# Production of MeV Photons by the Laser Compton Scattering using a Far Infrared Laser at SPring-8

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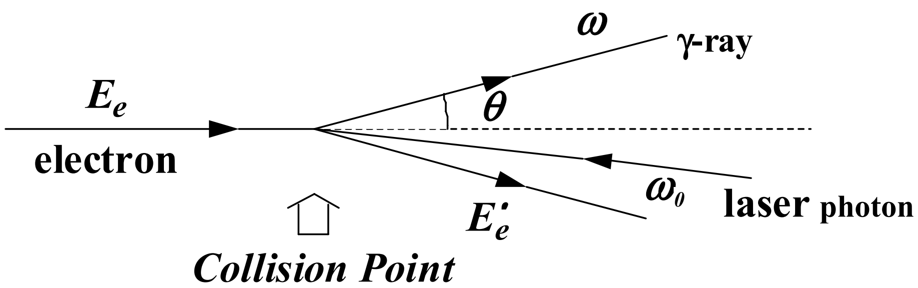
Bird's eye view of SPring-8
NewSUBARU
8 GeV Booster
8 GeV Storage Ring
23 Bending BL
38 ID BL
1 IR BL
Photon Energy < 300 keV
Linac
Hori. emitt. : 3.4nm•rad
Ver. emitt. : 6.8pm•rad
Lifetime : ~200 hrs. (multi)
~15 hrs. (single)
Momentum accept. : +- 200MeV

*We produce MeV photons by a Laser Compton scattering using a far-infrared (FIR) laser at SPring-8.*




Schematic diagram of laser Compton scattering

$$\omega = \frac{4\omega_0 E^2}{(m_e c^2)^2 + 4\omega_0 E_e}\left(\frac{1}{1+\left(\frac{E^2}{(m_e c^2)^2 + 4\omega_0 E_e}\right)\theta^2}\right)$$

γ-ray energy is proportional to $E_e^2$ and to $\omega_0$

**To generate 10 MeV photons with 8GeV electrons, FIR laser with a wavelength of 100μm is needed. Our choice: an optically-pumped FIR laser**

- **This laser has been used for plasma diagnosis, frequency standards, etc. with stable oscillation for a long time.**
- **As various laser oscillation lines are possible, energy region of LCS MeV photons can be changed in a wide rage.**

## *Advantages of FIR LCS at SPring-8*

**Collimated MeV photons**

**Divergence of produced MeV photons is approximately proportional to 1/γ ($=E_e/m_ec^2$ : Lorentz factor). In case of SPring-8, LCS MeV photons are collimated in small solid angle (≈ 0.06 mrad), γ = 15650.**

**Stored electrons are not lost by LCS process**

**Momentum acceptance is so large (±2.5% : ± 200 MeV) that the stored electrons are not lost by LCS process. Experiments using MeV photons can be performed parasitically, independent of synchrotron radiation user experiments.**

**High intense MeV photons can be possible**

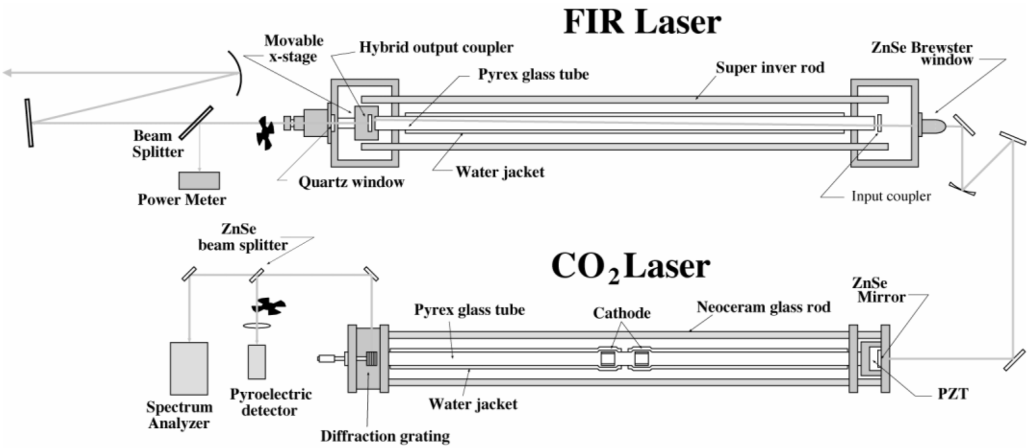
**FIR laser beams contains a huge number of the quantum photons ($6\times10^{20}$ photons/sec@1W, 119μm) compared with a visible laser ($1.8\times10^{18}$ photons/sec@1W, 351.1nm) as same output power.**

