



Two stage RF pulse compression

Ping Wang, Jiaru Shi, Huaibi Chen

HG2017, 11-June-2016, IFIC (CSIC-UV) Valencia, Spain



Outline

- **Background**
- Two stage pulse compression
- RF design and fabrication
- Upgrade of the S-band test stand
- Summary and plan





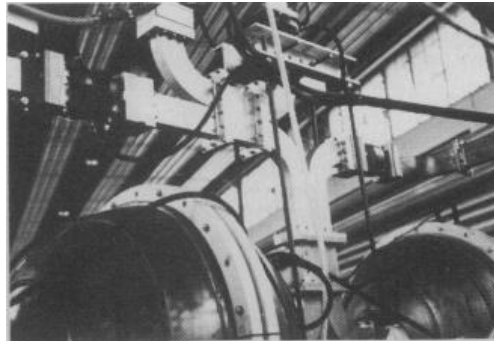
SLED type pulse compressors

1974,SLAC,S-band



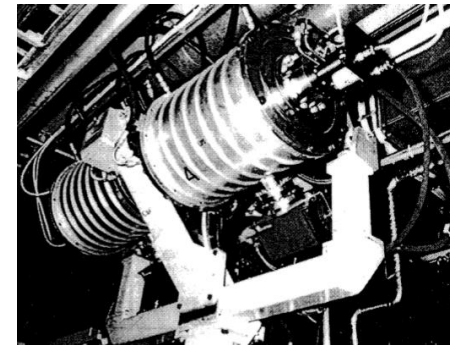
Cylinder Cavity: TE_{015}

1983,CERN,S-band



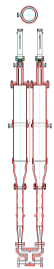
Spherical Cavity : TE_{461}

1984,CERN,S-band



Cylinder Cavity: TE_{038}

2009,CERN&SLAC&CEA,X-band



Cylinder Cavity : TE_{01} & TE_{02}

2013,CERN,X-band



Cylinder Cavity : $TE_{0,1,32}$

2016,SLAC,X-band



Spherical Cavity : TE_{114}

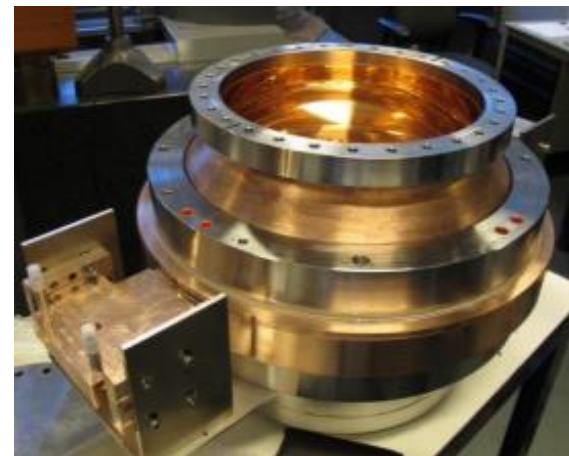
- [1] 1974-SLAC-Z. D. Farkas-A METHOD OF DOUBLING SLAC' s ENERGY
- [2] 1983-A. Fiebig and R. Hohbach STUDY OF PEAK POWER DOUBLERS WITH SPHERICAL RESONATORS
- [3] 2004-CERN-Note-High-power_Microwave_Pulse_Compression_of_Klystron
- [4] 2010-RuPac-A 12 GHZ PULSE COMPRESSOR AND COMPONENTS FOR CLIC TEST STAND
- [5] 2016-ipac16-Wanjuwen-R&D FOR A SUPER COMPACT SLED SYSTEM AT SLAC





BOC type pulse compressors

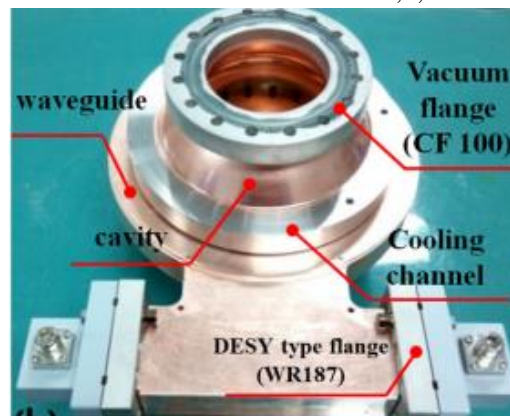
1990, Igor, For VLEPP, $TM_{25,1,1}$ 2000, CERN, For CTF3, $TM_{10,1,1}$ 2012, PSI, For SwissFEL, $TM_{18,1,1}$



1994, KEK, For KEKB, TE_{620}



2017, IHEP, $TM_{6,1,1}$



- [1] 1994-KEK-Linac-DEVELOPMENT OF AN RF PULSE COMPRESSOR
- [2] 2013-CERN-Igor-X-band SLED type Pulse Compressor
- [3] 2016-CLIC_Weokshop_PSI_FEL_BOC
- [4] 2017-DESIGN, FABRICATE AND COLD TEST OF A C-BAND BARREL OPEN CAVITY PULSE COMPRESSOR



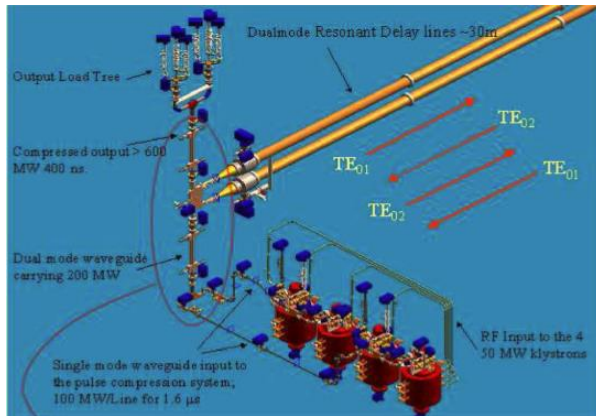


SLED II pulse compressors

2005, SLAC, For NLC
(11.424GHz)

2006, CERN, For CLIC
(30GHz)

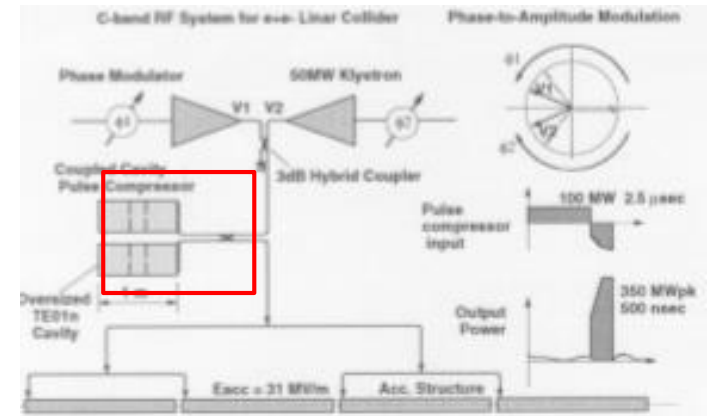
1997, KEK, For e+e- linear collider
(5.712GHz)



