Overview XFEL RF System

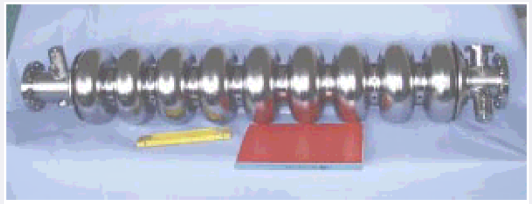
S. Choroba, DESY

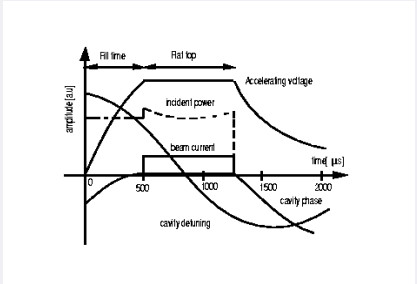
- XFEL RF Requirements
- RF Station Layout
- Overview RF Components

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

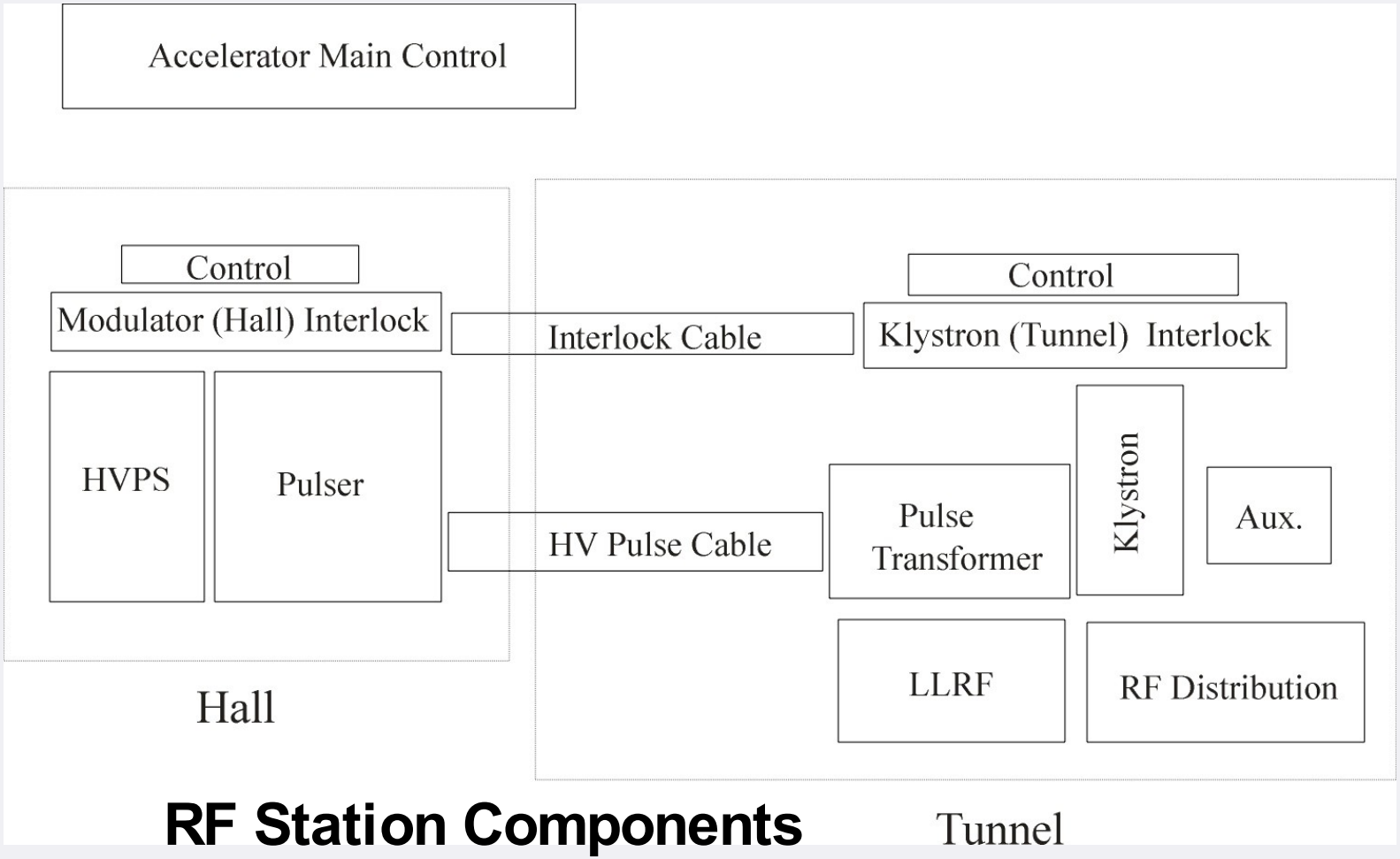
XFEL RF System Requirements

Number of sc cavities:	928 total
Power per cavity:	122 kW
Gradient at 20GeV:	23.6 MV/m
Power per 32 cavities (4 cryo modules):	3.9MW