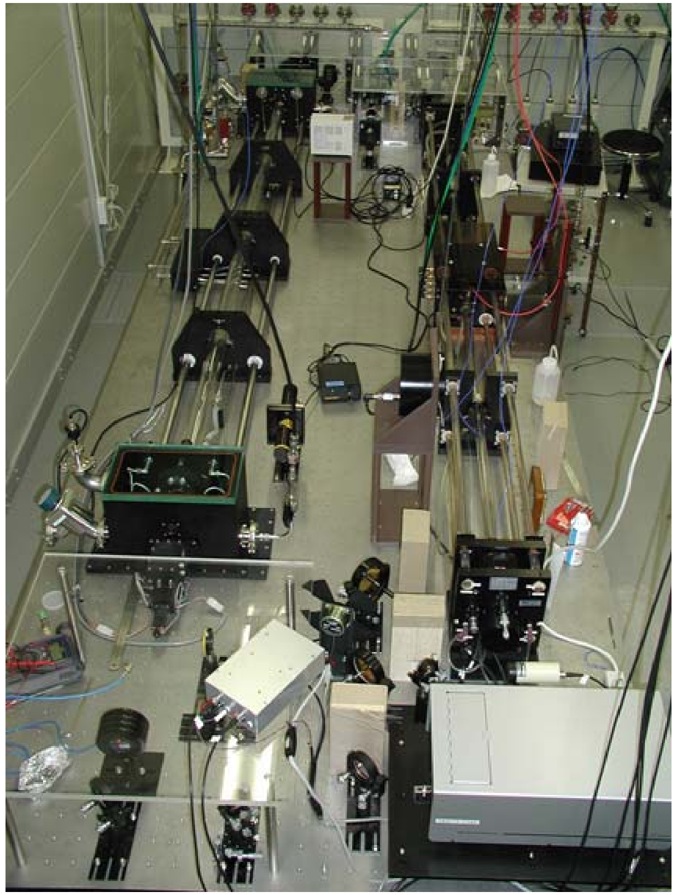
**There is a possibility to obtain the high production rate of MeV photons.**

## *Disadvantage*

**Beam divergence of FIR laser is large. Effective cross-section of Compton scattering is reduced. Long transportation of FIR is a disadvantage in free-space.**

*FIR laser system*



**$CO_2$ laser**

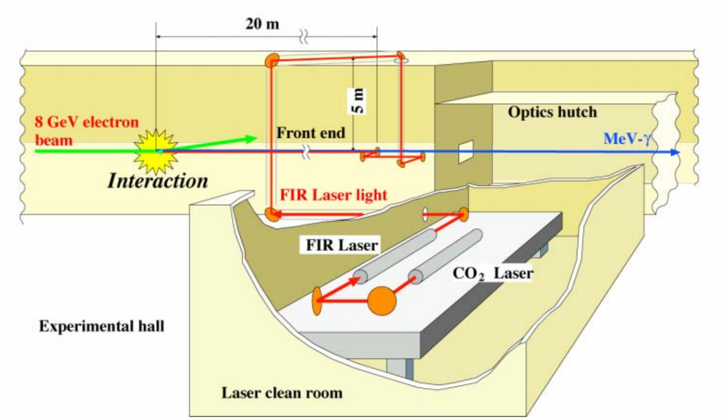
| | |
|---|---|
| Cavity length | : 3m |
| Max. Power @ 9P(36) lasing line | : 230 W(CW) |
| Output Stability | : ±0.6% |

**FIR laser**

| | |
|---|---|
| Cavity length | : 3m |
| Laser action medium | : $CH_3OH$ vapor |
| Wavelength | : 119 μm |
| Max. Power @ 119μm | : 1.6 W |
| Power at Normal operation | : ~1 W |
| Output Stability | : ±1.0% |

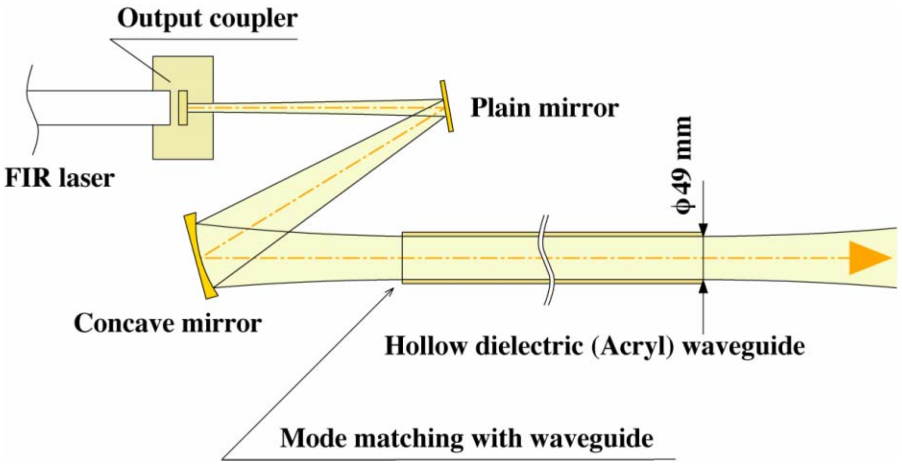
## *Laser Transportation with Hollow Dielectric Waveguide*