SLED II



SLED II



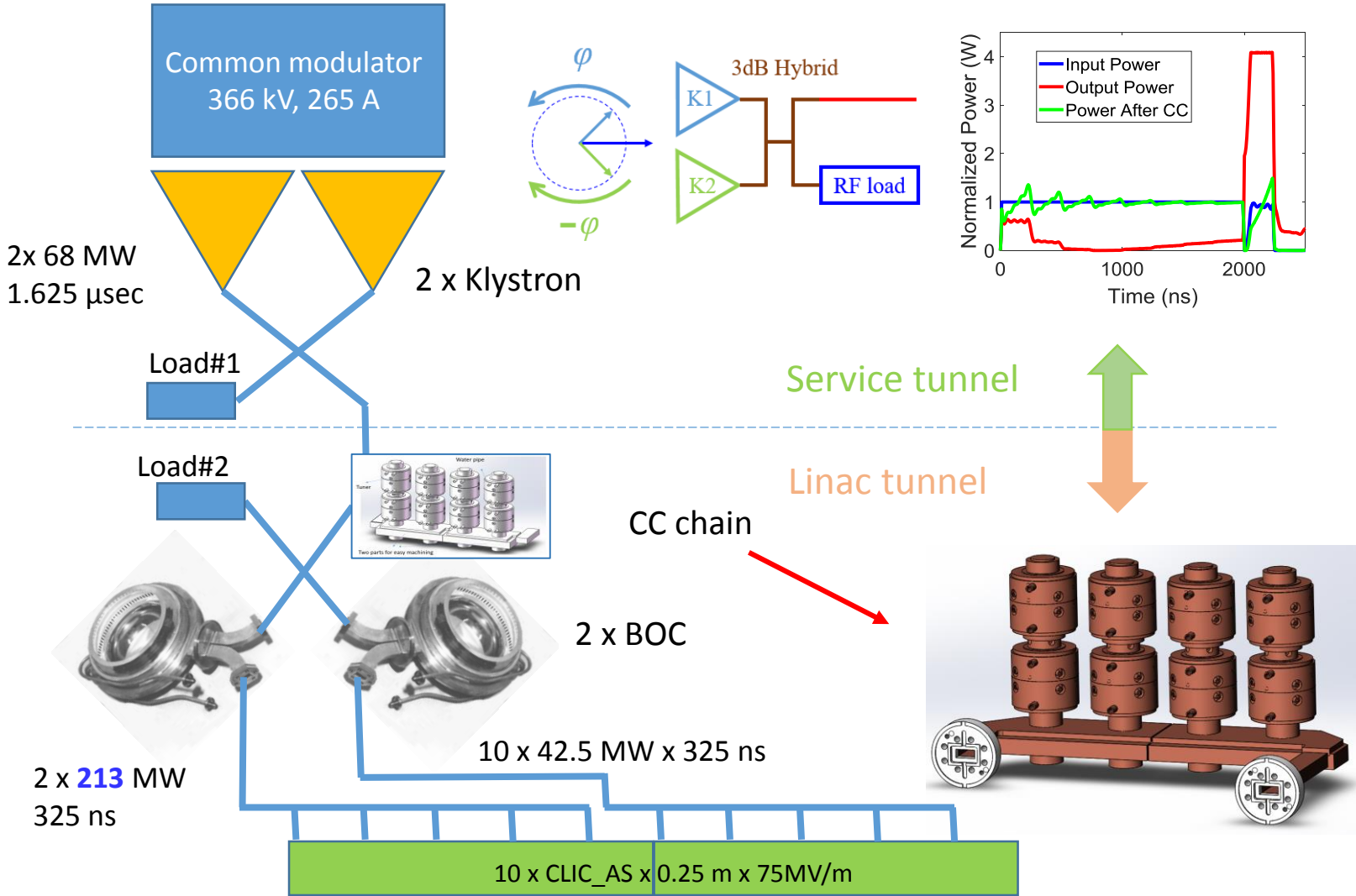
SLED with coupled cavities

- [1] 1997-KEK-T Shintake-IEEE-DEVELOPMENT OF C-BAND RF PULSE COMPRESSION SYSTEM
- [2] 2005-SLAC-SamiG.-PRST-High-power multimode X-band rf pulse compression system for future linear colliders
- [3] 2006-CERN-Igor-EPAC-STATUS OF 30 GHz HIGH POWER RF PULSE COMPRESSOR FOR CTF3





New CLIC'k RF unit layout



[1] I. Syrathev, CLIC Klystron based. Updates 2017, CLIC WS, CERN, March 2017





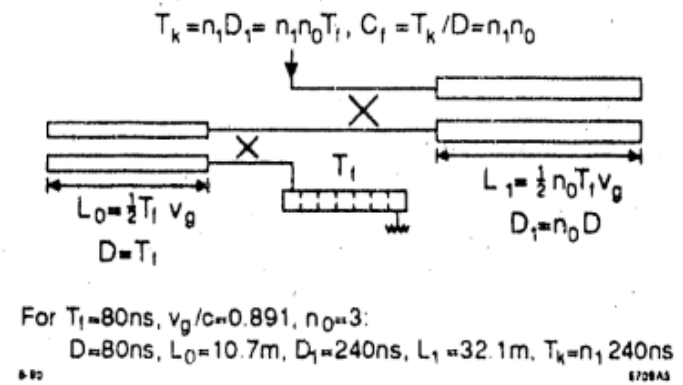
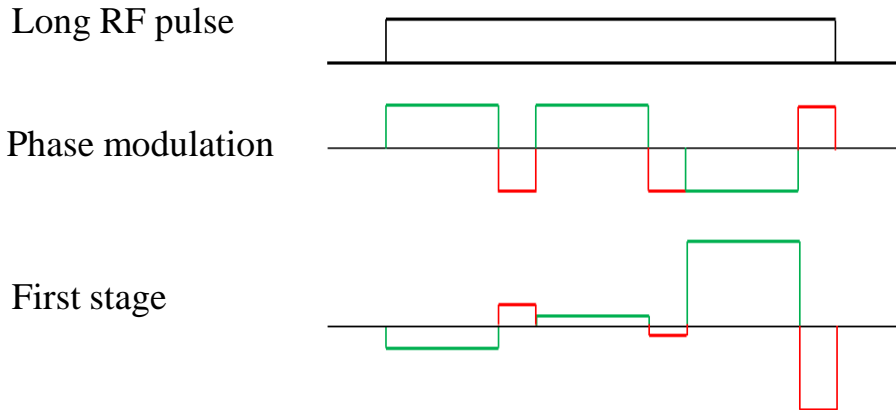
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- Two stage pulse compression
- RF design and fabrication
- Upgrade of the S-band test stand
- Summary and plan

