OPERATION OF A 10kW@1.3GHz SOLID STATE AMPLIFIER AT THE S.C. LINAC ELBE

HARTMUT BÜTTIG FOR

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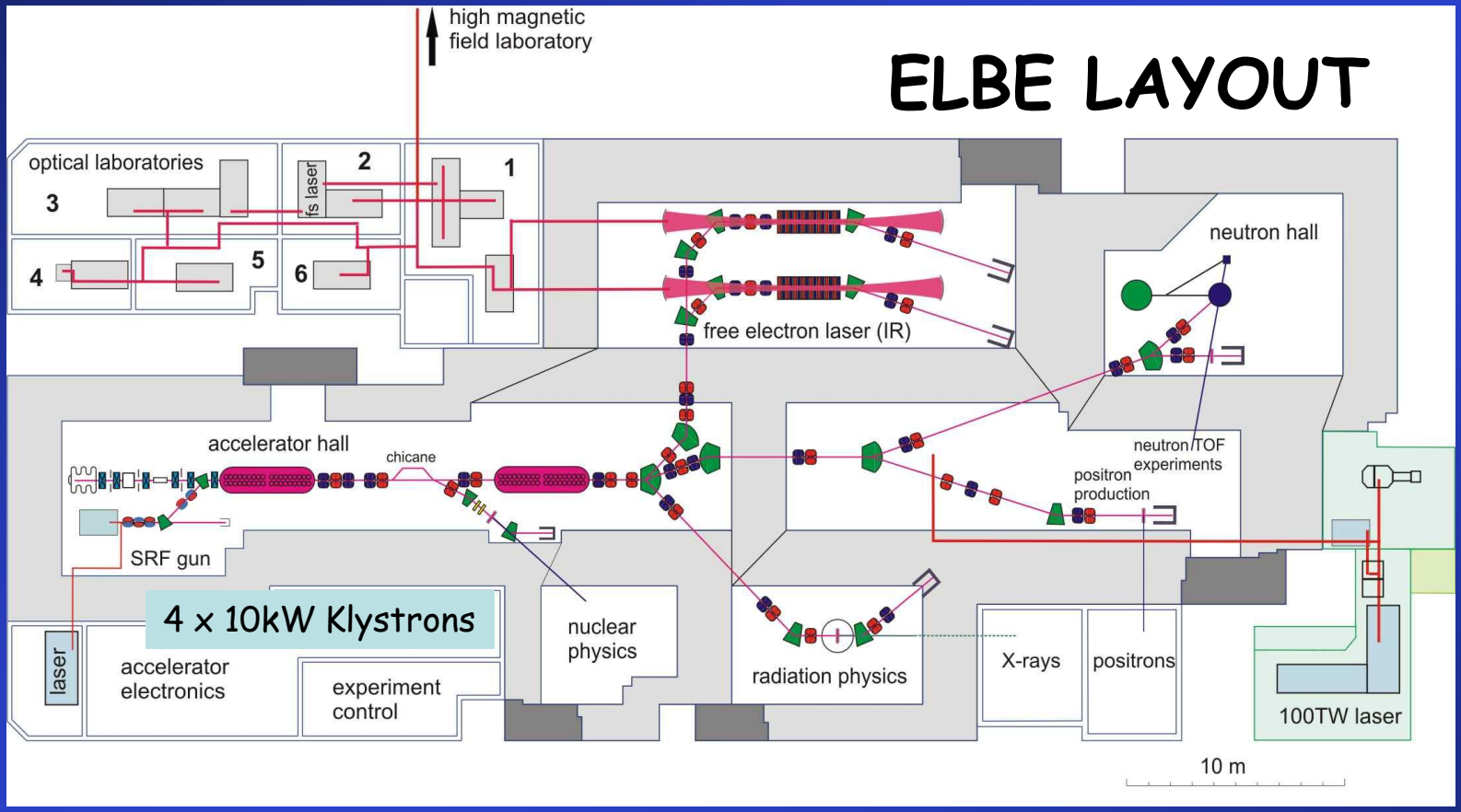
MOTIVATION

- ELBE UPGRADE AFTER 10 YEARS OF OPERATION (MANY ACTIVITIES)
- ONE TOPIC IS: DOUBLING THE RF POWER

- Has an impact on:
- RF power amplifiers, RF - couplers, WG-windows; diagnostics, beam dumps, water cooling, mains power…

Just to remember:



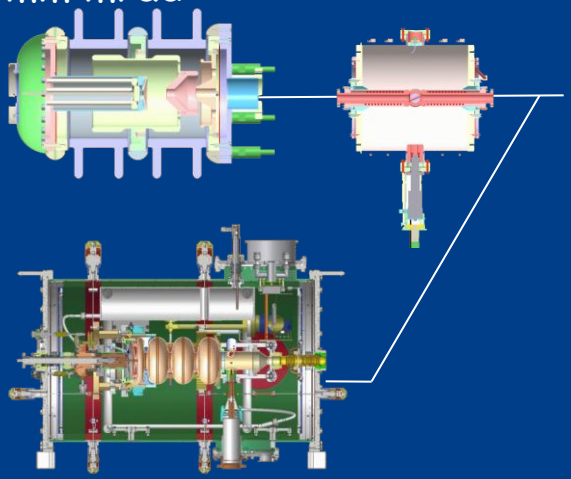
SC-LINAC: 40 MeV, 1mA (CW), based on 4 Tesla Cavities

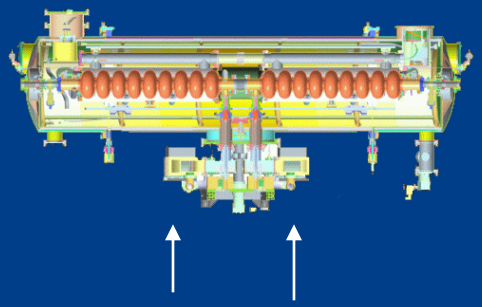
Thermionic
DC Gun
250 kV
<= 260 MHz
77
pC(1mA*13MHz)
~ 500ps
~10 mm mrad

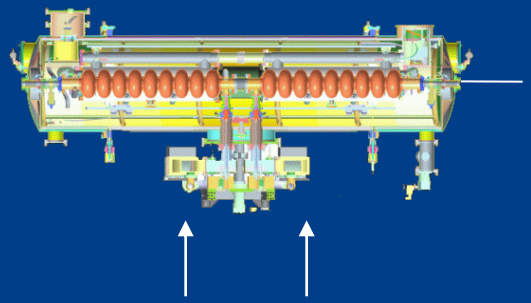
RF Bunchers
260 MHz
+1,3GHz
compr. ~ 100:1

Linac
1,3 GHz
~20MeV@10 MeV/m
<1mA CW

Linac
1,3 GHz
~20 MeV@10MV/m
<1mA CW







SRF photo gun
9.5 MeV
<= 13 MHz
80pC / 1nC / 2.5 nC
~ 5-20 ps
~ 1.5-3 mm mrad

4 x 10kW CW
Klystrons: CPI
VKL7811St
(-1dB comp.: 8.5 kW)

ELBE-UPGRADE: RF RELATED ACTIVITIES

- RESONANT RING (since 2005):

- Conditioning of RF couplers, WG-windows,
- (NIM A 612 (2010) 427 – 437)

- DOUBLING THE RF – POWER:

- Test of a 16 kW IOT at a SC-Cavity (2008), (Good cooperation with Bruker BioSpin+CPI)
- (SRF 2009, TUPP026)

Remarks on 16kW - IOT

- Test in 2008 with beam in principle ok
- Compared with a 10kW VKL7811St Klystron (permanent magnet system) IOT is more exp.
- Solid state technology becomes more and more competitive.
- (costs: 12…16 €/W@1.3GHz)
- The „border line between tube- and SSA-technology" may be in the range of 20 kW at present, but moving up quickly

SOLID STATE AMPLIFIER (SSA)

- ELBE was focused on IOT but not happy.
- INSPIRATION TO SSA-Technology by:

- BRUKER EXP. (NMR/MRI-SSA Technology)
- BRUKER EXP. (Big SSA for Orsay)
- BRUKER 1kW@1.3GHz CW IOT-drivers
- CWRF 2008 GENEVA (The trend was clear !)

