Sバンド RFガンとレーザースーパーキャビティ開発

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はじめに、
JASRI,東大,KEKはそれぞれ別々の手法と目標を持って、Photo-cathode RF Gunの研究開発を進めている。KEKは、Cs_2Te Photo-cathode, 1.6 Cell S-band RF Gunを使い、高QEマルチバンチビーム生成に関する開発研究を行っている。一方、東大はカートリッジ方式のカソード導入により短パルスビーム生成に関する研究開発を進めている。また、JASRIは先端安定レーザーシステム開発により、低エミッタンス電子ビーム生成に関する研究開発を行い、それぞれ相補的な研究成果を得ている。ここでは以下の報告を行う。

1. Cs_2Te Photo-cathode, 1.6 Cell S-band RF Gunによるマルチバンチ電子ビーム生成
2. レーザースーパーキャビティ開発の現状
3. X線生成実験
4. まとめ

1. Cs2Te Photo-cathode, 1.6 Cell S-band RF Gun によるマルチバンチ電子ビーム生成

平成17年度での開発状況

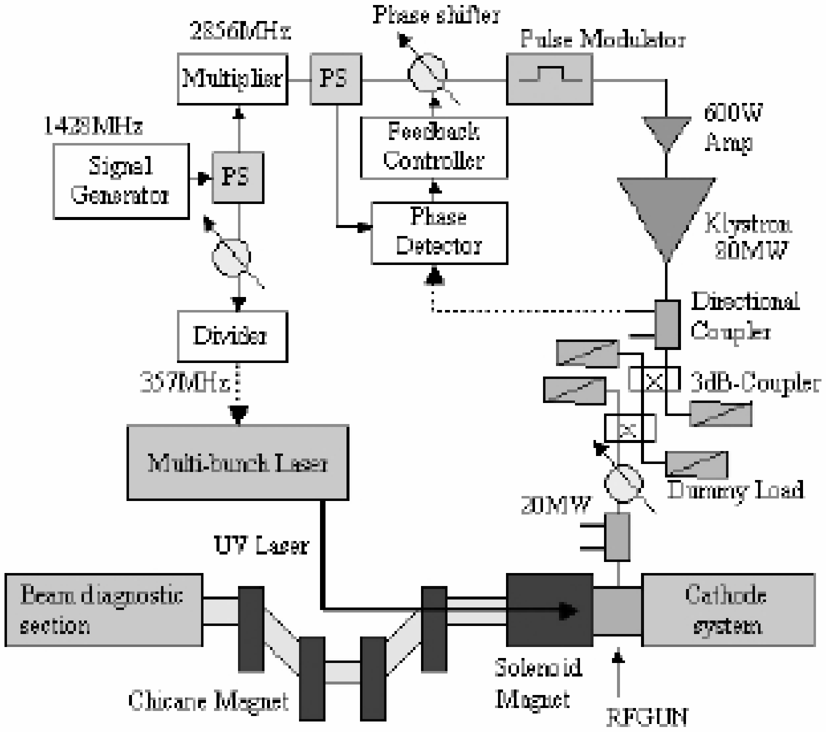


Figure 1: A schematic layout of the RFGTB

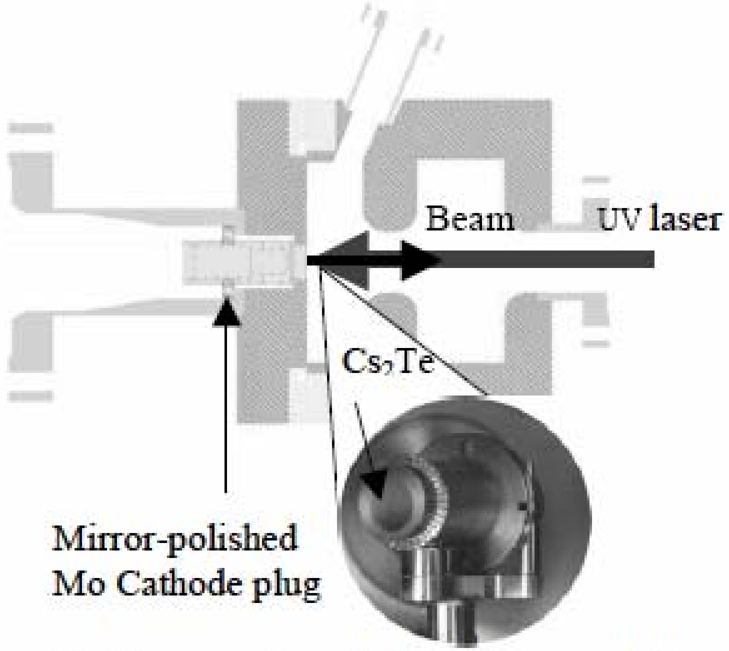


Figure 2: Cross section of the RF gun and the cathode plug.

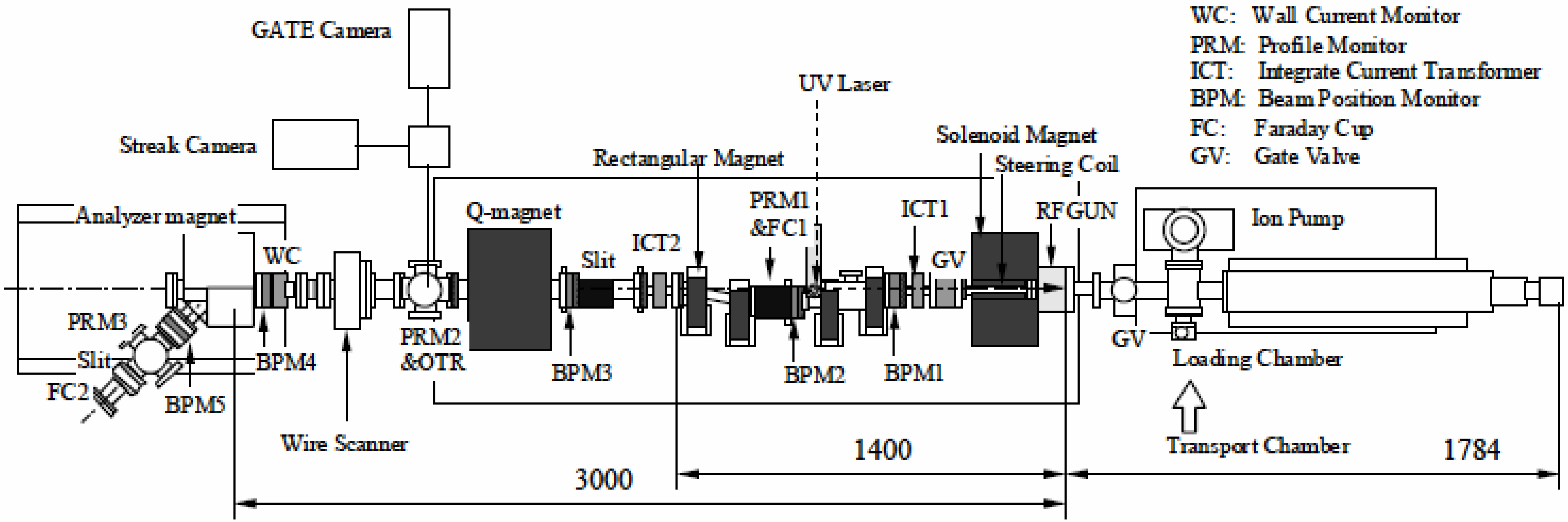


Figure 4: Schematic view of experimental setup

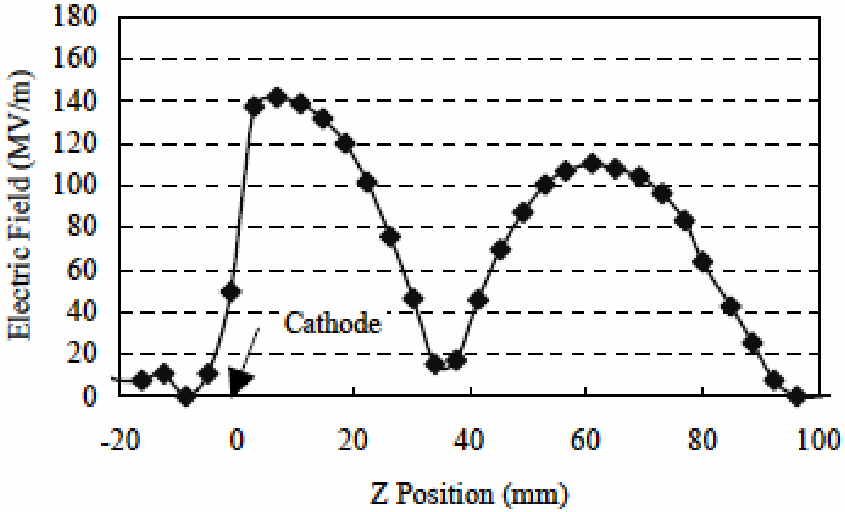


Figure 3: Electric field distribution in the RF gun cavity at the RF cavity power 15MW.