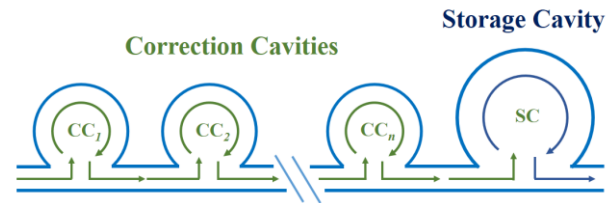
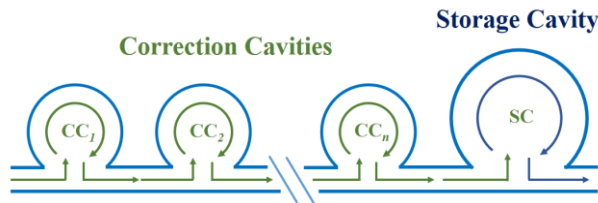




Two stage pulse compressor



Two stage pulse compression based on SLED II



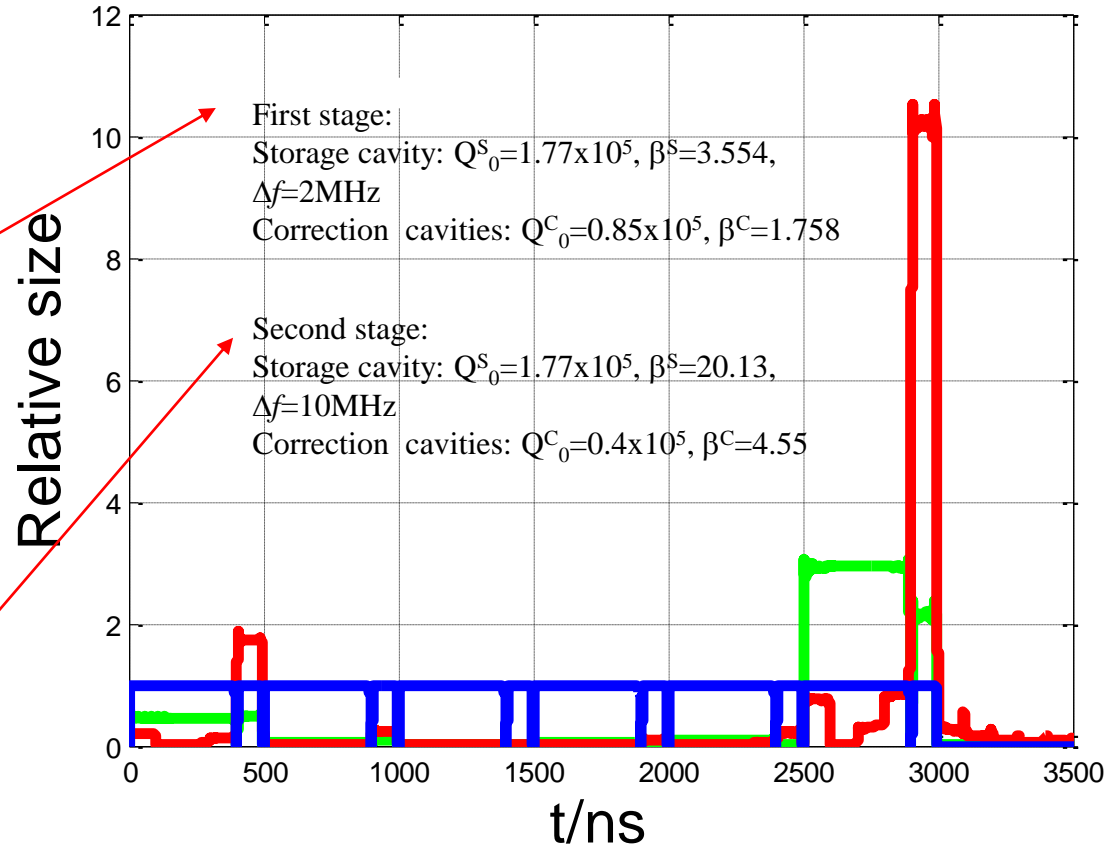
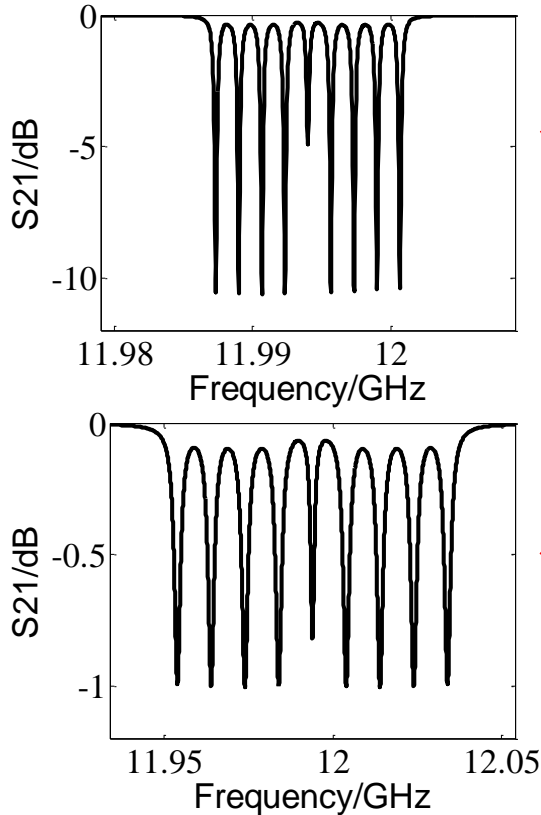
Two stage pulse compression based on pulse compressor with correction cavities





Two stage pulse compressor

- High power gain
- Low input power
- High repetition frequency



The output power is more than 70MW with input power of **only 7MW**.