Power per RF station:	**5.2MW** (including 10% losses in waveguides and circulators and a regulation reserve of 15%)
Number of RF stations:	**29** (26 active)
Number of RF stations for injectors:	**2 (5)**
Macro beam pulse duration:	600µs
RF pulse duration:	**1.38ms**
Repetition rate:	**10Hz (30Hz)**
Average RF power per station:	**72kW (150kW)**



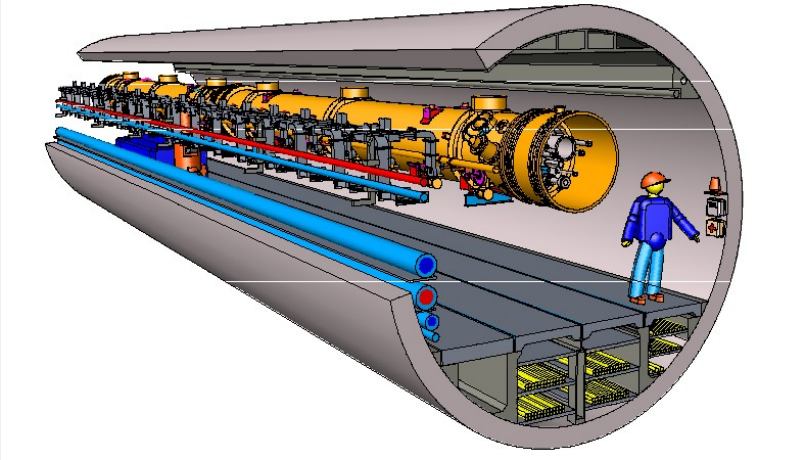


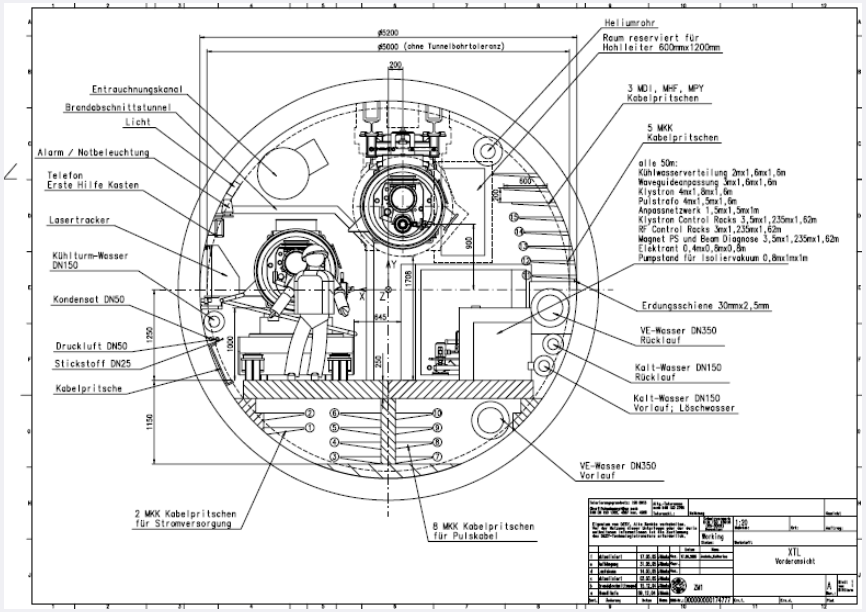
Layout of the RF System (1)



RF Station Components

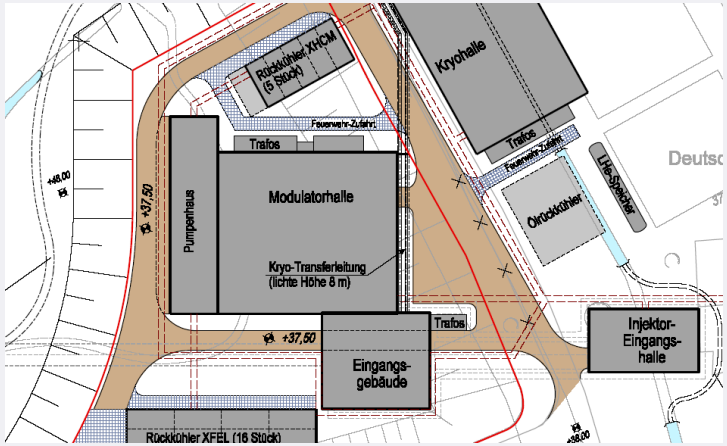
Layout of the RF System (2)

