1300 MHz Sources

Sept. 8, 2010

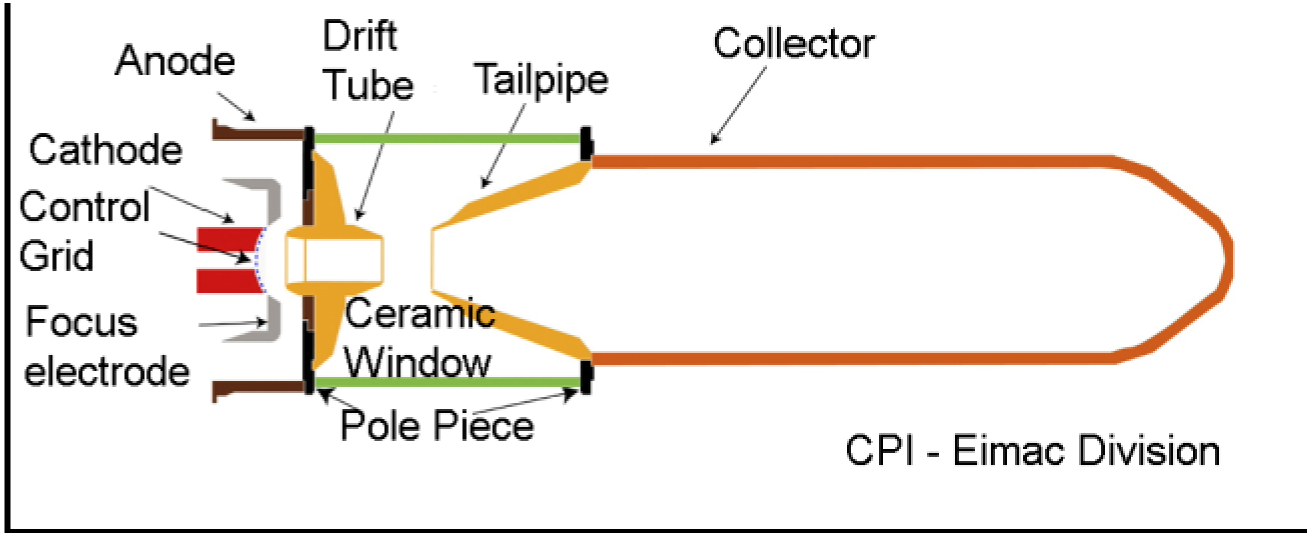
Basis

- ~ 30 kW CW per unit
- Look at what is existing out there
- ‘Evaluating’ both from the device POV and system POV
- Look at IOTs, Klystrons, and Solid State Devices (SSPA)

IOT

- Good efficiency (~ 60%) and would take advantage of TV transmitters for lower frequency systems – however 1.3 GHz only ‘recently’ developed, little reliability data (short cathode-grid spacing), low gain, 2x higher voltage modulator than klystron and needs more system development (drive power 500W)
- 1300 MHz IOT manufacturers: CPI (30 kW), E2V (16 kW – no longer in catalog), Thales (16 kW) and recently Mitsubishi (built 30 kW prototype for KEK ERL program)
- Costs for turn-key systems with 100 k$ CPI 30 kW IOT range from 400 – 900 k$ based on quotes from Bruker, ETM, DTI and Continental for small quantities

IOT Layout



Anode
Drift
Tube
Tailpipe
Collector
Cathode
Control
Grid
Focus
electrode
Ceramic
Window
Pole Piece
CPI - Eimac Division

CPI VKL-9130A

PRODUCT SPECIFICATION

INDUCTIVE OUTPUT TUBE (IOT) AMPLIFIERS, TYPE VKL-9130A AND VKL-9130B

DESCRIPTION: IOT Amplifier, 30 kW CW or 90 kw peak, 1300 ±1 MHz, with Integral Cavity, Waveguide Output and Coaxial Input; Electromagnetically Focused, Liquid and Air Cooled

ABSOLUTE RATINGS (Notes 1 and 2)

