

Status of the 10 MW klystron development, rf distribution schemes and rf distribution components development for the XFEL

S. Choroba, DESY
for the RF groups at DESY

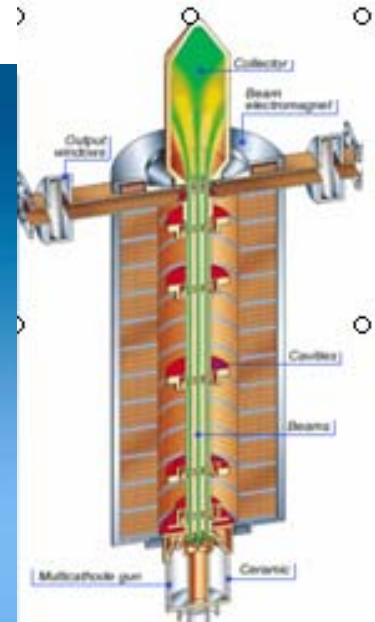
XFEL RF Requirements

Number of sc cavities:	960 total	
Power per cavity:	120 kW	
Gradient at 20GeV:	23 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%)	
	TESLA TDR: 10MW	
Number of RF stations:	30 (27 active)	
Number of RF stations for injectors:	5	
Macro beam pulse duration:	650μs	
RF pulse duration:	1.37ms	
Repetition rate:	10Hz (50Hz)	
Average RF power per station:	71.2kW (150kW)	

Multi Beam Klystron THALES TH1801

Measured performance

Operation Frequency:	1.3GHz
Cathode Voltage:	117kV
Beam Current:	131A
Number of Beams:	7
Cathode loading:	5.5A/cm ²
Max. RF Peak Power:	10MW
RF Pulse Duration:	1.5ms
Repetition Rate:	10Hz
RF Average Power:	150kW
Efficiency:	65%
Gain:	48.2dB
Solenoid Power:	6kW
Length:	2.5m
Lifetime:	~40000h



Multi Beam Klystron THALES

TH1801 cont.

- 4 klystrons have been manufactured
- The prototype PT has been in operation at TTF since May 2000 and has now 20000h operation hours
- Series klystron #1 has been returned to the vendor after ca. 3000h (gun arcing)
- Series klystron #2 has been tested and returned to the vendor
- Gun arcing has been investigated, the problem is identified and the klystron has been modified
- Modified klystron #1 has been sent back to DESY after successful factory test and it was successfully tested at DESY in Zeuthen. It is now in operation to power the new RF gun in Zeuthen.
- New klystron #3 has been successfully tested at Thales and DESY. It is now waiting for installation at TTF
- More klystrons have been ordered

New MBK/Waveguide Component Test Stand at DESY

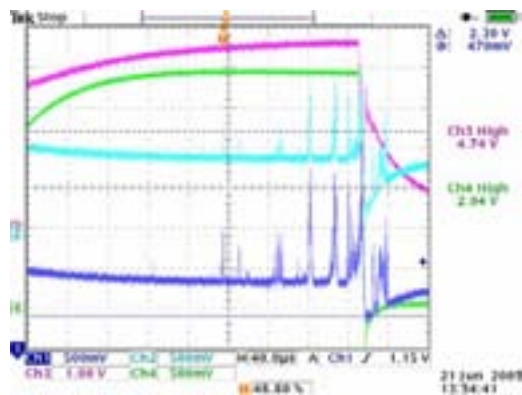
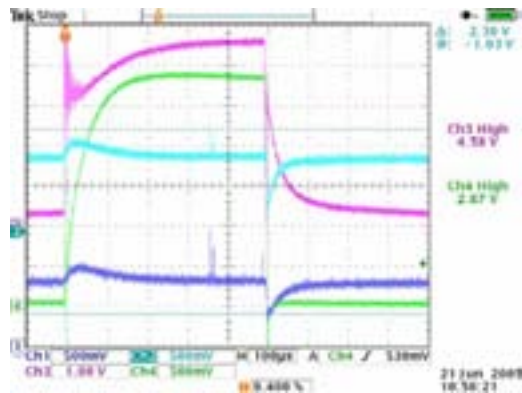


