X-band Facilities and High Gradient Tests Stands Around the World

CLIC Workshop

G. McMonagle

06/03/2016

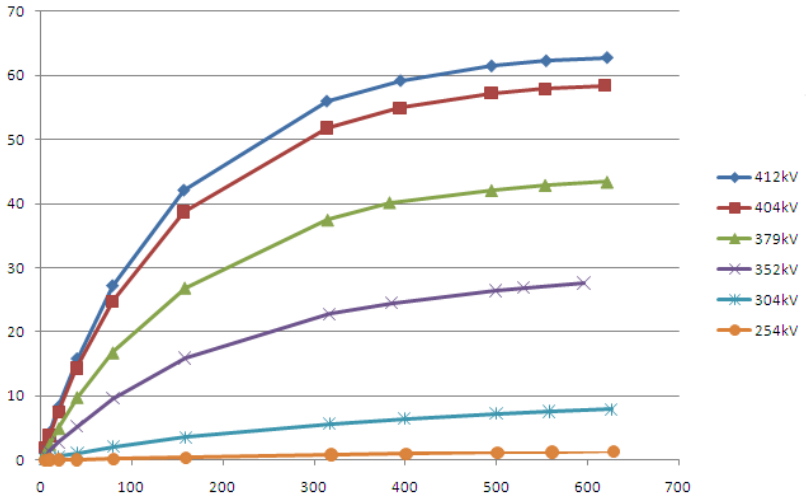
OUTLINE

- Geographic representation X band test facilities and high gradient test stands
  - Summary of frequency, power and modulator type per location
- Preliminary test results of High Efficiency BAC type multi-beam klystron at CERN

Location of Xband Facilities and High Gradient Tests Stands

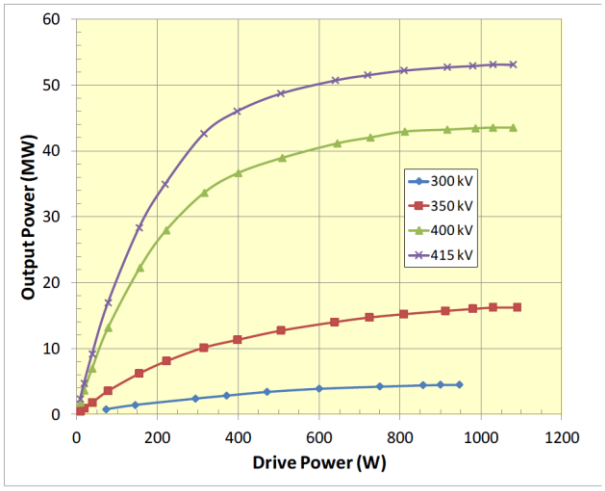
SLAC KLYSTRONS (XL5, XL4)

Parameters	Specifications		units
	XL5	XL4	
RF Frequency	11.9942	11.424	GHz
Peak RF power	50		MW
RF pulse length	1.5		µs
Pulse repetition rate	50 (100)		Hz
Klystron voltage	410-470		kV
Micro perveance	1.15E-6		



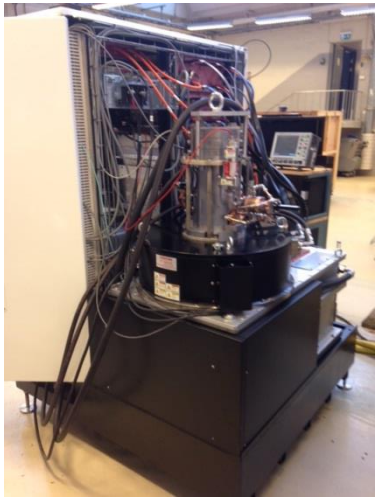
CPI KLYSTRONS (VKX-8311A, VKX- xxxx)

