HOM Coupler Notch Filter Tuning for the European XFEL Cavities.

A. Sulimov, Deutsches Elektronen-Synchrotron, DESY, Notkestrasse 85, 22607 Hamburg, Germany

Abstract

The notch filter (NF) tuning prevents the extraction of fundamental mode (1.3 GHz) RF power through HOM couplers. The procedure of NF tuning was optimized at the beginning of serial European XFEL cavities production. It allows keeping the filter more stable against temperature and pressure changes during cavity cool down. Some statistics of NF condition during cavities and modules cold tests is presented.

Geometry

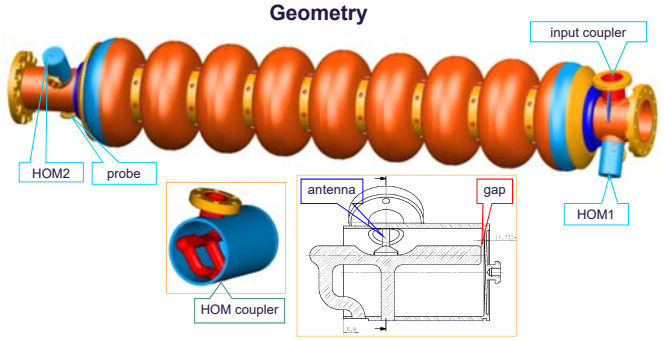

Figure 1. HOM couplers of the European XFEL cavities

Algorithm

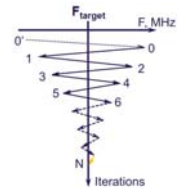

Figure 5: Algorithm of gap tuning

- Original filter frequency (Fig. 2 and 5) could be lower (0' – green curve) or higher 0 – red one) than the target (F_{target}).
- In any case the first iteration is filter detuning to opposite direction: (0' – 0) or (0 – 1).
- After each iteration, when the tuning tool is relaxed and the gap is free of extra forces, filter frequency should overcome the target, but be closer to it.
- To improve the stability of tuning it is necessary to increase the number of iterations and smoothness of frequency deviations $|F_{filter} - F_{target}|$ for sequence (0')-0-1-2-3-…-N.

Statistics for Separate Cavities

Table 1: Output power of fundamental mode from each antenna in XFEL Cavity

Average and Maximum values for an antenna	in Vertical Tests	in Module Tests
$< P_{Probe} >$, W	3.6 ± 1.2	2.8 ± 0.8
Max (P_{Probe}), W	9.5	9.4
$< P_{HOM} >$, W	0.24 ± 0.21	1.3
Max (P_{HOM}), W	7.8	78
$< P_{HOM} / P_{Probe} >$	0.07	0.5
Max (P_{HOM} / P_{Probe})	0.6…2.5	31

Statistics for XFEL Modules

Table 2: Output power of fundamental mode from all antennas in XFEL Module

Average and Maximum values for a module	in Module Tests
$< P_{Probe} >$, W	22 ± 4
Max (P_{Probe}), W	35
$< P_{HOM} >$, W	21 ± 20
Max (P_{HOM}), W	189
$< P_{HOM} / P_{Probe} >$	1.0
Max (P_{HOM} / P_{Probe})	9.9