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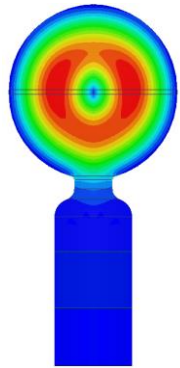




S-band RF design

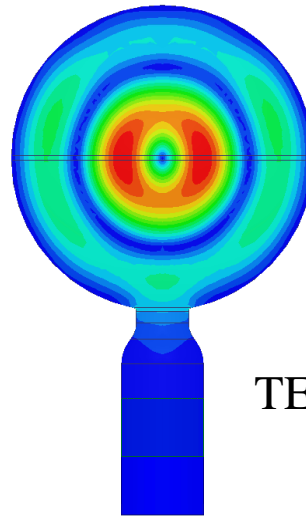
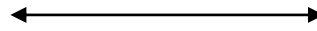
◆ Spherical Cavities

150mm



TE_{111}

260mm



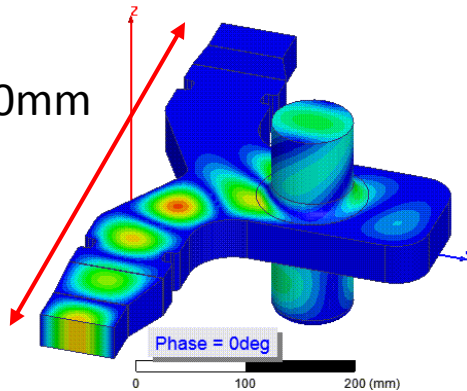
TE_{112}

Large	Q0	Qe	Beta
Eig	100650	14326	7.026
Drive	100830	14320	7.041

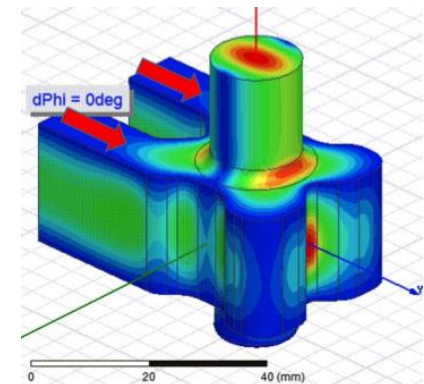
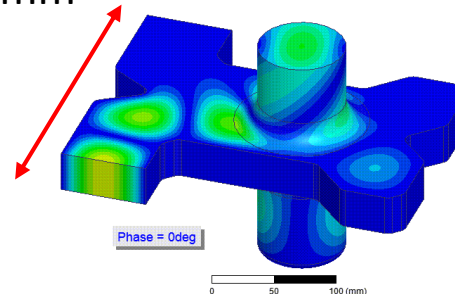
Small	Q0	Qe	Beta
Eig	58811	17150	3.429
Drive	58825	17223	3.415

◆ RF polarizers

530mm



220mm



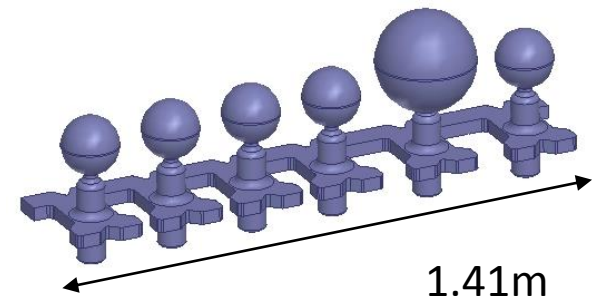
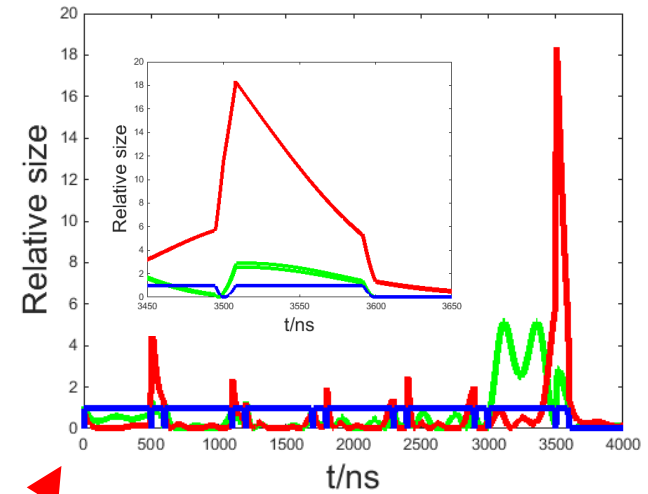
Alexej-2016-CLIC Note 1067





Two stage pulse compressor

	Peak Power Gain	Efficiency
9L&9L	18.7155	42.14%
9L&1L	22.2505	40.94%
9L&1S	21.9955	40.10%
9S&1S	19.2979	35.71%
(1L+8S)&1S	20.6935	37.41%
(3L+6S)&1S	21.2474	38.42%
(1L+6S)&1S	20.3325	35.18%
7S&1S	19.0187	33.60%
(1L+4S)&1S	18.3564	31.07%
(1L+2S)&1S	14.7390	25.32%
3S&1S	13.8318	23.95%