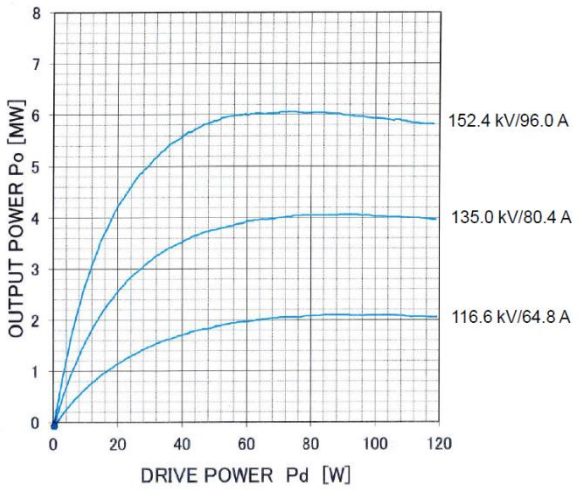
Parameters	Specifications		units
	VKX-8311A	**VKX-xxxx**	
RF Frequency	11.9942	11.424	GHz
Peak RF power	50		MW
RF pulse length	1.5		µs
Pulse repetition rate	50 (100)		Hz
Klystron voltage	410-470		kV
Micro perveance	1.15E-6		



TOSHIBA KLYSTRONS (E3768B, E37113)

Parameters	Specifications		units
	E3768B (PPM)	E37113	
RF Frequency	11.424	11.9942	GHz
Peak RF power	50	6	MW
RF pulse length	0.8	5	µs
Pulse repetition rate	60	400	Hz
Klystron voltage	450	150	kV
Micro perveance		1.5	

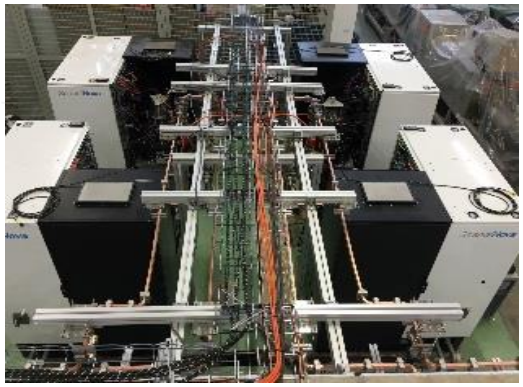




CERN Facilities

Xbox 1 and Xbox 2 (High Gradient Test facilities)
CPI VKX-8311A (previously XL5) klystrons
Scandinova solid state modulators

Xbox 3 (multi slot High Gradient Test Facility)
Toshiba E37113 klystrons
Scandinova solid state modulators



PSI and Sincretron Trieste

SwissFEL

XL5 klystrons (spare CPI VKX-8311A)

Scandinova solid state modulator

Note:- C band modulators also use Ampegon modulators

Could possibly be used in Xband as well

Elettra

XL5 klystrons

Pulse Forming Network , thyratron switch modulator (built in house)

SLAC, Lawrence Livermore,Berkeley, MIT BATES

FACET NLCTA ASTA ….

XL4 klystrons

Pulse Forming Network , thyratron switch modulator (built in house)

NLCTA , two pack four pack and 8 pack modulator studies

Lawrence Livermore

XL4 klystron

Scandinova solid state Modulator

Berkley

XL4 klystron

Modulator ?

MIT BATES

9.3 GHz L3 klystron

Modulator Solid State Scandinova

KEK and PAL

NEXTEF

PPM 11.424 GHz klystrons

Pulse Forming Network , thyratron switch modulator

PAL XFEL

XL4 klystron

Pulse Forming Network , thyratron switch modulator

Tsinghua, SINAP, DESY, Univesity Valencia, Melbourne University

Tsihghua test stand (2017)
VKX-xxxx, CPI 11.424 GHz Klystron
Solid State Scandinova Modulators

SINAP, Compact FEL (2017-18)
VKX-xxxx, CPI 11.424 GHz Klystron
Modulators being constructed in China

DESY, SINBAD and FLASH
CPI VKX-8311A and or Toshiba E37113
Modulator technology and manufacturer not yet chosen

University of Valencia IFIMED RF Test Infrastructure (2017)
CPI klystron Sband 7.5 MW 400Hz
Solid State Modulator, Jema Spain

Melbourne University (2018-19)
50% of Xbox3

Prepare and share a table within the community

- Facilities
- Experiments
- Expertise
- contacts

High Efficiency BAC type multi-beam klystron at CERN

The first prototype of a commercial S-band MBK, that employs the new bunching technology (Bunching, Alignment and Collecting, BAC) was designed and fabricated at VDBT Moscow and successfully tested at CERN.

