Development of pulse width measurement techniques of ultra-short gamma-ray pulses

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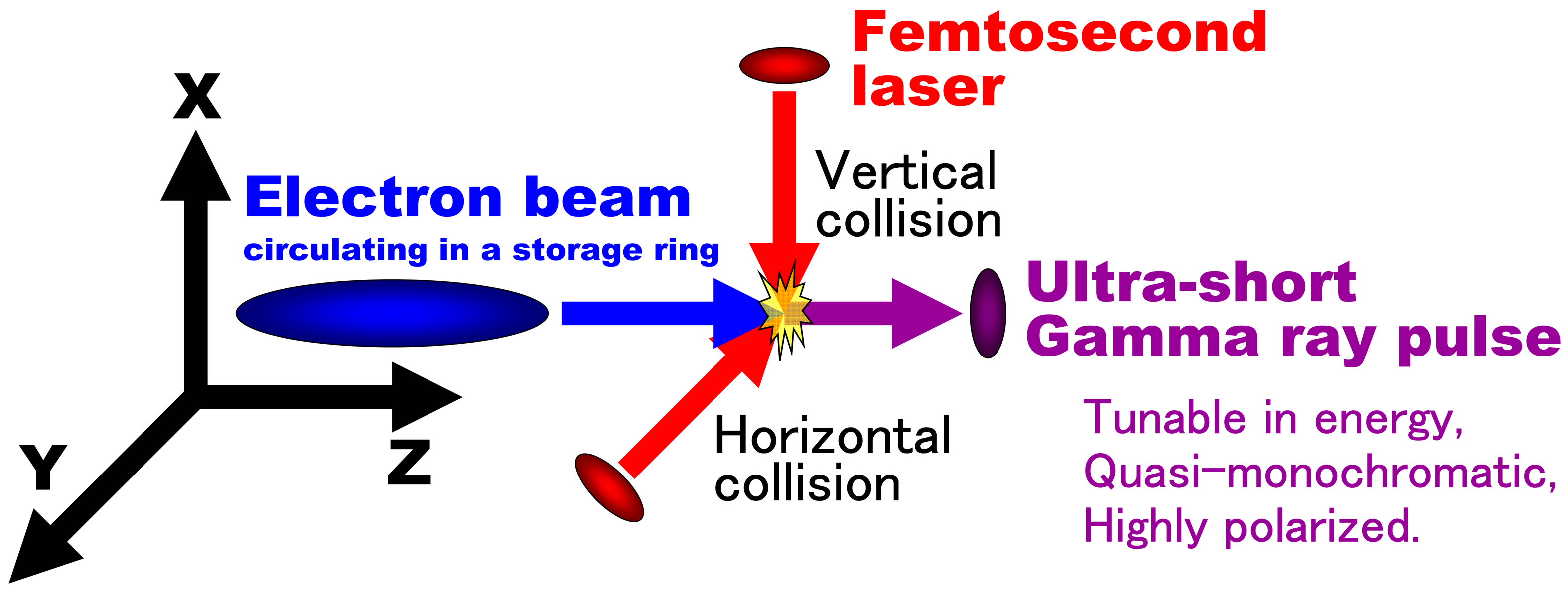
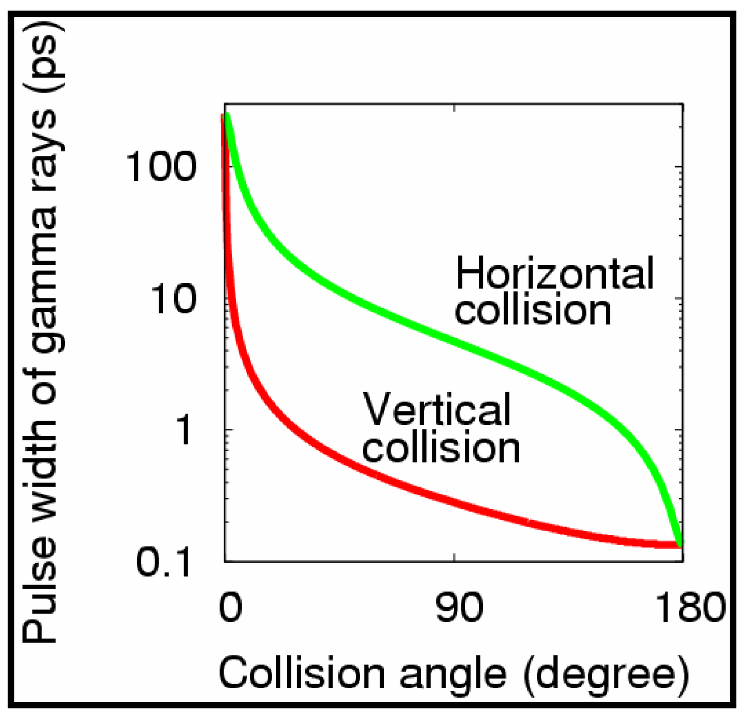
1. Motivation

