NEW ACCELERATING MODULES RF TEST AT TTF

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Abstract

Five new accelerating modules were installed into the TTF tunnel as a part of the VUV FEL Linac. They are tested prior to the linac operation. The RF test includes processing of the superconducting cavities, as well as maximum module performance tests. The test procedure and the achieved modules cavities performance are presented.

TTF ACCELERATING MODULES

The TESLA Test Facility (TTF) VUV FEL LINAC [1], [2], [3], [4] has now 5 accelerating modules (see Fig. 1), each module (see Fig. 2) consists of 8 9-cell niobium cavities with input RF power couplers (see Table 1) and a quadrupole in the cryomodule [5].

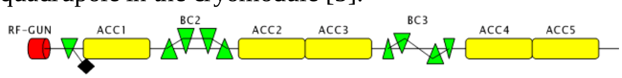

Figure 1: Accelerating modules ACC1 – ACC5 at TTF.

Figure 2: Accelerating module in the VUV-FEL tunnel.

Table 1: Accelerating Modules.

pos.	mod.	ready	coupler type	cold win.	warm win.
ACC 1	2*	Jan. 2004	FNAL/ TTF III	Conical /Cyl.	Planar /Cyl
ACC 2	1*	Mar. 2000	FNAL/ TTF II	Conical /Cyl.	Planar (WG)
ACC 3	3*	Feb. 2003	TTF II	Cyl.	Planar (WG)
ACC 4	4	Jul. 2001	TTF II	Cyl.	Planar, (WG)
ACC 5	5	Mar. 2002	TTF III	Cyl.	Cyl.

The cavities are operated at 2 K and have an accelerating gradient between 12 and 35 MV/m. The RF power sources for the accelerating modules are the 5 and 10 MW 1.3 GHz klystrons connected to the modules through the waveguide power distribution system (see Fig. 3). The RF power measurements are done using the waveguide directional coupler (DC) (1 coupler, forw. and refl., 1 DC pro module installed). The probe power measurement is done for the one cavity (where DC is also installed) pro accelerating module using the power meter. Power meters connected through GPIB-Ethernet network to the computers, controlling the test procedure using LabVIEW program.

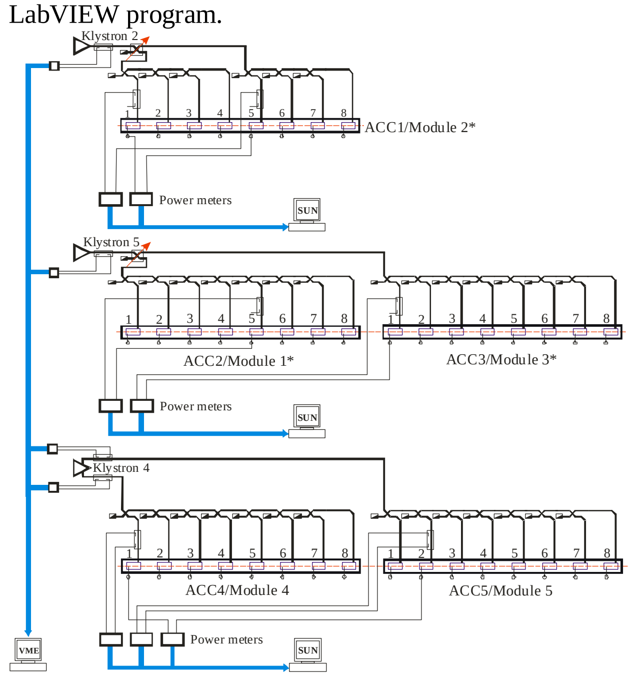

Figure 3: RF power distribution / measurement diagram.

Downconvertor/ADC channel for P_{for}, P_{ref} (from circulators) and P_{trans} (cavity probes) for each cavity is used to monitor the forward, reflected and transmitted power pulse shape. To measure power precisely enough proper power line calibration measurement must be ensured in order to get attenuation values between the power meter (PM) and measurement point. All measurement cables were calibrated before the test. To measure the accelerating gradient (E_{acc}) cavity pickup (transmitted) power value was used, calibration coefficient k_t is to be measured at lower power rectangular pulse, when pulse shape is precisely defined and E_{acc} is calculated (see Eq. 1).

$$E_{ACC} = \frac{\sqrt{4\frac{R_{sh}}{Q}Q_{load}P_{for}}}{L_{cavity}} \times \left[1 - e^{-\frac{\pi f_0 t_{fill}}{Q_{load}}}\right] = k_t \times \sqrt{P_{trans}}, [V/m] \qquad (1)$$

Standard parameters values are: $R_{sh}/Q=1030\Omega$, $L_{cavity}=1.035m$, $Q_{load}=3\times10^6$, $f_0=1.3GHz$, $P_{for}\approx5kW$ (for the calibration), $t_{fill}=1.3ms$ (for the calibration, 500µs for flat-top pulse (FT)). In this case such a measurement was not possible for each cavity, also most of the gradient values were obtained from forward power measurement using first part of the Eq. 1, assuming the symmetrical power distribution when using only one power measurement pro module. The non-symmetry of power distribution was measured to be about ±0.2dB. Other, most important measurement error origins are cable calibration coefficients (±0.1dB), non-rectangular power pulse shape at high RF power and dependence of the DC directivity coefficients from the standing wave distribution in the waveguide. The evaluated error margins for accelerating gradients in this test are about ±10..16%.