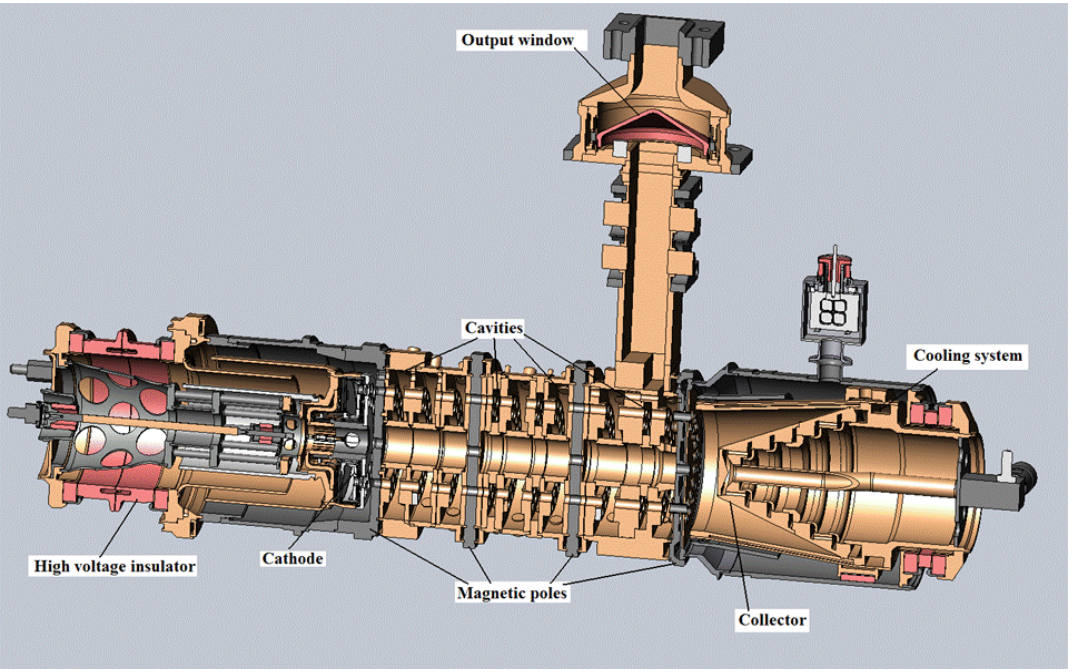
Design based on retrofitting an existing klystron
MBK-147 , 40 beamlets, 60kV, 290 A 42% RF power production efficiency, PPM focusing.

To minimise the development and fabrication costs
It was decided to keep
Original 40 beam cathode
PPM focussing
Collector
Original RF circuit length (24cm)

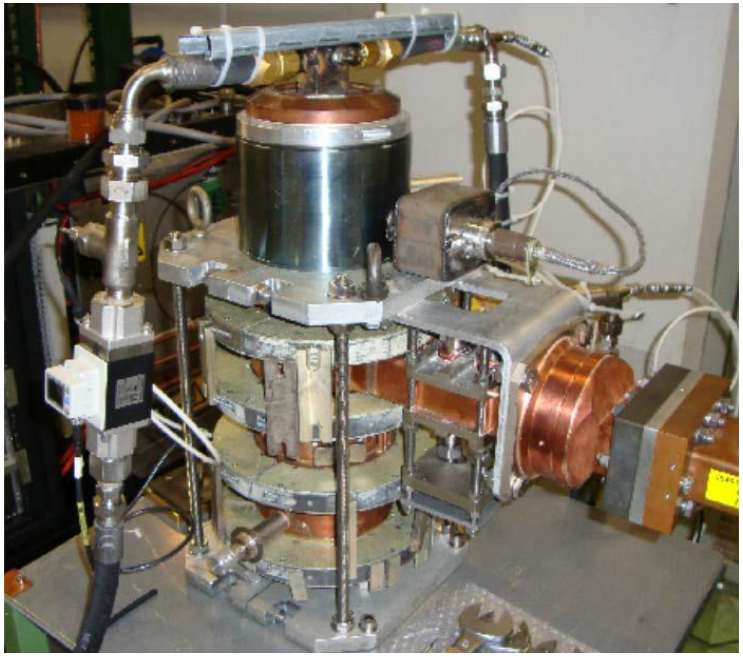
Frequency, GHz	2,9985
Peak output power, MW	>6
Average power, kW	30
Beam voltage, kV	<60
Number of beams	40
Pulse length, us	5
Efficiency, %	>60
Pulse repetition rate, Hz	300

BAC MBK klystron design parameters

High Efficiency BAC type multi-beam klystron at CERN



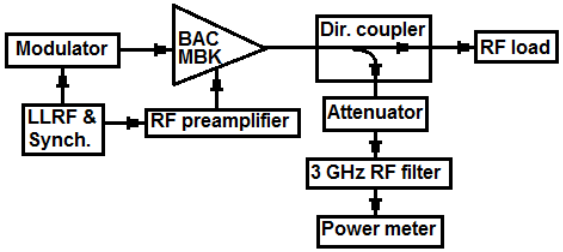
General view of BAK MBK (without magnets).