Thales MBK test

- Test of #1 and #3 was performed at the new MBK test stand at DESY
- #1 has been tested finally in Zeuthen and achieved 10MW with an efficiency of 61% at full pulse length and rep. rate
- #1 is in operation for RF gun conditioning in Zeuthen
- #3 reached full power with an efficiency of 61% during acceptance test at DESY
- #3 will be installed at TTF in September 05
- Calibration of measurements needs to be checked



Problem during Thales MBK Test



Intermittent short circuit in socket;
not a problem of the klystron

Multi Beam Klystron CPI VKL-8301

Design Features:

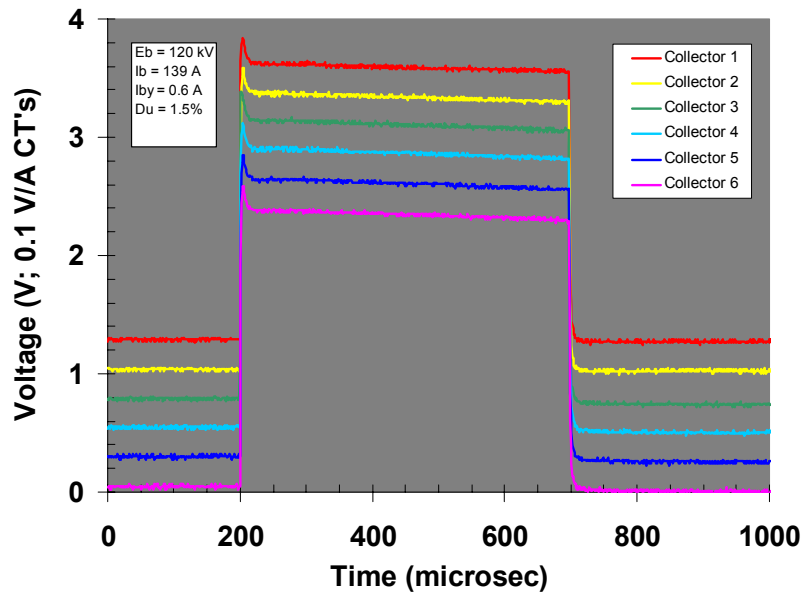
- 6 beams
- HOM input and output cavity
- Cathode loading: $<2.5\text{A/cm}^2$
lifetime prediction: $>100000\text{h}$

Status:

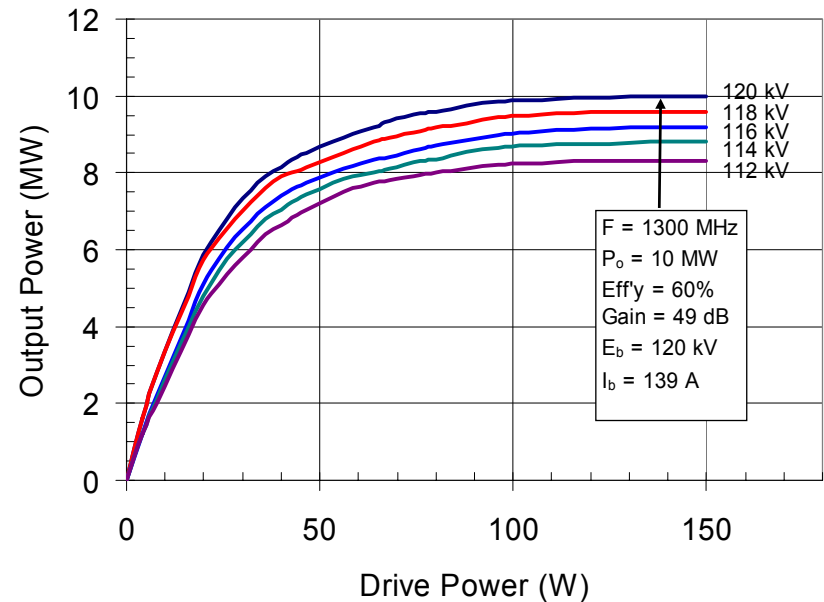
- Klystron has been successfully tested at CPI in January 2005 with full power, pulse width and rep. rate
- Klystron is at DESY and is being installed on the MBK test stand



CPI VKL-8301 cont.