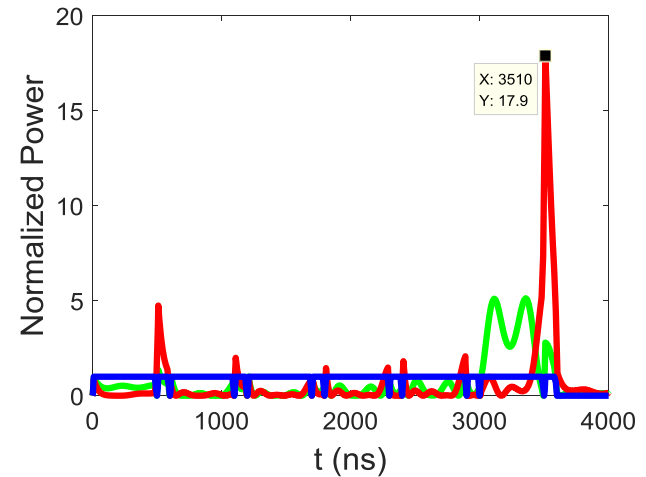
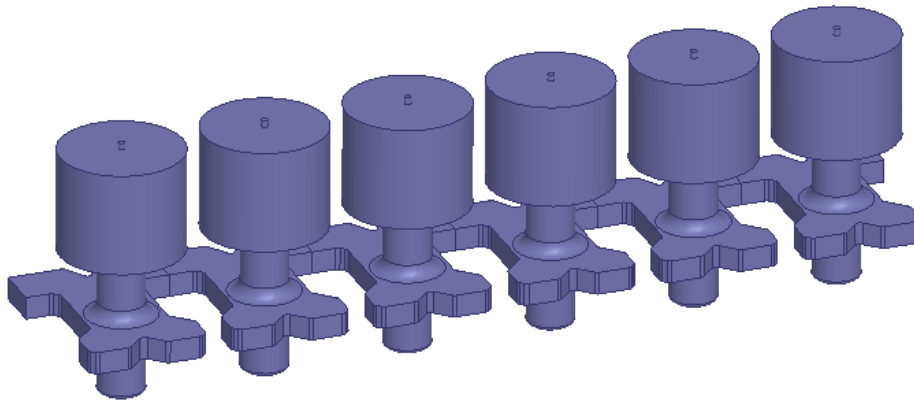
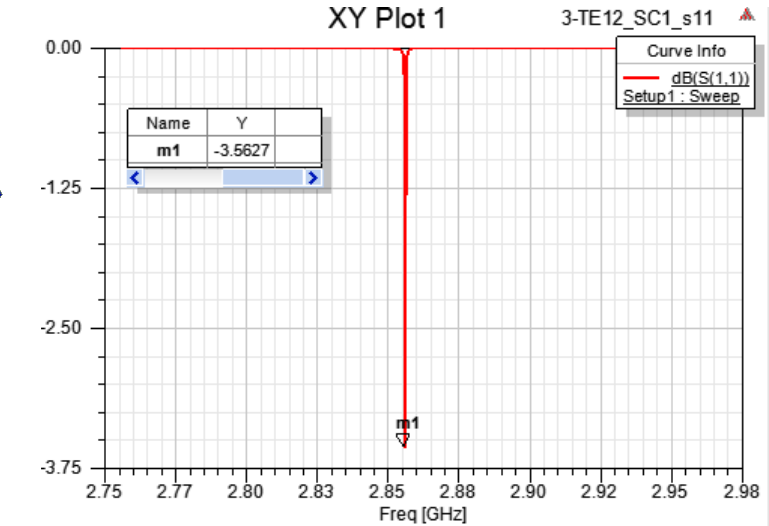
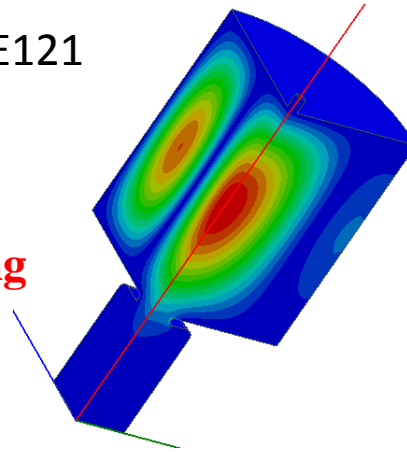


S-band RF design

$Q_0=72,000$
Diameter=190mm
Height=151mm

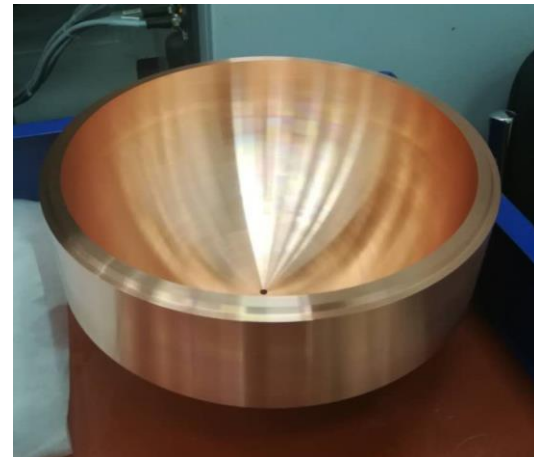
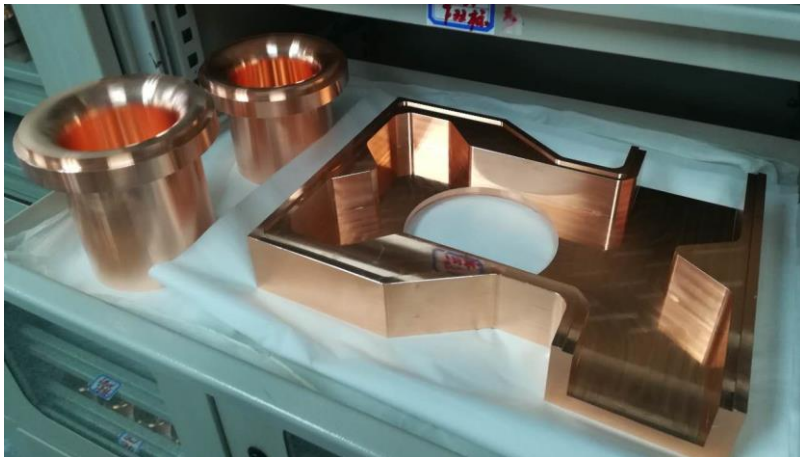
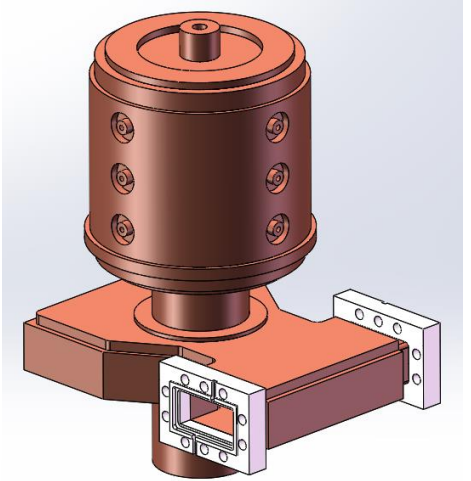
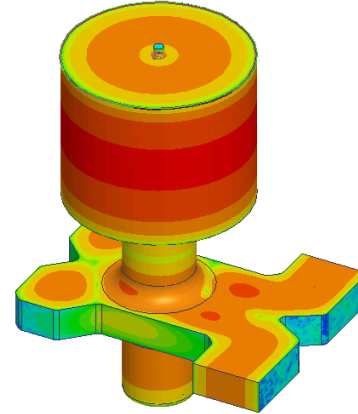
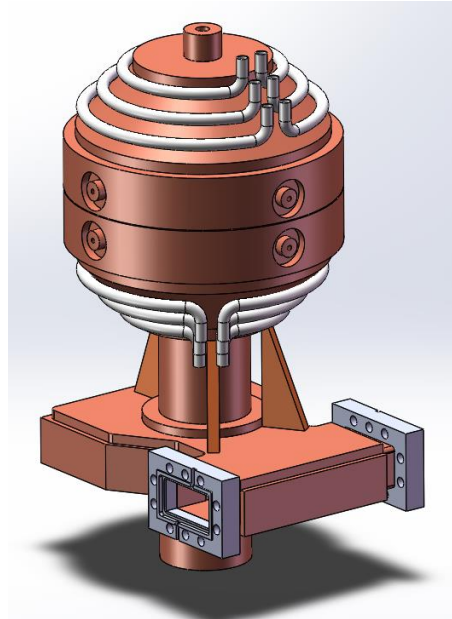
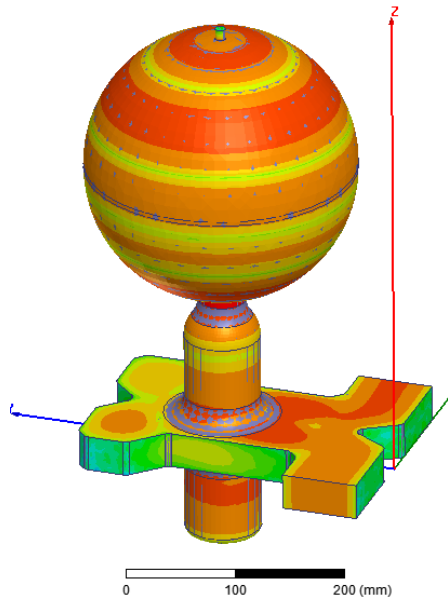
Easy frequency tuning
Easy fabrication