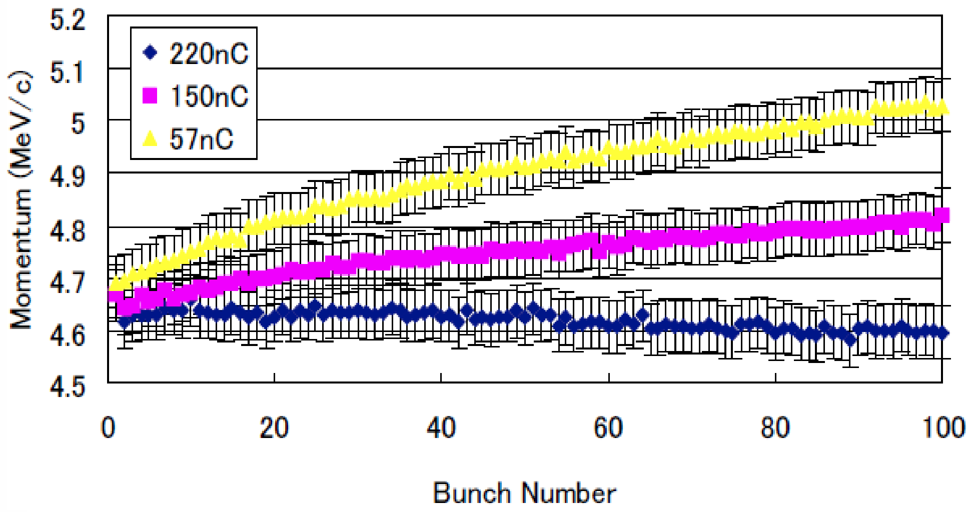
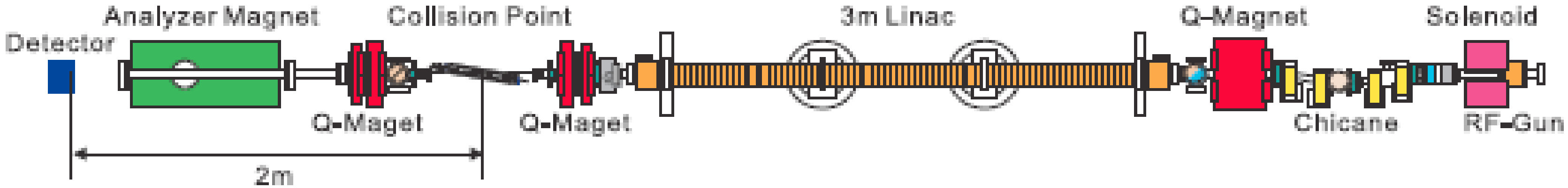


図5. 100 bunchesの運動量

平成19年、現在40MeVマルチバンチ電子線型加速器完成



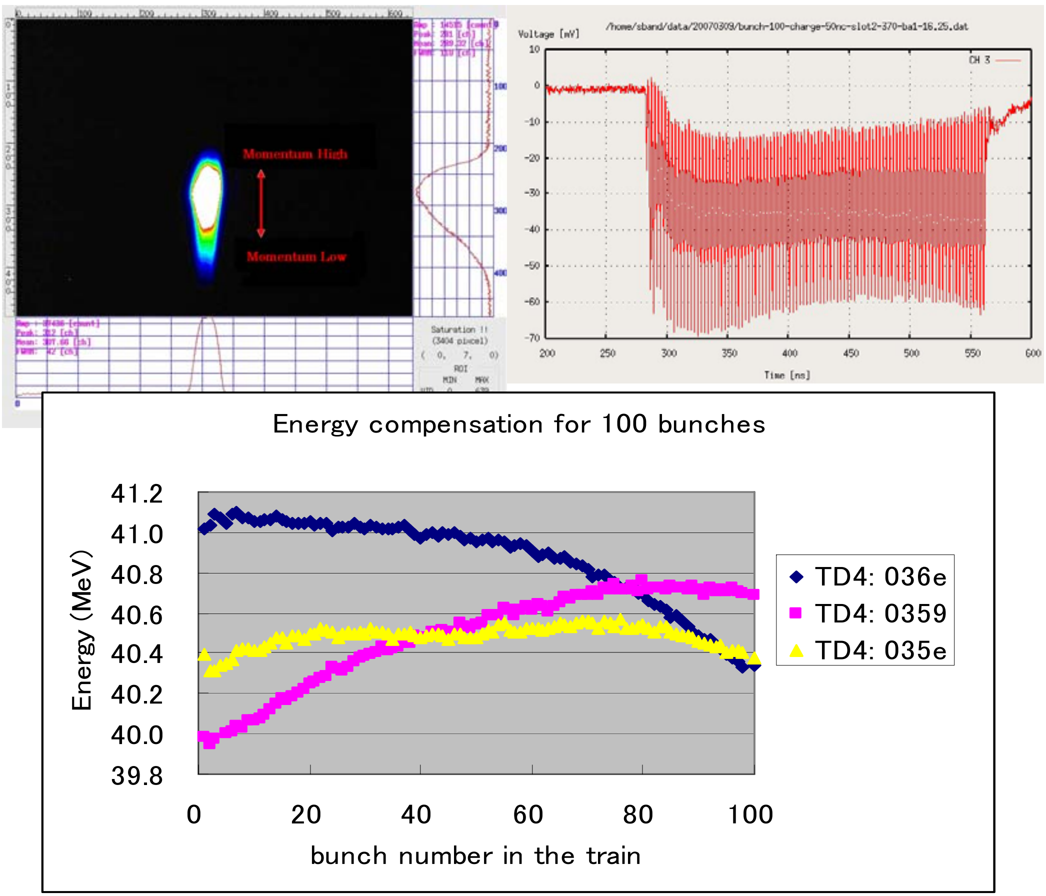
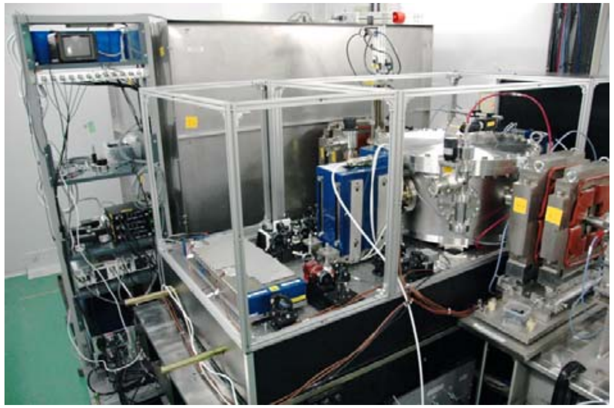
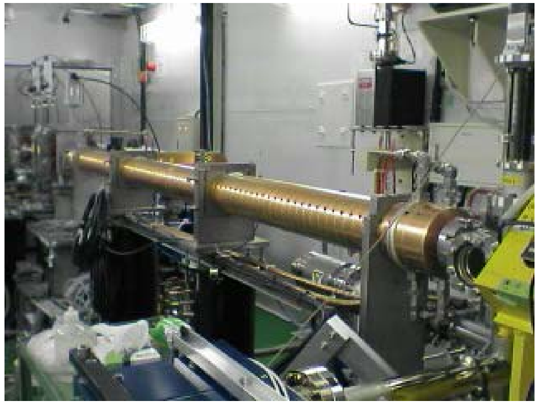


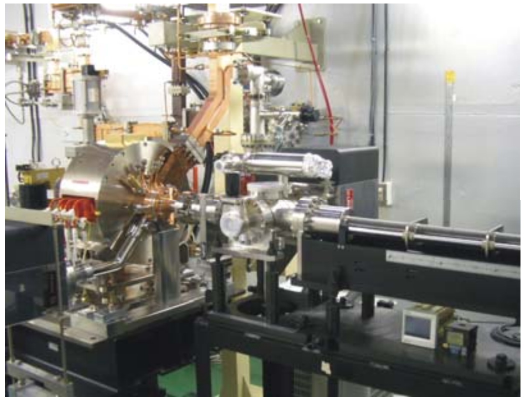
図7 Upper-left : ICT signal of 100 bunches, upper-right : 100 bunches on the OTR screen, bottom figure : energy of each bunch in the train

