3.2.2 Spontaneous sources

There are six insertion device straights in the high average current loop, one of which is allocated to the VUV-FEL. The remaining five will be used to generate spontaneous radiation. To maximise the potential of the spontaneous sources three different undulator straight lengths have been chosen; two 14 m straights; two 10 m straights and two 8 m straights. Thus the total space available for undulators is ~ 64 m, which exceeds all other existing low energy 3rd generation light sources. More than one insertion device can be placed in each straight with a small corrector magnet between them so as to angularly separate the photon output. Distributed pulse compression will be employed in the high average current loop in order to deliver to users pulse lengths optimised for their experiments ranging from a few ps down to 100 fs (RMS).

Two representative undulators for 4GLS, with 30 and 60 mm period, have been selected for illustrative purposes in Figure 3.9 to Figure 3.14. The peak photon source levels are enhanced by the very short electron bunch lengths that are generated. They are typically a factor of ~ 100 shorter than in 3rd generation light sources such as Diamond and Max III.

It is well known that electrons in a bunch radiate coherently (with a photon intensity proportional to the square of the number of electrons per bunch) at wavelengths of the order of, and longer than, the bunch length. Since 4GLS has very short bunch lengths this so-called Coherent Synchrotron Radiation (CSR) is emitted over a broad wavelength range. Calculations indicate that the onset of the CSR for 4GLS is at around 40 μm and hence it will be an extremely intense source THz radiation.

3.2.3 Summary of 4GLS photon source outputs

Figure 3.9 to Figure 3.14 and Table 3.1 summarise the photon source output of 4GLS in comparison with other planned or operational world sources.

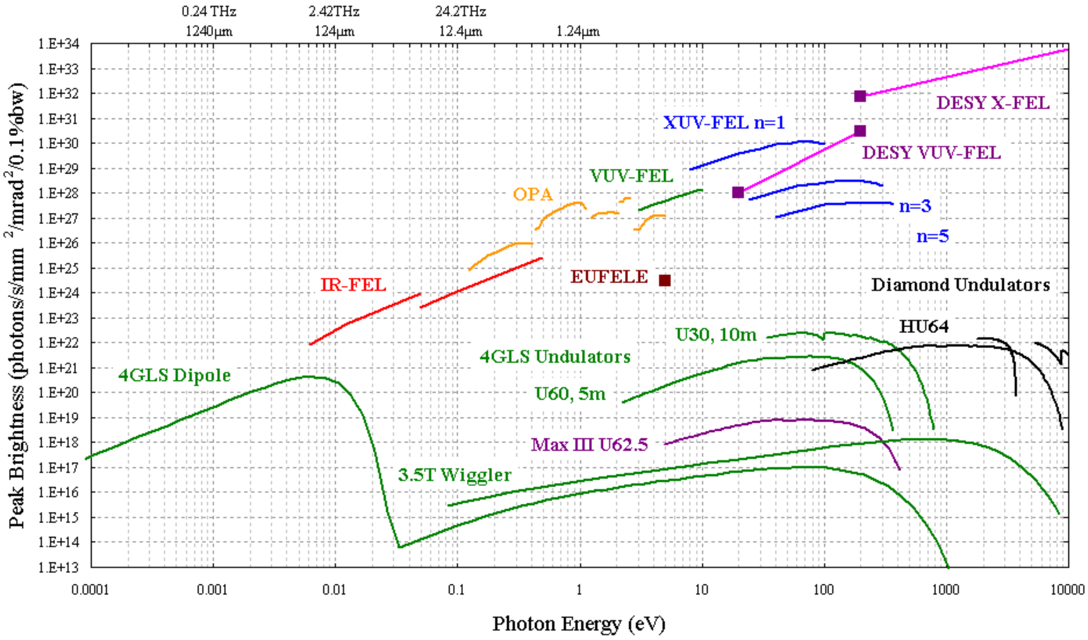

Figure 3.9 Peak brightness for 4GLS FELs, undulators, wiggler, OPA and dipoles compared with EUFELE, X-FEL, Diamond and Max III undulators