Collector Currents



Transfer Curves

Measurements at CPI, more information in the talk by Ed Wright

CPI MBK at DESY



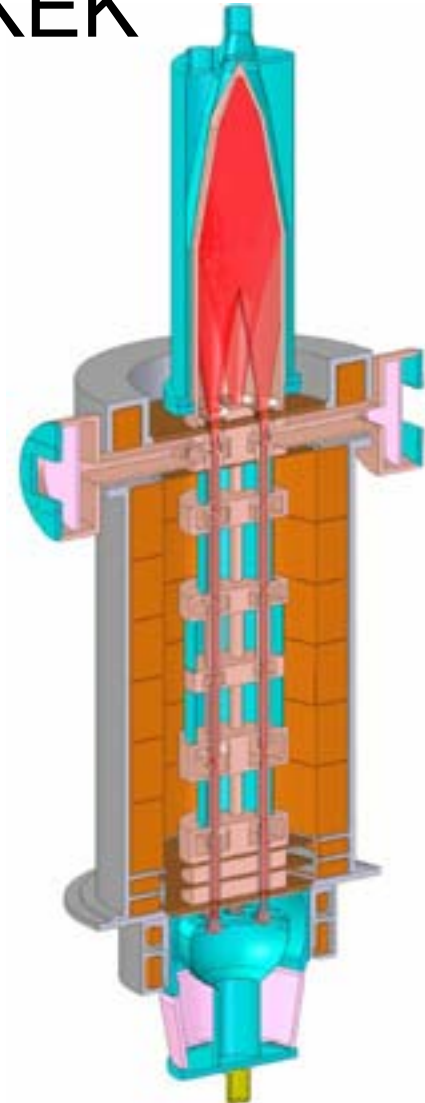
The TOSHIBA E3736 MBK in cooperation with KEK

Design Features:

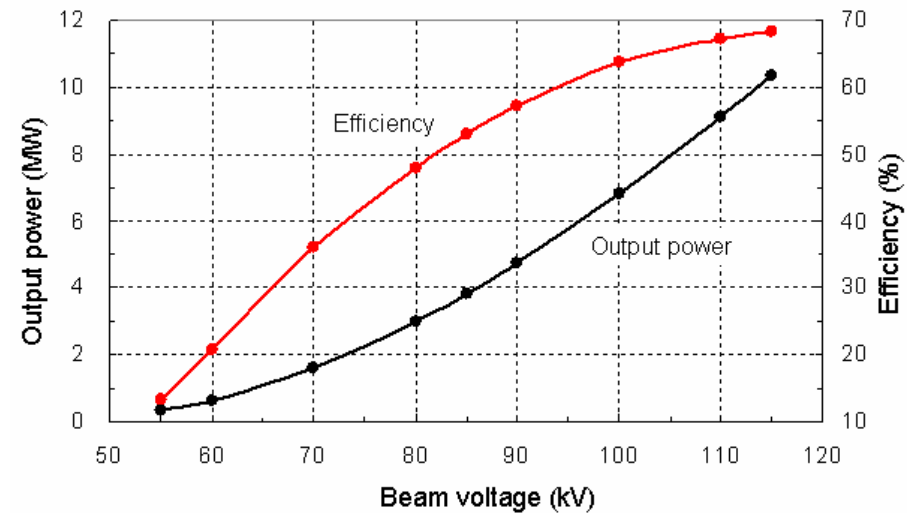
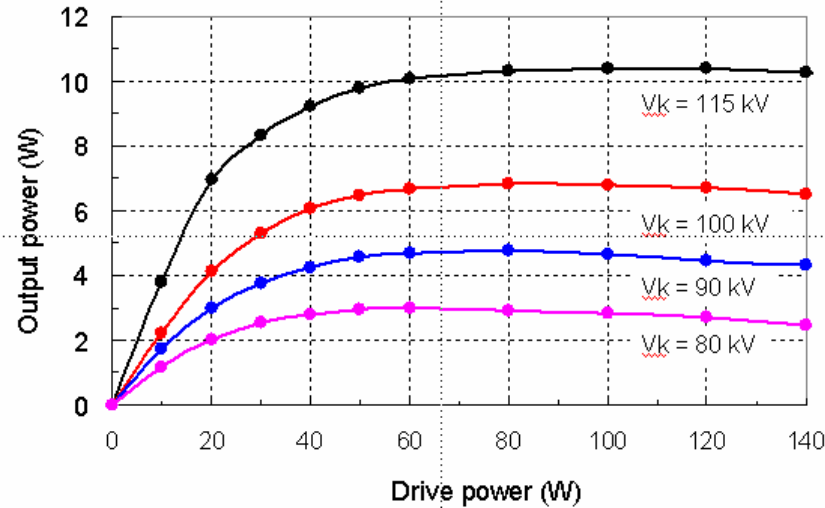
- 6 beams
- Ring shaped cavities
- Cathode loading: $<2.1 \text{ A/cm}^2$

