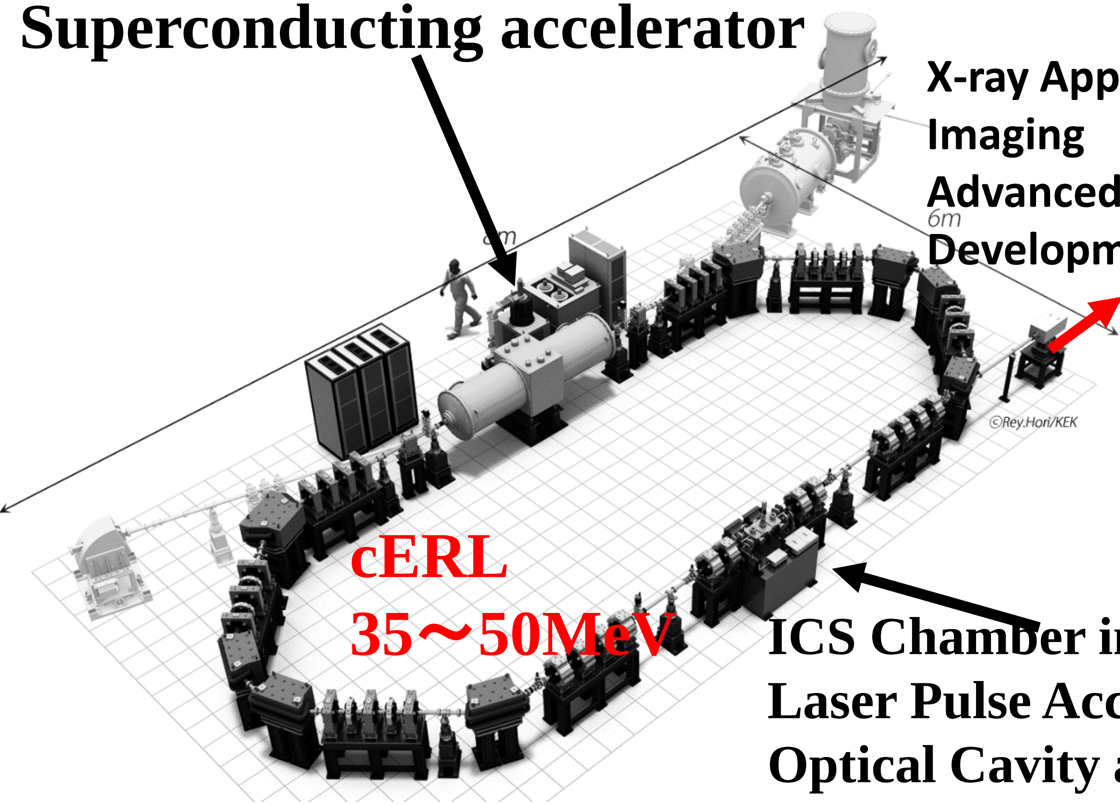
Conventional e+ source: 300 Hz linac R/D

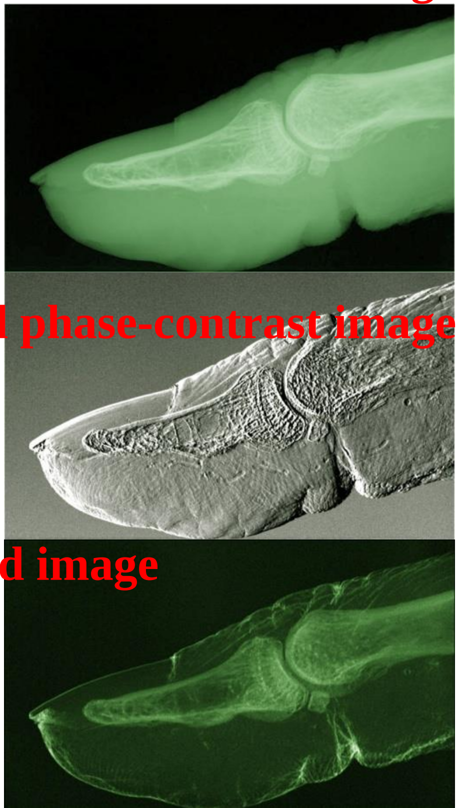
Beam loading compensation study at ATF

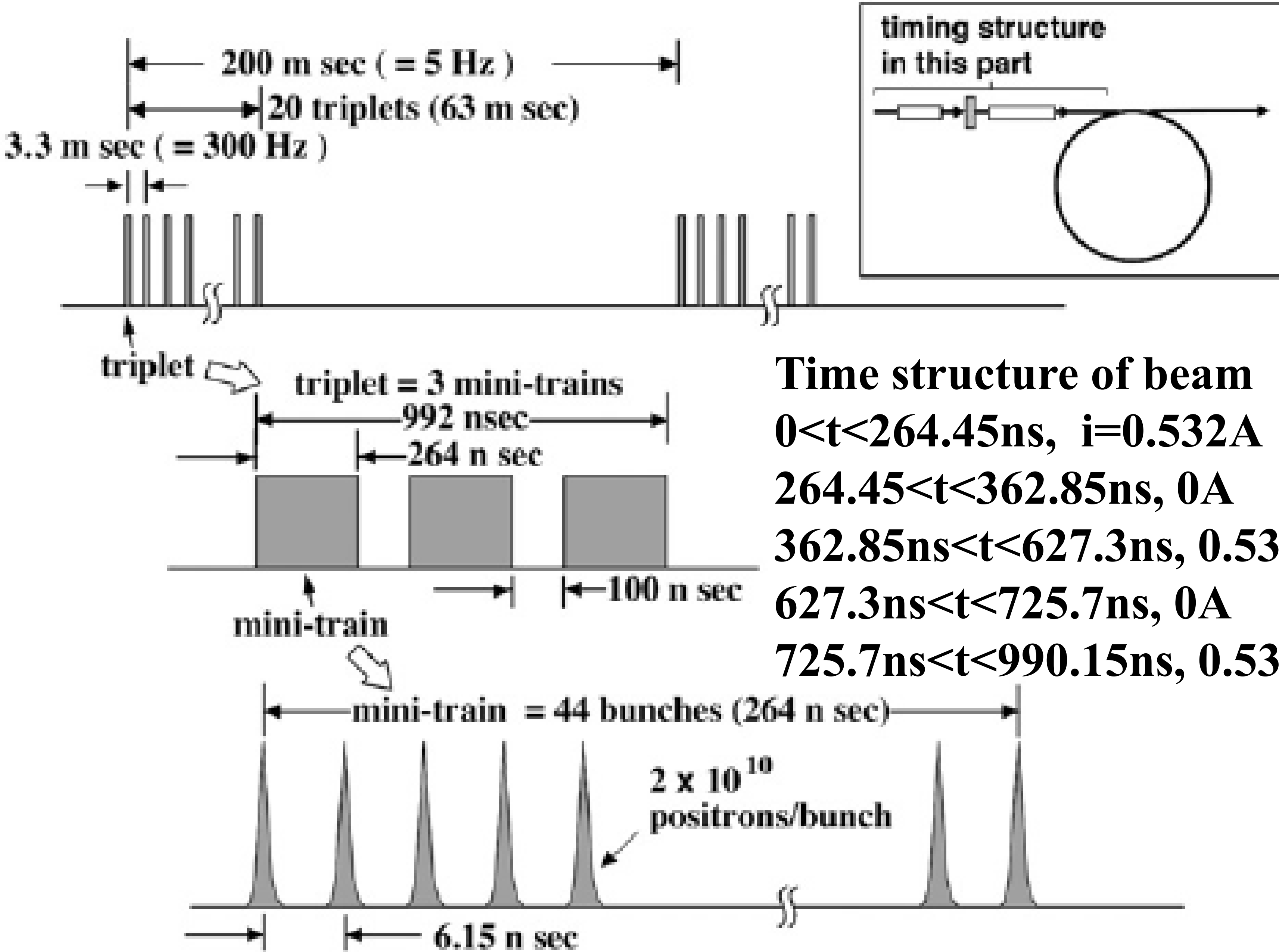
ECFA LC2013 at DESY

29.5.2013

KEK Junji Urakawa







Time structure of beam

0<t<264.45ns, i=0.532A

264.45<t<362.85ns, 0A

362.85ns<t<627.3ns, 0.532A

627.3ns<t<725.7ns, 0A

725.7ns<t<990.15ns, 0.532A

Fig. 2. Timing structure in the positron source and in the booster linac.

Bunch by bunch extraction from Damping Ring to make ILC beam train.

