Laser System of Photocathode RF Gun in Pohang Accelerator Laboratory

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Laser System

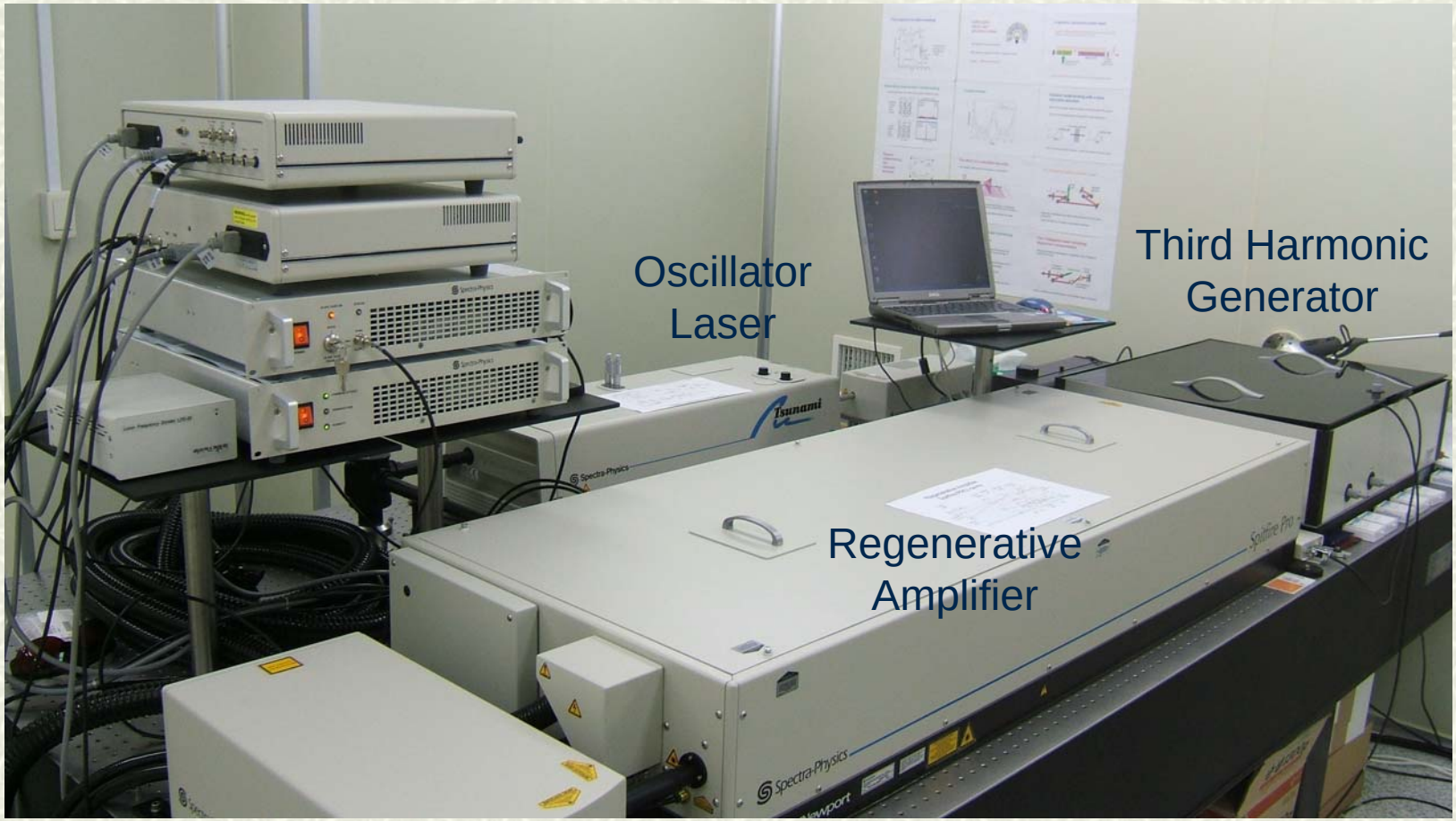
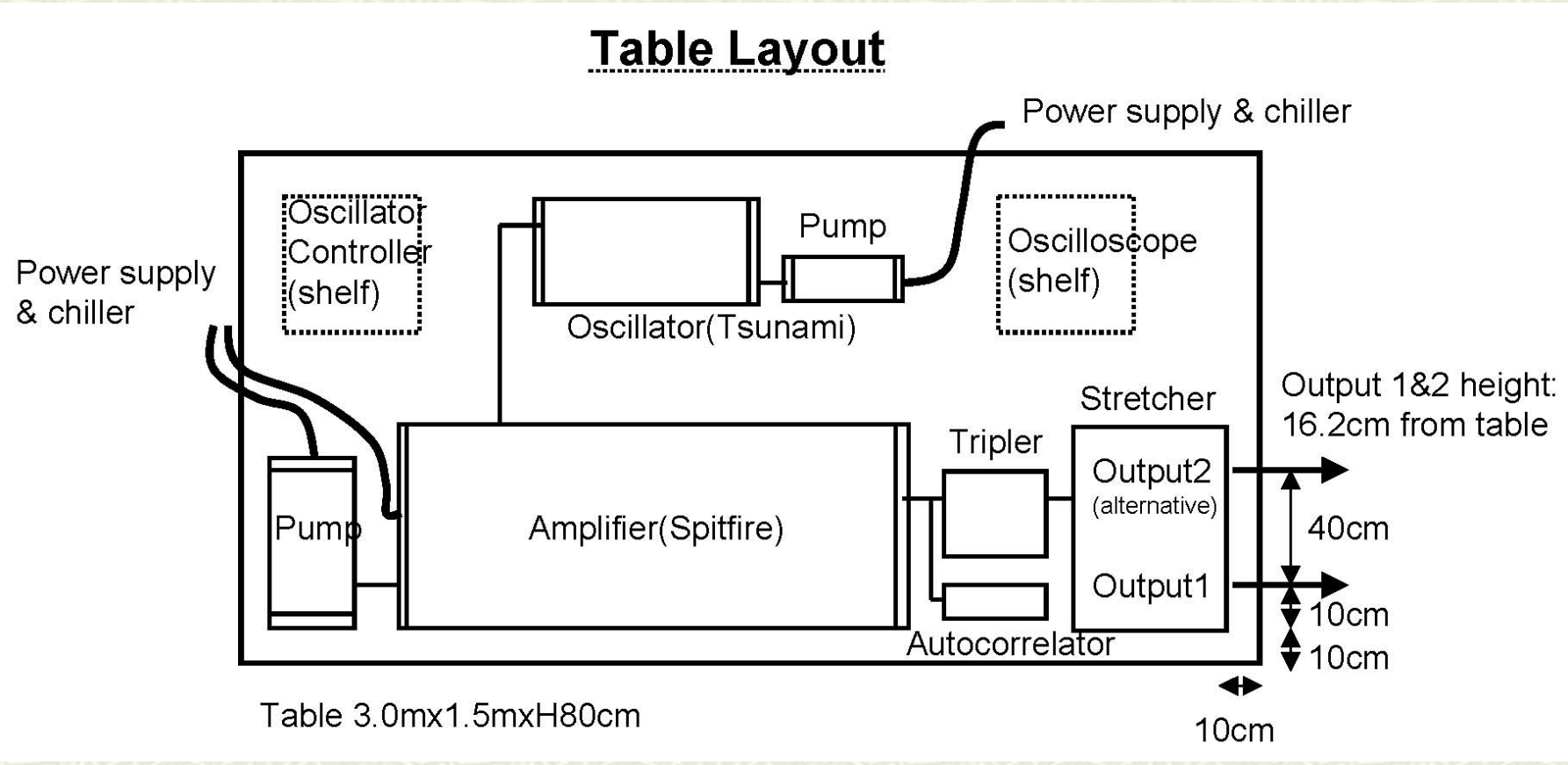
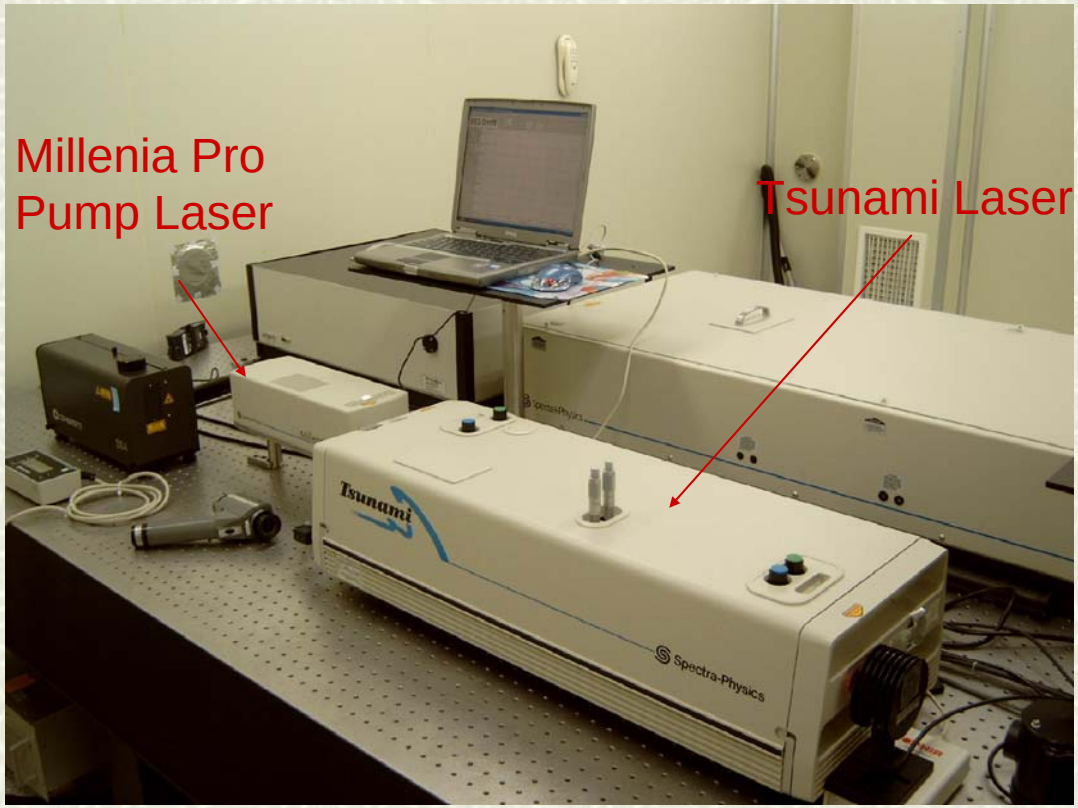


