



3rd ILSF Advanced School on Synchrotron Radiation and Its Applications



September 14-16, 2013

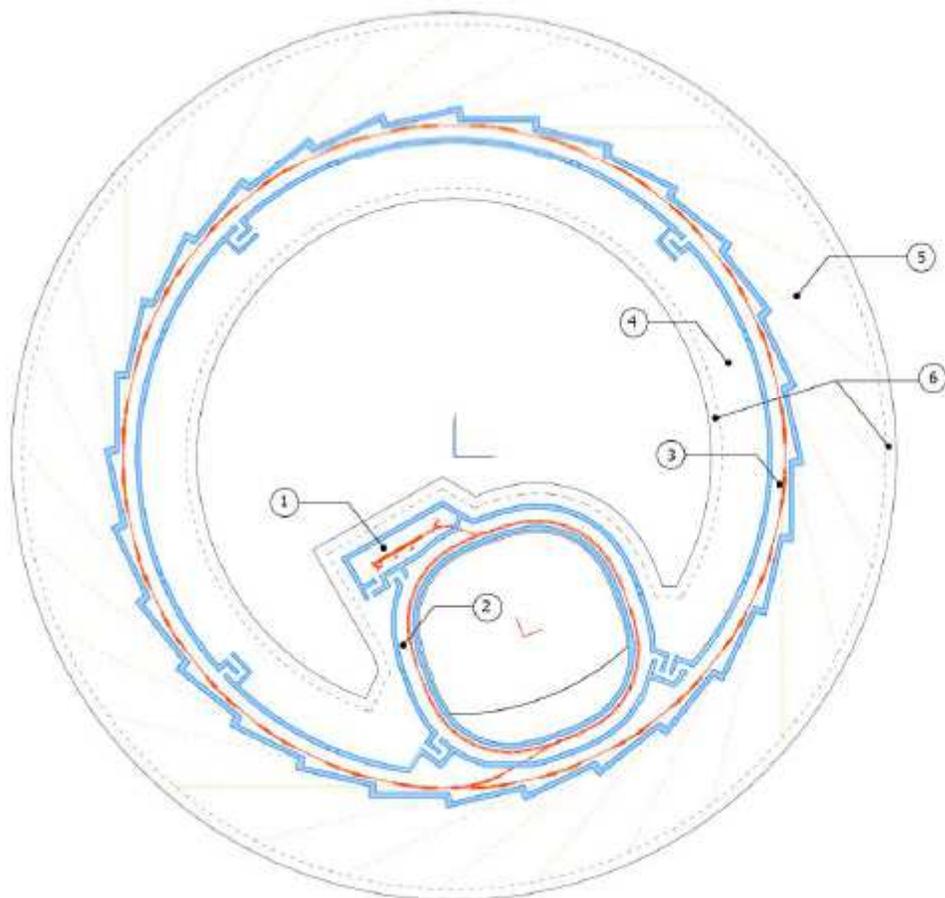
ابزارهای تشخیصی باریکه

ارائه دهنده: مهدی شفیعی

تاریخ ارائه: ۱۳۹۲/۰۶/۲۳

ابزارهای تشخیصی باریکه چیست؟

طرح پایه شتابگر ملی



- 1 Linac
- 2 Booster
- 3 Storage Ring
- 4 Service Area
- 5 Experimental Hall
- 6 Access Corridors

مشخصات حلقه انبارش (Storage Ring)

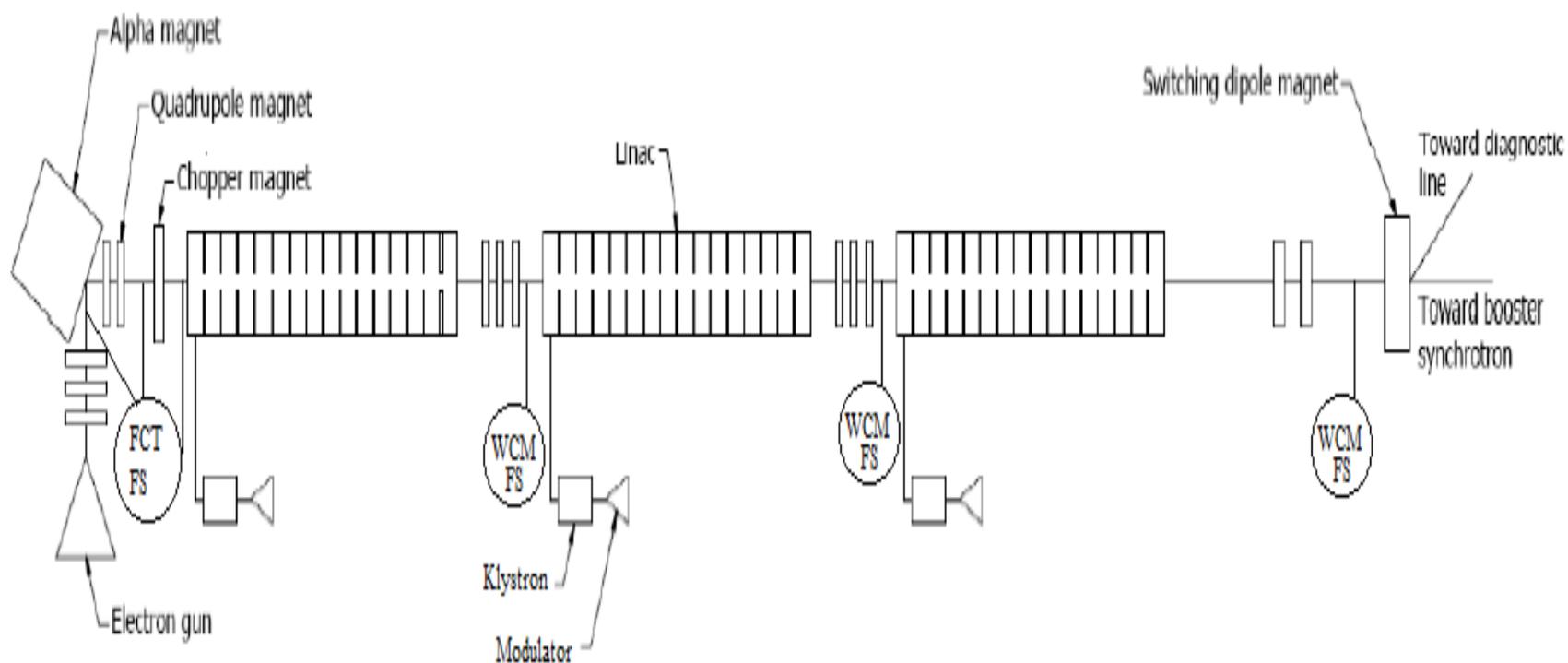
Parameter	Unit	Value
Energy	GeV	3
Circumference	m	489.60
Natural emittance	Nm.rad	0.93
Number×Length of Straight Section	-×m	14×8+14×6
Tune (Q _x /Q _y)	-	31.25
Natural Chromaticity (ξ_x/ξ_y)	-	-84.75/-45.79
Energy Spread	-	6.91E-4
Radiation loss per turn	KeV	518.64
RF frequency	MHz	500
Harmonic Number	-	816
Dipole/Quadrupole/Sextupole	-	56/252/196

مشخصات حلقه افزایشده انرژی (Booster)

Parameter	Unit	Value
Energy@ injection/extraction	GeV	0.150/3
Circumference	m	168
Maximum Current	mA	10
Natural emittance	Nm.rad	33.035
Harmonic Number	-	280
Tune (Q _x /Q _y)	-	11.229/4.290
Natural Chromaticity (ξ_x / ξ_y)	-	-20.290/-10.119
Energy Spread	-	7.236E-04
Radiation loss per turn	KeV	573.200

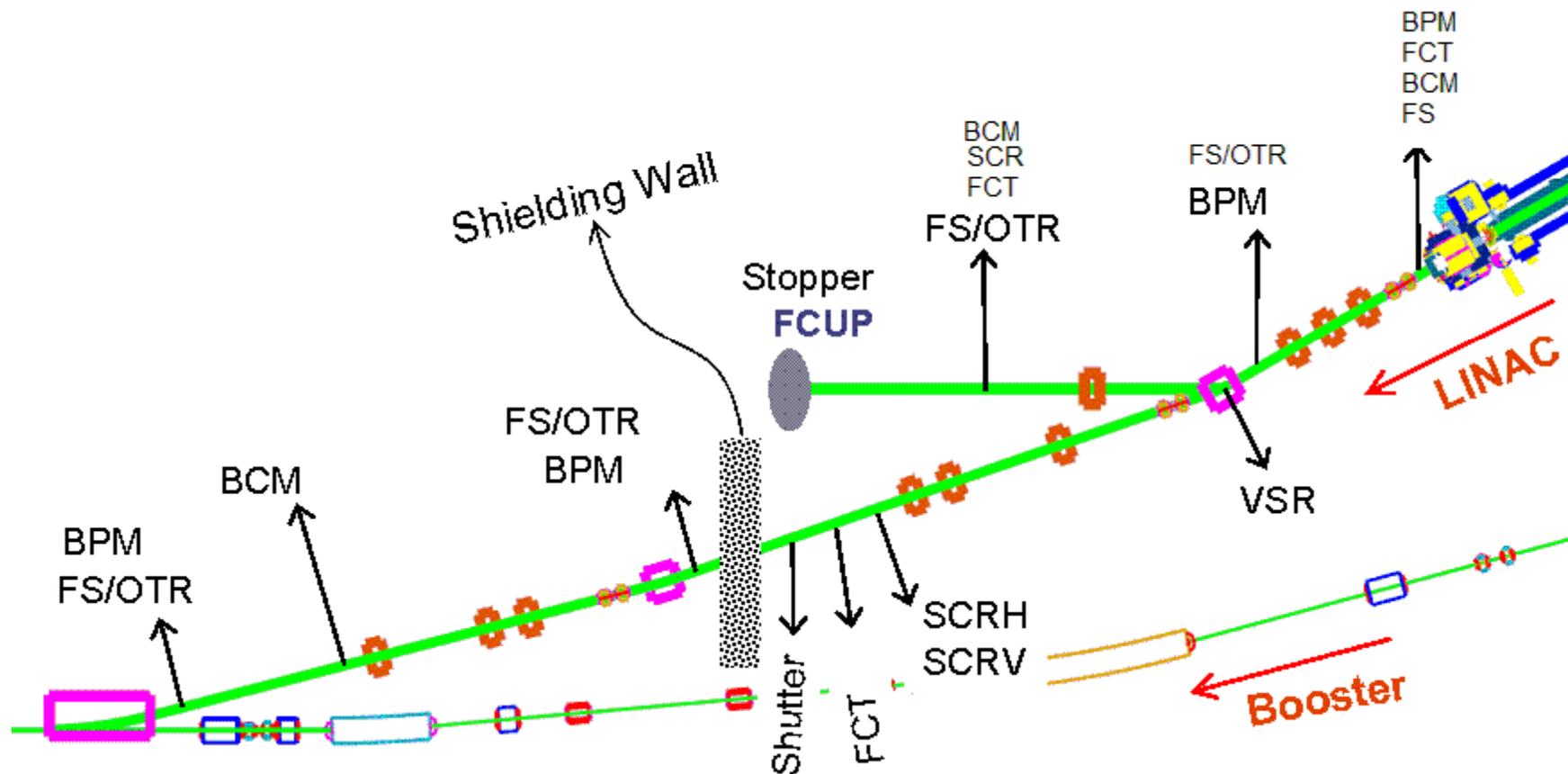
ابزار	ویژگی	تاثیر روی باریکه
WCM	اندازه گیری جریان و ساختار طولی باریکه	غیر مخرب
FCT	اندازه گیری جریان	غیر مخرب
DCCT	اندازه گیری جریان میانگین	غیر مخرب
Faraday Cup	اندازه گیری جریان	مخرب
FS	اندازه گیری پروفایل	مخرب
OTR	اندازه گیری پروفایل و سائز	مخرب
SRM	اندازه گیری سائز و پروفایل عرضی و طولی باریکه	غیر مخرب
Button BPM	اندازه گیری مکان باریکه	غیر مخرب
Stripline	اندازه گیری مکان باریکه و تیون	غیر مخرب
BLM	اندازه گیری مکان و شدت تلفات	غیر مخرب
Scraper	اندازه گیری پارامترهای دینامیکی و حذف هالو باریکه	مخرب