Start 1/2009; Prototype 1/2010

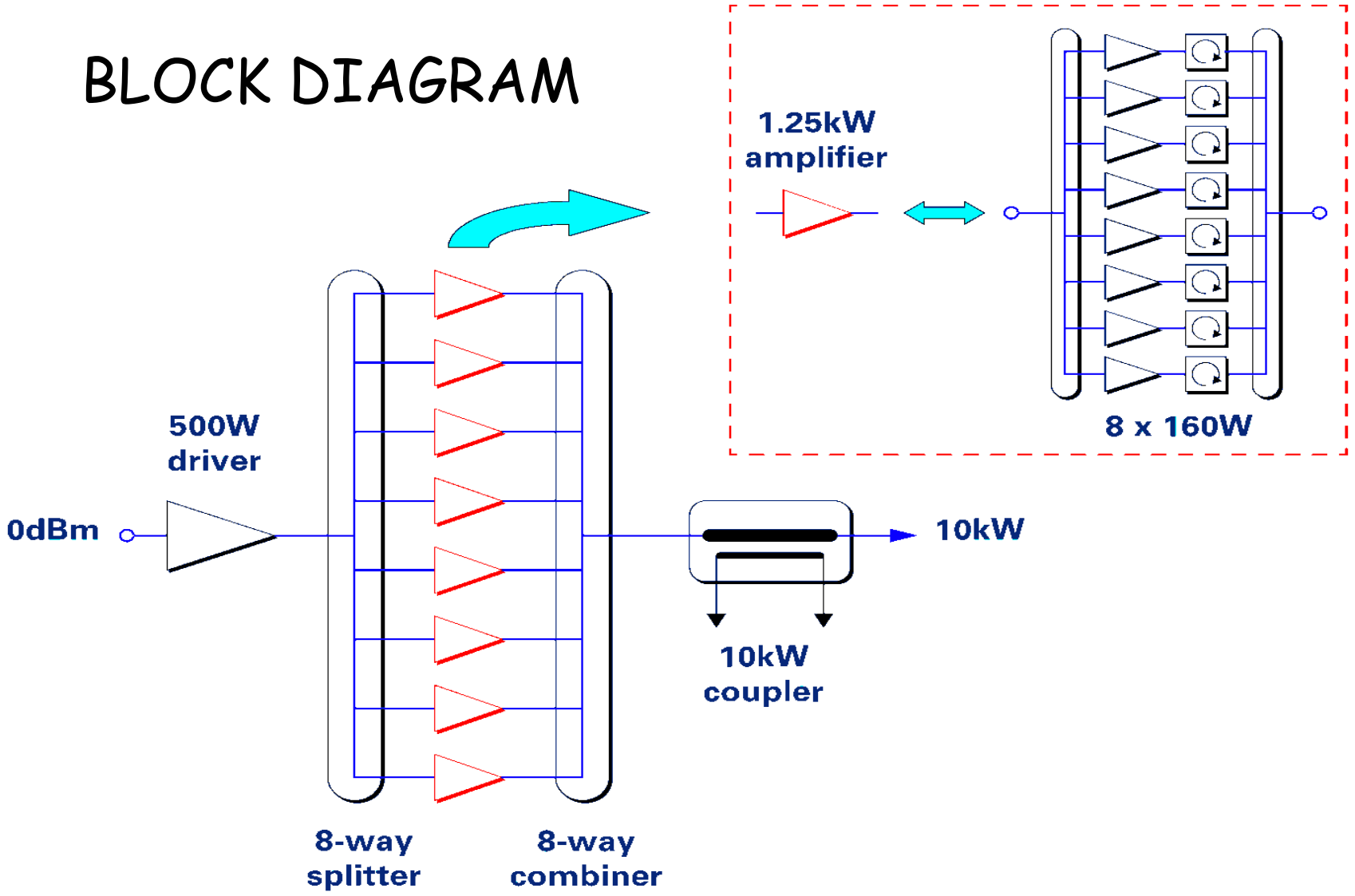
- Email: 6.Jan 2009: (H.Büttig to L.Martinache)
- End of 2008 we discussed briefly the possibility to test a SSA 1.3GHz at ELBE…hw?
- Answer: We are currently working on a water cooled 800W – 1000W SSA. We will do the first tests in a few weeks. Next step is…..
  6 modules … in May 2009. 10kW at SRF Berlin
- Delivery of the complete 10kW SSA: Jan2010

10kW transmitter presented at SRF Berlin October 2009

- 42U cabinet
- WR650 waveguide output at the top

- water cooled power modules
- water cooled driver
- built in 24kW 28V power supply