**FIR laser beam are transported from laser clean room constructed at experimental hall to the front-end of the beam diagnostics beamline (BL38B2) in the storage ring tunnel.**

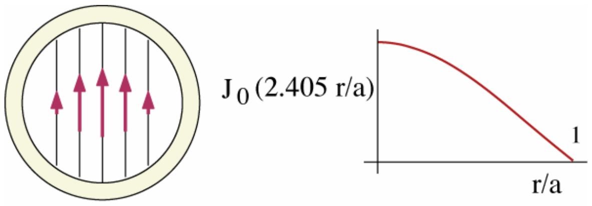



**Schematic view of laser transportation system**

**Total transportation length is about 20m to the front-end of beamline.**
**Transmission efficiency : 70%**

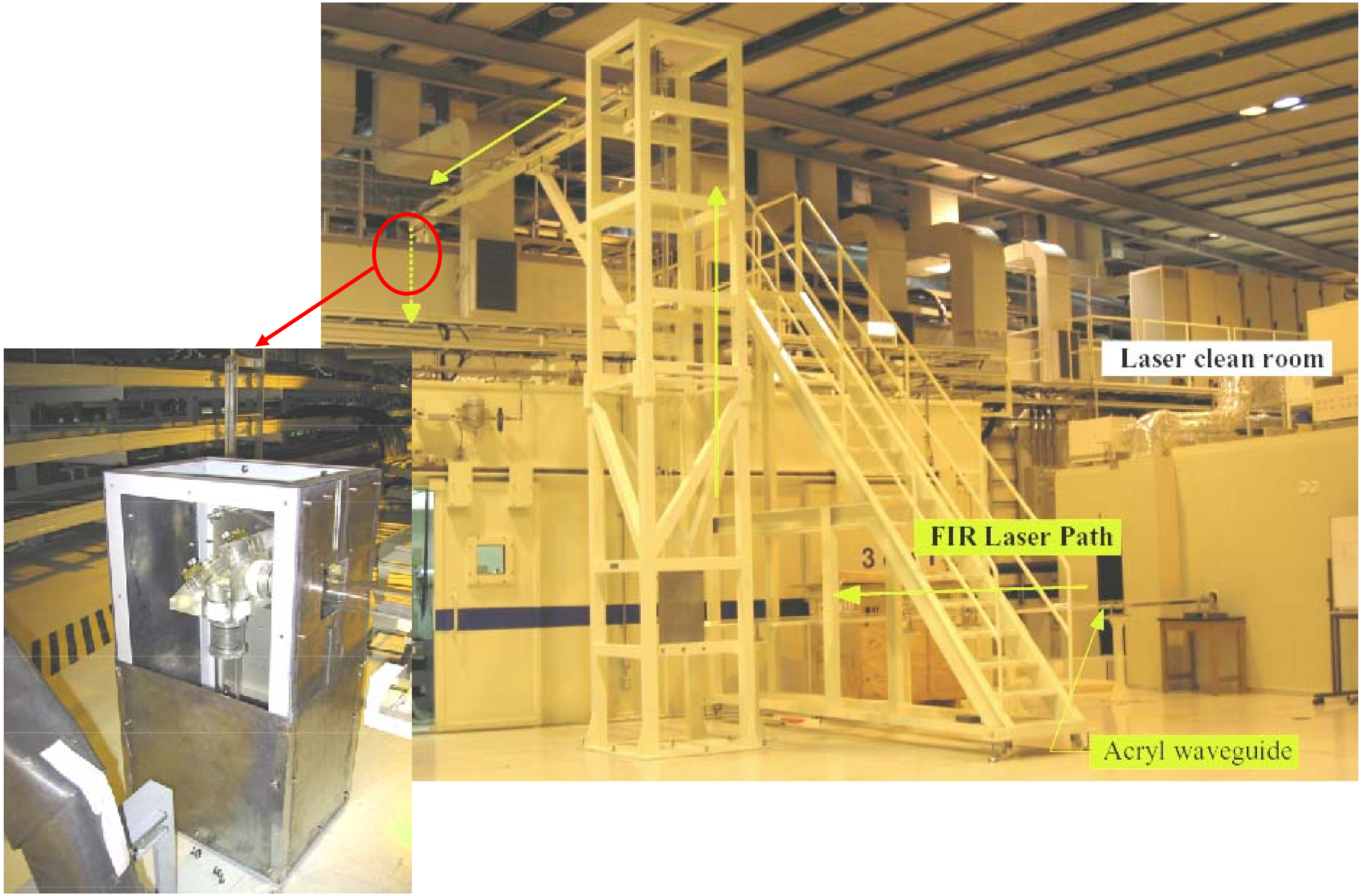



**Schematic view of FIR laser into waveguide**



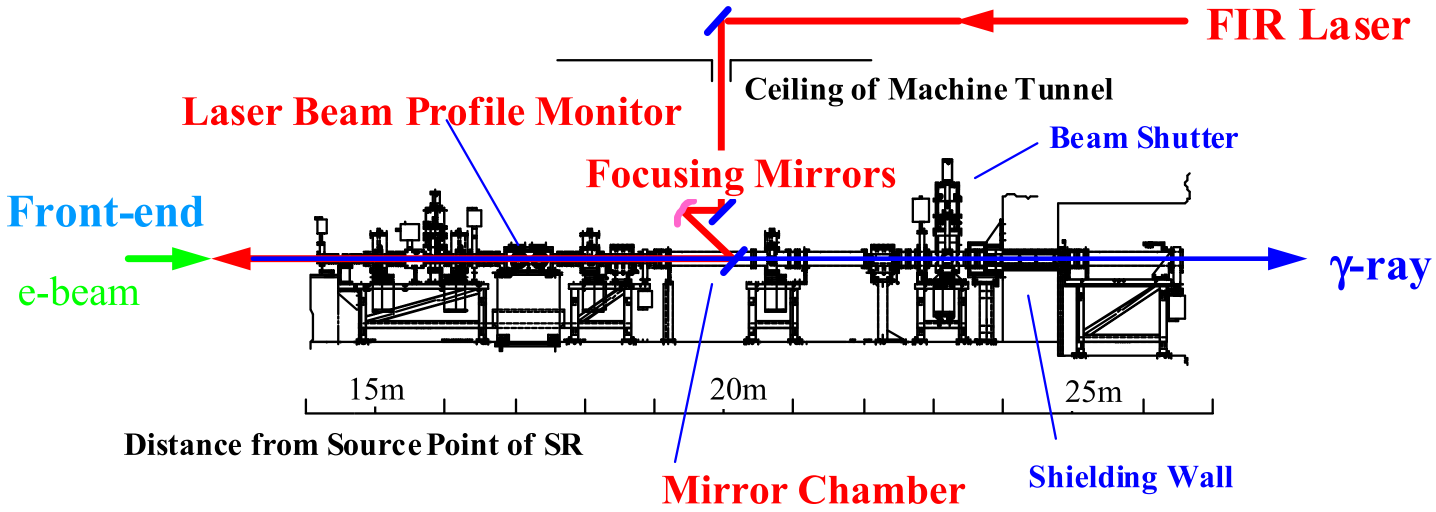

**$HE_{11}$ Mode**

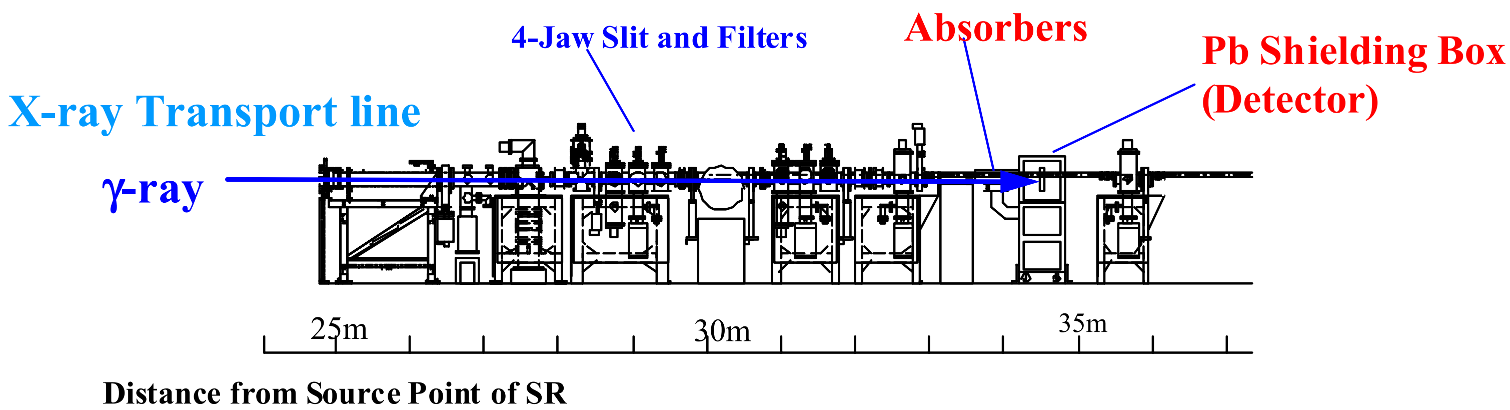
## *Waveguide Tower*



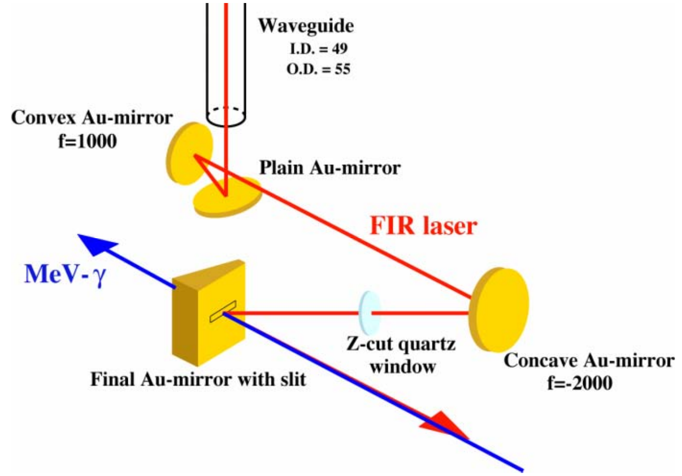

**Top ceiling of storage ring tunnel**

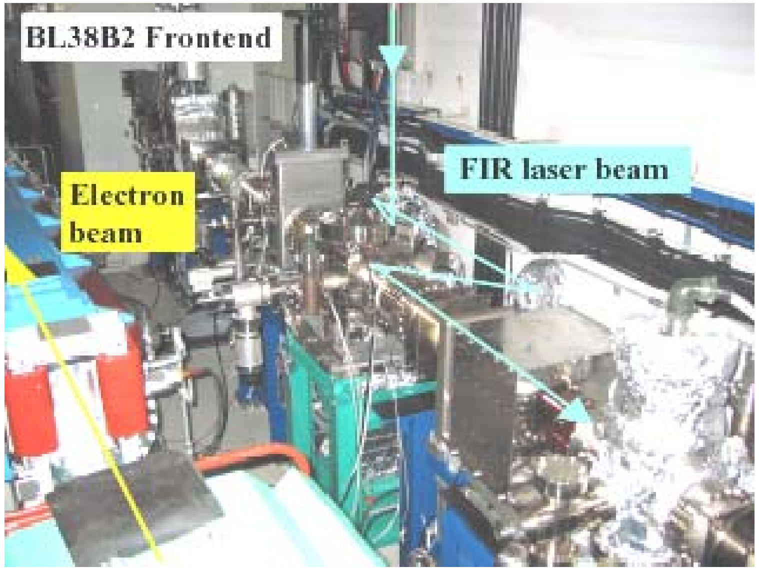