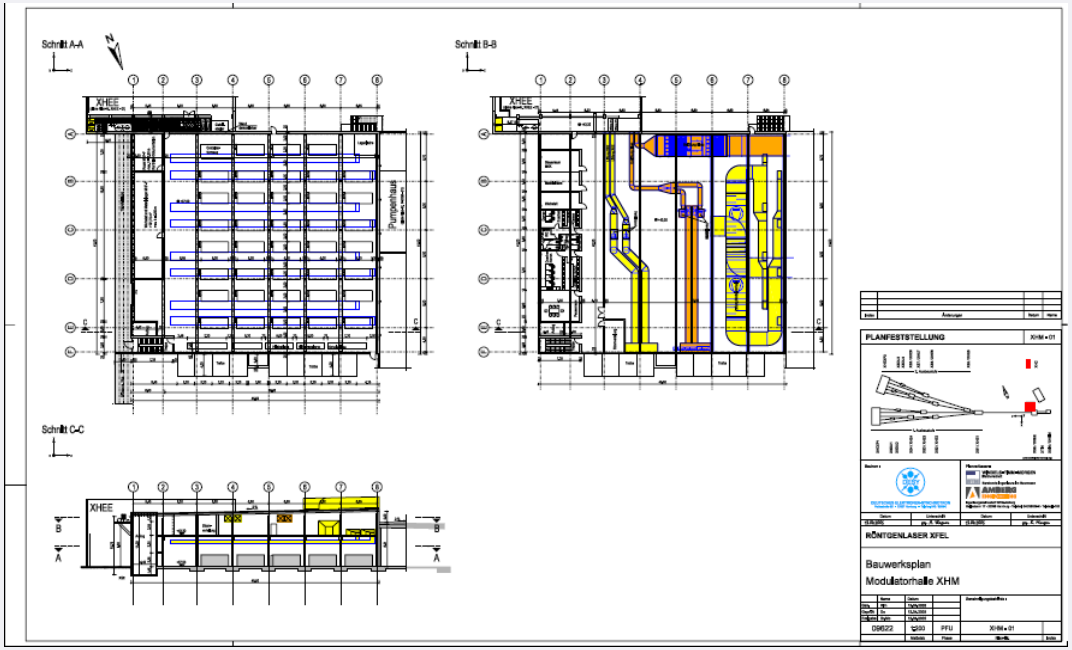




- Tunnel components (klystrons, pulse transformers, aux. power supplies etc.) will be installed below the cryo module.
- The waveguide distribution will be installed on the side of the cryo module.
- They are not accessible during accelerator operation.

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.

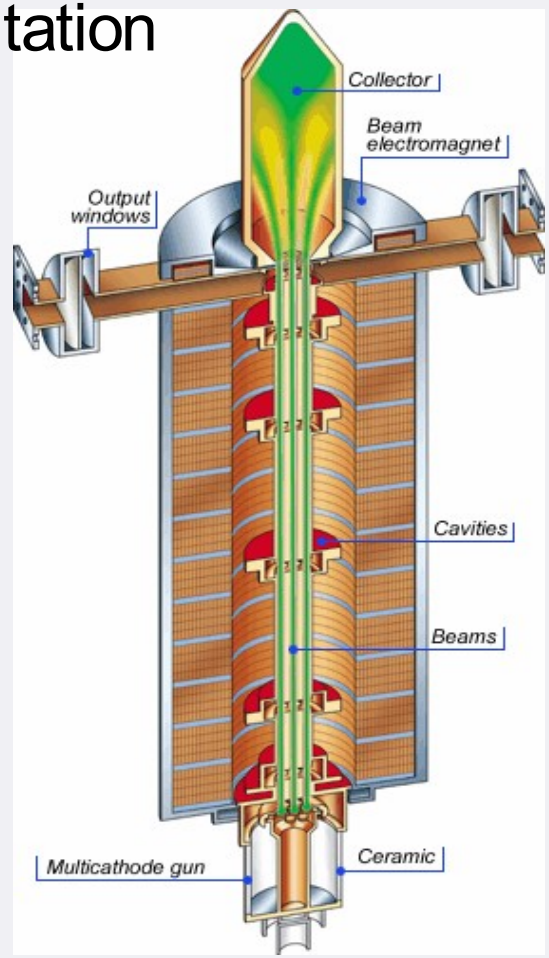
Multibeam Klystron

→ Details in V. Vogels presentation

Multibeam Klystron Requirements

Operation Frequency:	1.3GHz
Cathode Voltage:	< 120 kV
Beam Current:	< 140 A
Max. RF Peak Power:	10MW
RF Pulse Duration:	1.5ms
Repetition Rate:	10Hz
RF Average Power:	150kW
Efficiency:	65%
Solenoid Power:	< 5.5kW
Length:	2.5m