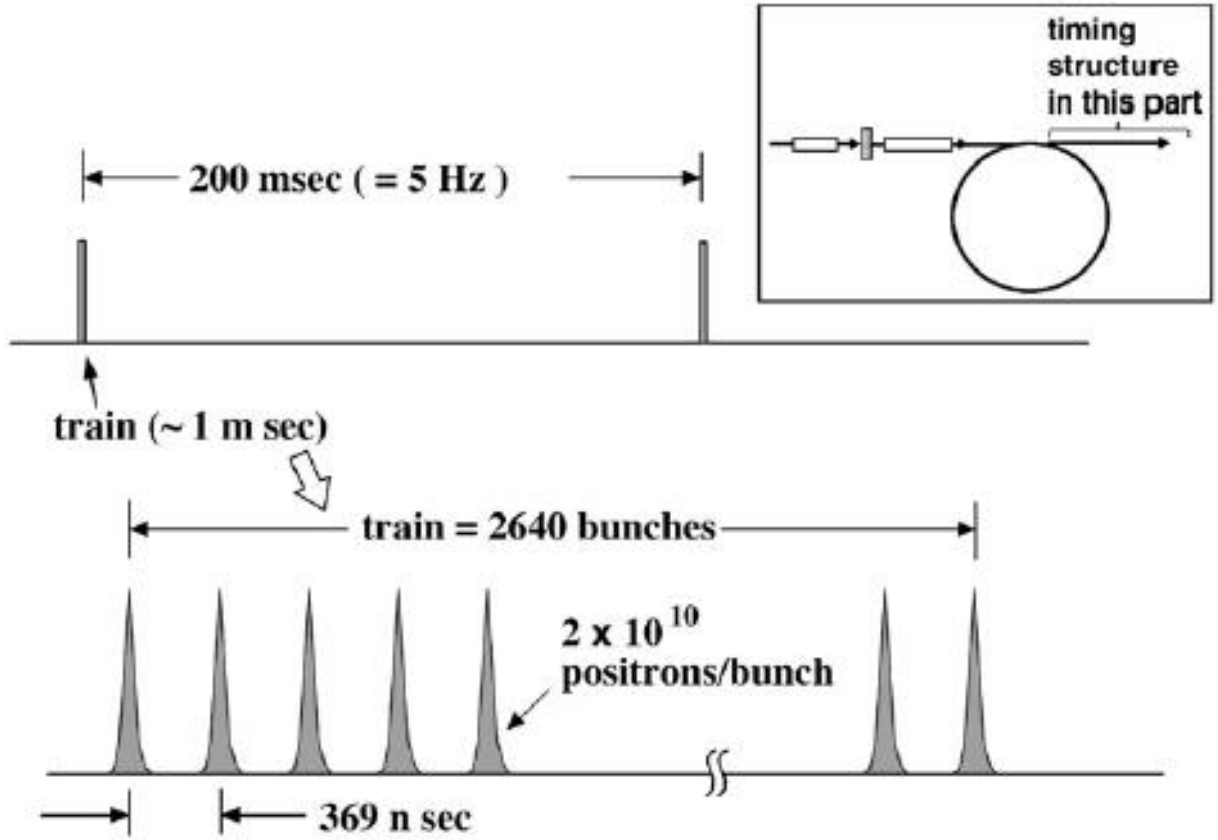
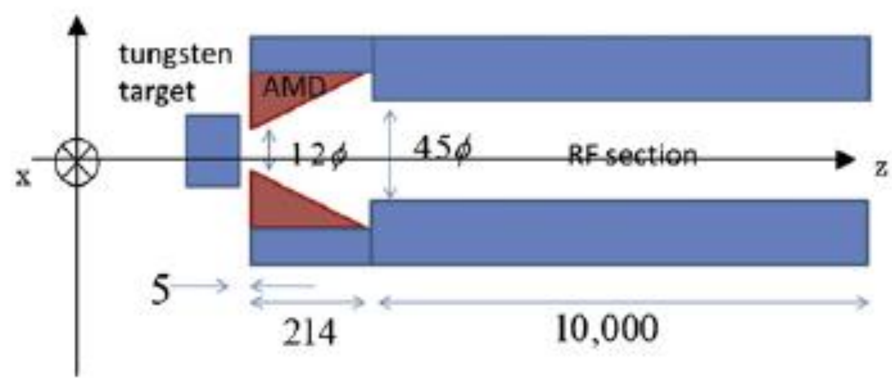
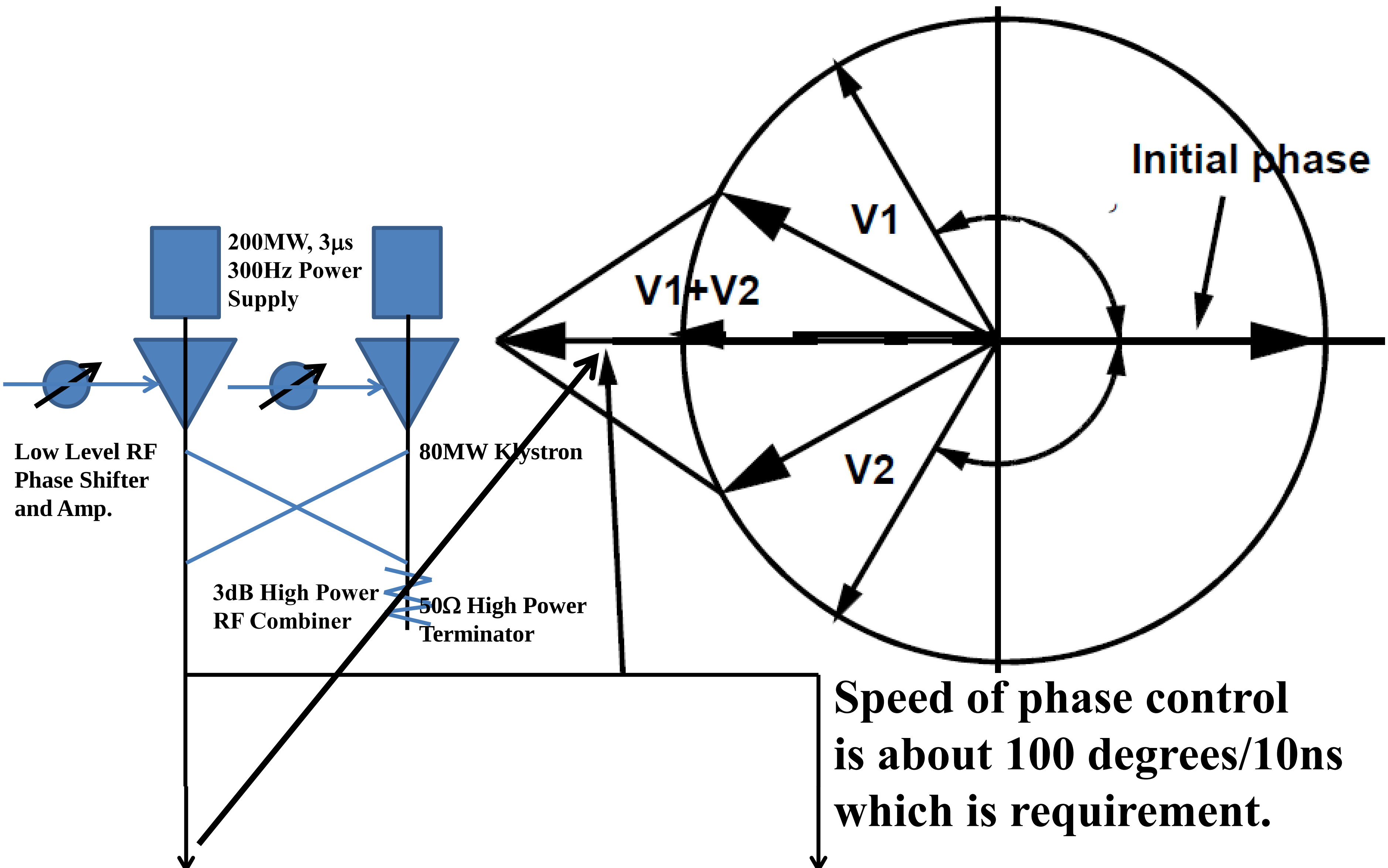


Fig. 4. Time structure after the damping ring.

This is the model for positron target system to confirm the generation of ILC positron beam.

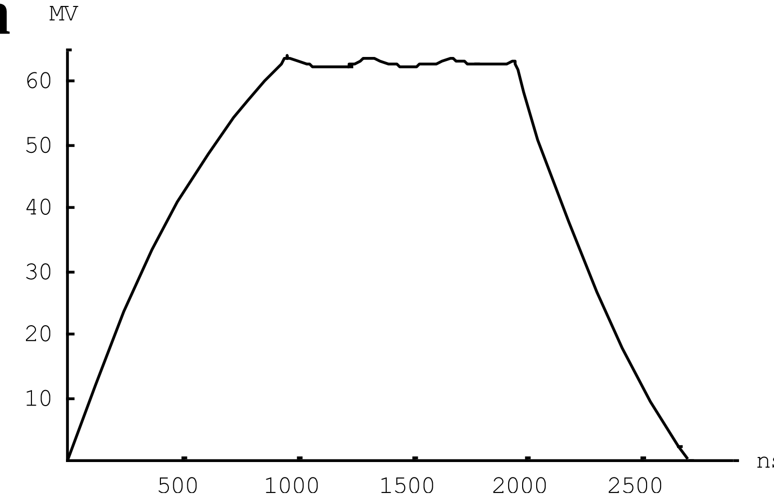


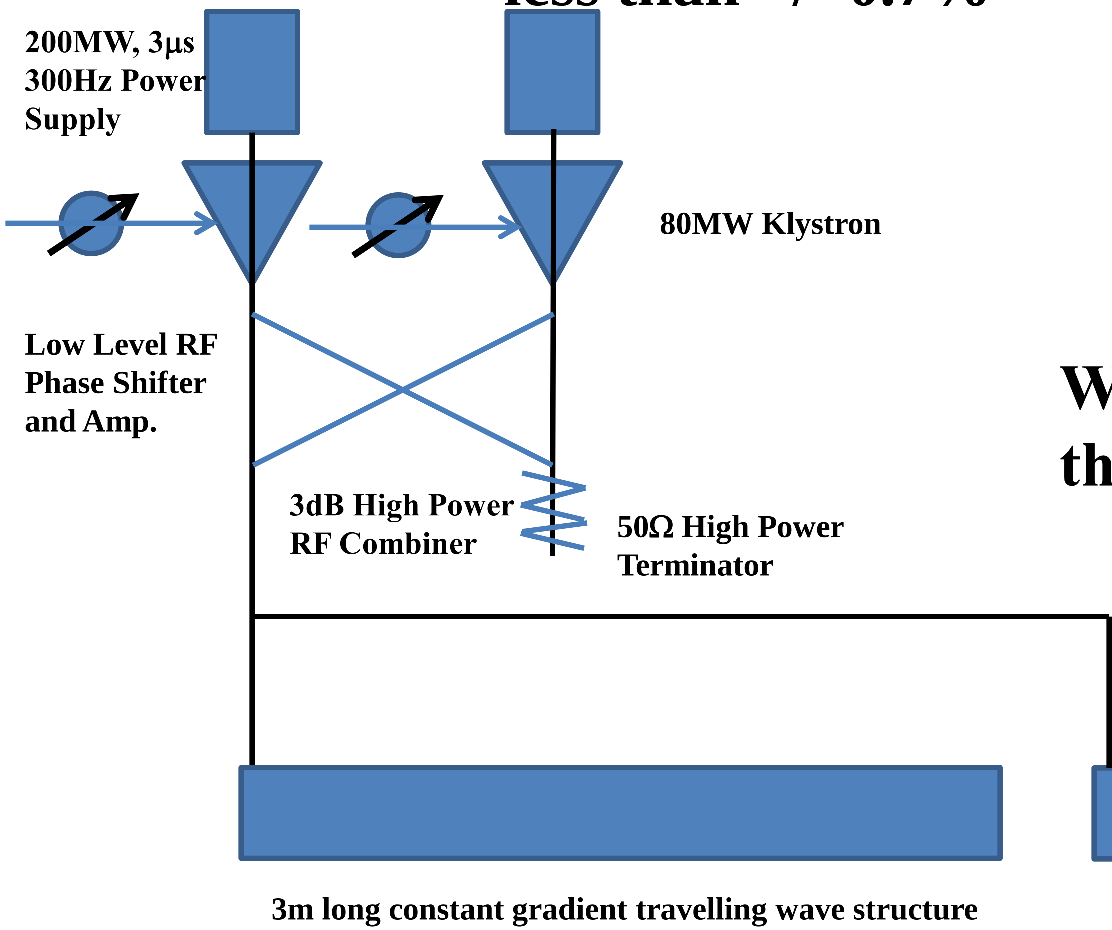
Phase to Amplitude Modulation Method for Beam Loading Compensation



Speed of phase control is about 100 degrees/10ns which is requirement.