ابزارهای تشخیصی متداول در شتابگر خطی

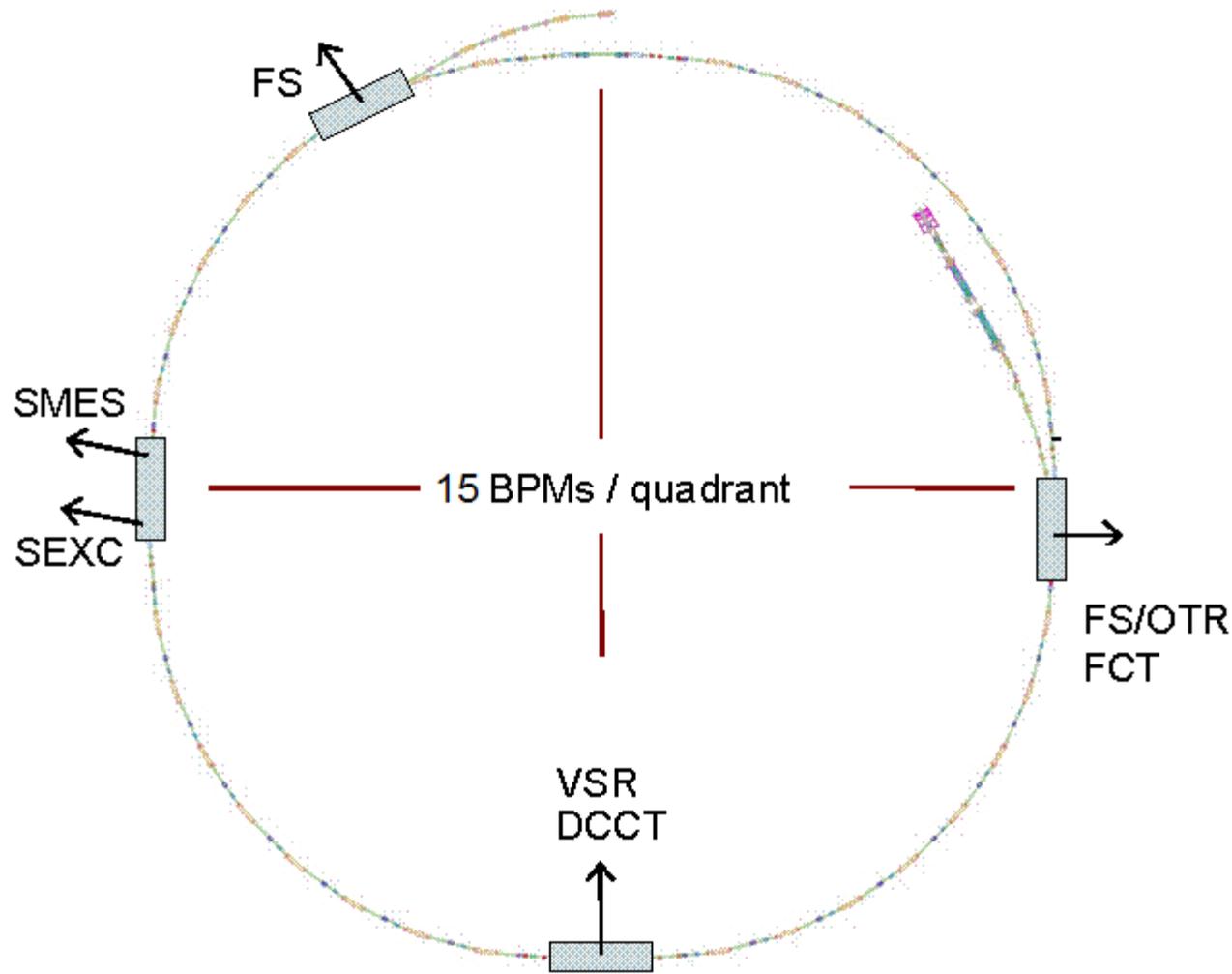


ابزارهای تشخیصی متداول در خط انتقال LTB

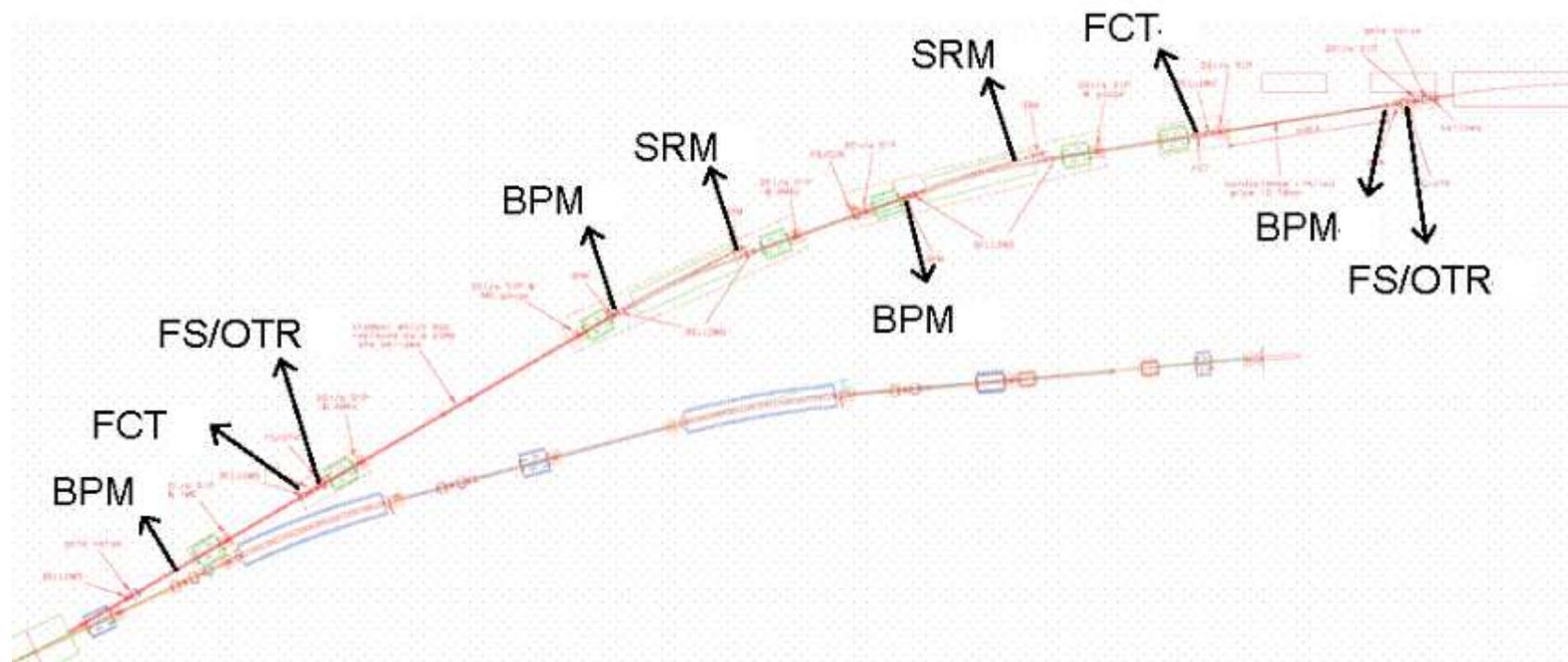
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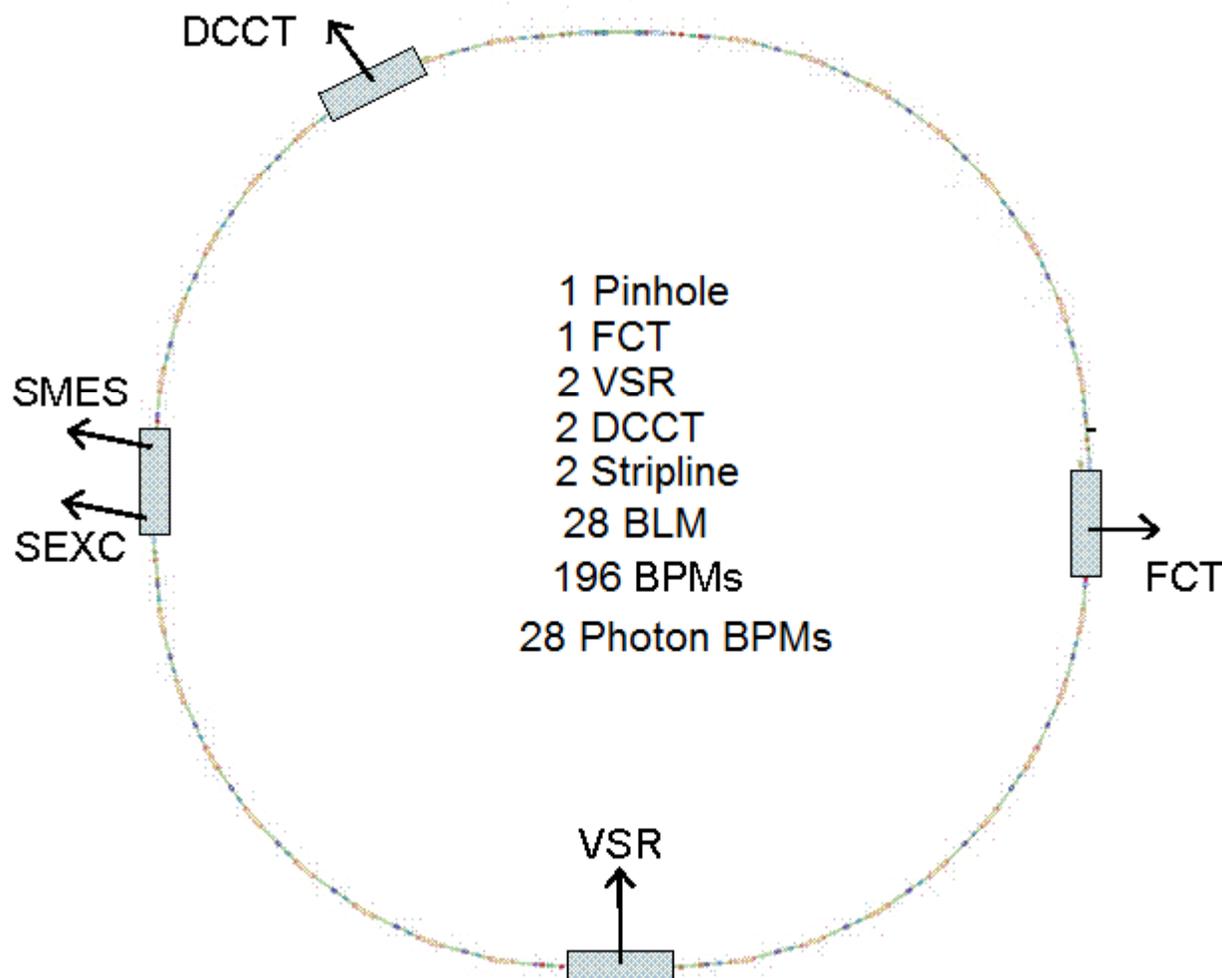
ابزارهای تشخیصی متداول در حلقه افزایشده انرژی Booster



ابزارهای تشخیصی در خط انتقال BTS



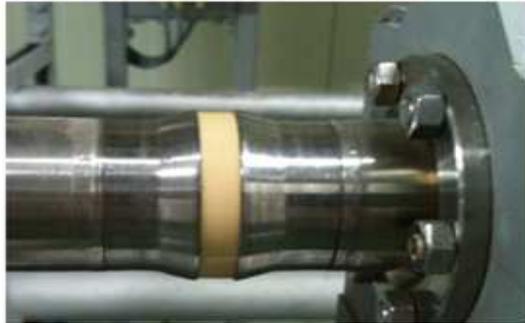
ابزارهای تشخیصی متداول در حلقه انبارش Storage Ring



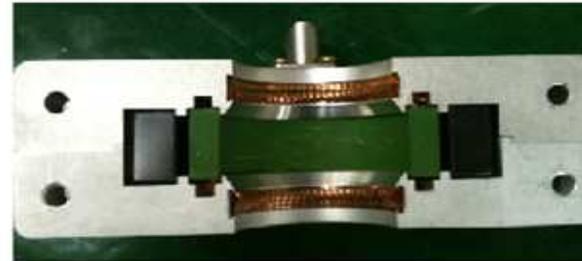
اندازه گیری جریان باریکه

- Wall current Monitor (WCM)
- Fast Current Transformer (FCT)
- DCCT
- Faraday Cup

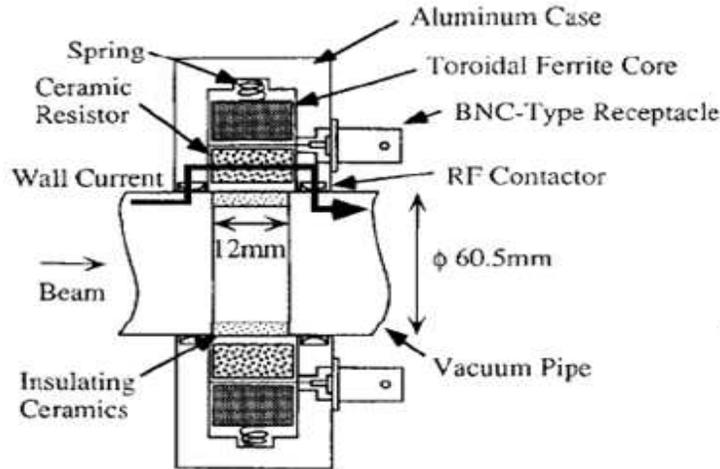
Wall Current Monitor



(1)



(3)

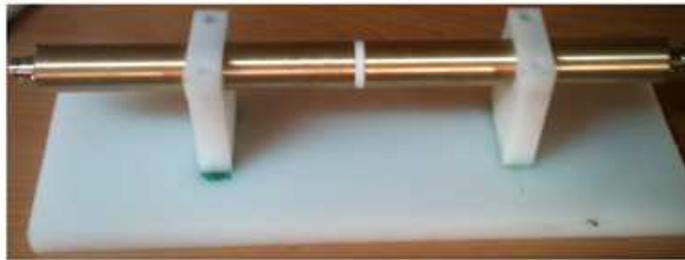


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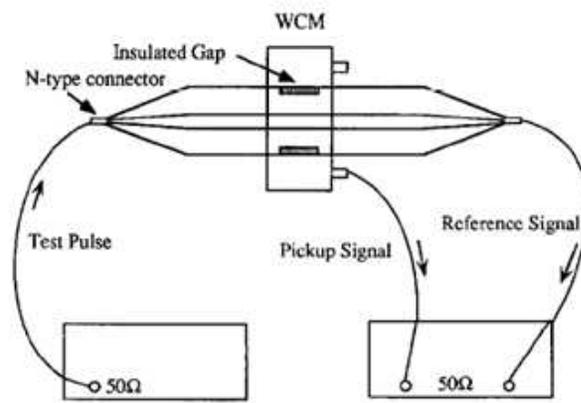


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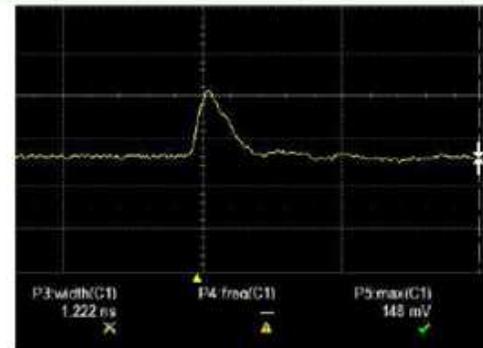
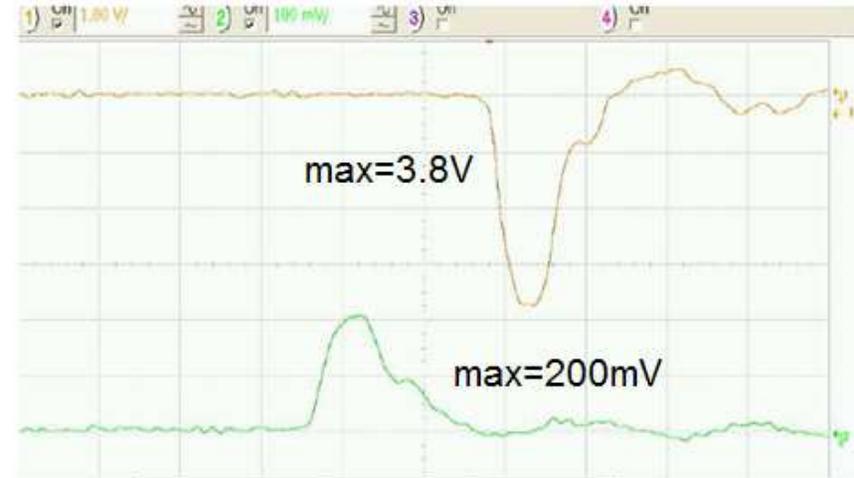
Toolkit



