CCLRC
Daresbury Laboratory

4GLS - Interests in Optics

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Second Meeting on Future XFEL Optics
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23rd November 2006

Presentation Outline

- The 4GLS concept
- Problems that it poses (so far…)
- What we need to know
- What we can offer
- Sample details

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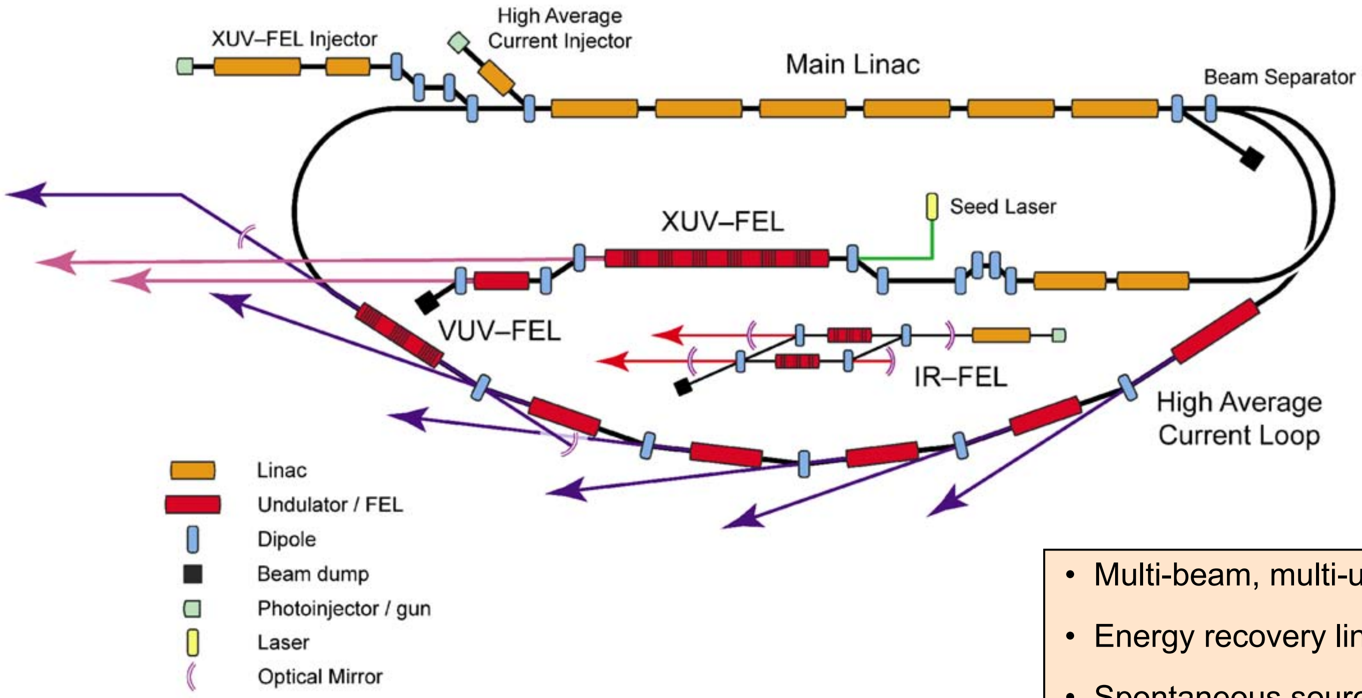
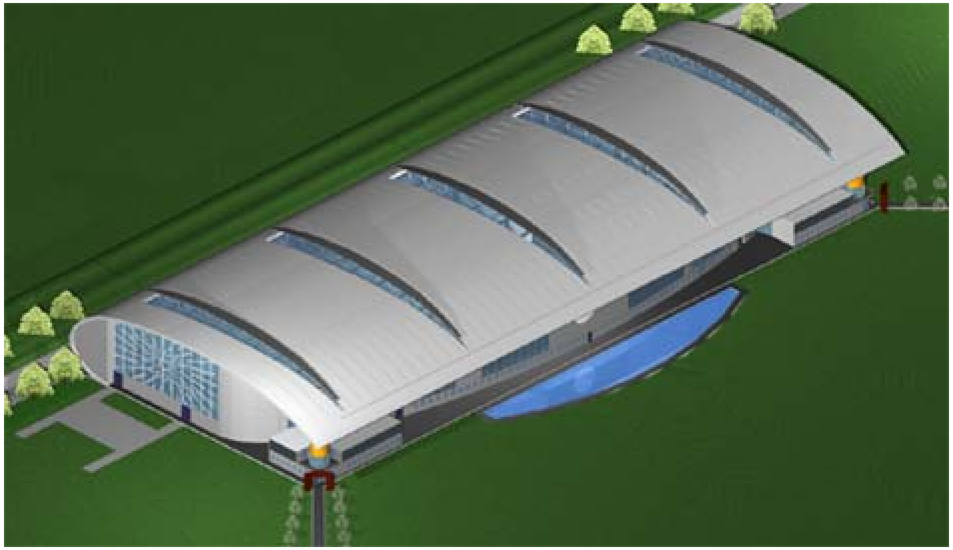
What is 4GLS?