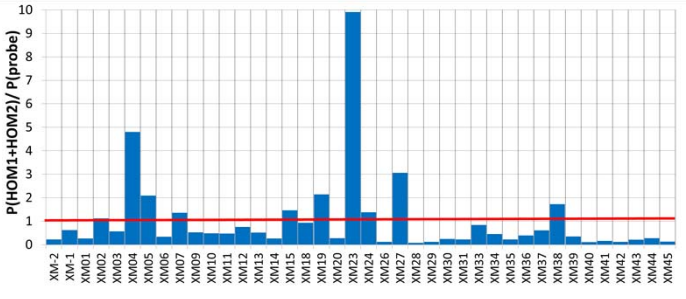

Figure 6: Average ratio P(HOM1 + HOM2) / P(probe) for 8 cavities in module

Control Measurements

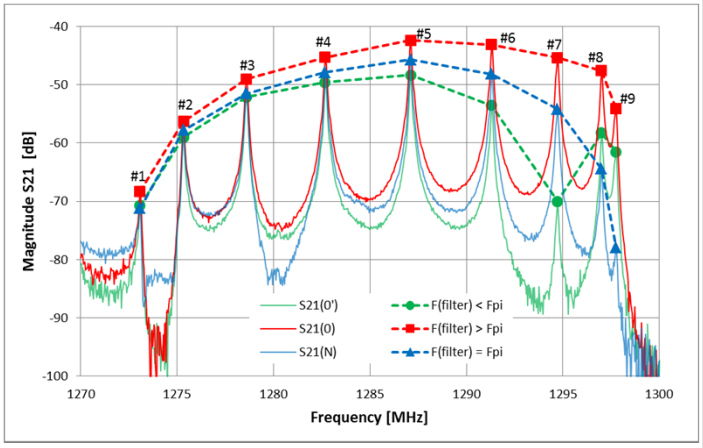

Figure 2: Fundamental mode spectrum with amplitudes (Fpi = 1297.75 MHz)

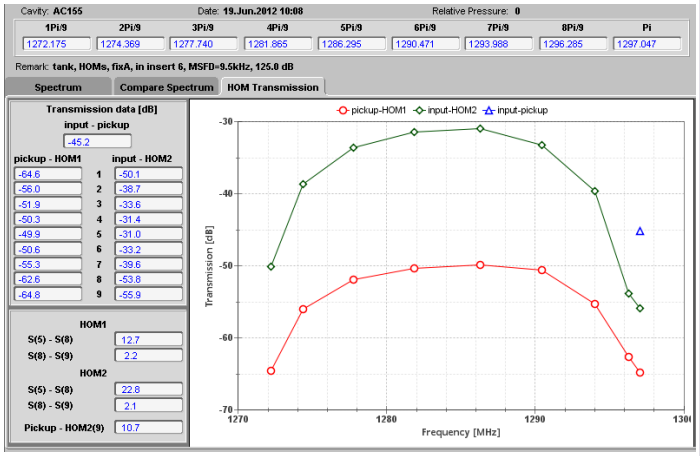

Figure 3: Control measurements at room temperature

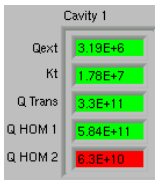

Figure 4: Control measurements at 2 K

Output power of fundamental mode 1.3 GHz for different antennas depends on cavity gradient and for TESLA shape geometry can be calculated as:

$$P_{Probe,\,HOM} = \frac{(E_{acc}\,L)^2}{R/Q\;Q_{Trans,\,HOM}} = 1.04 \cdot 10^{-3}\,\frac{{E_{acc}}^2}{Q_{Trans,\,HOM}}, \quad (1)$$

where: E_{acc} – operational gradient [V/m],

Q – quality factor of probe or HOM coupler antenna.

Ratio (2) depends only on calibration parameters (Fig. 4):

$$\frac{P_{HOM}}{P_{Probe}} = \frac{Q_{Trans}}{Q_{HOM}}. \quad (2)$$

Summary

Based on our experience we can come to the following conclusions:

- use of iterative tuning algorithm allows to increase the stability of fundamental mode filtering against relative pressure changes by reduction of local stresses and hardening the material of HOM coupler. It prevents detuning during cool down and warming up between room temperature and 2 K;
- control measurements before and after cavities / modules transportation show the good notch filter stability against vibrations;
- strong (critical) filter detuning is very seldom and appears only by HOM coupler deformations during module assembly.

References:

[1] A. Sulimov et al., "Description and First Experience with the RF Measurement Procedure for the European XFEL SC Cavity Production", 2nd IPAC'11, San Sebastian, Spain, 2011, pp. 277-279.

[2] http://xfel.desy.de/cavity_database/rf_measurements/