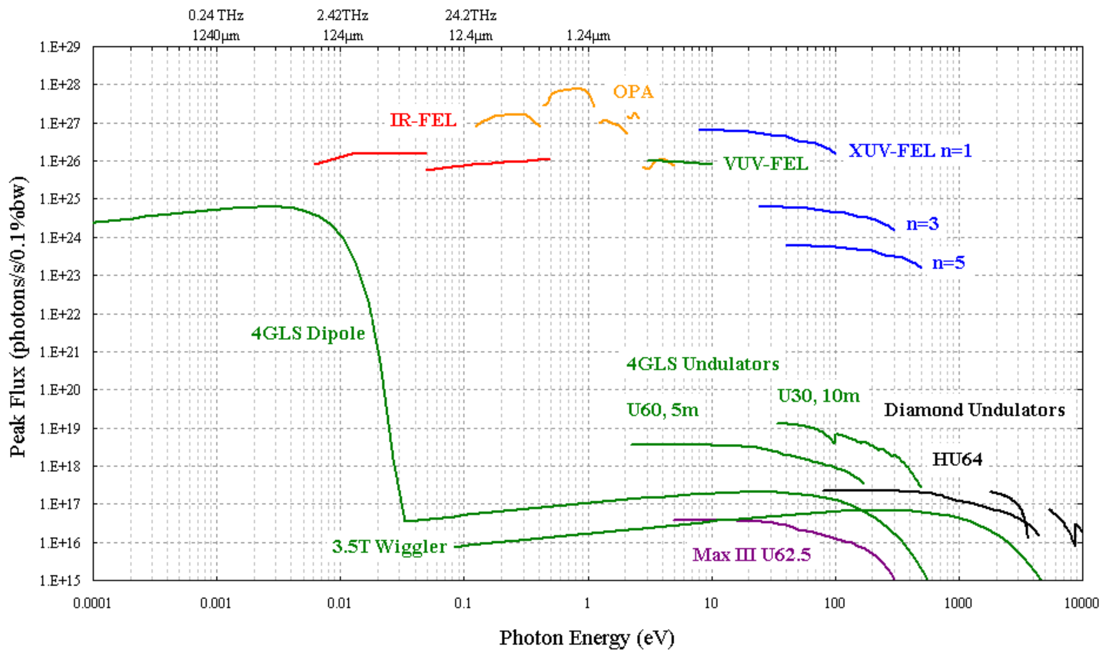

Figure 3.10:Peak flux for 4GLS FELs, undulators, wiggler, OPA and dipoles compared with Diamond and Max III undulators