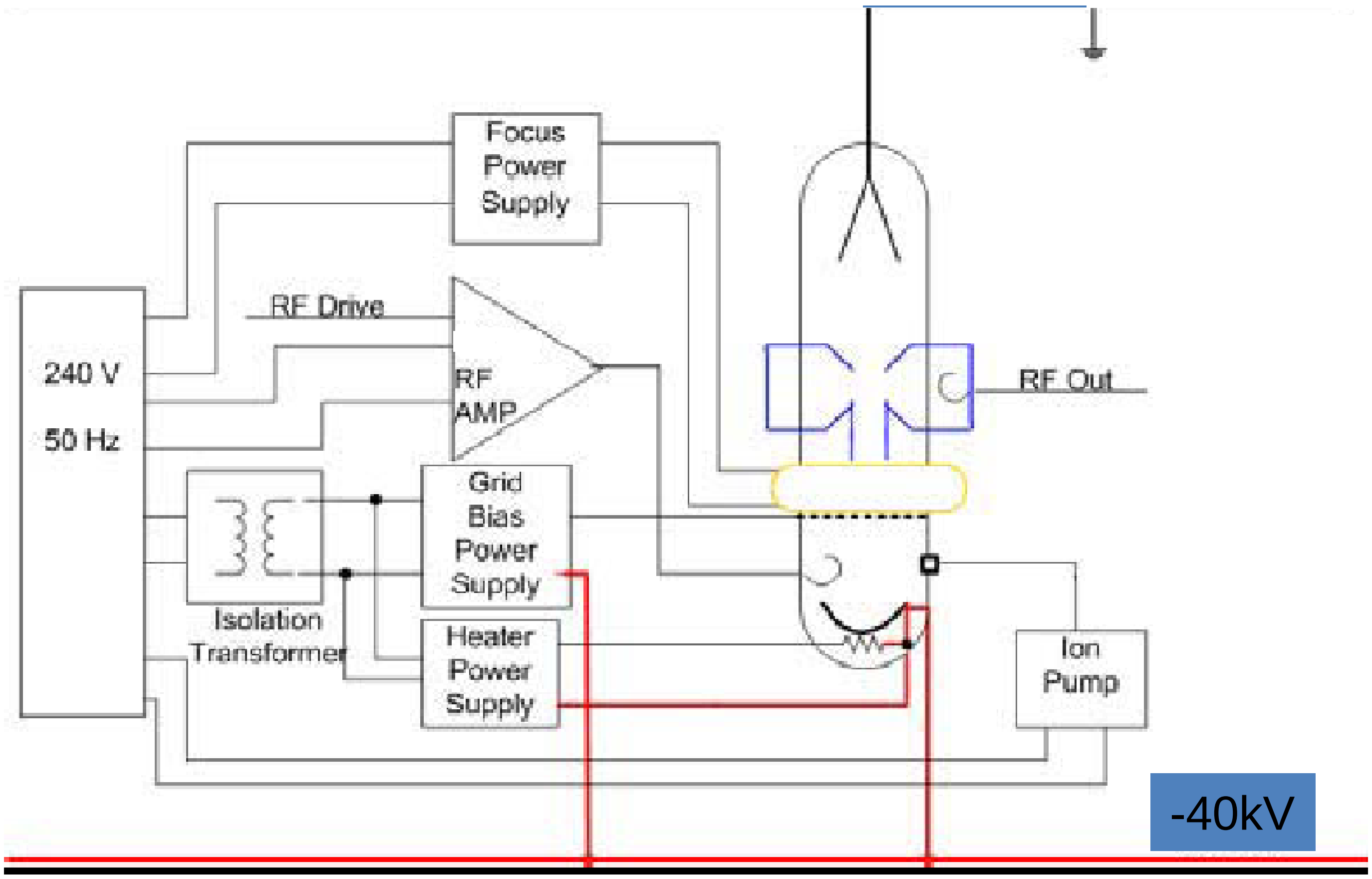
Parameters:	Ef	If	If (Surge)	Eb	Ik	Eg	tk
Units:	Vdc	A	A	kV	Adc	Vdc	minutes
Maximum:	10.0	9.5	15	50	5.5	–50	- - -
Minimum:	8.0	- - -	- - -	- - -	- - -	–150	15
Notes:	2, 3, 4	- - -	3	6, 7	8	2	3