- Multi-beam, multi-user facility
- Energy recovery linac (ERL)
- Spontaneous sources
- XUV-FEL (8 – 100eV)
- VUV-FEL (3 – 10eV)
- IR-FEL (2.5 – 200 μm)



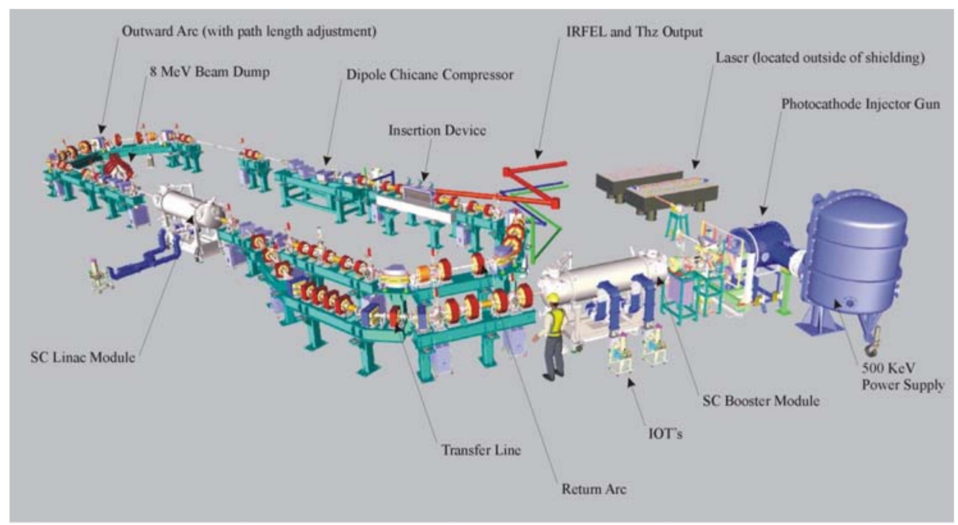
4GLS artists impression

- Naturally synchronised
- Variable polarisation
- Variable repetition rate
- "Time-resolved measurements in the life sciences and nanoscience"