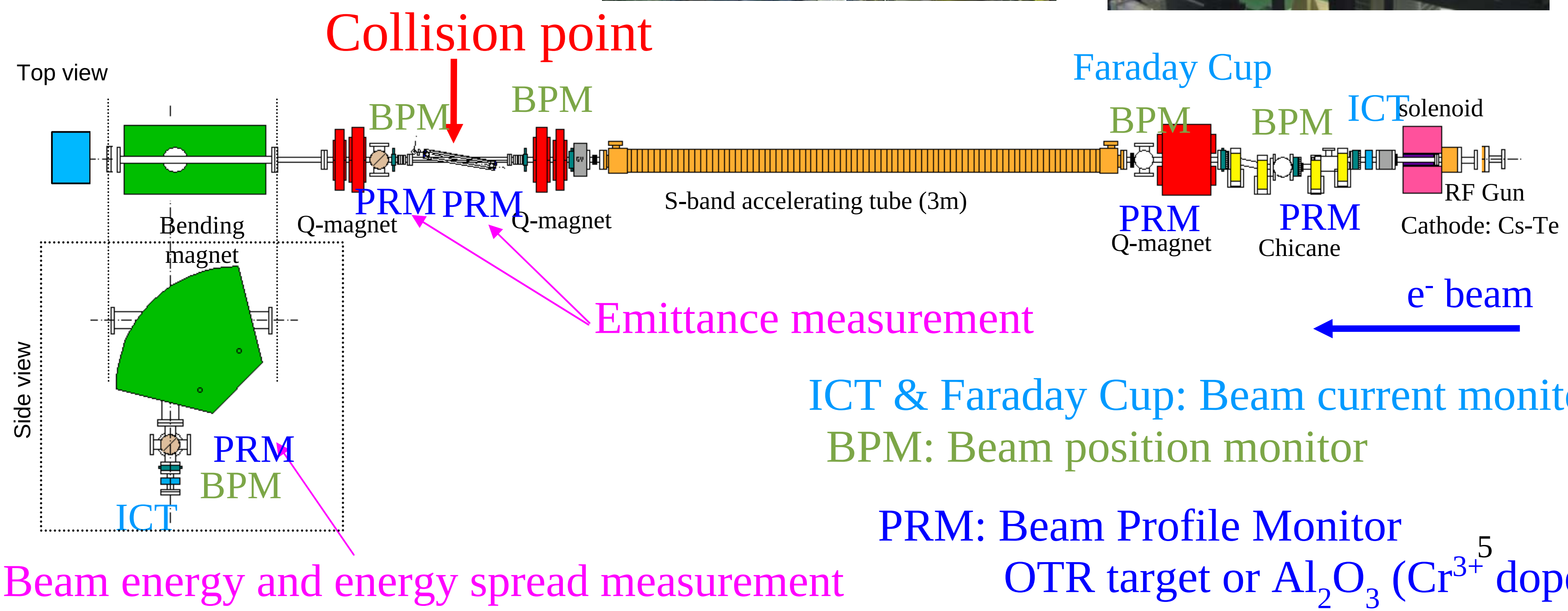
100 bunches/pulse energy spread is less than 0.5%.
問題点：S-band高周波源一台と高周波パルス圧縮装置を使用している為に50nC/100 bunches加速が限界である。12MWの高周波源を1台追加すれば、300nC/100bunchesを60MeVまで加速して、X線生成衝突に使える。

Laser Pulse Stacking Chamber, 3m long S-band accelerating tube and Photo-cathode RF Gun









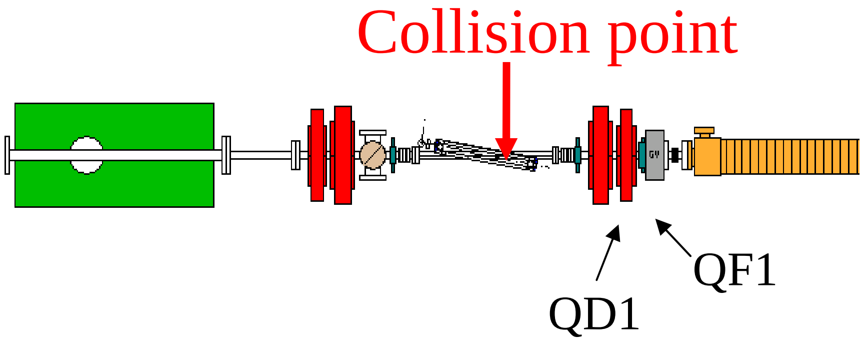
ICT & Faraday Cup: Beam current monitor

BPM: Beam position monitor

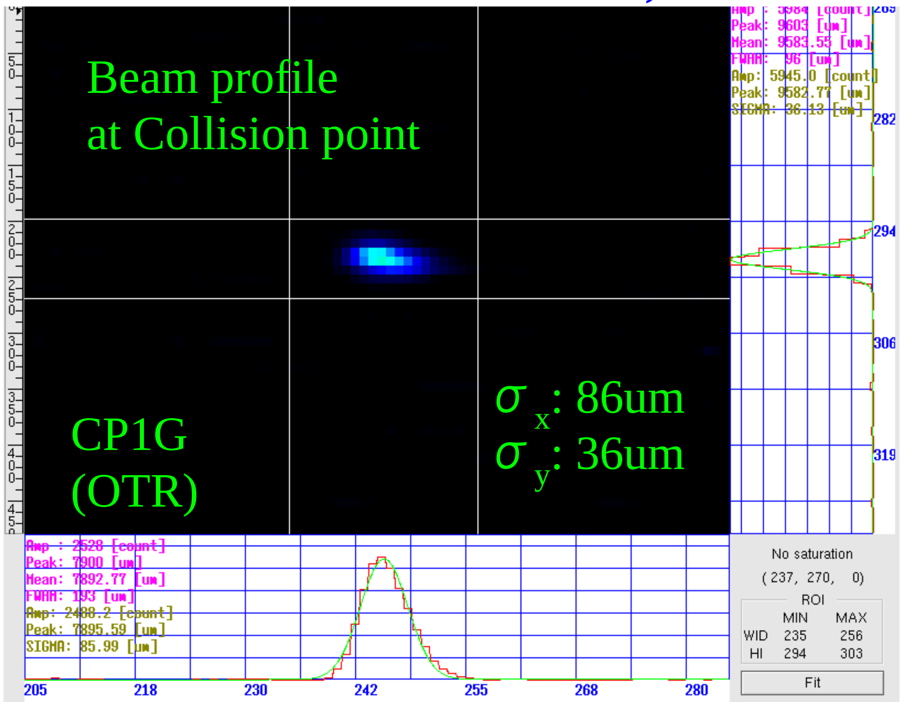
PRM: Beam Profile Monitor

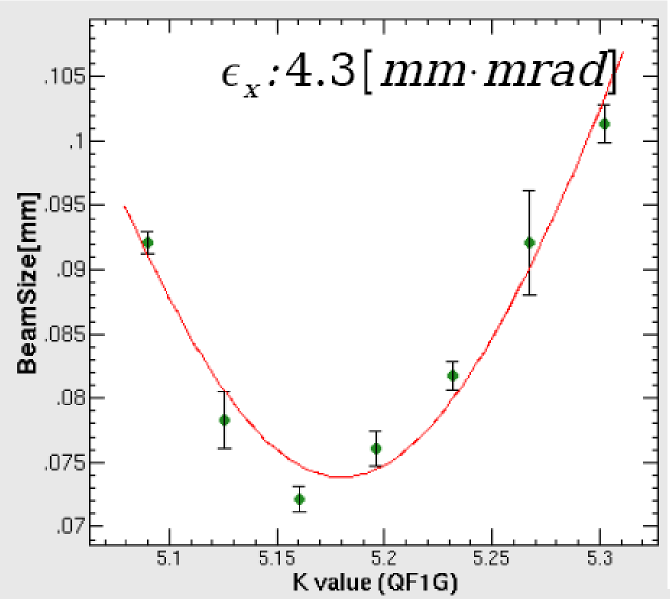
OTR target or Al_2O_3 (Cr^{3+} doped)