Status:

- Klystron has been tested successfully up to 10MW peak, 1ms, 10Hz
- Modulator needed modification for operation at full pulse width
- Test continued at Toshiba in June/July 2005

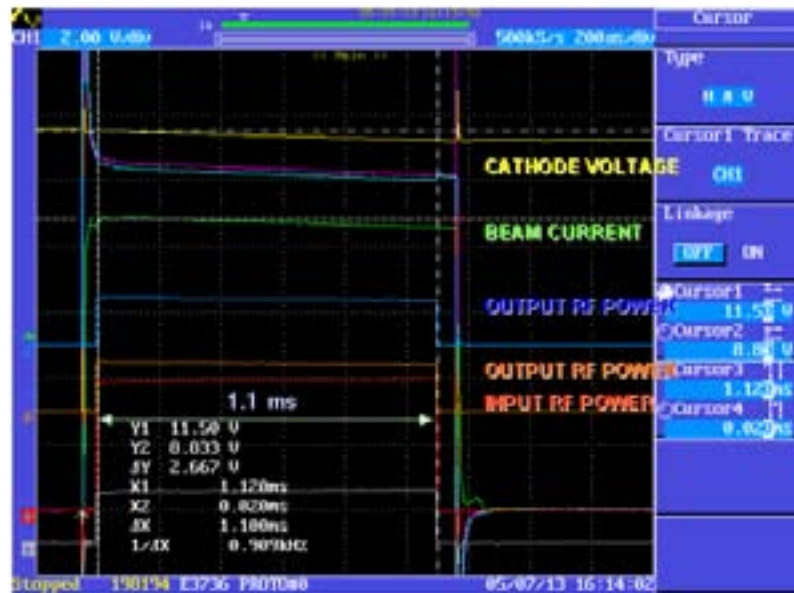


Toshiba E3736 cont.



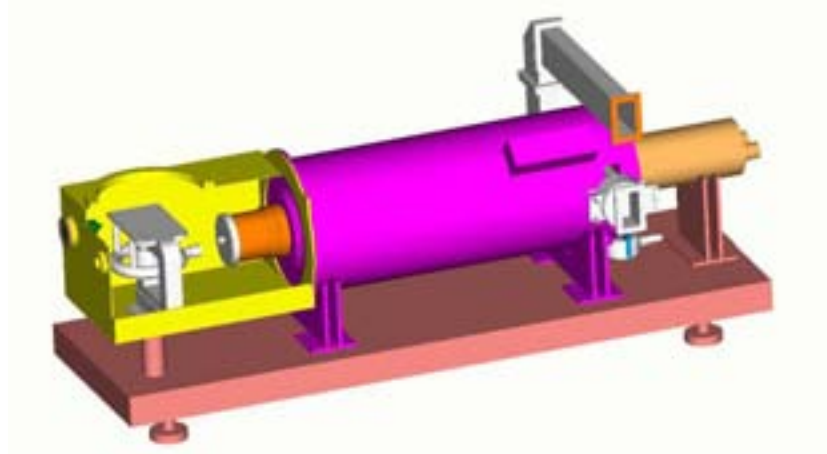
- Measurements with $40\mu\text{s}$ pulses and directional couplers
- Measurements must be repeated with long pulses and calorimetric measurements