## Beam Diagnostics Beamline, BL38B2



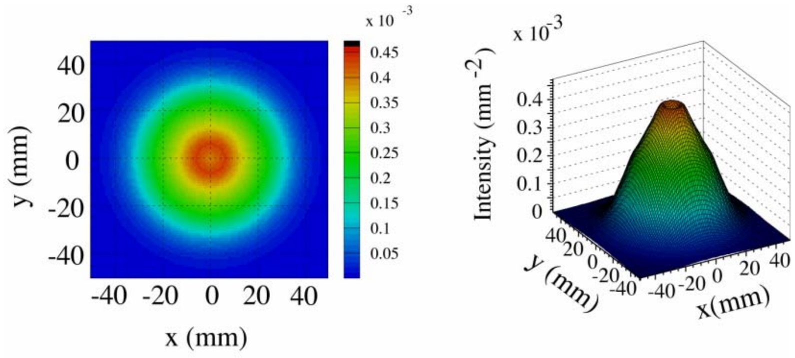
## *Laser mirror chamber at Front-end of BL38B2*



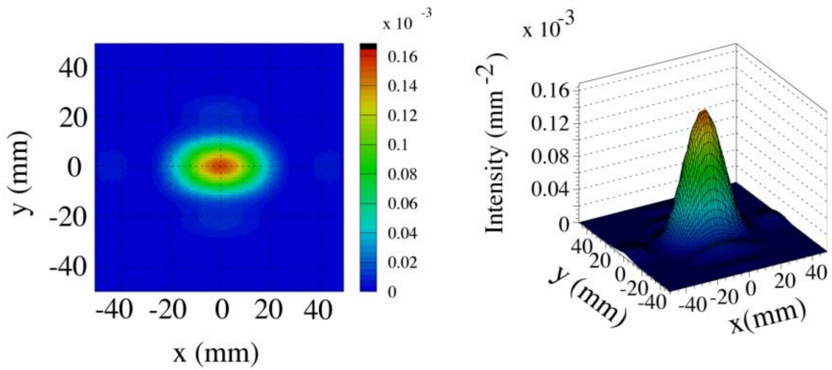




**Mirror chamber are equipped with quartz window and Au-coated mirror.**

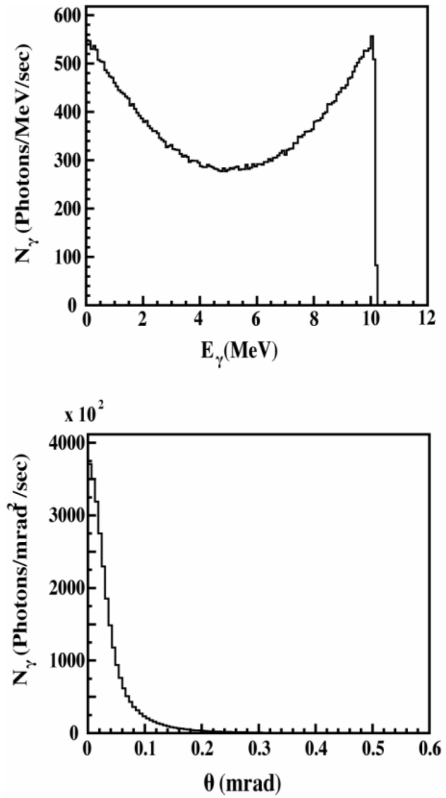
*Laser beam profile*
*and calculated energy and angular distributions of MeV photons*