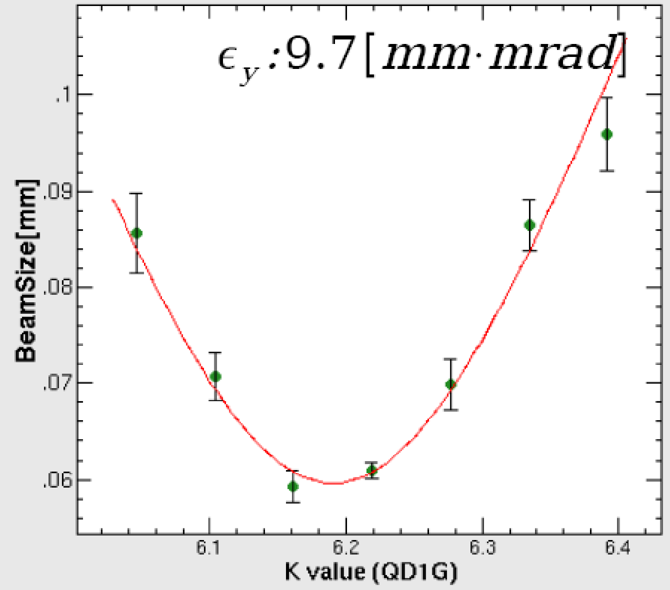
Emittance measurement



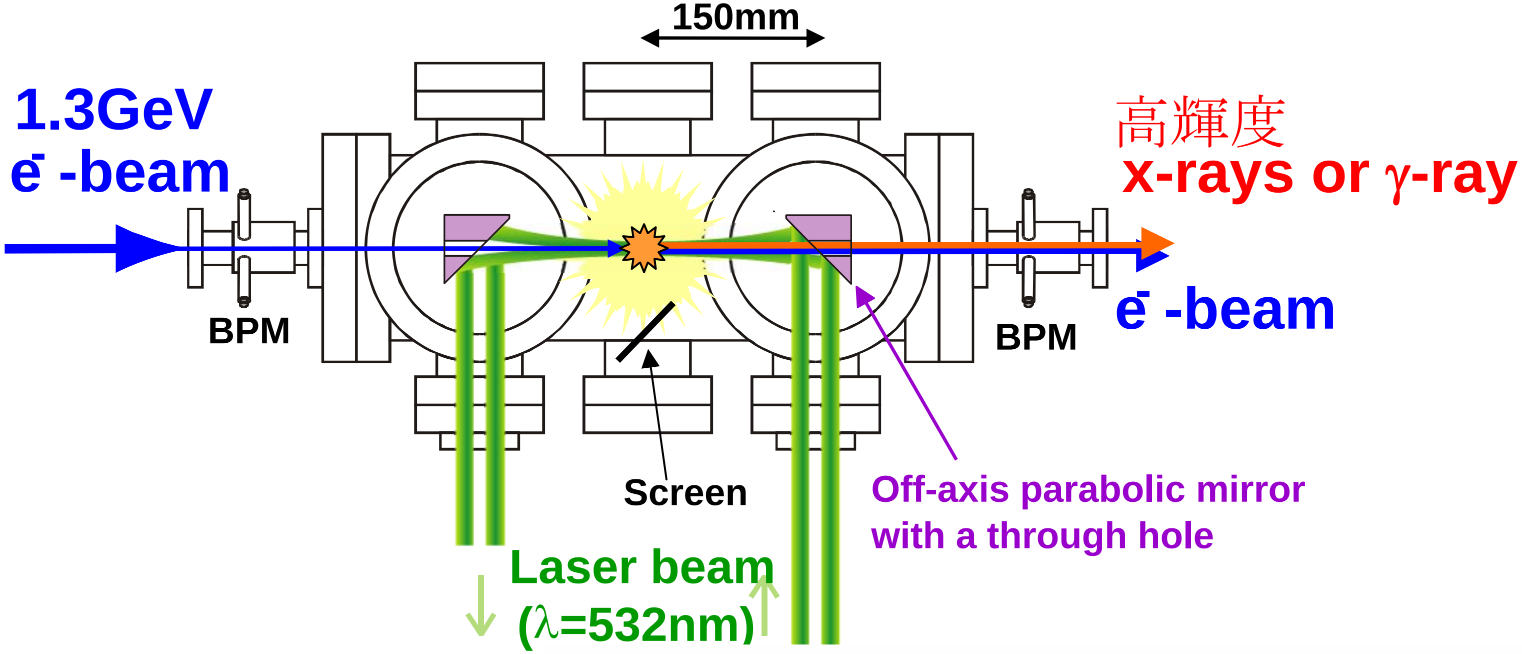
Beam current : 2.5nC/train, 5bunches





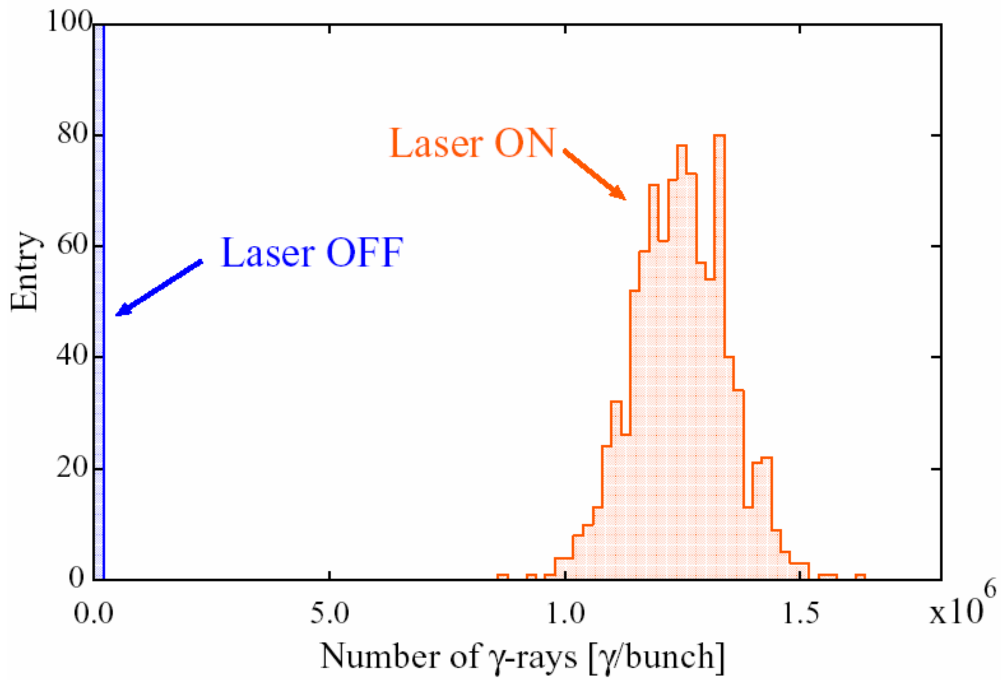


衝突技術:Head on collision



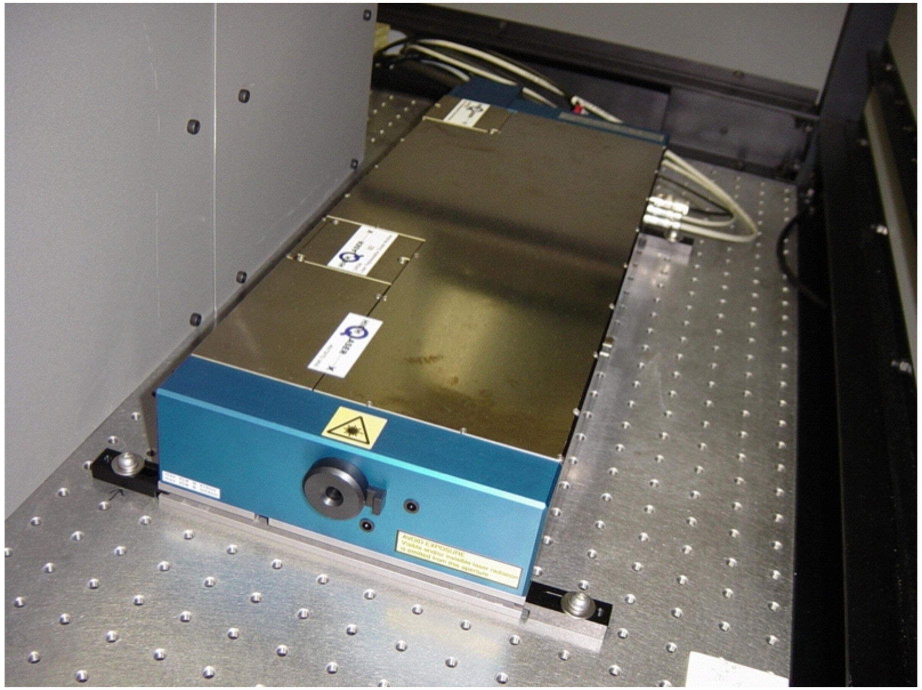
56MeV Photon Beam
Measured Number of γ-rays
$N\gamma = (1.1 \pm 0.1) \times 10^6$/bunch
in 31 p sec

$N\gamma = (2.1 \pm 0.1) \times 10^7$/bunch
This is highest result.



2. レーザースーパーキャビティ開発の現状

Laser:

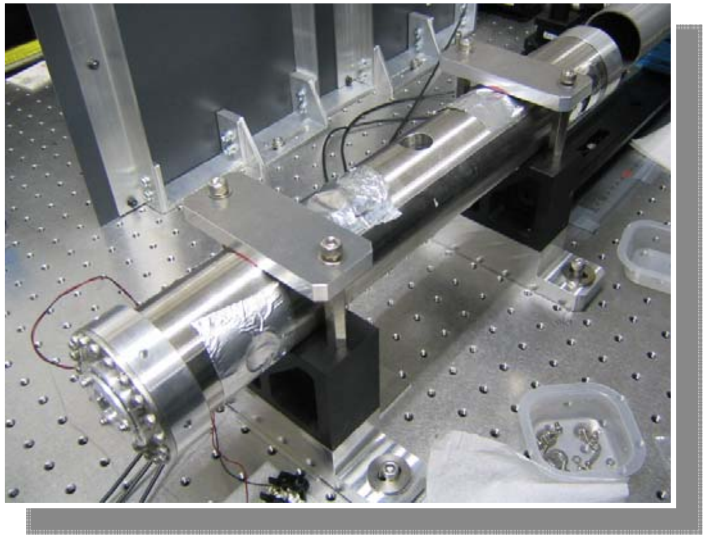


Mode Lock:	Passive SESAM
Frequency:	357MHz
Cavity length:	0.42 m
Pulse width:	7.3 p sec (FWHM)
Wave Length:	1064 nm
Power:	~ 6W