RF TEST RESULTS

In order to get the maximum performance from the LINAC accelerating cavities and input power couplers must be conditioned. Each step in the coupler conditioning is limited by plasma density in the coupler caused by rf discharge. Standard sensors set used for coupler processing – photo multipliers, infrared temperature sensors, spark detectors and coupler pick-ups (3 pro coupler, paralleled) [6], [7]. After couplers conditioning off resonance was completed all the cavities were tuned to the resonant frequency of 1.3GHz and loaded quality factor was adjusted by changing the coupler antenna position. Cavity 4 at module 3* (ACC3) was not tested because of minor problem with the coupler, at the next LINAC run this coupler was successfully conditioned. The cavities were tested with the flat-top RF pulse with 0.5 ms rise time and 0.8 ms flat-top.

In the Fig. 4 single cavities tests results are presented, vertical test cryostat, horizontal test cryostat and accelerating module tests are compared. In the position 5 of the module 2* / ACC1 a high gradient cavity (AC72, electropolished [8]) was installed and tested successfully reaching the gradient of 35 MV/m with own quality factor $Q_0=10^{10}$. The summary of the modules tests is presented in Fig. 5, where average accelerating gradients of the modules are shown. The own quality factors Q_0 measurements done using the cryogenic losses measurement, results are summarized in Fig. 6.

Some cavities in the accelerating modules have the field emission. Module 2* / ACC1: cavity 7 is a source of a dark current, up to 10 mGy/min measured on axis. Module 5 / ACC5: cavity 6 is a source of a dark current of 1 µA (peak) at 25 MV/m. Radiation level measured at 1 m distance from module 5 dump side was about 18 µSv/min

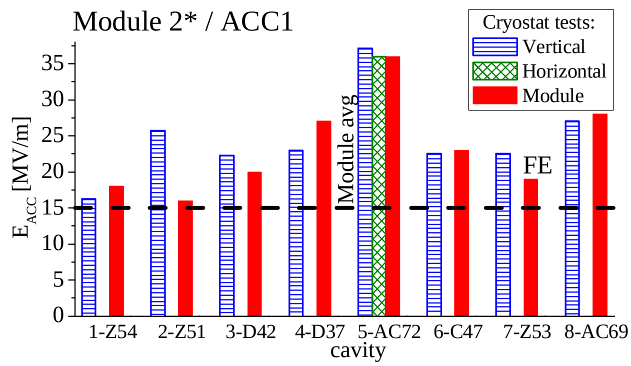

Figure 4a: Single cavities tests: ACC1.

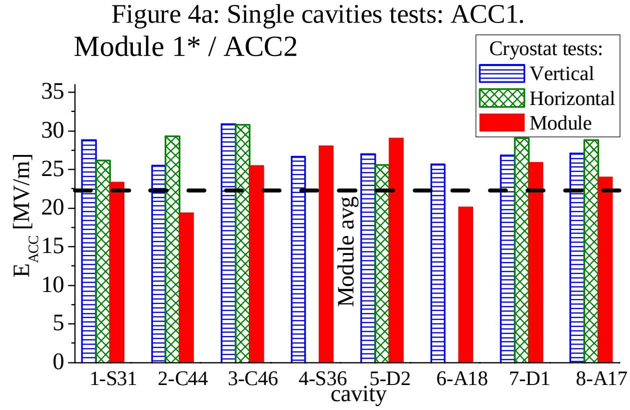

Figure 4b: Single cavities tests: ACC2.

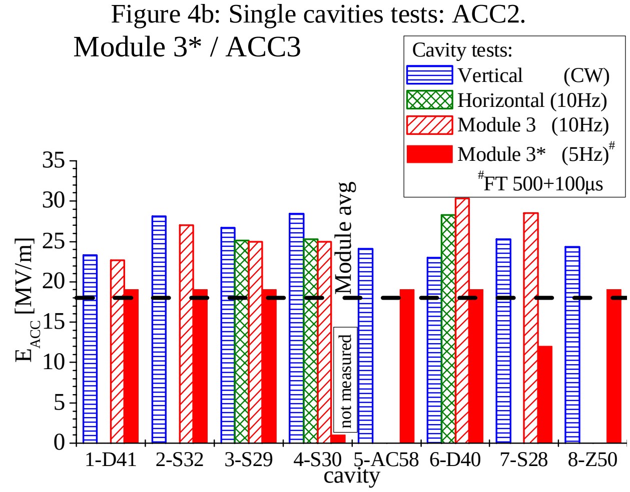

Figure 4c: Single cavities tests: ACC3.