CW OPERATION							
Parameters:	Eb	Ik	Eg	Ig	Iq	Pd	Po
Units:	kV	Adc	Vdc	mA	mA	W	kW
Maximum:	45	2.5	–40	300	500	500	35
Minimum:	- - -	- - -	–150	- - -	- - -	- - -	- - -
Notes:	6, 7	8	2	- - -	- - -	9, 18	- - -

	Focus Solenoid		Collector and O/P Cavity	
Parameters:	Esol	Isol	Coolant Flow	Inlet Temp.
Units:	Vdc	Adc	gpm	°C
Maximum:	10.5	25	20	45
Minimum:	4.5	15	10	15
Notes:	- - -	- - -	11, 12	11, 12

	Load	Electron Gun, Input Circuit, and O/P Window		
Parameters:	VSWR	Air Inlet Temperature	Air Flow	Inlet Air Pressure
Units:	- - -	°C	cfm	in-H_2O
Maximum:	1.2:1	50	- - -	- - -
Minimum:	- - -	15	50	5.0
Notes:	10	5	3, 19, 20	- - -

System layout



Transmitter *(Thomson)*

HVPS Cabinet:

36 kV – 4 A power supply
60 Pulse Step Modulation Cards

New PSM card 700V – 4A

IOT Cabinet:

80 kW IOT
400 W SSA
Auxiliaries
Controls PLC

Reliability Statistics

- “old” design 3-4 shipped, the 66% efficient one failed after 6 months
- “new” design 1-2 shipped, better performance and still out in field (service time less than one year)
- Sentiment in building klystron rather than making more 1300 MHz IOTs (from CPI)

klsytron

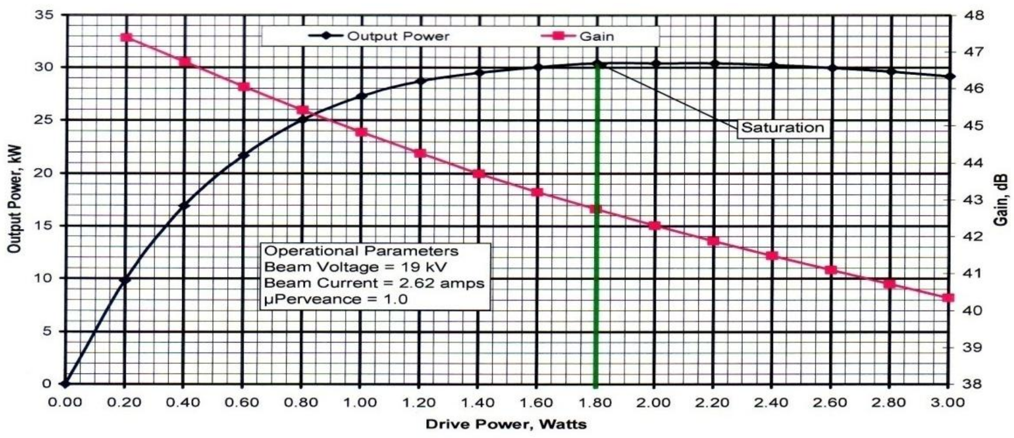
- Good efficiency (~ 60%) and high gain, but ‘slow’ approach to saturation compared to IOTs
- Klystron manufacturers: CPI sells a ‘reliable’ 11 kW tube and has a design for a 30 kW tube (would build one for 440 k$) and Toshiba is developing a 25 kW tube (probably for KEK)
- For the 12 GeV upgrade at JLab, they chose klystrons over IOTs for their 1.5 GHz, 13 kW sources. L3 is currently building 24 (out of 84 required) at 45 k$ each. They claim the modulators would also be ~ 50 k$, so using two such tubes (modified to 1.3 GHz) could cost as little as 200 k$ and be industrialized to a large extent

CPI Klystron (proposed)

Proposed Specifications for a
1.3 GHz, 30 kW CW Klystron

Parameter	Minimum	Nominal	Maximum	Units
RF Operating Frequency		1.3		GHz
CW Output Power	30			kW
DC to RF Efficiency	60	62		%
Beam Voltage		19		kV
Beam Current		2.62		A
Micro-Perveance		1.0		
RF Power Gain	40	42		dB
Instantaneous Saturated Bandwidth (-1dB)		+/- 4		MHz
VSWR Tolerance			1.2:1	
Filament Voltage			15	V
Filament Current			15	A