Table Layout



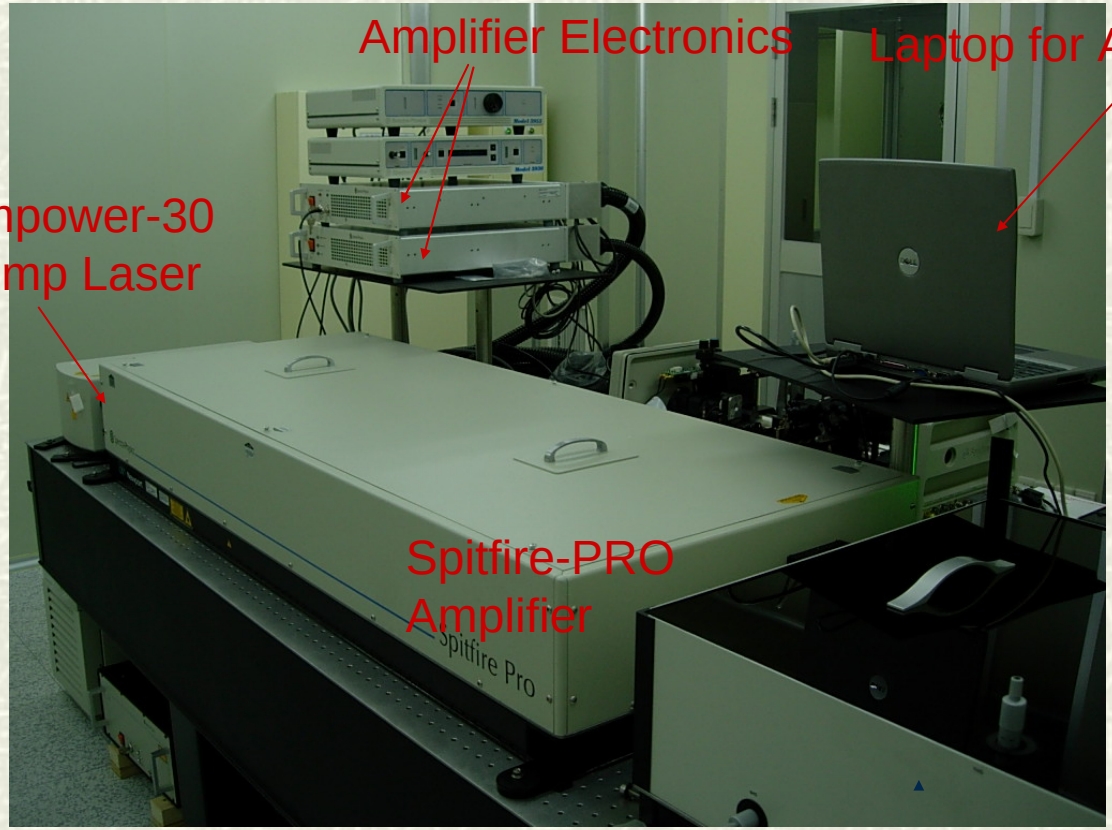
Oscillator Laser



Tsunami
(Spectra Physics)

Pulse width: 110 fs
Wavelength: 800 nm
Rep. Rate: 80 MHz

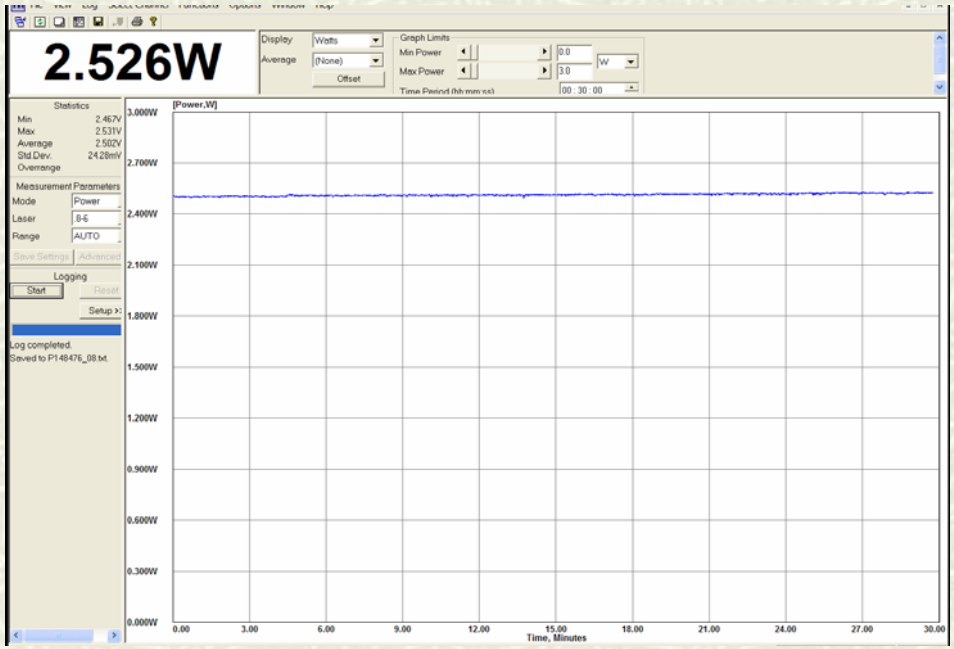
Amplifier Laser

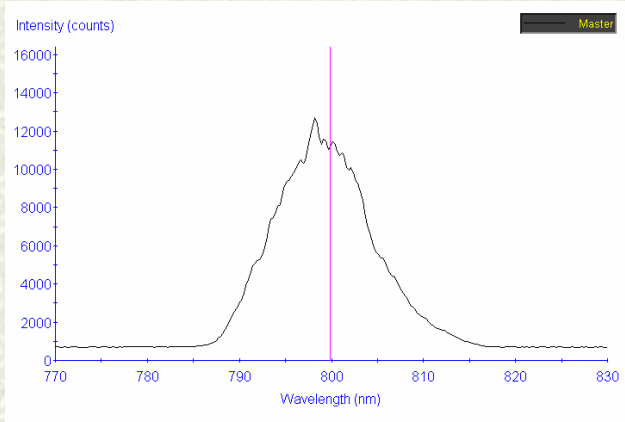


Spitfier Pro
(Spectra Physics)

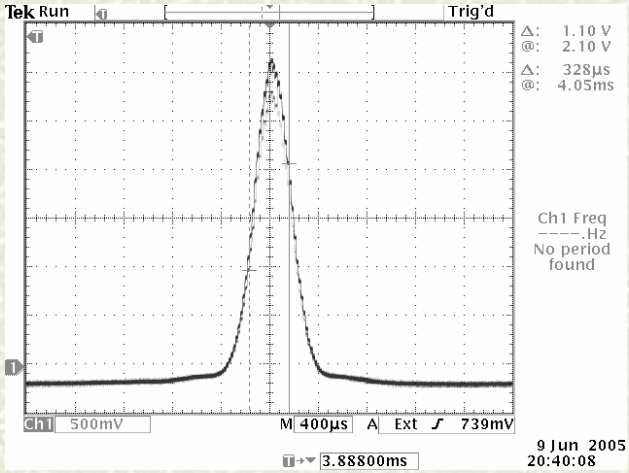
Pulse width: 110 fs
Wavelength: 800 nm
Rep. Rate: 1 kHz
Beam Size: 10 mm

