TESTING THE FLASH SUPERCONDUCTING ACCELERATING MODULES

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Abstract

The Free-electron LASer in Hamburg (FLASH), operating in the VUV wavelengths range, is not only the outstanding research facility in Europe, but also the test bench for the ILC superconducting linac technology. Started XFEL, as well as planned ILC, both depend on the progress made here. [1], [2], [3]. New module test stand was recently put into operation at DESY. The FLASH linac has been upgraded to 6 superconducting modules.

The accelerating modules testing experience and the results of the tests are put in the base of this paper, describing the recent developments of the XFEL / ILC technology.

INTRODUCTION

After the upgrade FLASH LINAC has 6 accelerating SRF modules, containing each 8 TESLA-type SRF cavities.

Figure 1: FLASH LINAC SRF modules.

Table 1: FLASH LINAC SRF modules.

pos.	mod.	ready	coupler type	cold win.	warm win.
ACC1	2*	Jan. 2004	FNAL/ TTF III	Conical /Cyl.	Planar /Cyl
ACC2	1*	Mar. 2000	FNAL/ TTF II	Conical /Cyl.	Planar (WG)
ACC3	7	Dec. 2006	TTF III	Cyl.	Cyl.
ACC4	4	Jul. 2001	TTF II	Cyl.	Planar, (WG)
ACC5	5	Jun. 2007	TTF III	Cyl.	Cyl.
ACC6	6	May 2006	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 two 5 and one 10 MW 1.3 GHz klystrons connected to the modules through the waveguide power distribution system.

MODULE TEST BENCH

The Cryo Module Test Bench (CMTB) was built at DESY to test the accelerating SRF modules and cavities independently from the FLASH operation. At CMTB RF and cryogenic tests are being done.

Figure 2: FLASH LINAC SRF module on the CMTB.

MODULE TESTS RESULTS

RF Couplers Performance

- Total of 48 RF power couplers connected to the superconducting cavities in the FLASH linac, eight in a module.
- RF power couplers were tested up to 1 MW of pulsed power at 1.3 ms pulse length 2 Hz at the test stand.
- TTF III couplers are tested together with cavities at gradients of 35 MV/m (600 kW) 10 Hz without degradation of cavity or coupler.
- All couplers in the FLASH linac could be conditioned and operated up to the cavity performance limits.

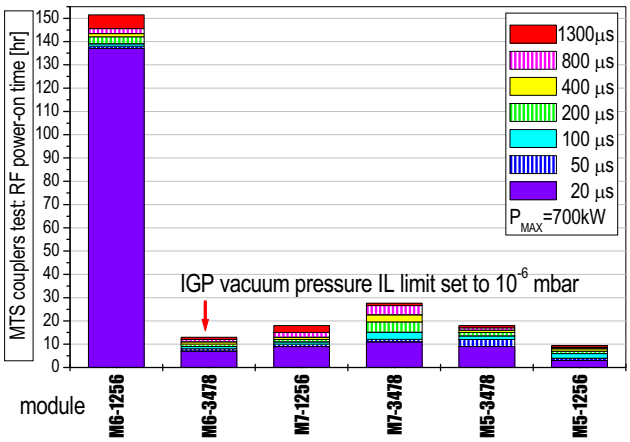

Figure 3: RF power rising time for different pulse lengths during the couplers conditioning on the CMTB.

RF Cavities Performance

The RF power measurements are done using the waveguide directional couplers with calibrated RF cables and the RF power meters. Power meters are connected through GPIB-Ethernet network to the computers, controlling the test procedure using LabVIEW program. Downconverter / 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 the accelerating gradient (E_{acc}) cavity probe (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).

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

$$= k_t \times \sqrt{P_{trans}}, [V/m]$$

Standard parameters values are: R_{sh}/Q=1030Ω, L_{cavity}=1.035m, Q_{load}=3×10^6, f_0=1.3GHz, P_{for}≈3kW (for the calibration), t_{fill}=1.3ms (for the calibration, 500μs for flat-top pulse (FT)). Evaluated error margins for accelerating gradients in this test are about ±10..16%.

Two new modules were assembled at DESY and tested at CMTB, see Fig.4,5, one module was reassembled after replacing the cavity tuner motors and also tested at CMTB, see Fig.6. After the test at CMTB modules were installed in the FLASH LINAC and operating together with older three modules at the accelerating gradients distributed as shown at Fig.7. The cavities were tested with the flat-top RF pulse with 0.5 ms rise time and 0.8 ms flat-top.

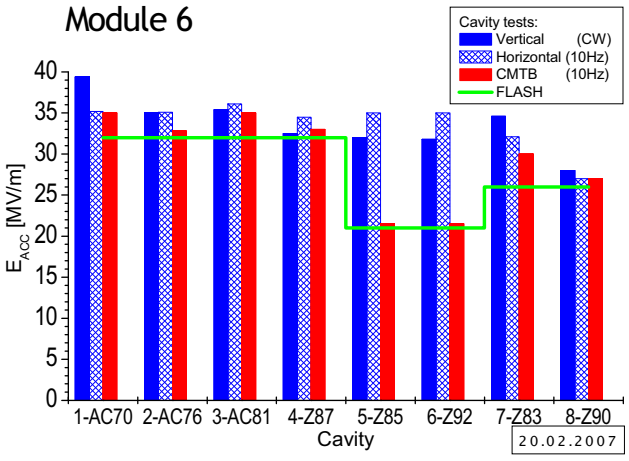

Figure 4: New FLASH SRF module 6 gradients.