Toshiba 3736 cont.



- Waveforms after Modulator Modification at 1.1ms Pulse width
- On July 13th a small leak opened during testing probably as a result of mechanical stress on the insulating ceramics between body and collector.
- The leak could be fixed, but the klystron could not be conditioned anymore.
- Tube will be opened and brazed again. New tentative delivery date to DESY Jan. 2006

Horizontal Klystron



- Next step: Modification towards a horizontal version
- Horizontal klystrons are already in use e.g. the LEP klystrons at CERN or the B-factory klytrons at SLAC
- One vendor has already made a conceptual design of a horizontal version
- Final specification including all interfaces is pending, prototypes must be built
- Goal: test 2-3 horizontal prototypes within 2 years

Klystron Status Summary

- Multi beam klystrons have been in use at TTF since 2000, gun arcing has been investigated, the problem has been identified and modifications have been made
- 3 vendors have already manufactured or are near to manufacture klystrons meeting the XFEL klystron requirements
- Lifetime of the klystron is expected to be >40000h limited by cathode lifetime, for cathode current densities <2.5A/cm² the lifetime might be >100000h
- Specification, layout and construction for horizontal tunnel installation is pending

RF Waveguide Components

3 Stub Tuner (IHEP, Beijing, China)



Changing phase, degree
Impedance matching range
Max power, MW

± 60
 $1/3Z_w \text{ } \ominus 3Z_w$
2

* Z_w – waveguide impedance

E and H Bends (Spinner)



Circulator (Ferrite)



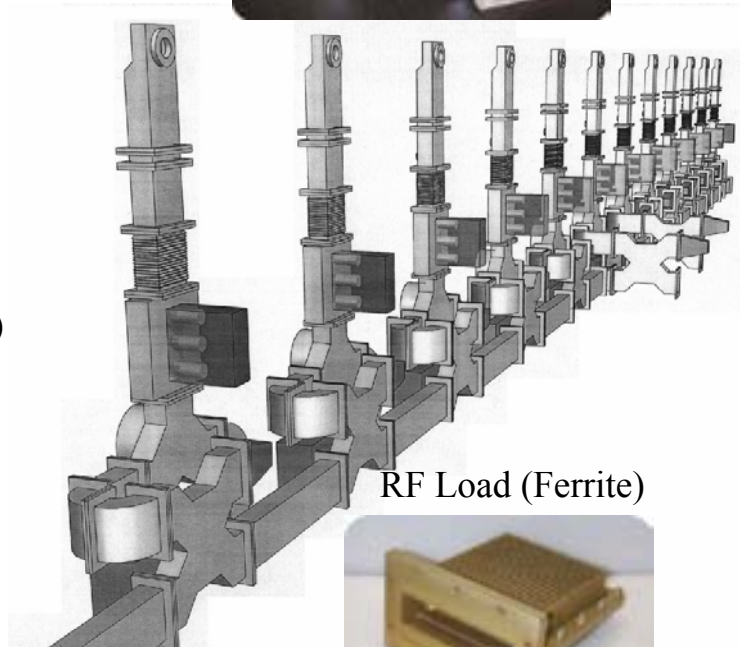
Type	WFHI 3-4
Peak input power, MW	0.4
Average power, kW	8
Min isolation at 1.3 GHz, dB	>30
Max insertion loss at 1.3 GHz, dB	≤0.08
Input SWR at 1.3 GHz (for full reflection)	1.1