3×10^{10} positron/bunch
300Hz triplet beam
less than +/- 0.7%

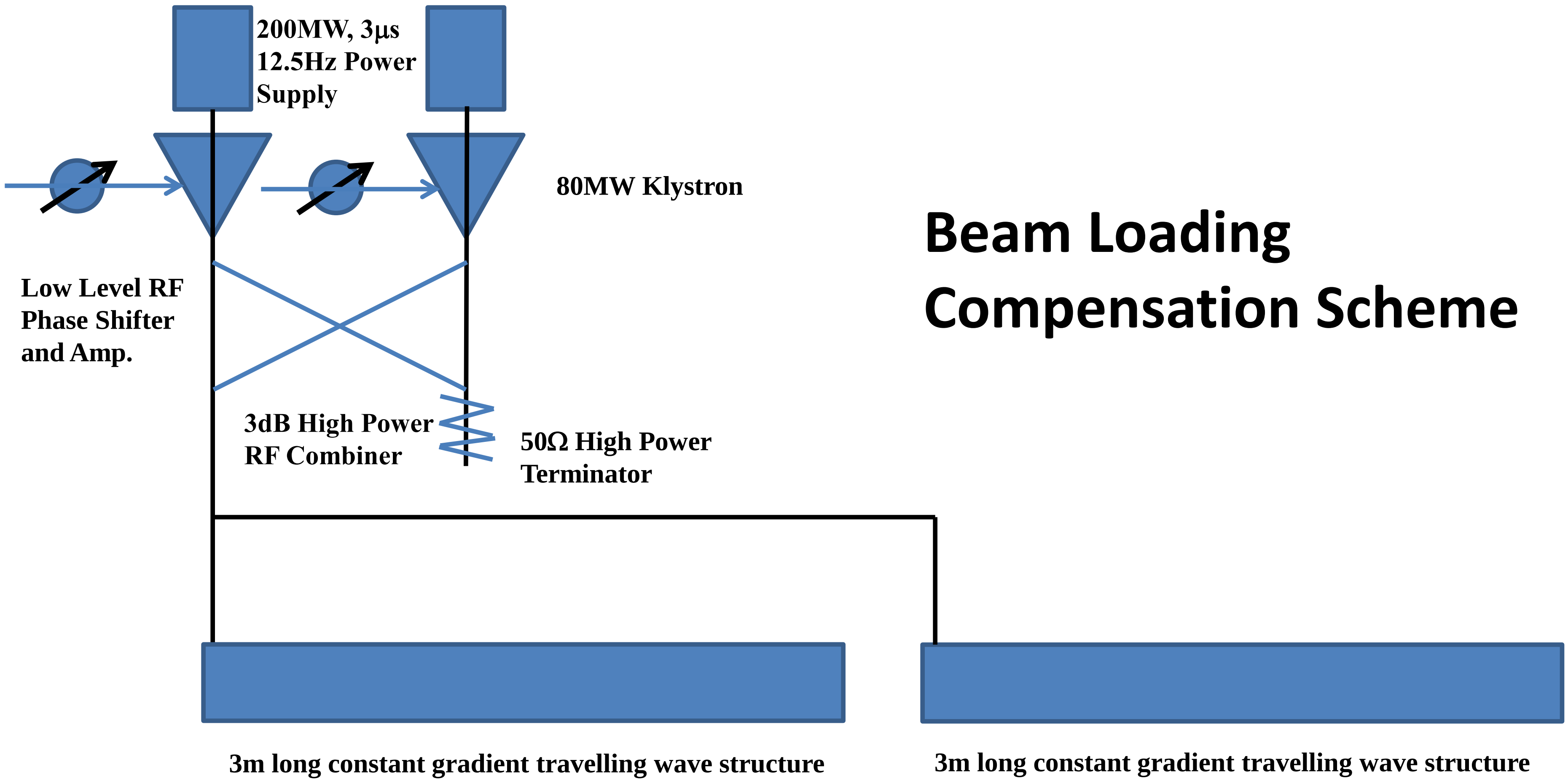




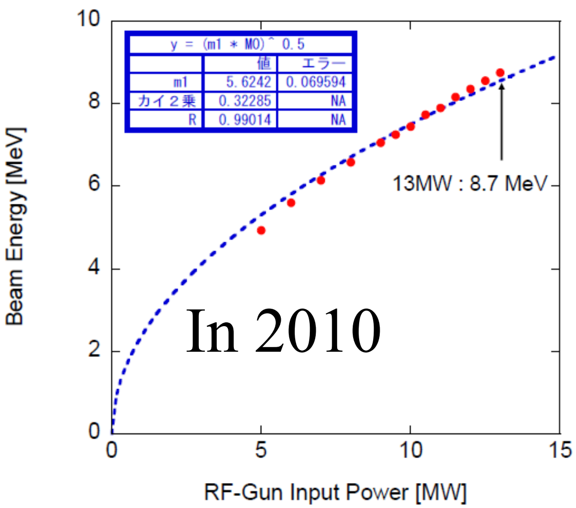
We need the precise control of the phase shifters.

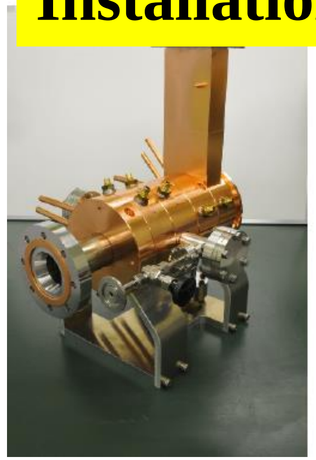
Almost perfect beam loading compensation scheme is necessary to make the energy spread of the triplet beam less than +/-0.2% if the energy acceptance of DR is +/- 0.5%.

Beam Loading Compensation Scheme

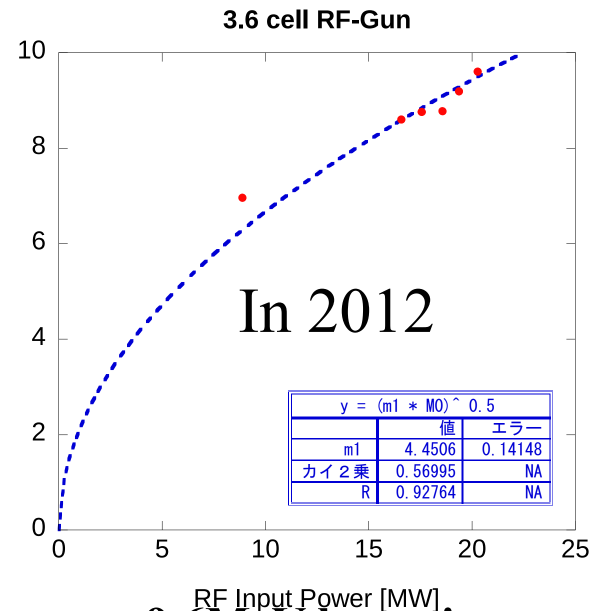


3.6 cell RF Gun Installation

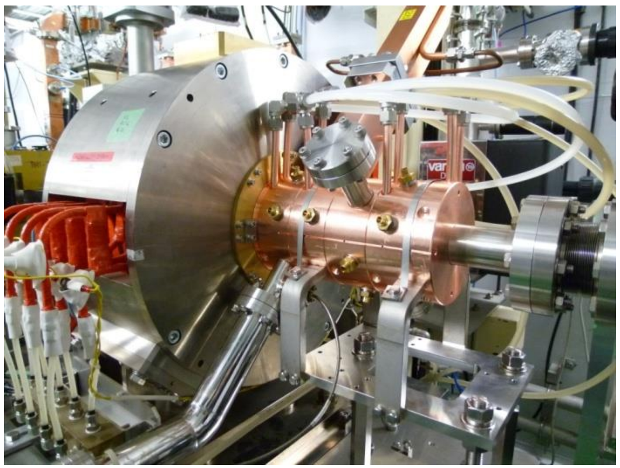




ATF インストールの様子

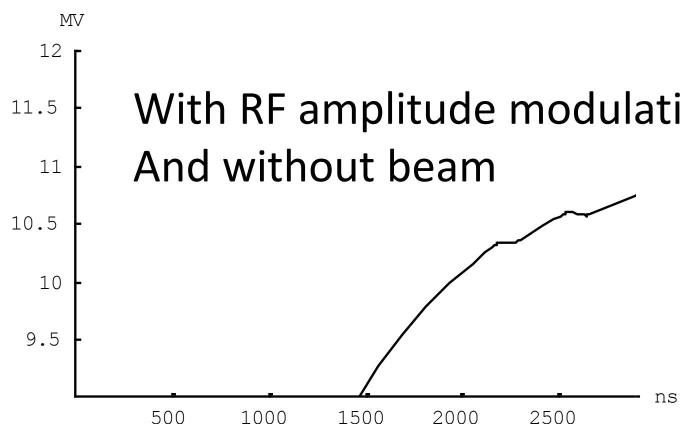


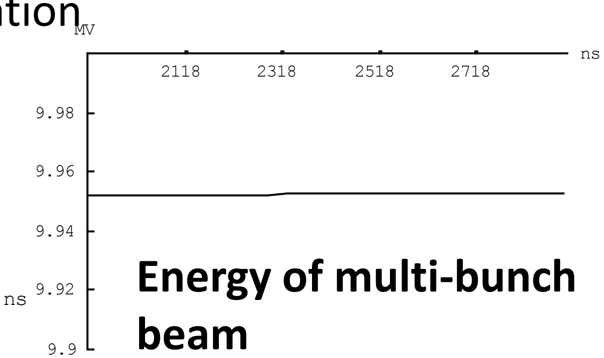
9.6MeV beam in a week RF aging with ~20.3MW RF input power



3.6 cell RF-Gun started beam acceleration test from 1/11,2012.

