



Status of the C-band system at SINAP

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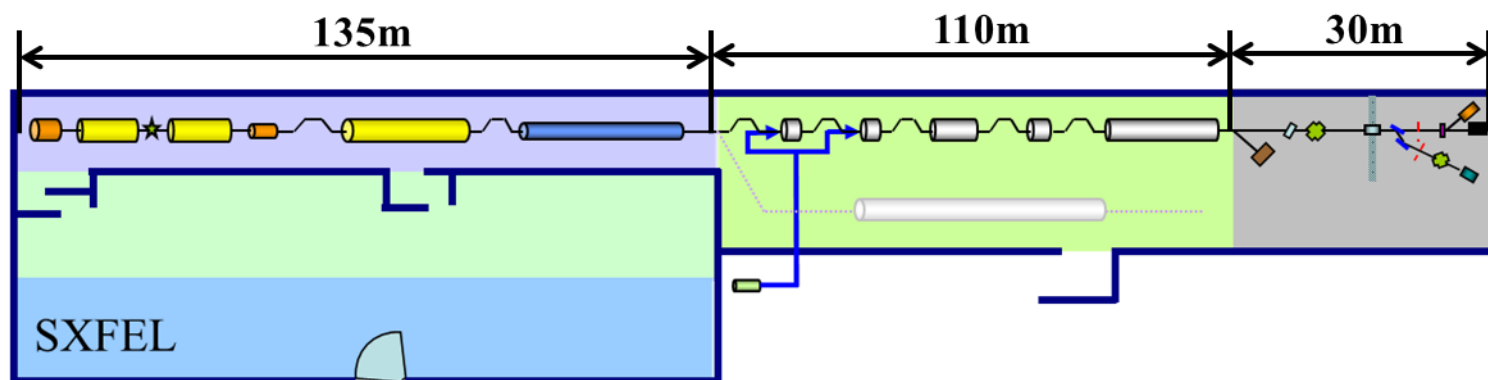


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Shanghai Institute of Applied Physics, Chinese Academy of Sciences

Outline

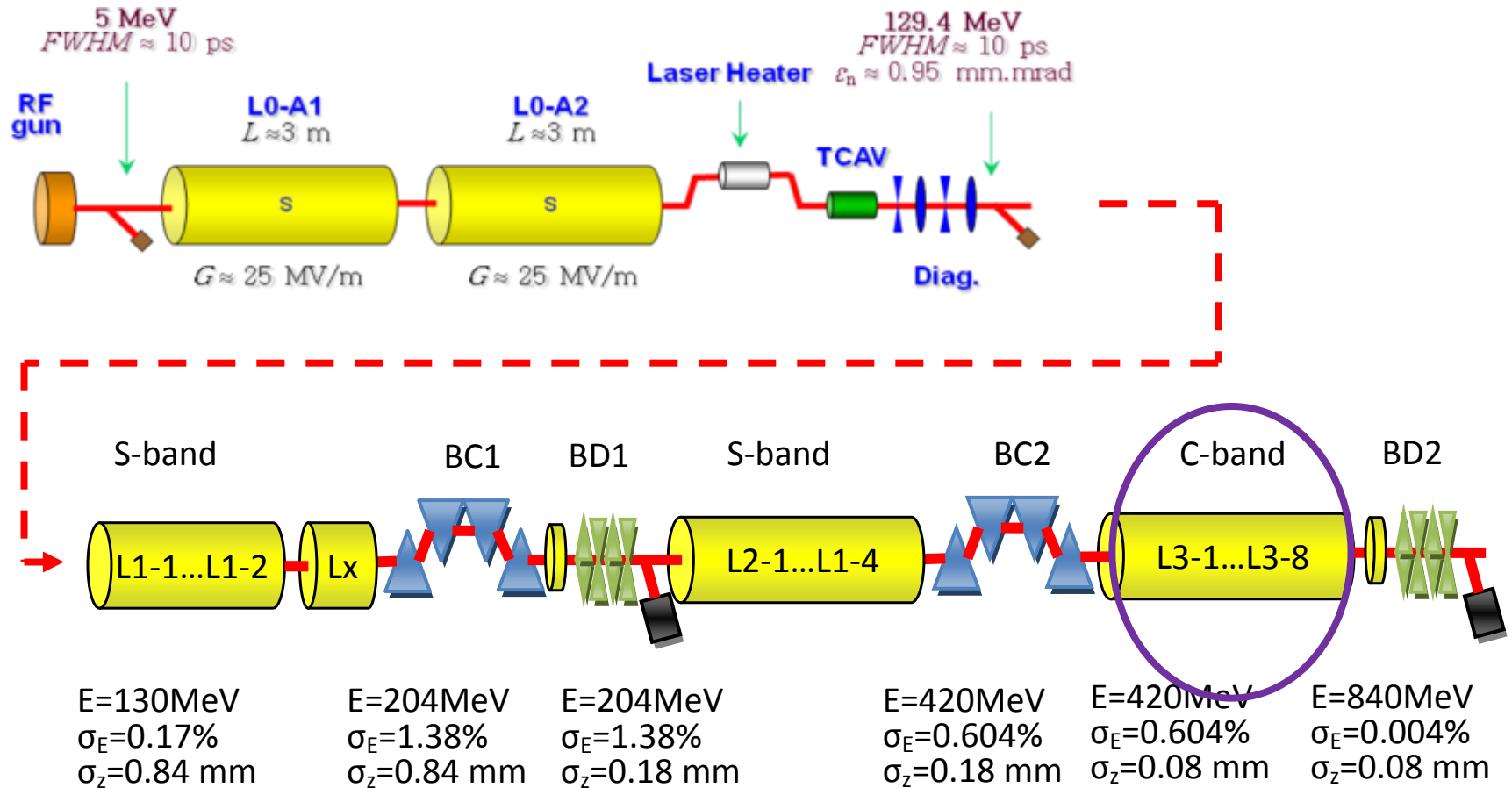
- Short introduction to Shanghai X-ray Free Electron Laser
- Requirements on the C band system
- Components of the C band system
 - Accelerating structure
 - RF compressor
 - RF power plant
 - LLRF
- Future work
- Summary

Shanghai X-ray Free Electron Laser



Parameter	Value	Unit
e-energy	0.84	GeV
Energy spread (rms, global)	0.15	%
Norm. emittance (rms)	<2.5	mm·mrad
Bunch length (FWHM)	<1	ps
Charge	0.5	nC
Peak current	~500	A
Repetition rate (max)	10	Hz