New photon source; Ultra-short gamma ray pulses

We have developed an ultra-short pulse gamma ray source using a laser Compton scattering technique at an electron storage ring, UVSOR-II.



Energy, pulse width, and intensity of gamma rays



Dependence of the gamma ray pulse width on the collision angle between the electron beam and the laser. (0 degree is frontal collision.)

In a 90° collision

Maximum energy: 6.6 MeV

Vertical collision
Pulse width: 350 fs (FWHM)
Intensity: 2.4 × 10^6 photons s^{-1}

Horizontal collision
Pulse width: 4.8 ps (FWHM)
Intensity: 3.4 × 10^7 photons s^{-1}

Ti:Sa laser
Wavelength: 800 nm
Pulse energy: 10 mJ
Repetition rate: 1 kHz
Pulse width: 130 fs
Size: 0.03 mm (rms)

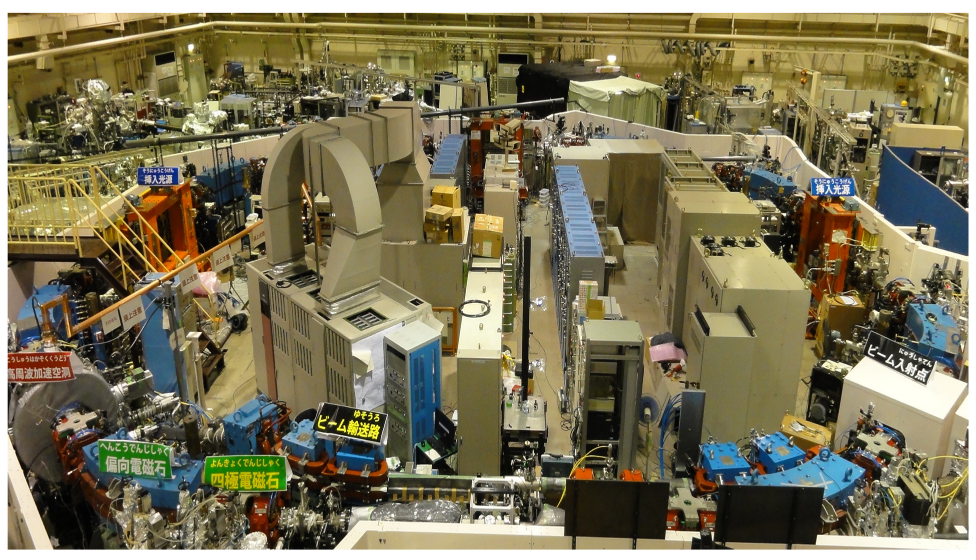
Electron beam
Energy: 750 MeV
Beam current: 100 mA
Frequency: 5.64 MHz
Pulse width: 108 ps (rms)
Size: 0.6, 0.03 mm (rms) (Hor) (Ver)

Application of the ultra-short gamma ray pulses

➡ **Positron annihilation lifetime study**

How do we measure the pulse width of the ultra-short gamma rays?