Amplifier Performance





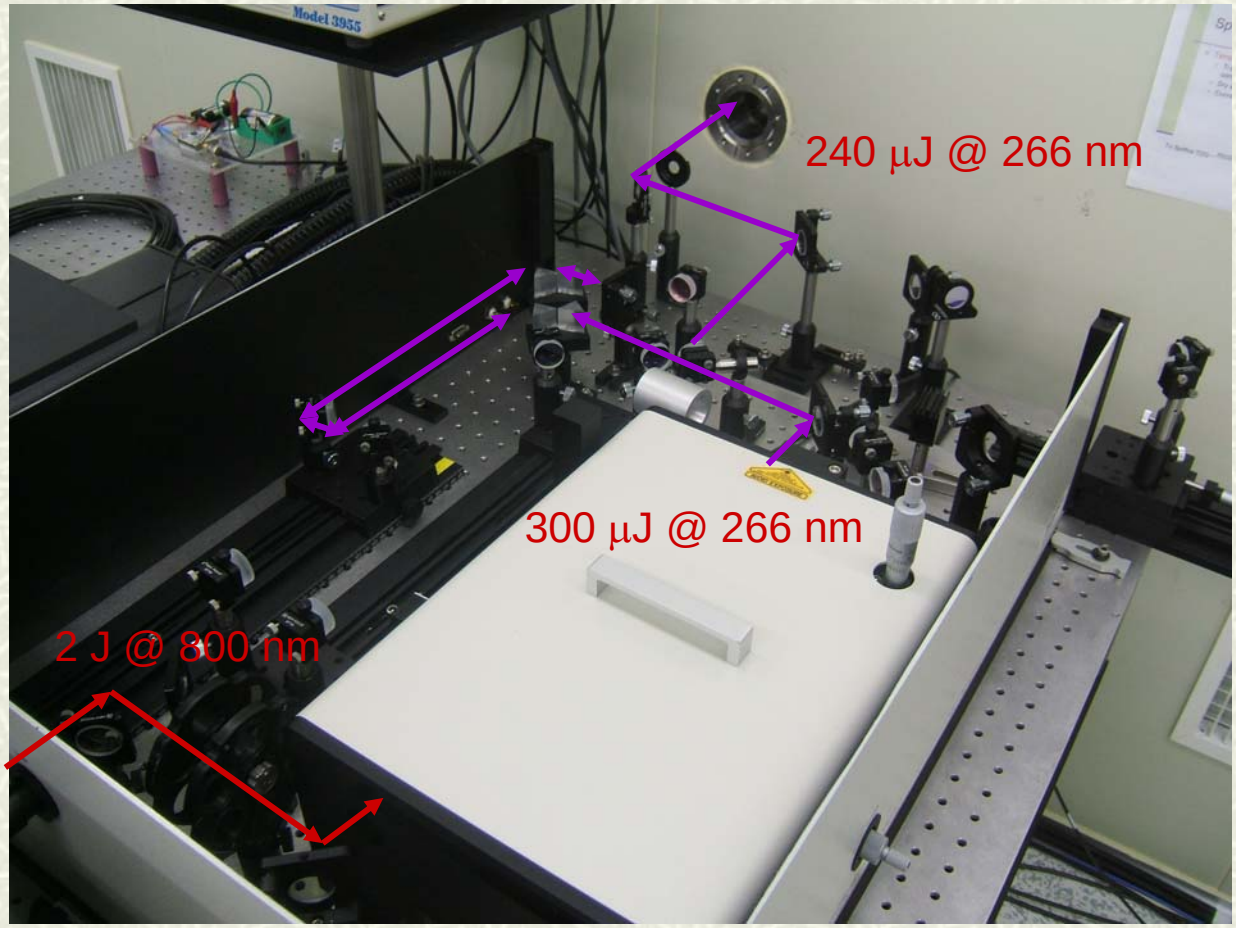
13 nm Wavelength Bandwidth



Auto correlation signal

- Maximum Power: 2.5 W
- Pulse Energy: 2.5 mJ
- Pulse Width: 110 fs

THG & Stretcher



2.5 mJ @ 800 nm

X 10% efficiency

=250 μJ @ 266 nm

X 50% Loss

=125 μJ

=>1 nC from Cathode with 10^{-5} Q.E.

Prism-Pair Dispersion

- Prism pair has been traditionally designed to compensate the GVD in the laser cavity, and to compress the output pulse.
- Prism-pair produces a negative GVD

$GVD = (\lambda^3/2\pi c^2) d^2P/d\lambda^2$

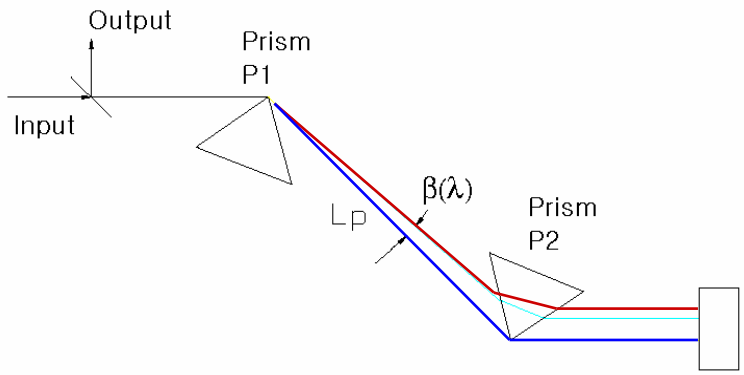
Path length $P = 2L_p \cos(\beta(\lambda))$