The Linac for SXFEL



The requirements on the C band system

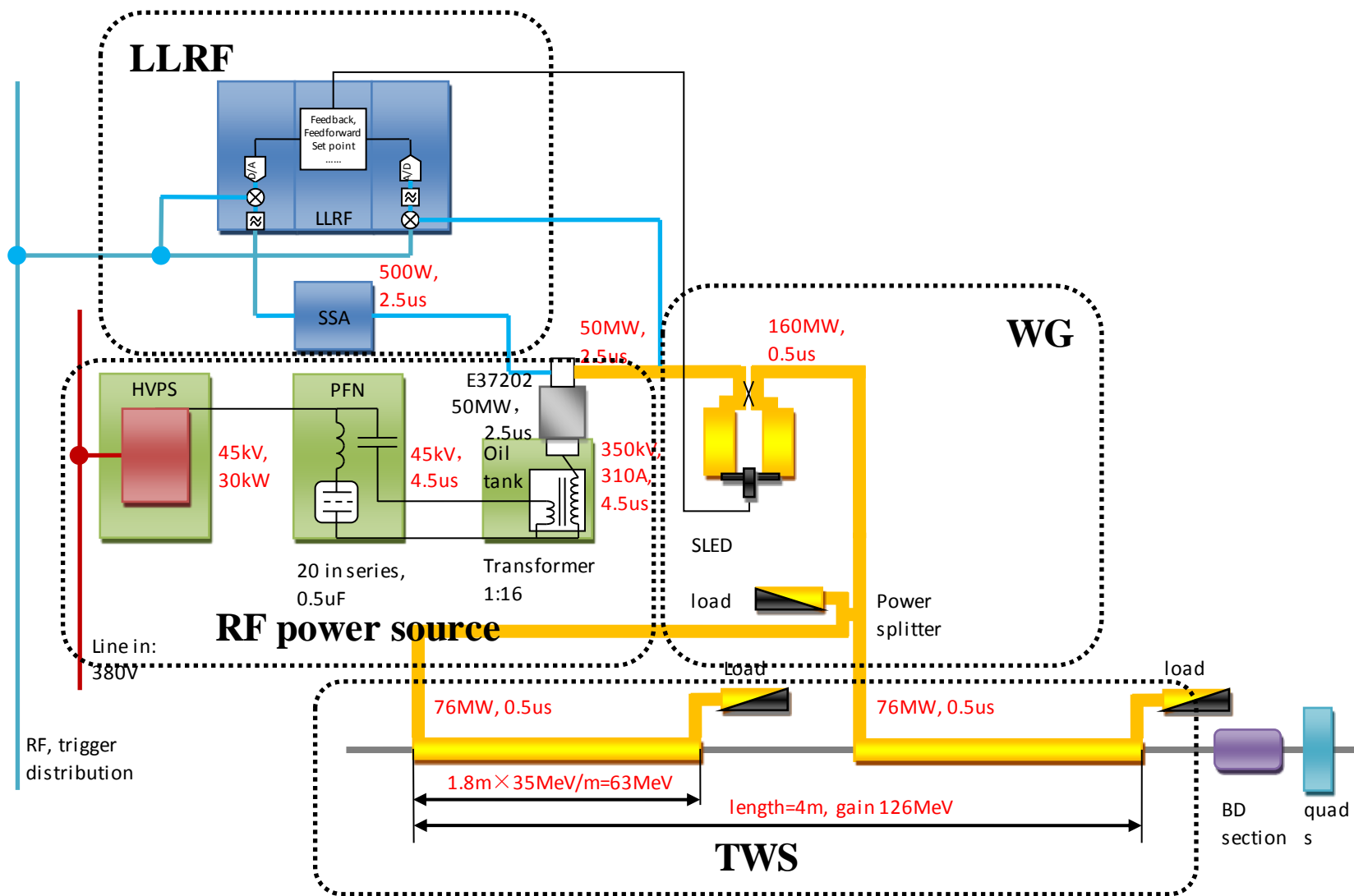
Energy gain per RF station / Gradient

- >126 MeV per RF station
- <5.5 m per cell (include the BI, Magnets, ...)
- ~35MV/m

Stability of the phase and amplitude

	error	dE(%)	dI(%)	dt(fs)
inj_arr	0.25ps	0.031	6.7	10.4
inj_Q	5%	0.030	1.5	23.6
L1_pha	0.09deg	0.061	3.2	88.1
L1_volt	0.04%	0.022	0.027	31.5
Lx_pha	0.4deg	4.9E-3	6.2	6
Lx_volt	0.1%	8.7E-3	0.14	12.6
L2_pha	0.09deg	2.6E-3	0.15	2.1
L2_volt	0.04%	0.016	0.067	10.2
L3_pha	0.18deg	0.048	-	4.6E-6
L3_volt	0.04%	0.020	-	1.6E-6
BC1_R 56	0.02%	8.9E-3	0.13	16.0
BC2_R 56	0.02%	2.8E-3	0.021	-5.0
total		0.096	9.8	100

C-band RF system

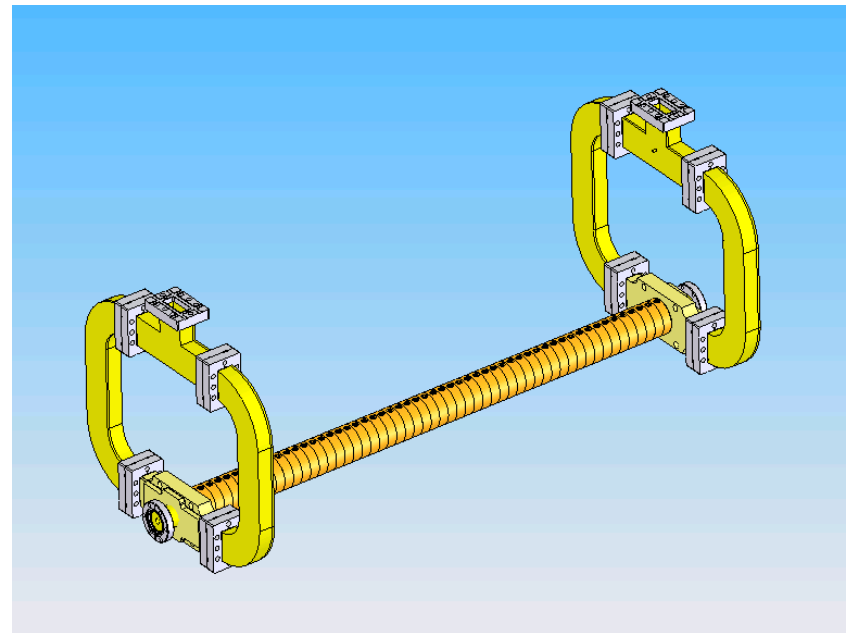
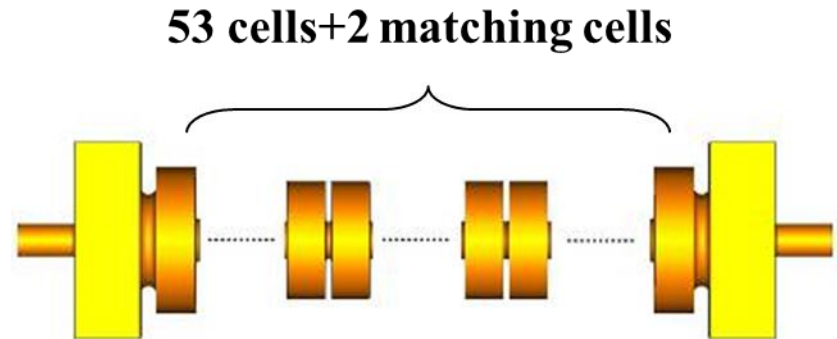


The RF structures

- The accelerating structure
 - The 1m, CI, $2\pi/3$ prototype I (for understanding the design, fabrication, tuning, and high power test)
 - The optimization of the 1.8m structure
 - The 0.5m, CG, $4\pi/5$ prototype II (for understanding the design, fabrication, tuning, and high power test)
- The RF compressor
 - The design and preliminary RF measurements

C-band TWS – the prototype I

- Frequency: 5712MHz
- Length: about 1m, 53 regular cells and 2 matching cells
- Mode: $2\pi/3$
- Constant Impedance
- Group velocity: $1\% * c$
- Mode launch coupler



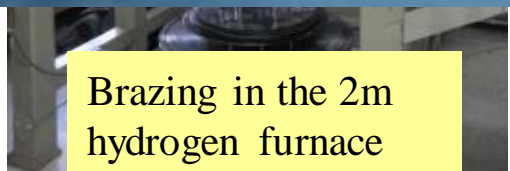
Fabrication (Beijing Institute of Vacuum electronics technology)