**Calculated laser beam profile on the mirror in vacuum chamber.**



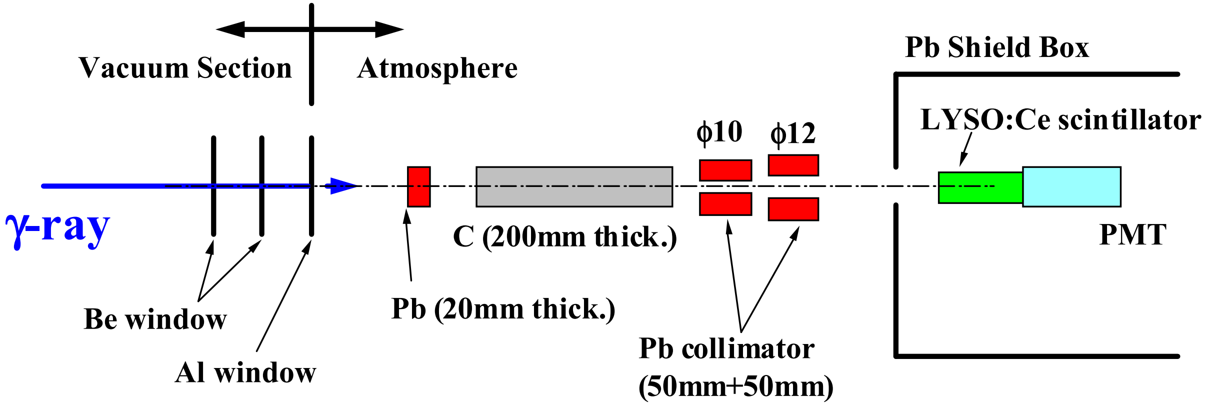

**Calculated laser beam profile at interaction point.**



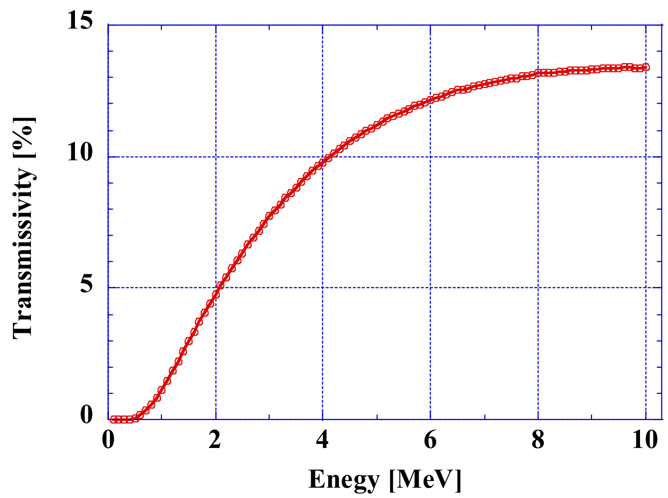

**Calculated energy and angular distribution.**

**$N_{\gamma} = 2.4 \times 10^{3}$ photons/sec@1W**

## *Measurements system of MeV photons*

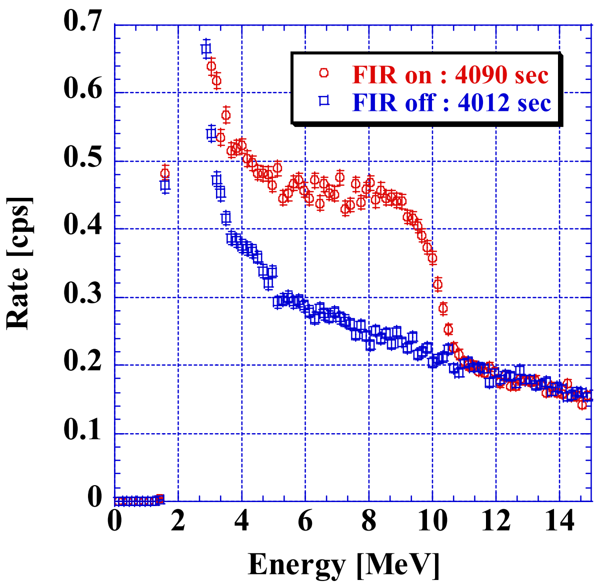


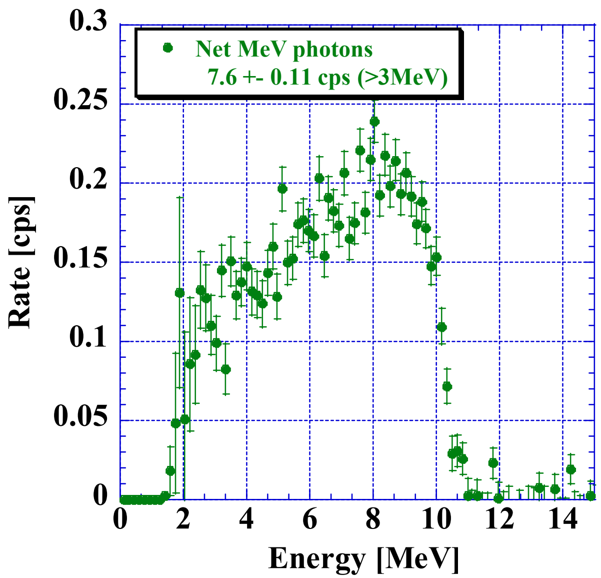

- In this beamline (BL38B2), SR from bending magnet is emitted to same direction of LCS MeV photons.
  Absorbers and collimators were installed for reduction of background SR.
- Detector is LYSO:Ce scintillator + PMT in the Pb shielding box.



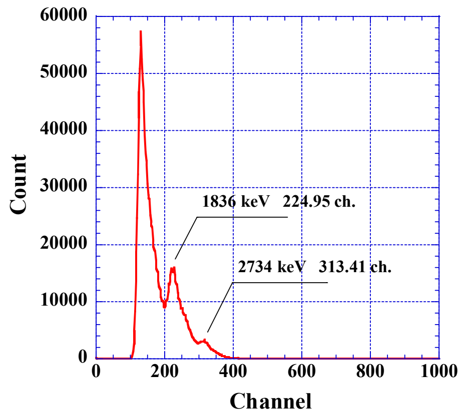

## *Measurement Result*

- **Output power of FIR laser is 890mW at wavelength of 119 μm**
- **Measuring time with FIR laser on : 4090 sec, laser off : 4012sec.**
- **Counting rate: 7.6±0.11 cps (>3MeV)**
- **Production rate is estimated from this data : $2\times10^{3}$ photons/sec**
  **This is in agreement with the calculated prediction.**