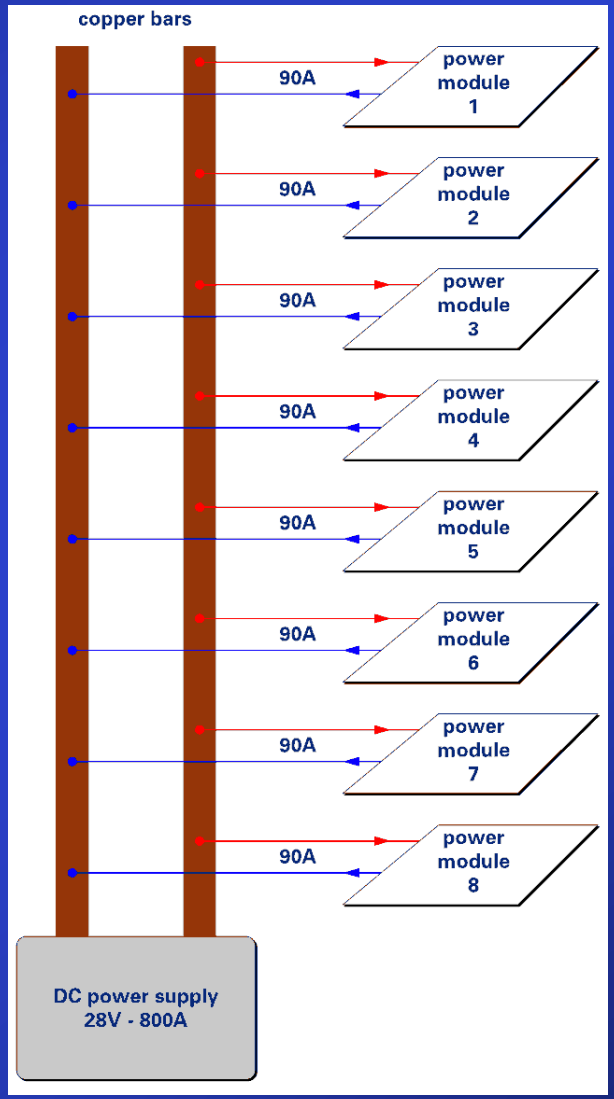
BLOCK DIAGRAM

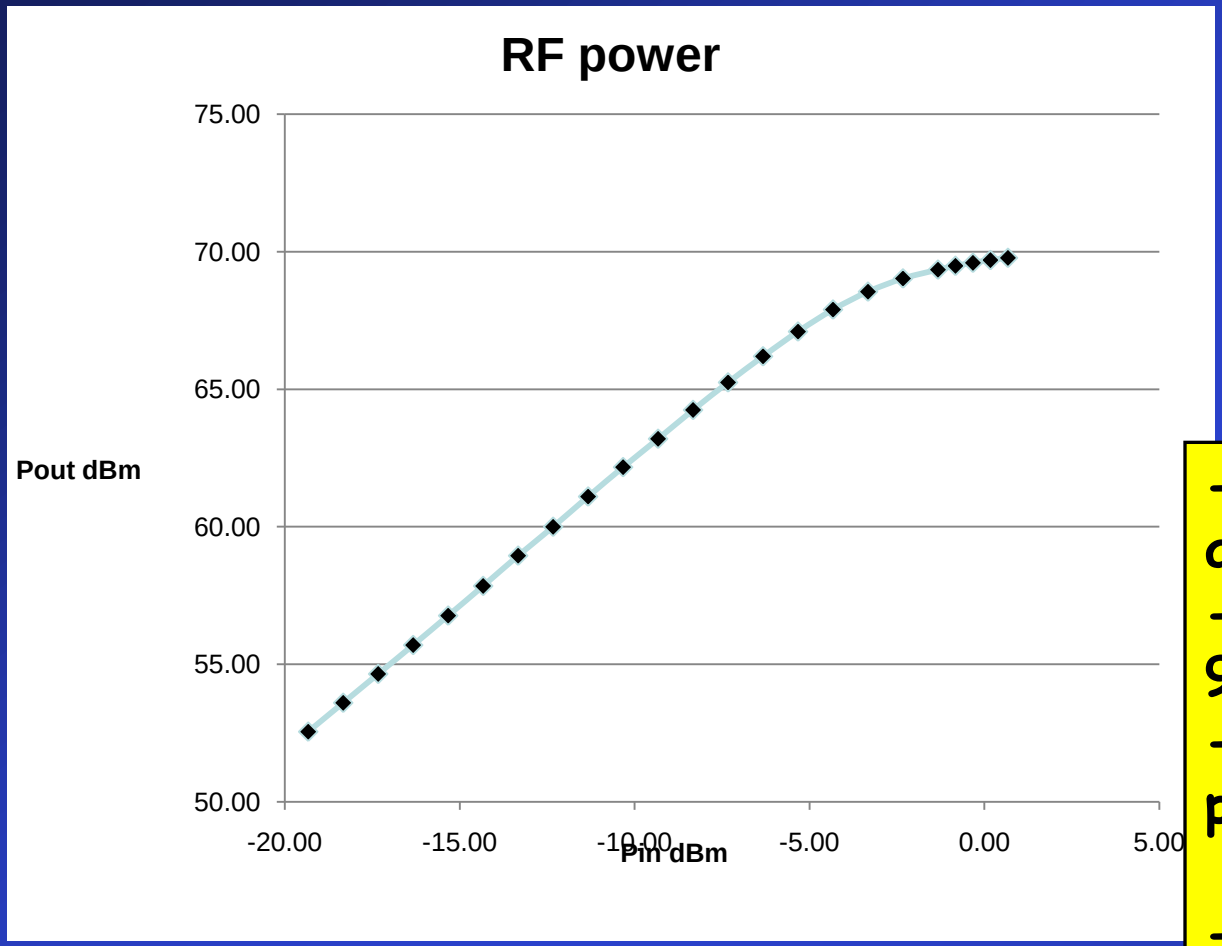


8 RF-power units in parallel

24kW 28V power supply

current distribution
via copper bars



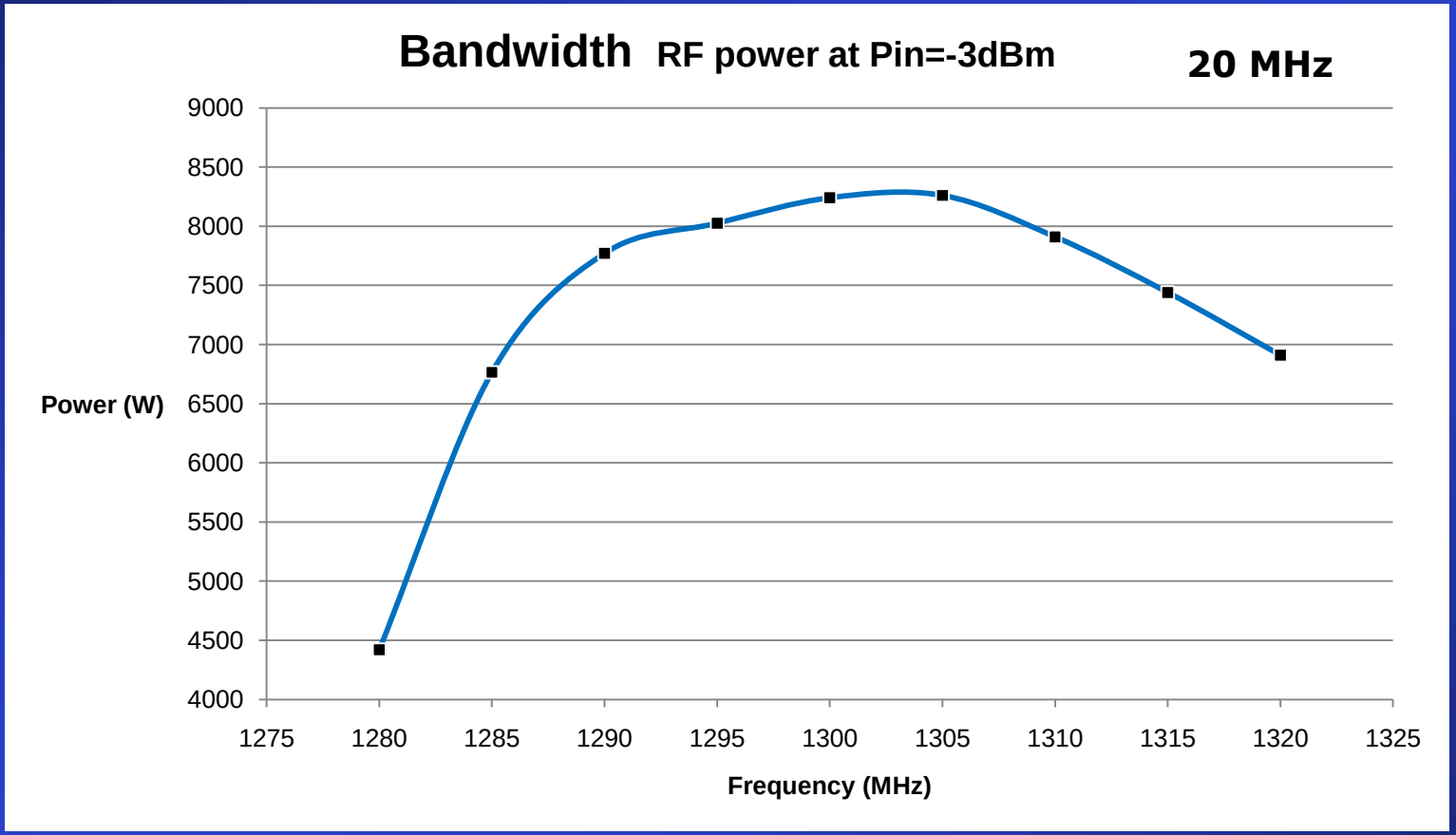


typical flow rates for CW 35l/min

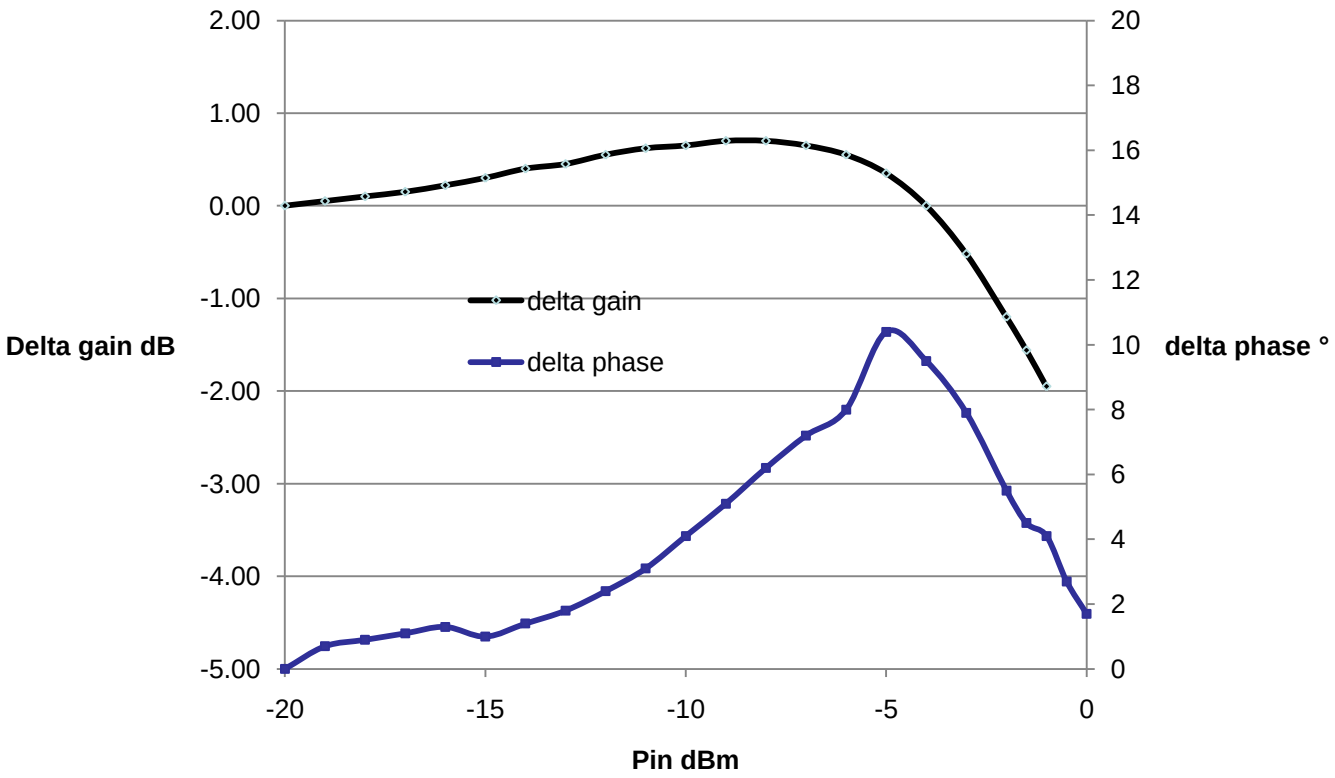
-1dB compression point at 8.5kW CW
-2dB compression point 9.1kW CW