2. UVSOR-II electron storage ring



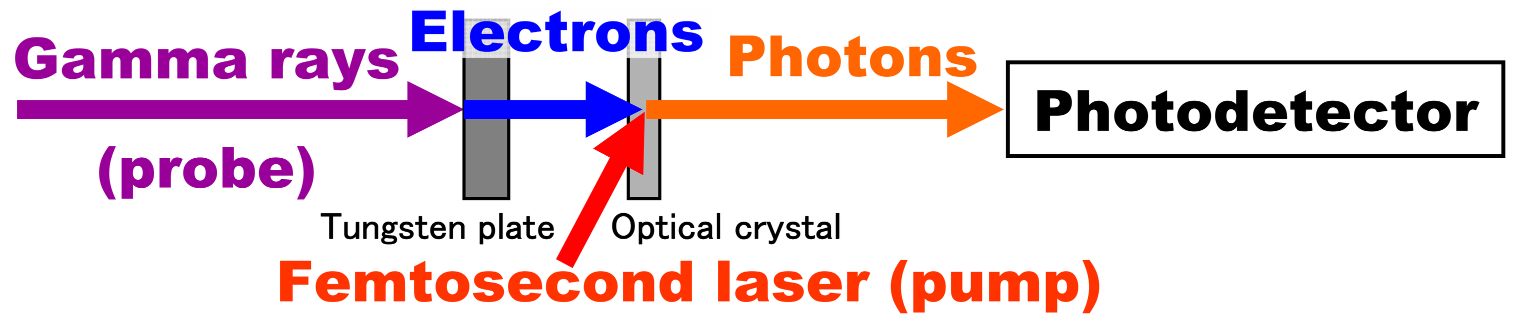
Synchrotron radiation facility

Energy: 750 MeV
Stored current: 300 mA
Natural emittance: 27.4 nm-rad
Circumference: 53 m