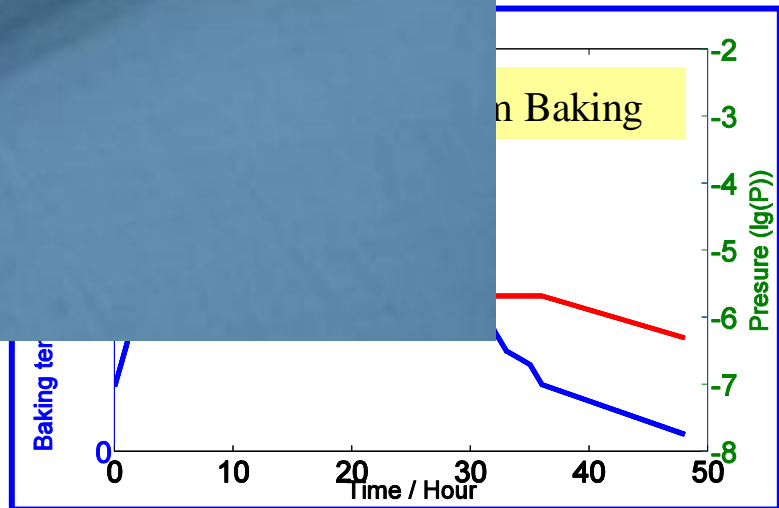
Assembling for Ag-Cu brazing



Leak checking

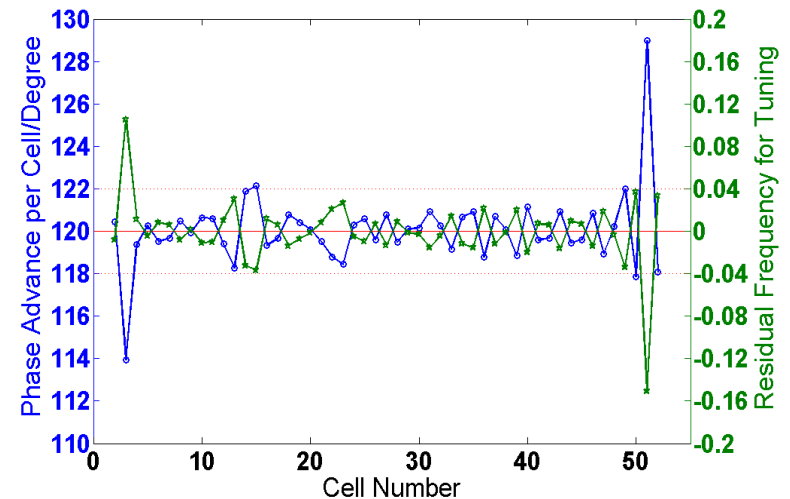
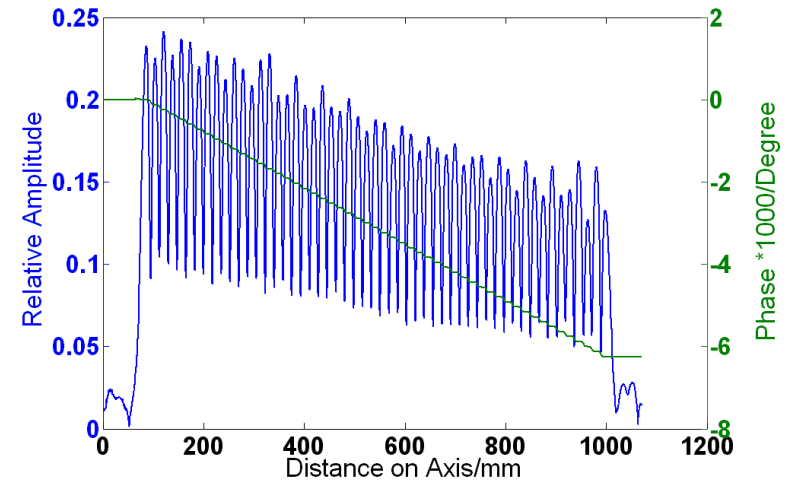
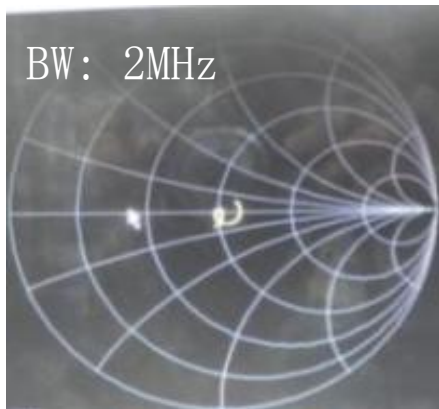


Brazing in the 2m hydrogen furnace

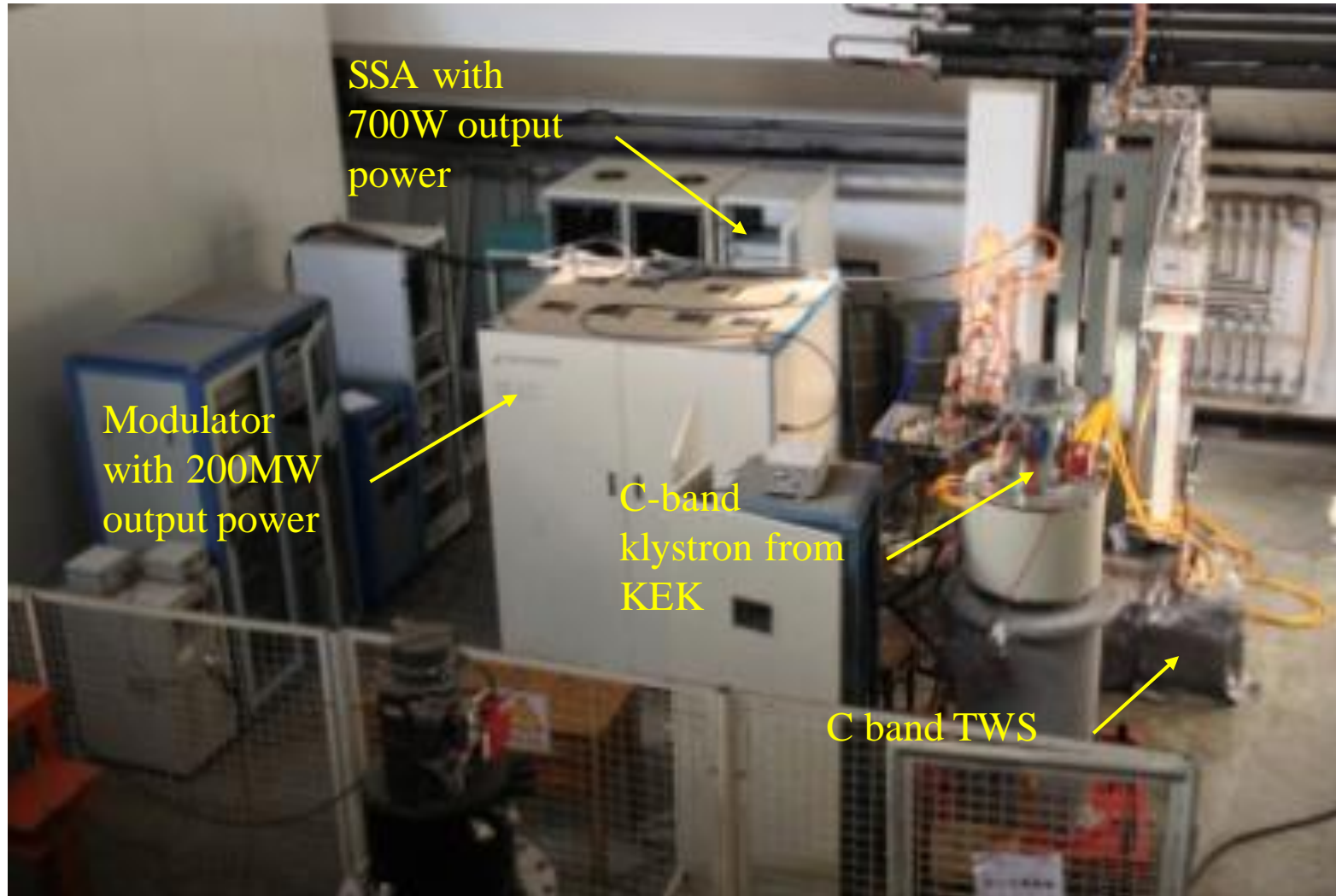


Tuning

- VSWR: 1.05 @ 5712MHz, < 1.2 within 2MHz BW
- The field amplitude drops along the structure, according to the CI TWS
- The phase advance error is < 2 degrees between any two cells

