



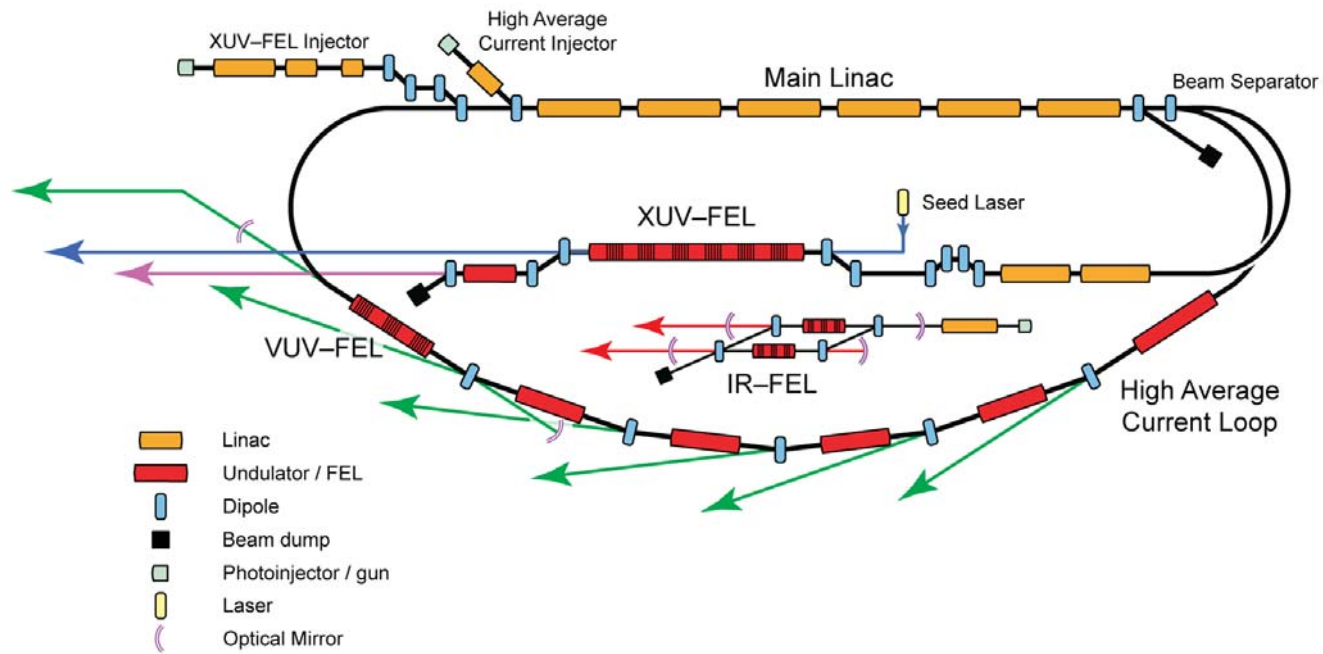
Synchronisation Activities
for 4GLS Supported by
EUROFEL DS3

G J Hirst
CCLRC Central Laser Facility

July 2006

- 4GLS - review
- DS3 tasks
- Progress on tasks
- Plan update

4GLS Schematic



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ERLP is a 35 MeV **ERL** with 1.3 GHz **SCRFF** and an 81.25 MHz, 6mA **photoinjector**

It will also support experiments in
THz generation and use and in
X-ray generation by Compton scattering

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- XUV FEL: 1 kHz, using high-charge bunches substituted into the low-charge train
- “XUV” spontaneous: From same bunches as XUV FEL
- VUV FEL: 4.33 MHz cavity round-trip rate
- Undulators & BMs: Up to the accelerator RF rate (1.3 GHz)
- IR FEL: 13 MHz cavity round-trip rate
- Conventional lasers: Arbitrary

Following user consultation (July 4th 2005) aims are:

- to deliver ~100-200 fs synchronisation between any pair of sources, including conventional lasers, in most machine operating modes
- to deliver ~10-20 fs synchronisation between specified pairs of sources, by prior arrangement, in specific machine operating modes

In addition there are <100 fs synchronisation requirements for seeding of the XUV FEL and stable operation of the VUV FEL

- **ERLP photoinjector laser:**
Can a commercial laser's synchronisation be improved to ~ 100 fs, measured at the accelerator ?
- **Local sensors:**
If the machine is not stable enough then local sensors will be needed. Can these be sufficiently accurate and cheap to be fielded in many locations ?
- **Machine stability:**
Can a machine like 4GLS be designed and built with enough stability for a distributed RF system to be a good timing reference everywhere ?
- **Complex time structures:**
Can signal processing systems be developed to allow feedback jitter correction when the pulse time structure is irregular ?