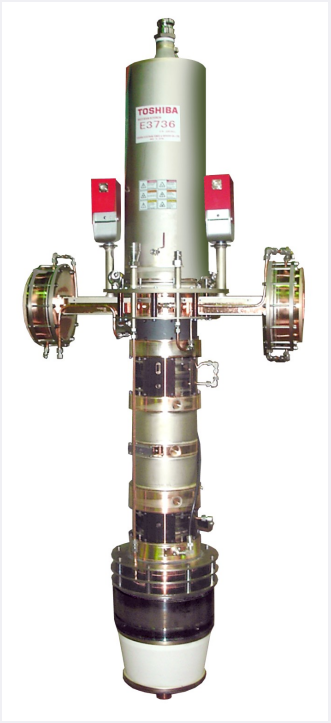
developed for TESLA



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

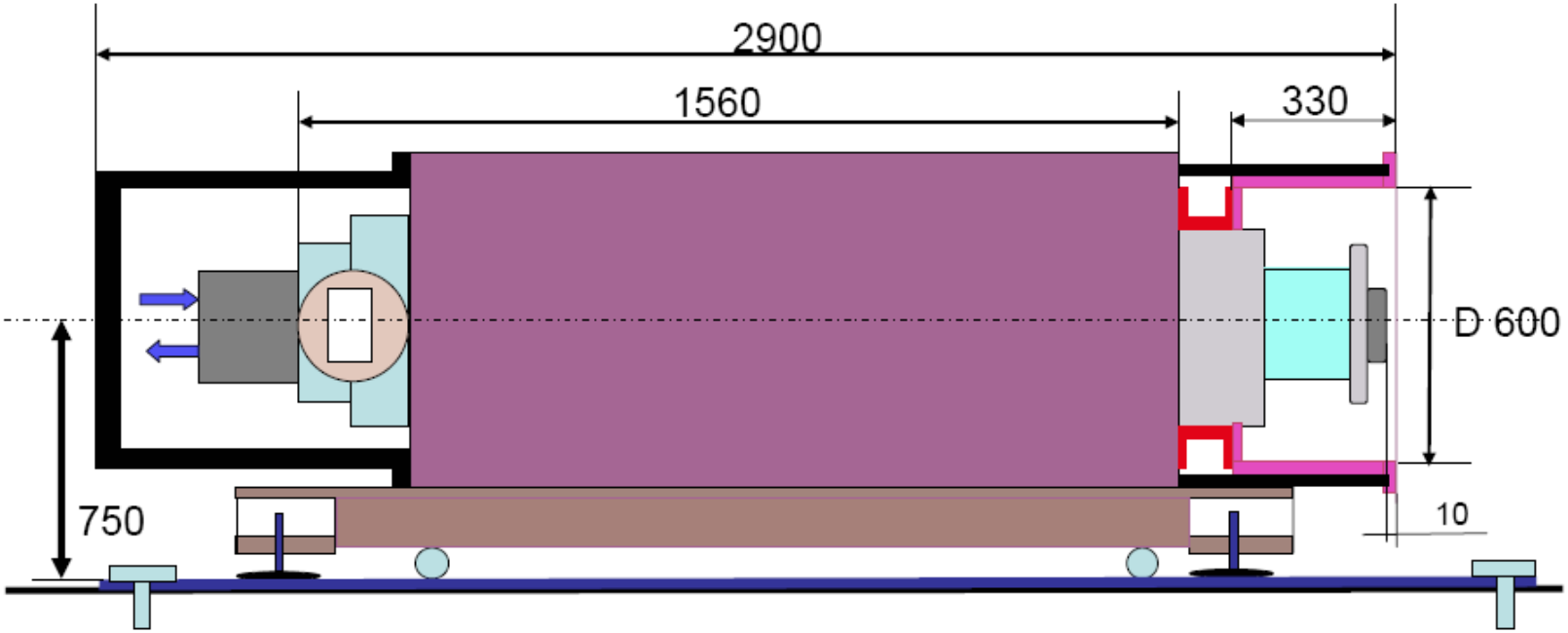
  (Best tube 10MW, 1.5ms, 10Hz, 63%)