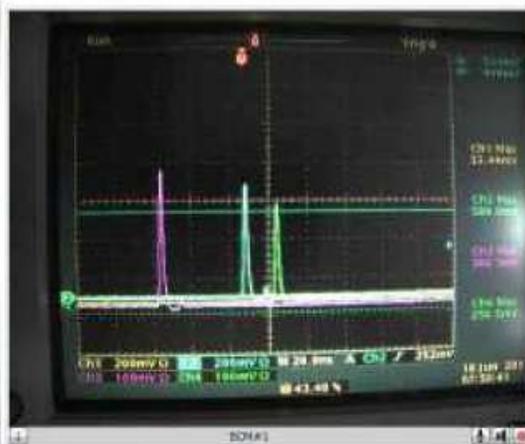
(1)



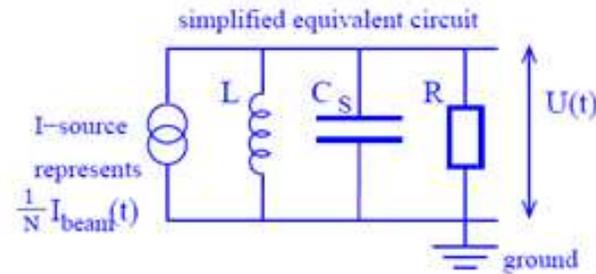
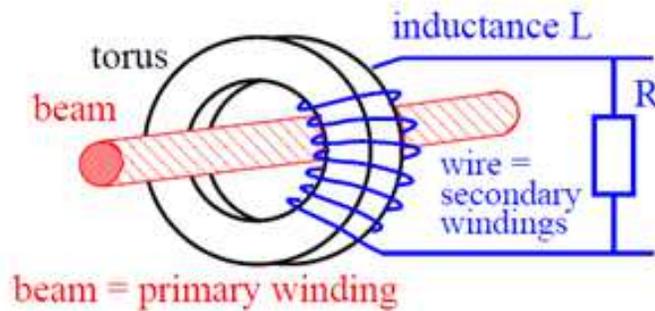
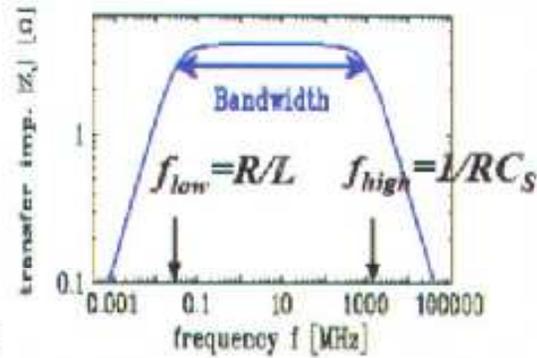
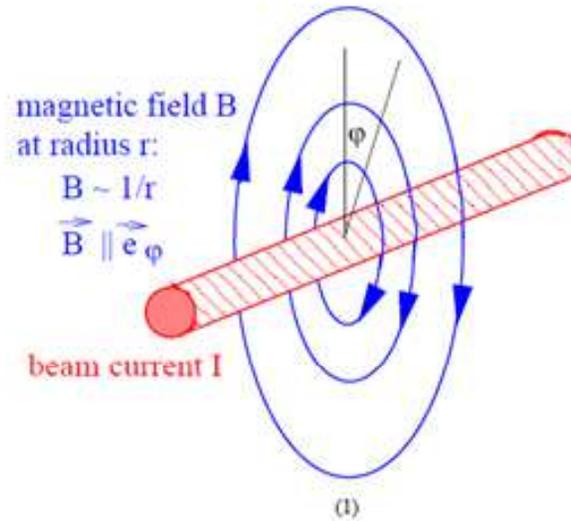
(2)



نحوه نمایش جریان WCM

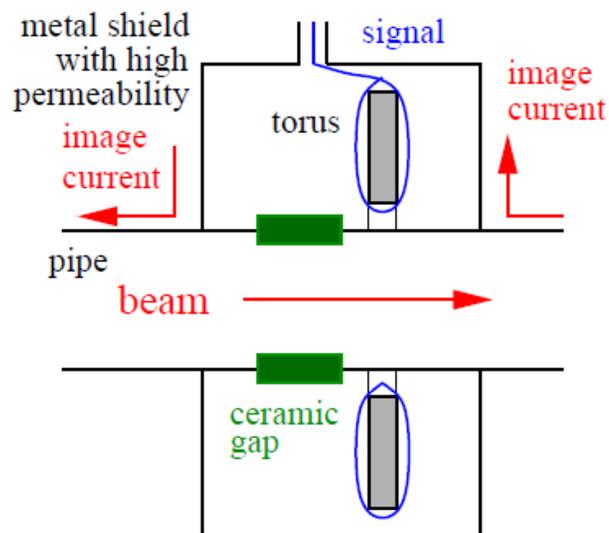


Fast Current Transformer



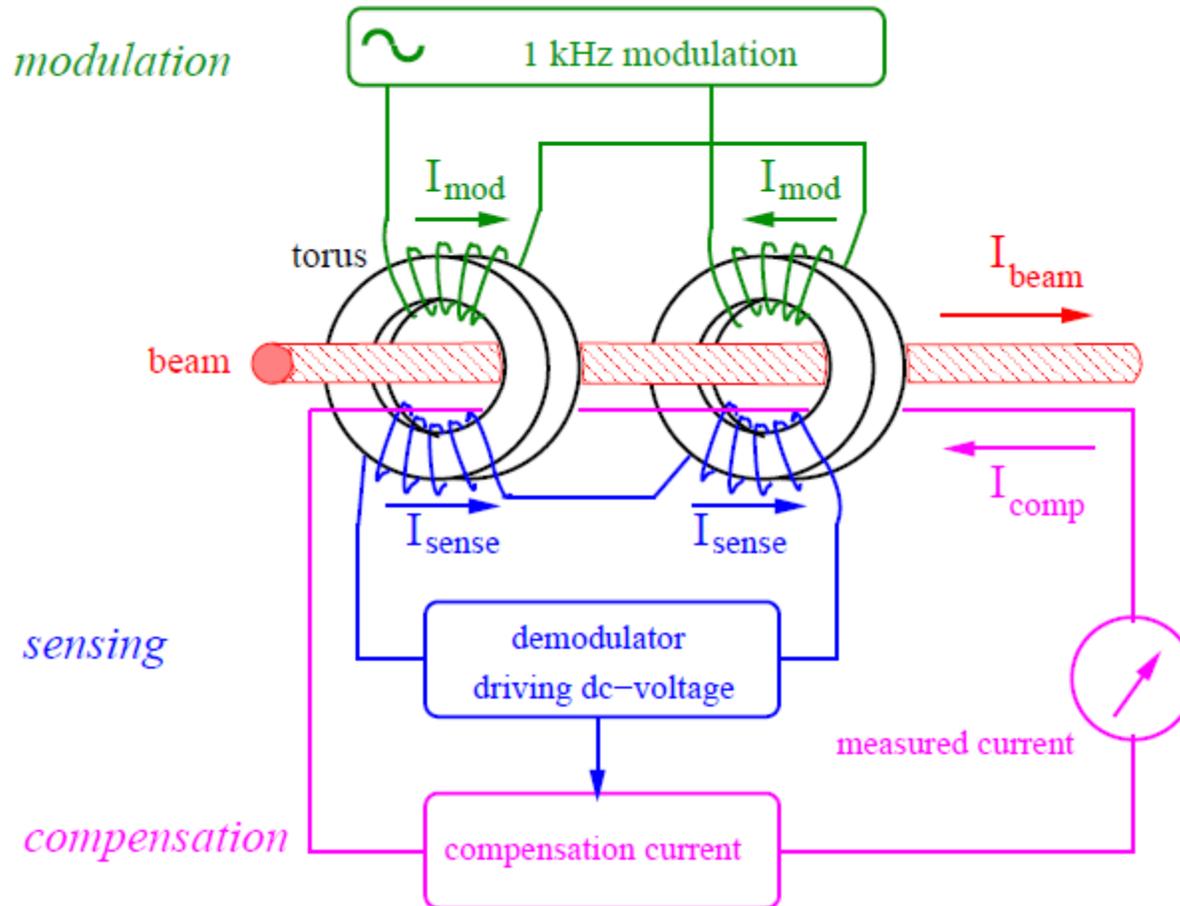
(2)

Fast Current Transformer



Sensitivity (nominal)	0.5	1.25	2.5	5.0	V/A
Turns ratio (old reference)	50:1	20:1	10:1	05:1	Units
Rise time (typ.)	300	200	300	390	ps
Droop	<3	<6	<10	<20	%/μs
Upper cutoff frequency -3dB typ.	1.17	1.75	1.17	0.9	GHz
Lower cutoff frequency -3dB	<4.8	<9.5	<16	<32	kHz
L/R time constant (min.)	35	17	10	5	μs
Max. rms current ($f > 10$ kHz)	14	5.6	2.8	1.4	A

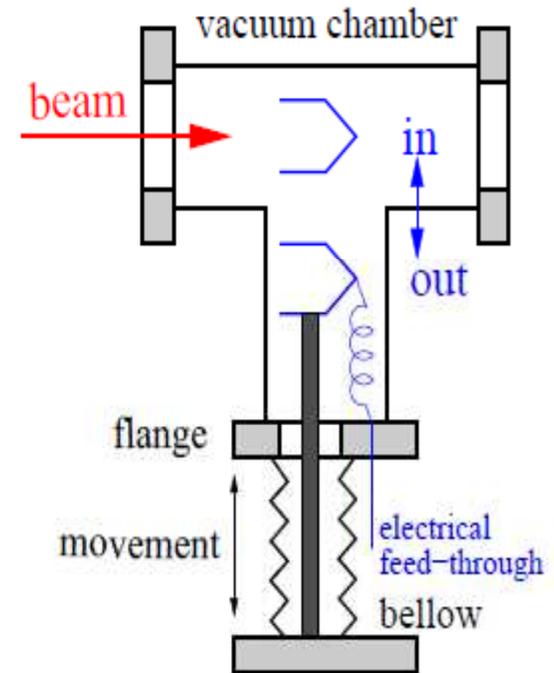
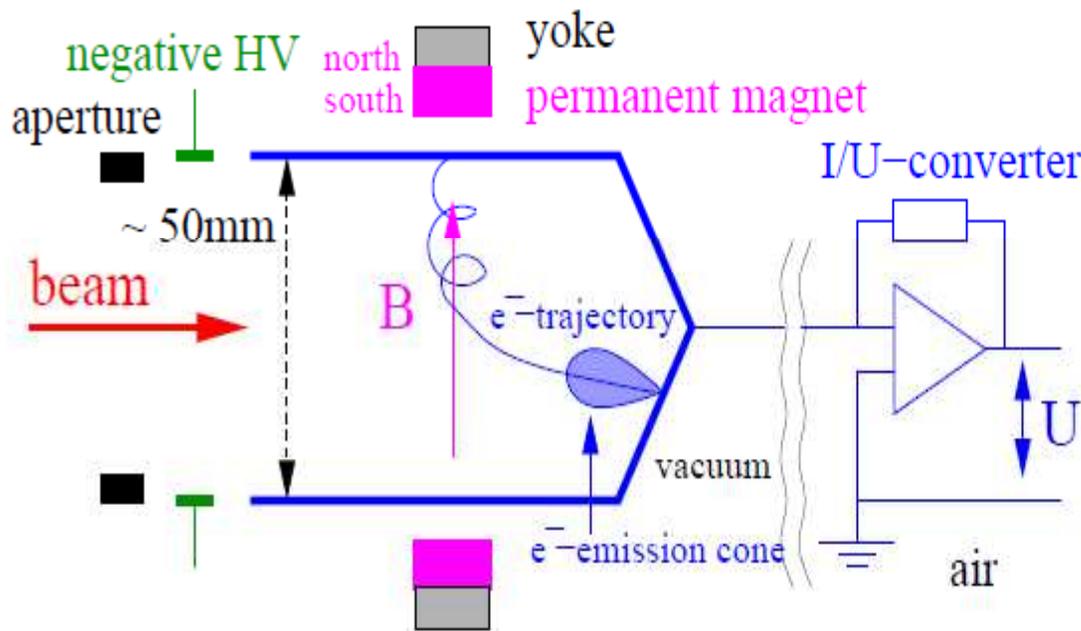
DCCT



