## CW OPERATION OF THE SRF LINAC ELBE

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#### USAGE (in 2007)





#### **ELBE LINAC Beam Parameters**

	Thermionic Gun	SRF Photo Gun
Maximum Energy	36 MeV (CW)	40 MeV (CW)
Bunch Charge	77 pC	77pc / 2.5 nC
Beam Current	1 mA	1 mA
Bunch Length (rms)	1 – 10 ps	4 / 20 ps
Transv. Emittance	2/10 mm mrad (rms)	0.5 / 2.5 mm mrad
Max. Rep.Rate	260MHz@0.77pC 13 MHz@ 77pC	13 MHz
Energy Spread	35 keV /55 keV	40 keV

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## CW-RF (at ELBE: 8.5 kW /Cavity)



Cavities : TESLA DESY
different from DESY:
thicker He-Vessel
other Tuner
fixed RF Power coupler
He: all on 1.8K level







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#### Rossendorf 3 = Cell SRF Gun - Principle

#### Generation of high brightness electron beams



 direct production of short pulses:
 laser & photo cathode

2. high acceleration field at cathode: radio frequency field

3. CW operation for high average current: superconducting cavity



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#### PERFORMANCE OF THE RF-SYSTEM

Cavities: Frequency Bandwidth (3dB) Phase noise related microphonics

1.3 GHz 114 Hz

2...6 deg peak-peak

*RF System:* Frequency stability < 1 10-9Phase noise < 0.05 deg rms )\* \*) gradient 10MV/m, no beam Measurements at a gradient of 10 MV/m without beam Phase stability rms /< 1 sec 0.02 deg

Amplitude stability

rms

2 10-4

LHe pressure stability

+/- 0.1 mbar







#### Klystron

#### VKL7811St (CPI) 6-klystrons running (3000...9000 hrs)

PS: SMPS 15 kV;2.5A Water: 46 l/min, 6 Bar







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SMPS FuG-Rosenheim -15kV, 2.5 A Remote control (homebrew using Simatic )







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### Remark on Beam Matching for CW Using Macro Pulses



- beam matching at full bunch charge
- results in cw-matchable RF-load
- allows maloperation without damage
- -Beam-ON Time: 0.1ms....36ms -Duty Cycle. 40ms....1s
- "Diagnosemode" enables beam matching at full bunch charge but at an average (cw-comparable) beam current of 10 µA

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All "macropulse-relevant" measurements must be triggert



Some remarks on bad experiences with CW

Be aware that "Murphy" is always present!

or a bit more optimistic

Sometimes "Murphy" helps to find the best diagnostics !



#### Murphys Attack Nr.1 RF-Waveguide Window Crash 1



#### Rexolite, WR650 (MEGA)

20.Jan. 2001

Reason: CW (1-st day pwr RF) -without windows diagnosis -bad /unknown vacuum at the warmwindow

#### Result:

-beamline vacuum not broken
-waveguide window replaced
-window diagnosis added
-since that time ok

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#### **RF-Windows-Diagnostics**







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#### Murphys Attack Nr.2 RF-Waveguide Window Crash 2



4.Nov.2001

Reason: •self-excitation of a klystron

Result: •RF (1.3GHz) interlock fired •beamline vacuum not broken •waveguide window replaced •circulator added at klystron input,



#### Murphys Attack Number 3 Vacuum Leak at a Klystron



klystron has shown multipacting earlier, cured
vacuum leak (detected at CPI)
Result:
complete burn out of cathode because: klystron-PS switched to CC-mode (200V, 2.5A),

•ensure switch off at Imax,

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#### Murphys 4-th "Stroke" with ELBE (First try to operate CW)

#### Result: - Hole in a bellow flange - 2 cavities polluted

- In between: New diagnostics (BLM, DCM)

 $S_{c} = 20 \text{MeV}$   $I_{e} = 1 \text{mA}$  c = 450 J/Kg K  $m = \Delta V \varsigma = 63 \text{mg}$   $(d_{beam} = 1 \text{mm}, r = 10 \text{mm})$   $T_{M} = 1400 \text{ °C}$ 

20...40 MeV Electrons  $\Rightarrow$  Range 1,5..4 cm (St.Steel)



 $\frac{dT}{dt} = \frac{S_c}{I_e}(t) - \lambda(T - T_{RT})$ dt  $C \cdot m$ 



 $t_{crit} \sim 2 ms$ 





#### BLM: Beam Loss Monitoring

Ionisation Chambers based on HJ4.5-50 Coax (Andrews)









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#### DCM: Difference Current Monitoring Based on Beam Profile Monitors (BPM)





#### Overview MIS - Difference Current Monitors (Release: 26.11.2007)



#### Observations during CW Operation Gradient drifts





# Beam Energy Stabilisation using SIMATIC tools Input: BPM x -Signal (dispersive part of the beamline) Output: changes setting of a gradient





## Field Emission and Cavity Training





#### Cavity Training With Pulsed RF





HOM-Heating at CW								
Cavity C4								
HOM 1 T-Sensor: DT.08	RF-Pick T-Senso Fe-R sor: DT.09	kup r: DT.14 h Thermometer		DUR <sup>S</sup> (				
	GRADIENT MV/m	DT.08 K	DT.09 K	DT.14 K	DT.16 K			
CONDITIONS: BEAM OFF		HOM (CPL)	HOM(Tuner)	Pickup	Beamtube			
STEADY STATE (20 min)	ZERO	14.0	11.4	10.6	4.6			
	2	16.4	12.3	10.6	4.6			
	4	36.4	23.7	10.7	4.6			
	6	60.0	43.2	10.9	4.7			
	8	75.5	58.3	11.2	4.8			

## HOM Temperature vs. Time



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#### Summary





#### -High Power CW Operation Require:

- proper designed components and systems
- redundancy to make service practicable
- good and highly reliably diagnostics
- Macro puls mode to match the beam
- -Test benches to make components better and to check them independently of the Linac-Op.

(Example: G.Staats: Resonant Ring Presentation , Friday)



#### Resonant Ring (200 kW with a 10 kW klystron)



#### Thank you for your attention, enjoy your meal !