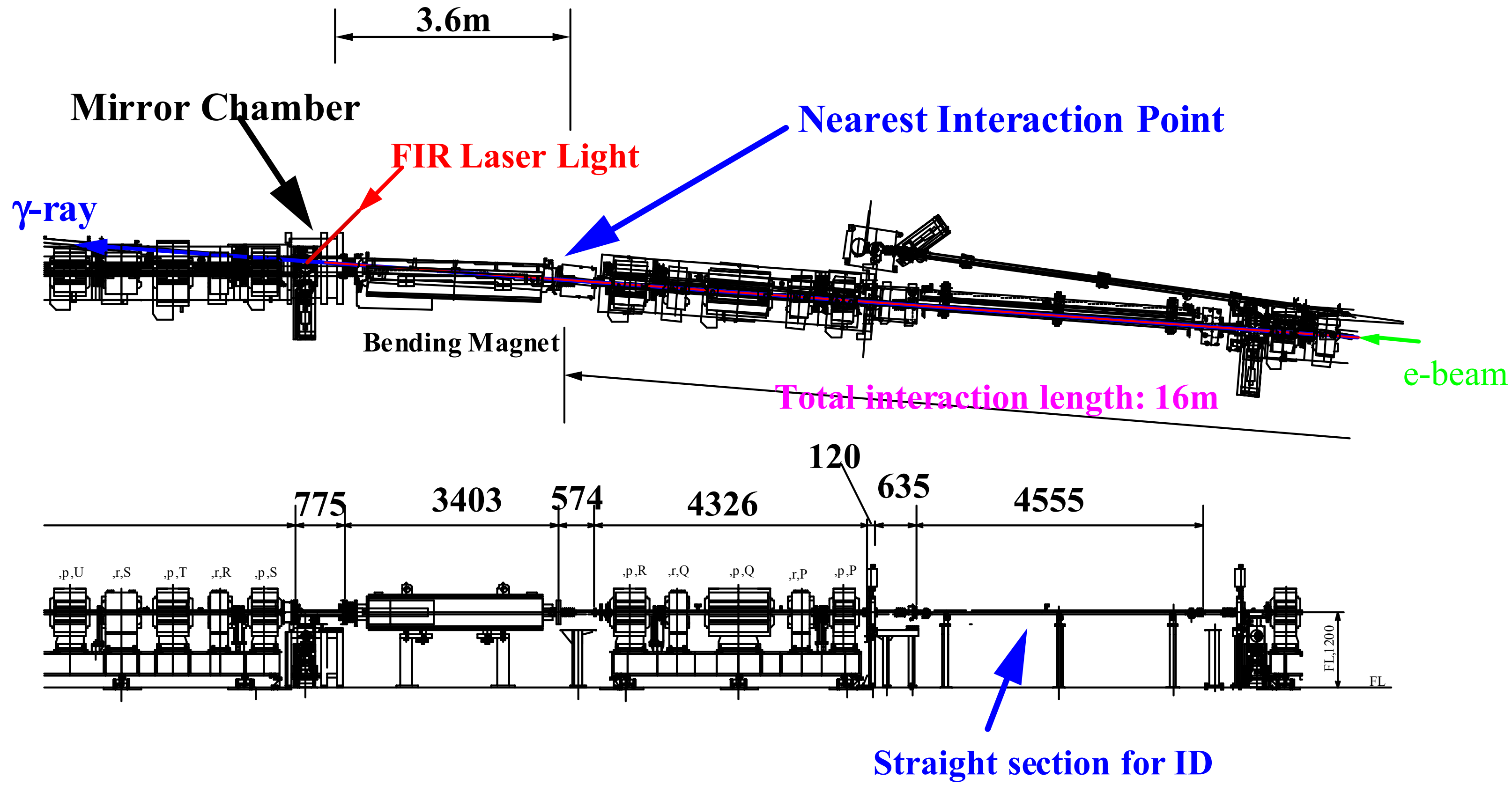




**Energy calibration : $Y^{88}$**

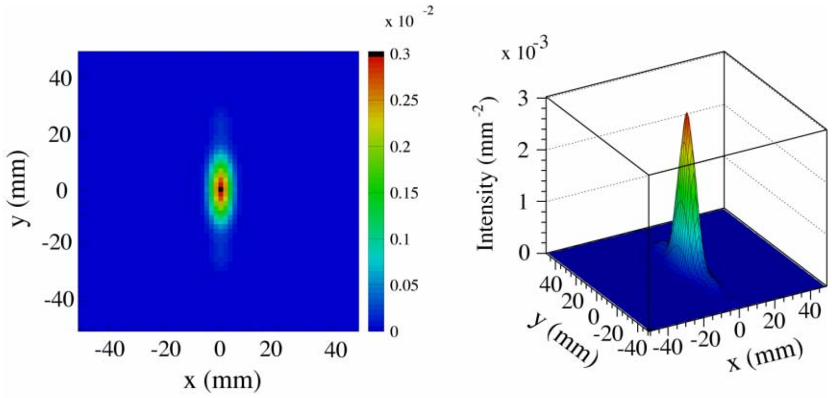


## *Advanced Plan of MeV Photons production at a beam diagnostics beamline, BL05SS (under construction)*

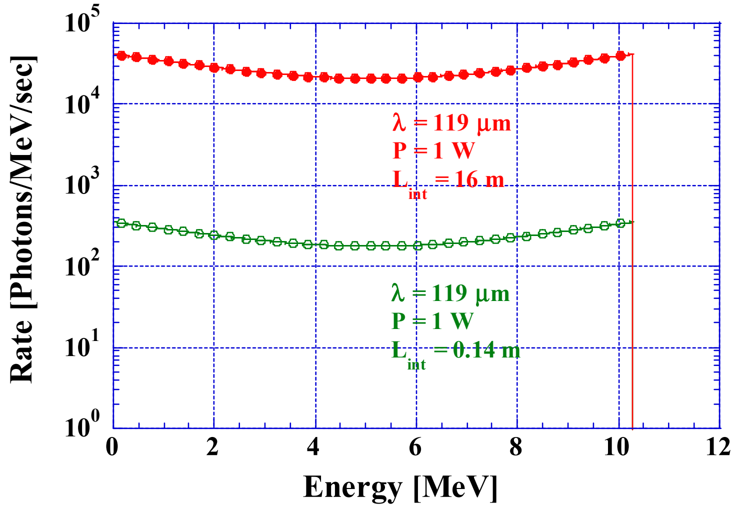
- Long interaction region can be used.
- Incident mirror chamber was installed near the interaction region.
- Background SR are not directly overlapped with MeV photons.



*Expected production rate of MeV photons at BL05SS*




**Laser beam profile at interaction point.**




**N$\gamma$=2.8×10$^5$ photons/sec@1W**

## *Summary*

- The 1.6-Watts output power of FIR laser was achieved at $\lambda$=119$\mu$m.

- Production study of MeV photons at the diagnostics beamline, BL38B2 of SPring-8 has been done.

  Estimated production rate of MeV photons is $2\times10^{3}$ photons/sec.

  This is in agreement with the simulation result ($2.4 \times 10^{3}$ photons/sec).

- Intense MeV photons production system is under construction at the beam diagnostics beamline, BL05SS.

  Mirror chamber was installed near the interaction region in the storage ring of SPring-8.

  Estimated production rate of MeV photons at this beamline is $2.8\times10^{5}$ photons/sec.

- If we can reduce a laser beam spread at the interaction region, so very high intense MeV photons will be obtained by FIR laser Compton scattering.

**Thank you for your attention !!**