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Outline:

• High Field Gradients in TESLA 9-Cell Cavities
  - TTF modules
  - CW performance tests
  - High power full system tests

• News from
  - TTF II
  - DESY XFEL
  - TESLA

• Conclusion
High Gradients

- Theoretical limit
- Electro-polished TESLA cavities
- TESLA 800 goal
- TESLA 500 goal
- BCP polished TESLA cavities
- TESLA 9-cell cavity
- Niobium, $f = 1.3$ GHz

Optimize cell shape

1991 — Today
Experience from the TESLA-Test-Facility

- Cryomodule 4 and 5 with 25 MV/m cavities installed and tested with high gradients.
- Module 6 with EP cavities will be installed later.
- Beam operation as user facility in 2004.
**TTF Cavity-Module Performance (Pulsed Operation)**

- High gradient cw performance preserved during cavity installation into linac.
- BCP cavity modules #4 and #5 reach TESLA500 performance goal.
BCP Cavity Module ACC 5: Cavity Performance

- 6 cavities exceed 30 MV/m.
- 1 cavity shows field emission at high field.
- 1 cavity is quenching at 25 MV/m.

Cavity tests:
- Vertical (CW)
- Horizontal (10Hz)
- Module 5 (1Hz)
- Module 5 (5Hz)

**Module 5**

- 6 cavities exceed 30 MV/m.
- 1 cavity shows field emission at high field.
- 1 cavity is quenching at 25 MV/m.

**BCP Cavity Module ACC 5: Cavity Performance**

- 6 cavities exceed 30 MV/m.
- 1 cavity shows field emission at high field.
- 1 cavity is quenching at 25 MV/m.

**Field emission limited**

**Quench limited**
Electropolished 9-Cell Cavities (1)

- Electropolishing done in industry (Nomura Plating) in collaboration with KEK.
- Cleaning (HPR) and test at DESY.
- Vertical test: low power cw test of naked cavity (high power coupler, LHe vessel and tuner not installed).

7 cavities exceeded 30 MV/m.
Electropolished 9-Cell Cavities: CW Test Results
EP done at Nomura Plating

TESLA800 gradients have been achieved repeatedly.
Electropolished 9-Cell Cavities (2)

- Electropolishing done at DESY with new setup.
- 9-cell cavity polished and tested.
- Vertical test: low power cw test of naked cavity.

Outstanding result:
TESLA 9-cell cavity reached 40 MV/m.
Electropolished 9-Cell Cavities: CW Test Results
EP done at DESY

- TESLA800 gradient has been exceeded (39.4 MV/m at 2K)!
- Performance very close to best single-cell cavities.
- Negligible field emission.
- Only 800 C annealing, no 1400 C ⇒ cost reduction.
Horizontal High Power Pulsed Test of 9-Cell Cavities

- Cavity is fully assembled, including:
  - Power Coupler
  - Helium vessel
  - Tuner (… and piezo)

- RF Power is fed by a klystron through the high power coupler.

- Similar to 1/12 of a TESLA cryomodule.

- Pulsed RF operation using the pulse shape foreseen for TESLA.

Two electropolished 9-cell cavities tested so far (AC73 and AC72).
Electropolished TESLA 9-Cell Cavity AC 73: Horizontal Pulsed High Power Test

AC 73 – CW and high power pulsed test results

- TESLA800 performance goal has been exceeded (> 36 MV/m).
- Performance comparable to cw acceptance test.
- No field emission up to 35 MV/m.
- Long term operation test at 35 MV/m done.
Electropolished TESLA 9-Cell Cavity AC 73: Horizontal Pulsed High Power Test (2)

Time Distribution of RF Test:

Long term test: Cavity and input coupler did not cause a single trip event!
Electropolished TESLA 9-Cell Cavity AC 73: Horizontal Pulsed High Power Test (3)

- Fully equipped cavity exceeds TESLA800 performance goal.
- Cavity performance can be preserved during assembly of the main input coupler and installation into a cryomodule.
- Long term (1 ½ months) test at 35 MV/m shows that s.c. cavities can reliably be operated very close to the quench limit.
- No performance degradation of has been seen in neither the cavity nor the input coupler. Induced quenches did not affect the cavity performance.
- Piezo compensation of Lorentz-force frequency detuning at 35 MV/m has been demonstrated.
Electropolished TESLA 9-Cell Cavity AC 73: Piezo Actuated Lorentz-Force Detuning Compensation

Detuned cavity ⇒ More RF power is required to maintain an accelerating gradient.