Hybrid Coupler (RFT, Spinner)



Directivity, dB	± 30
Return loss, dB	± 35
Coupling factor, dB	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

(due to tolerance overlapping only 13 different coupling factors instead 18 are necessary)



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 \ominus 40
Max VSWR at 1.3 GHz	1.05
Max surface temperature, $\varnothing T$ $^{\circ}C$ (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 \pm 40	32 \pm 40
Max VSWR at 1.3 GHz	<1.05	<1.05
Max surface temperature, ΔT $^{\circ}C$ (for full average power)	20	30
Physical length, mm	385	850

Some waveguides



5MW isolator filled with SF₆



5 MW phase shifter

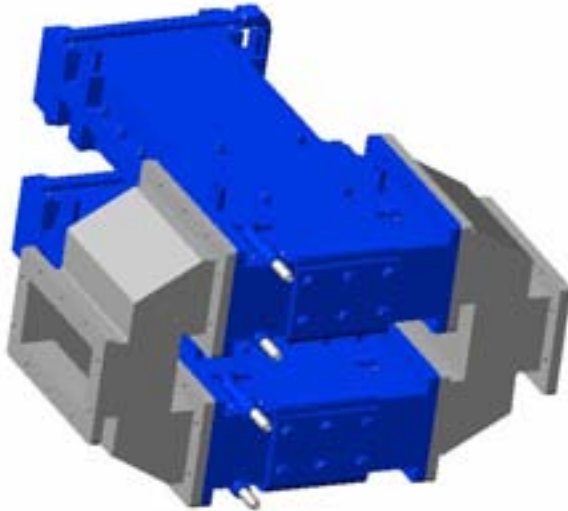


3 stub tuner now with
remote control

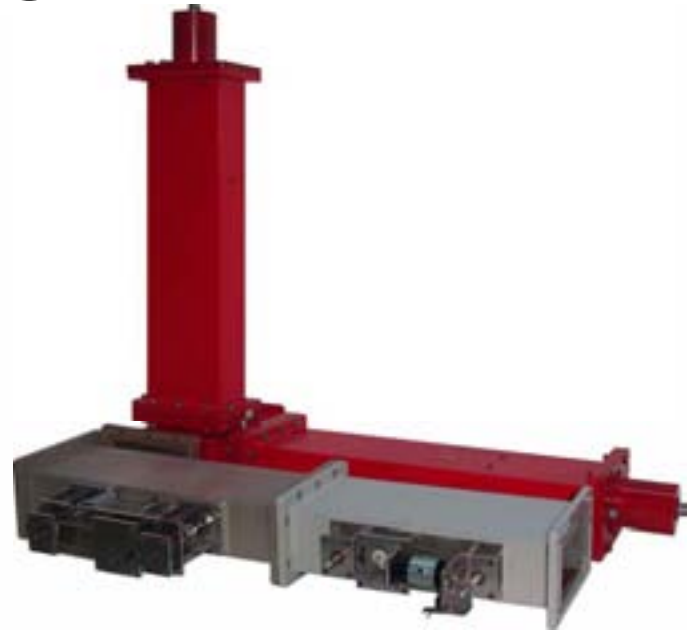


Gas tight directional couplers

Some new waveguides cont.