  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%)

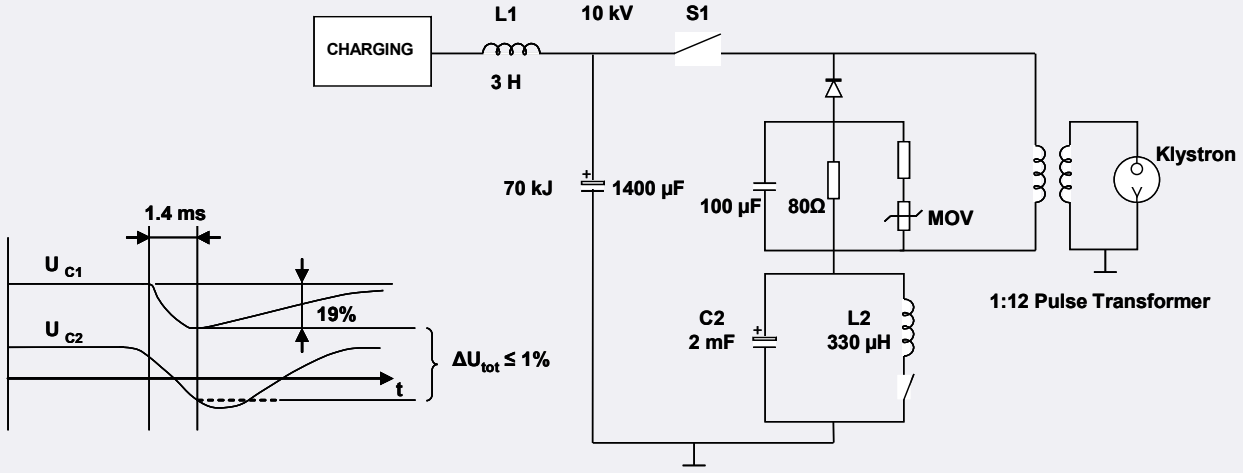
Horizontal MBK Prototypes



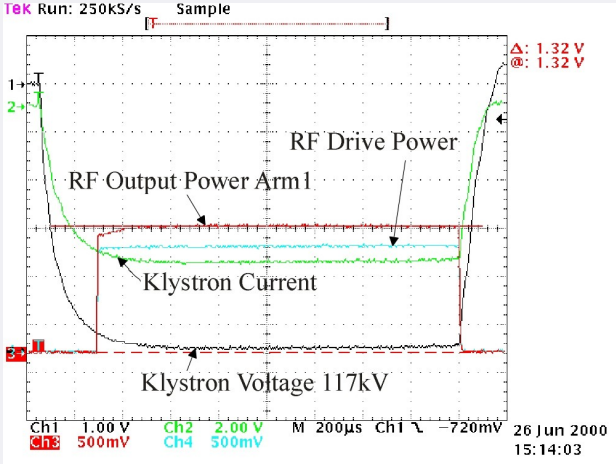
Horizontal versions of MBKs by all 3 vendors are under construction (total length of spec. 11 pages): first deliveries are expected early 2008

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



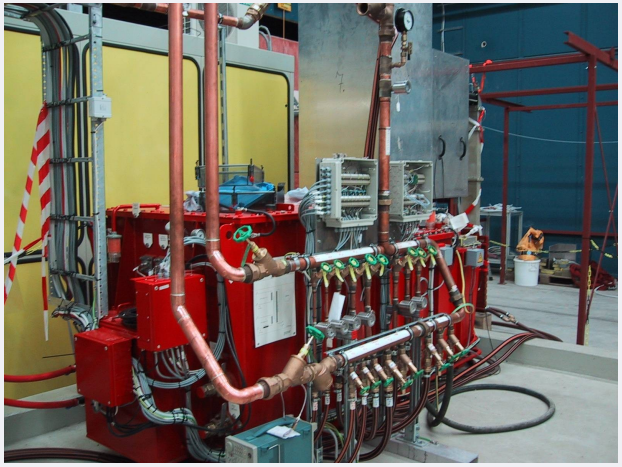
Bouncer Modulator (1)