TE121





Cavities fabrication





Outline

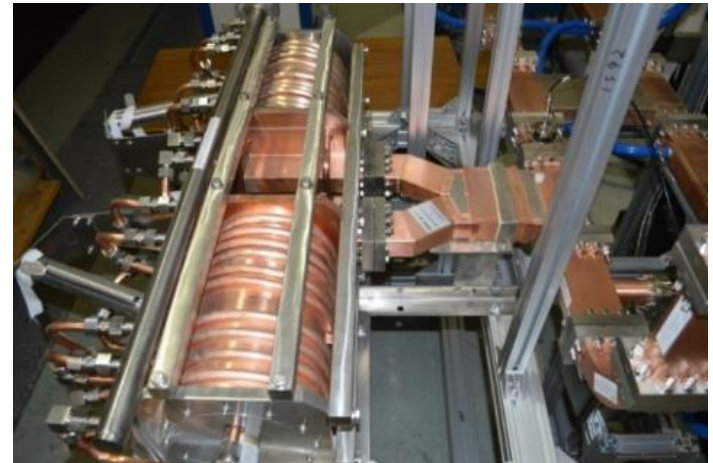
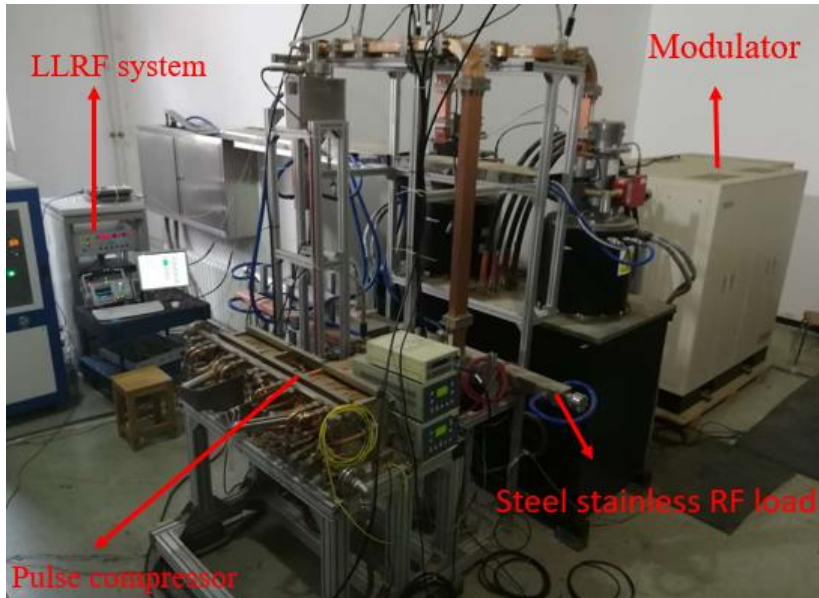
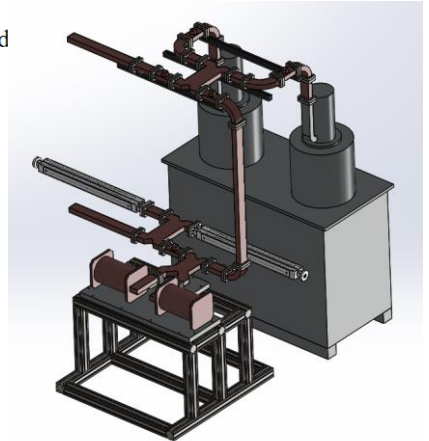
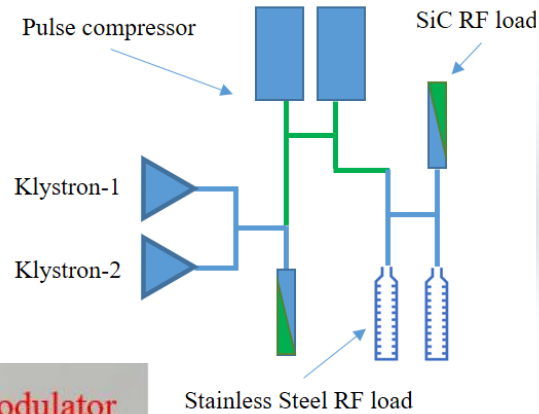
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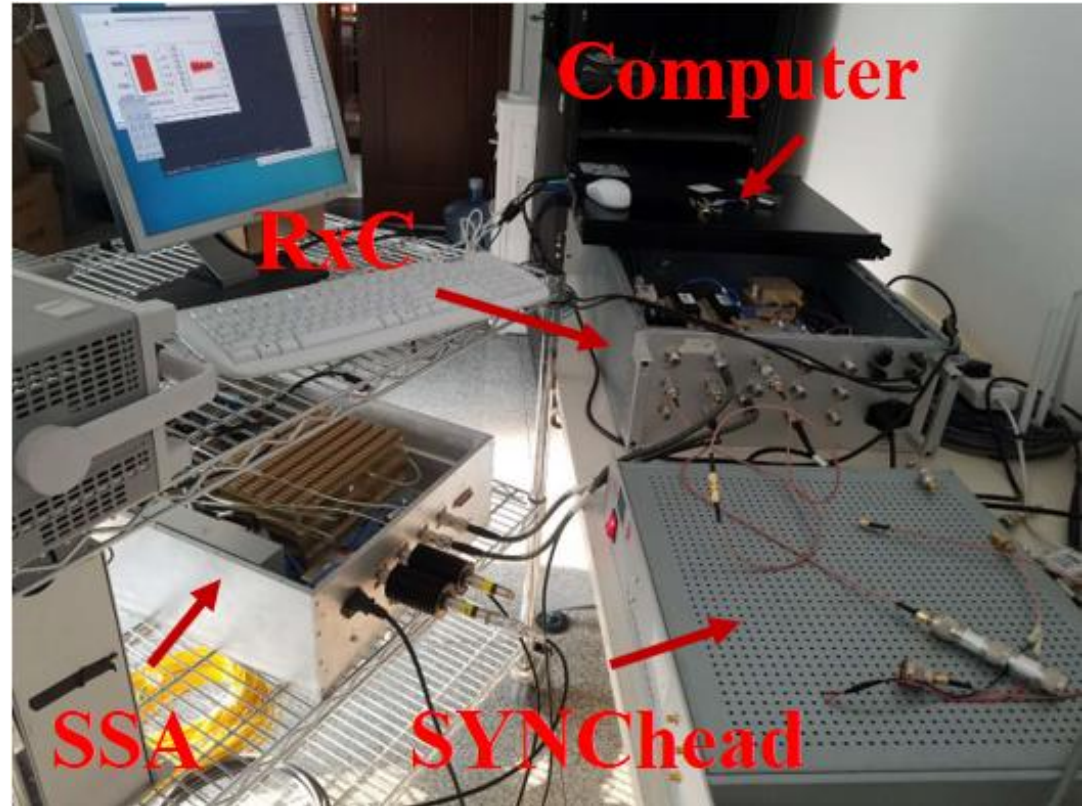
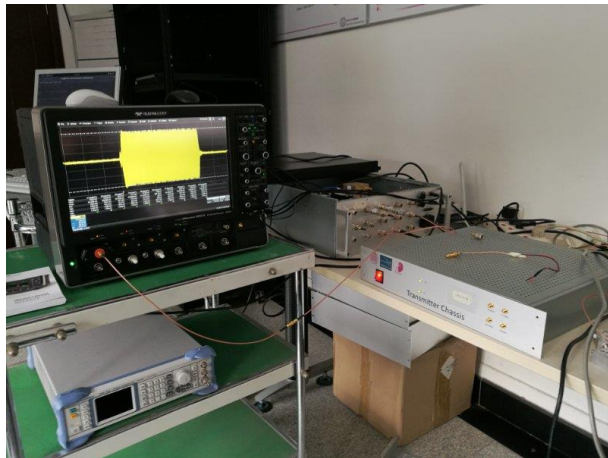
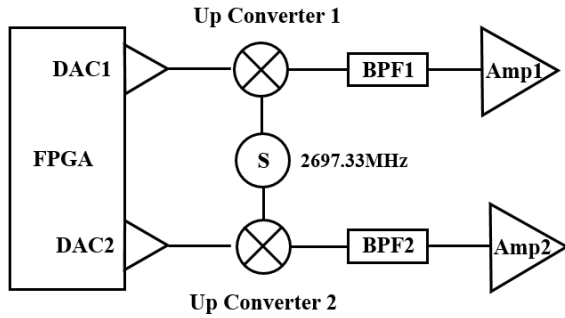
S-band test stand at Tsinghua