-2.5dB compression point 9.5kW CW

-10kW achieved in pulsed mode

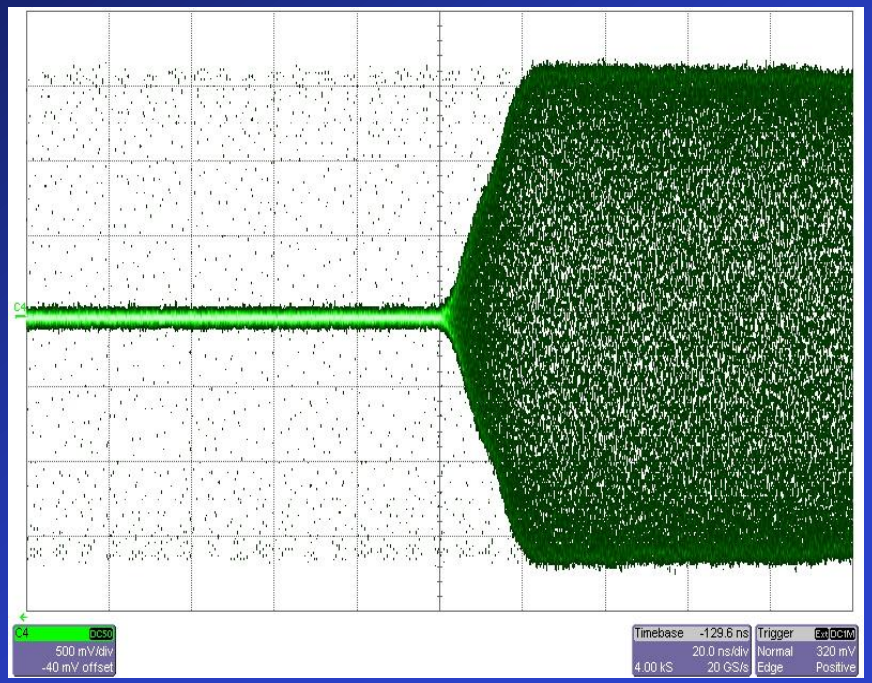
Bandwidth at 8 kW

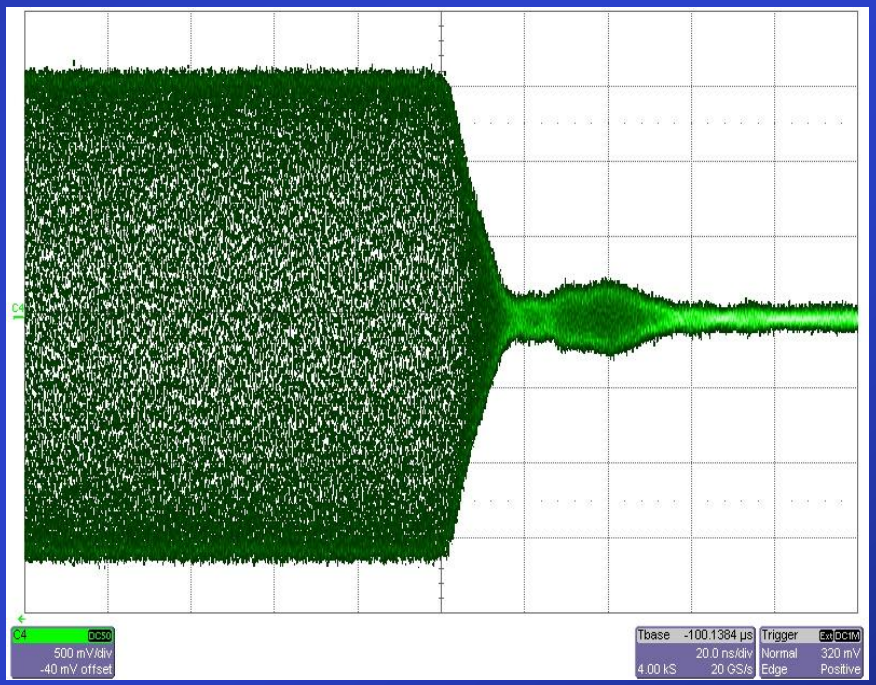


LINEARITY


Gain and phase variations over dynamic range
Delta gain dB
delta phase °
Pin dBm
delta gain
delta phase
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
20
18
16
14
12
10
8
6
4
2
0
-20
-15
-10
-5
0