- HighQ IC532-10000 laser was locked to ultra low noise 81.25 MHz crystal oscillator (Wenzel 500-12729) with 300 fs jitter in Nov 2005, measured using phase output from synchronisation controller
- Jitter has now been reduced to <120 fs by improving environmental control (EM pickup at AC line frequency, acoustics)

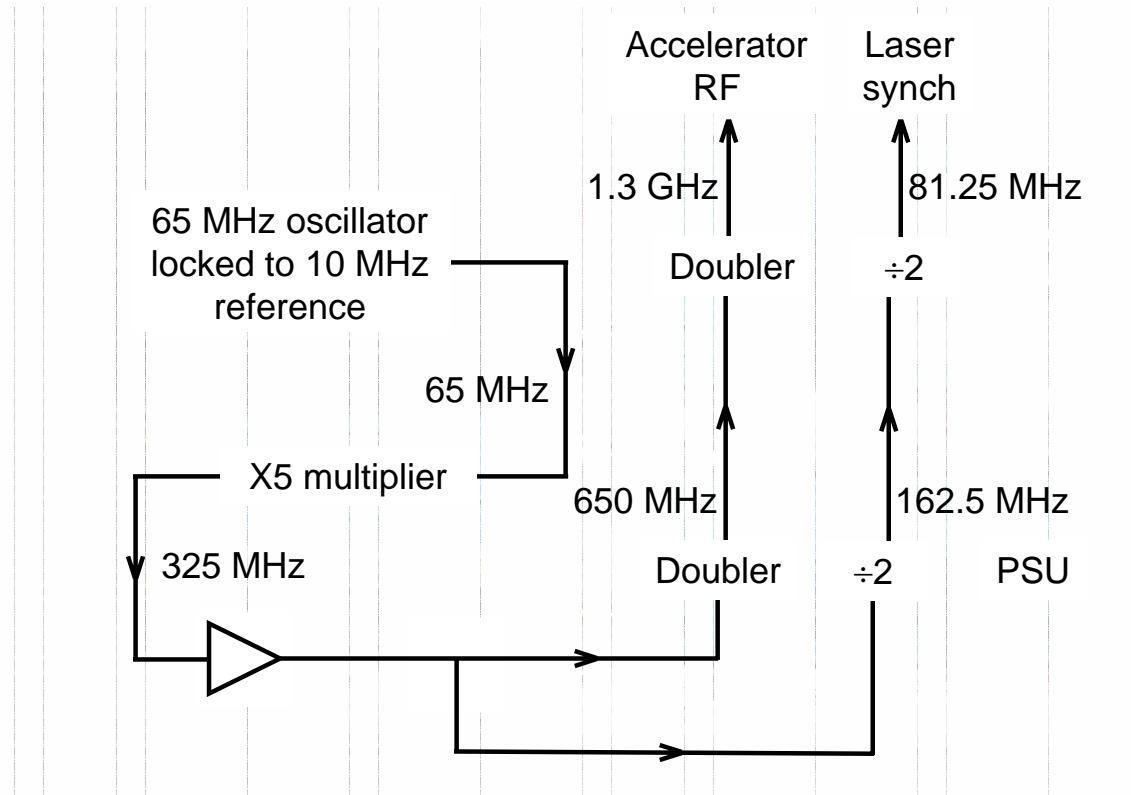


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- Comparable jitter has been achieved using the ERLP master oscillator system