SESAM: <u>SE</u>mi-conductor <u>S</u>aturable <u>A</u>bsorber <u>M</u>irrors

Ext. Cavity:

Cavity:	Super Invar
Cavity length:	0.42 m
Mirrors:	
Reflectivity:	99.7%, 99.9%
Curvature:	250 mm (ω_0 = 180 μm)



High Power Test: R= 99.7%

P_{out} = 3.0W

P_{in} = 3.0W

Finesse = 1100

Cavity Transmission = Pout/Pin = 63%

Enhancement Factor = 220

P(cavity) = 660W (1.8 μ J/Pulse)

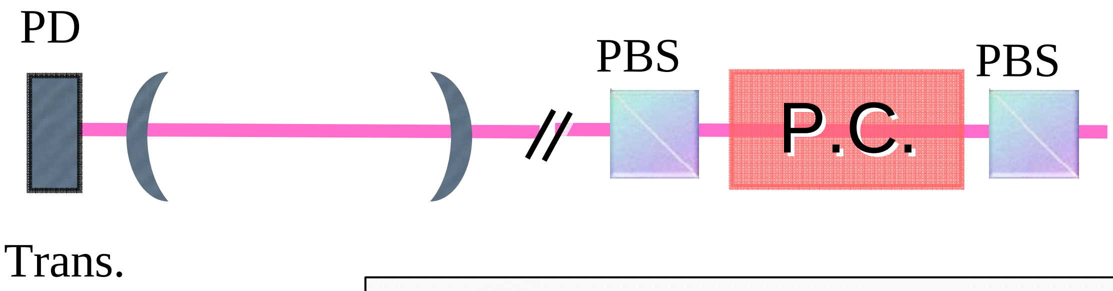
▪ Finesse: R = 99.9%

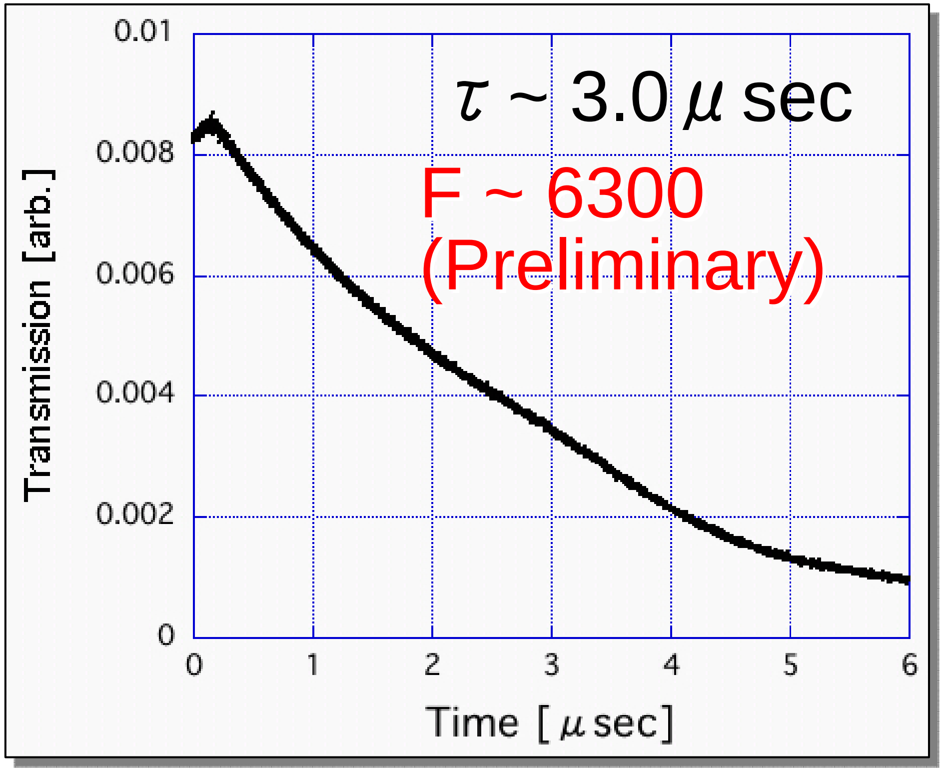
$$\text{Finesse} = \pi \tau c / l$$

τ :decay time

c: light verocity

l: cavity length





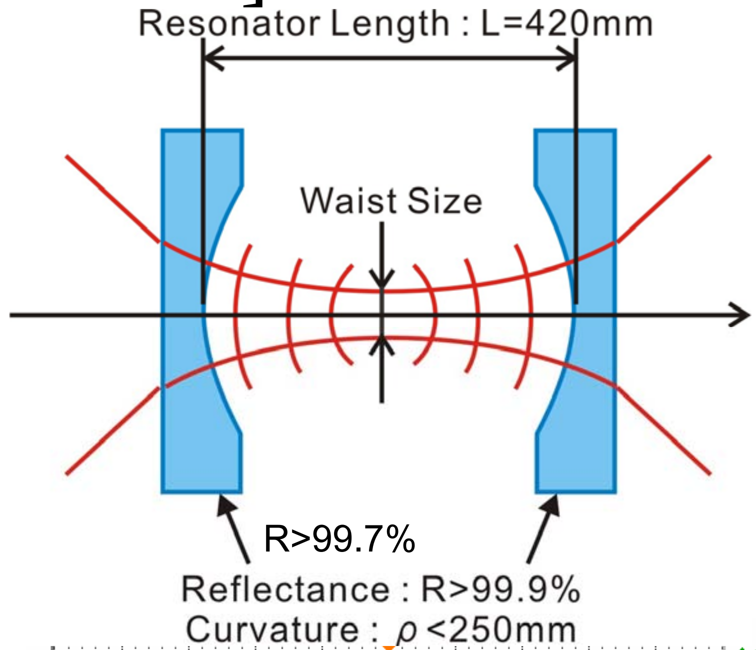
3000倍以上
期待値

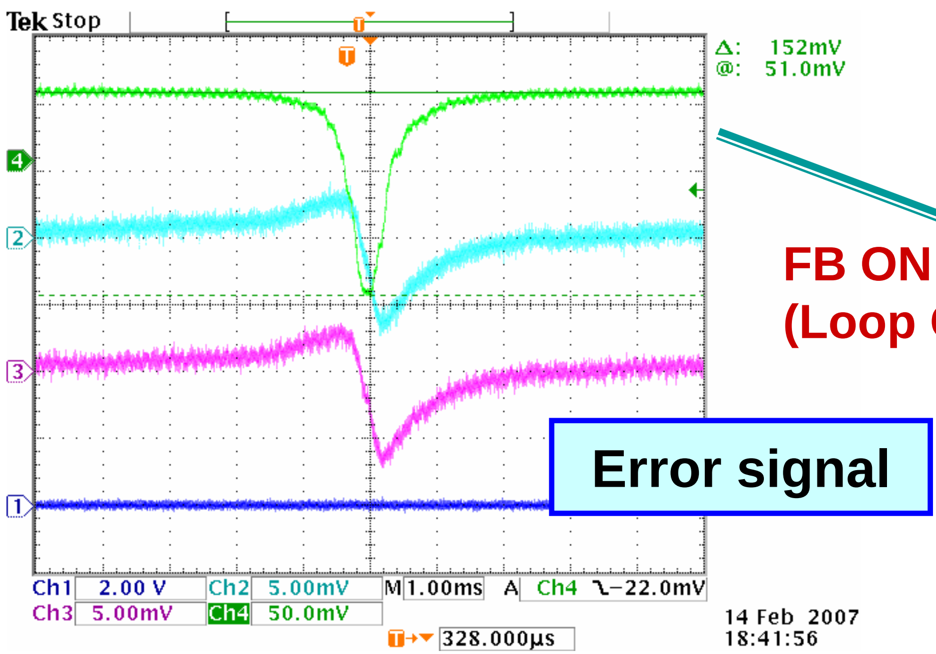
Required Spec. of Optical Resonator
[pulsed laser-wire]

Initial Laser : >6W@357MHz
⇨ Cavity Length : 420mm

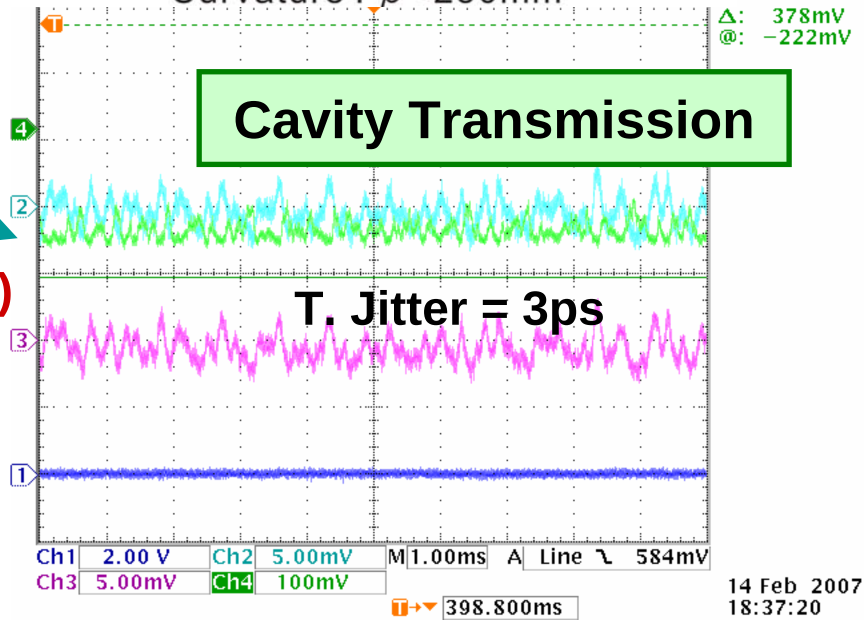
Beam Waist : <170um in 2σ
⇨ Mirror Curvature : <250mm