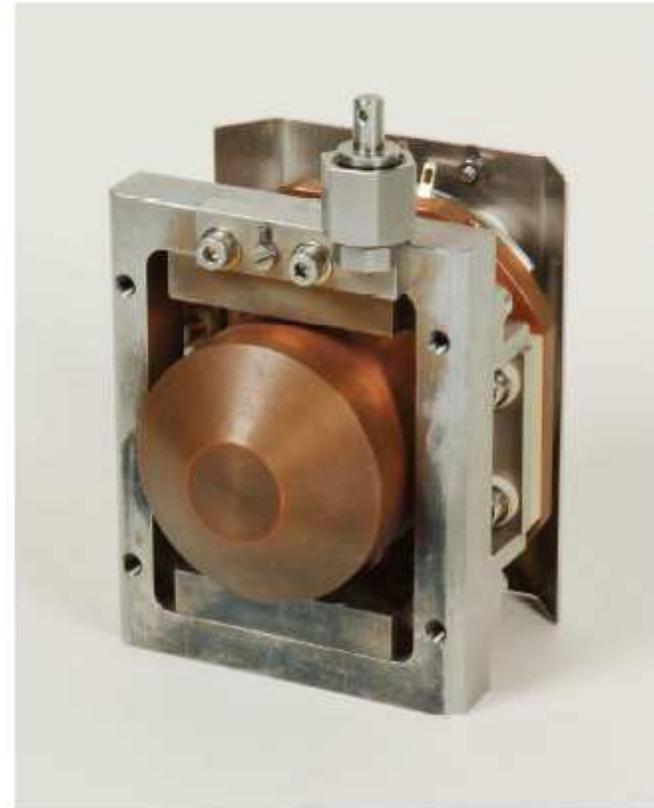
DCCT



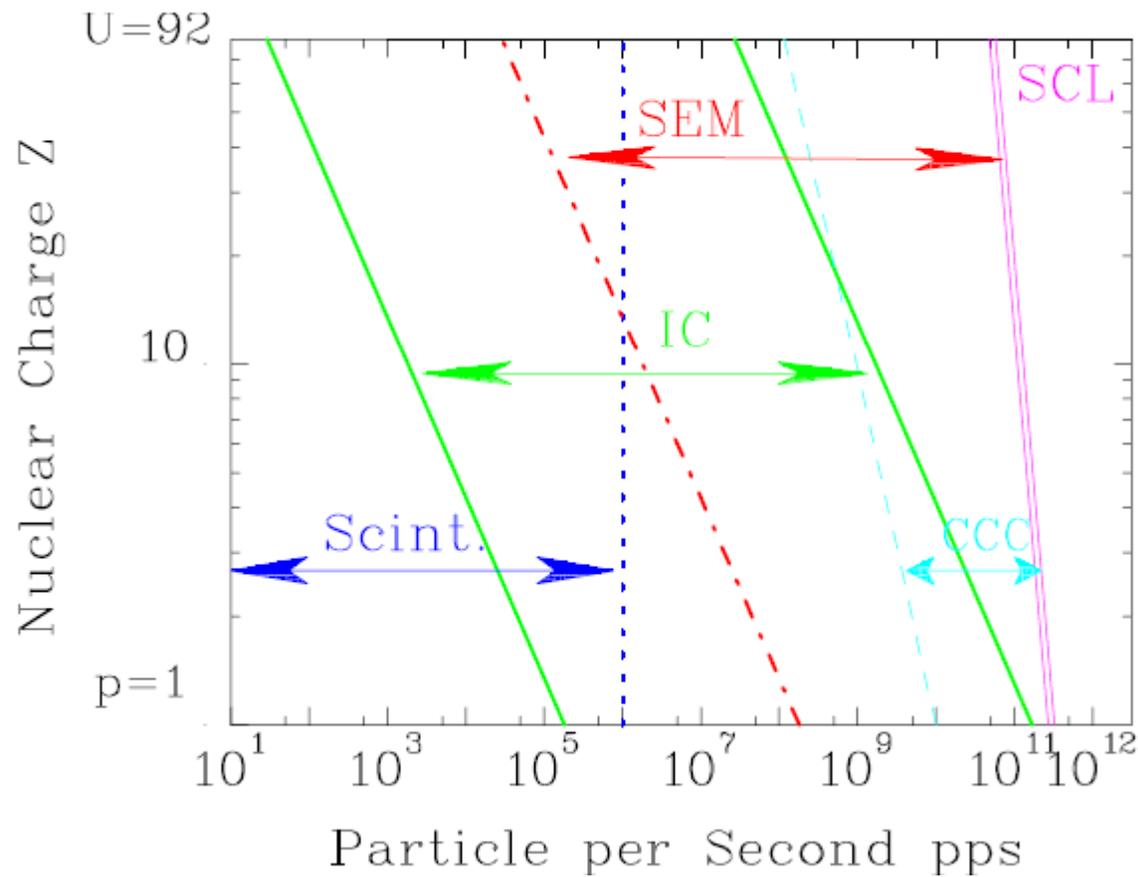
Faraday Cup



Faraday Cup



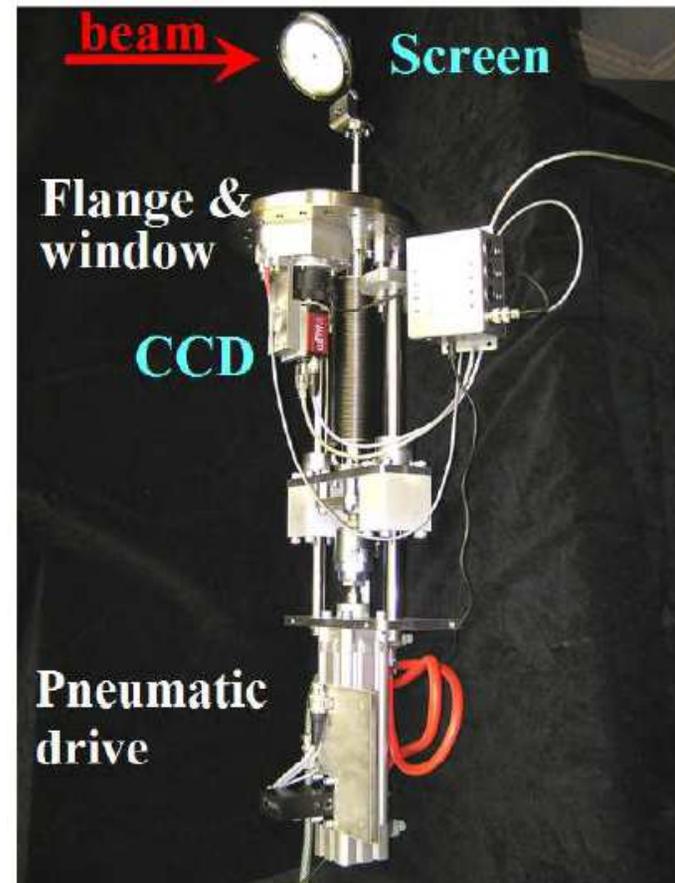
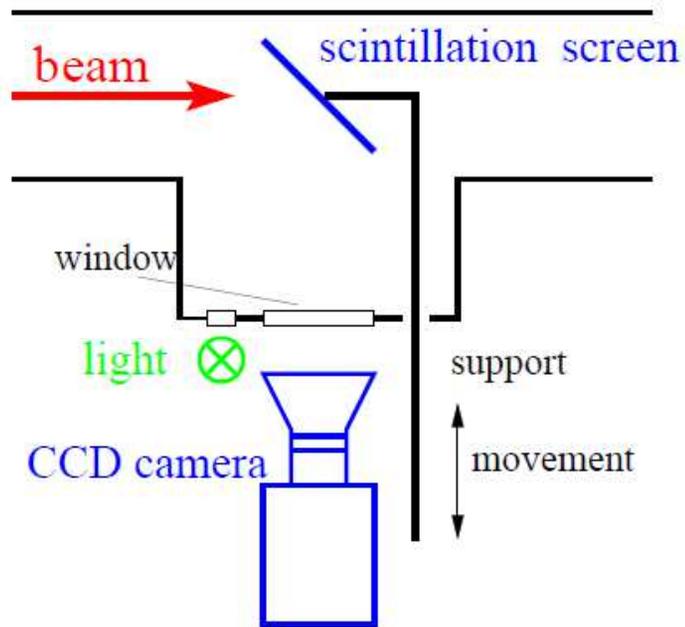
اندازه گیری جریان های کم



اندازه گیری پروفایل باریکه

- Scintillation Screen (FS)
- Optical Transition Radiation (OTR)
- Synchrotron Radiation Monitor

صفحات سوسوزن (Scintillation Screen)



صفحات سوسوزن (Scintillation Screen)

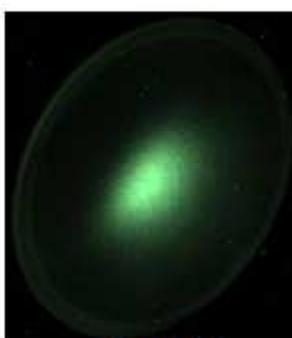
Abbreviation	Material	Activator	max. emission	decay time
Quartz	SiO ₂	none	470 nm	< 10 ns
	CsI	Tl	550 nm	1 μs
Chromolux	Al ₂ O ₃	Cr	700 nm	100 ms
YAG	Y ₃ Al ₅ O ₁₂	Ce	550 nm	0.2 μs
	Li glass	Ce	400 nm	0.1 μs
P11	ZnS	Ag	450 nm	3 ms
P43	Gd ₂ O ₂ S	Tb	545 nm	1 ms
P46	Y ₃ Al ₅ O ₁₂	Ce	530 nm	0.3 μs
P47	Y ₂ Si ₅ O ₅	Ce&Tb	400 nm	100 ns

صفحات سوسوزن (Scintillation Screen)

پروفایل اندازه گیری شده توسط صفحات سوسوزن برای اورانیوم با انرژی 300MeV



Al_2O_3



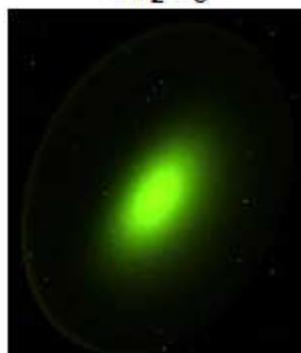
CsI:Tl



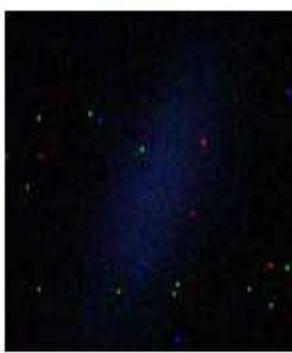
$\text{Al}_2\text{O}_3\text{:Cr}$



P43



YAG:Ce



Herasil

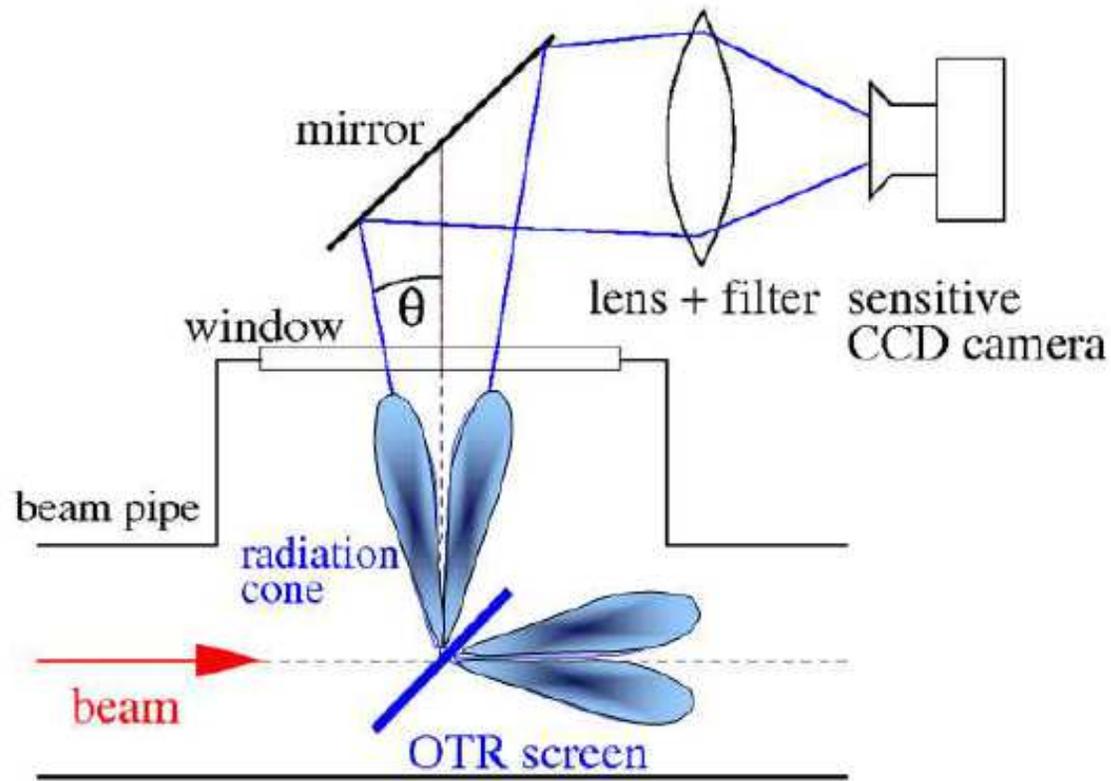


Quartz:Ce

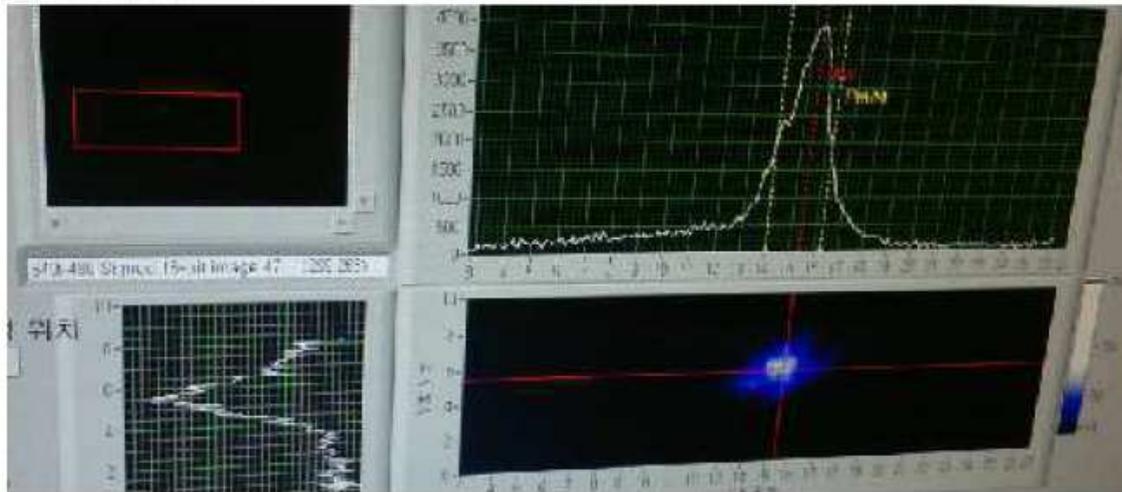
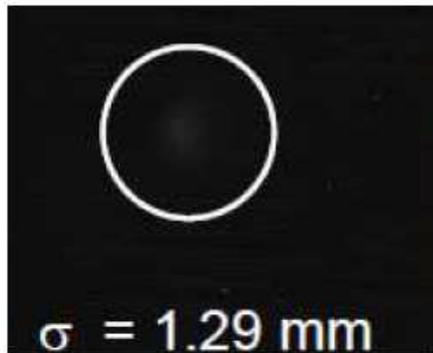