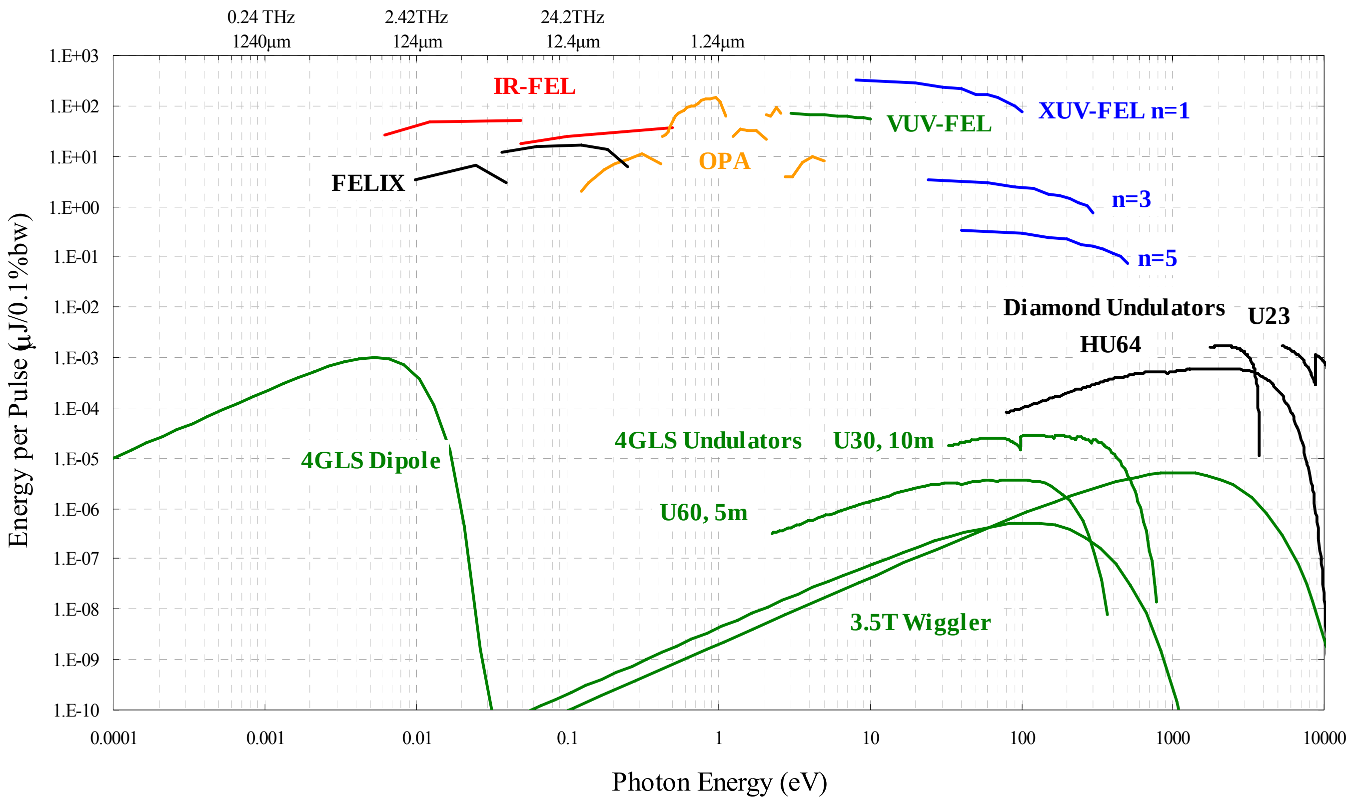
- CDR completed Spring 2006. TDR to be published March 2008. Funding in 2008?
- Energy Recovery Linac Prototype (ERLP) nearing completion

4GLS Conceptual Design Report, Council for the Central Laboratory of the Research Councils, UK, http://www.4gls.ac.uk/documents.htm#CDR (2006)