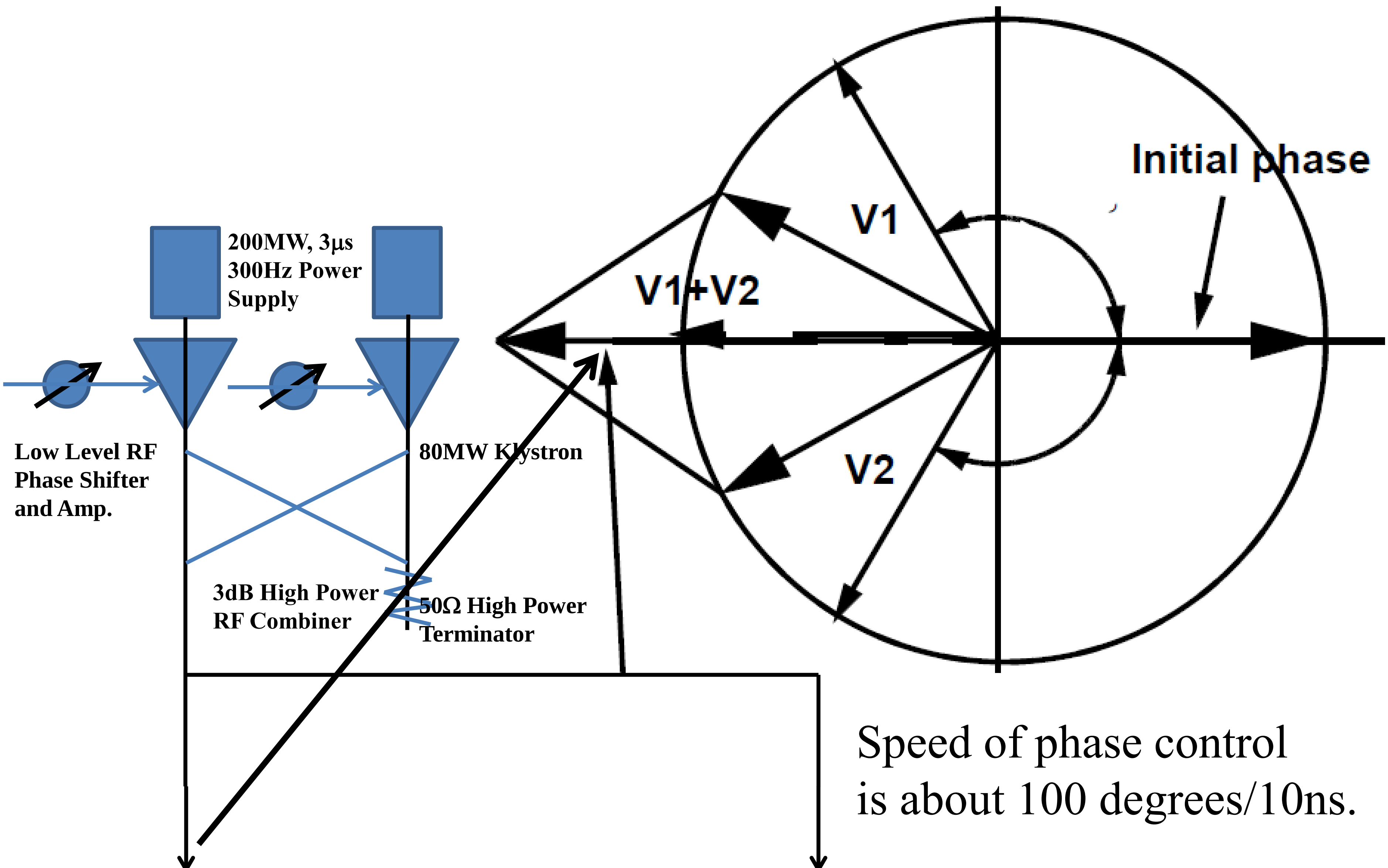
Now, 10MeV multi - bunch trains are generated and accelerated.





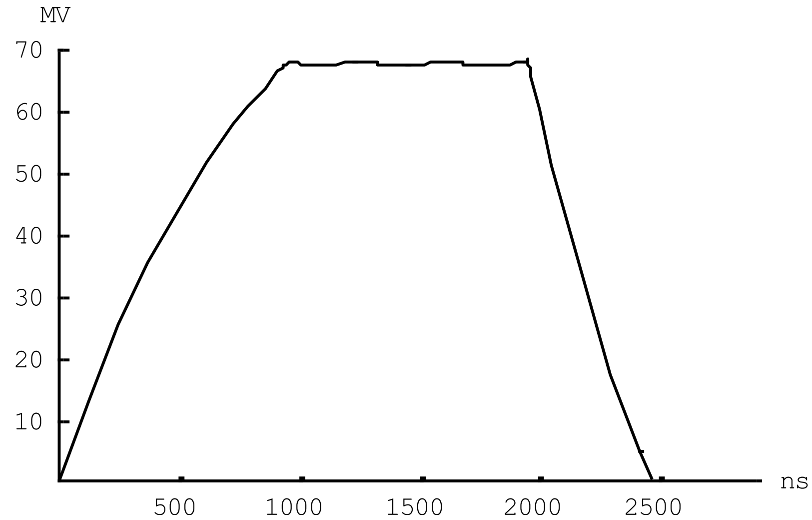
11MeV beam at 120MV/m, from 100bunches/pulse to 1000bunches/pulse beam generation

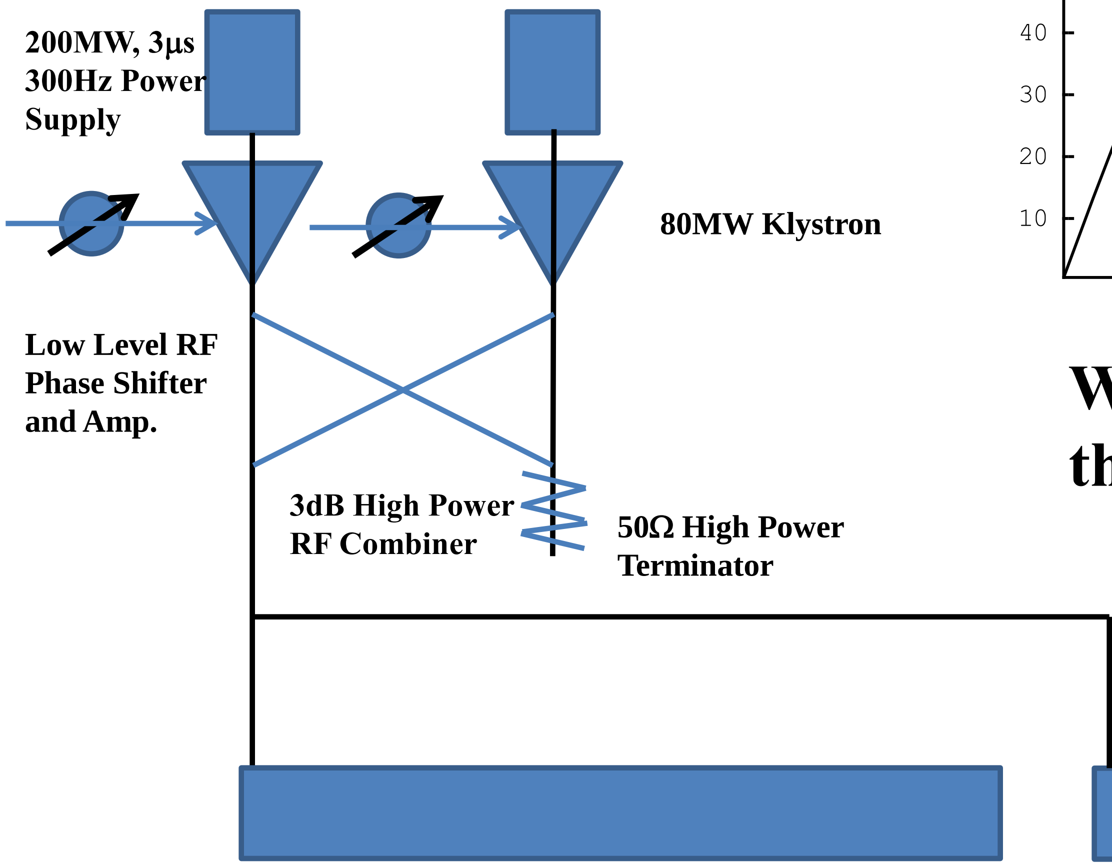
Phase to Amplitude Modulation Method for Beam Loading Compensation



Speed of phase control is about 100 degrees/10ns.

0.9×10^{10} electrons/bunch
With 2.8nsec bunch spacing
And 2856MHz Linac



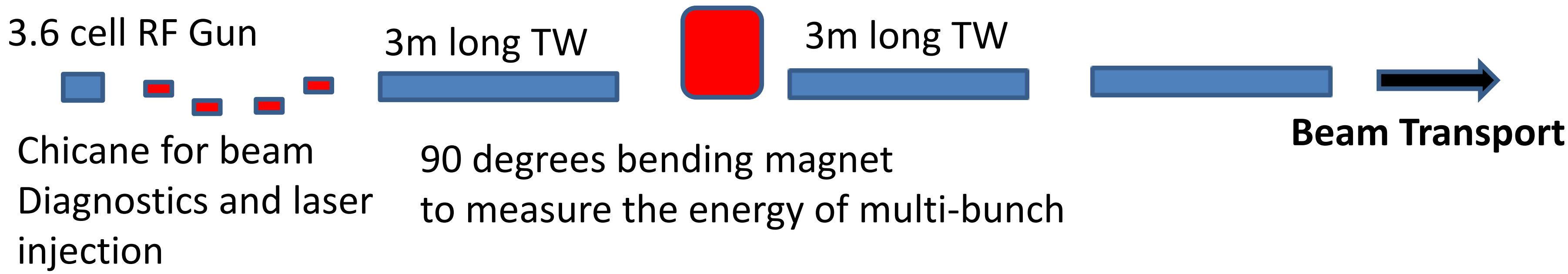


We need the precise control of the phase shifters.