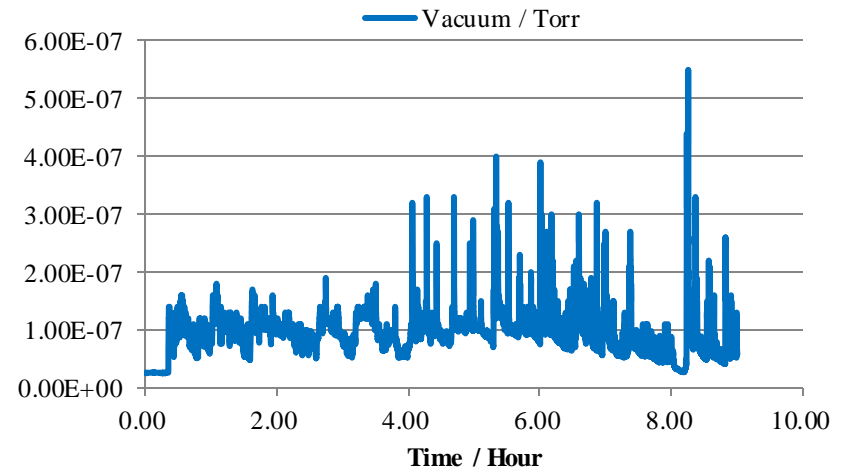
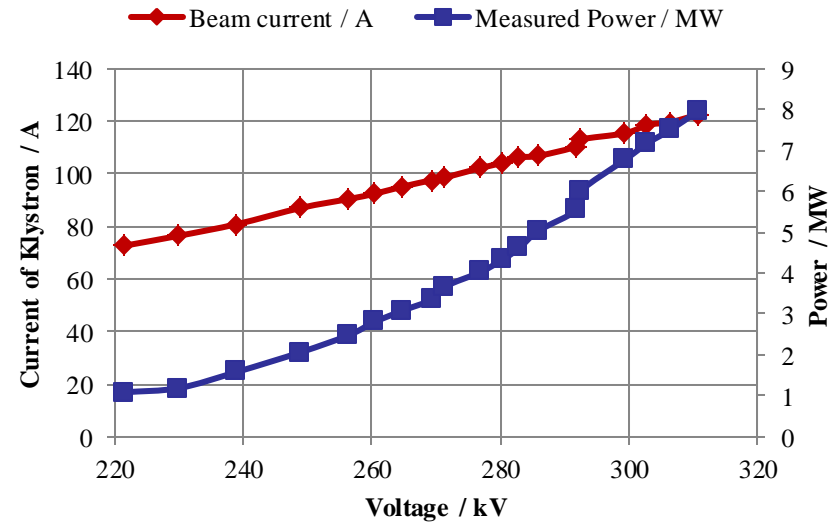


High power test setup

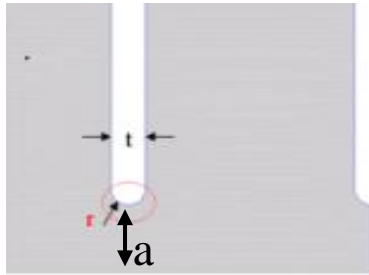


High power test results

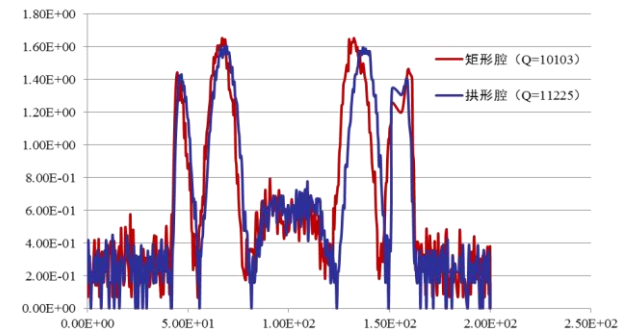
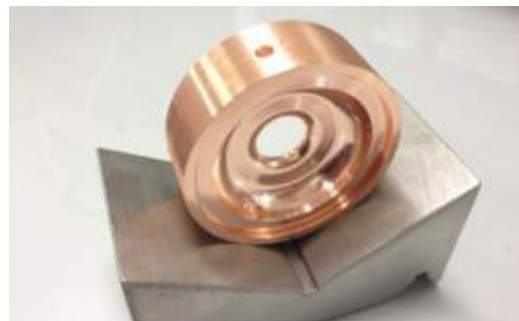
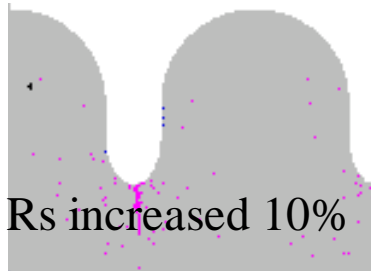
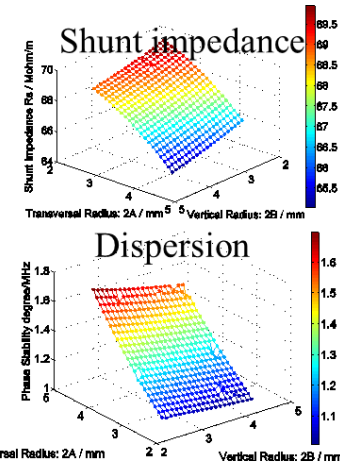
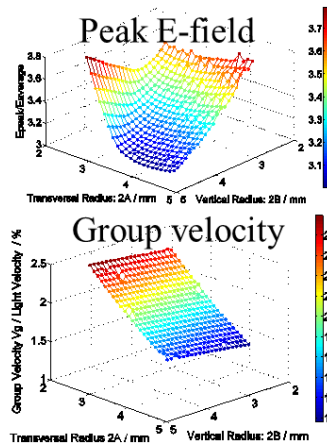
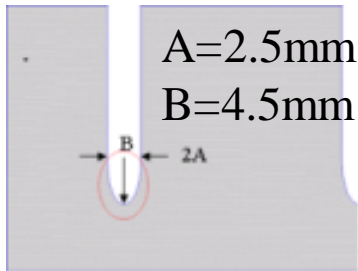
- 8 MW was measured at the output of the klystron. The estimated gradient is about 20MV/m at the accelerating structure
- Several breakdowns was observed from the vacuum pressure monitor
- We discussed with KEK colleagues on the status of this klystron, and some conclusion has been made that there should be some calibration problem on the HV capacitor divider.



