

HIGS flux performance table for high-flux, quasi-CW operation, DFELL/TUNL, November, 2017 (Version 2.4).

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: $E_\gamma < \sim 16$ MeV					
$E_\gamma = 1 - 2$ MeV	($E_e = 237 - 336$ MeV)	$1 \times 10^8 - 4 \times 10^8$	$6 \times 10^6 - 2.4 \times 10^7$	1064	Linear and Circular (a), (b)
$E_\gamma = 2 - 2.9$ MeV	($E_e = 336 - 405$ MeV)	$4 \times 10^8 - 1 \times 10^9$	$2.4 \times 10^7 - 6 \times 10^7$	1064	Linear and Circular (a), (b)
$E_\gamma = 2 - 3$ MeV	($E_e = 288 - 353$ MeV)	$2 \times 10^8 - 6 \times 10^8$	$1.2 \times 10^7 - 3.6 \times 10^7$	780	Linear and Circular (a), (b)
$E_\gamma = 3 - 5.4$ MeV	($E_e = 353 - 474$ MeV)	$6 \times 10^8 - 2 \times 10^9$	$3.6 \times 10^7 - 1.2 \times 10^8$	780	Linear (a), (b)
$E_\gamma = 3 - 6.3$ MeV	($E_e = 353 - 512$ MeV)	$6 \times 10^8 - 3 \times 10^9$	$3.6 \times 10^7 - 1.8 \times 10^8$	780	Circular (a), (b)
$E_\gamma = 5 - 8$ MeV	($E_e = 380 - 481$ MeV)	$4 \times 10^8 - 1 \times 10^9$	$2.4 \times 10^7 - 6 \times 10^7$	540	Linear and Circular (a), (b)
$E_\gamma = 8 - 11$ MeV	($E_e = 481 - 565$ MeV)	$1 \times 10^9 - 2 \times 10^9$	$6 \times 10^7 - 1.2 \times 10^8$	540	Linear (a), (b)
$E_\gamma = 8 - 13$ MeV	($E_e = 481 - 615$ MeV)	$1 \times 10^9 - 4 \times 10^9$	$6 \times 10^7 - 2.4 \times 10^8$	540	Circular (a), (b)
$E_\gamma = 8 - 11$ MeV	($E_e = 439 - 516$ MeV)	$5 \times 10^8 - 1 \times 10^9$	$3 \times 10^7 - 6 \times 10^7$	450	Linear and Circular (a), (b)
$E_\gamma = 11 - 16$ MeV	($E_e = 516 - 624$ MeV)	$1 \times 10^9 - 2 \times 10^9$	$6 \times 10^7 - 1.2 \times 10^8$	450	Linear (a), (b)
$E_\gamma = 11 - 18.5$ MeV	($E_e = 516 - 671$ MeV)	$1 \times 10^9 - 2 \times 10^9$	$6 \times 10^7 - 1.2 \times 10^8$	450	Circular (a)
$E_\gamma = 15 - 25$ MeV	($E_e = 533 - 691$ MeV)	$2 \times 10^8 - 3 \times 10^8$	$1.2 \times 10^7 - 1.8 \times 10^7$	350	Linear (a)
$E_\gamma = 15 - 30$ MeV	($E_e = 533 - 758$ MeV)	$3 \times 10^8 - 5 \times 10^8$	$1.8 \times 10^7 - 3 \times 10^7$	350	Circular (a)
Loss Mode: $E_\gamma > \sim 16$ MeV					
$E_\gamma = 21 - 65$ MeV	($E_e = 526 - 940$ MeV)	$\sim 2 \times 10^8$	$\sim 1.2 \times 10^7$	240	Circular (c)
$E_\gamma = 21 - 54$ MeV	($E_e = 526 - 854$ MeV)	$\sim 2 \times 10^8$	$\sim 1.2 \times 10^7$	240	Linear (c)
$E_\gamma = 50 - 100$ MeV	($E_e = 738 - 1060$ MeV)	$0.7 - 1 \times 10^8$	$\sim 4 - 6 \times 10^6$	193	Circular (c)
$E_\gamma = 50 - 85$ MeV	($E_e = 738 - 973$ MeV)	$0.5 - 0.8 \times 10^8$	$\sim 3 - 5 \times 10^6$	193	Linear (c), (d)

- (a) The listed numbers for $E_\gamma < \sim 16$ 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 ($E_\gamma < \sim 16$ MeV). The flux is peaked around 10 MeV, with total flux about 3×10^{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.
- (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:
- $$\frac{\text{Collimated Flux}}{\text{Total Flux}} = a * \left[\frac{E_e \text{ [MeV]} \cdot r \text{ [mm]}}{0.511 \cdot 52.8 * 10^3} \right]^2, \quad a \sim 1.2 \text{ to } 1.5,$$
- where E_e 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

- 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;
- 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;
- 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.