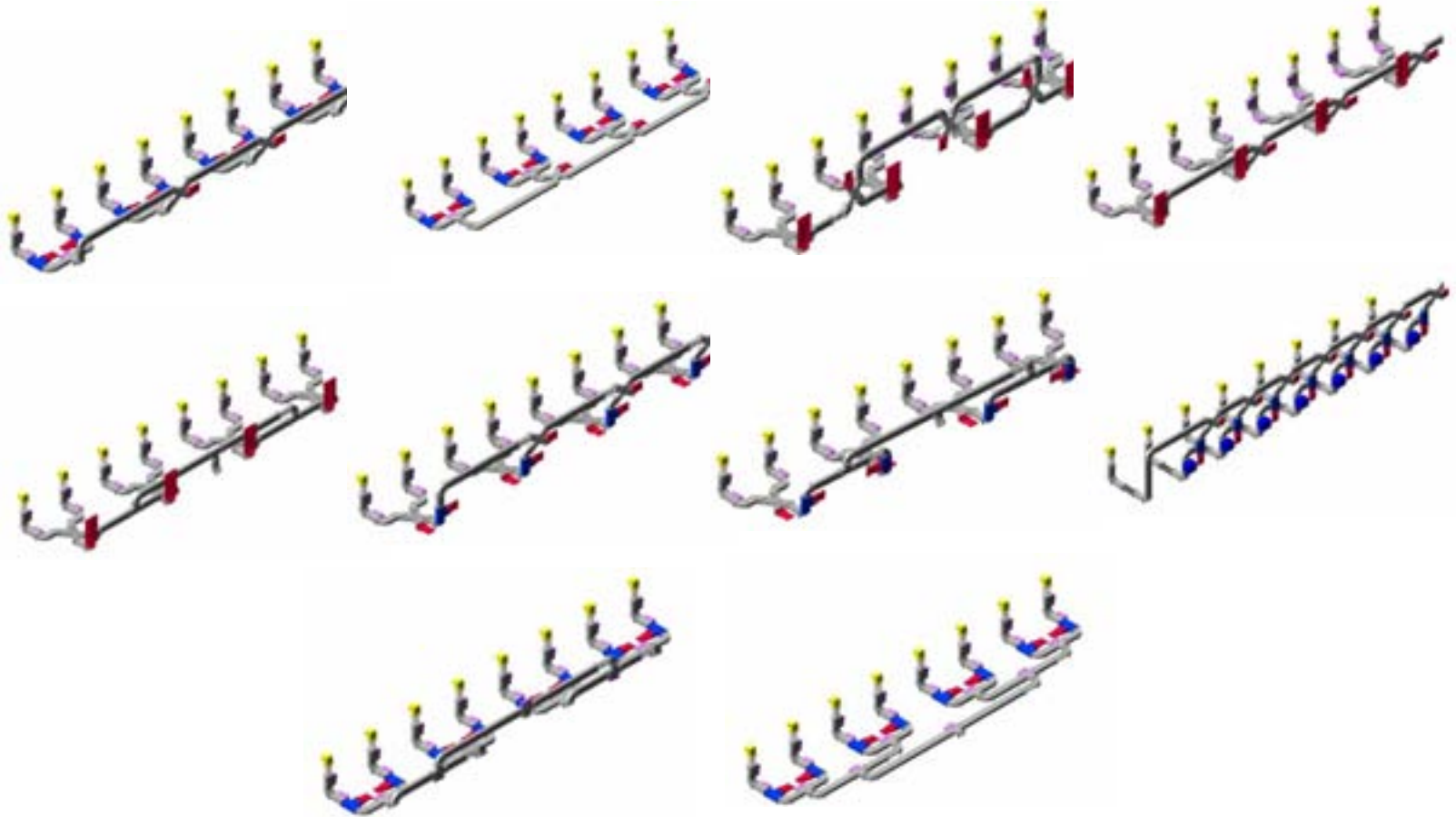


1MW air filled
circulator for
Modultestfacility made
by Ferrite Inc.
(delivery Autumn
2005)



E-H-Tuner made in Russia
and I-Tuner developed by
V. Katalev als alternative
for 3stub tuner
Advantage: Higher power
capability, easier tuning

Alternative waveguide distribution schemes



RF Waveguide Distribution Status

- Waveguide components for the XFEL have been developed in cooperation with industry or are standard of the shelves components
- Operation experience of 10 years from TTF
- Development of integrated components has been started (e.g. circulator with integrated load) to allow faster and more reliable installation
- MBK test stand has an additional pulse transformer for the permanent installation of a klystron. This will be used as waveguide component test stand.
- Linear distribution is the baseline but alternative schemes are possible