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

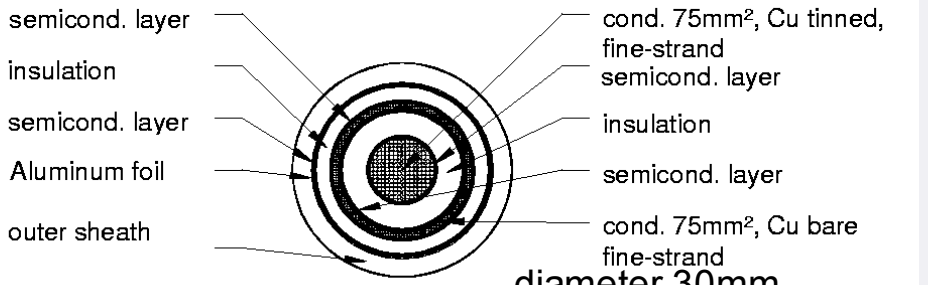
Bouncer Modulator (2)

- 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 <200µs
- Light Triggered Thyristor crowbar avoiding mercury of ignitrons



HV Pulse Cable

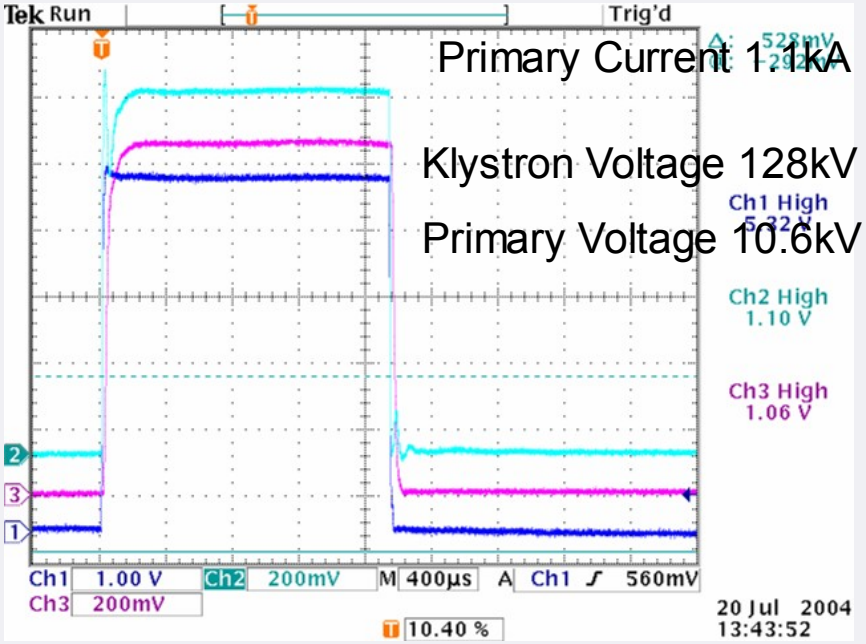
- Transmission of HV pulses (10kV, 1.6kA, 1.57ms, 10Hz (30Hz)) from the pulse generating unit (modulator hall) to the pulse transformer (accelerator tunnel)
- Maximum length 1.5km
- Impedance of 25 Ohms (4 cable in parallel will give 6.25 Ohms in total) to match the klystron impedance
- Triaxial construction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



diameter 30mm
dielectric material: XLPE

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



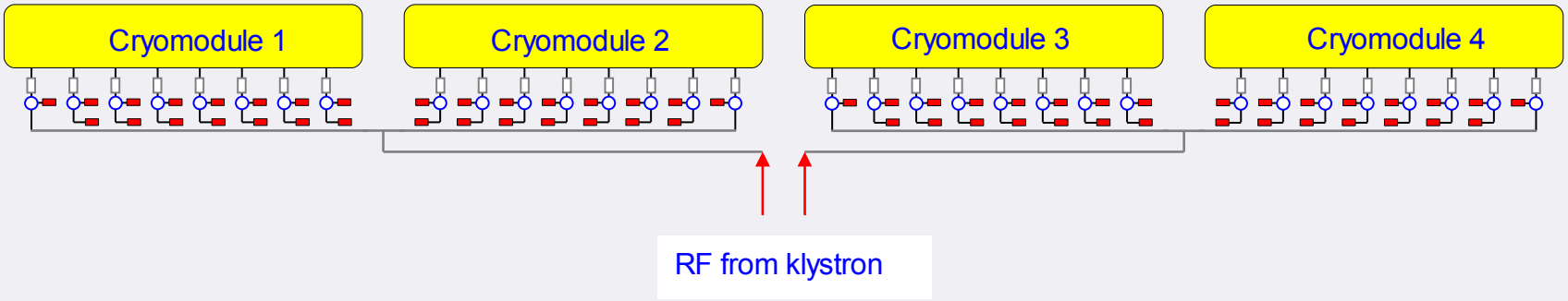
Bouncer Modulator (3)

