

Overview XFEL RF System S. Choroba, DESY

•XFEL RF Requirements •RF Station Layout •Overview RF Components

Many people from DESY groups in HH and Zeuthen, other labs and companies have contributed to the RF System



EMEINSCHAFT

XFEL 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:

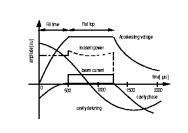
Average RF power per station:

928 total 122 kW 23.6 MV/m



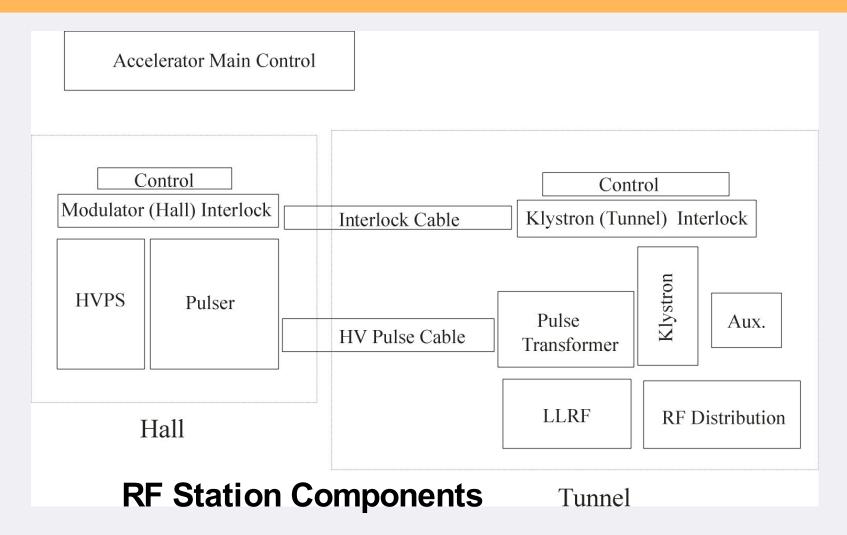
3.9MW

- 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)





Layout of the RF System (1)

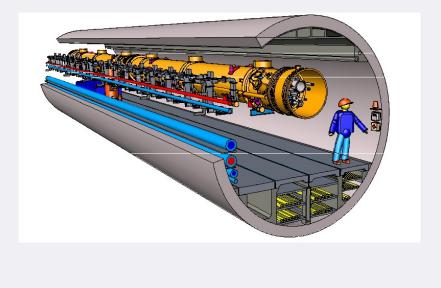


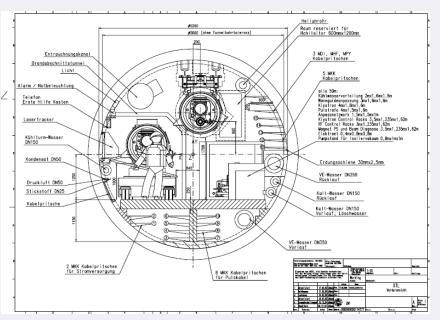
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Layout of the RF System (2)





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

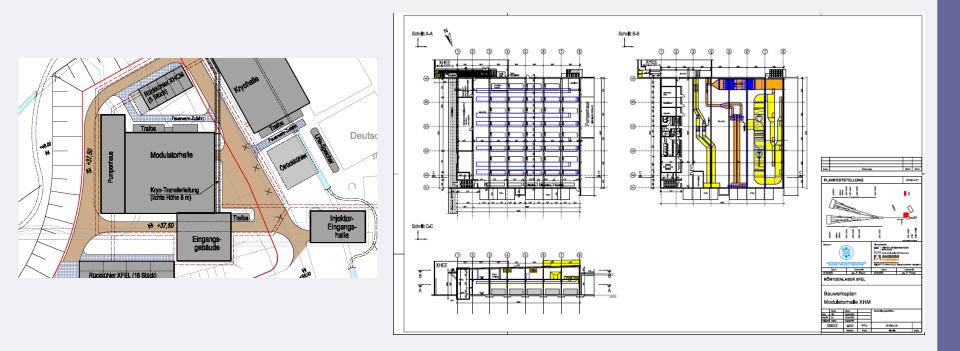
•The waveguide distribution will be installed on the side of the cryo module.

•They are not accessible during accelerator operation.



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

Layout of the RF System (3)



•The modulators will be installed in the modulator hall. 7x5 modulators in one hall.

•Maintenance and repair is possible during accelerator operation.