- ◆ Double klystrons
- ◆ SLED pulse compressor
- ◆ Stainless steel RF load





Development of LLRF system

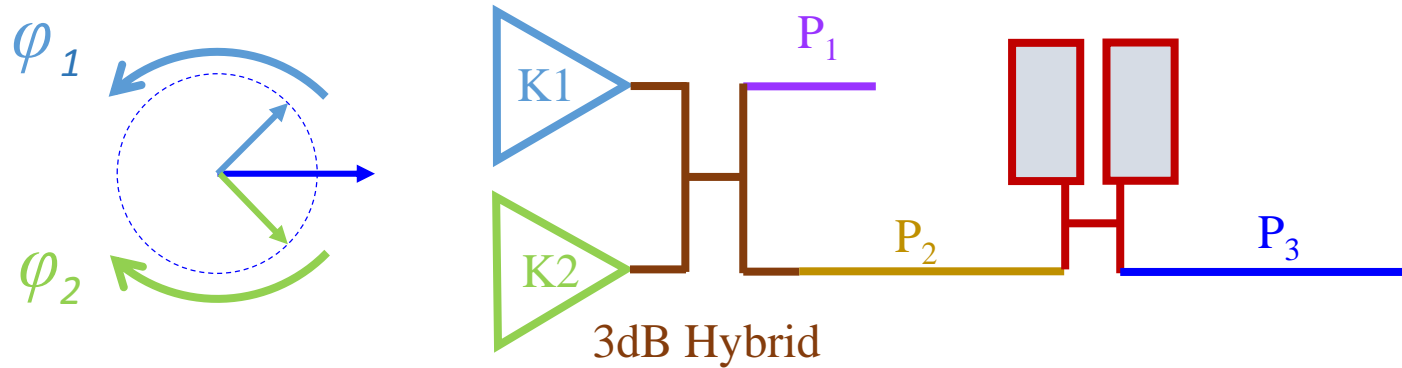


Test of LLRF system

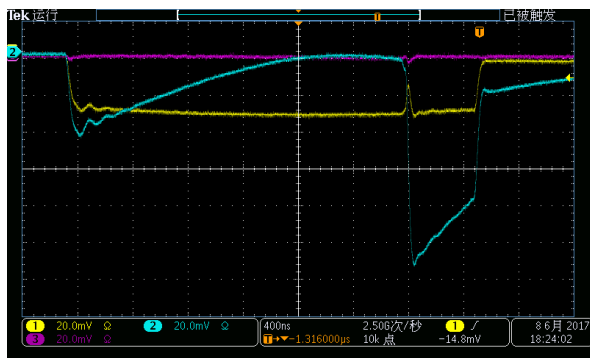




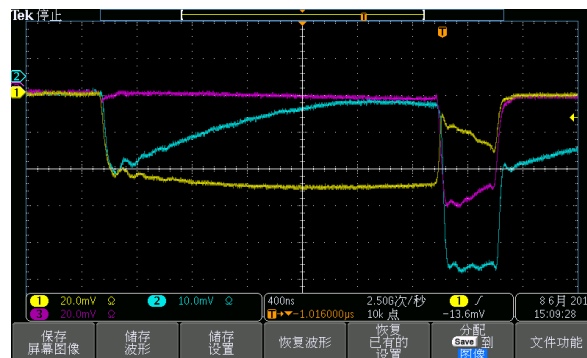
Phase and Amplitude Modulations



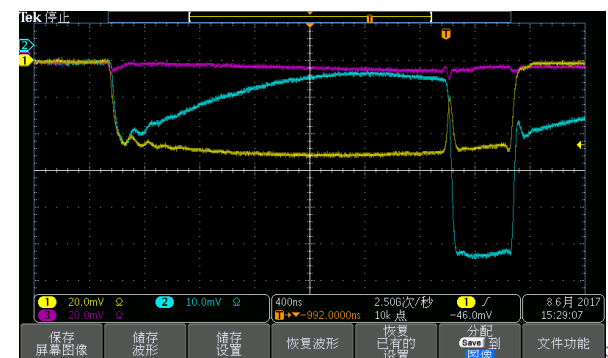
$$\frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 0 \\ \exp[i(\omega t + \varphi_0)] \cdot [\exp(i\varphi_1) - \exp(i\varphi_2)] \\ \exp[i(\omega t + \varphi_0)] \cdot i \cdot [\exp(i\varphi_1) + \exp(i\varphi_2)] \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 0 & 1 & i \\ 0 & 0 & i & 1 \\ 1 & i & 0 & 0 \\ i & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} \exp[i(\omega t + \varphi_0 + \varphi_1)] \\ i \cdot \exp[i(\omega t + \varphi_0 + \varphi_2)] \\ 0 \\ 0 \end{bmatrix}$$