L_p = distance between P1 & P2

$GVD \sim -(4\lambda^3 L_p/\pi c^2)(dn/d\lambda)^2$

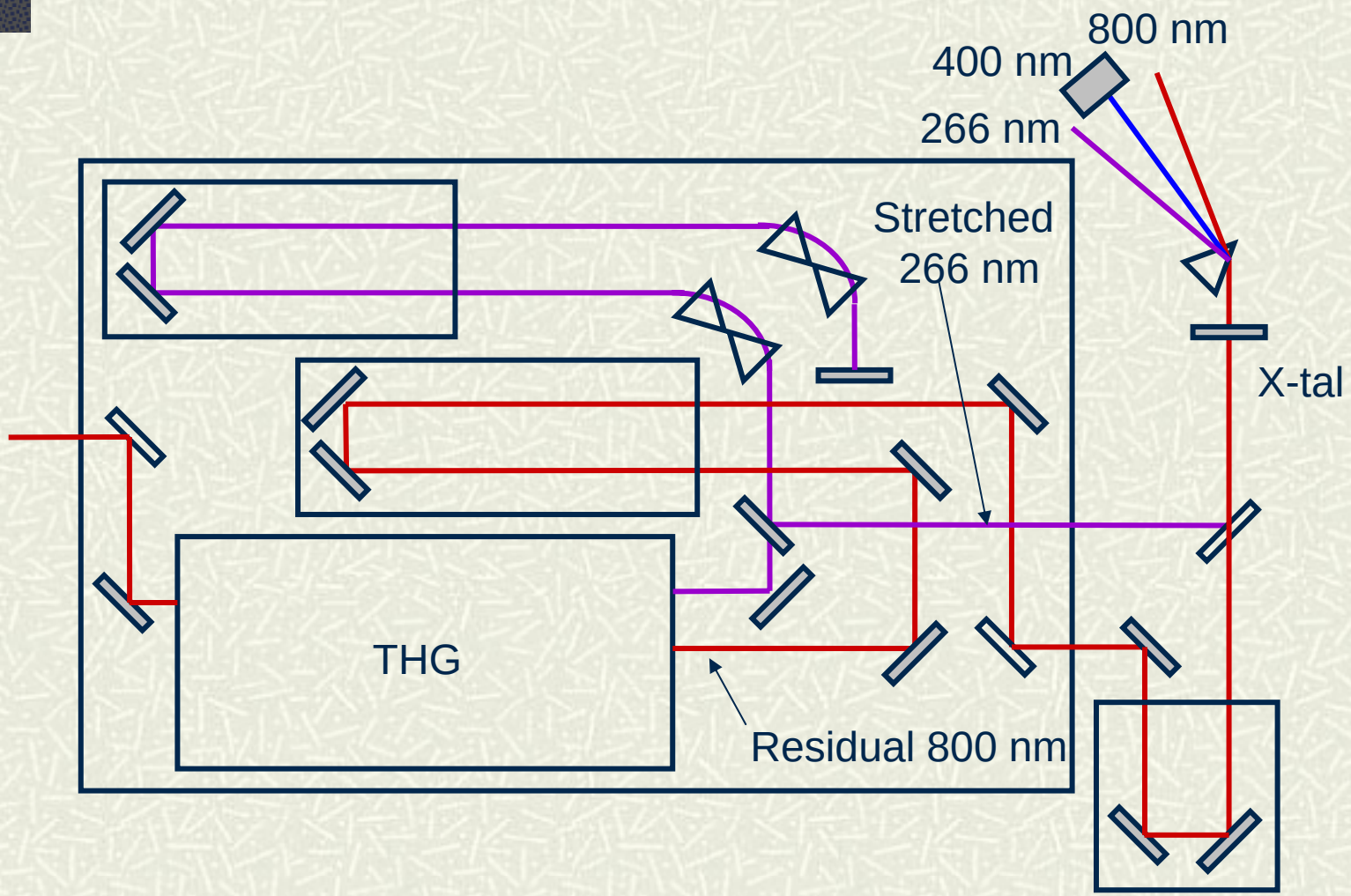
$= -550 fs^2/cm \times L_p (cm)$

for fused silica at 266nm

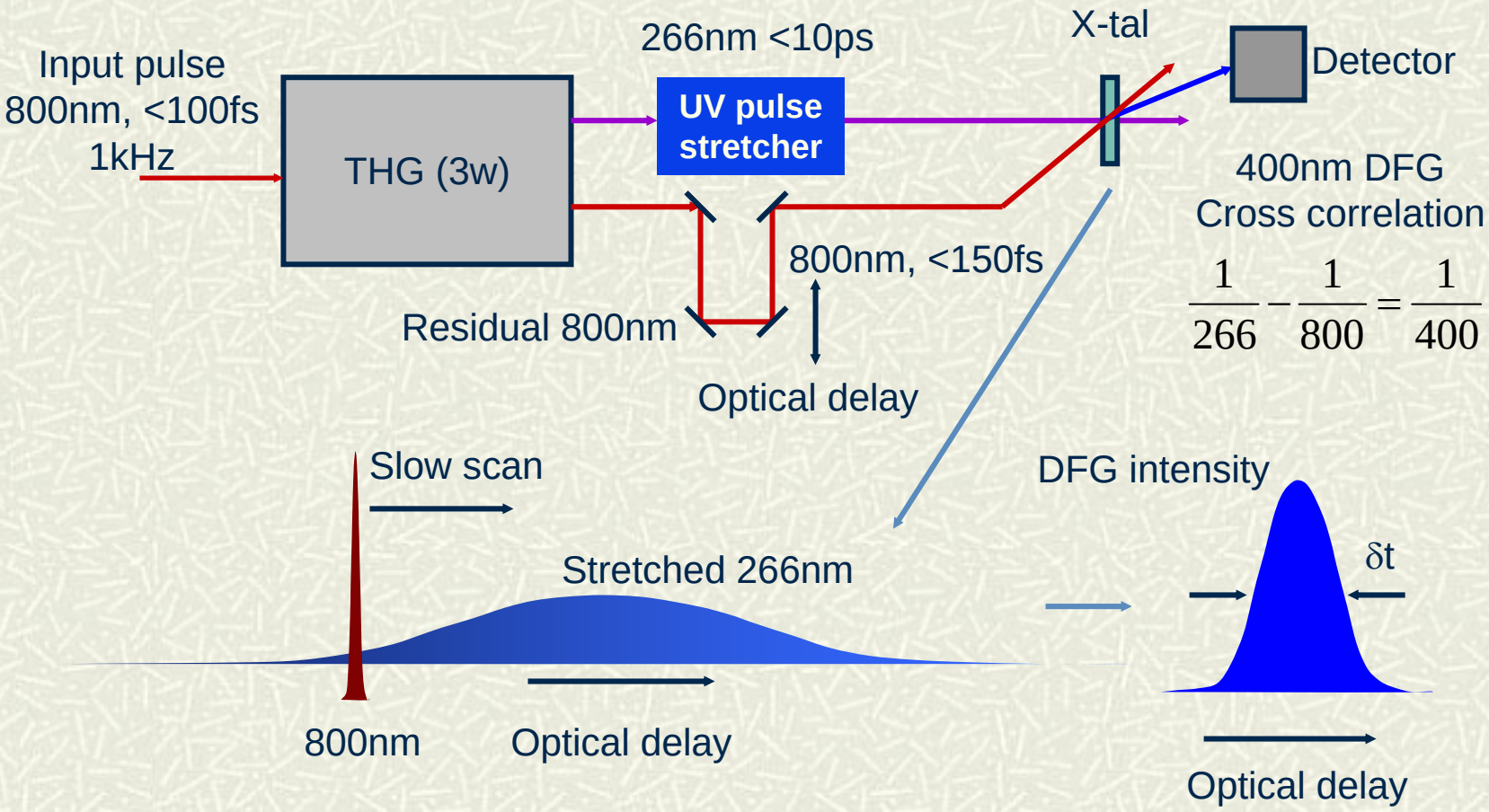


"Red" component of the pulse propagates in glass where group velocity is smaller than for the "blue" component

UV Stretcher

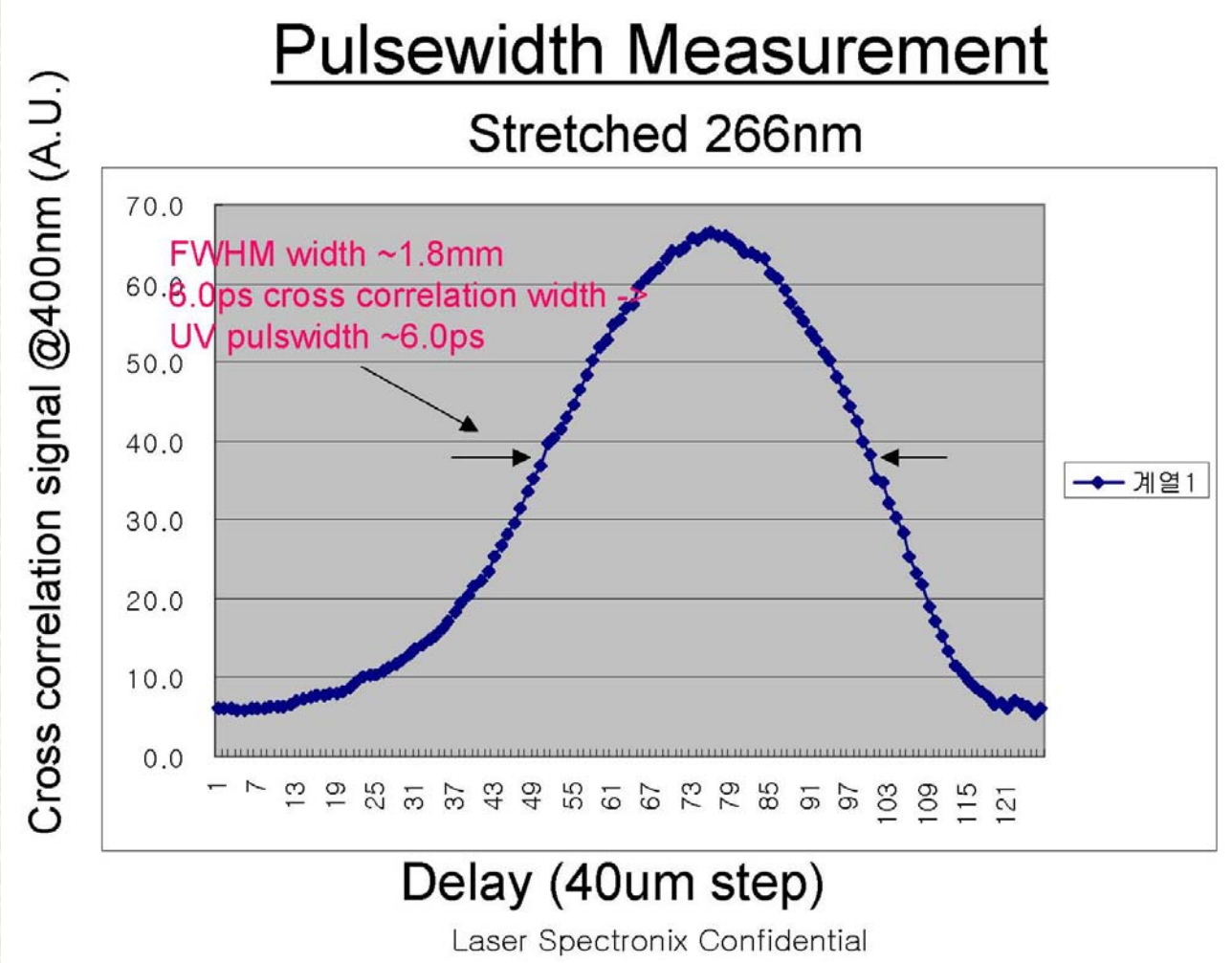


Cross Correlator



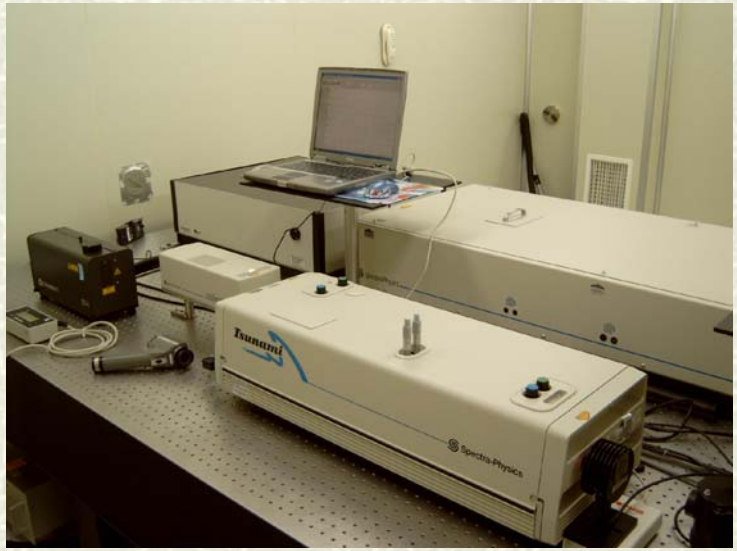
δt measurement -> UV 266nm pulsewidth calculation