The optimization of the C band accelerating structure

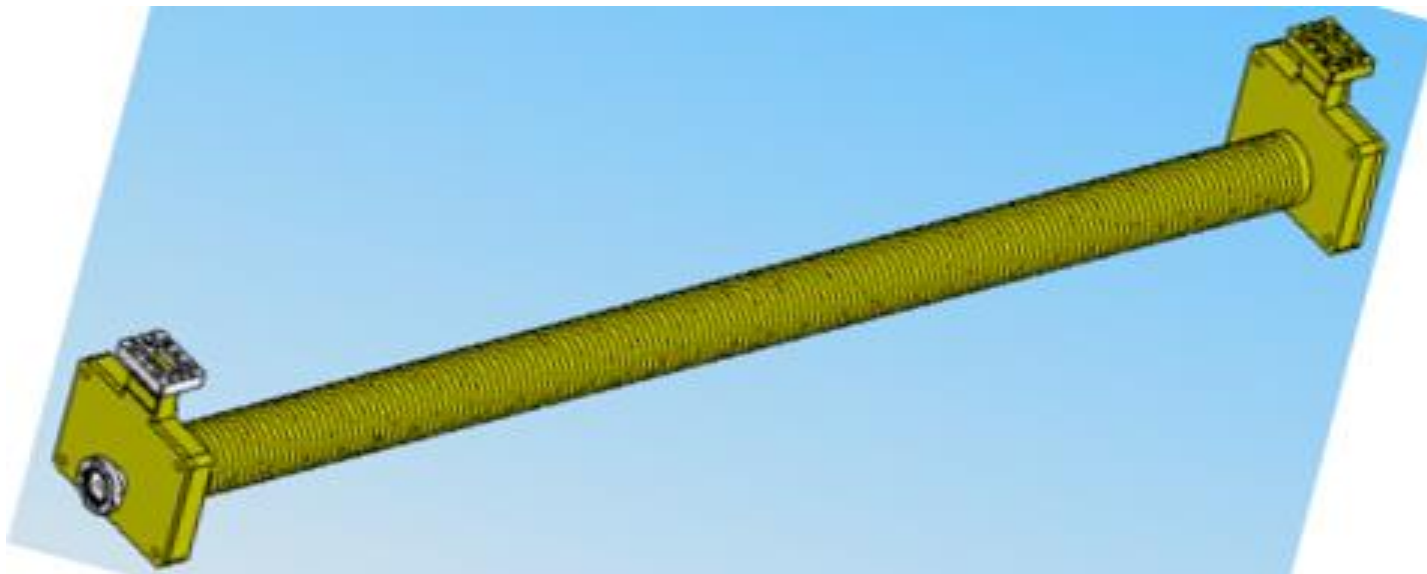


Mode	Group velocity V_g/c %	Rsh $M\Omega/m$	Quality factor Q	Dispersion $d\theta/df$ ° /MHz
$2\pi/3$	3.441	64.50	9943	0.61
$3\pi/4$	2.846	63.43	10754	0.84
$4\pi/5$	2.356	69.96	11202	1.07
$5\pi/6$	1.986	69.31	11488	1.32



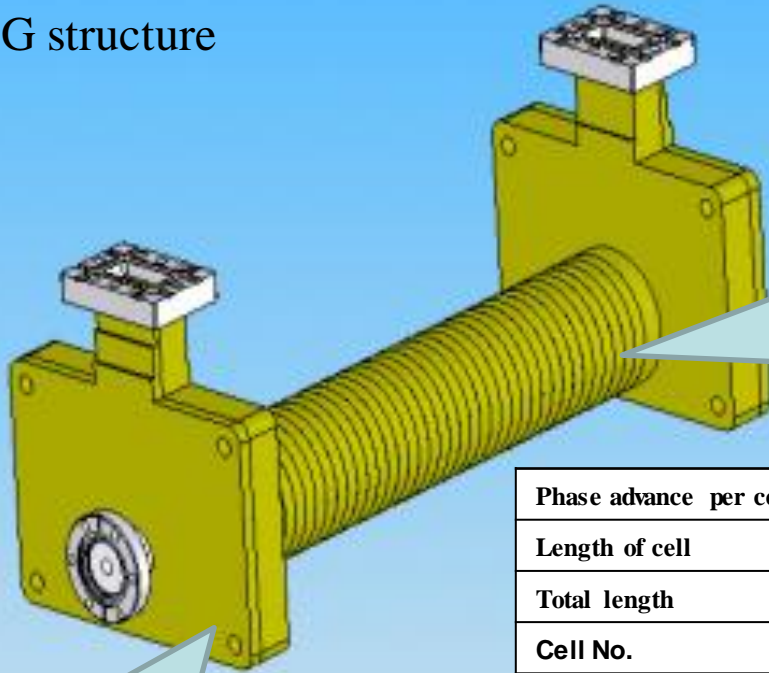
The parameters of 1.8m C-band TWS

CG/CI	CG	Width of iris: t	5mm
Phase advance per cell	$4\pi/5$	Peak field E_{peak}/E_0	2.79 ~ 2.39
Length of cell	20.988mm	Shunt impedance: R_s	62 ~ 78.4 Mohm/m
Cell No.	79 cells + 2 matching cells	Quality factor: Q	11848 ~ 11648
Total length	About 1.8m	Group velocity : v_g/c	2.4% ~ 0.95%
Average 2a	15mm	Filling time	372ns
Elliptical tip radius: 2B/2A	9mm/5mm	Attenuation factor: τ	0.569

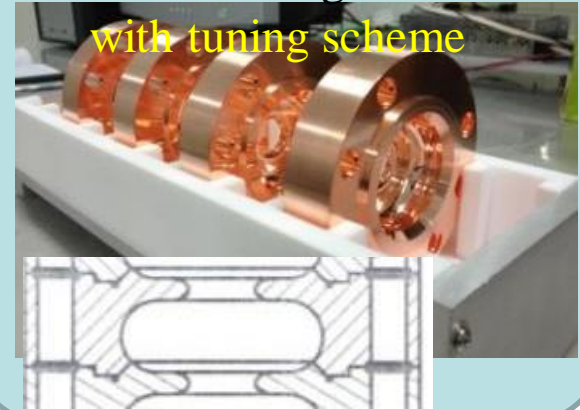


C-band TWS – the prototype II

CG structure



Inner cooling channel
with tuning scheme



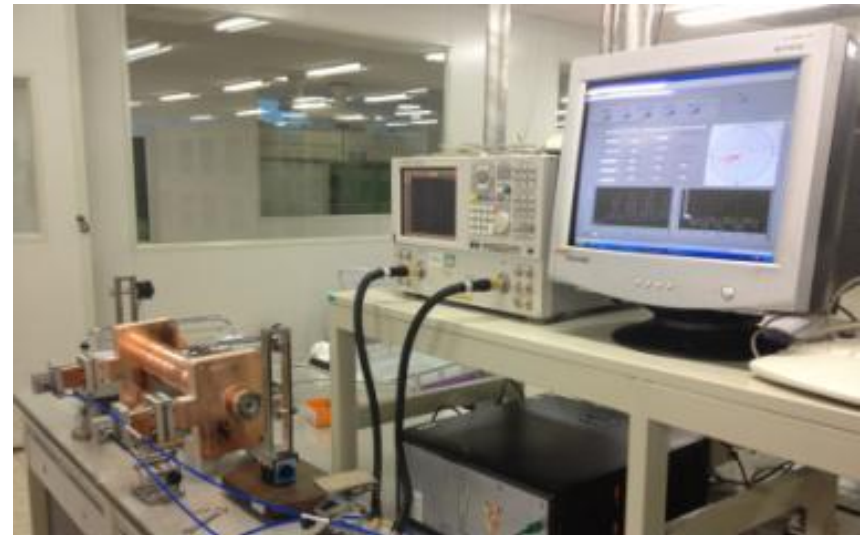
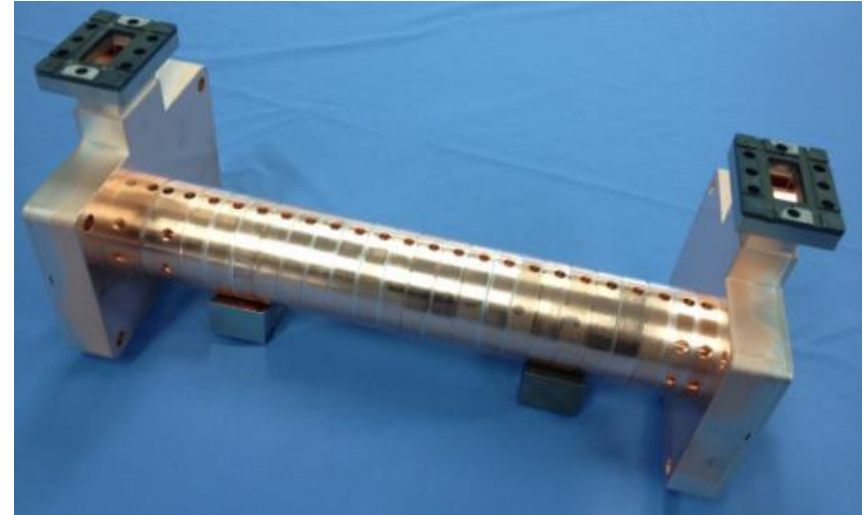
Compact coupler