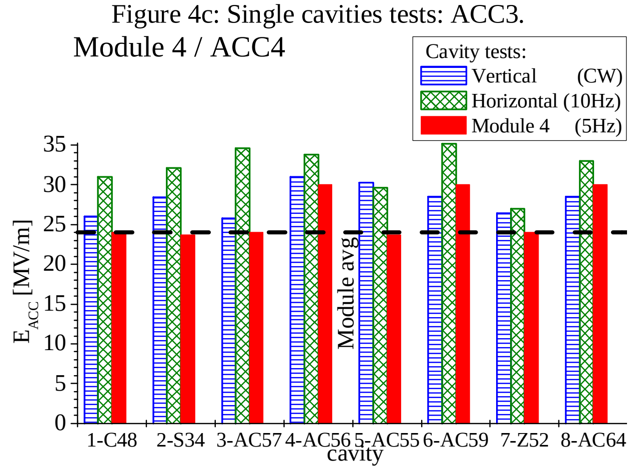

Figure 4d: Single cavities tests: ACC4.

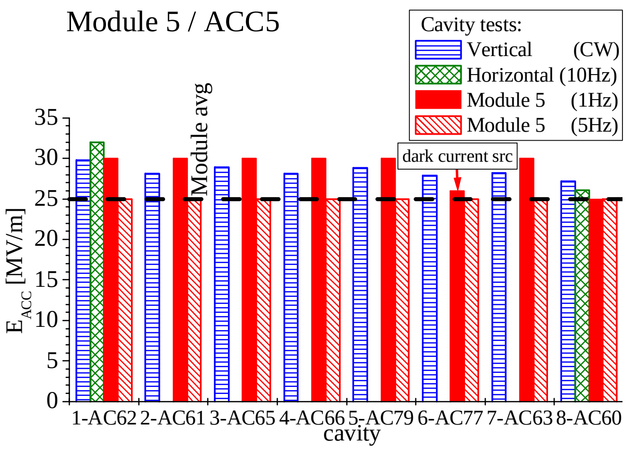

Figure 4e: Single cavities tests: ACC5.

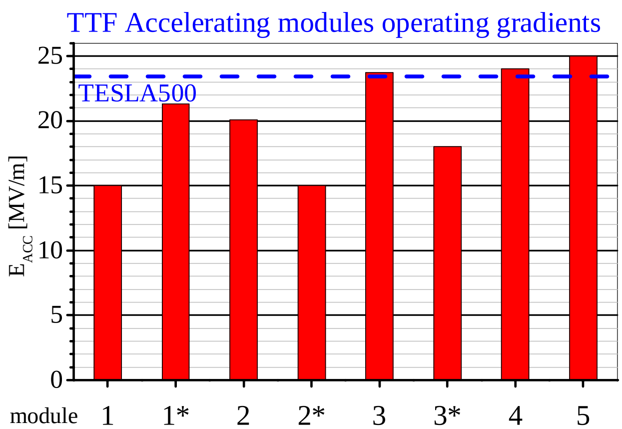

Figure 5: Modules operating (average) gradients.

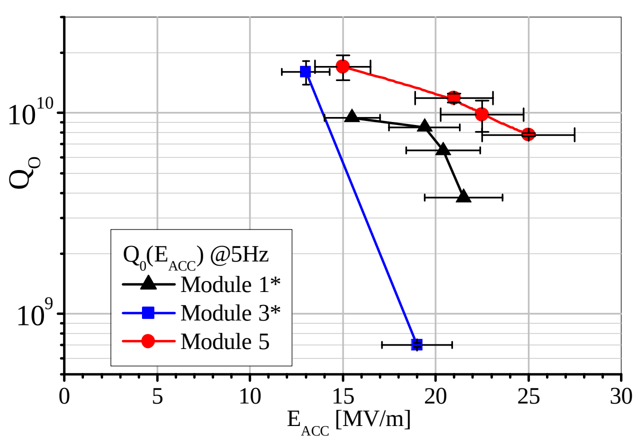

Figure 6: Q_0 vs E_{acc} measurements.

CONCLUSIONS

The last two modules, 4 and 5, fulfill the TESLA500 specifications. All modules have functioned continuously during certain periods of time, no one was taken immediately out for repair.

ACC5 / module5: tested at the repetition rate of 5 Hz was operating at the accelerating gradient of 25 MV/m, 500 + 800 µs full length flat-top pulse and quality factor of 8×10^9. Cavity 6 is a source of a dark current of 1 µA (peak) at 25 MV/m. Radiation level measured at 1 m distance from module 5 dump side: 18 µSv/min.

Module 2* / ACC1 was operated with beam for about 2 months. Cavity 5 (AC72) tested in Module 2* / ACC1 reached 35 MV/m, confirmed with beam. Cavity 7 is a source of a dark current, up to 10mGy/min measured on axis.

ACKNOWLEDGEMENT

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