HIGS flux performance table for high-flux, quasi-CW operation, DFELL/TUNL, May 2020 (Version 2.5).

HIGS Flux Performance Projection		Total Flux [g/s] CW Operation Two-Bunch (*)	Collimated Flux ($\Delta E_\gamma / E_\gamma$ = 5% FWHM) (#), (@)	FEL λ [nm]	Comment Linear Pol. with OK-4 Circular Pol with OK-5
No-loss Mode: E_γ < ~16 MeV					
E_γ = 1 – 2 MeV	(E_e = 237 – 336 MeV)	1 x 10^8 – 4 x 10^8	6 x 10^6 – 2.4 x 10^7	1064	Linear and Circular (a), (b)
E_γ = 2 – 2.9 MeV	(E_e = 336 – 405 MeV)	4 x 10^8 – 1 x 10^9	2.4 x 10^7 – 6 x 10^7	1064	Linear and Circular (a), (b)
E_γ = 2 – 3 MeV	(E_e = 288 – 353 MeV)	2 x 10^8 – 6 x 10^8	1.2 x 10^7 – 3.6 x 10^7	780	Linear and Circular (a), (b)
E_γ = 3 – 5.4 MeV	(E_e = 353 – 474 MeV)	6 x 10^8 – 2 x 10^9	3.6 x 10^7 – 1.2 x 10^8	780	Linear (a), (b)
E_γ = 3 – 6.3 MeV	(E_e = 353 – 512 MeV)	6 x 10^8 – 3 x 10^9	3.6 x 10^7 – 1.8 x 10^8	780	Circular (a), (b)
E_γ = 5 – 8 MeV	(E_e = 380 – 481MeV)	4 x 10^8 – 1 x 10^9	2.4 x 10^7 – 6 x 10^7	540	Linear and Circular (a), (b)
E_γ = 8 – 11 MeV	(E_e = 481 – 565 MeV)	1 x 10^9 – 2 x 10^9	6 x 10^7 – 1.2 x 10^8	540	Linear (a), (b)
E_γ = 8 – 13 MeV	(E_e = 481 – 615 MeV)	1 x 10^9 – 4 x 10^9	6 x 10^7 – 2.4 x 10^8	540	Circular (a), (b)
E_γ = 8 – 11 MeV	(E_e = 439 – 516 MeV)	5 x 10^8 – 1 x 10^9	3 x 10^7 – 6 x 10^7	450	Linear and Circular (a), (b)
E_γ = 11 – 16 MeV	(E_e = 516 – 624 MeV)	1 x 10^9 – 2 x 10^9	6 x 10^7 – 1.2 x 10^8	450	Linear (a), (b)
E_γ = 11 – 18.5 MeV	(E_e = 516 – 671 MeV)	1 x 10^9 – 2 x 10^9	6 x 10^7 – 1.2 x 10^8	450	Circular (a)
E_γ = 15 – 25 MeV	(E_e = 533 – 691 MeV)	2 x 10^8 – 3 x 10^8	1.2 x 10^7 – 1.8 x 10^7	350	Linear (a)
E_γ = 15 – 30 MeV	(E_e = 533 – 758 MeV)	3 x 10^8 – 5 x 10^8	1.8 x 10^7 – 3 x 10^7	350	Circular (a)
Loss Mode: E_γ > ~16 MeV					
E_γ = 21 – 65 MeV	(E_e = 526 – 940 MeV)	~ 2 x 10^8	~ 1.2 x 10^7	240	Circular (c)
E_γ = 21 – 54 MeV	(E_e = 526 – 854 MeV)	~ 2 x 10^8	~ 1.2 x 10^7	240	Linear (c)
E_γ = 50 – 110 MeV	(E_e = 738 – 1,114 MeV)	0.2 – 1 x 10^8	~ 1.5 – 6 x 10^6	193	Circular (c)
E_γ = 50 – 85 MeV	(E_e = 738 – 973 MeV)	0.4 – 0.8 x 10^8	~ 3 – 5 x 10^6	193	Linear (c), (d)

(a) The listed numbers for E_γ < ~16 MeV are conservative, readily available for user operation with FEL mirrors in house.

(b) With new FEL mirrors (not always available, special operation only), the flux of the circularly polarized gamma beam can be 2 to 5 times as the listed numbers (E_γ < ~16 MeV). The flux is peaked around 10 MeV, with total flux about 3 x 10^{10} g/s (cir. pol.) using new mirrors with high reflectivity. The flux is lower as FEL mirrors degrade due to radiation.

(c) The flux is limited by the capability of sustaining a high intra-cavity laser power by the FEL mirrors. Consult the accelerator physics group on the flux performance for specific energy operation.

(d) The 193 nm FEL mirror life for linearly polarized beam production is limited to about 100 hr only.

(*) The flux numbers are projected for the high-flux operation with two symmetric electron bunches. The gamma flux will be different in other operation modes, including the high-resolution mode, and giant-pulse mode.

(#) The energy resolution of the collimated gamma beam depends on parameters of the electron and FEL beams, as well as the collimator opening aperture. The 5% FWHM flux in the table is used only for the purpose of illustrating the collimated flux. A higher resolution beam can be produced at the expense of a reduced gamma-beam flux. Using a given FEL mirror set, the portion of the flux selected by the collimator is inversely proportional to the gamma beam energy.

(@) It is critical to match the target with the collimated gamma beam. A useful formula to estimate the portion of the gamma-ray beam after collimation is:

$$\frac{\text{Collimated Flux}}{\text{Total Flux}} = a * \left[\frac{Ee\,[\text{MeV}]}{0.511} * \frac{r\,[\text{ mm}]}{52.8*10^3}\right]^2, \qquad a \sim 1.2 \text{ to } 1.5,$$

where Ee is the electron energy in MeV and r is the radius of the collimating aperture in mm. The distance between the collision point and the collimator is 52.8 m.

Modes of HIGS Operation

1. ***High-flux, quasi-CW operation, micropulses with sub-ns durations at 5.5796 MHz***
   Typical energy spread (FWHM): 4 – 10%, selected by collimation; the flux performance is found in the above table;
2. ***High-resolution, quasi-CW operation, micropulses with sub-ns durations at 2.7898 MHz (the main beam)***
   Typical energy spread (FWHM): 0.8 – 1.5%; the flux is lower by a factor of 50 – 100 compared to high-flux mode;
3. ***Pulsed operation***
   Typically, macropulses with 0.5 – 3 ms durations are produced with a repetition rate of 2 to 50 Hz, depending on electron beam energy, FEL gain, and other operation parameters. The flux performance is somewhat lower than that in the quasi-CW mode, especially if the repetition rate is not optimized.