Phase advance per cell	$4\pi/5$
Length of cell	20.988mm
Total length	0.6m
Cell No.	20 (70 th ~79 th)
$2a/mm$	13.94 ~ 12.85
Width of iris: t	5mm
Peak field E_{peak}/E_0	2.47 ~ 2.39
Shunt impedance: R_s	73.3 ~ 78.4 Mohm/m
Quality factor: Q	11700 ~ 11648
Group velocity : v_g/c	1.3% ~ 0.95%
Filling time	126ns
Attenuation factor: τ	0.193

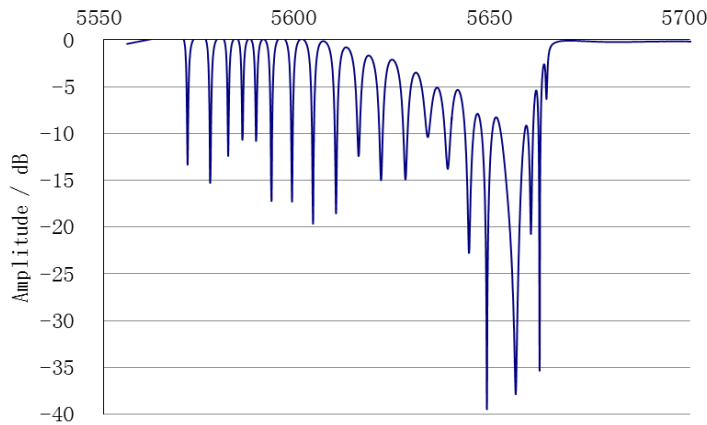
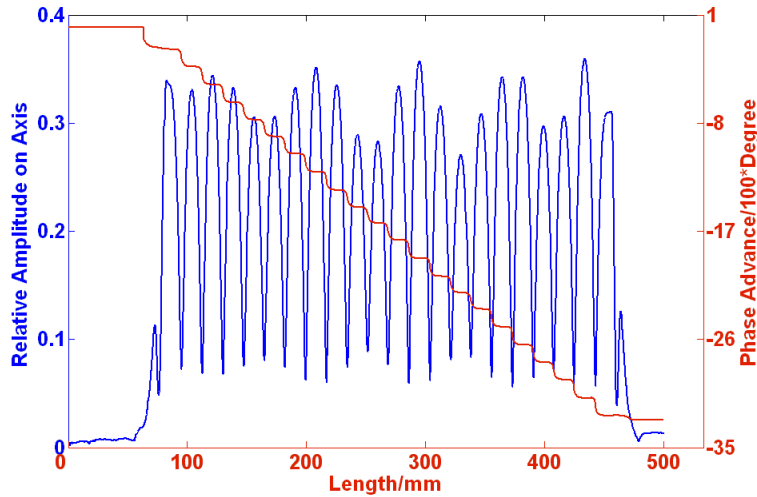
Status

- The regular cells are overcutted. The average frequency is about 5655.5MHz, while the matching cells' are kept at 5712MHz
- A small perturbation is added to the matching cavity to reduce to frequency during the tuning

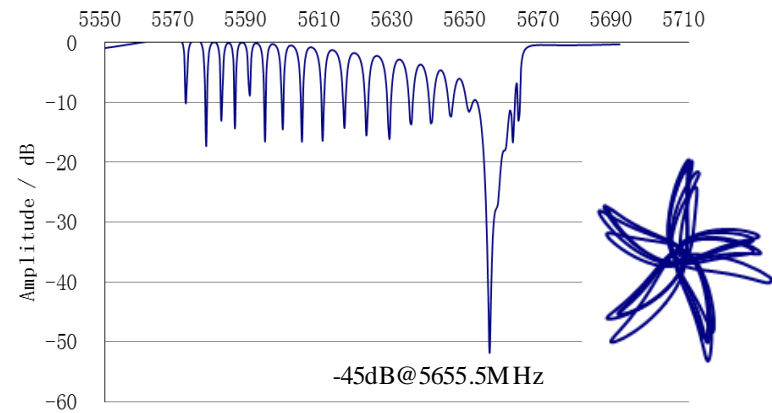
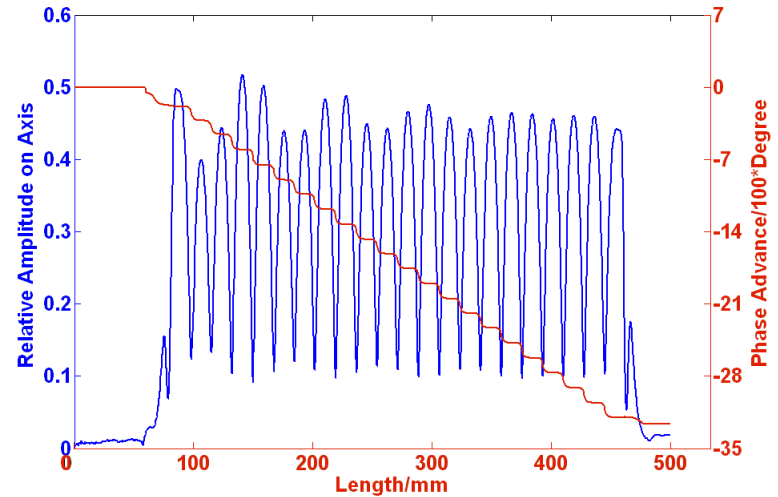


Tuning results- Preliminary

Before tuning

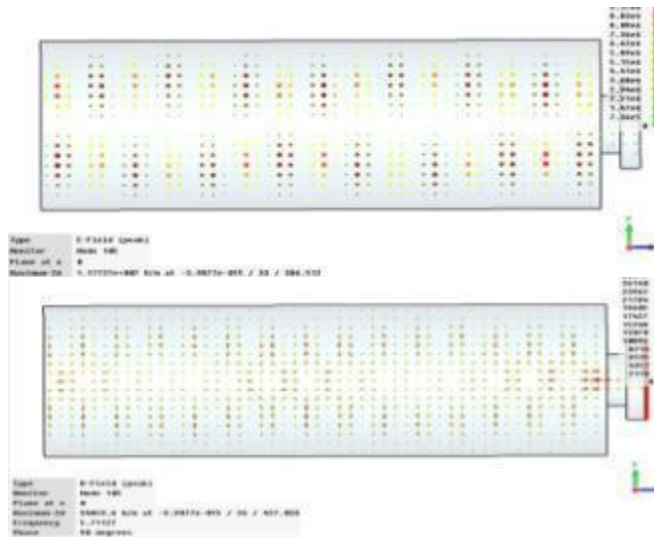
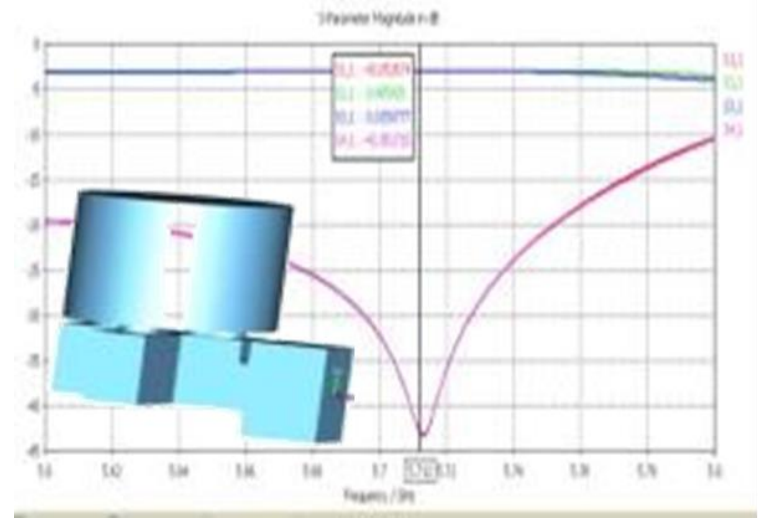
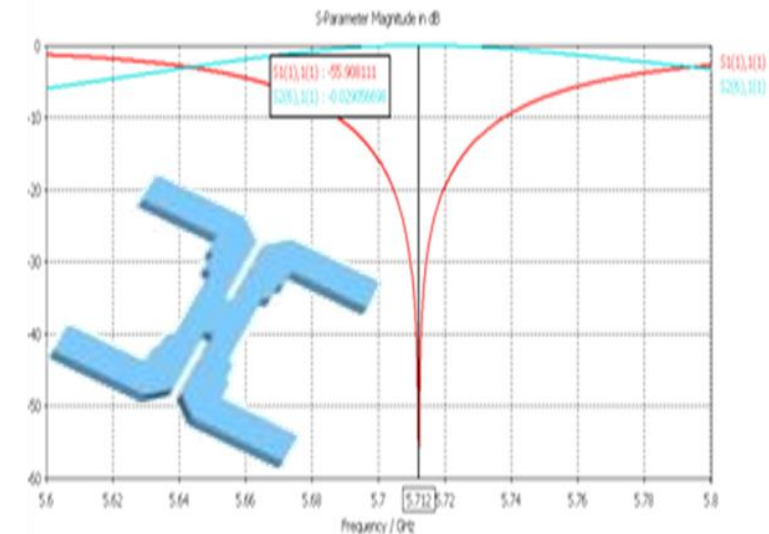


