a tuning free, fully brazed structure equipped with electric-coupled RF couplers to lower electric and magnetic surface field in the coupler region. It will be tested at high power at Elettra in the first half of 2018.

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