$\text{ZrO}_2\text{:Mg}$

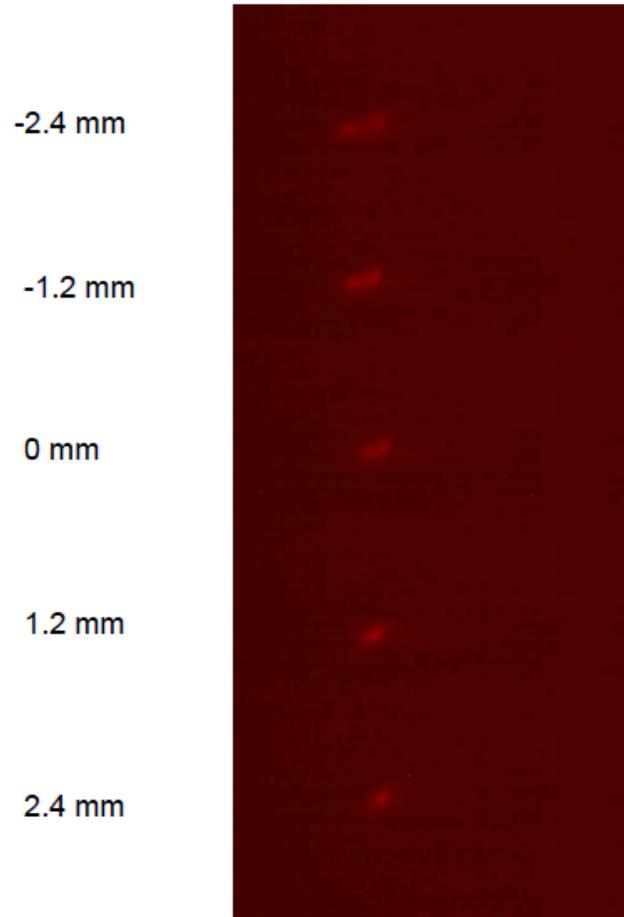
Optical Transition Radiation (OTR)



Optical Transition Radiation (OTR)



OTR



Synchrotron Radiation Monitor (SRM)



first mirror



second mirror



third mirror

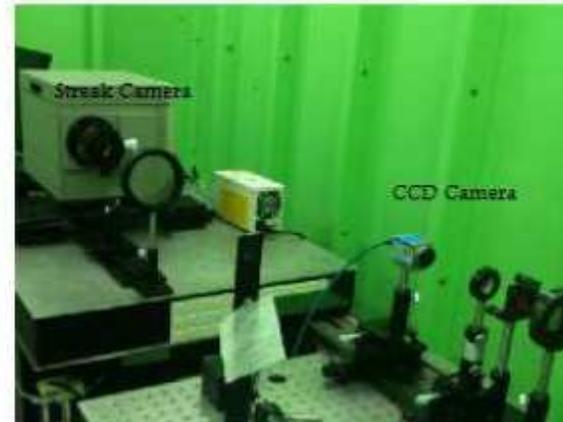
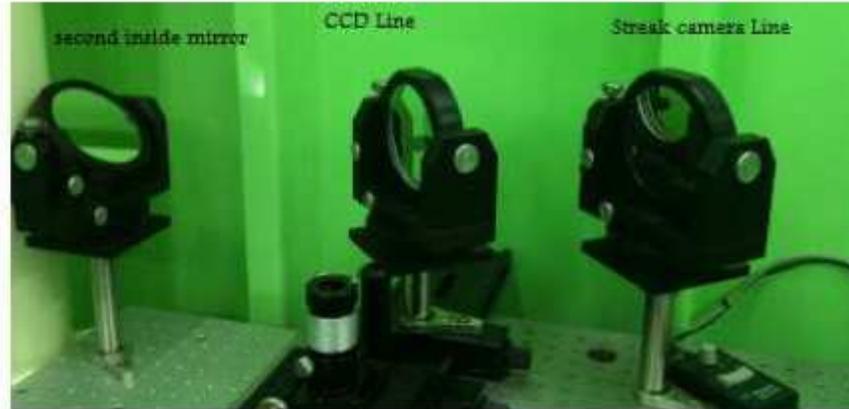


SRM constituent after
bending magnet

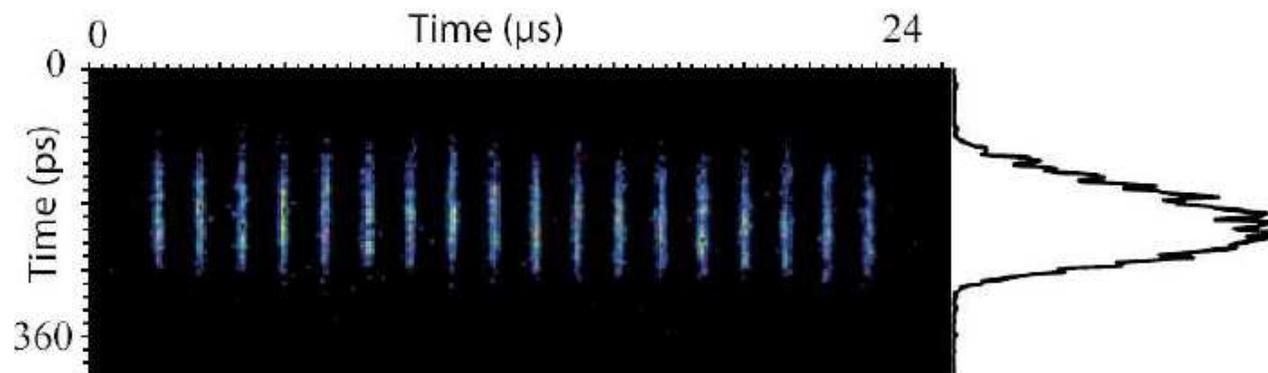
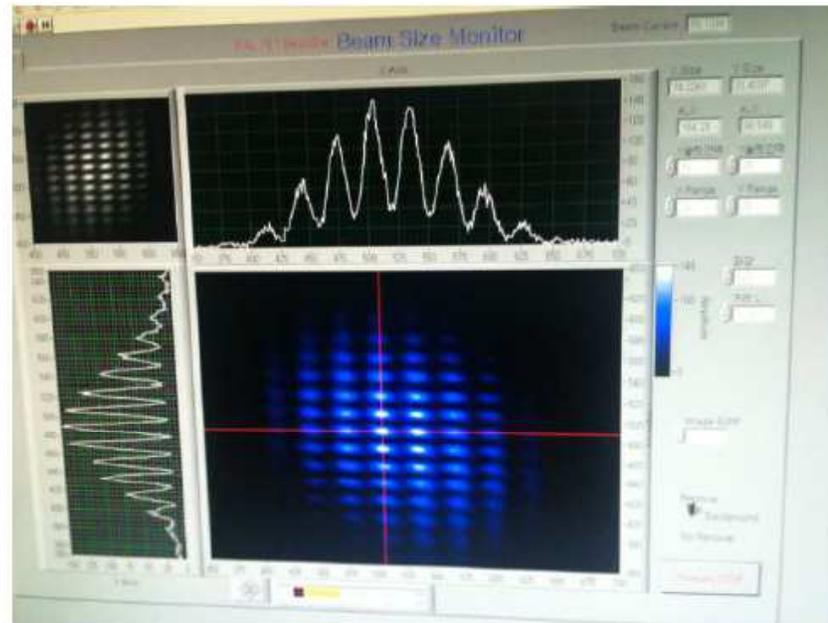
Synchrotron Radiation Monitor (SRM)



first mirror inside hutch



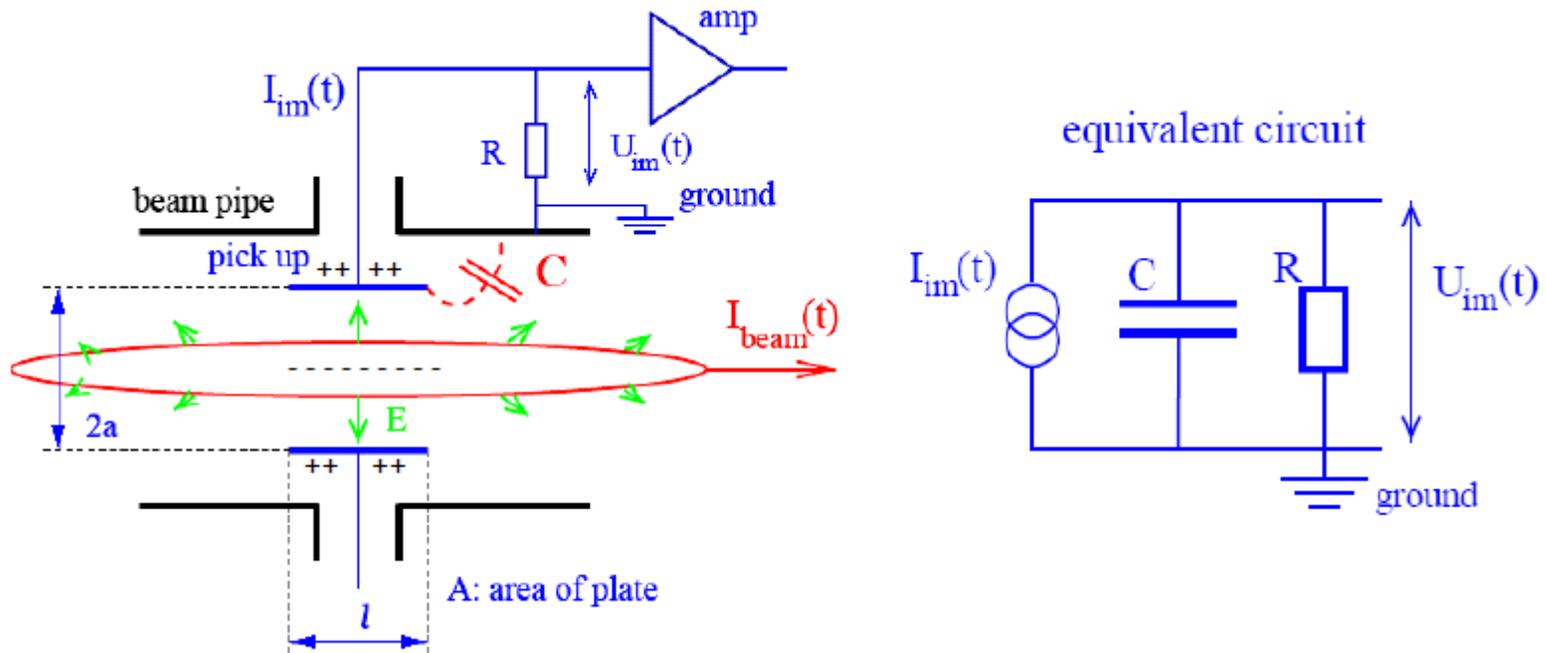
Synchrotron Radiation Monitor (SRM)



اندازه گیری مکان باریکه

- Button BPMs
- Stripline
- Test Stand

Button BPMs



$$I_{im}(t) = -\frac{dQ_{im}(t)}{dt} = \frac{-A}{2\pi al} \cdot \frac{dQ_{beam}(t)}{dt} = \frac{-A}{2\pi a} \cdot \frac{1}{\beta c} \cdot \frac{dI_{beam}(t)}{dt} = \frac{A}{2\pi a} \cdot \frac{1}{\beta c} \cdot i\omega I_{beam}(\omega)$$

$$I_{beam} = I_0 e^{-i\omega t} \Rightarrow dI_{beam}/dt = -i\omega I_{beam}$$

Button BPMs

$$U_{im} = \frac{R}{1+i\omega RC} \cdot I_{im} = \frac{A}{2\pi a} \cdot \frac{1}{\beta c} \cdot \frac{1}{C} \cdot \frac{i\omega RC}{1+i\omega RC} \cdot I_{beam} \equiv Z_t(\omega, \beta) \cdot I_{beam}$$

$$|Z_t| = \frac{A}{2\pi a} \cdot \frac{1}{\beta c} \cdot \frac{1}{C} \cdot \frac{\omega / \omega_{cut}}{\sqrt{1 + \omega^2 / \omega_{cut}^2}}$$

$$\varphi = \arctan(\omega_{cut} / \omega)$$

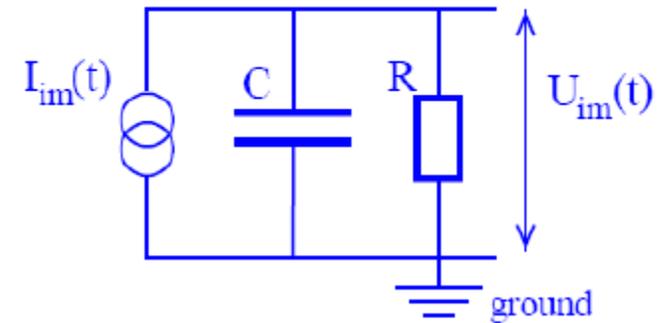
$$f_{cut} = \omega / 2\pi = (2\pi RC)^{-1}$$

➤ $\omega \gg \omega_{cut}$:

$$Z_t \propto \frac{i\omega / \omega_{cut}}{1 + i\omega / \omega_{cut}} \rightarrow 1 \Rightarrow U_{im}(t) = \frac{1}{C} \cdot \frac{1}{\beta c} \cdot \frac{A}{2\pi a} \cdot I_{beam}(t)$$

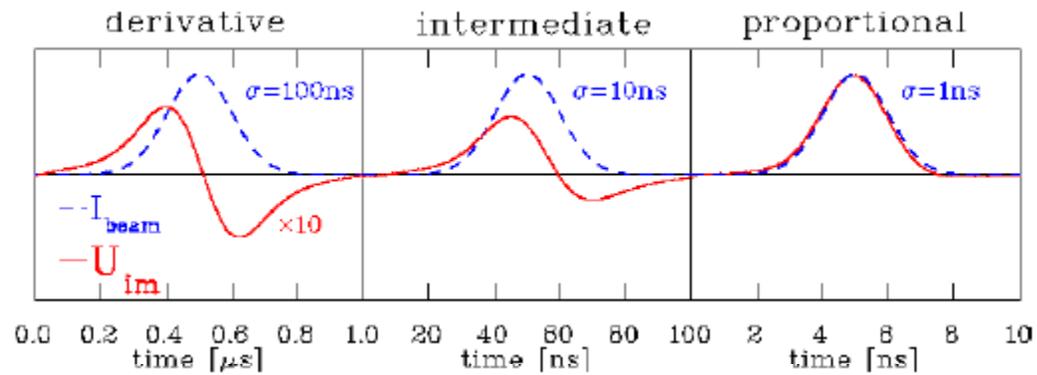
➤ $\omega \ll \omega_{cut}$:

$$Z_t \propto \frac{i\omega / \omega_{cut}}{1 + i\omega / \omega_{cut}} \rightarrow i \frac{\omega}{\omega_{cut}} \Rightarrow U_{im}(t) = R \cdot \frac{A}{\beta c \cdot 2\pi a} \cdot i\omega I_{beam}(t) = R \cdot \frac{A}{\beta c \cdot 2\pi a} \cdot \frac{dI_{beam}}{dt}$$