After tuning

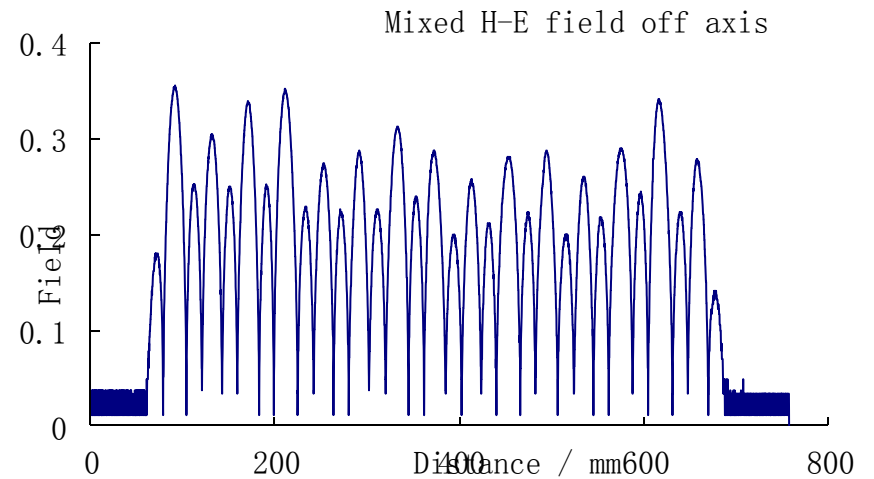
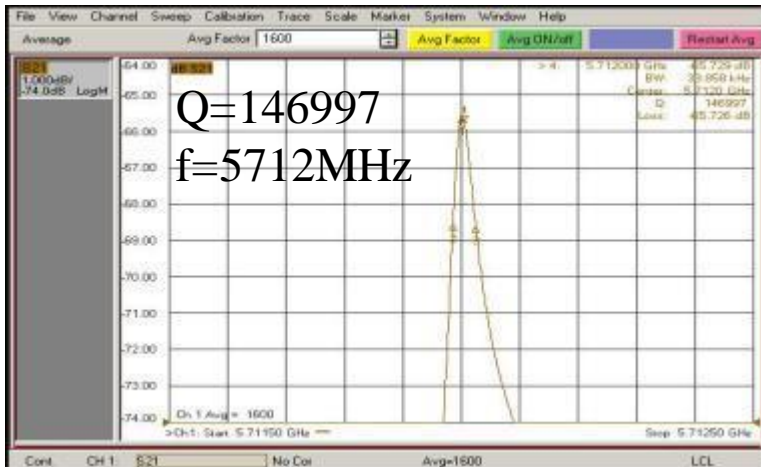
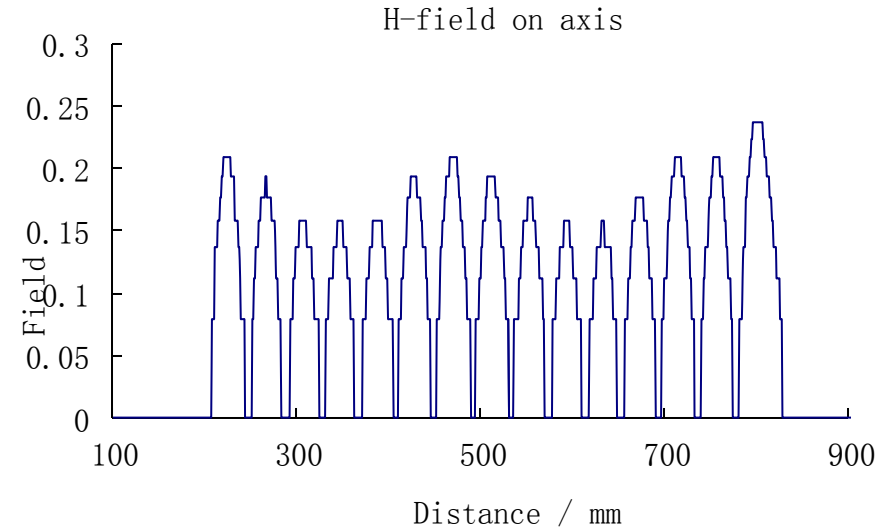