ERLP RF Master Oscillator



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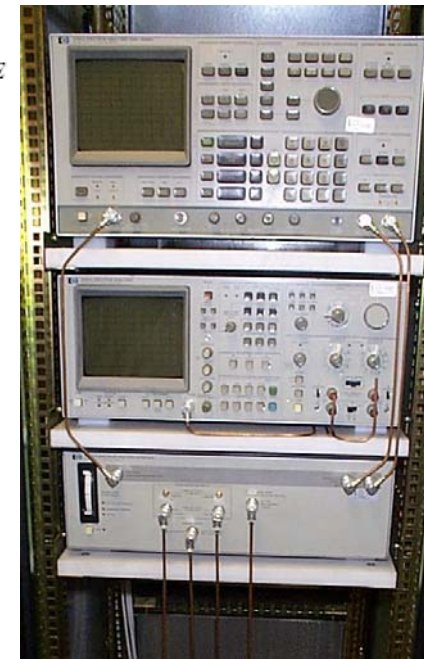
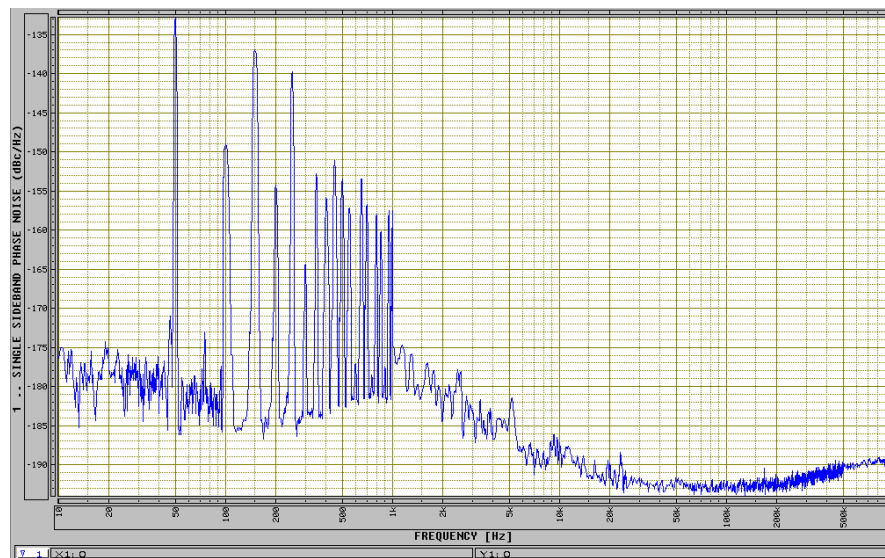


- Comparable jitter has been achieved using the ERLP master oscillator system
- An independent phase noise measurement system (HP3047A) is now functional, detectors have been built, integration and measurement is scheduled for w/b July 24th

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High-Dynamic-Range Laser Amplitude and Phase Noise Measurement Techniques

Ryan P. Scott, *Student Member, IEEE*, Carsten Langrock, and Brian H. Kolner, *Member, IEEE*



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- A review of the current state of the art suggests that most 4GLS subsystems could be synchronised to <10 fs stability either with existing technology or with foreseeable technical developments
- The most challenging task is to stabilise electron bunch arrival time against injector and RF fluctuations:

$$\Sigma_t^2 = (1/C)^2 \cdot \Sigma_{in}^2 + (R_{56} \cdot \sigma_A / c \cdot A)^2 + (1-1/C)^2 \cdot (\sigma_\phi / \omega_{RF})^2$$

Injection jitter	RF amplitude noise	RF phase noise
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- Electron timing has recently been sensed with ~30 fs resolution*
- A sensor such as this might be used with a closed-loop feedback system for bunch timing stabilisation

*K Hacker, F Löhl et al, WG5 paper at FLS2006, DESY Hamburg, 2006

- Initial EO testing on ERLP will use a Toptica EDFL* for spectral decoding of Coulomb field & CSR (2 nJ/pulse, $\sigma = 300$ fs
81.25 MHz = 1.3 GHz / 16
81.23 MHz = 0.998 GHz \times 7/86)
- A Coherent TiS system† will also be used for cross-correlation measurements of EO signals (2 mJ/pulse, $\sigma = 400$ fs, 1 kHz picked from 81.25 MHz)
- Ultimately, high-resolution sensing will require fast electron monitoring and a fs-stabilised fibre oscillator, probably of the MIT design§



* Funded by CCLRC/PPARC

† Funded by UK NWSF

§ Consumables to be part-funded by EUROFEL

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- The 4GLS Conceptual Design Report was produced in April 2006 (<http://www.4gls.ac.uk/documents.htm#CDR>)
- The principle that “passive stabilisation will be implemented first on 4GLS and the only limits ... will be budgetary ones” was agreed
- Areas of importance have been identified e.g.
 - Temperature stability (air, cooling water)
 - Floor slab stability (vibration, creep)
 - Power supply stability (RF, magnets)
 - Machine structural stability (girders, optical transport)
- More detailed technical design has now begun to model both the passive and active stability of the system



Thank you for your attention !