3m long constant gradient travelling wave structure

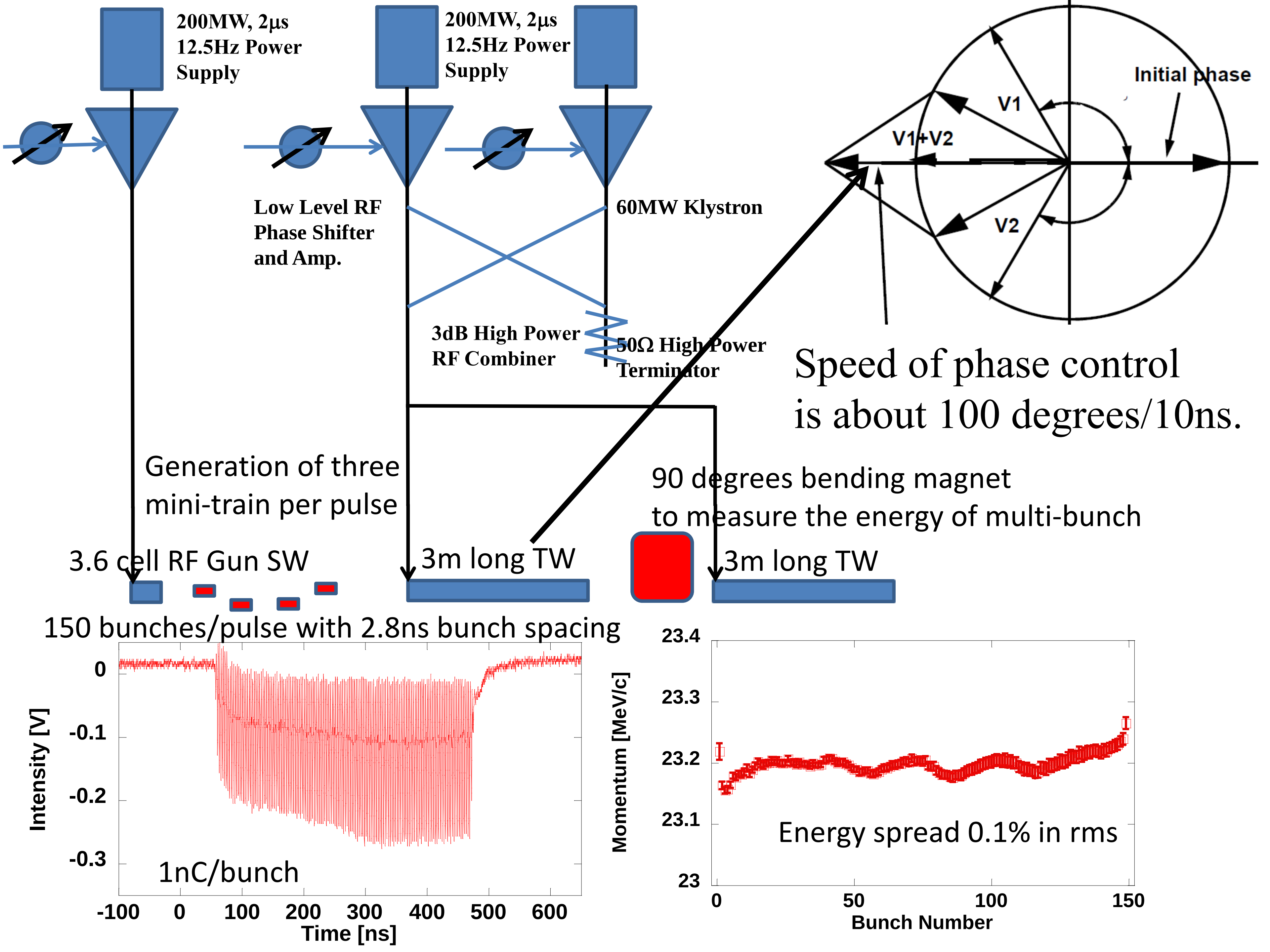
Almost perfect beam loading compensation scheme is necessary to make the energy spread of the triplet beam less than +/-0.2% if the energy acceptance of DR is +/- 0.5%.

ATF Injector for 1.3GeV ATF Linac will be modified for beam loading compensation experiment by next year (2014).
Due to the lack of 2013 budget, we delayed this experiment.



2×10^{10} with 6.15nsec bunch spacing corresponds to 0.9×10^{10} in the case of 2.8nsec bunch spacing as same beam loading in multi-bunch trains.

ATF Triplet Beam : 10 bunches/train with 30nsec train gap and 2.8nsec bunch spacing.


200MW, 2μs
12.5Hz Power
Supply
200MW, 2μs
12.5Hz Power
Supply
Low Level RF
Phase Shifter
and Amp.
60MW Klystron
3dB High Power
RF Combiner
50Ω High Power
Terminator
V1
V1+V2
V2
Initial phase
Speed of phase control
is about 100 degrees/10ns.
Generation of three
mini-train per pulse
90 degrees bending magnet
to measure the energy of multi-bunch
3.6 cell RF Gun SW
3m long TW
3m long TW
150 bunches/pulse with 2.8ns bunch spacing
Intensity [V]
0
-0.1
-0.2
-0.3
1nC/bunch
-100
0
100
200
300
400
500
600
Time [ns]
Momentum [MeV/c]
23.4
23.3
23.2
23.1
23
Energy spread 0.1% in rms
0
50
100
150
Bunch Number

1.6 cell RF Gun already Demonstrated Multi-bunch Beam loading Compensation.

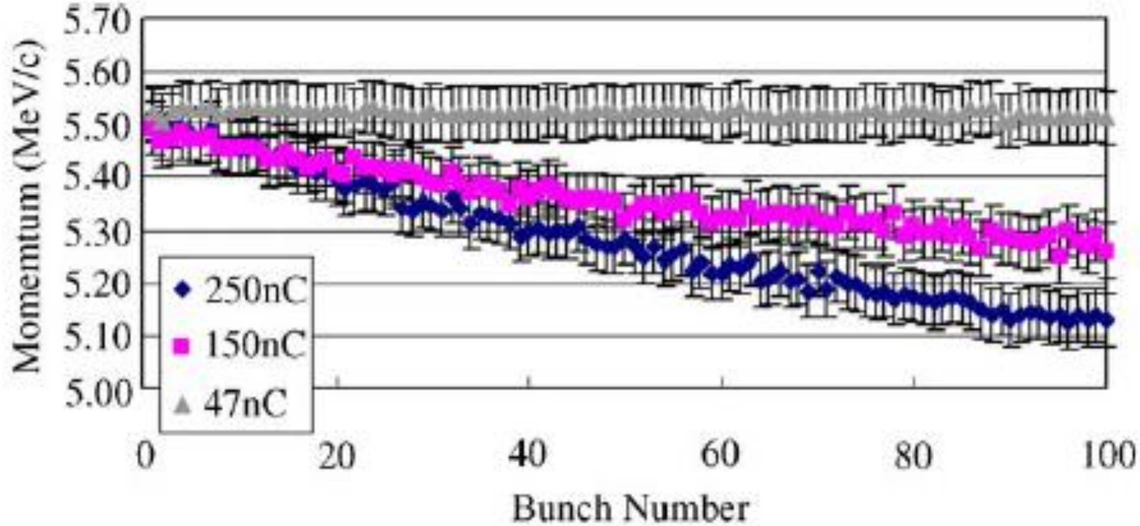
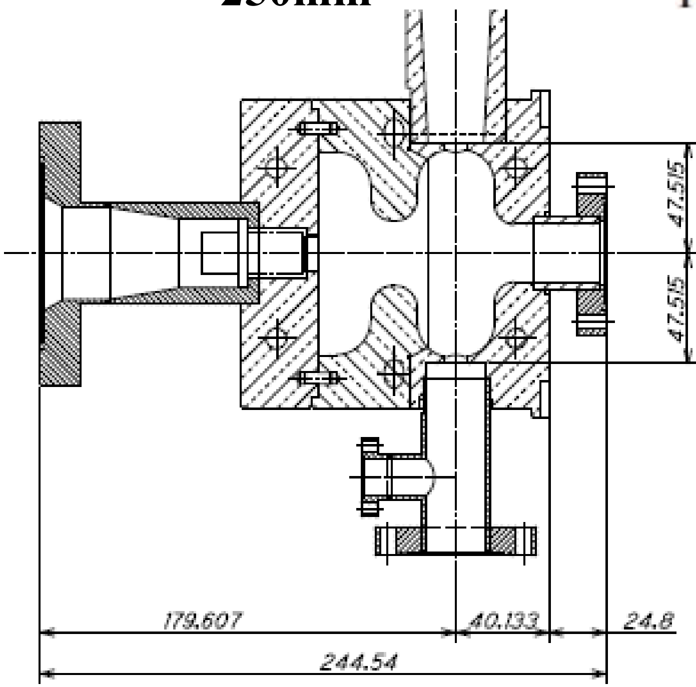
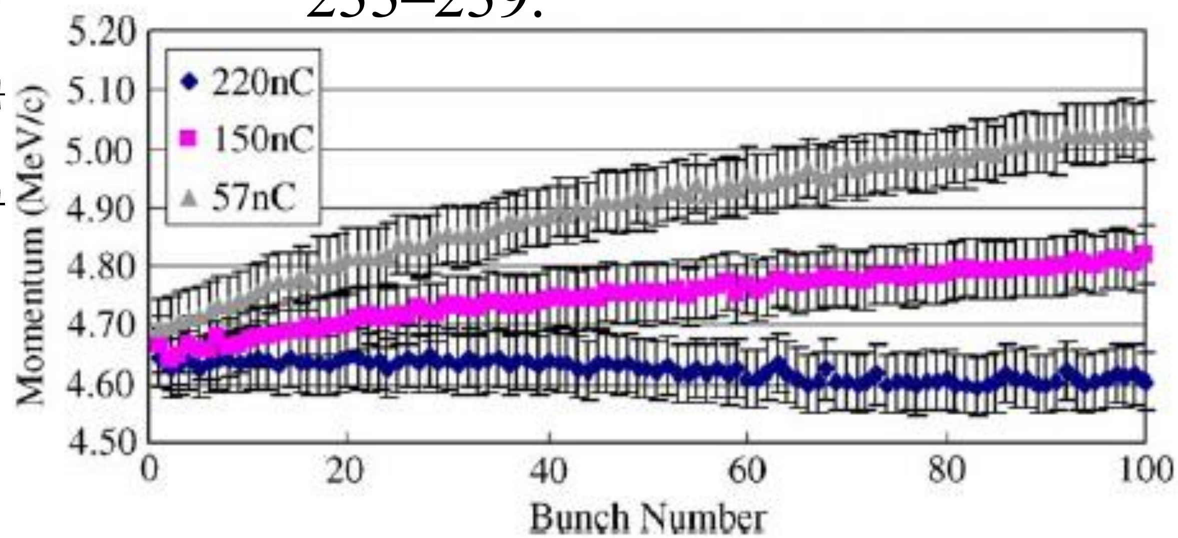


Fig. 11. Momentum of a multi-bunch beam at a laser injection timing of 0.703 µs.

250mm

From NIM A 560 (2006) 233–239.