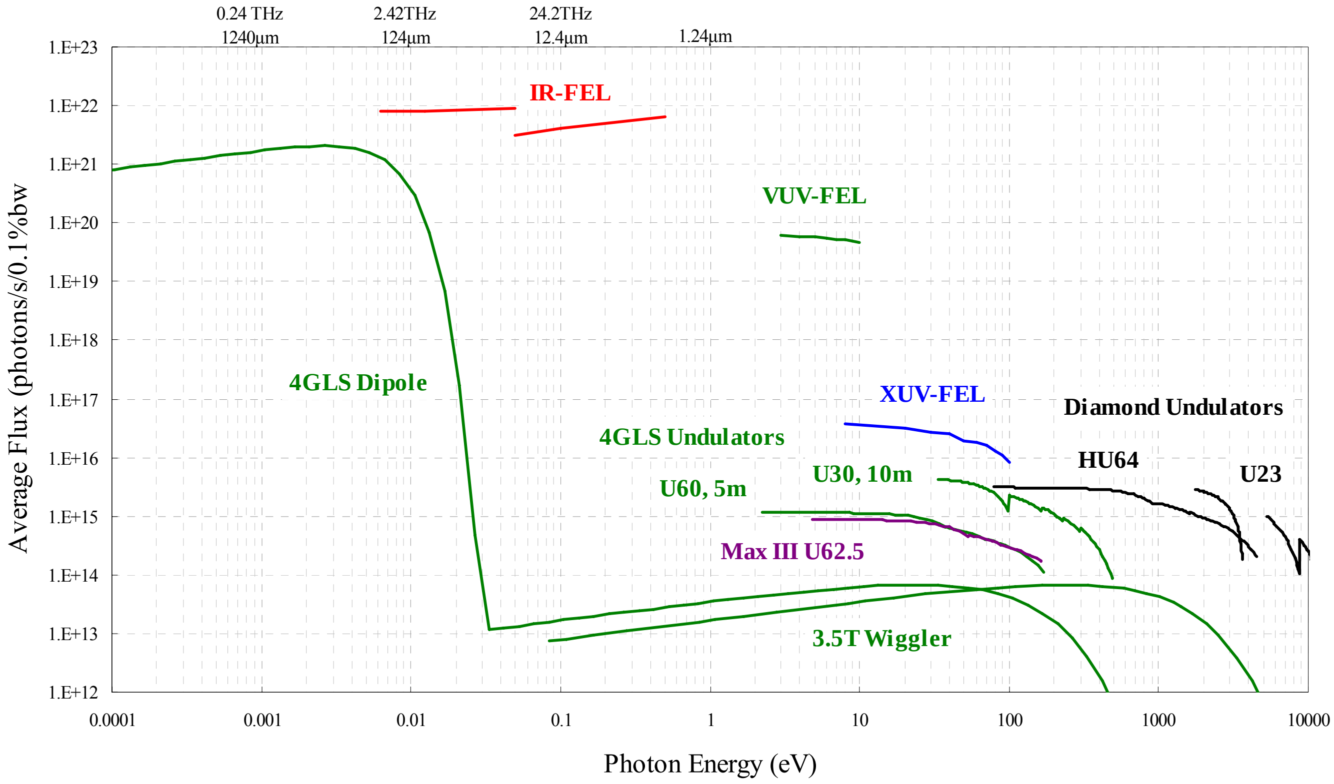
ERLP 3-D schematic



Output Curve - Energy per Pulse



Output Curve - Average Flux



Problem 1 - High Heat Loads

XUV-FEL

Can generate up to 8 GW peak power in ~60 fs FWHM pulses. But repetition rate is low at 1 kHz so CW power output is <0.4 W. This is well within 2^{nd} generation synchrotron limits and cooling of beamline components should not be necessary. For sub-picosecond pulses no heat affected zone (HAZ) is created - transient thermal damage not apparent.

VUV-FEL

500 MW peak power in 170 fs FWHM pulses. Repetition rate of up to 1.3 GHz (n*4.333 MHz) gives a CW power of n* ~300 W. Away from focii, the high divergence of the beam will allow this to be handled by 3rd generation synchrotron methods. What about at the focii (e.g. entrance slits) though? Cavity mirrors at normal incidence – mirror distortion affects output beam quality

IR-FEL

1.4 kW but opening angles are very large (>10 mrad). Heat loads similar to other IR-FELs.

Problem 2 - Ablation

XUV-FEL

High pulse energy (400 μJ) and ultra short pulse length (60 fs). Fluence rates of >60 mJ/cm^2 (at 10 m, 100 eV) may be possible. How does the angle of incidence and material reflectivity affect the fluence threshold? Can we make these assumptions about scaling?

VUV-FEL

Maximum Pulse energy of 70 μJ in 170 fs pulses. Fluence rates of > 0.7 mJ/cm^2 (at 10 m, 10 eV) anticipated. Should not be a problem away from beam focii. Cavity mirrors at normal incidence require ~ 60% reflectivity at 10 eV – assume MgF_2 coated Al – coating may damage.

IR-FEL

No problems anticipated that have not been solved on existing IR-FELs

Further Problems

Gratings	What effect does grating geometry have on ablation thresholds?
Polarisation	Grazing angles of incidence for VUV and low energy XUV optics introduce strong polarisation and phase shifts between s- and p- components. Wavelength requirements determine the angle of incidence. Uncertainty over optical constants below 30 eV. Highly dependent on surface morphology - need to test specific material.
Coherence	Waviness of surface leading to speckle pattern.
Pulse Length	Use of grating pairs to correct for pulse stretching in short duration pulses.
Synchronisation	Jitter from vibration of optical mounts, optical delay lines with ~ns delay at 100 eV

What Do We Need?