- 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

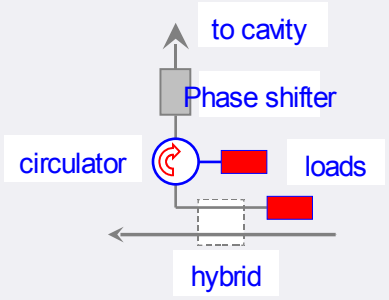
→ Details in W. Köhlers presentation

Waveguide Distribution

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



DETAIL



→ Details in V. Katalevs presentation

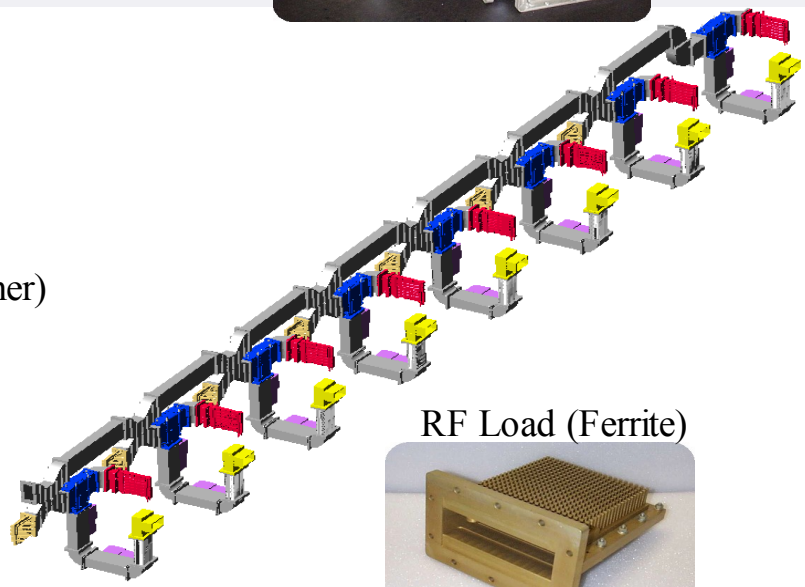
Waveguide Distribution

3 Stub Tuner (IHEP, Bejing, China)

Changing phase, degree	±60
Impedance matching range	1/3Z_w – 3Z_w
Max power, MW	2

* Z_w – waveguide impedance

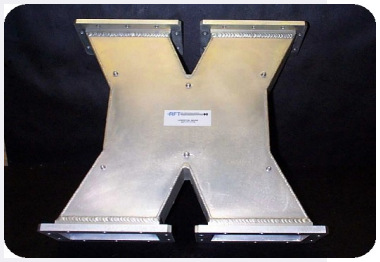
E and H Bends (Spinner)



Circulator (Ferrite)

Type	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 (for full reflection)	1.1

Hybrid Coupler (RFT, Spinner)

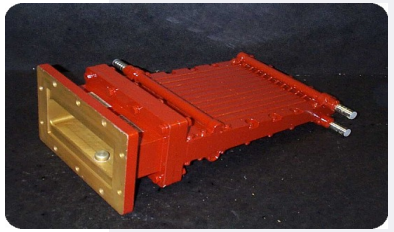


Directivity, dB	30
Return loss, dB	35
Coupling factor, dB (due to tolerance overlapping only 13 different coupling factors instead 18 are nessesary)	12.5; 12.0; 11.4; 10.7; 10.1; 9.6; 9.1; 8.5; 7.8; 7.0; 6.0; 4.8; 3.0
Accuracy of coupling factor, dB	±0.2

RF Load (Ferrite)

Type	WFHLL 3-1
Peak input power, MW	1.0
Average power, kW	0.2
Min return loss at 1.3GHz, dB	32 40
Max VSWR at 1.3 GHz	<1.05
Max surface temperature, T °C (for full average power)	50
Physical length, mm	230

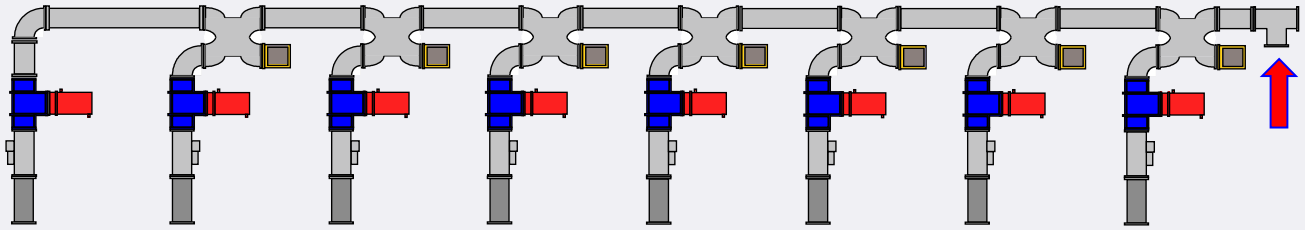
RF Load (Ferrite)