UV Pulse Width



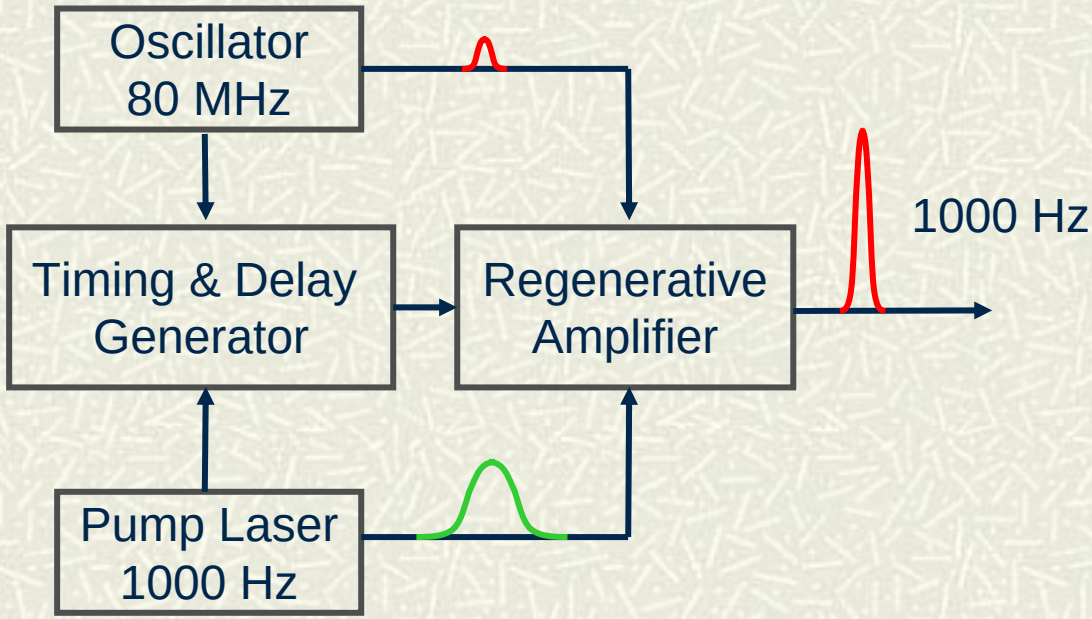
Synchronization with RF

Freq.: 2856 MHz
Rep. Rate: 30 Hz
Pulse Width: 4 μs

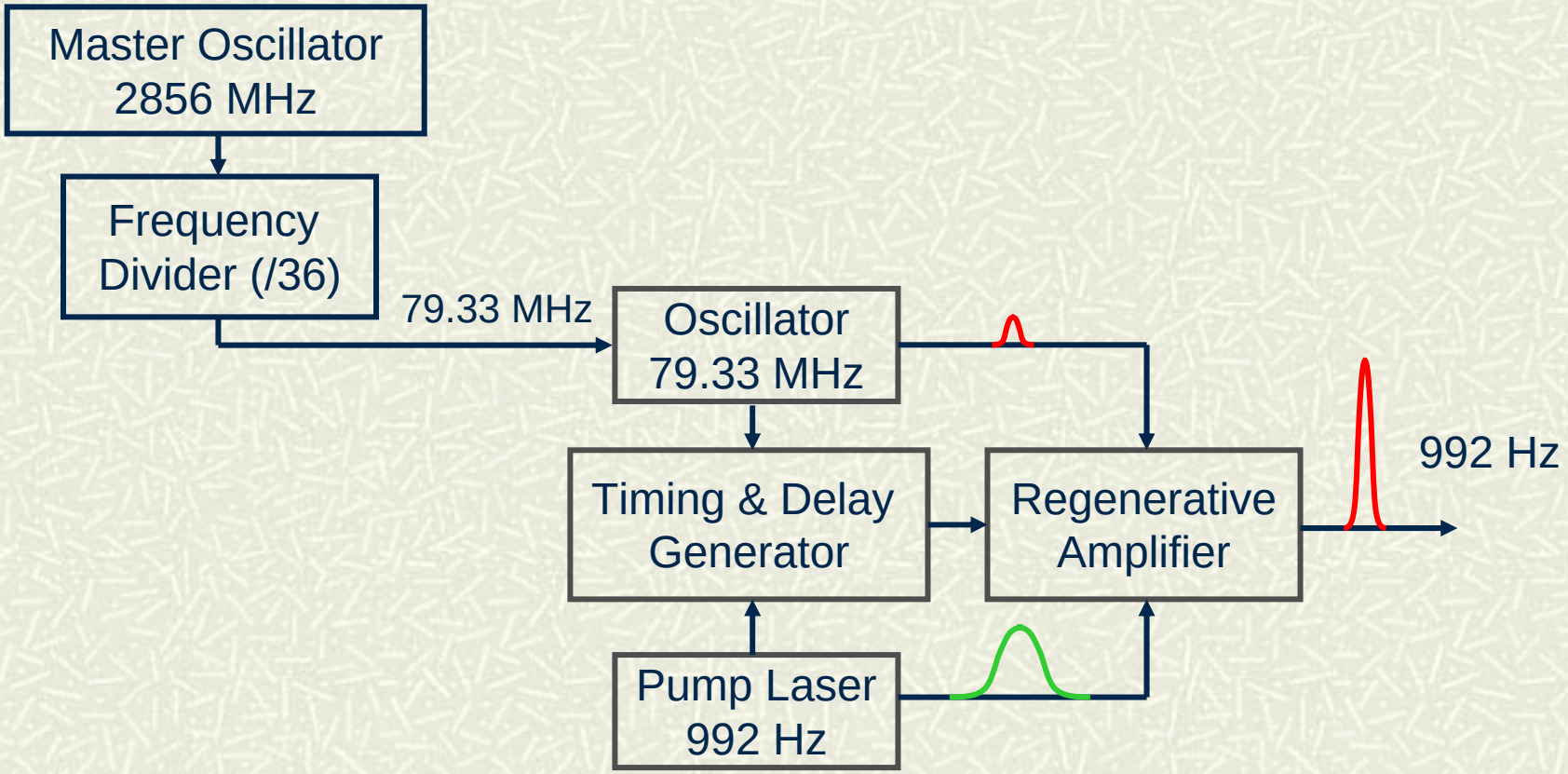


Wave Length: 800 nm
Rep. Rate: 1 kHz
Pulse Width: 100 fs

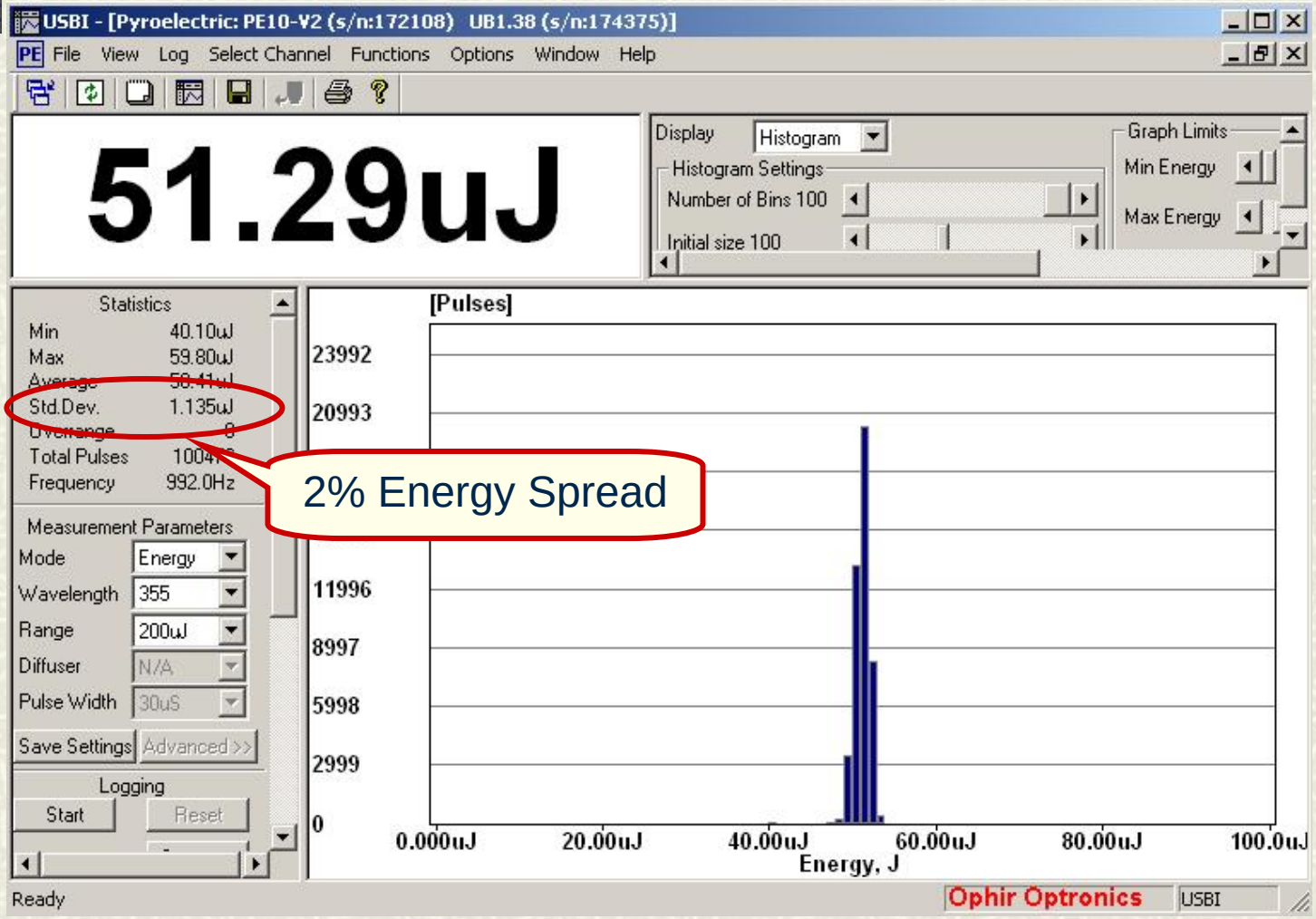
Laser Timing



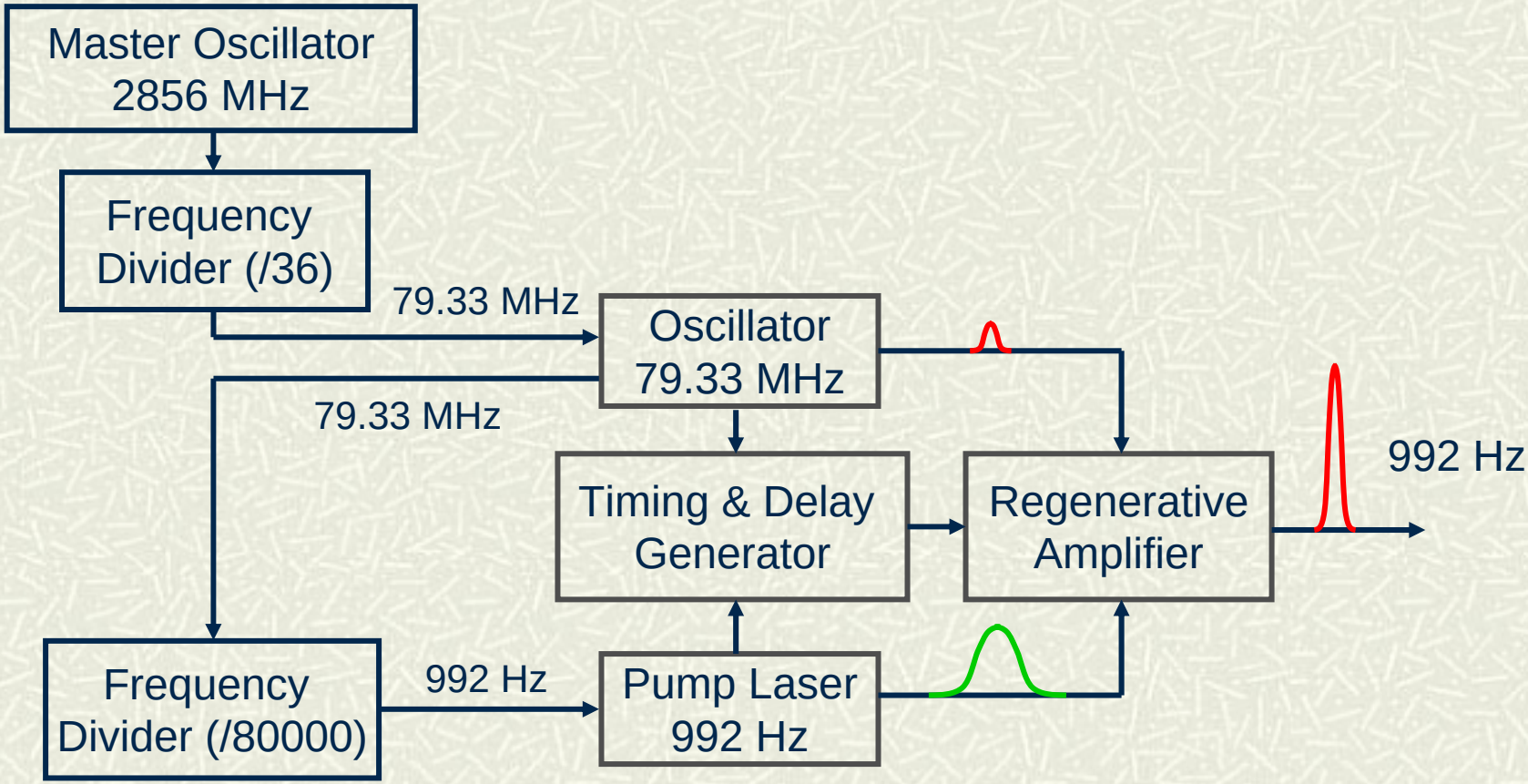
RF Synchronized Laser Timing I