Multibeam Klystron

\rightarrow Details in V. Vogels presentation Collector Multibeam Klystron Requirements Beam electromagnet **Operation Frequency:** 1.3GHz Output windows Cathode Voltage: < 120 kV Beam Current: < 140 A Max. RF Peak Power: 10MW **RF Pulse Duration:** 1.5ms 10Hz Repetition Rate: Cavities 150kW RF Average Power: Beams 65% Efficiency: Solenoid Power: < 5.5 kWLength: 2.5m

developed for TESLA



Ceramic

Multicathode gun

The European X-Ray Laser Project

Vertical MBK Prototypes







THALES TH1801

CPI VKL8301

TOSHIBA E3736

3 klystron vendors have developed MBKs during the last years



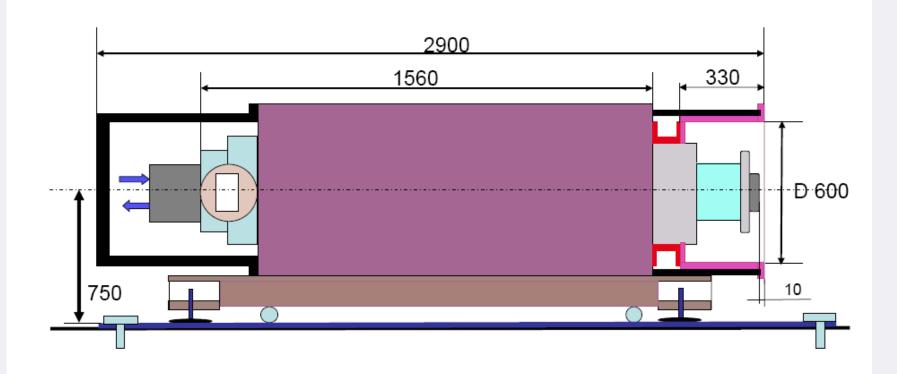


Vertical MBKs

- 5 THALES TH1801 have been built, 1 is in bakeout at THALES
 (Best tube 10MW, 1.5ms, 10Hz, 63%)
 klystrons in use at FLASH, PITZ, MBK Test
- 1 TOSHIBA E3736 at DESY (10.4MW, 1.5ms, 10Hz, 66%)
- 1 CPI VKL8301 at DESY (8.1MW, 1.3ms, 10Hz, 53%)



Horizontal MBK Prototypes



Horizontal versions of MBKs by all 3 vendors are under construction (total length of spec. 11 pages): first deliveries are expected early 2008



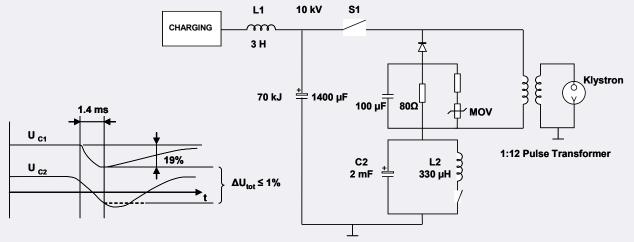


Modulator Requirements

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

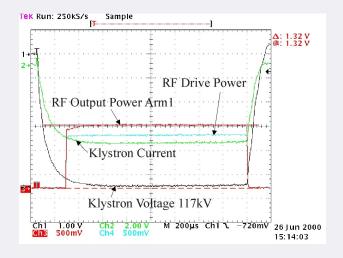
•The top of the pulse must be flat within 1%

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





Bouncer Modulator (1)



3 modulators have been developed, built and delivered to TTF by FNAL since 1994
They are continuosly in operation under different operation conditions





Bouncer Modulator (2)

•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<200µH resulting in shorter HV pulse rise time of <200µ s

•Light Triggered Thyristor crowbar avoiding mercury of ignitrons







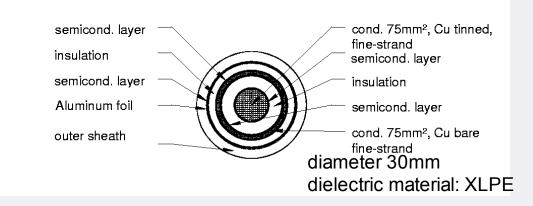
HV Pulse Cable

•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)

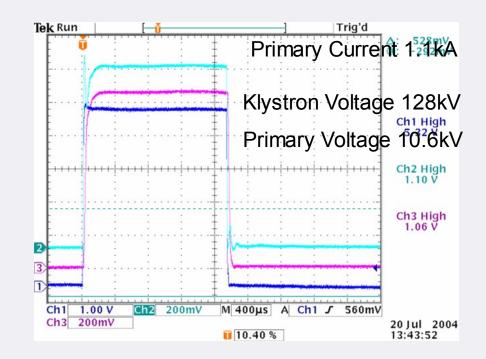


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HV Pulse Cable Test

- •Pulse transmission has been successful at FLASH, Mod. 5.
- •Remaining problem: EMI needs investigation
- Modifications of the modulator are required (high bouncer, better EMC cabinets) already integrated in new specification
 Collaboration MKK/MHFp





Bouncer Modulator (3)