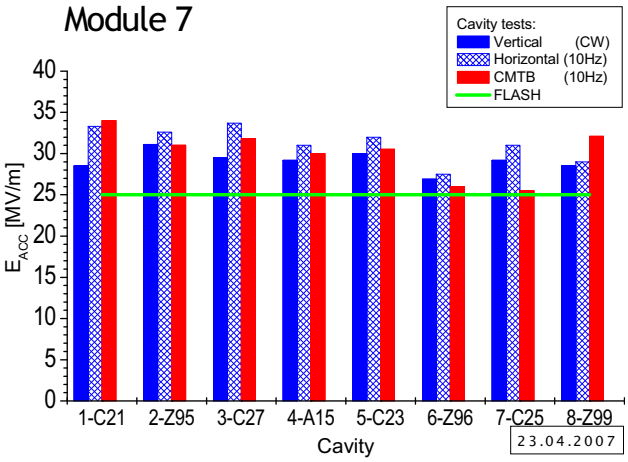

Figure 5: New FLASH SRF module 7 gradients.

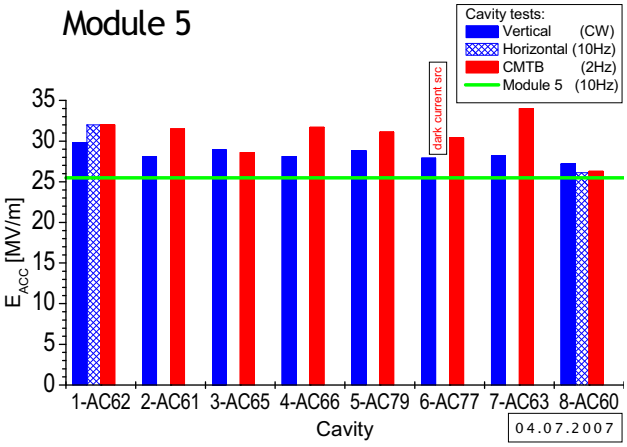

Figure 6: Repaired FLASH SRF module 5 gradients.

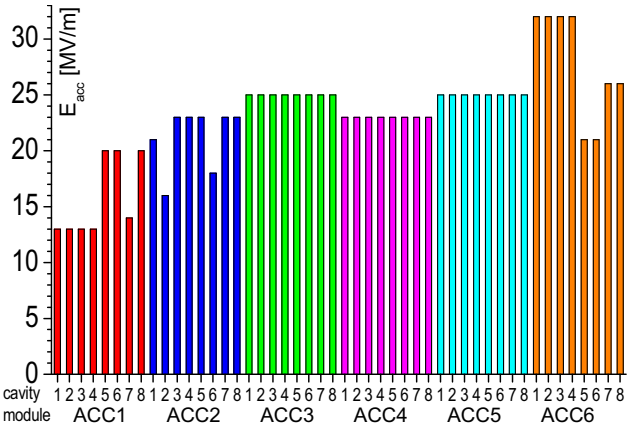

Figure 7: SRF Cavities gradients in FLASH LINAC.

The own quality factors Q_0 measurements were done using the cryogenic losses measurement on the CMTB, modules dark current radiation measurements done as well, see Fig.8 - 10.

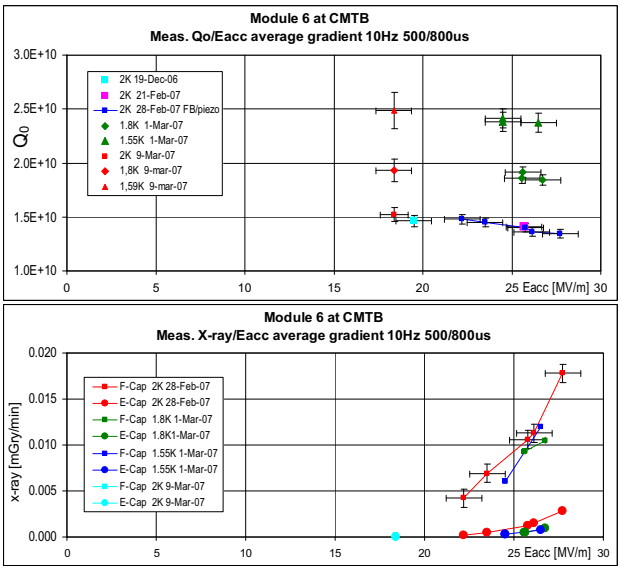

Figure 8: New FLASH module 6 (ACC6) test results.