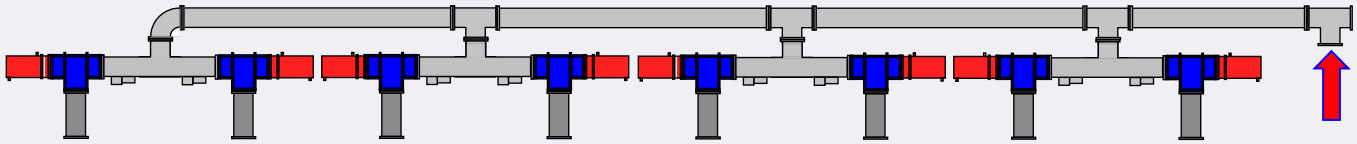
Type	WFHL 3-1	WFHL 3-5
Peak input power, MW	2.0	5.0
Average power, kW	10	100
Min return loss at 1.3 GHz, dB	32÷40	32÷40
Max VSWR at 1.3 GHz	<1.05	<1.05
Max surface temperature, ΔT °C (for full average power)	20	30
Physical length, mm	385	850

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

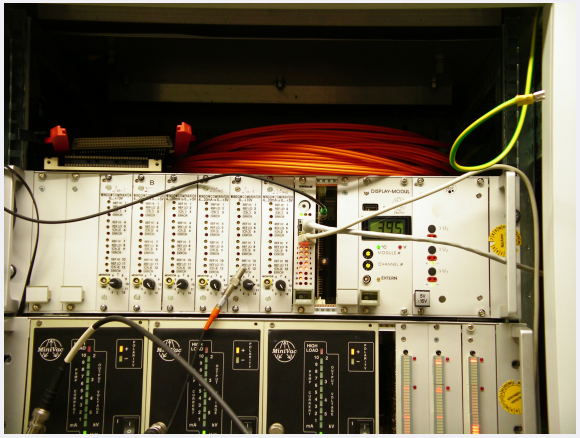


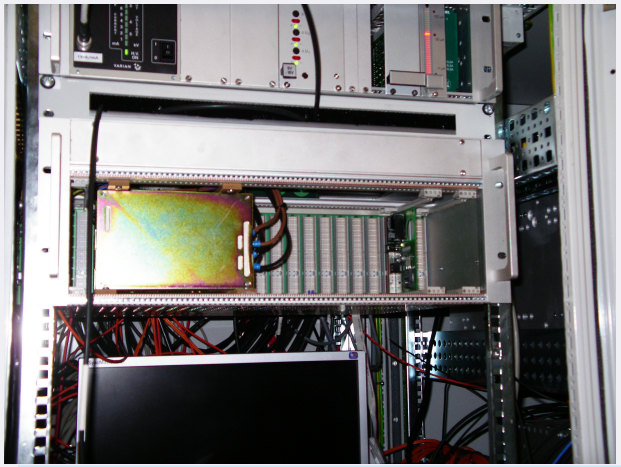
Preamplifier

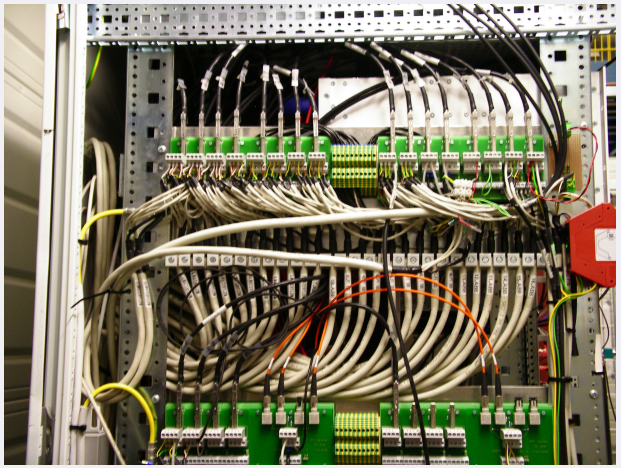
- Specification reworked
- Several new amplifiers are ordered, some received and in test
- Will be used at MBK teststand, FLASH, Zeuthen

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