SLED: $\varphi_1 = \varphi_2 = 0$



AM: $\varphi_1 = -\varphi_2$

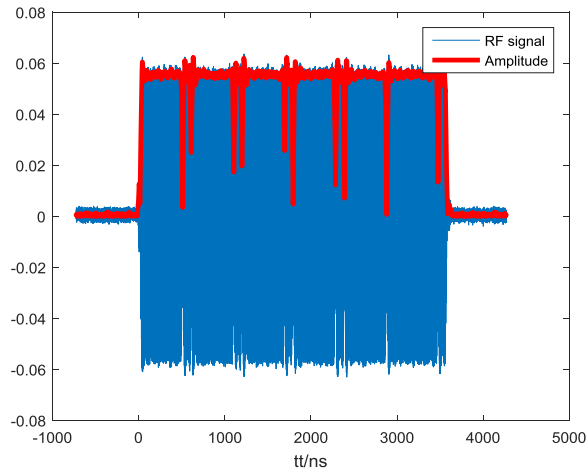


PM: $\varphi_1 = \varphi_2$

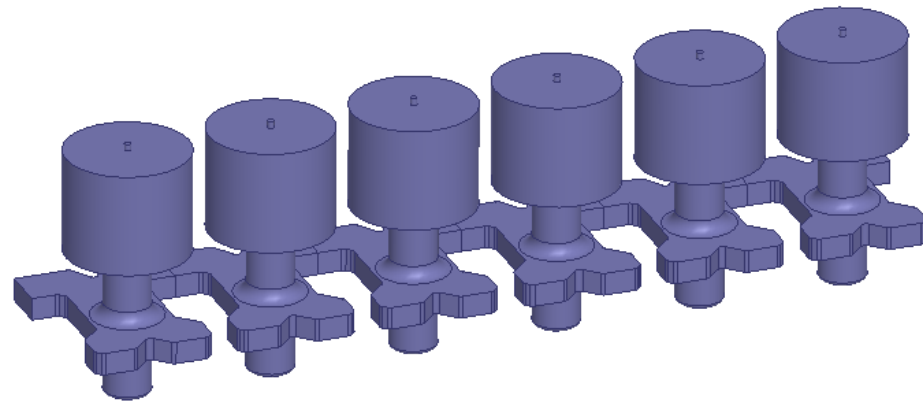
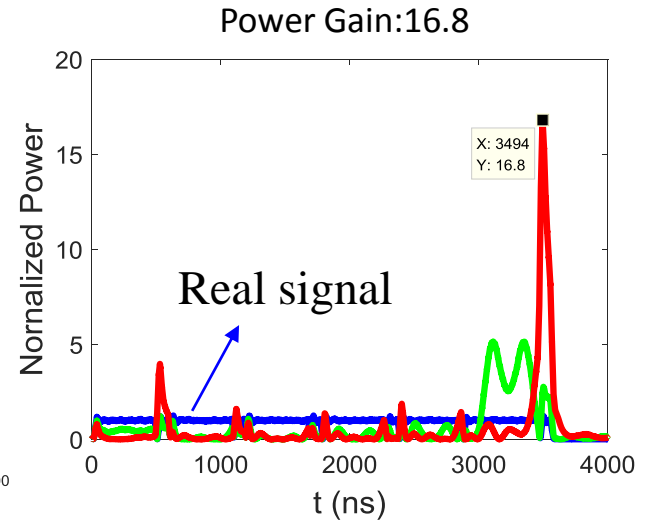
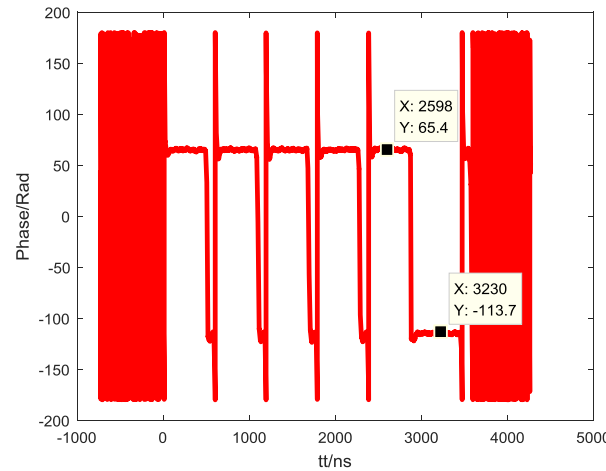




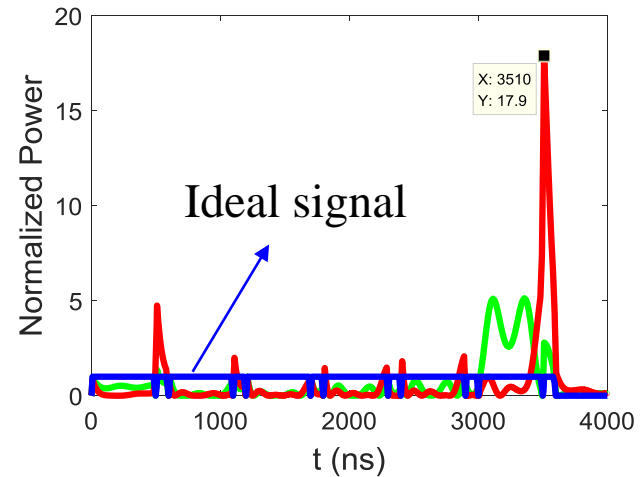
Performance of LLRF system



RF signal from experiment



Two stage pulse compressor from simulation





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Summary and plan

Summary

- Two type of resonant cavities are being fabricated for two stage RF pulse compression
- LLRF system has been developed to generate phase modulated pulse for two stage pulse compression

Plan

- More resonant cavities to be fabricated and high power test for the two stage pulse compressor





Thanks for your attention !

Acknowledgement

Many thanks to Igor Syrathev (CERN) and Hao Zha (Tsinghua)

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