Predicted Output Power and Gain vs. Drive Power
for 1.3 GHz, 30 kW CW Klystron



SSA

- Solid State Transmitters
- Reasonable efficiency (~ 50%), high gain, modular design provides high reliability but cost on high side (although may lower over time with advances in cell phone transmitters)
- At the recent CW rf workshop in Spain, much interest in solid state approach, especially in Europe where the 352 MHz SOLEIL solid state source will be upgraded and the approach will be adopted by ESRF
- Bruker makes a 10 kW single rack unit that sell for 162 k$ - combining three for 30 kW would cost around 500 k$. Also seems like there is a lot of Asian companies marketing lower power, lower frequency devices

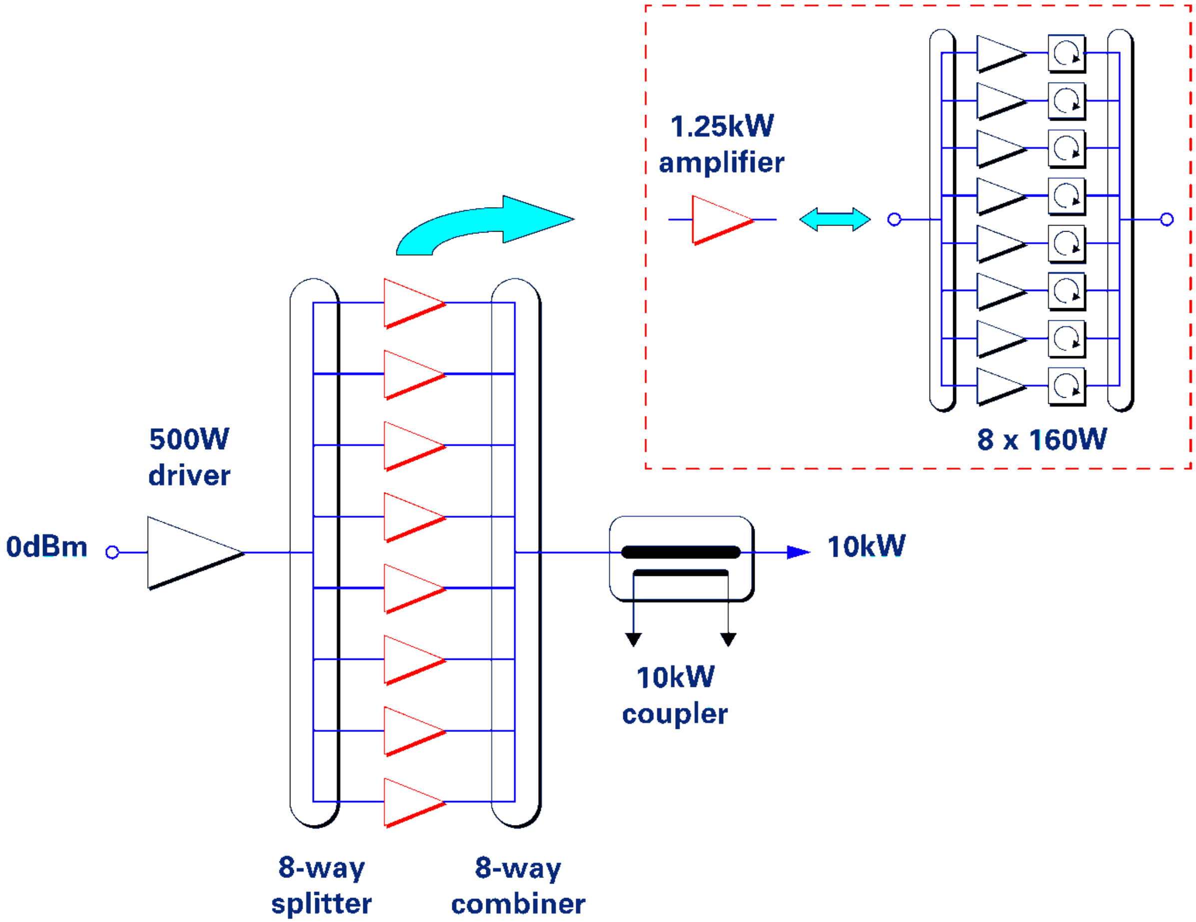
Bruker 10 kW CW Source

Consists of eight 1.25 kW water-cooled modules - each module has eight 160 W, isolated transistor units that are summed in a coaxial combiner – the output of the each module drives a common WR650 waveguide – no solenoid, HV PS, filament PS nor vacuum pump