RF pulse duration
Piezo-compensation on
Piezo-compensation off
Electropolished TESLA 9-Cell Cavity AC 72: Horizontal Pulsed High Power Test

AC 72 – CW and high power pulsed test results

- TESLA800 performance goal has been exceeded.
- Performance comparable to cw acceptance test.
High Gradient Cavity Work: What remains to be done?

- TESLA800 performance goal has been exceeded in several 9-cell cavities.
- But:
  - Beam acceleration at 35 MV/m still needs to be demonstrated (R1 TRC rank for TESLA800).
  - A full cryomodule with eight electropolished cavities will not be tested with beam before 2005, but
  - The EP cavity AC72 will be installed in a TTF module and tested with beam acceleration in 2004.
  - More electropolished 9-cell cavities will be tested in pulsed high power mode to finalize the cavity preparation procedure. ⇒ Minimize cost, reproducible high gradients
News from TTF II

TTF1 is being extended to reach 1 GeV in 2003 and becomes a user facility in 2004.
News from TTF II

- Acc. Module Commissioning: Fall 2003
- Installation finished: Febr. 2004
- Injector Commissioning: Spring 2004
- High gradient EP cavity operation with beam acceleration: 2004
- First Lasing: Fall 2004
- Stable Operation /Saturation: End of 2004

At 35 MV/m this length corresponds to an acceleration of 280 MeV
High Power RF for TTF, XFEL, TESLA

All components build by industry.

TH1801 Multi-Beam Klystron

Matthias Liepe 01/07/2004
**News from the DESY XFEL**

- Site for XFEL chosen to maximize use of DESY infrastructure and to avoid interference XFEL/LC.
- European project, 50% of funding from German government.

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**X-ray laboratory**

1200 m

2000 m

**20 GeV superconducting main linac**

**source**
News from the DESY XFEL (2)

- DESY has established a XFEL project group.
- Technical specifications are under discussion.
- Reference parameter:
  - 20 GeV
  - 22.9 MV/m accelerating gradient
  - 116 cryomodules with 8 cavities each
  - 5 mA beam current, 10 rep. rate

Superconducting LC would profit from experience with XFEL.
“The German government has decided … not to proceed nationally and at this moment not to propose a German site for TESLA. We have to wait for the international development. But we will continue our efforts to be able to participate in a global linear collider project. Let me underline: my (German) government is the first one to have announced to be principally committed to participating in the project.”

(Dr. H. Schunck)

See LC as global project. ⇒ Importance international consensus.
Components for the TTF/XFEL/TESLA Main Linac

- 10 MW Klystrons and modulators built by industry.
- Input coupler built by industry.
- Tested to > 1 MW.
- Cavities built by industry.
- EP done in industry.
- Reach 35 MV/m.
- Parts for cryomodule built by industry.
- Assembly done at DESY.
Conclusion

• TESLA800 gradients (35 MV/m) have been achieved repeatedly in 9-cell cavity tests.

• The EP system at DESY is in operation and the 9-cell cavity reached an cw accelerating gradient of 40 MV/m.

• The high cw cavity performance of cavities can be preserved:
  – BCP cavities in the TTF linac show performance similar to their cw test results. The BCP cavity module #4 and #5 with eight 9-cell cavities each reached TESLA500 performance.
  – Two out of two EP cavities reached 35 MV/m in a full system high power test. Only minimal cavity processing was required. Stable long term operation at 35 MV/m was demonstrated.

• TTF II and the XFEL will give valuable information for a superconducting LC.