Energy Fluctuation

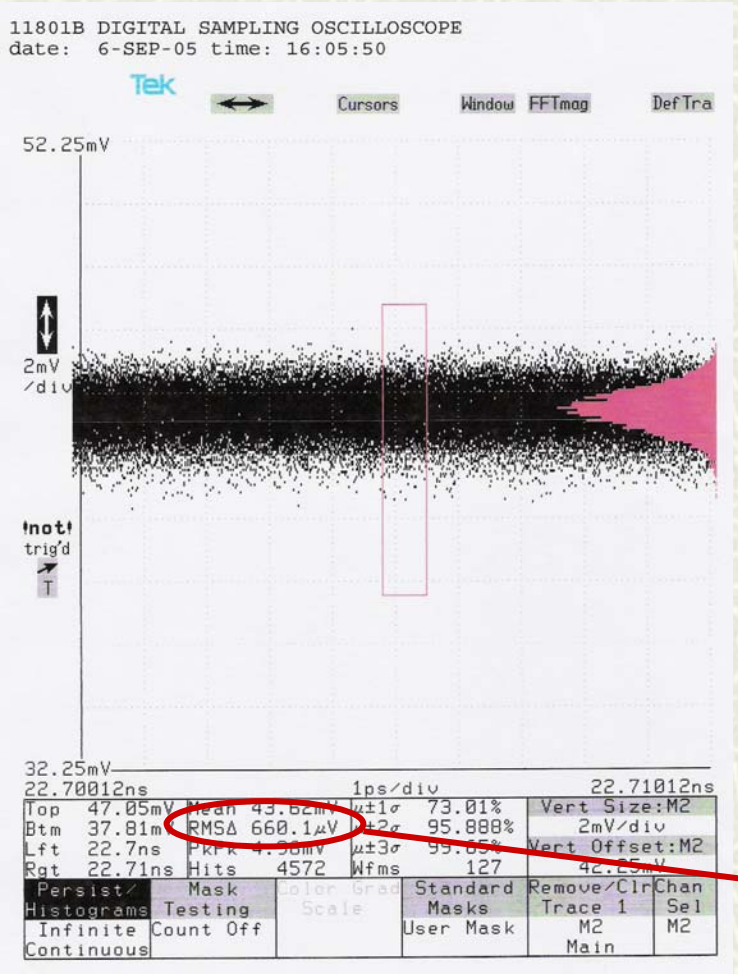


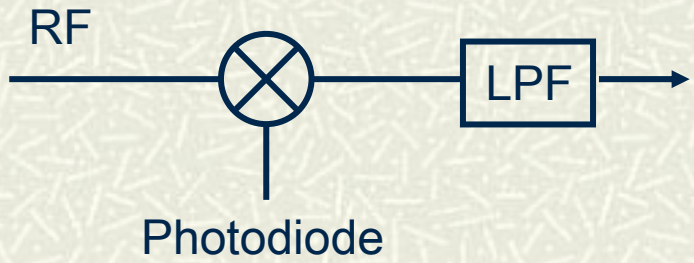
RF Synchronized Laser Timing II



Energy spread decreased to 1%

Jitter Measurement





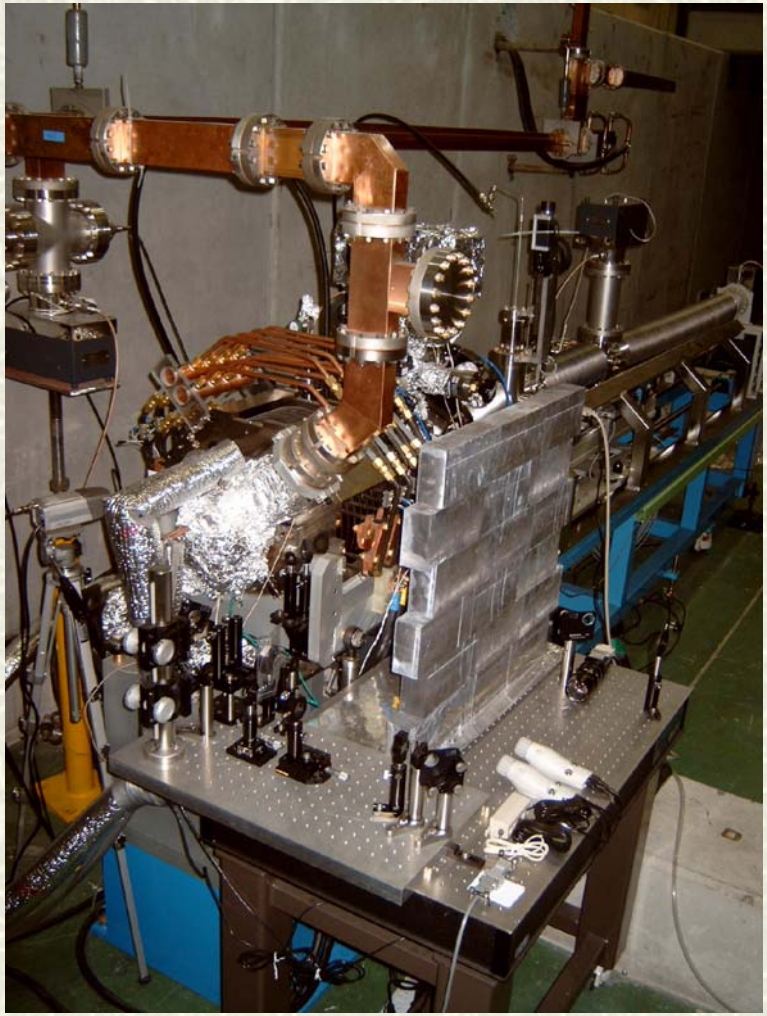
$$\cos\omega_1 t - \cos\omega_2 t$$

$$= 2\sin\left(\frac{\omega_1+\omega_2}{2}t\right)\sin\left(\frac{\omega_2-\omega_1}{2}t\right)$$

