Photoinjector Driver Laser Temporal Shaping and Diagnostics for Shanghai Soft X Ray Free Electron Laser

WEPP25

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Abstract

- Driver laser intensity distribution infulence electron bunch character (emittance, longitudinal structure).
- Flattop beam produced from α-BBO stacking is more benefit for producing electron beam with lower emittance, but significantly increase the microbunch instability effect on copper cathode.
- α-BBO stacking was designed for producing flattop UV laser beam. UV grating pair shaping was designed for reducing the mircobunch effect.
- Two pulses cross-correlation method for characterization the laser pulse temporal structure are also presented.

Shanghai XFEL Driver Laser System

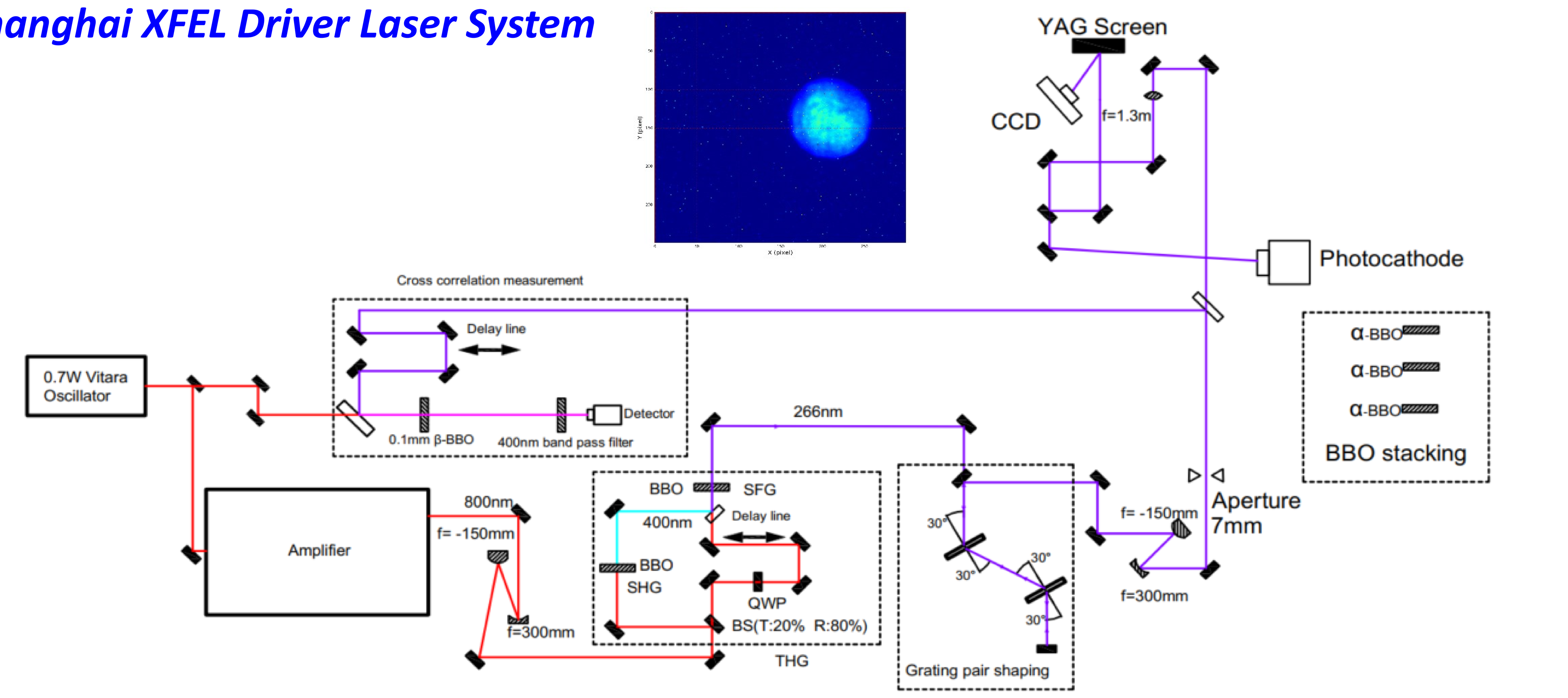
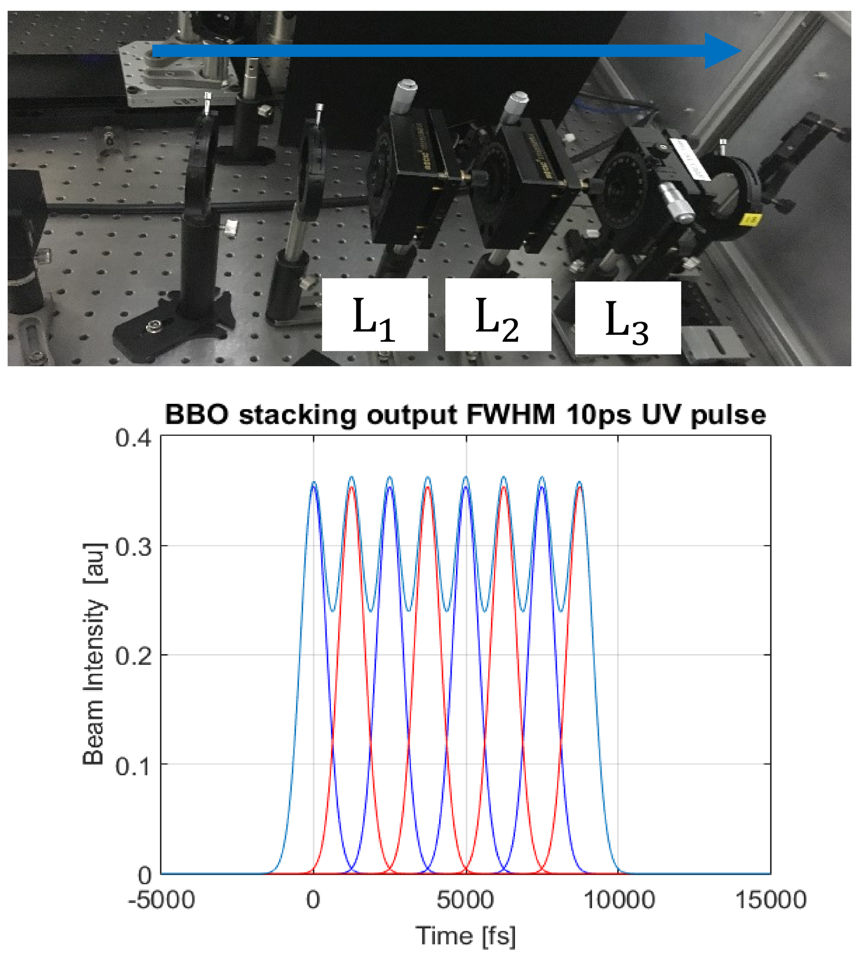
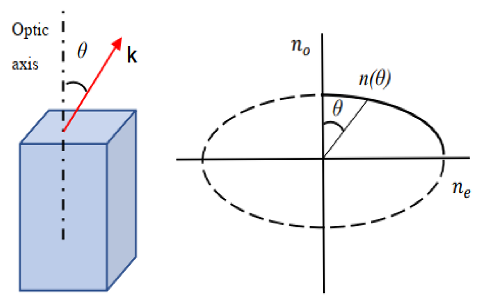