- Ablation limits at grazing angles for ‘real world’ samples - verification of our assumptions - feedback into optics design

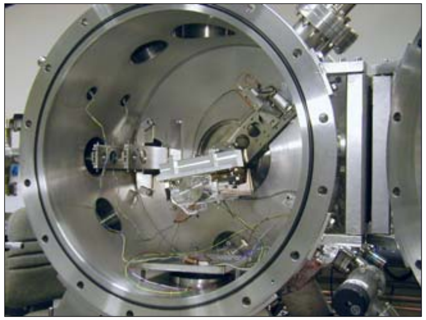
- At lower XUV energies, reflectivities are not well known due to the lack of reliable optical constants. We require accurate measurements of s- and p- polarised components to aid material selection

- Damage thresholds for MgF_2 coated aluminium mirrors for VUV-FEL cavity

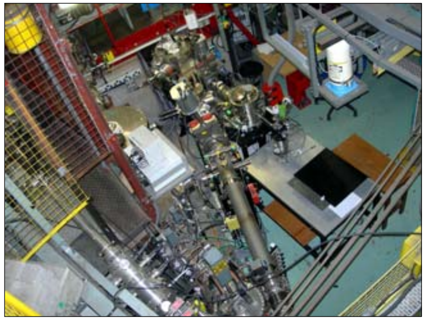
- Optimum coating thicknesses

- Estimates for achievable metrology standards

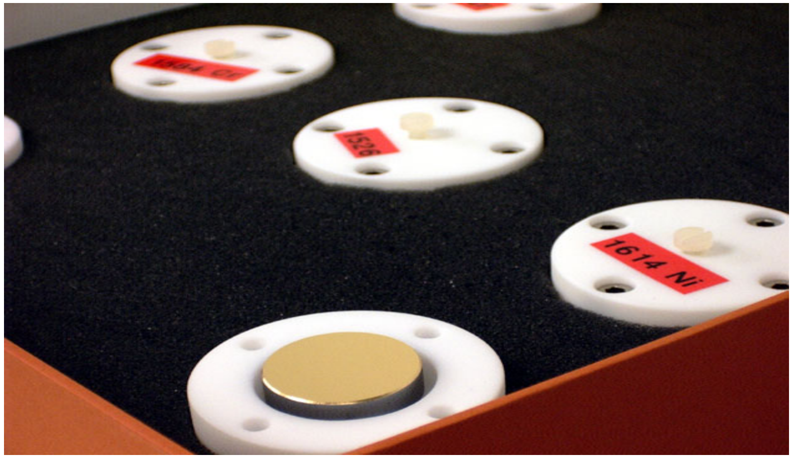
What Can We Offer?



- Synchrotron-based diffractometer measurements
- Access to metrology facilities
- Collaboration on the effect of slope errors on coherence
- SHADOW waviness simulation on mirrors - future work
- Wavefront propagation modelling