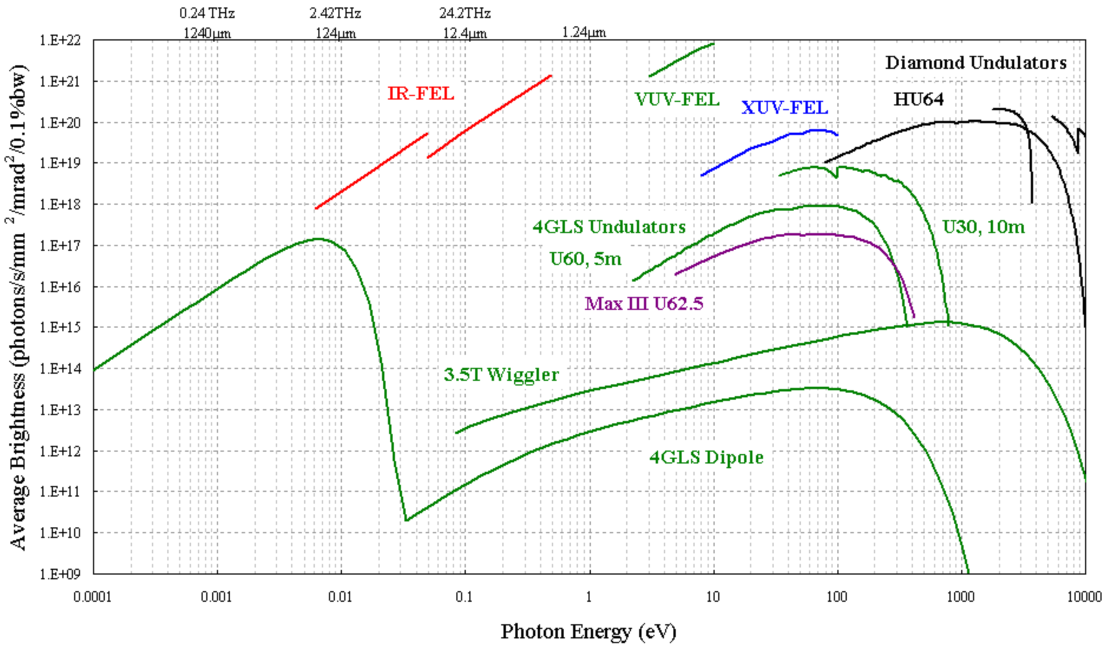

Figure 3.11 Average brightness for 4GLS FELs, undulators, wiggler and dipoles compared with Diamond and MaxIII undulators

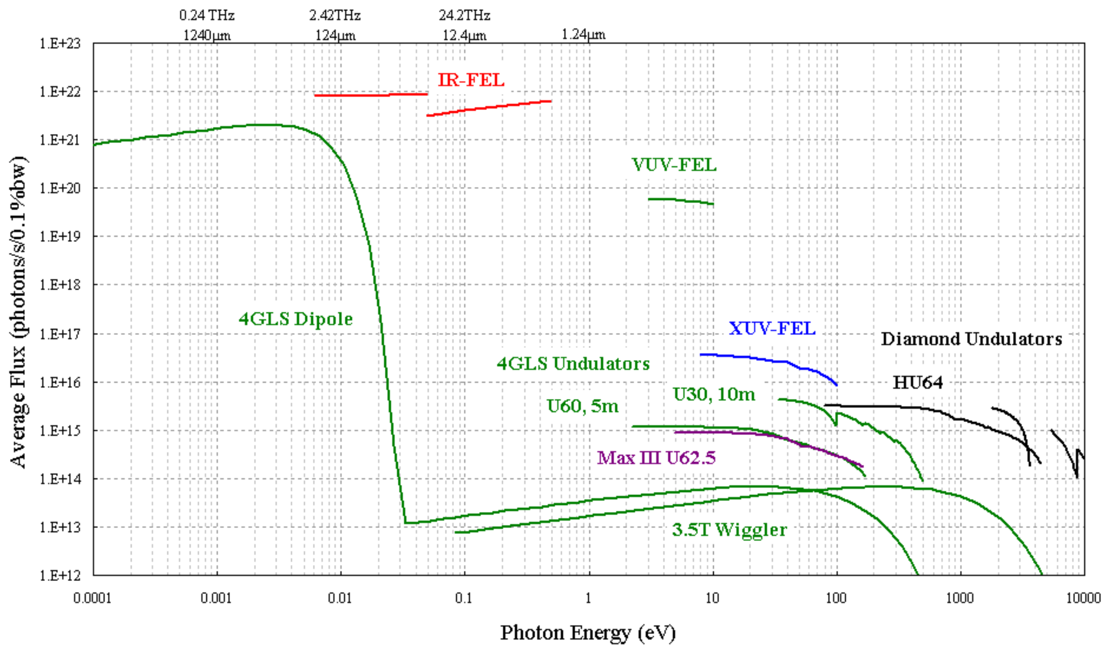

Figure 3.12 Average flux for 4GLS FELs, undulators, wiggler and dipoles compared with Diamond and MaxIII undulators