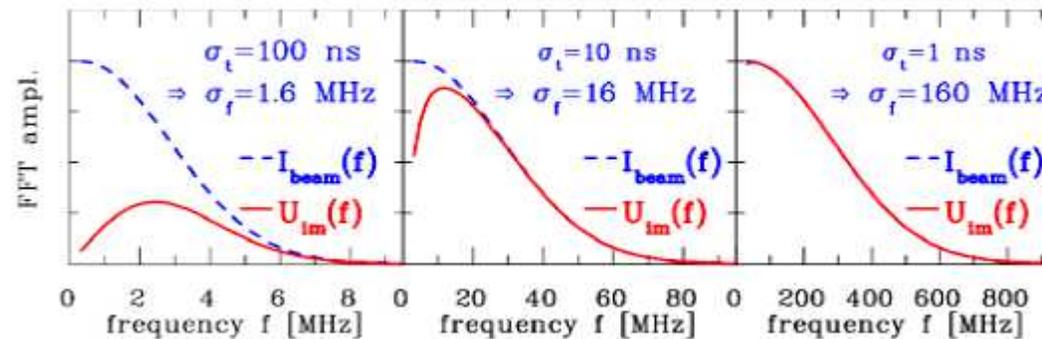


Button BPM

تحلیل در حوزه فرکانس



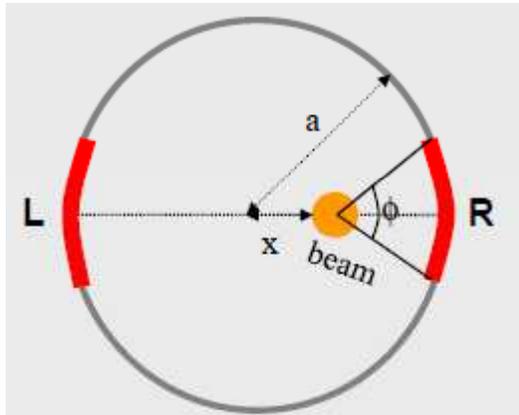
تحلیل در حوزه فرکانس



$$\sigma_f = (2\pi\sigma_t)^{-1}$$

$$R=50 \Omega \quad C \approx 5 \text{ pF} \quad \Rightarrow f_{cut} = 1/(2\pi RC) \approx 700 \text{ MHz}$$

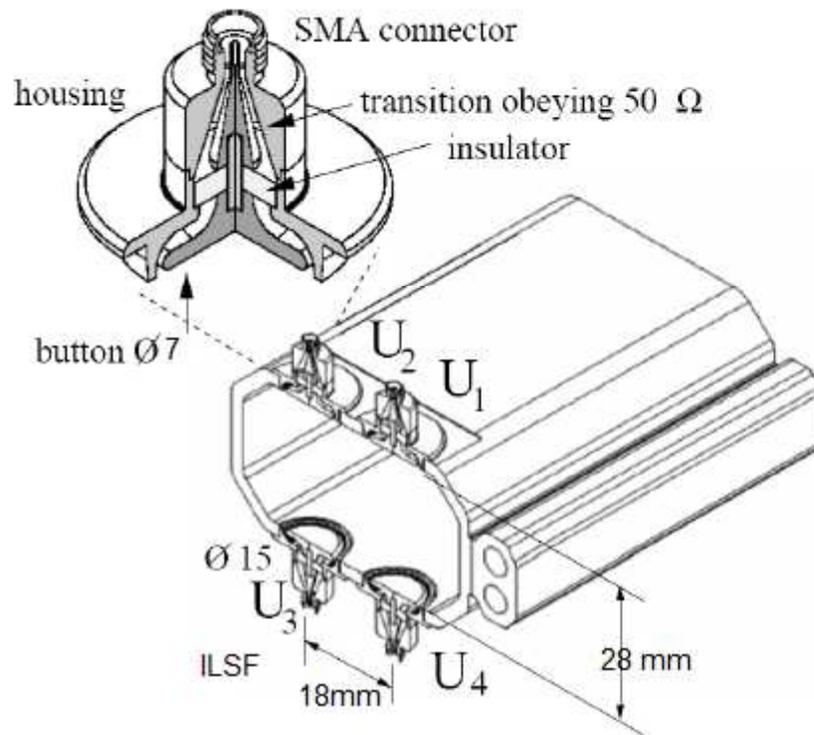
Button BPM در حلقه افزایشده انرژی (Booster)



$$\begin{cases} V_R = k \frac{Q}{a-x} \frac{\phi}{2\pi} \cong k \frac{Q}{a} \left(1 + 2 \frac{x}{a}\right) \\ V_L = k \frac{Q}{a+x} \frac{\phi}{2\pi} \cong k \frac{Q}{a} \left(1 - 2 \frac{x}{a}\right) \end{cases}$$

$$x = \frac{a V_R - V_L}{2 V_R + V_L} = \frac{a \Delta}{2 \Sigma}$$

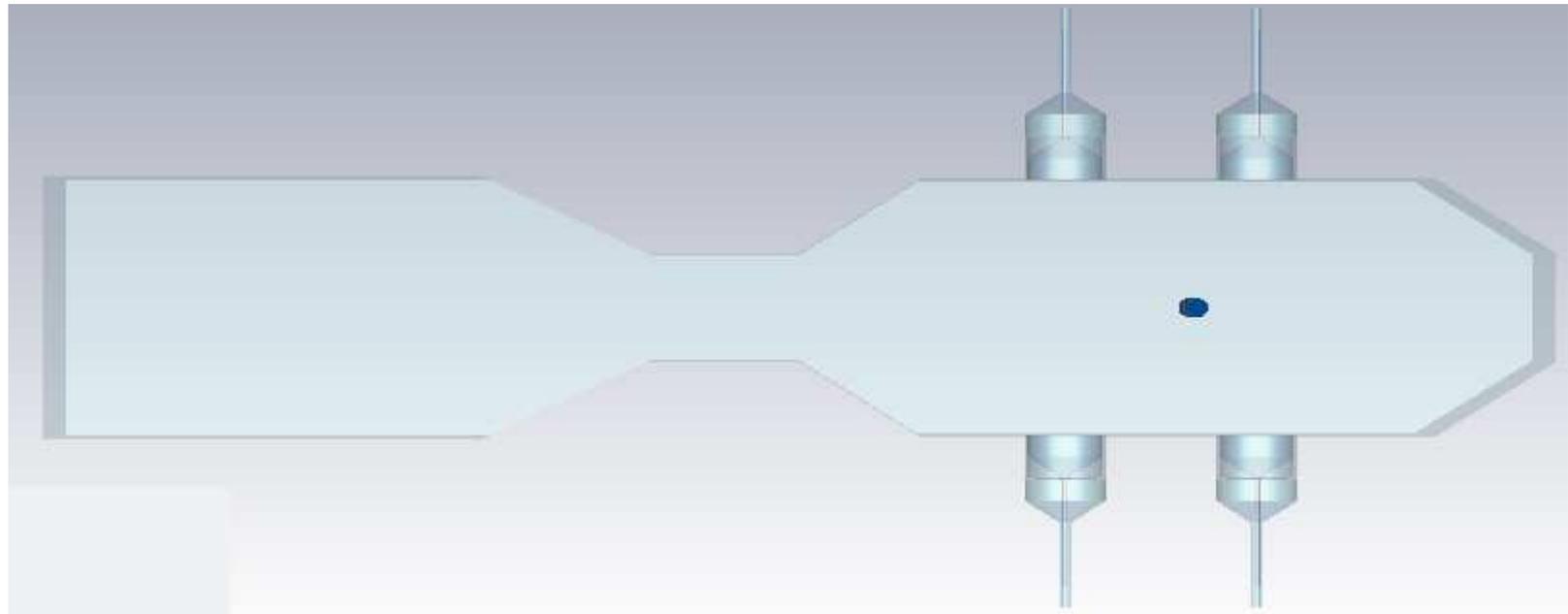
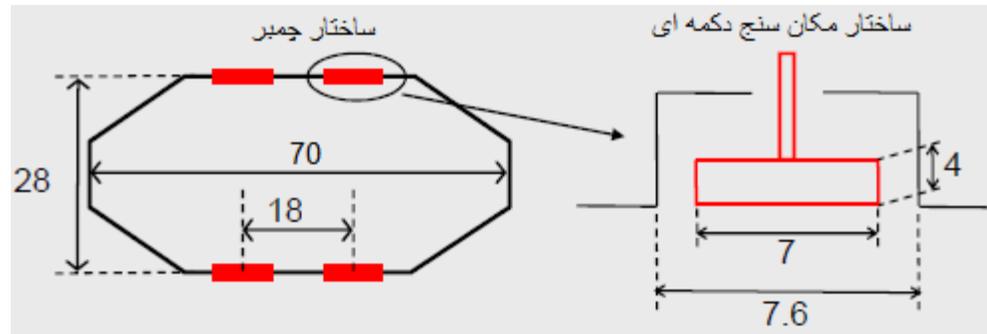
Button BPM در حلقه انبارش



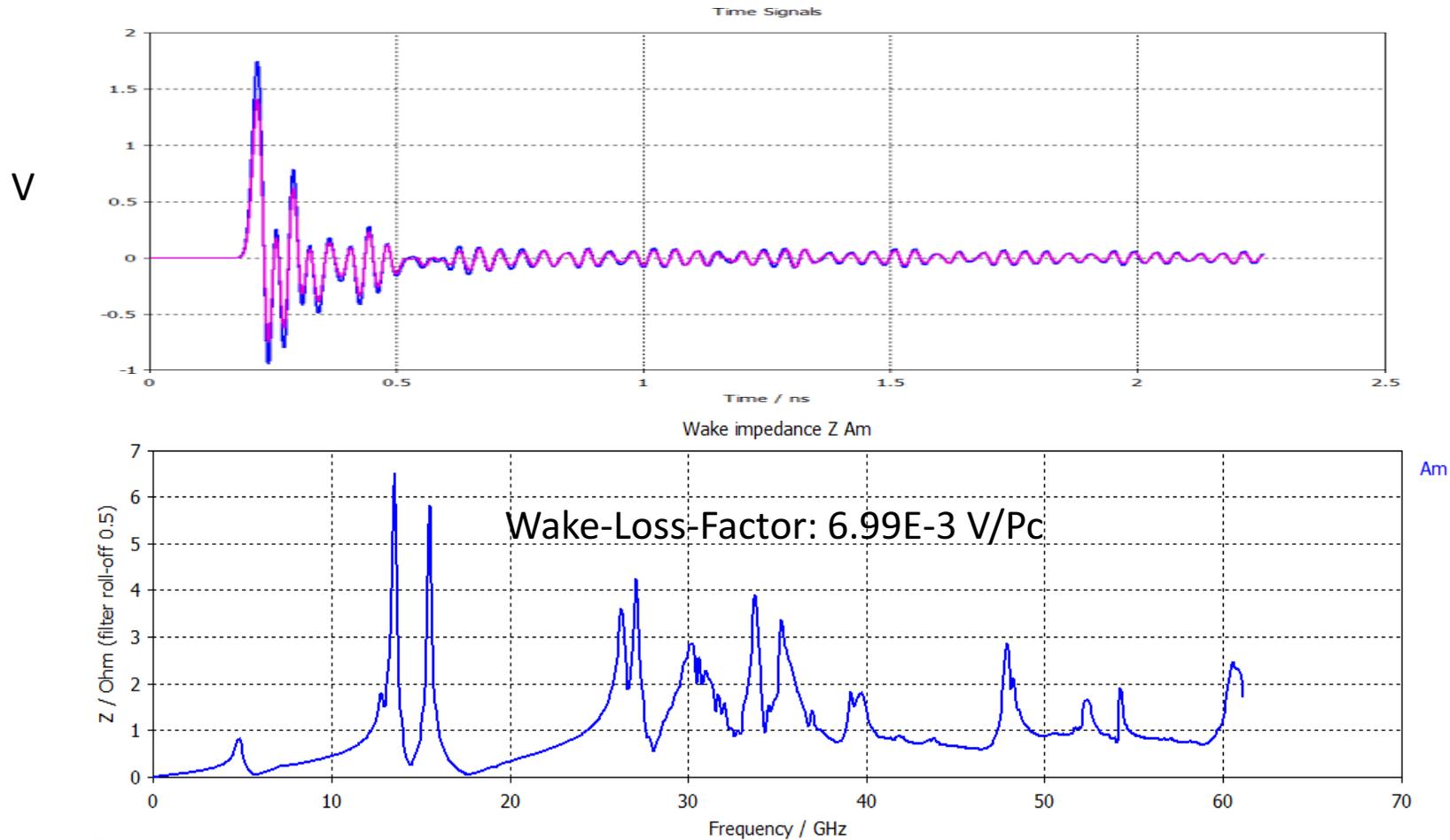
$$\text{horizontal: } x = \frac{1}{S_x} \cdot \frac{(U_2 + U_4) - (U_1 + U_3)}{U_1 + U_2 + U_3 + U_4}$$

$$\text{vertical: } y = \frac{1}{S_y} \cdot \frac{(U_1 + U_2) - (U_3 + U_4)}{U_1 + U_2 + U_3 + U_4}$$