- 11 Modulators have been built, 3 by FNAL and 8 together with industry
- 11 modulators are in operation (FLASH, PITZ, Teststands)
- 10 years operation experience exists
- Modulator forseen 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 XFEL prototypes has been placed (27 pages of specification) (1 Bouncer plus 1 PSM)
- Test of prototypes in Zeuthen starting early 2008

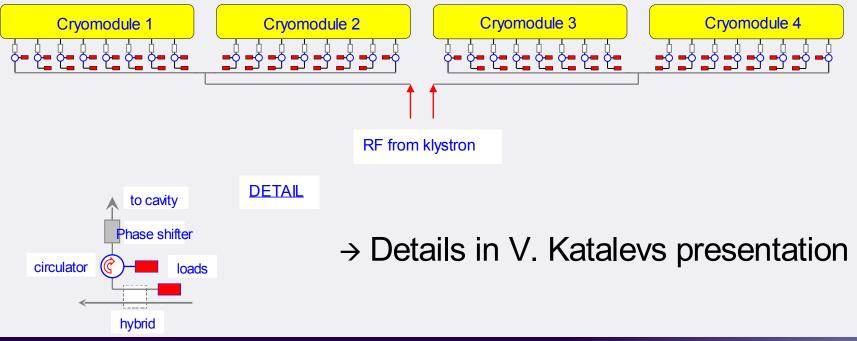
 \rightarrow Details in W. Köhlers presentation





Waveguide Distribution

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



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HELMHOLTZ

Waveguide Distribution

3 Stub Tuner (IHEP, Bejing, China)



Changing phase, degree Impedance matching range Max power, MW

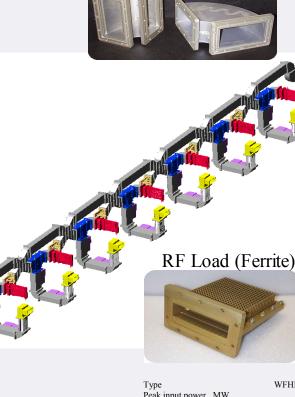
 ± 60 1/3Zw 3Zw

* Z_w – waveguide impedance

Hybrid Coupler (RFT, Spinner)



| Directivity, dB | □ 30 |
|---|----------------------------|
| Return loss, dB | □ 35 |
| Coupling factor, dB | 12.5; 12.0; 11.4; |
| (due to tolerance overlapping only 13 different | 10.7; 10.1; 9.6; |
| coupling factors instead 18 are nessesary) | 9.1; 8.5; 7.8; |
| Accuracy of coupling factor, dB | 7.0; 6.0; 4.8; 3.0 ±0.2 |



E and H Bends (Spinner)

WFHLL 3-1 Peak input power, MW 1.0 Average power, kW 0.2 32040 Min return loss at 1.3GHz, dB Max VSWR at 1.3 GHz <1.05 Max surface temperature, IT °C 50 (for full average power) Physical length, mm 230

Circulator (Ferrite)



| Туре | WFHI 3-4 |
|-----------------------------------|----------|
| Peak input power, MW | 0.4 |
| Average power, kW | 8 |
| Min isolation at 1.3 GHz, dB | >30 |
| Max insertion loss at 1.3 GHz, dB | 0.08 |
| Input SWR at 1.3 GHz | 1.1 |
| (for full reflection) | |

RF Load (Ferrite)



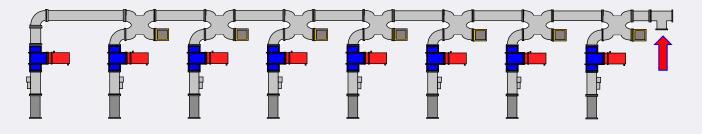
| Туре | | WFHL 3-1 | WFHL 3-5 |
|---|------------|----------|--------------|
| Peak input power, | MW | 2.0 | 5.0 |
| Average power, kV | V | 10 | 100 |
| Min return loss at 1 | .3 GHz, dB | 32÷40 | $32 \div 40$ |
| Max VSWR at 1.3 | GHz | < 1.05 | < 1.05 |
| Max surface temper (for full average power | | 20 | 30 |
| Physical length, mi | m | 385 | 850 |



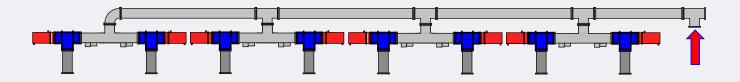


New Waveguide Distribution

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





Preamplifier

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



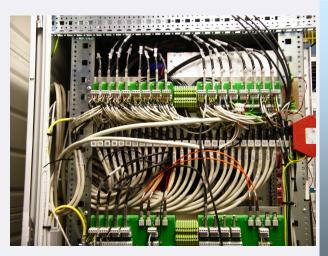


RF Interlock

•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







Interlock WebServer – Screenshot 1

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