3. Pulse width measurement

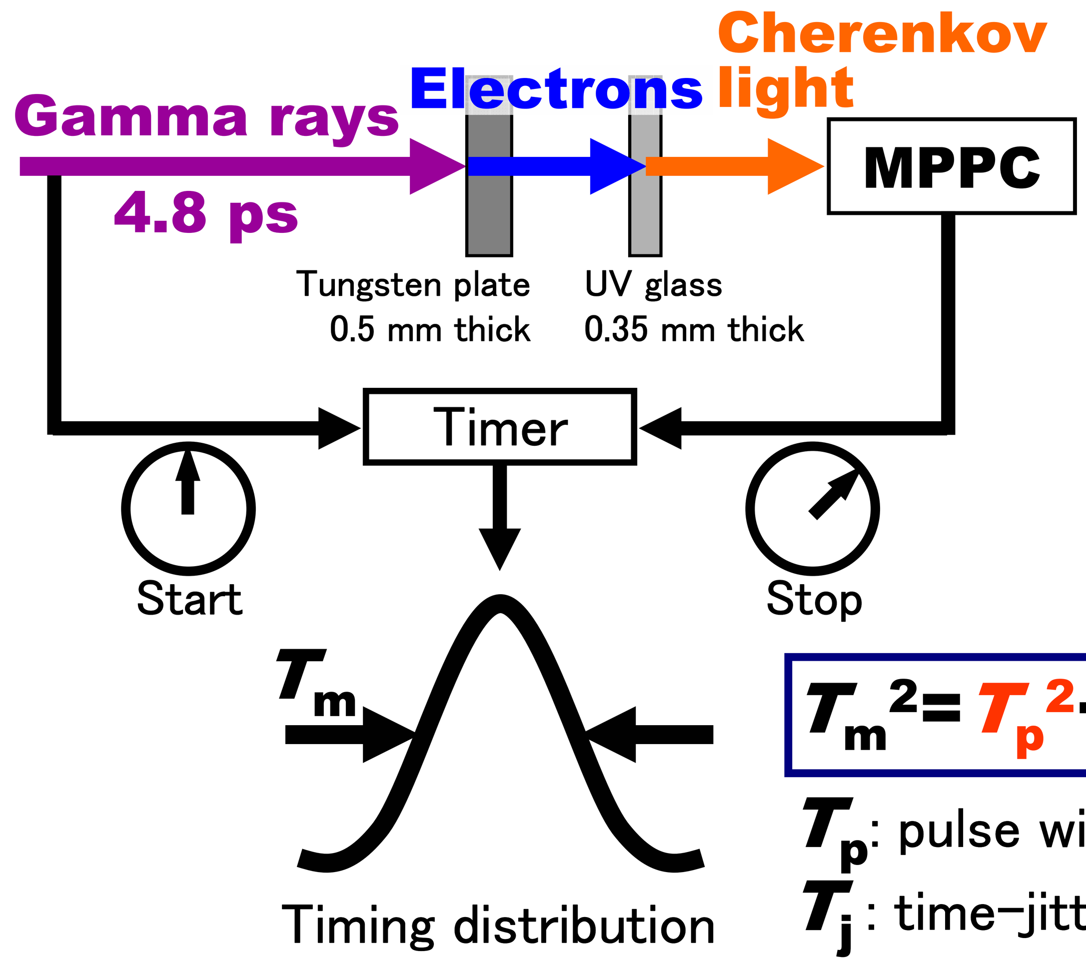
Goal

Evaluation of the gamma ray pulse width in the femto-second range based on a pump-probe technique. (under consideration)



1st stage (this work)

Evaluation of an upper bound value of the gamma ray pulse width in the picosecond range by using a photodetector with a picosecond time resolution.



Geiger-mode APD, Time resolution: T_r = 477±7 ps

$$T_m^2 = T_p^2 + T_r^2 + T_j^2$$

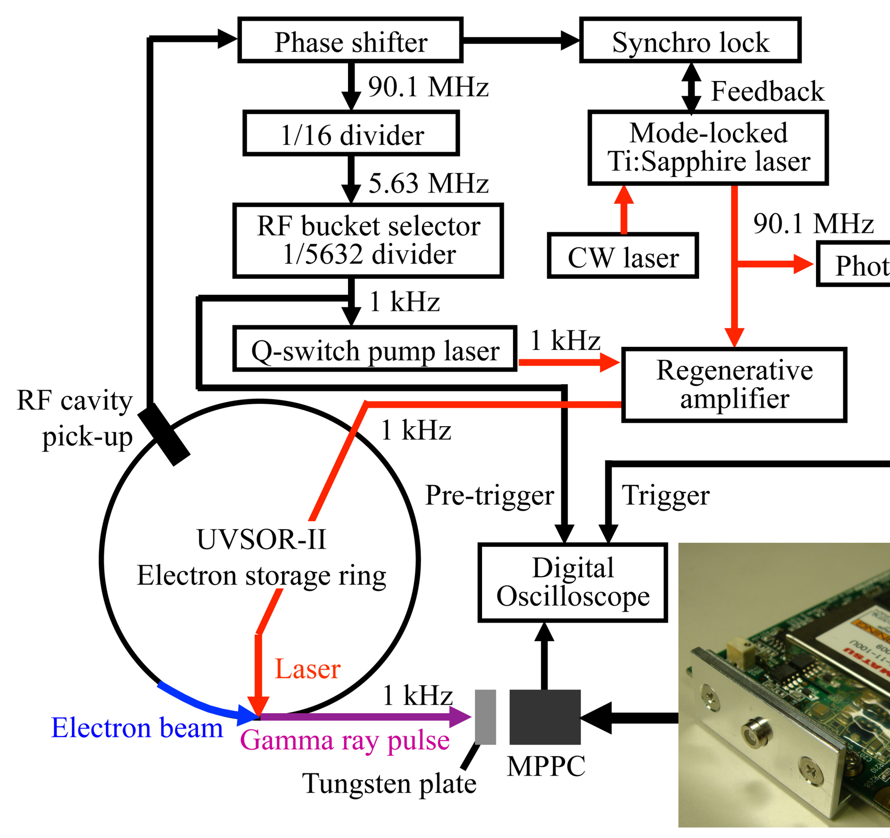
T_p: pulse width of gamma rays
T_j: time-jitter of all equipments