Figure 1: Schematic of SXFEL Driver laser system.

UV Laser Pulse BBO stacking





$$\frac{1}{n_e{}^2(\theta,\omega)} = \frac{\cos^2\theta}{n_o{}^2(\omega)} + \frac{\sin^2\theta}{n_e{}^2(\omega)}$$

Figure 2: BBO stacking for SXFEL photoinjector. Thicknees of BBO L_1 =4.3306mm, L_2 =2.1653mm, L_3=1.0826mm.

The temporal separation (Δt) between *o* beam and *e* beam when they propagate through the BBO birefringence crystal.

$$\Delta t = L * GVM$$

Group velocity mismatch: $\mathrm{GVM} = \Delta\left(v_g^{-1}\right)_{cc} = \frac{1}{V_g^o} - \frac{1}{V_g^e}$

Group velocity: $v_g = \frac{c}{n}\left(1 + \frac{\lambda}{n}\frac{dn}{d\lambda}\right)$

Group refraction indices for two different polarization:

$$n_{og}(\lambda) = \frac{n_o(\lambda)}{1 + \frac{\lambda}{n_o(\lambda)}\frac{dn_o(\lambda)}{d\lambda}}$$

$$n_{eg}(\lambda) = \frac{n_e(\lambda)}{1 + \frac{\lambda}{n_e(\lambda)}\frac{dn_e(\lambda)}{d\lambda}}$$