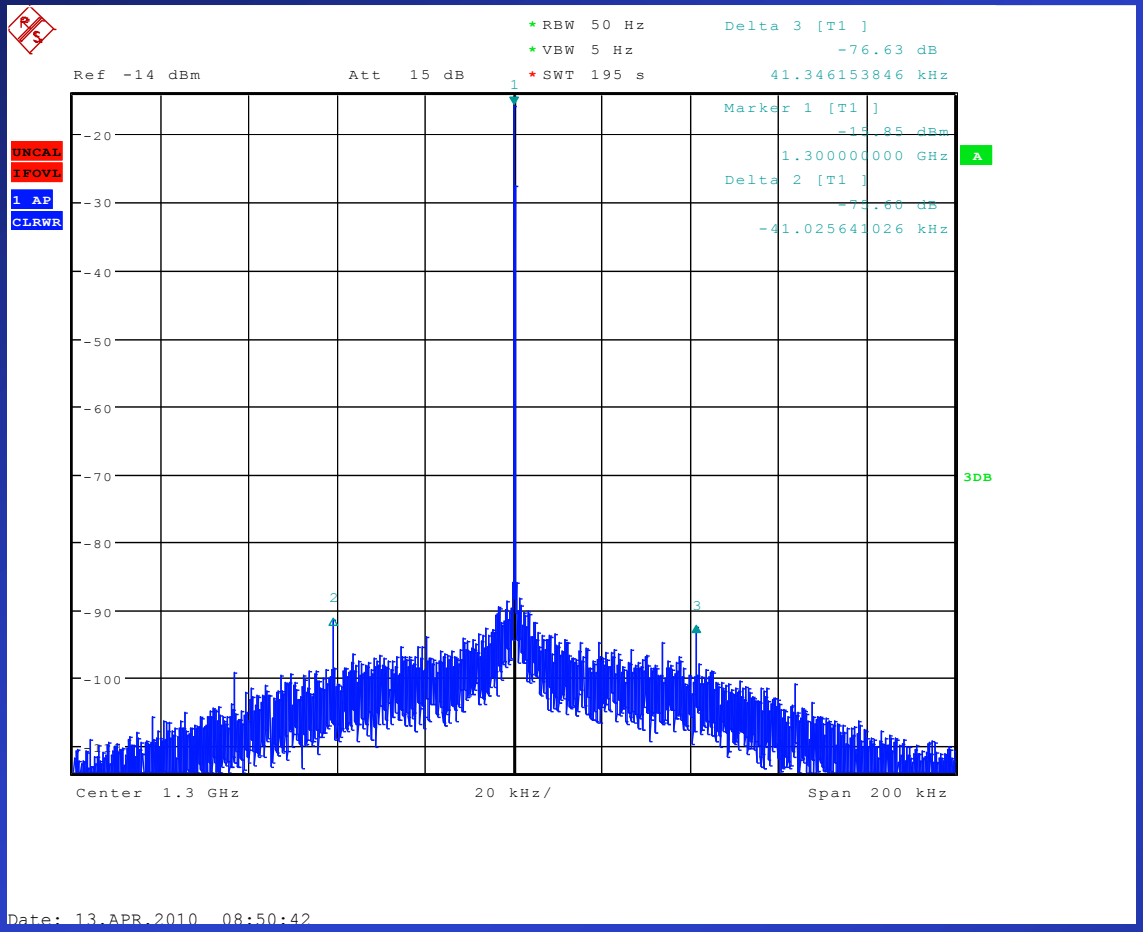
RAISE TIME and FALL TIME





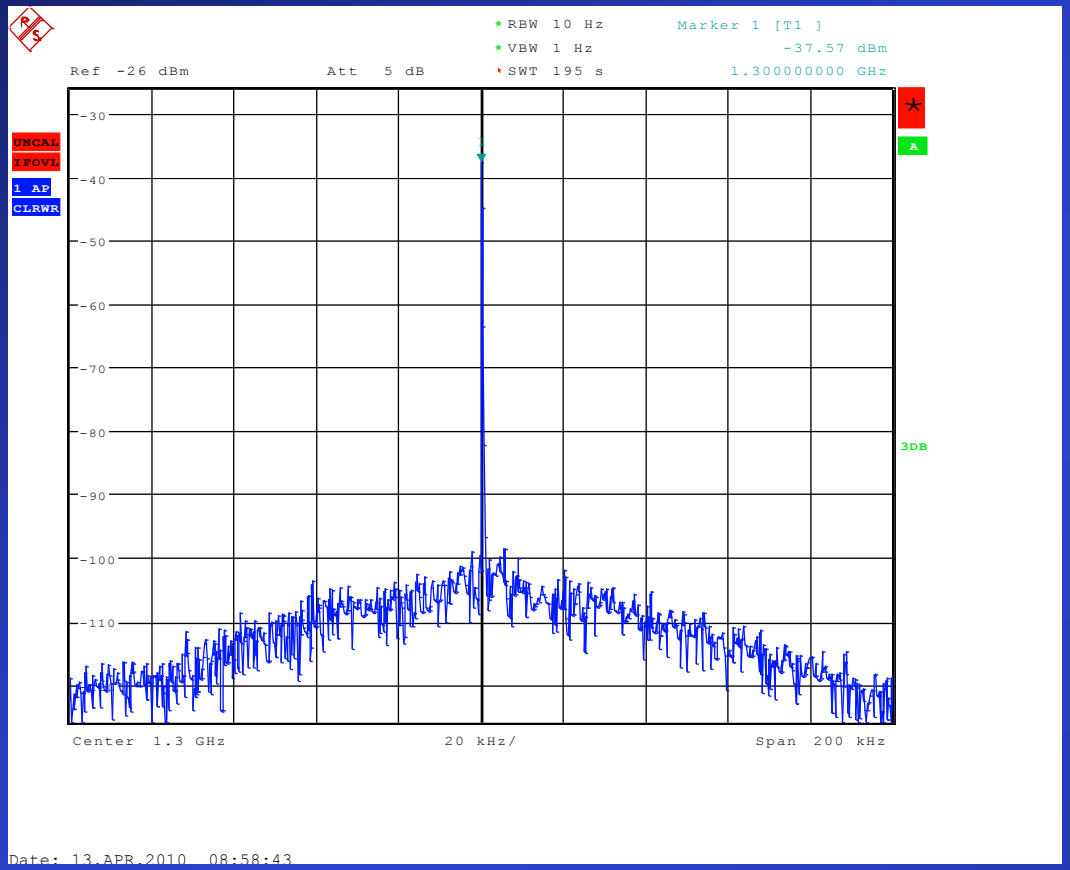
measured at 8kW output power
rise time ≈20ns fall time ≈ 60ns

SPURIOUS SIGNALS (200kHz)