RF compressor

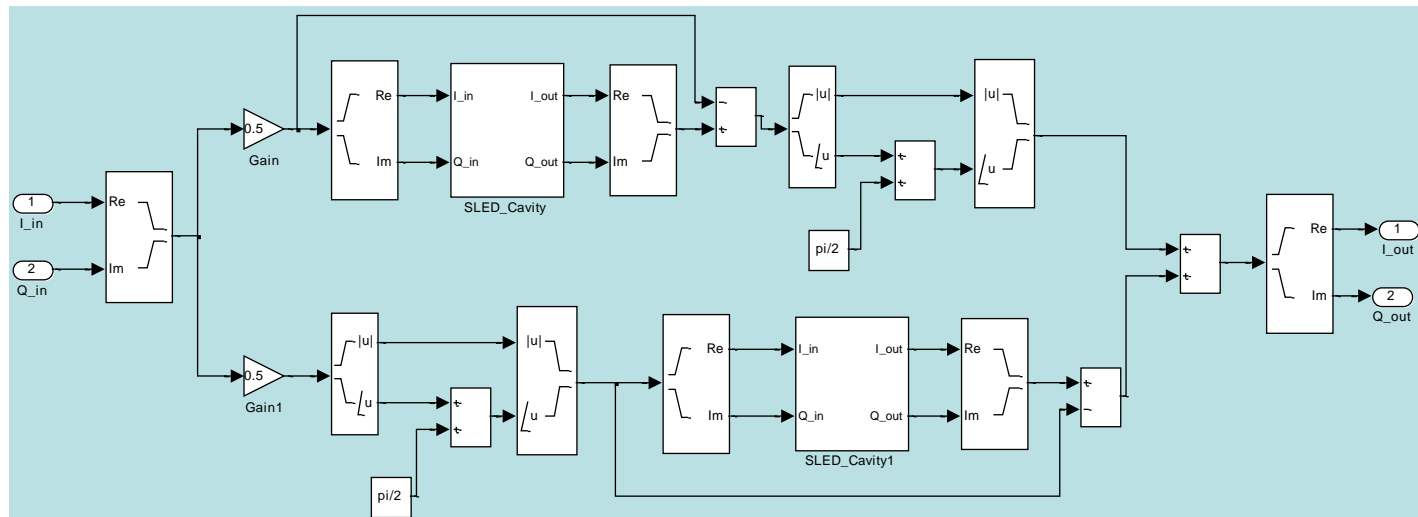
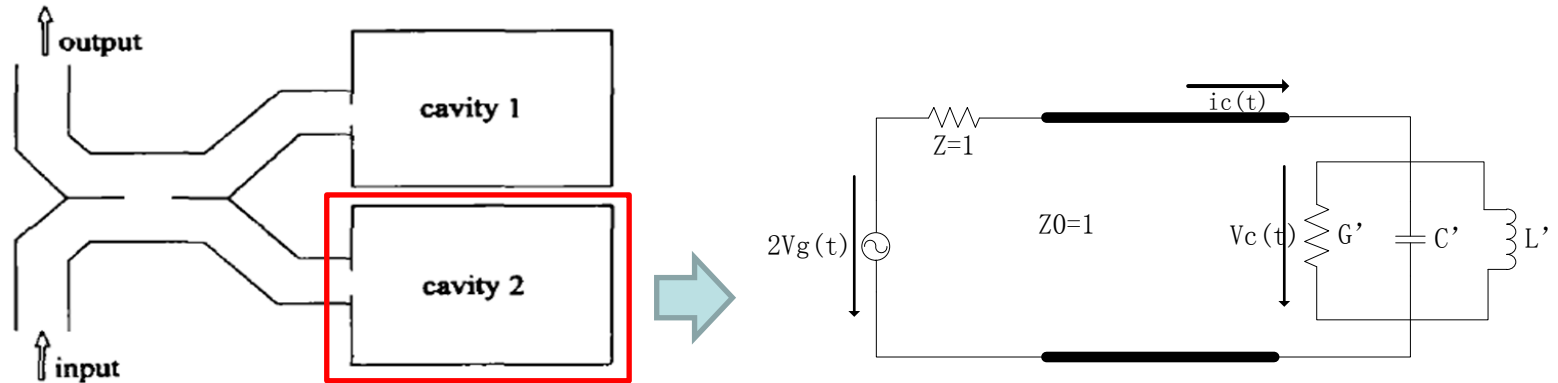
- SLED I type RF compressor is adopted
 - Cavity: TE_{0,1,15}
 - Mode convertor: 4-ports
- The RF design value
 - Q₀: 1.8×10^5
 - β : 8.5
 - power gain: 3.2 (non flat-top)



TE_{0,1,15}

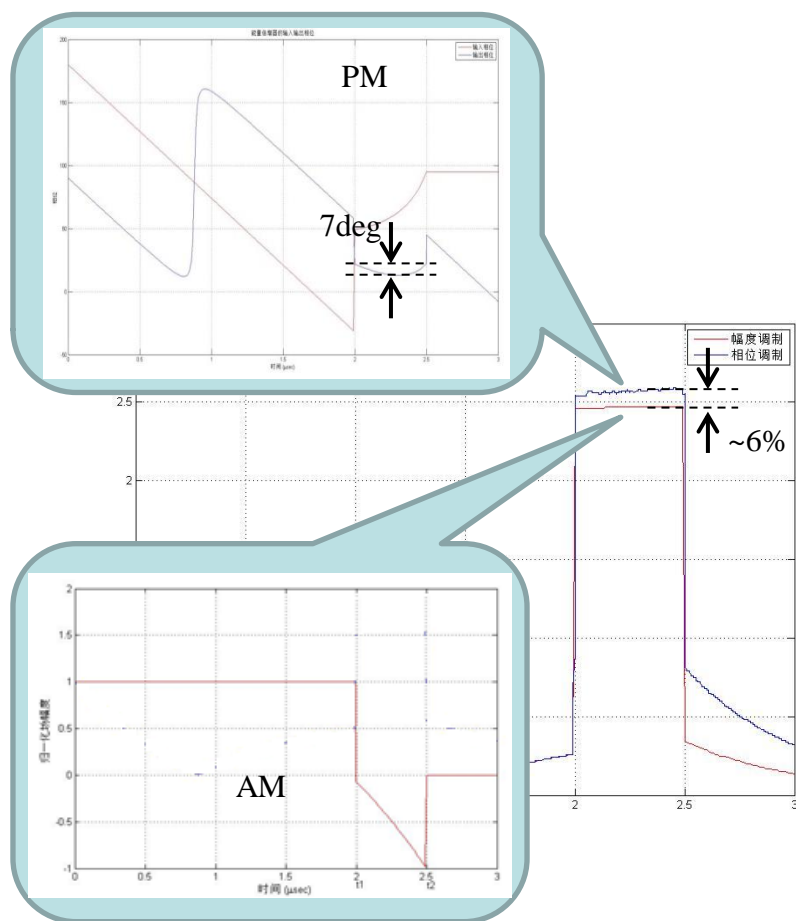


Modeling SLED in low level RF system

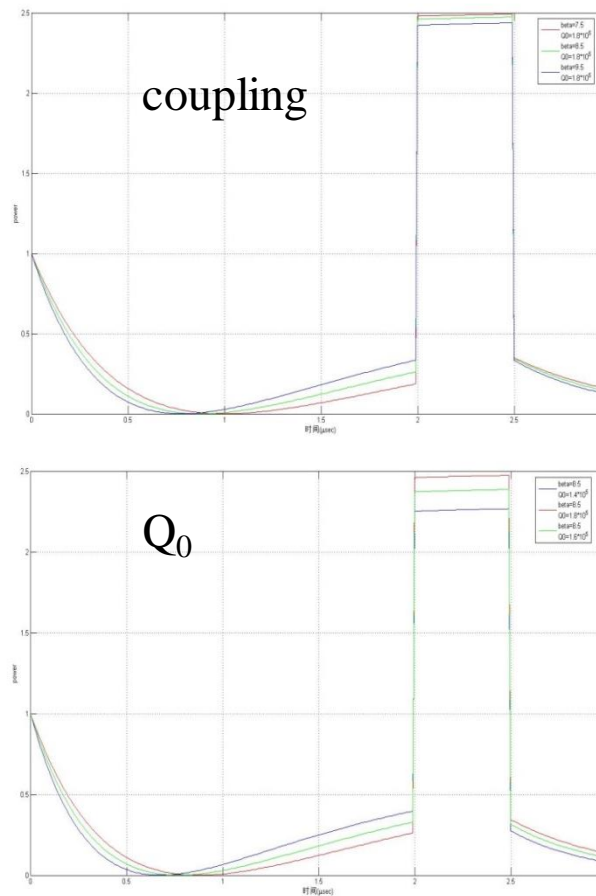


Simulation

Flat-top



Error study - preliminary



Future work on the C Band system

- 2015.6, Finish the installation of the linac
- 2014.6, Finish the high power test of the C band system
- 2014.3, Finish the integration of the C band system
- 2014.1, Finish the integration of the RF power plant
- 2013.10, Finish high power test of the 1m and 0.5m (**new one**) C band TWS using the KEK klystron
- 2013.9, Send one person to CLIC to learn high gradient processing
- 2013.8, Fix the LLRF design and start hardware purchasing
- 2013.8, Sign the contract for the RF compressor
- 2013.7, Sign the contract for the new C band klystron and accessories
- 2013.6, Sign the contract for two 1.8m C band TWS
- 2013.6, Sign the contract for the modulator

Summary

- With the efforts of all the colleagues, the 1m CI and 0.5m CG C band accelerating structures have been cold tested.
- During the high power test of 1m CI structure, a gradient of 20MV/m has been realized. More power is expected after reconfiguration of the existing klystron. And both of the structure will be tested to the design value.
- The RF design of C band accelerating structure for SXFEL has been fixed and the successfully high power test of the two prototype structure will provide the proof of the fabrication.
- The RF compressor has been designed and the cold test of the cavity has shown the promising results.
- The C band system will get power at the beginning of 2014 and we could start taking data on the high gradient operation of C band system

Thank you for your attention!