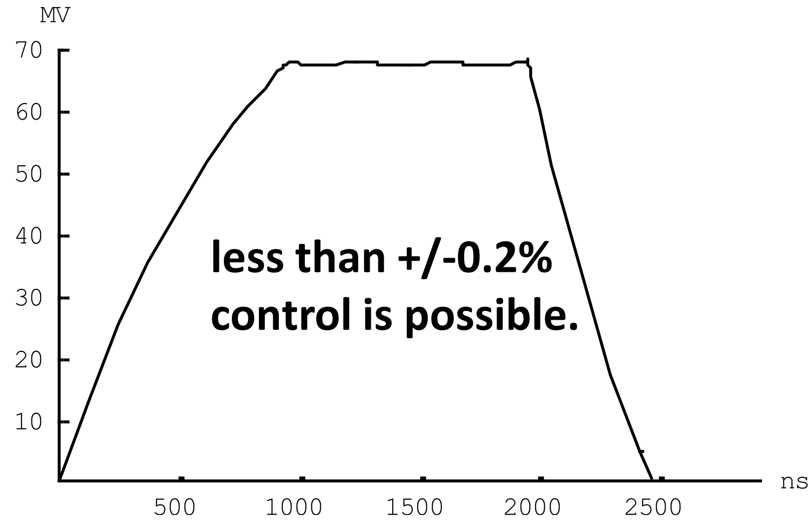




S-band RF Gun, more than 100MV/m
Operation:120MV/m,max.:140MV/m

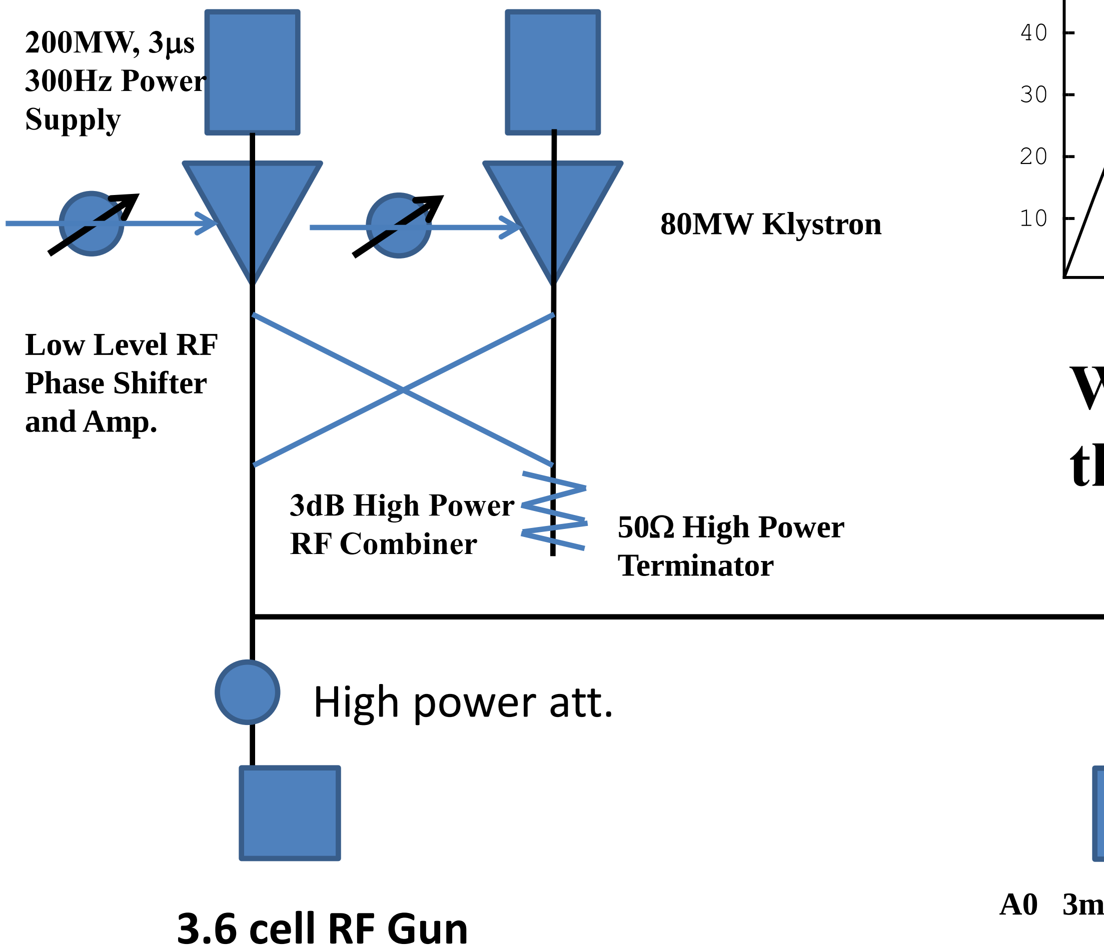
Fig. 12. Momentum of a multi-bunch beam at a laser injection timing of 0.906 µs.

0.9×10^{10} electrons/bunch
With 2.8nsec bunch spacing
and 2856MHz Linac



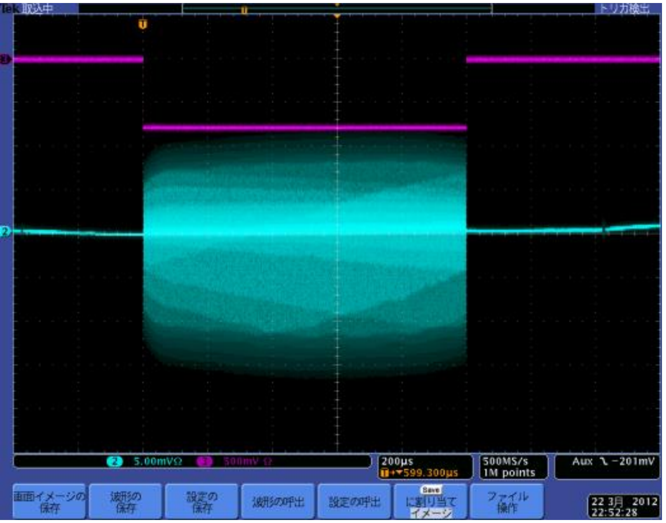
We need the precise control of the phase shifters.

Speed of RF amplitude control is essential to make the perfect beam loading compensation.

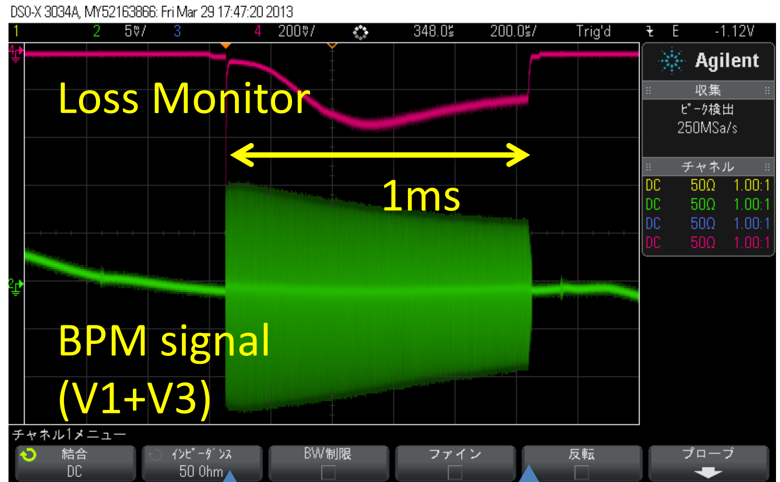


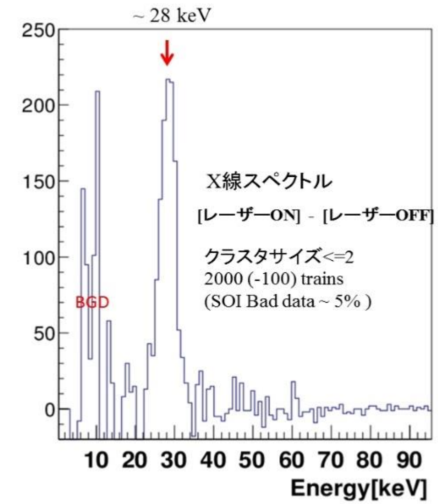
Almost perfect beam loading compensation scheme is necessary to make the energy spread of the triplet beam less than +/-0.2% if the energy acceptance of DR is +/- 0.5%.

1ms flat intensity beam from L-band RF gun
(RF feedback ON) 03.22.2012 , 50pC/bunch



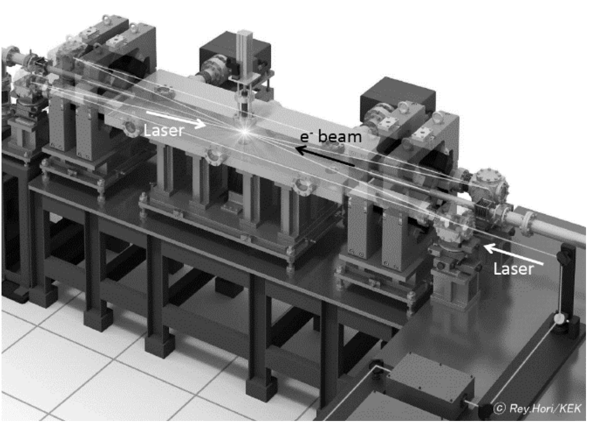
1ms beam acceleration in STF accelerator
40MeV, 1ms, 7.5mA Beam Operation



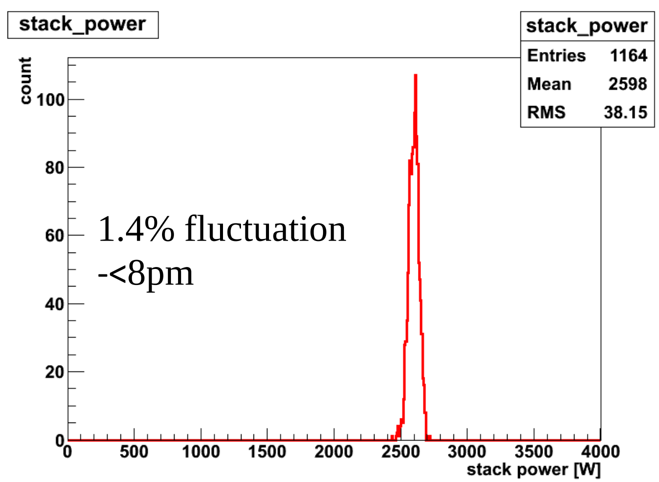


Success on 28keV X-ray Detection!

Success on generation and acceleration of 162.5k electron bunches by 2K-superconducting Linac!

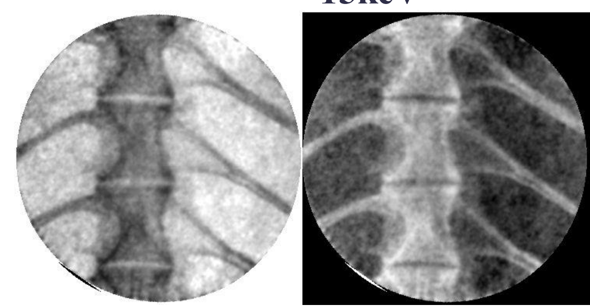


2m 2D-4 mirror optical cavity storages more than 100kW, 1MW storage is our target which is possible. 375MHz electron bunch and laser pulse collision was established.



Relative mirror position control accuracy is less than 8pm in the optical cavity. Fast pol. Control of X-ray is possible more than 10kHz. Stable laser IP size 13μm

～15keV

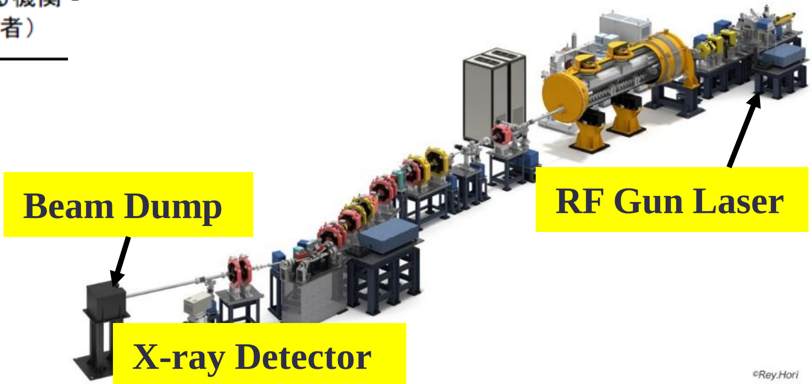


From X-ray absorption imaging to X-ray phase contrast imaging by Talbot Interference method. Measurement of the absorption imaging will be within one second by normal conducting Linac (LUCX) soon.