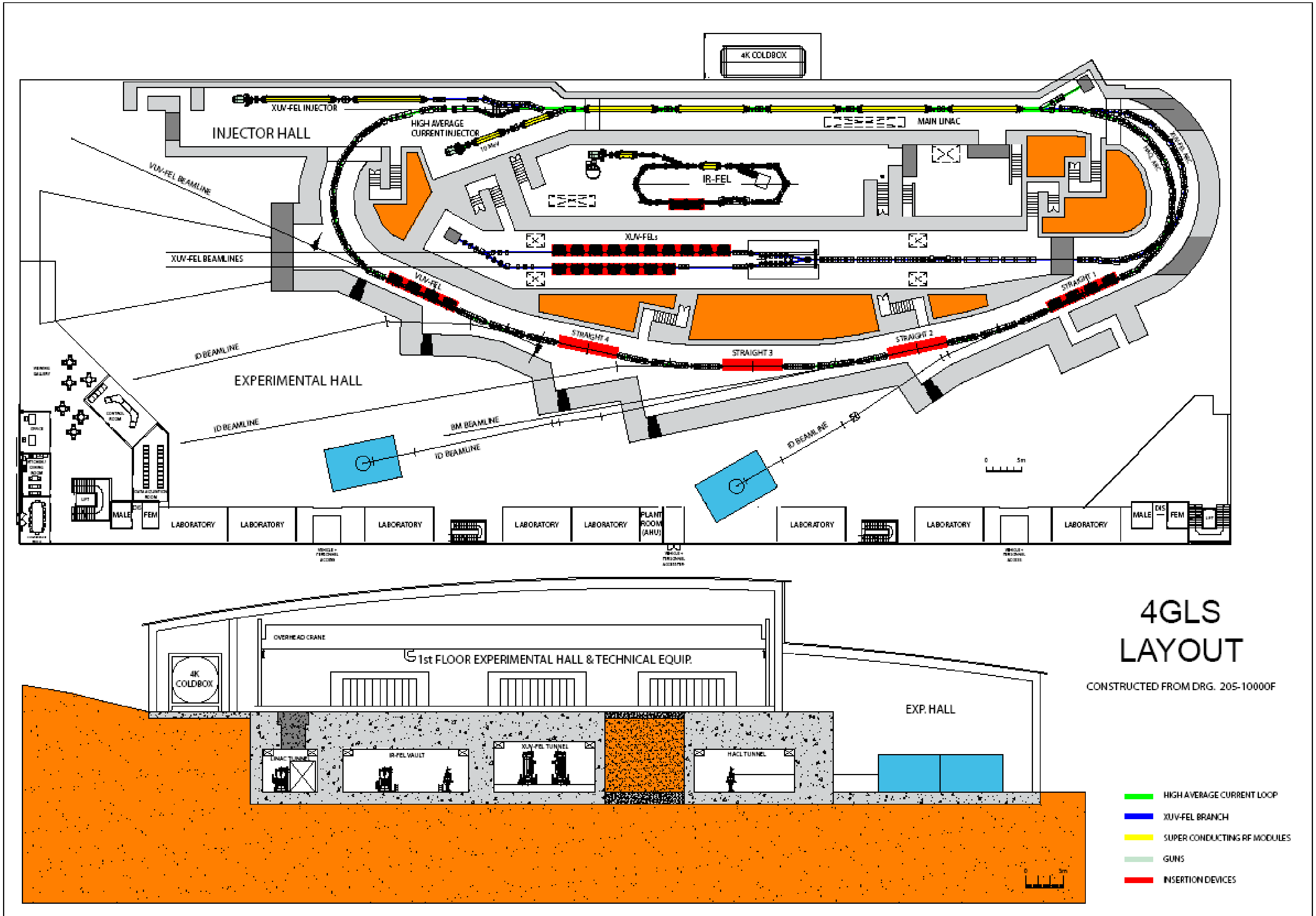
Test Sample Specifications



HORIBA Jobin Yvon gold sample mirror

Suppliers	General Optics and HORIBA Jobin Yvon
Size	1” x 0.25”
Substrate	Silicon
Flatness	λ /5 and λ /20
Roughness	<1Å RMS (uncoated)
Scratch/dig	80/60 or better
Coatings	Gold, Rhodium, Silicon Carbide, uncoated (GO) Gold, Nickel, Chromium, uncoated (HJY)

Additional Info


4K COLDBOX
XUV-FEL INJECTOR
HIGH AVERAGE CURRENT INJECTOR
INJECTOR HALL
MAIN LINAC
IR-FEL
XUV-FEL BEAMLINE
XUV-FEL BEAMLINES
XUV-FELs
VUV-FEL
STRAIGHT 1
STRAIGHT 2
STRAIGHT 3
STRAIGHT 4
ID BEAMLINE
BM BEAMLINE
EXPERIMENTAL HALL
LABORATORY
PLANT ROOM (AHU)
MALE
FEM
DIS
OVERHEAD CRANE
1st FLOOR EXPERIMENTAL HALL & TECHNICAL EQUIP.
4K COLDBOX
LINAC TUNNEL
IR-FEL VAULT
XUV-FEL TUNNEL
HACL TUNNEL
EXP. HALL
4GLS LAYOUT
CONSTRUCTED FROM DRG. 205-10000F
HIGH AVERAGE CURRENT LOOP
XUV-FEL BRANCH
SUPER CONDUCTING RF MODULES
GUNS
INSERTION DEVICES

Diffractometer