Sellmeier equations:

$$n_o(\lambda) = \sqrt{2.7405 + \frac{0.0184}{\lambda^2 - 0.0179} - 0.0155\lambda^2}$$

$$n_e(\lambda) = \sqrt{2.3730 + \frac{0.0128}{\lambda^2 - 0.0156} - 0.0044\lambda^2}$$

UV Grating Pair Shaping

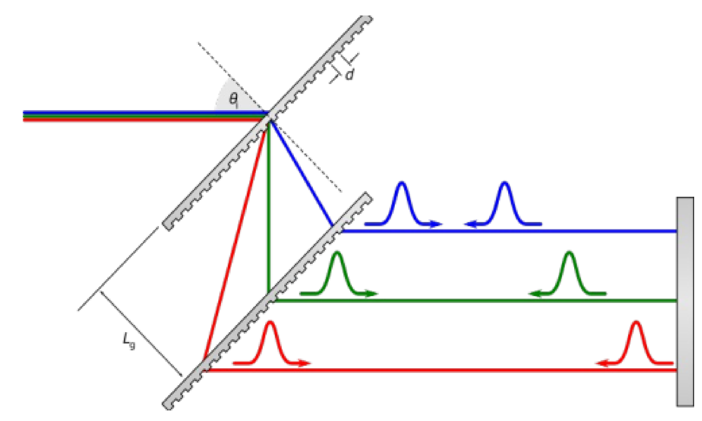


Figure 3: Principle of grating pair shaping

Group delay dispersion (GDD):

Second order dispersion has the strongest influence on the pulse duration.

$$\mathrm{GDD} = \frac{d^2\phi}{d\omega^2} = \frac{m^2\lambda^3 L_g}{2\pi c^2} \times \left[1 - \left(-m\frac{\lambda}{\Lambda} - \sin\theta_i\right)^2\right]^{-3/2}$$

m-diffraction order (usually -1);
λ -center wavelength;
L_g - distance between the two parallel gratings;
Λ-period of the grating;
θ_i - angle of incidence on the first grating.

For given GDD, dispersed pulse length τ is related to the initial pulse length τ_0

$$\tau = \tau_0\sqrt{1 + \left(\frac{GDD \cdot 4\ln(2)}{\tau_0^2}\right)^2}$$

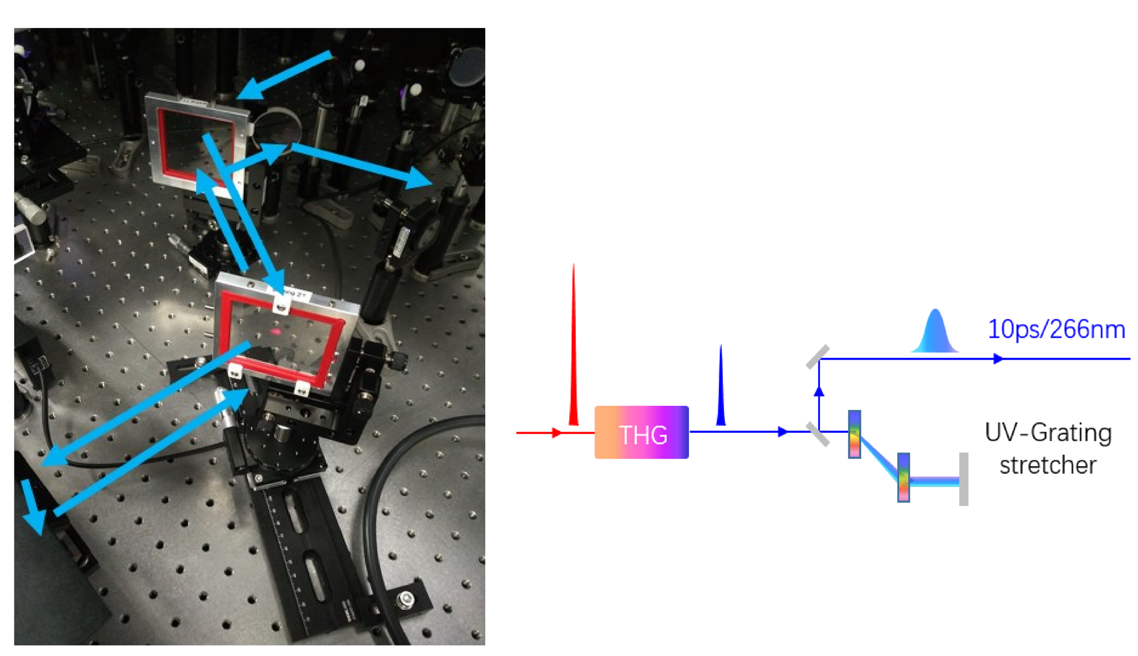


Figure 4: UV grating pair shaping of SXFEL Driver laser.