６．研究開発推進に必要な施設及び設備備品・機器

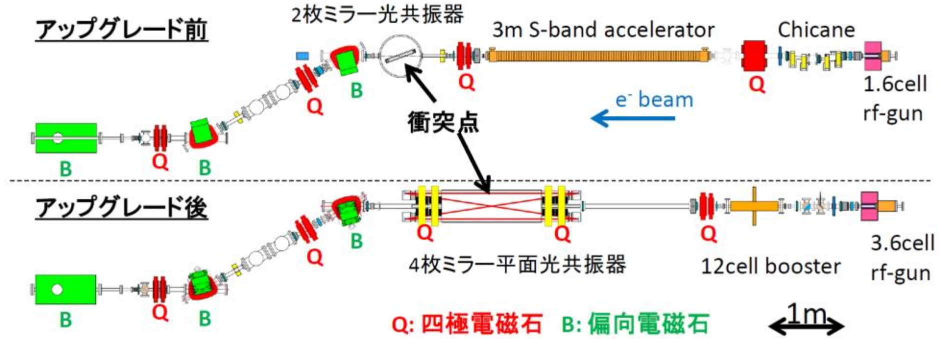
保有・購入・賃貸の区分	品名	仕様	用途	金額（千円）	購入・賃貸の場合の調達時期	賃貸する機関（当事者）
〔小型加速器X線生成実験〕保有（LUCX）・	LUCX	40MeV, 12.5Hz Max. beam power: 320W	X線光源、THz光源開発、利用実験用	800,000	2013-2019	KEK
〔高輝度X線生成実験〕将来保有（cERL、将来計画のR&Dの為建設中）・	cERL	35MeV, 10mA Max. beam power: 350kW	ERL技術開発用、X線およびTHz利用実験	3,800,000	2015-2019	KEK
〔パルス高輝度X線生成実験〕将来保有（STF、将来計画のR&Dの為改造中）	STF	300MeV, 10mA 5Hz-1ms beam Max. beam power: 15kW	ILC技術開発用、X線およびガンマ線利用実験	6,800,000	2016-2019	KEK

STF Facility



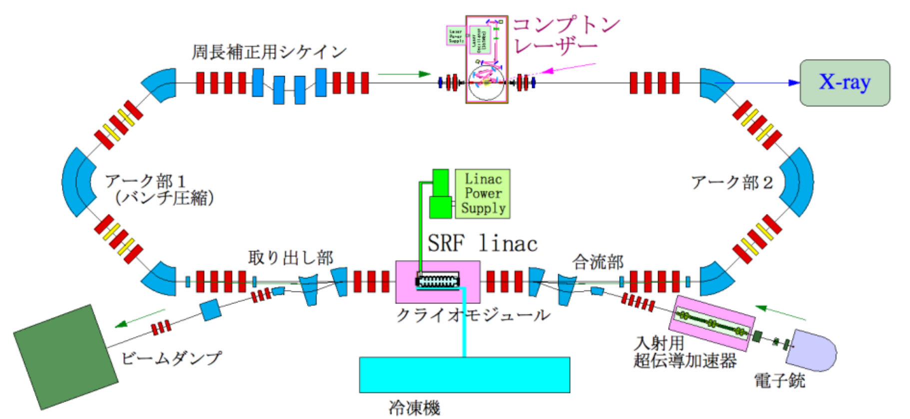
Energy upgrade from 60MeV to 300MeV is under way. Operation will be in 2016 to generate High energy X-ray around 150keV (2016-2019).

LUCX Facility(40MeV)



1MW pulse laser accumulation will be realized 357MHz～10μm collision technology will be Realized stably soon. Development for X-ray imaging techniques(2013-2019).

cERL Facility(35MeV)



～10mA ERL operation will be achieved by JFY2015 ICS X-ray application (2015-2019).

研究組織、責任体制

研究開発運営委員会
構成委員：参画メンバー＋外部委員

マルチビームクライストロンの小型化・高安定化

高周波源開発

協力機関
東芝電子管デバイス
小型高周波源開発

参画機関
産総研(AIST)
X-ray利用
レーザー開発

協力機関
日立製作所
小型冷凍機開発

参画機関
（株）リガク
X-rayイメージング装置開発

協力機関
大阪大学（産研）
電子源利用・運転協力
大学院生教育
施設の供用：線型加速器

カソード・
電子銃開発

代表機関
高エネルギー加速器研究機構
超伝導高周波加速器開発
装置の構築・運転、性能測定
ポスドク・大学院生教育
提供施設：LUCX, STF, cERL
開発打合せ、運営会議の開催

イメージング装置開発

参画機関
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レーザー蓄積装置開発
高周波電子源開発、カソード開発
大学院生教育
施設の供用：カソード試験装置
可視光励起の高量子効率カソード開発

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干渉イメージング装置

ミラー開発

レーザー開発

参画機関
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レーザー・電子衝突実験
大学院生教育
施設の供用：小型加速器

協力機関
国立天文台
（重力波測定グループ）
高強度耐性高反射率ミラー開発

参画機関
原機構(JAEA)
4k超伝導spoke空洞開発
cERL電子源試験装置
500kV電子銃運転

両ビームの品質を
向上して、良質の
X線発生・検出

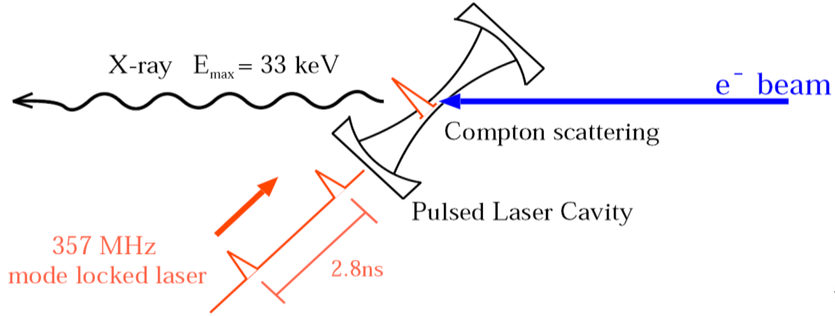
参画機関
日本大学
20kクライオ高周波電子銃
大学院生教育

参画機関
京都大学
4k超伝導spoke空洞
大学院生教育

協力機関
東京大学
高強度耐性高反射率ミラー開発
大学院生教育
破壊試験

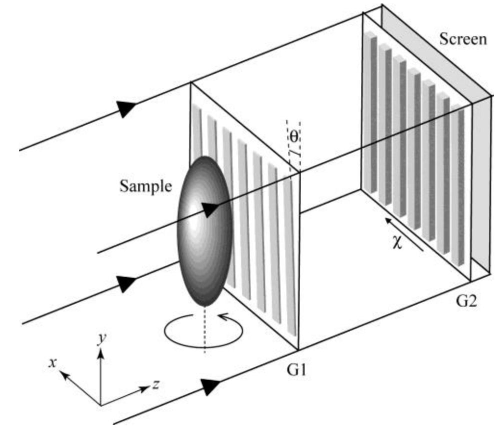
ICS X-ray source comparing large synchrotron radiation.

- **pulse(imaging by one pulse)**
- **angular divergence to project into large size.**
- **pol. X-ray generation with fast switching of pol.**