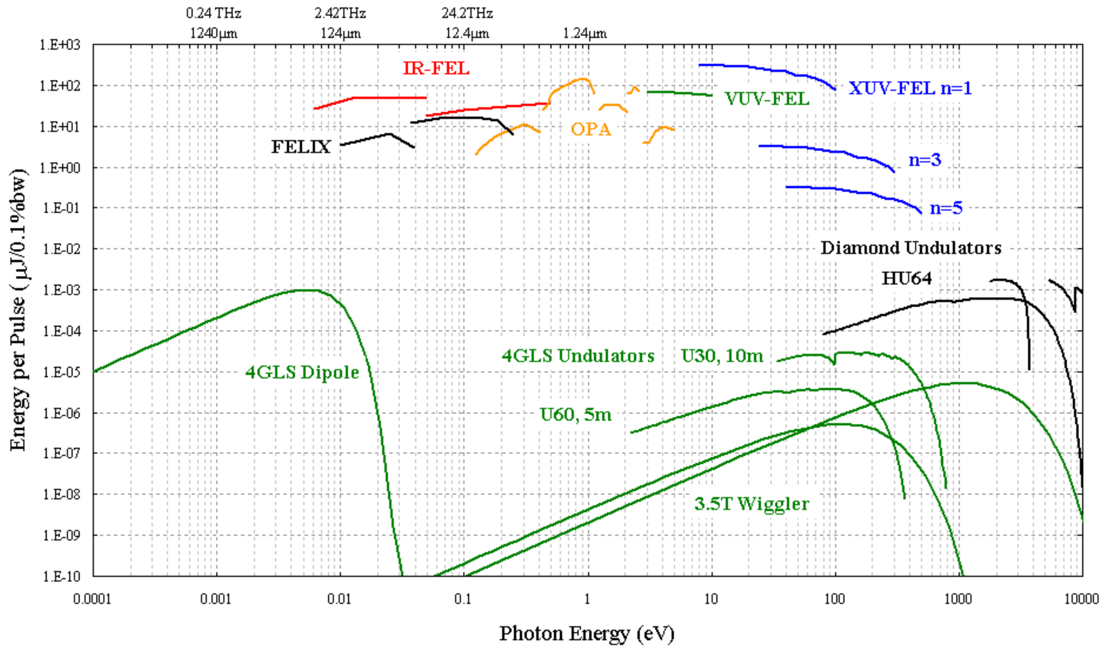

Figure 3.13 Energy per pulse for 4GLS FELs, undulators, wiggler, OPA and dipoles compared with Diamond undulator.

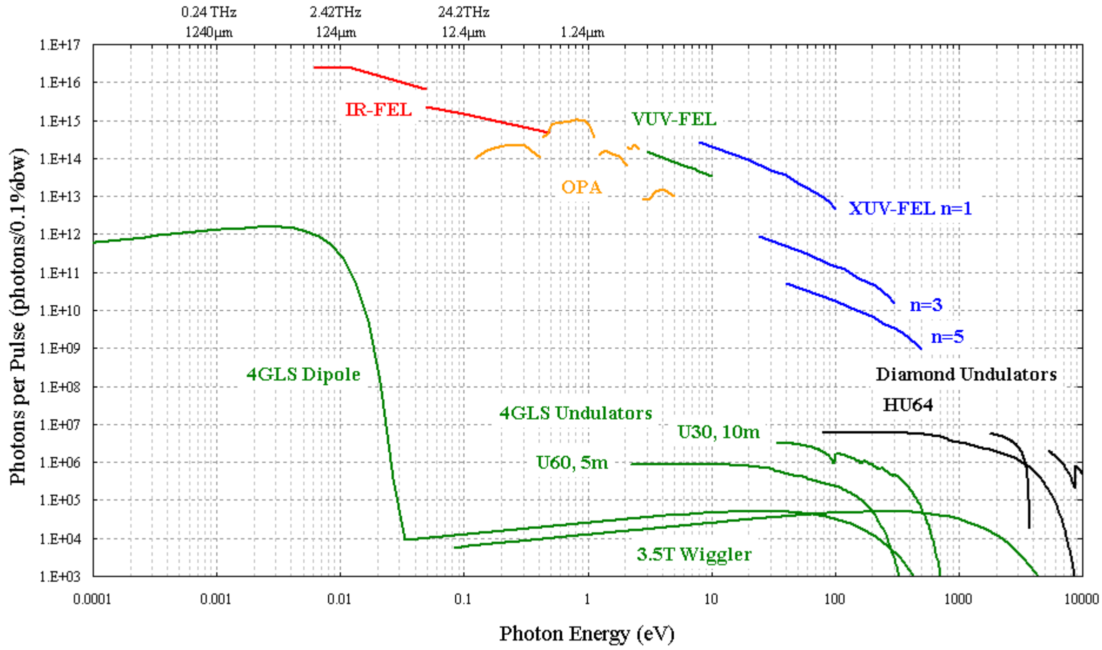

Figure 3.14 Photons per pulse for 4GLS FELs, undulators, wiggler, OPA and dipoles compared with Diamond undulator.