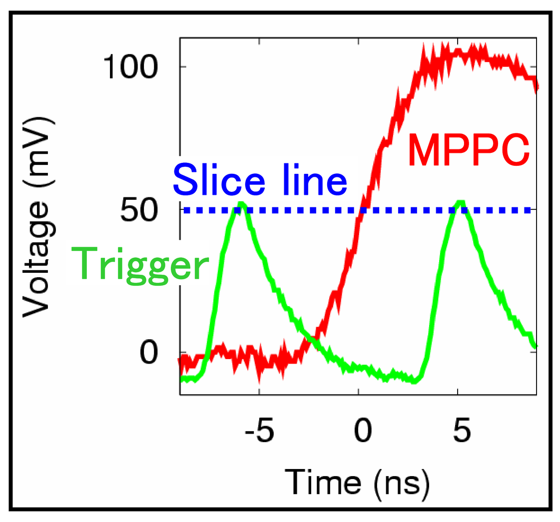
Estimation of the upper bound value

If the pulse width of the gamma rays (T_p) is larger than 82 ps, a measured timing distribution (T_m) is larger than a time resolution of a MPPC module (T_r) in the ideal condition where a time-jitter is negligible.

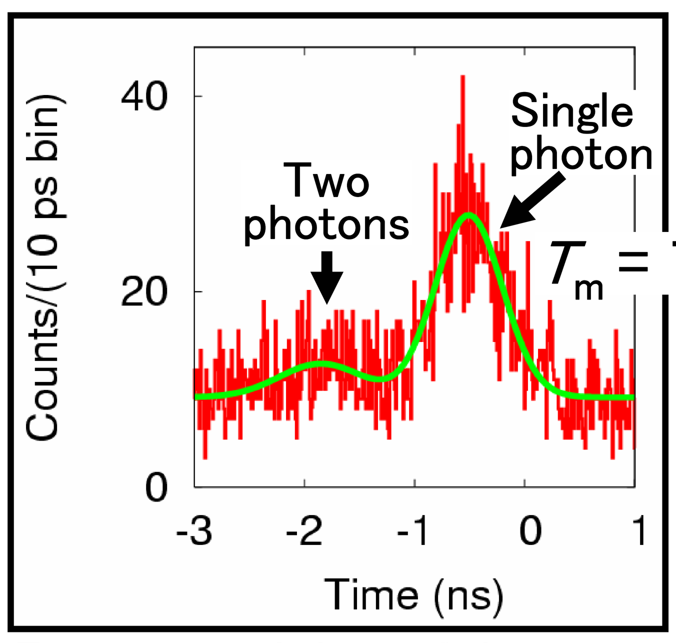
➡ The shortest pulse width that a MPPC can evaluate is 82 ps.

Measurement of the upper bound value





We measured a timing distribution output signals of a MPPC crossed a slice line.



Experimental data of the timing distribution.

$$\sqrt{(T_p^2 + T_j^2)} = \sqrt{(T_m^2 - T_r^2)} = \sqrt{(720^2 - 477^2)} = 540 \text{ ps}$$

- The main reason of a large time-jitter is considered as low S/N ratio of the trigger signal.
- By increasing a S/N ratio of the trigger signal, we can lower the upper bound value of the gamma ray pulse width.

4. Conclusion

- Measurement techniques in the femtosecond and picosecond range of the gamma ray pulse width is being developed.
- We have succeeded in measuring the gamma ray pulse width including a time-jitter as 540 ps.