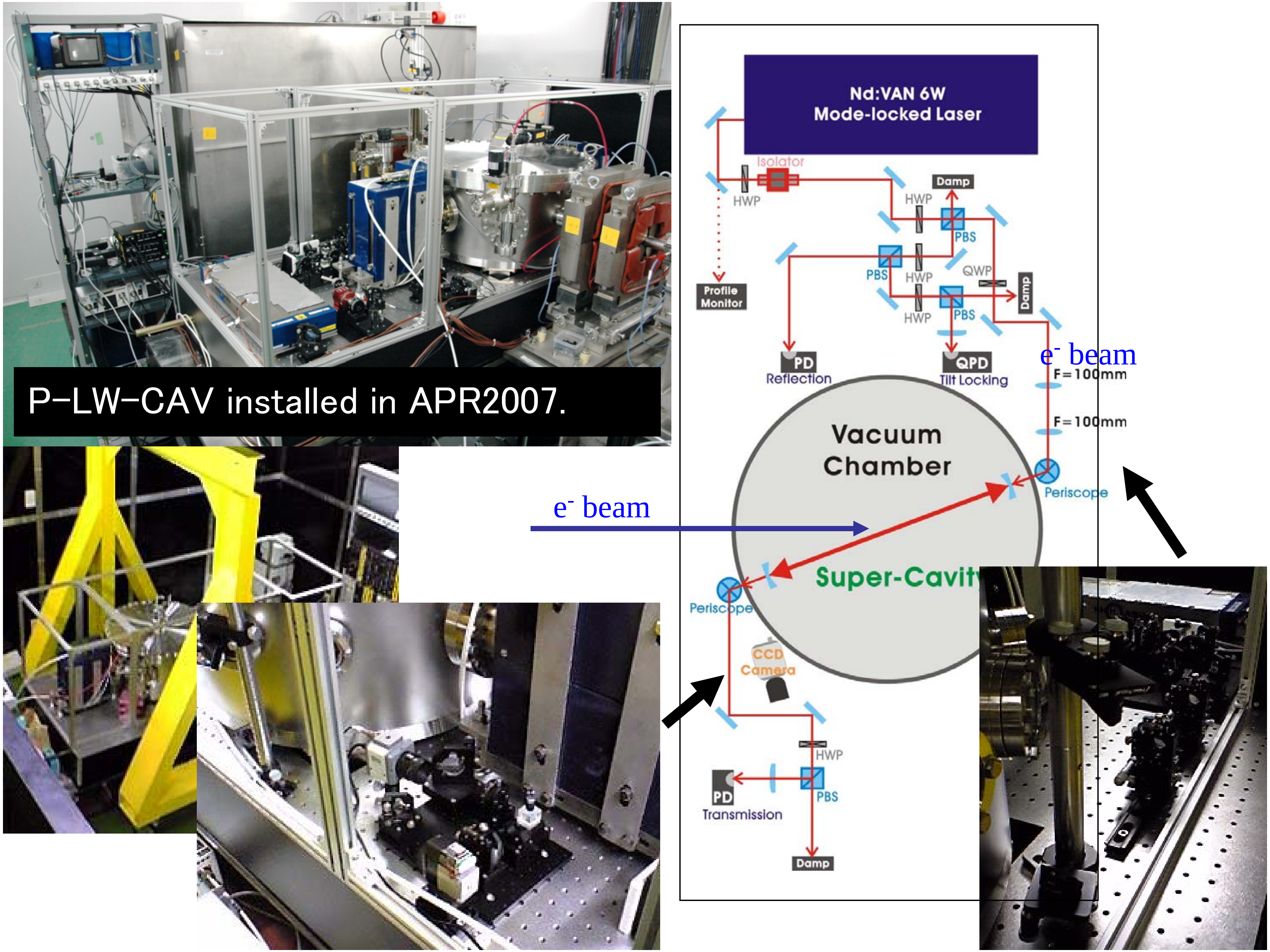
Finesse : >1550
⇨ Mirror Reflectivity : 99.7%, 99.9%





FB ON
(Loop Close)





P-LW-CAV installed in APR2007.

最近の実験結果:加速器高周波ClockでMode-locking

Electron		Laser	
RF Rep.	12.5Hz	Crystal	Nd:VAN
Energy	40MeV	Wavelength	1064nm
Pulse Rep.	357MHz	Laser Freq.	357MHz
Bunch Num.	100/train	Enhancement	630
Charge	0.5nC/bunch	Power	2.45kW
Bunch length	20ps	Pulse width	7ps
Beam size	X:80μm	Waist size	X:89μm
	Y:40μm		Y:89μm
Collision angle		20degrees	

Transmittance of Input	Transmittance of Output	Finesse	Waist Size
0.221%	0.071%	1889.9	89.2μm

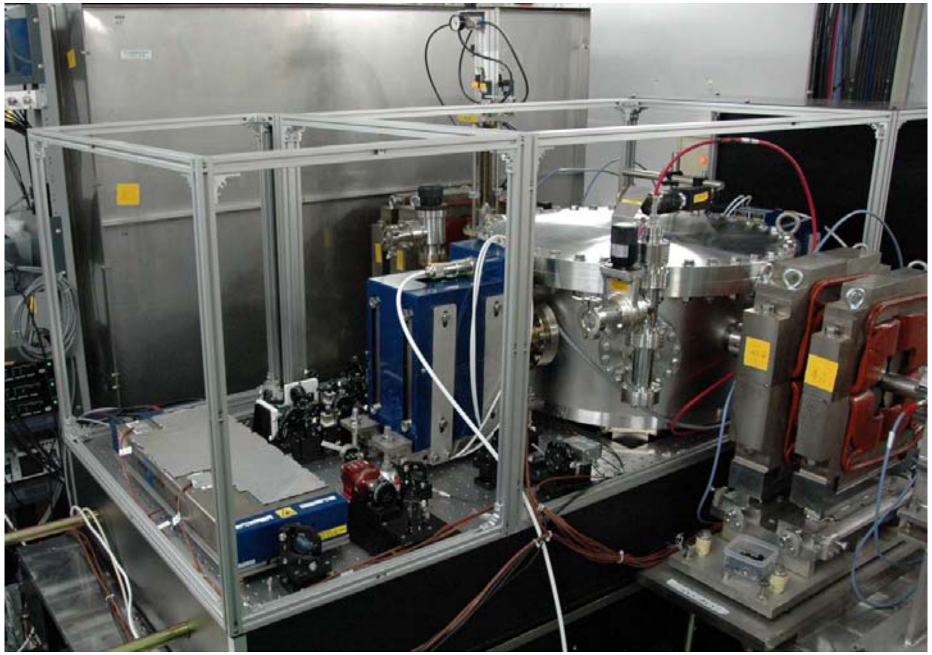
Input Power	Power in Cavity	Enhancement
4.05W	2.45kW	605

6.86μJ/7ps 達成。

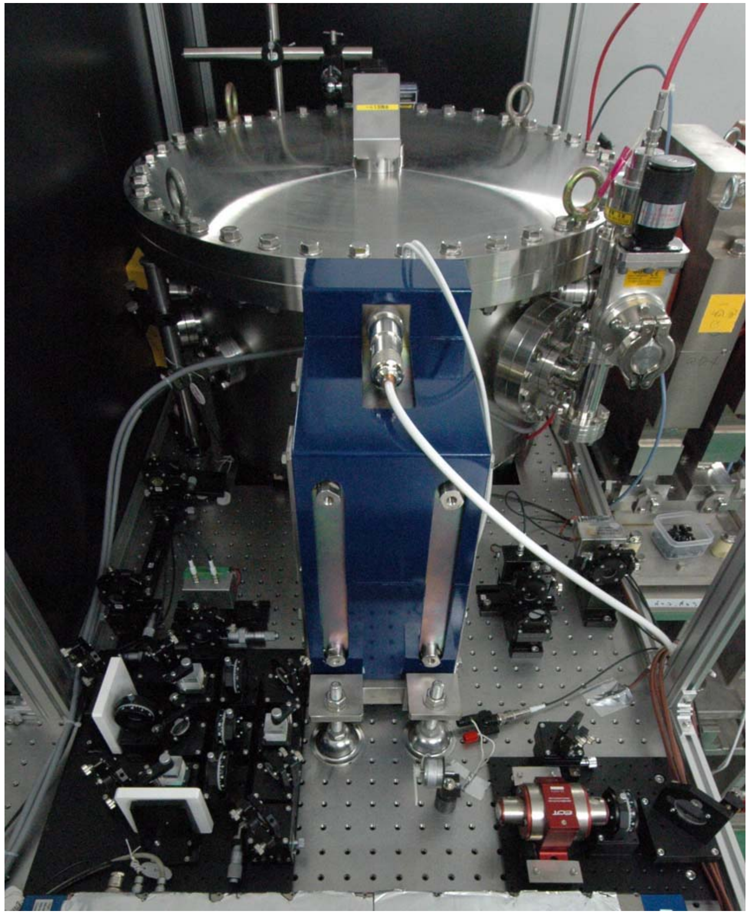
↓

10mJ/7psへ。

3. X線生成実験



43MeV end station to separate X-ray and e-beam. 33keV X-ray is deflected by Crystals.