Table 3.1 Summary of the photon output from the various sources of 4GLS.

	XUV-FEL	*VUV-FEL*	*IR-FEL*	*U30*	*U60*	*Dipole CSR (HACL)*	*Wiggler*	*OPA Laser*
Harmonic	1	1	1	1 to 9	1 to 9	—	—	—
Photon Energy Range (eV)	8 to 100	3 to 10	0.006 to 0.5	33 to 600	2 to 300	0.0001 to 0.03	1 to 5000	0.1 to 6
Wavelength Range (μm)	0.15 to 0.012	0.4 to 0.12	2.5 to 200	0.04 to 0.002	0.6 to 0.004	10000 to 40	1 to 0.0002	11 to 0.2
Repetition Rate	1 kHz	n x 4.33 MHz	13 MHz	1.3 GHz	1.3 GHz	1.3 GHz	1.3 GHz	1 kHz
FWHM Photon Pulse Length (fs)	50	170	2000 to 10000	300 to 2000	300 to 2000	235	500 to 2000	130
Peak Flux (/s/0.1%)	~5 $x10^{26}$	~1 $x10^{26}$	~1 $x10^{26}$	~1 $x10^{19}$	~3 $x10^{18}$	~6 $x10^{24}$	~6 $x10^{16}$	~1 $x10^{27}$
Peak Brightness ($/s/mm^2/mrad^2/0.1\%$)	~1 $x10^{30}$	~1 $x10^{28}$	~1 $x10^{22}$ to ~2 $x10^{25}$	~2 $x10^{22}$	~2 $x10^{21}$	~1 $x10^{20}$	~5 $x10^{17}$	~1 $x10^{27}$
Energy per Pulse (μJ/0.1%)	~200	~60	~40	~3 $x10^{-5}$	~3 $x10^{-6}$	~1 $x10^{-4}$	~1 $x10^{-6}$	~30
Photons per Pulse (/0.1%)	~5 $x10^{13}$	~1 $x10^{14}$	~6 $x10^{14}$ to ~2 $x10^{16}$	~2 $x10^{6}$	~1 $x10^{6}$	~1 $x10^{12}$	~4 $x10^{4}$	~1 $x10^{14}$
Average Flux (/s/0.1%)	~3 $x10^{16}$	~6 $x10^{19}$	~7 $x10^{21}$	~3 $x10^{15}$	~1 $x10^{15}$	~1 $x10^{21}$	~5 $x10^{13}$	~1 $x10^{17}$
Average Brightness ($/s/mm^2/mrad^2/0.1\%$)	~5 $x10^{19}$	~5 $x10^{21}$	~8 $x10^{17}$ to ~1 $x10^{21}$	~7 $x10^{18}$	~7 $x10^{17}$	~1 $x10^{16}$	~7 $x10^{14}$	~1 $x10^{17}$

3.2.4 Complementary tabletop laser facilities

In order to make full use of 4GLS it is important to allow integration of its sources with conventional lasers. Continuous coverage of the visible and near-IR parts of the spectrum is provided by the spontaneous sources as illustrated in Figure 3.9. However, there are currently no plans to provide FEL radiation in the spectral range from 0.5 – 3 eV, as this is covered more cost-effectively by tabletop laser systems. These wavelengths will be made available by using continuously tuneable mid-infrared laser systems, such as mid-infrared OPO (Optical Parametric Oscillators)/OPA {Optical Parametric Amplifier) systems, DFG (Difference Frequency Generators) and diode lasers. Ability to synchronise the additional lasers to within the temporal profile of the 4GLS sources is required. Current synchronisation is achievable to within <100 fs, and is the subject of a vigorous worldwide research and development programme.

3.3 Summary

Overall, 4GLS has an extraordinarily flexible design that encompasses spontaneous SR and FEL sources that are cutting-edge in their own right and in combination give rise to world-leading capability. The underpinning electron beam technology is extremely challenging, but can be delivered by exploitation of the latest accelerator innovations. The 4GLS specification is unique in the world and will give the UK international leadership in this exciting new area of opportunities.