UV grating pair stretcher	
Grating lines/mm	3846
Incident angle	30°
Input pulse duration	100fs
Output pulse duration	10ps
Grating separation	230mm
material	Fused silica

Results and discussions

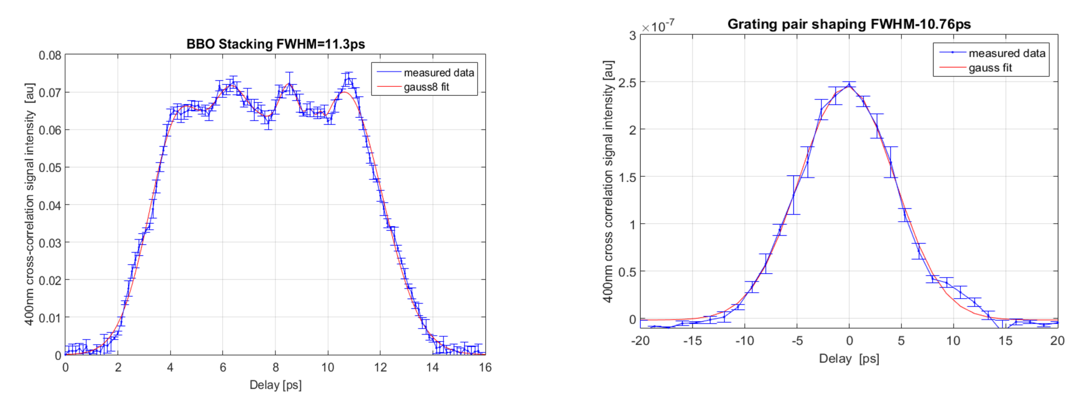


Figure 5: UV laser pulse cross-correlation measurement

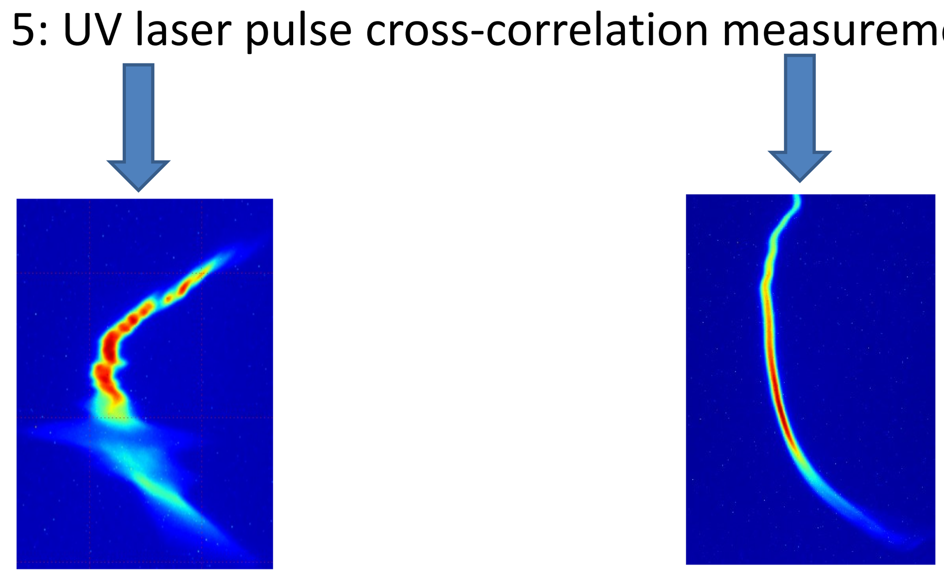


Figure 6: Electron beam temporal structure measured at transverse deflection cavity

Summary

1. Design of drive laser system for SXFEL and investigate UV pulse temporal shaping technique based on BBO stacking method and UV grating pair shaping.
2. Electron beam microbunching instability was significantly reduced using UV grating pair shaping.
3. Further investigation will attempt to characterize the microbunching instability based on different cathode material and shaping methods.

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