Pulsed laser stacking chamber

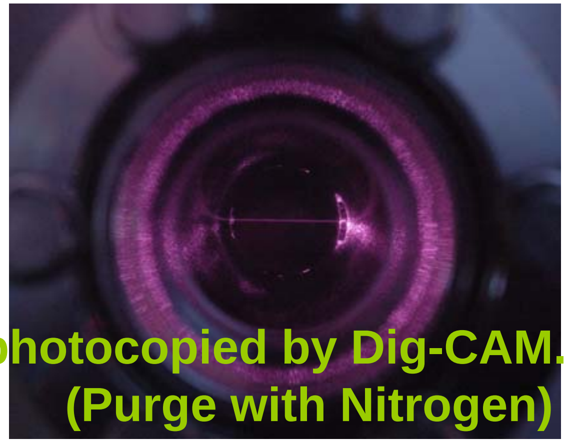
実験結果：３日間のX線検出実験を行ったが、30 keV-X rayの信号確認はできなかった。何か見落としがあると思われる。

コリメータを通過する生成X線のエネルギーと強度

コリメータ条件（受け入れ角）	X線エネルギーと強度
無し	1.16eV～32.7keV, $6.2\text{x}10^5$ photons/sec
1/γ(±11.5mrad)	16.3～32.7keV, $3.2\text{x}10^5$ photons/sec
0.23/γ(±2.64mrad)	31.1～32.7keV, $4.5\text{x}10^4$ photons/sec

Frequency	Finesse	Waist Size (2σ)	Inject laser power	Laser power in resonator with FB
357 MHz	1889 ±31.5	178.4 ±7.5 μm	4.05 W @357 MHz	2.40 ±0.05 kW → x 630





Inside of e-beam chamber was photocopied by Dig-CAM.
(Purge with Nitrogen)

まとめ（目標を述べる。）

１．X線生成実験を１０月から再開して、S/Nの高い測定結果を得る。

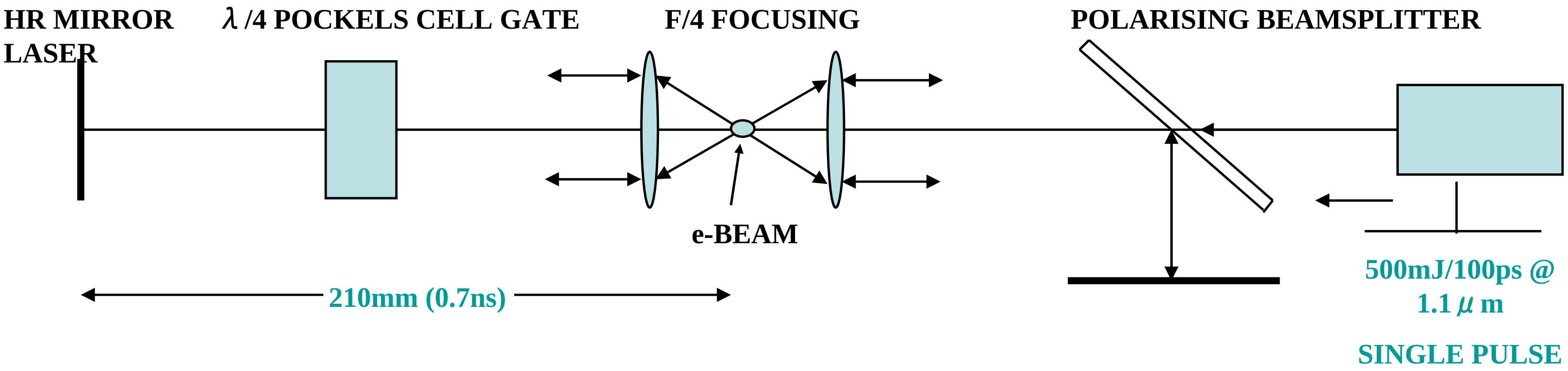
２．レーザースーパーキャビティの増幅率を4000倍以上にする。

３．電子ビームのさらなるマルチバンチ化により1000nC/pulseを達成する。

４．十分なX線生成が可能であることを示す。

Burst mode amplification or New Idea by UK（別グループに依頼）

Use a Misaligned Multipass Cavity



Mirror spacing determines the inter-pulse interval to match to 2.8ns

Slight mirror tilt from perfect auto-collimation or slight shear of one lens gives scanning with equally spaced foci and a controllable spacing

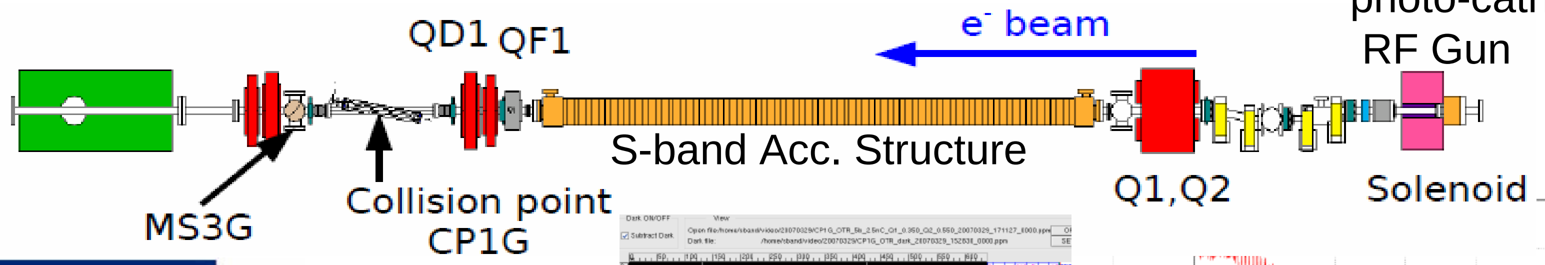
PC gate switches pulse into cavity

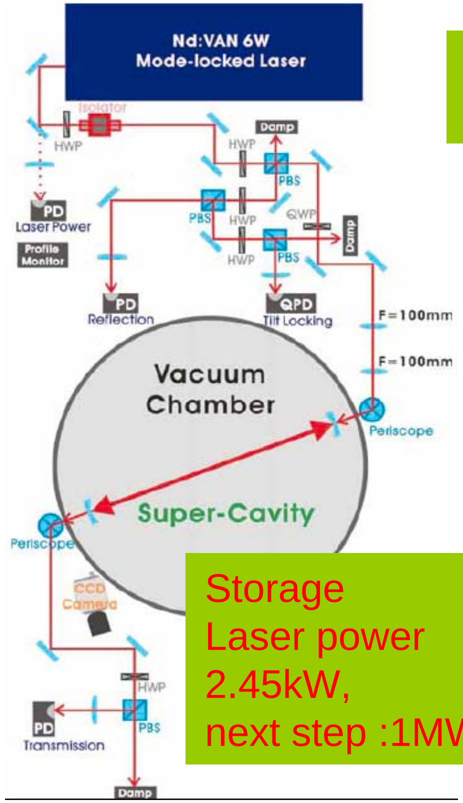
Need to keep round-trip losses very low to ensure sufficient passes at sufficient power

Other designs possible

Laser Undulator Compact X-ray (LUCX) Project at KEK-ATF

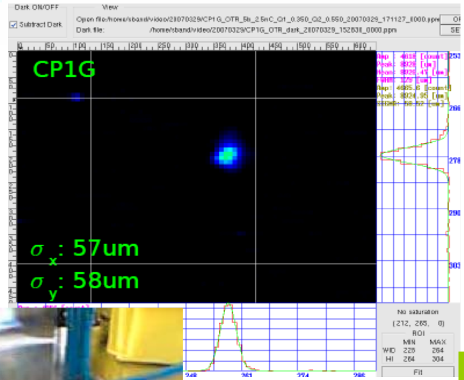
43MeV Multi-bunch beam+ Super-Cavity = 33keV X-ray.