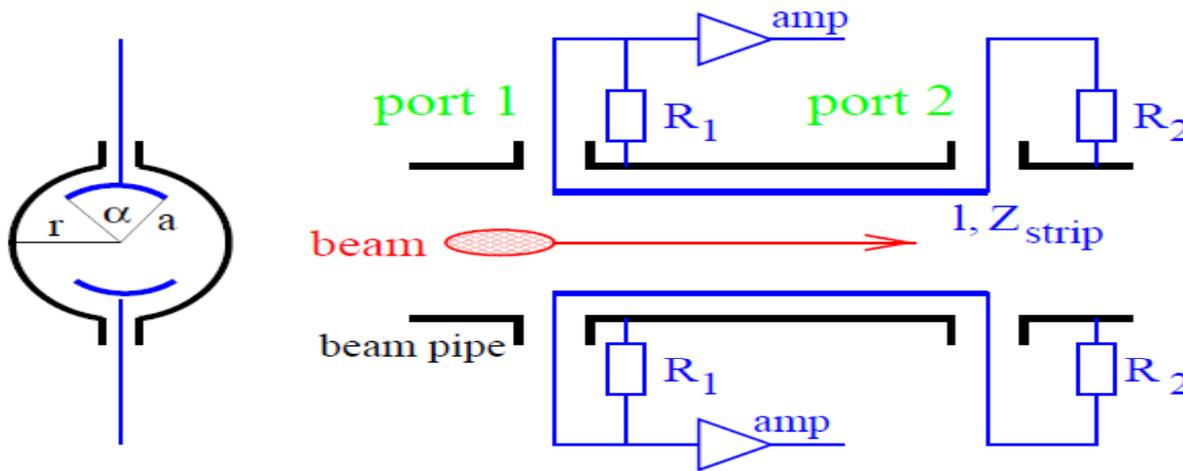
ILSF در Button BPM



ILSF در Button BPM



Stripline



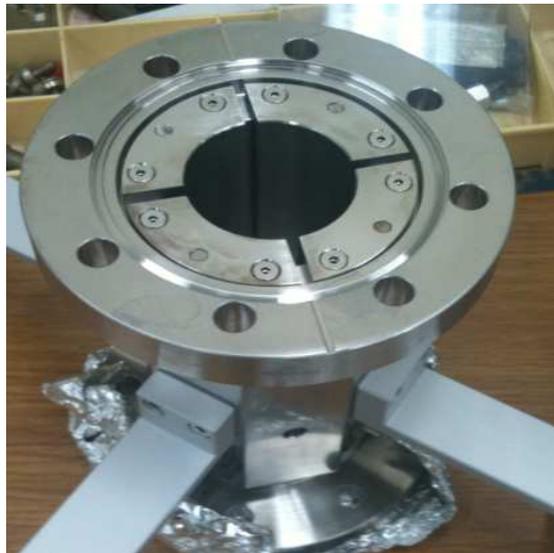
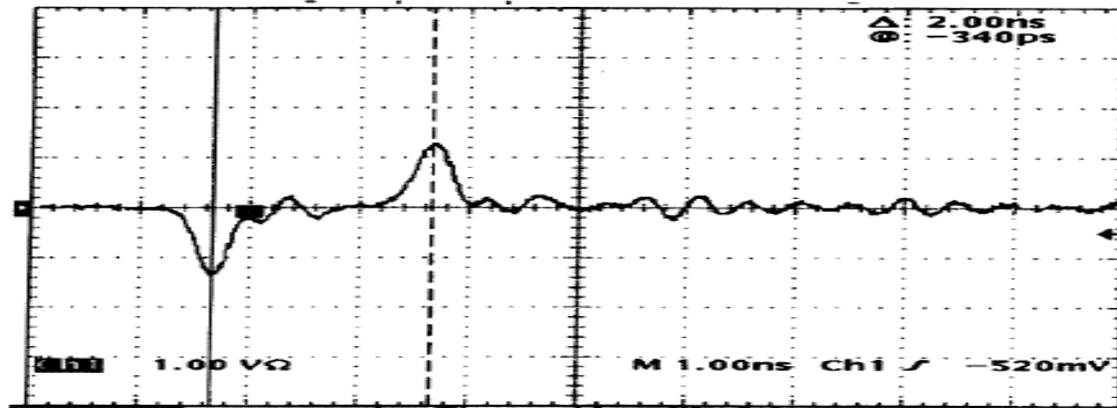
$$U_1(t) = \frac{1}{2} \cdot \frac{\alpha}{2\pi} \cdot R_1 (I_{beam}(t) - I_{beam}(t - 2l/c))$$

$$Z_t(\omega) = Z_{strip} \cdot \frac{\alpha}{2\pi} \cdot \sin(\omega l/c) \cdot e^{i(\pi/2 - \omega l/c)}$$

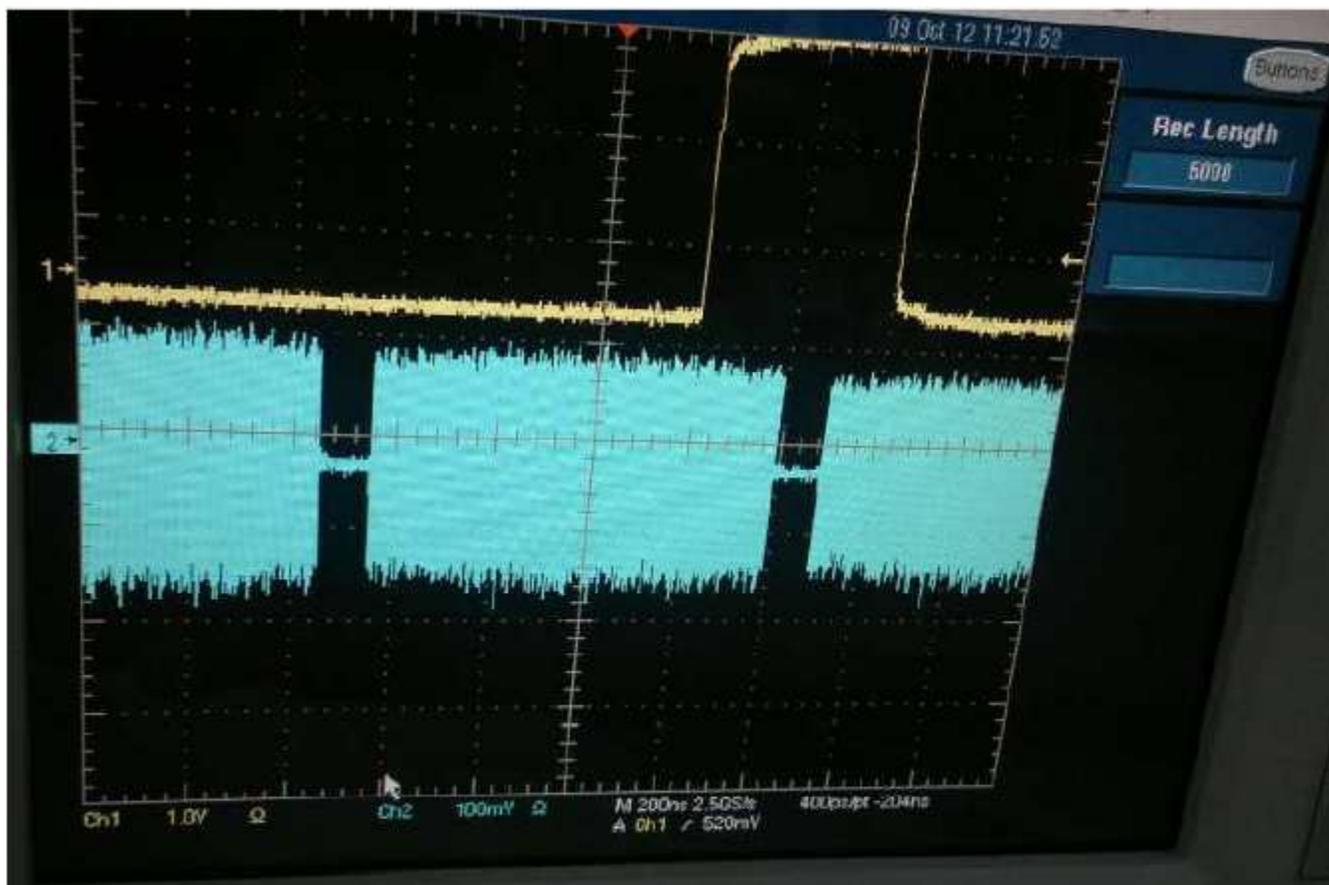
$|Z_t| \longrightarrow l = c/4f = \lambda/4 \longrightarrow$ بیشترین حساسیت

$|Z_t| \longrightarrow l = \lambda/2 \longrightarrow$ سیگنالی در سر پایانه ها وجود ندارد