BAC MBK installation at the test stand in CERN

High Efficiency BAC type multi-beam klystron at CERN

Test Setup



Original Scandinova K1 modulator
Thanks to ADAM
Turns ration modified to achieve
60kV, 190 A (original 190kV 90A)
New heater power supply needed

Vacuum pumping port

RF Load

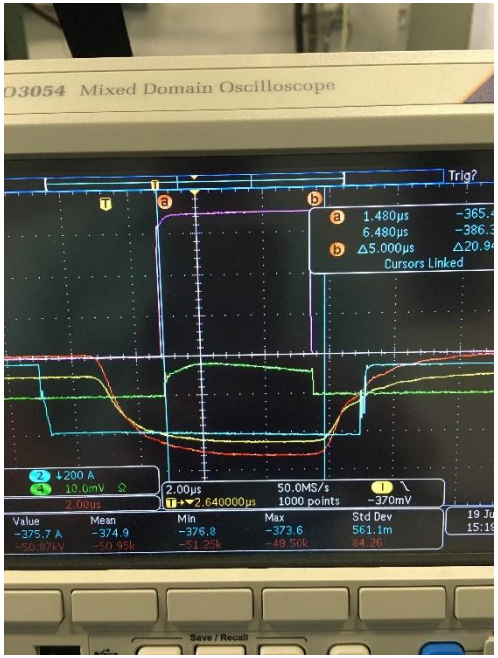
Klystron cathode in air

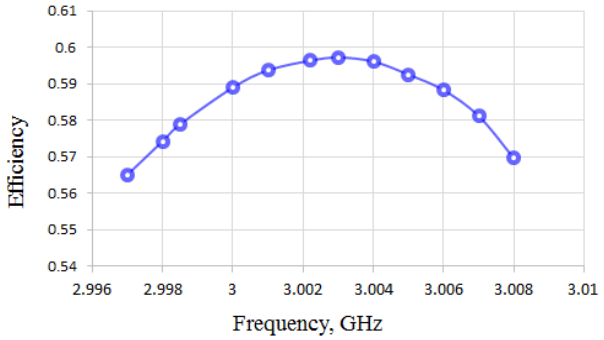
Current transformer

Capacitive voltage divider

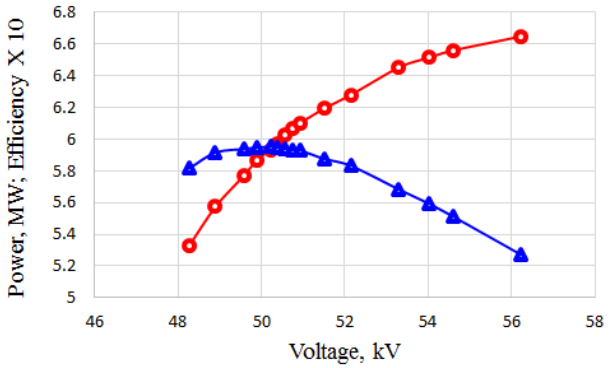
High Efficiency BAC type multi-beam klystron at CERN

Beam transmission optimized at 50.25kV
Pulsed with pulse length up to 9 µs
Repetition rate 120 Hz
Frequency optimization slightly off





Klystron efficiency vs. frequency at 50.25 kV and 195 A (in saturation)



The efficiency (triangular) and RF power production (circle) in saturation at 3.003 GHz as functions of high voltage.

High Efficiency BAC type multi-beam klystron at CERN

Conclusions

The first commercial prototype of a high efficiency BAC S-band MBK was successfully tested at CERN
The results are very encouraging and prove that new bunching technology can significantly boost the efficiency of klystron amplifiers.

The klystron efficiency was increased from 42 % to 60 % simply by replacement of the original RF circuit with the new BAC RF circuit.

Second klystron built in Moscow, initial results show correct frequency and 62% efficiency.

Smaller and more compact modulator design being considered by Scandinova and final testing may take place at CERN this year.