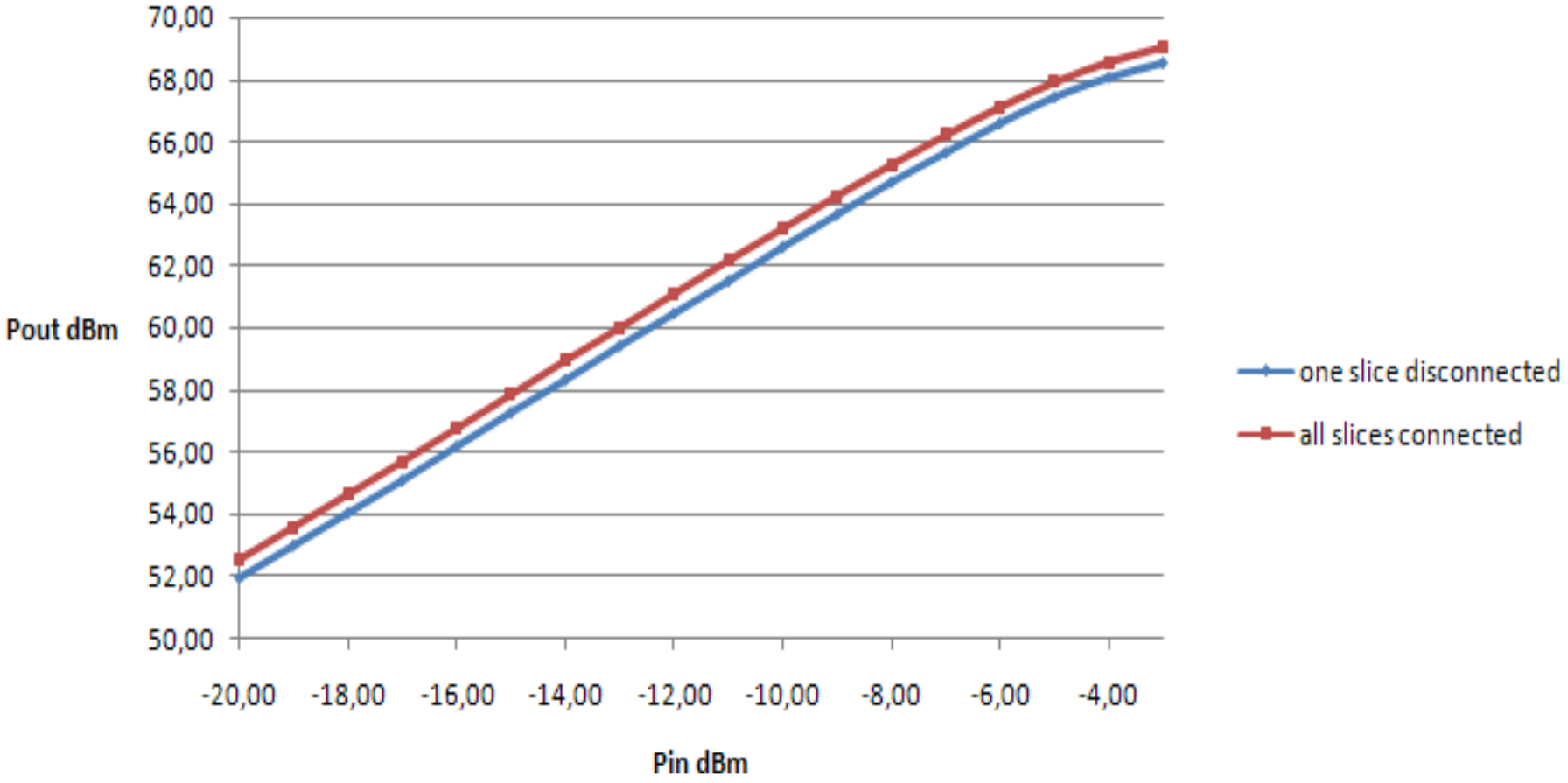
Pout=8 kW
Source: SMR20
R&S:FSQ26 (Aly.)
Span: 200 kHz
VBW: 5 Hz
SWT: 195 s
Fc= 1300 MHz
M2: -41 kHz/-76dB
M2: +41kHz/-75dB

SPURIOUS SIGNALS (20kHz)



Pout=8 kW
Source: SMR20
R&S:FSQ26
Span: 20 kHz
VBW: 1 Hz
SWT: 195 s
Fc= 1300 MHz

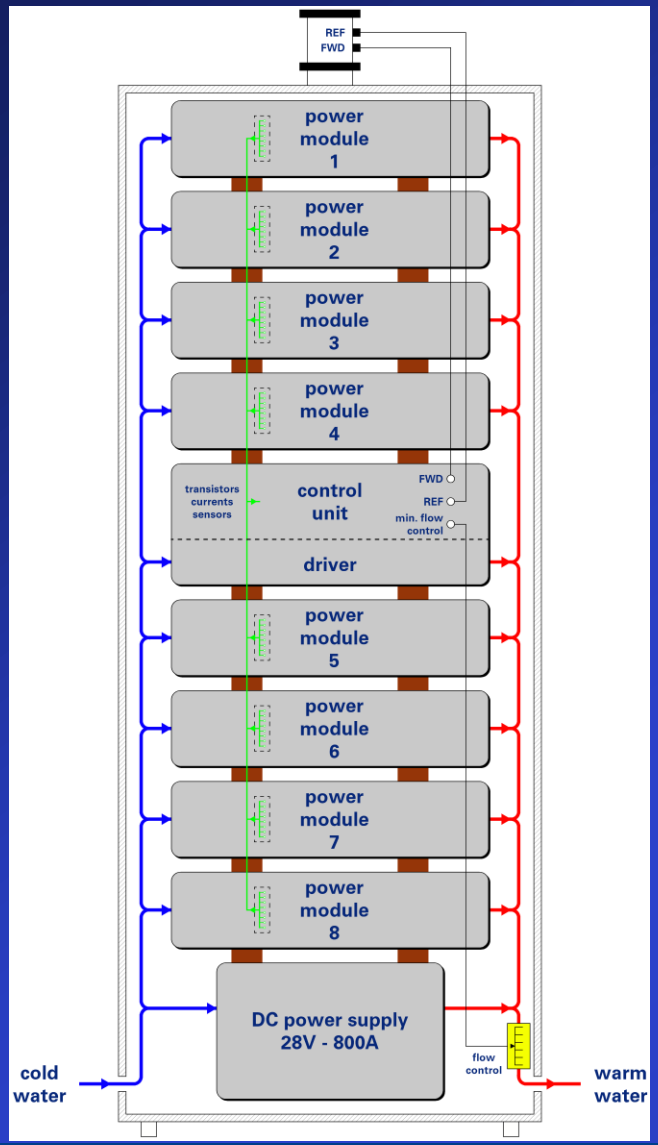
simulation of failure, one slice disconnected



GAIN and PHASE CHANGE vs POWER SUPPLY VOLTAGE

sensitivity to voltage changes measured at different power levels

	2kW	4.6kW	8.5kW	9.1kW
Δgain/ΔV	0.01dB/V	0.01dB/V	0.08dB/V	0.06dB/V
Δphase/ΔV	0.08°/V	0.25°/V	1°/V	0.6°/V