Stripline



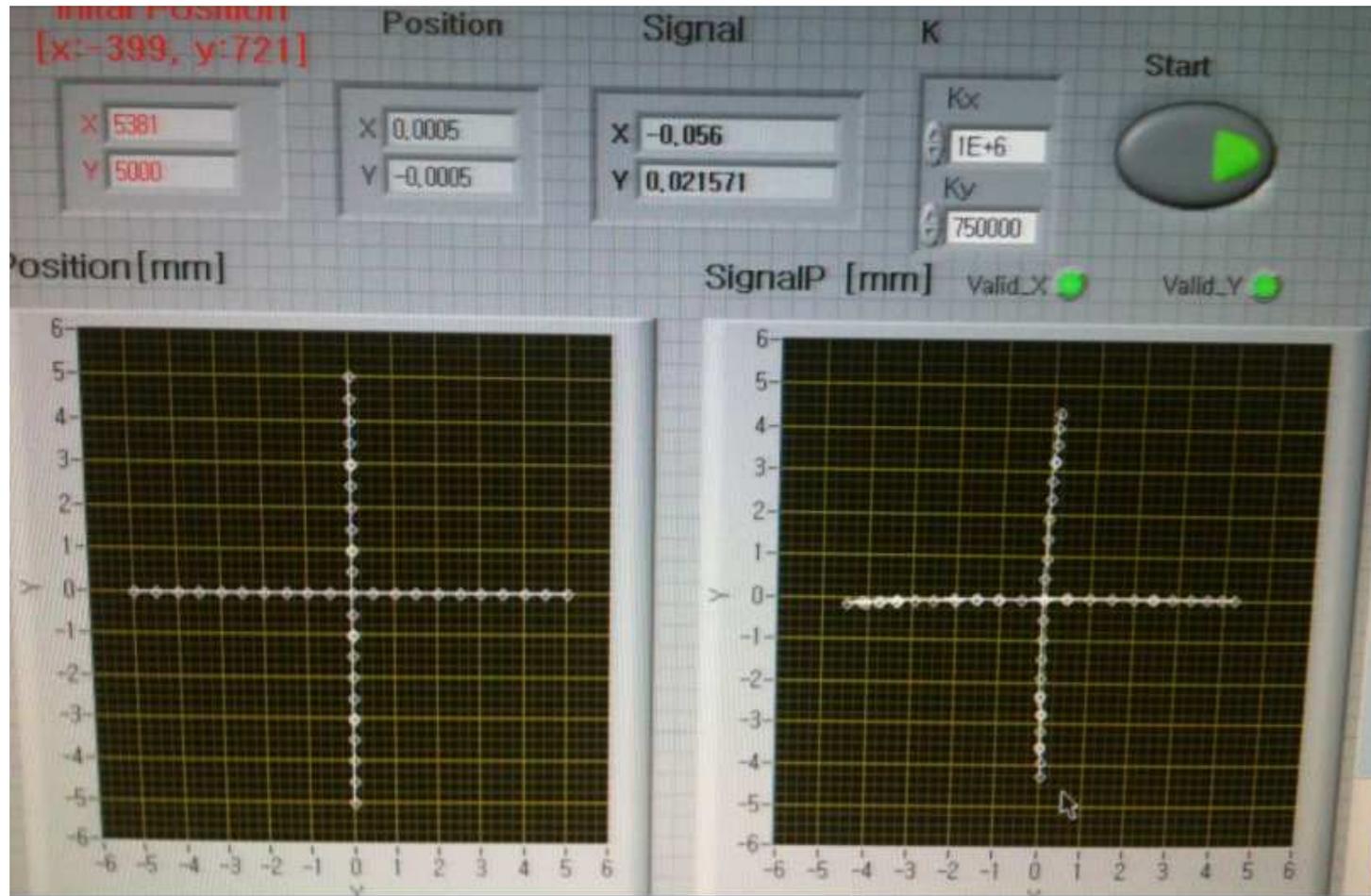
Stripline



Test Stand

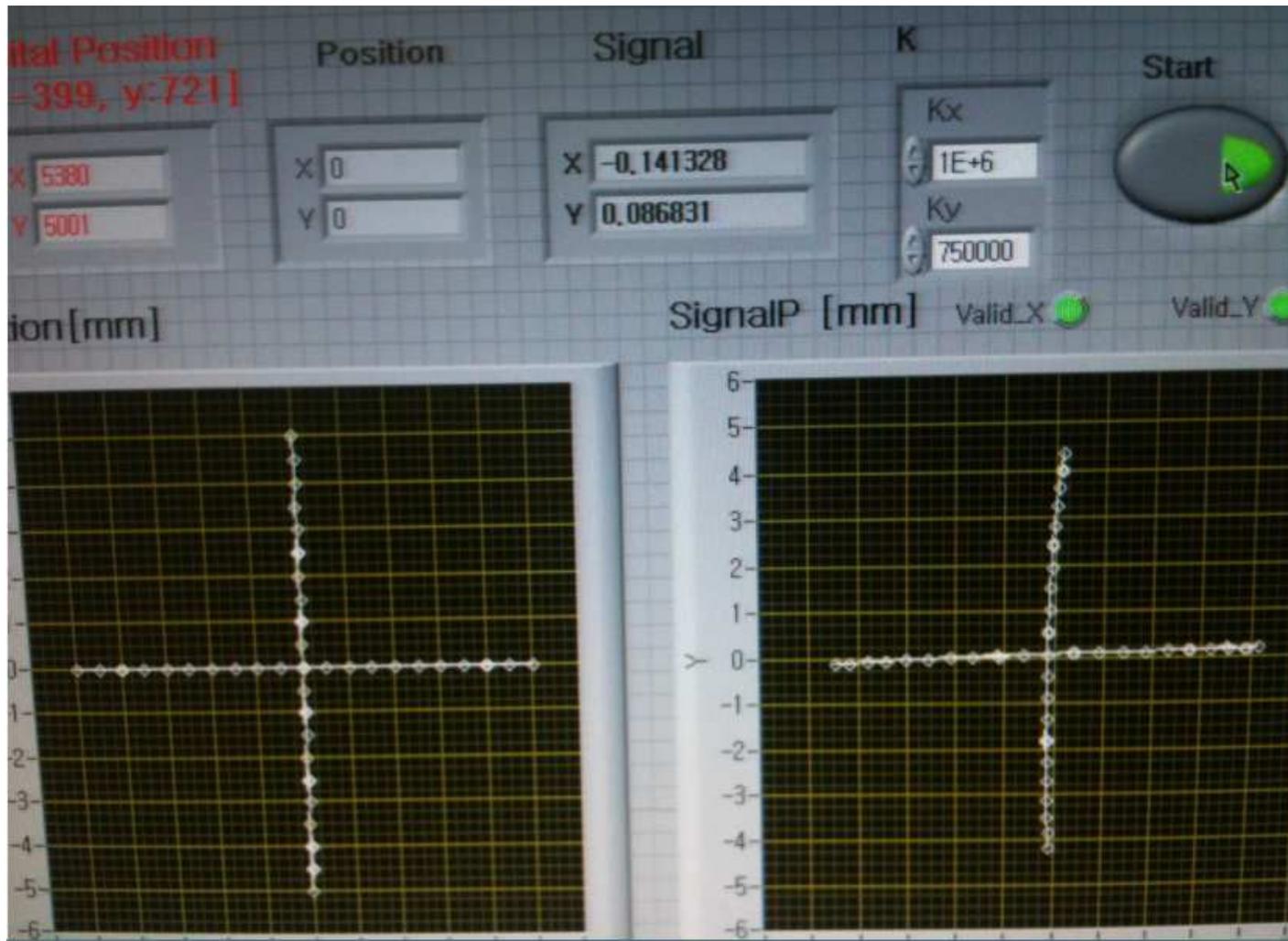


Test Stand

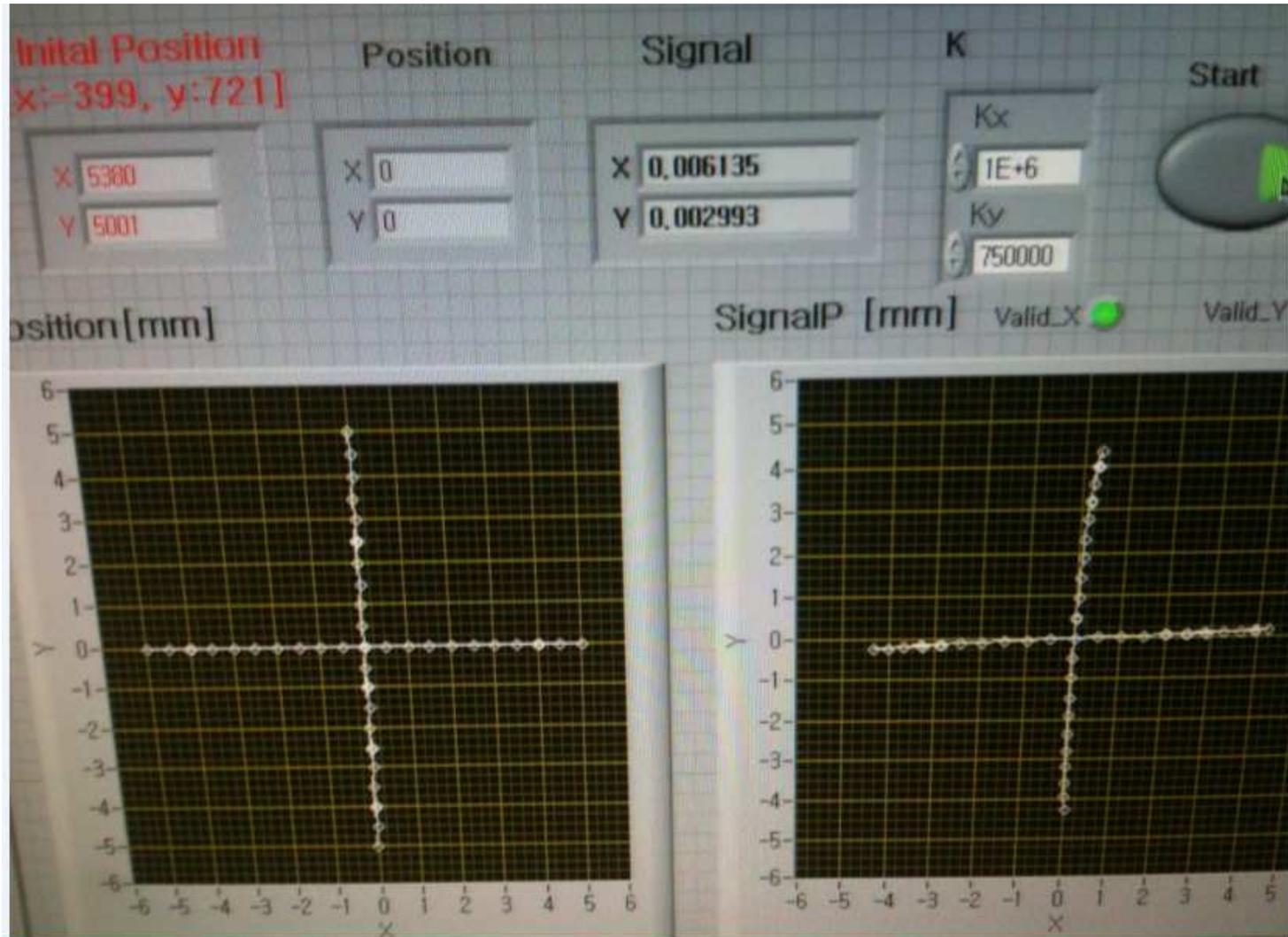


(1)

Test Stand



Test Stand



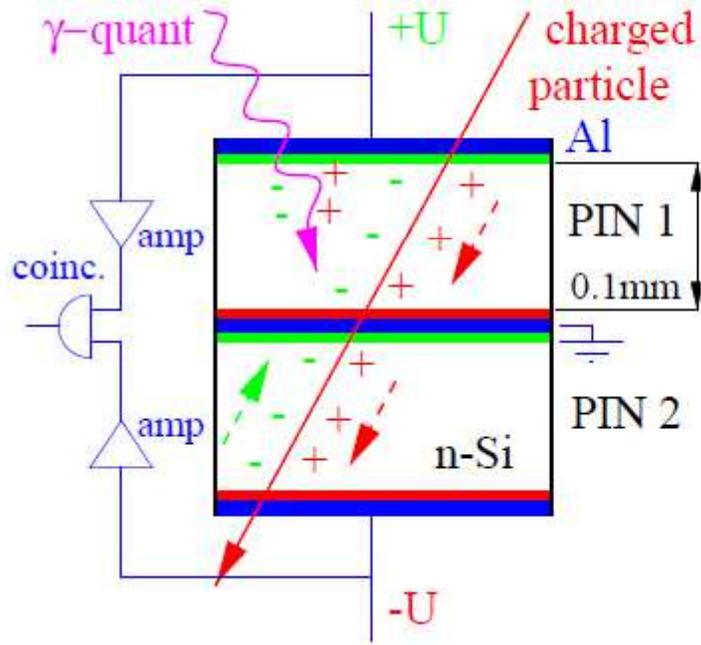
Vacuum Test



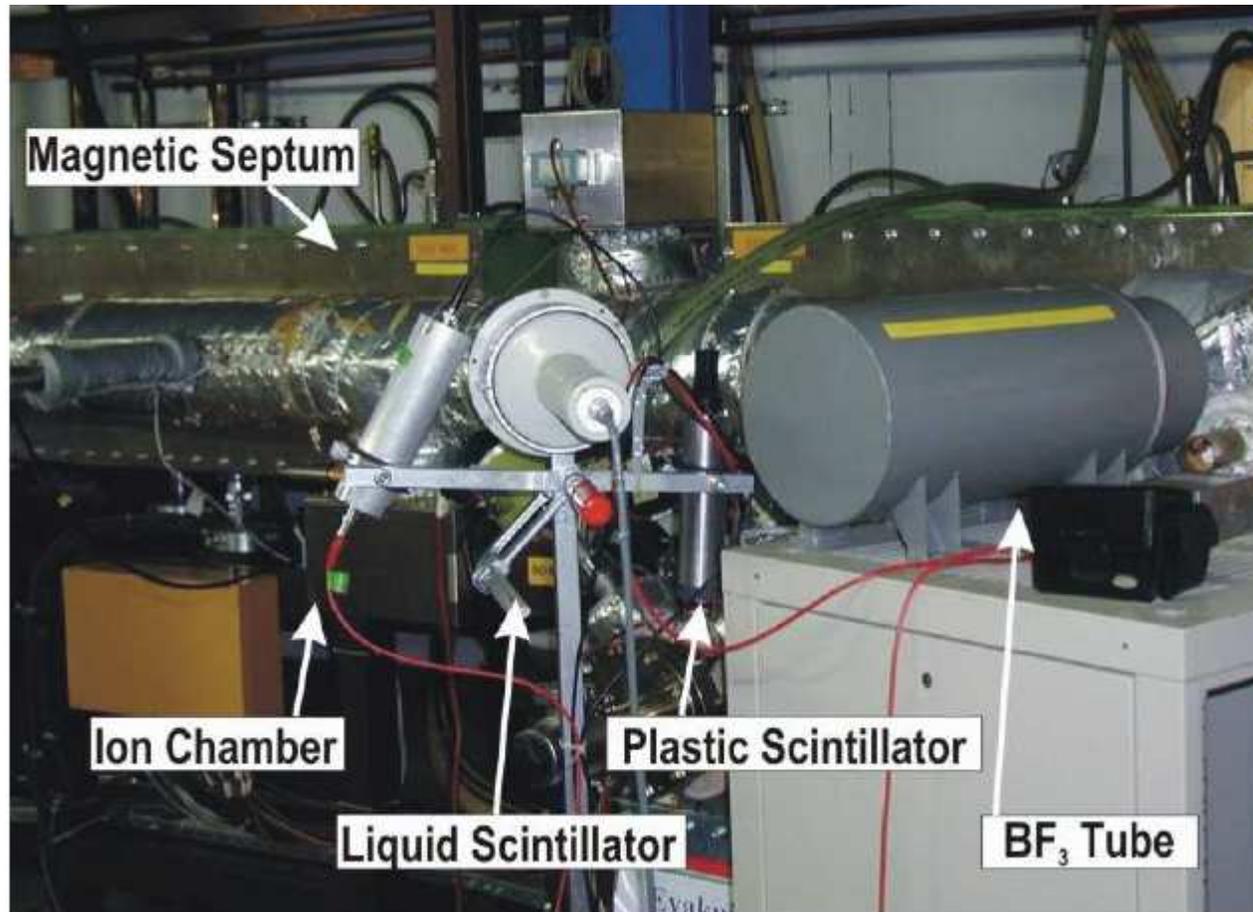
Beam Loss Monitor (BLM)



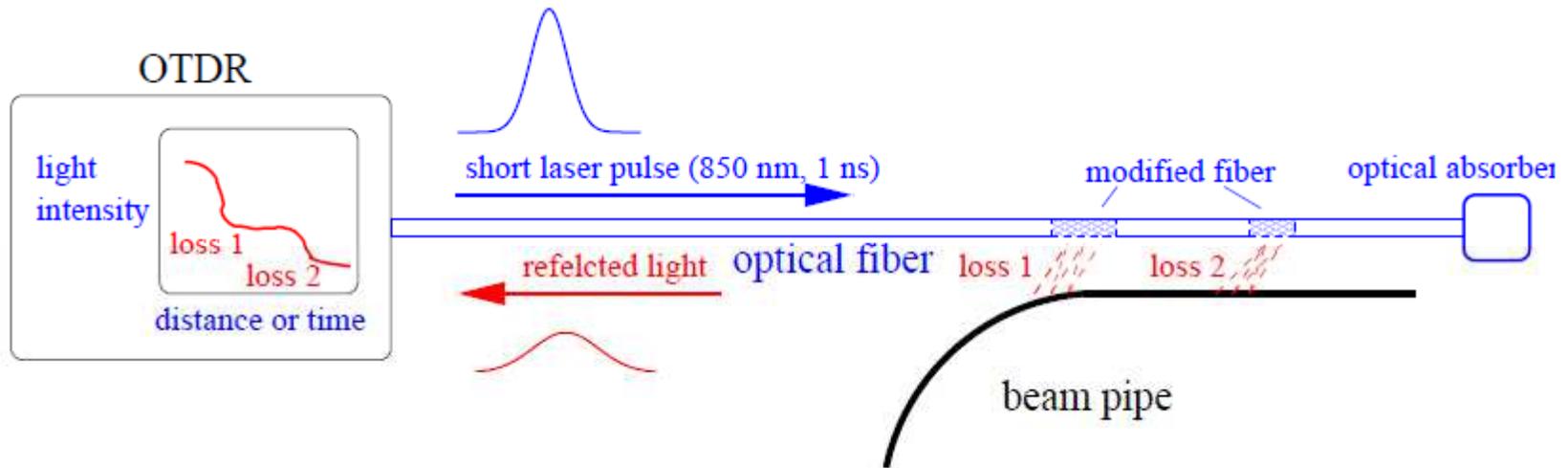
BLM



BLM



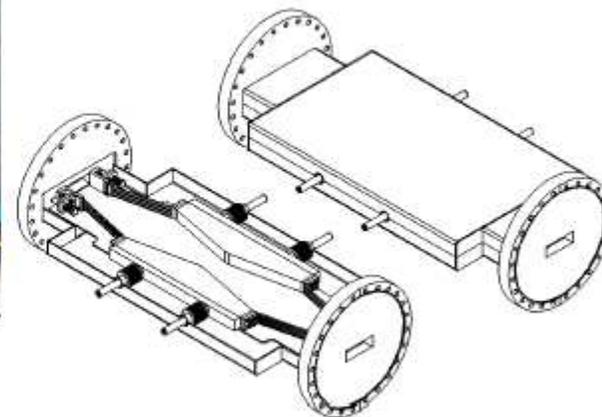
BLM



Scraper



Vertical & Horizontal Scraper

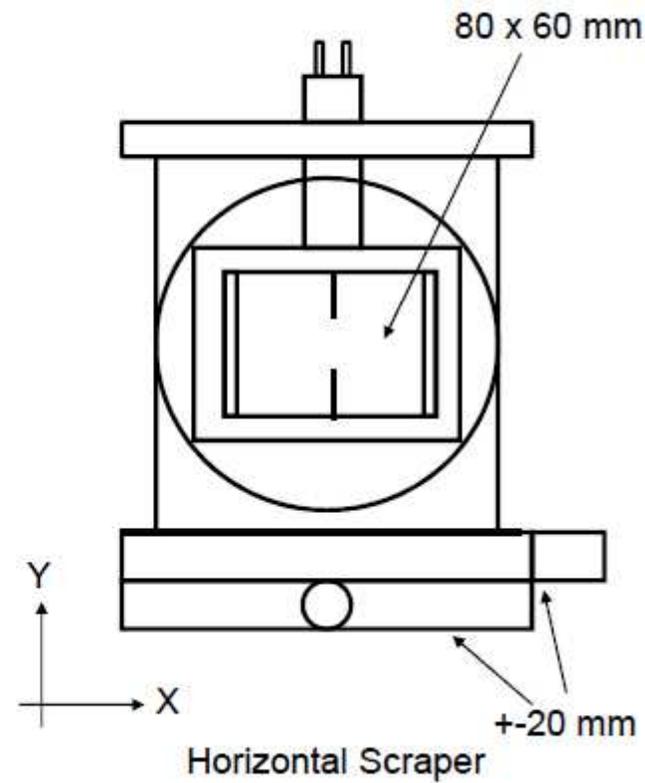


Horizontal Scraper

Photon BPMs



PLS-II PBPM



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با تشکر از توجه شما