$$\approx \frac{\omega_2-\omega_1}{2}t$$

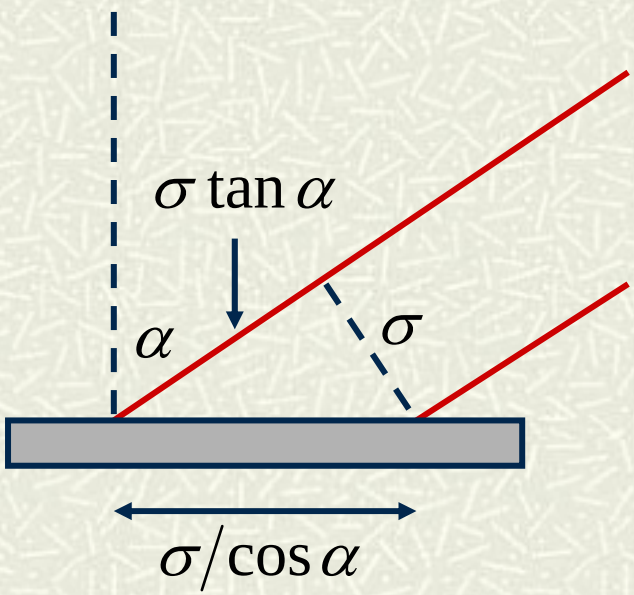
191.6 ps/V X 660.1 µV=126.5 fs

Laser Transport Line



Photocathode RF gun,
laser transport line,
and emittance meter

Oblique Incidence



- Spot size on the cathode is

$$\sigma_{cat} = \frac{\sigma}{\cos\alpha}$$

- Time slew across the pulse is

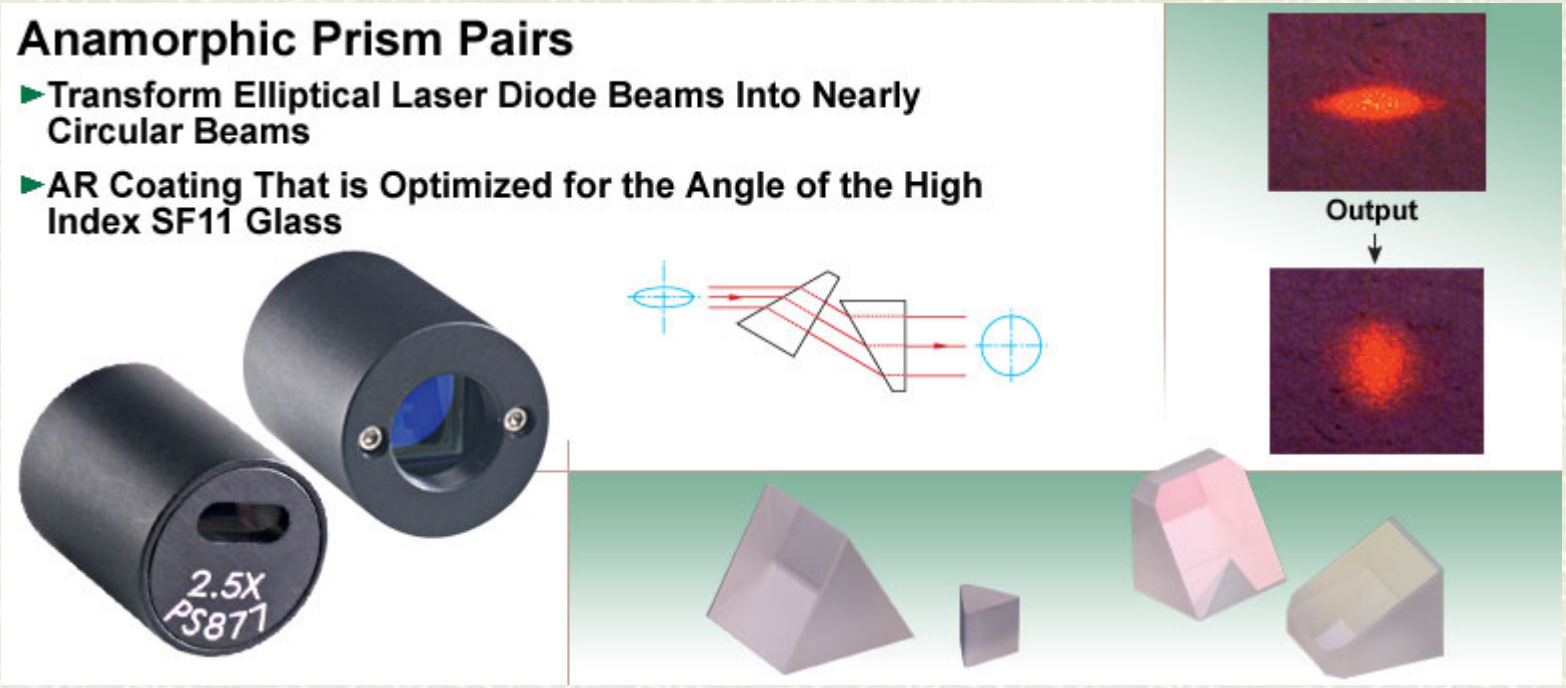
$$ct = \sigma \tan\alpha$$

- If α=67 degree

$$\sigma_{cat} = 2.56\sigma$$

$$ct = 2.36\sigma$$

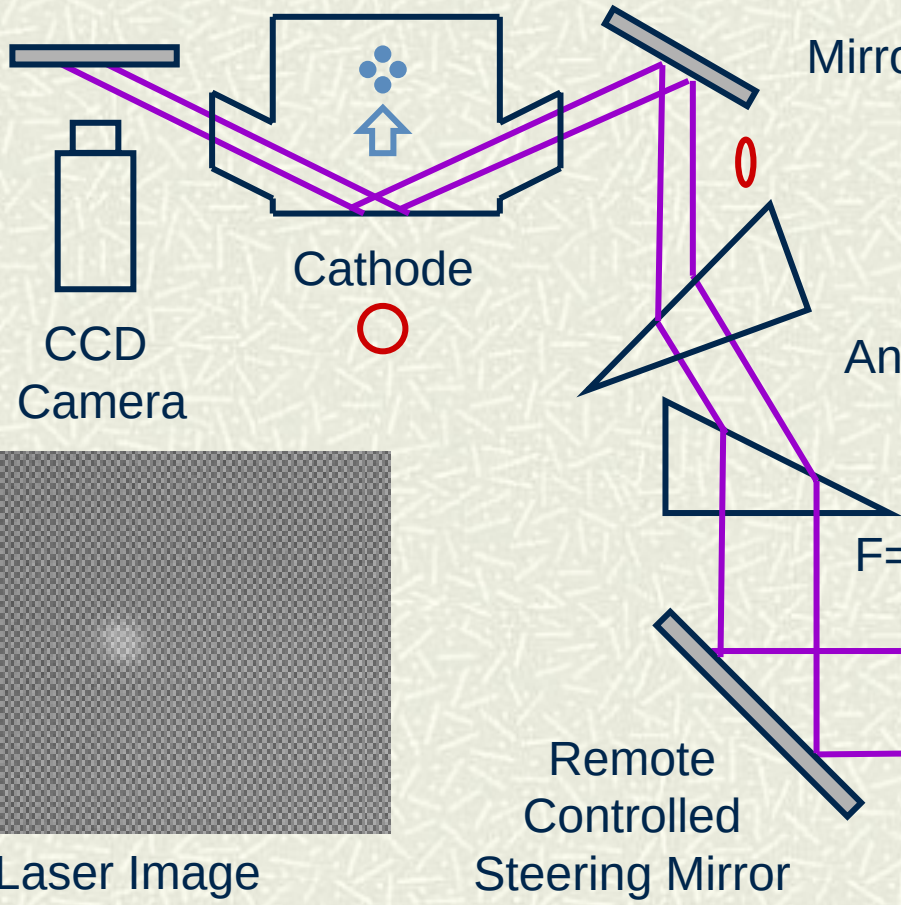
Anamorphic Prism



Refractive index of SF11 =1.7 at 670 nm
Refractive index of Supracil1 = 1.5 at 266 nm

