

XFEL High Power RF System Recent Developments

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Stefan Choroba, DESY ILC 2007, May 31, 2007



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Outline

- XFEL RF System Requirements
- Overview Basic Layout
- RF System Main Components
 - Multibeam Klystrons
 - Modulator
 - RF Waveguide Distribution
 - RF Interlock
 - Preamplifier



RF System Requirements

Number of sc cavities: Power per cavity: Gradient at 20GeV: Power per 32 cavities (4 cryo modules): Power per RF station:

Number of RF stations: Number of RF stations for injectors: Macro beam pulse duration:

RF pulse duration:

Repetition rate:

Average RF power per station:

928 total 122 kW 23.6 MV/m



3.9MW

5.2MW (including 10% losses in waveguides and circulators and a regulation reserve of 15%)
29 (26 active)

2 (5)

600µs

1.38ms 10Hz (30Hz) 72kW (150kW)





RF System Requiremets

Overview Layout of the RF Station





RF System Requirements

Layout of the RF Station in the Accelerator Tunnel



•Tunnel components (klystrons, pulse transformers, aux. power supplies etc.) will be installed under the cryo module.

- •The waveguide distribution will be installed on the side of the cryo module.
- •These components are not accessible during accelerator operation.





RF System Requirements

Layout of the RF Station in the Modulator Hall



The modulators will be installed in the modulator hall. 7x5 modulators in one hall.
Maintenance and repair is possible during accelerator operation.



Multibeam Klystrons

DESY asked 3 klystron vendors to develop MBK



THALES TH1801





TOSHIBA E3736

The European

X-Ray Laser Project X-Ray Free





THALES TH1801

Operation Frequency:1.Cathode Voltage:<</td>Beam Current:<</td>Max. RF Peak Power:10RF Pulse Duration:1.Repetition Rate:10RF Average Power:15Efficiency:65Solenoid Power:<</td>Length:2.

1.3GHz < 120 kV < 140 A 10MW 1.5ms 10Hz 150kW 65% < 5.5kW 2.5m





Status of the THALES TH1801

- •prototype: 20,000 hours operation since May 2000, stored at DESY
- series tube #003 in operation at FLASH since March 2006 (total operation time: ca: 6500+2100h)
- #001 was in operation at PITZ in Zeuthen till November 2006, now in operation at the klystron test stand in Hamburg
- #002 under reconstruction at Thales
- #004 fully tested at klystron test stand in Hamburg (250 hours), now in operation at PITZ, Zeuthen
- #005 new tube with modification in test at Thales

Summary: all tubes which are now in operation do not show signs of degradation (no arcing, no perveance drops)



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Multi Beam Klystron CPI VKL-8301

Design Features:

•6 beams

•HOM input and output cavity

•Cathode loading: <2.5A/cm² lifetime prediction: >100000h Status:

Data taken at the klystron test stand at DESY

- \bullet 9 MW at 300 μs and 10Hz
- 8.1 MW at 1.3 ms and 10Hz



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The TOSHIBA E3736 MBK

Design Features:

- •6 beams
- •Ring shaped cavities
- •Cathode loading: <2.1 A/cm² Status:

June 8 - October 12, 2006

- 10.4 MW, 1500 $\mu s,$ 10 Hz, 116.1 kV, h ~ 66%
- 750h at full power, at present stored at DESY







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Status of the vertical MBK development

- 6 THALES TH1801 have been built (10MW, 1.5ms, 10Hz, 63% for #3), 1 is in test at THALES klystrons in use at FLASH, PITZ, MBK test stand, several thousends of operation hours under different conditions, now stable operation
- 1 TOSHIBA E3736 at DESY (10.4MW, 1.5ms, 10Hz, 66%), 750h operation hours
- 1 CPI VKL8301 at DESY (8.1MW, 1.3ms, 10Hz, 53%)



Horizontal MBK prototypes



Horizontal versions of MBKs by all 3 vendors (THALES, CPI, TOSHIBA) are under construction
First klystron is expected in second half of 2007



Modulator

Modulator Requirements

•Modulators must generate HV pulses up to 120kV and 140A, 1.57ms pulse length and 10Hz (30Hz) repetition rate