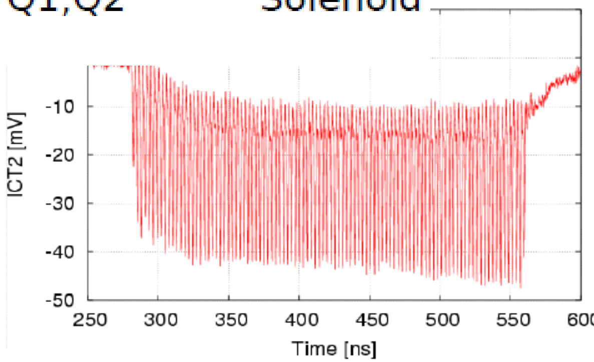




Storage Laser power 2.45kW, next step :1MW

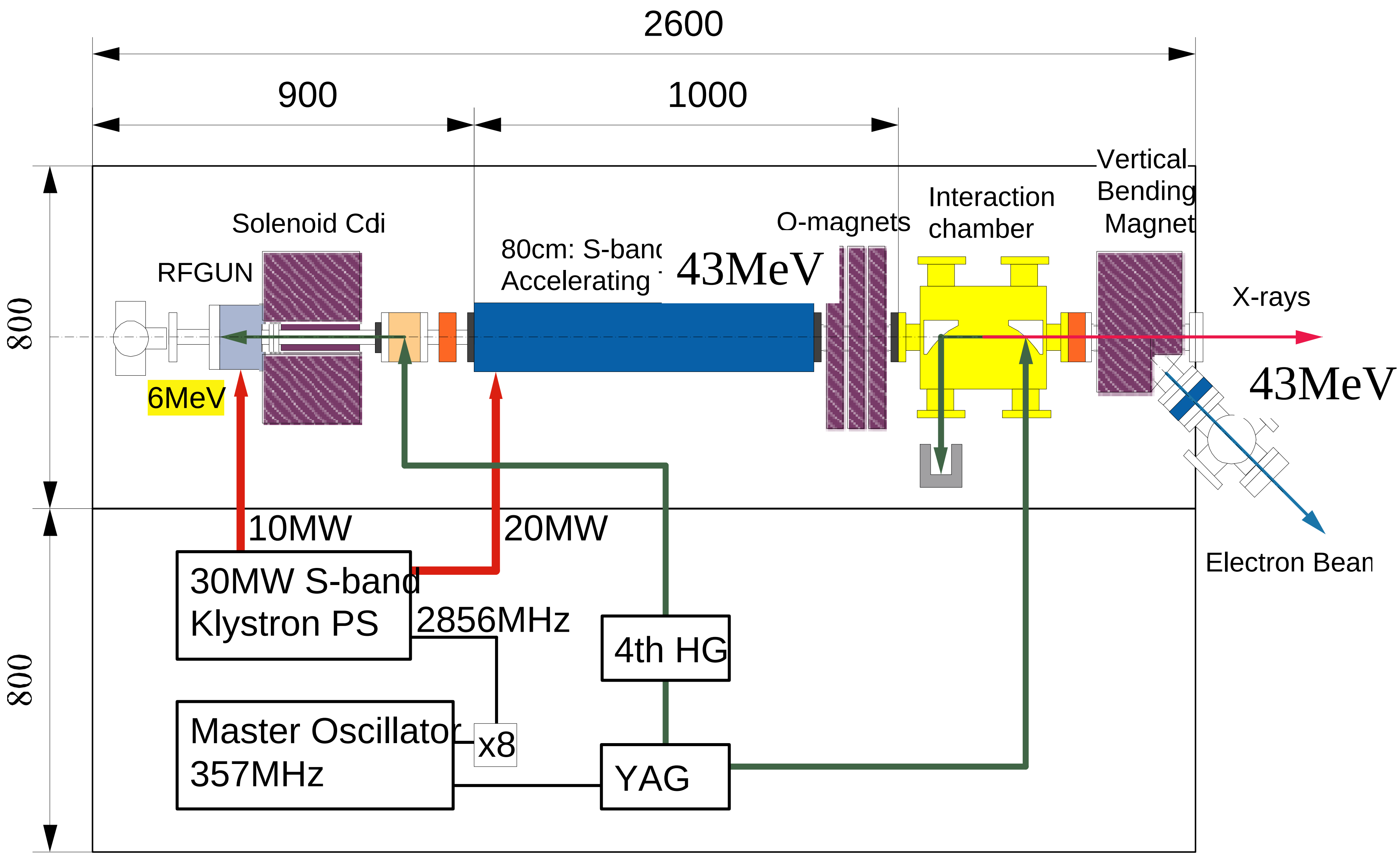
Beam size at CP 60μm in σ



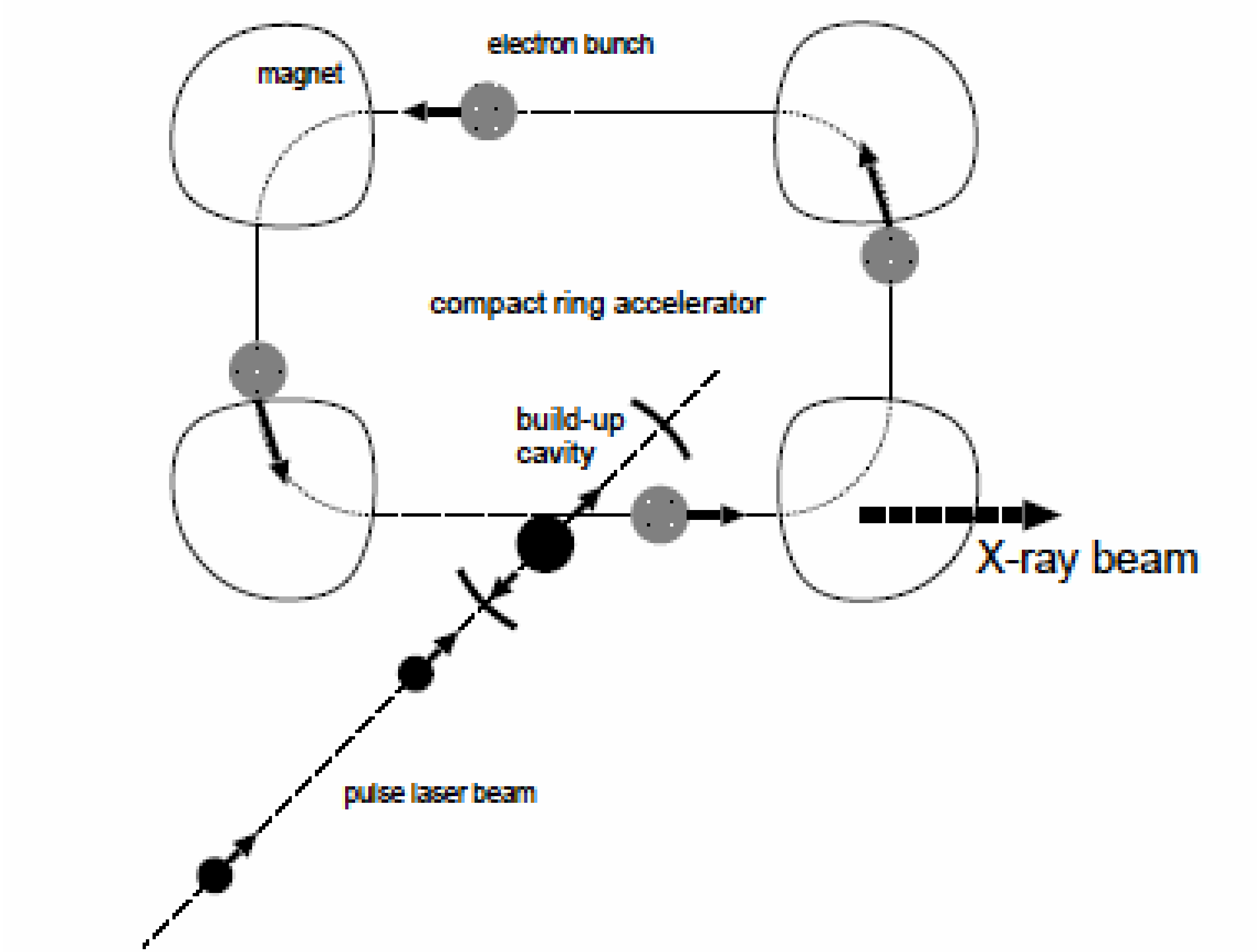


Multi-bunch e- beam 300nC at gun

At present, laser waist size is 90μm in σ. We should reduce both beam size at CP down to 40μm.
33keV X-ray generation based on inverse Compton scattering will start from Oct. 2007 with Super-Cavity.


2600
900
1000
800
800
Vertical
Bending
Magnet
Interaction
chamber
O-magnets
Solenoid Cdi
80cm: S-band
Accelerating
43MeV
RFGUN
X-rays
6MeV
43MeV
Electron Bean
10MW
20MW
30MW S-band
Klystron PS
2856MHz
4th HG
Master Oscillator
357MHz
x8
YAG

開発装置概念図



>10^{13} photons/sec, >33keV, 1% energy spread
小型高輝度X線源開発（周長10m程度）と実用化が目標。