Optics Layout

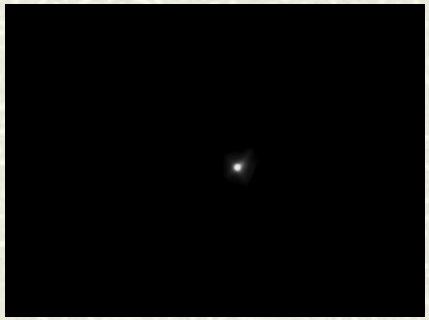
Generated Electron Beam



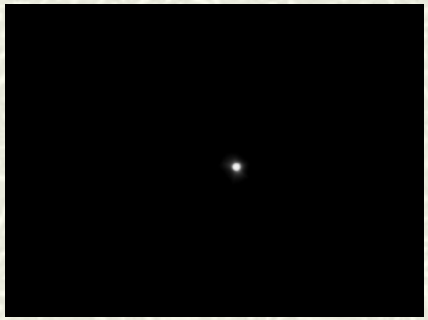
Laser Image
on Virtual Cathode

Electron Images

10 degree

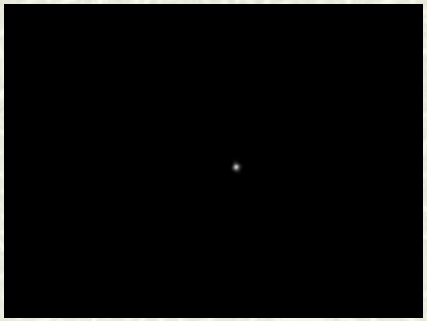


30 degree

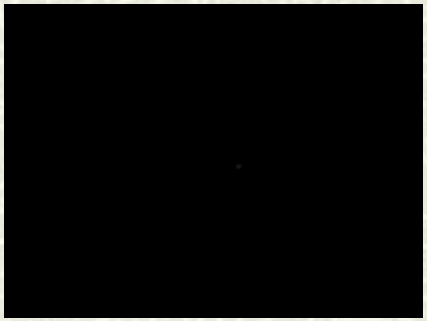


50 degree

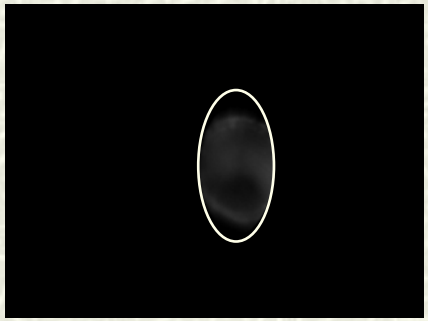
70 degree



90 degree



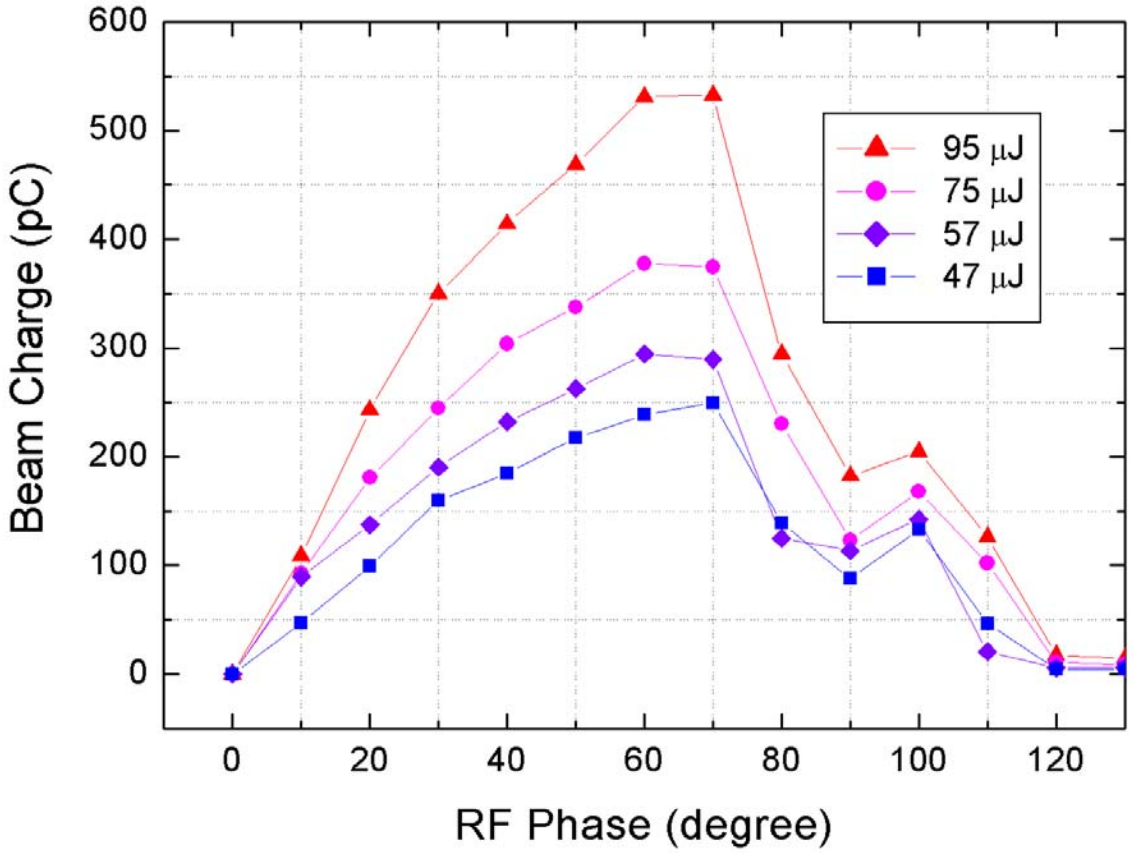
110 degree



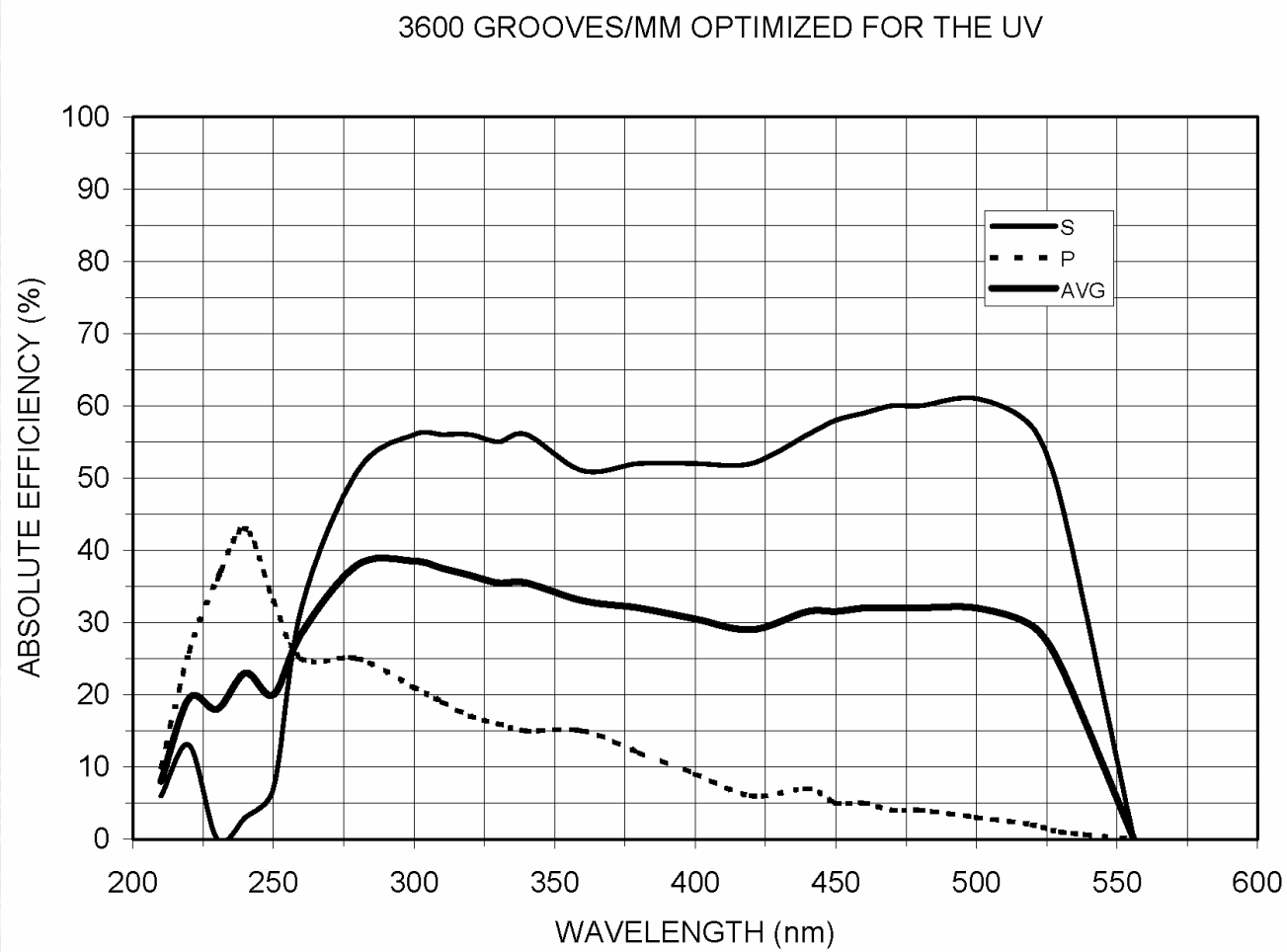
70 degree
Dark Current

Laser Energy:
47 μJ @ Cathode
Electron Energy:
2.5 MeV
Solenoid Current:
54.33 A

Charge vs. RF Phase



Efficiency of Grating



Dispersion of Grating

$$d\sin\theta = n\lambda$$

$$d\theta = \frac{nd\lambda}{d\cos\theta}$$

If $n = 1$

$$d\lambda = 13\,\mathrm{nm}$$

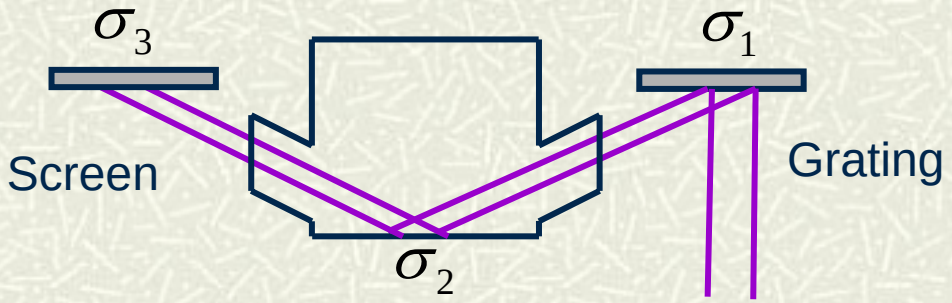
$$1/d = 3600/mm$$

$$\theta = 67^{\circ}$$

Then

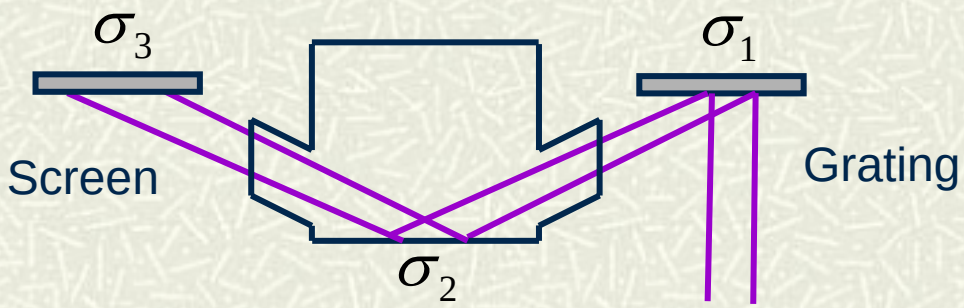
$$d\theta \approx 0.1$$

If $d\theta = 0$



$$\sigma_1 = \sigma_2 = \sigma_3$$

If $d\theta \neq 0$



$$\sigma_2 = \sigma_1 + d\theta \cdot l = \frac{\sigma_1 + \sigma_3}{2}$$

Summary

- Laser system is installed for photocathode RF gun study in PAL XFEL project.
- It shows good energy stability and small timing jitter.
- UV stretcher is developed and UV pulse width is measured by cross correlator.
- Laser transport line is under installation and electron beam is successfully generated.