•The top of the pulse must be flat within 1%

•The bouncer type modulator with its simple circuit diagram was chosen





Modulator

- •3 bouncer modulators have been developed, built and delivered to TTF by FNAL since 1994
- •They are continuosly in operation under different operation conditions
- •Industry made subunits (PPT, ABB, FUG, Poynting)
- •Constant power power supply for suppression of 10Hz repetition rate disturbances in the mains
- Compact storage capacitor bank with self healing capacitors
- •IGCT Stack (ABB); 7 IGCTs in series, 2 are redundant
- •Low leakage inductance pulse transformer (ABB) $L<200\mu$ H resulting in shorter HV pulse rise time of $<200\mu$ s
- •Light Triggered Thyristor crowbar avoiding mercury of ignitrons







Modulator for Pulse Cable Tests

Bouncer at high potential



Modulator in hall 2

Low leakage inductance circuit

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- •Pulse transmission has been successful tested at TTF/FLASH Modulator 5.
- EMI caused by cable required modification of modulator internal layout (lower leakage inductances, EMC cabinets, bouncer at high potential)
 New modified modulator is installed at DESY hall 2 and will supply HV pulses via a 1.5km long cable to PT/Klystron in hall 3 (FLASH) during part of the next operation period of FLASH



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Qualification of additional modulator vendors

- 2 additional XFEL prototype modulators have been ordered to qualify additional vendors besides the already know vendors of bouncer modulator components like PPT, ABB, FUG, Poynting
- One modulator is a bouncer modulator by Imtech/Vonk NL
- The other modulator is a PSM modulator by Thomson BM CH:

Much experience of about 20years exists with PSM modulators for SLS, fusion or radio station applications

• Test of these devices is planned for 2008 at the modulator test facility at DESY Zeuthen.





Modulator

Planned Modulator Test Facility at DESY in Zeuthen





Bouncer Modulator Test

- Bouncer Type, as specified by DESY
 - 12kV HVPS
 - Bouncer 300uH/4.6kA 690Vac
- 7st IGCT main switch
- Digital Regulation Circuit
- Analog In- and Outputs
- Well known and tested principle
- delivery time: 12 month

Installation at DESY Zeuthen is foreseen for spring 2008



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PSM Modulator

PSM Modulator by Thomson BM

- Different Type:
 - 12kV/2kA w. transformer
 - Pulse Width Modulation
 - 24 switching stages in series
 - FPGA based control
 - 2 stages for redundancy
- Slew rate and pulse shape controllable
- detailed description available, principle already successfully tested (worldwide, i.e. W7/X)
- delivery time: 14 month

Installation at DESY Zeuthen is foreseen for spring 2008





Modulator

Status Modulator

- 11 Bouncer Modulators have been built, 3 by FNAL and 8 together with industry
- 11 modulators are in operation (FLASH, PITZ, XFEL Teststands)
- 10 years operation experience exists
- Modulator foreseen for waveguide tests will be installed in DESY hall 2 and connected to PT and klystron in hall 3 (Bouncer type plus improvements) and used for pulse cable tests
- Order for more XFEL prototypes has been placed (1 Bouncer plus 1 PSM)
- Test of prototypes in Zeuthen starting spring 2008



Waveguide Distribution

- Distribution of klystron output power to the superconducting cavities
- Protection of the klystron from reflected power
- Control of phase





Waveguide Distribution

Many wave guide components have been developed over the last years and have been used for the operation of TTF/FLASH





Waveguide Distribution

A New Waveguide Distribution for the XFEL has been developed. It will be tested with ACC6 at TTF/FLASH

Standard FLASH like Distribution



Combined System with shunt tees: less space, less parts, less weight, lower costs, must be tested, planned for ACC6 at FLASH











Waveguide distribution in Halle II





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Waveguide distribution with shunt tees





The European X-Ray Laser Project X-Ray Free-Electron Laser

New Binary Cell with shunt tee with integrated phase shifter















Phasing of wavegude distribution

Combined system with asymmetric shunt tees







RF Interlock

Zeuthen/HH development
FPGA Based
Version #2 installed at FLASH
Version #3 installed at PITZ and module test facility, will be tested at FLASH too
Version #3 allows setting of interlocks remote controlled







Preamplifier

- •Specification reworked
- •Several new amplifiers are ordered, some received and in test
- •Will be used at MBK teststand, FLASH, Zeuthen



HV Pulse Cable

- •Transmission of HV pulses (10kV, 1.6kA, 1.57ms, 10Hz (30Hz)) from the pulse generating unit (modulator hall) to the pulse transformer (accelerator tunnel)
- •Maximum length 1.5km
- •Impedance of 25 Ohms (4 cable in parallel will give 6.25 Ohms in total) to match the klystron impedance
- •Triaxial construction (inner conductor at 10kV, middle conductor at 1kV, outer conductor at ground)