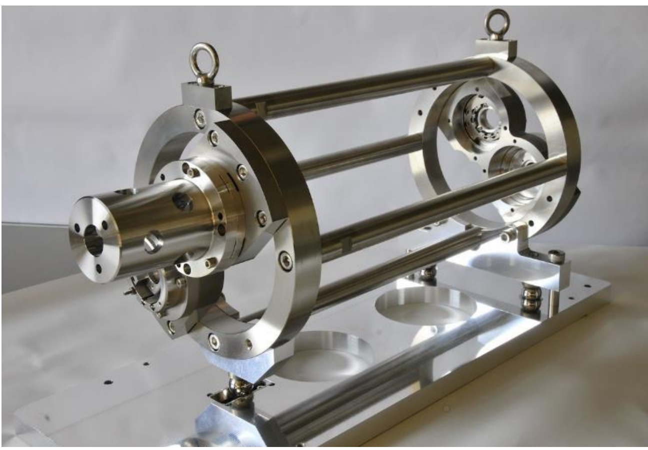


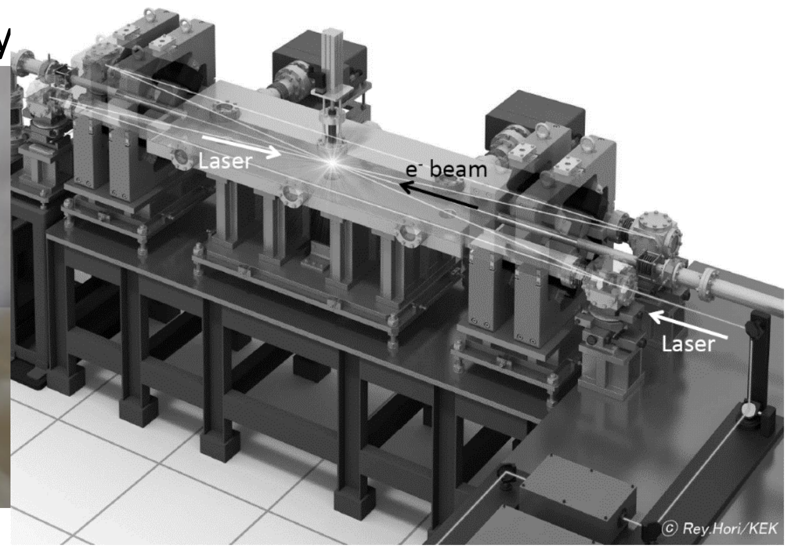
2m 2D 4 mirror optical cavity

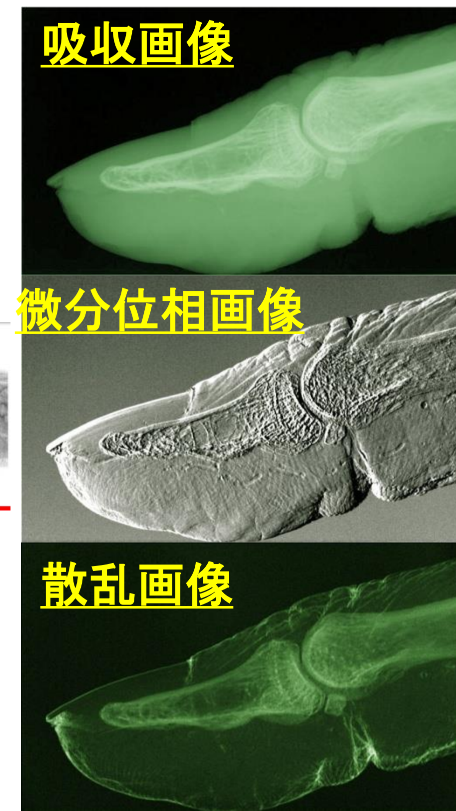
X-ray Talbot干渉計



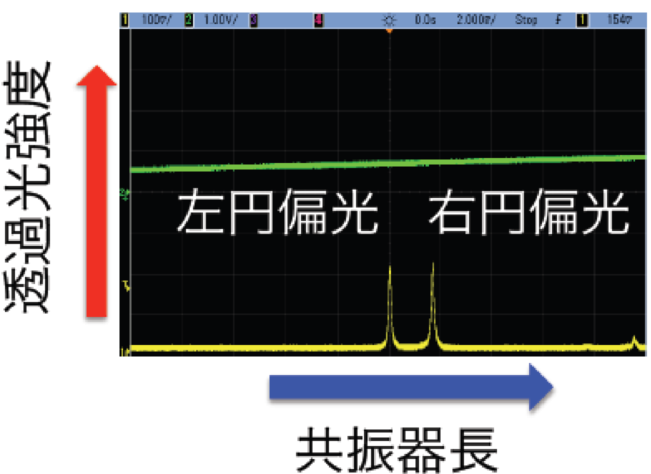
0.42m 3D 4 mirror optical cavity



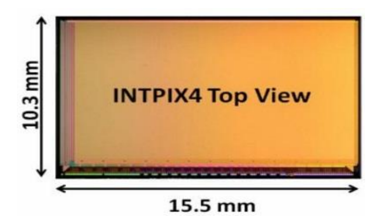




Circular pol. Control quickly

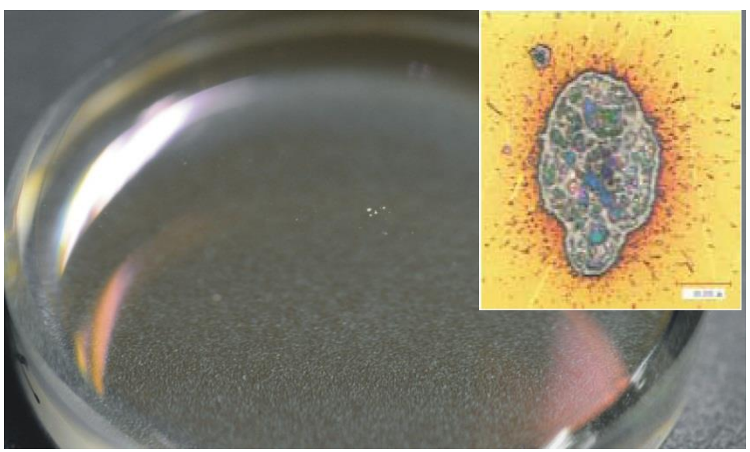


X-ray Imaging by SOI Pixel Detector

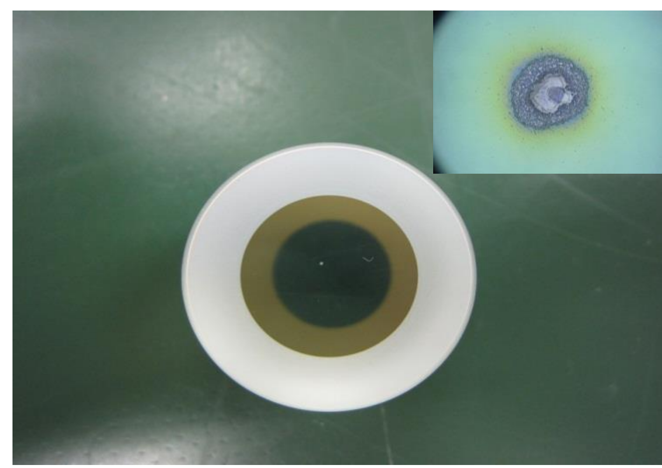


We destroyed the mirror coating two times. First occurred when the waist size was ~100μm with burst amplification and 42cm two mirror cavity. Second occurred when the waist size was 30μm with the burst amplification and the 42cm two mirror cavity. Now we are using 4 mirror cavity with smaller waist size at IP. From our experience, we have to reduce the waist size to increase the laser size on the mirror and need precise power control for the burst amplification. I guess about storage laser pulse energy from 2mJ to 4mJ destroyed the mirror coating with the waist size of 30μm. Also, we found the damaged position was not at the center.

2008



2011



From experimental results at LUCX X-ray generation based on ICS.

Development for stronger mirror : I want to start the collaboration with NAO (Gravitational Wave Observatory group), Tokyo University (Ohtsu Lab.), Japanese private Co., LMA and LAL hopefully.

1. Enlarge mirror size : we started the change from one inch to two inch mirror.
2. LMA prepared mirrors with reflectivity of 99.999% and loss (absorption and scattering) less than 6ppm.
3. We ordered many substrates with micro-roughness less than 1 A to approach low loss mirror.
4. We understood the necessity of good clean room to handle the high reflective mirrors in the case of the mirror which has high reflectivity more than 99.9%.
5. We have to develop how to make the stronger surface which has higher damage threshold.

Measurement of surface roughness for super-polish. Reduce the loss ,which means low absorption and scattering.

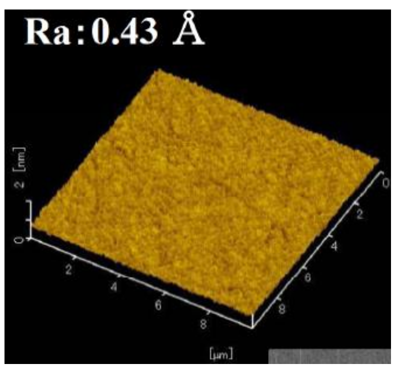
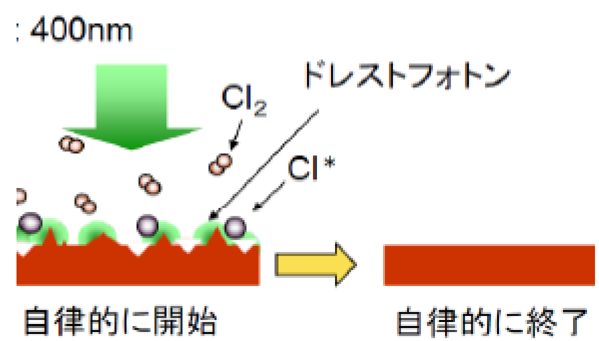
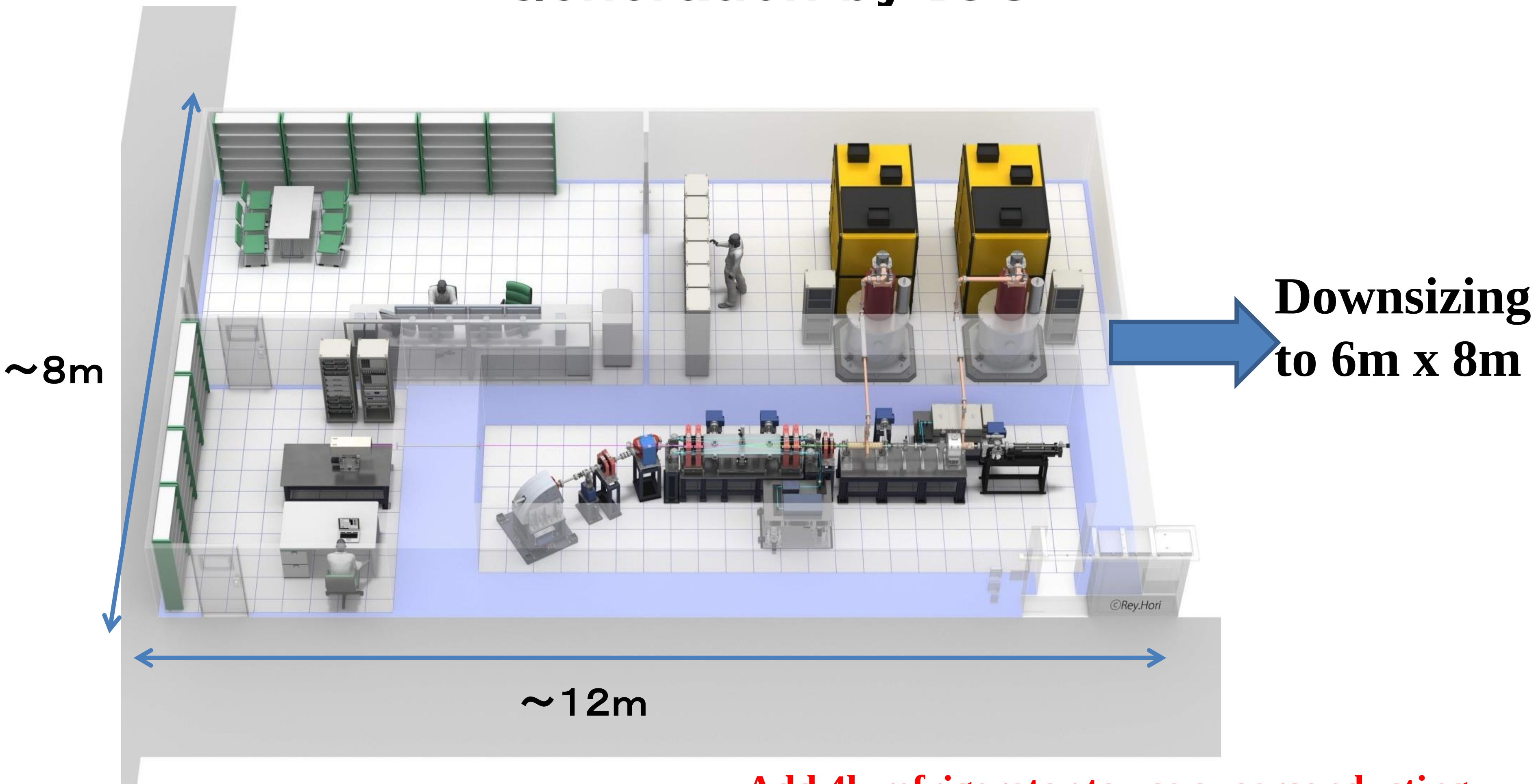


Photo-chemical etching occurred by dressed photon.



We learnt a lot of things which humidity in Japan is high and makes OH contamination to increase the mirror absorption. 50% humidity is suitable to handle the mirrors, especially high quality mirrors. We confirmed this problem.

Compact Facility for High Brightness X-ray Generation by ICS



Add 4k refrigerator to use superconducting cavity keeping compactness in future.

Normal conducting accelerator system for compact high brightness X-ray