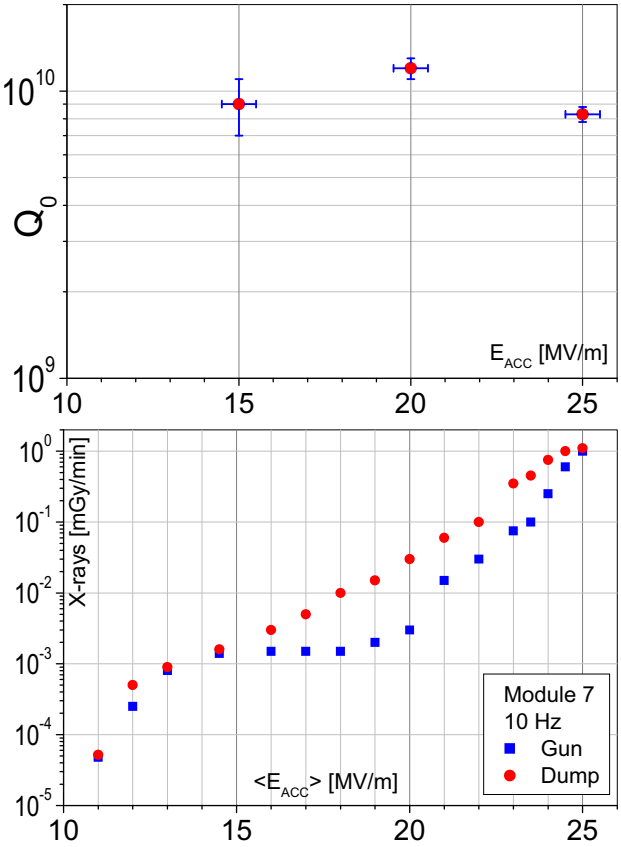

Figure 9: New FLASH module 7 (ACC3) test results.

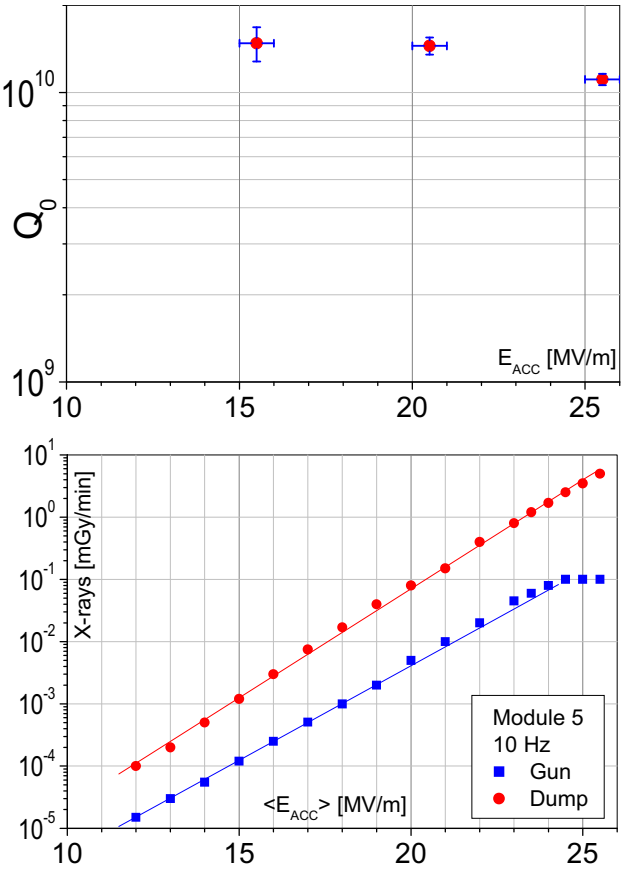

Figure 10: Repaired FLASH module 5 (ACC5) test results.

SUMMARY

- All couplers in the FLASH linac could be processed and operated up to the cavity performance limits.
- The four modules: 4, 5, 6 and 7 fulfil the XFEL specifications.
- ACC5 / module 5, tested at the repetition rate of 5 Hz was operating at the accelerating gradient of 25.5 MV/m , 500 + 800 μs full length flat-top pulse and quality factor of 1×10^{10}. 10 Hz operation was done at 23 MV/m.
- FLASH LINAC successfully upgraded:
  ACC3: new module 7, Eacc = 25 MV/m;
  ACC5: repaired module 5, Eacc = 25.5 MV/m;
  ACC6: new module 6, <Eacc> = 27 MV/m.
- All modules have functioned continuously during certain periods of time.
- 1 GeV was reached by the FLASH LINAC.

ACKNOWLEDGEMENT

I am thanking all the many colleagues from the TESLA collaboration who made it possible to develop, fabricate, prepare, assemble, test and operate the FLASH accelerating modules.

REFERENCES

[1] H.Weise, “The TESLA X-FEL Project”, Proceedings of EPAC 2004, Lucerne, Switzerland.

[2] J.Rossbach et al., "First operation of a Free-Electron Laser generating GW power radiation at 32 nm wavelength", Eur.Phys.J. D 37, 297-303, Springer-Verlag GmbH, 2005.

[3] W.Ackermann et al., “Operation of a free electron laser from the extreme ultraviolet to the water window”, Nature Photonics, vol.1, 2007, pp. 336-342.