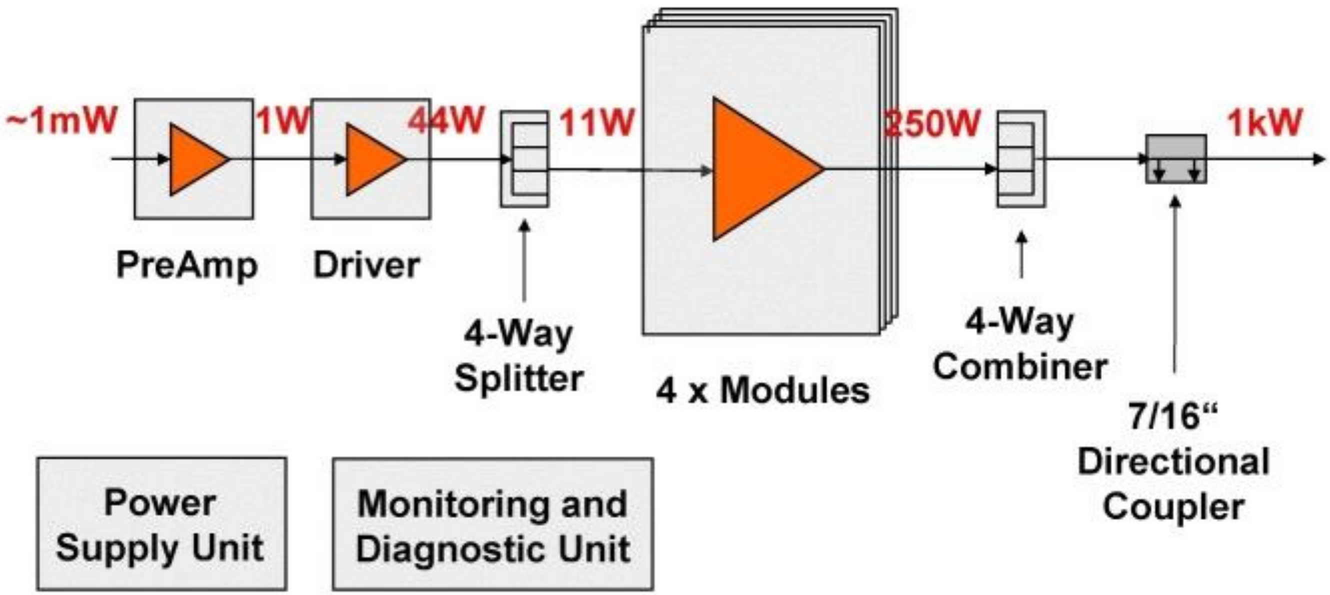
42U cabinet
- WR650 waveguide output at the top

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

Basic Topology



Other 1 KW modules



Learn From Others

- ELBE (Elektronen-Linearbeschleuniger für Strahlen hoher Brillanz und niedriger Emittanz) (Germany) was focused on IOT but not happy.
- They are looking at SSA-Technology because:

- BRUKER EXP. (NMR/MRI-SSA Technology)
- BRUKER EXP. (Big SSA for Orsay)
- BRUKER 1kW@1.3GHz CW IOT-drivers

Learn From Others Con’t

- Solid state technology becomes more and more competitive.
- (costs: ~18 USD/watt 30 kW 500 k$ full system)
- Other demand will continue to drive SSA technoloy
- SSA works at low voltage 50 volt as compared to 35 kV (IOT) and 15 kV (klystron)

Summary

- 1300 MHz IOTs are available from CPI
- Need 500 watt driver
- Solid State device should be looked at as driver and back-up system in case IOTs do not work out