SAFETY AND CONTROL

-control system monitors forward and reflected power in real time

-control of : peak power, duty cycle, pulse width and mismatch

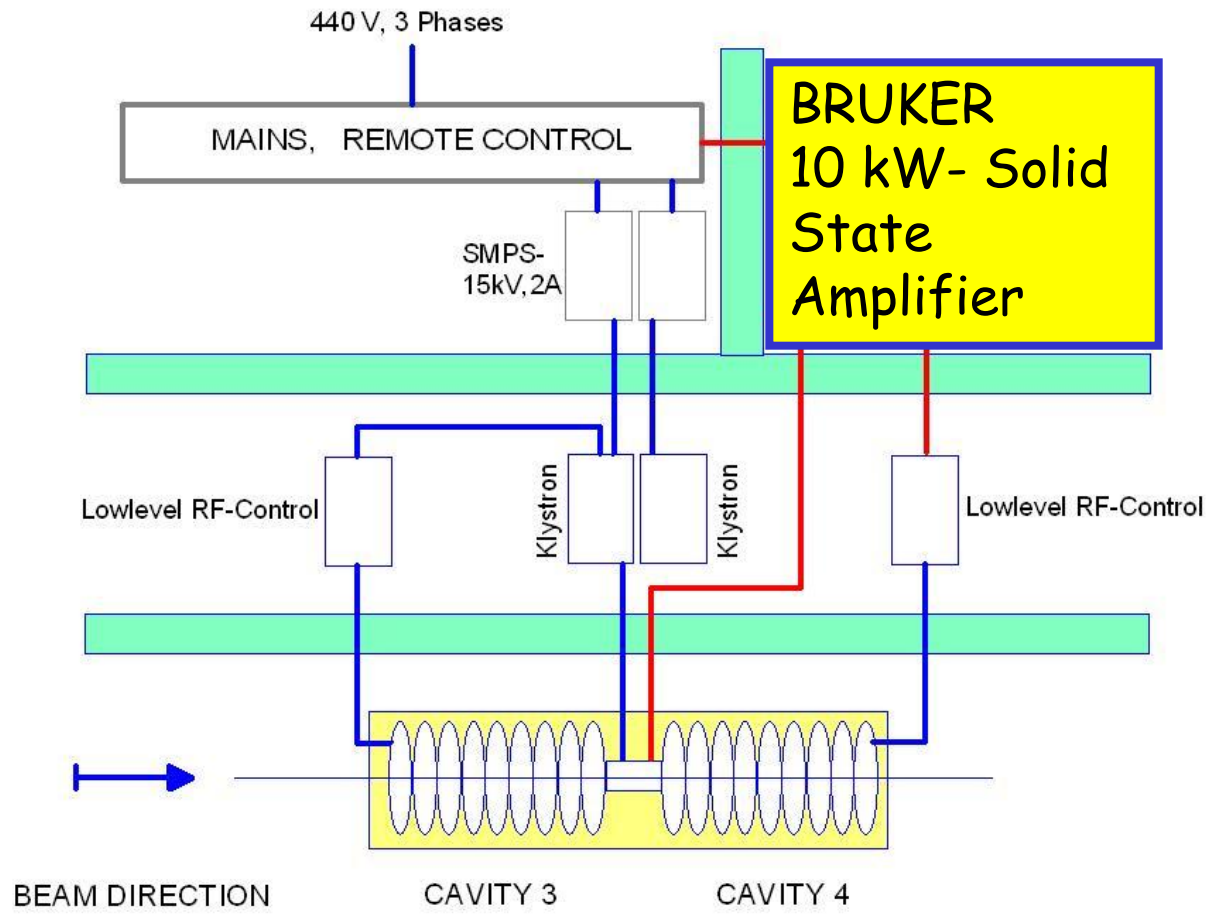
-user defined peak power, duty cycle, pulse width and mismatch limits

-control of all individual transistor currents

-control of water flow rate

-control of power modules temperatures

OPERATION AT ELBE

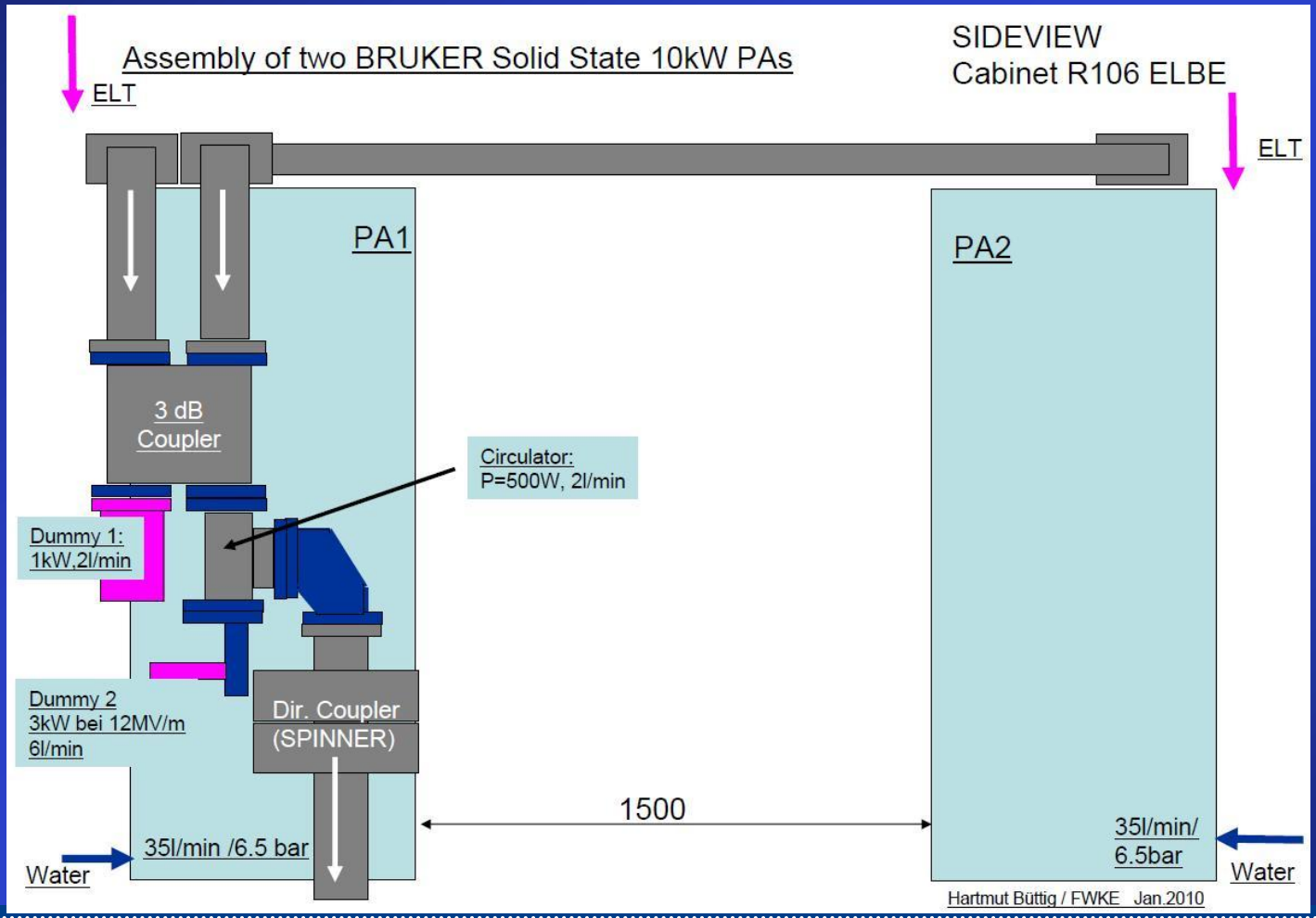


OPERATION AT ELBE

- Routine OP : 08.Feb. to 30.Apr.2010
- No failures
- Regimes of operation:

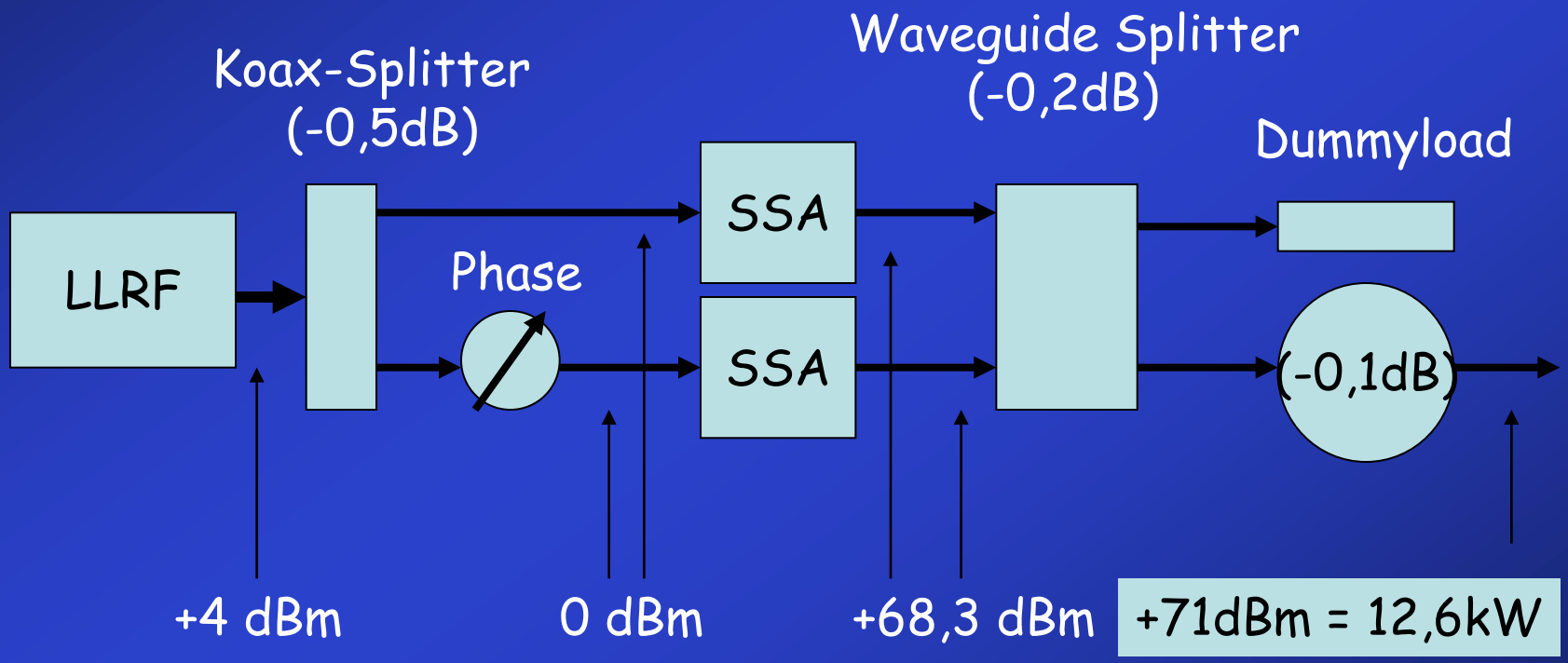
- CW (FEL, Cavity C4: 8MV/m/ 0.7 mA)
- Raise-/Fall time sufficient to run macropulse mode (0.1ms/40ms)
- Ok for single pulse mode
- Pulse Mode (cavity training)

ELBE UPGRADE

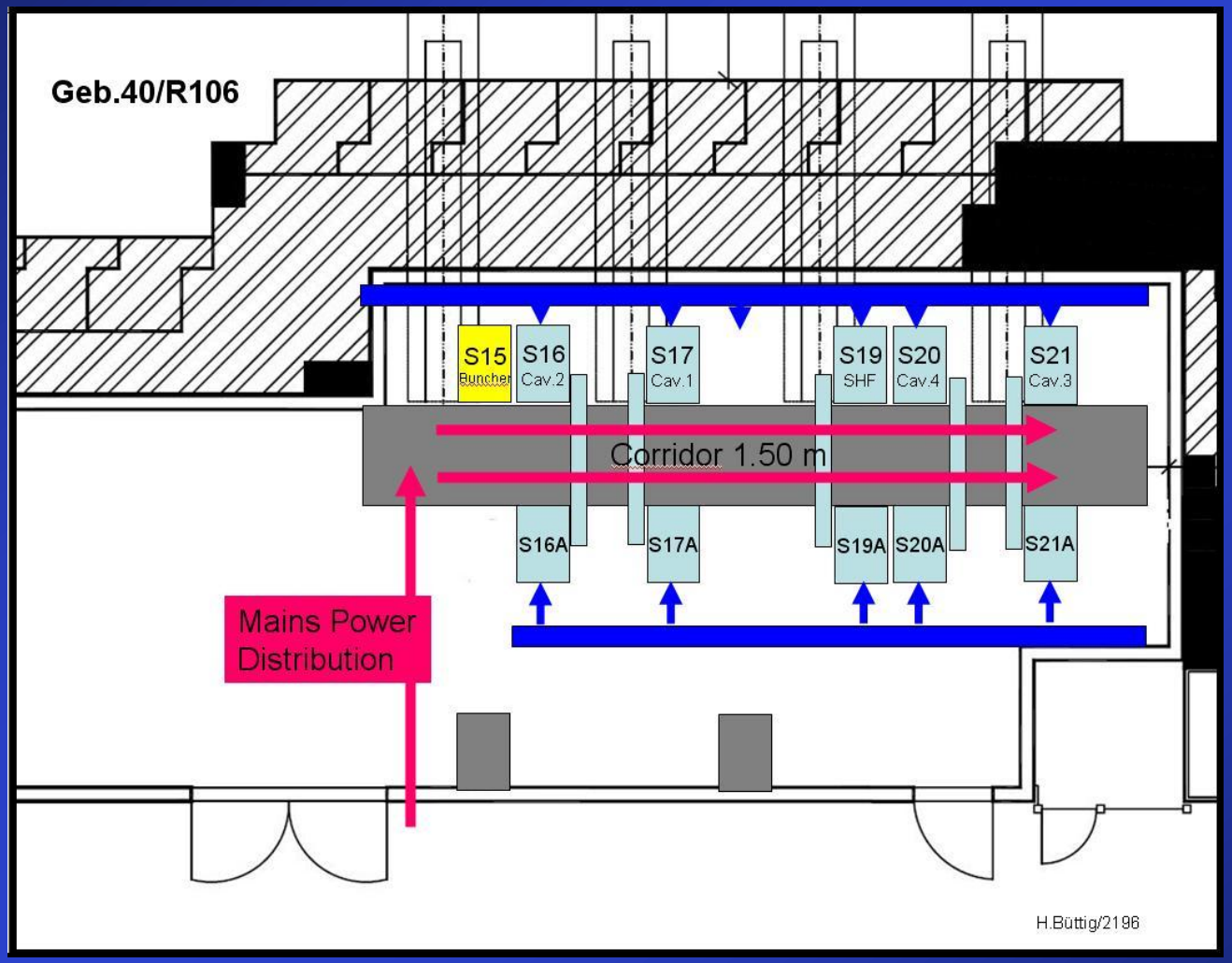


Block Diagram

RF-POWER (1dB reserve below -1dB comp.: +71 dBm = 12,6 kW
(LIMIT: (each amp.8,5 kW): 72,3dBm-0,3dB= 15,58 kW



ELBE UPGRADE



Thanks for the excellent cooperation !