NLS Timing and Synchronisation

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Talk Outline

- NLS Timing
- Synchronisation overview
- Requirements
- Status
- Example subsystem
- Issues and conclusions

NLS Timing

The NLS timing parameters which will be visible as *outputs* will be the durations of the photon pulses and the time structure of the pulse trains

On Day 1 the durations will be 20fs FWHM for the FELs and comparable, or shorter for the conventional lasers

The time structure will be 1kHz equispaced, increasing to 100kHz/1MHz as the machine is developed

In addition 1.3GHz has been chosen as the accelerator RF

The timing parameters determine many of the machine's features, but in some areas there is still room for optimisation

Timing Optimisation

Subsystem pulse rates should be integer-related to 1.3GHz (if recirculation is used the integer choice may be constrained)

A 1.3GHz clock rate could, with a count-and-pick architecture, allow *any* such subsystem rate (e.g. 4.333MHz = 1.3GHz/300)

A clock rate below 1.3GHz will involve an integer choice which may constrain other subsystems.

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Nominal	Actual	Integer
1kHz	1.102kHz	$2^{17} \times 3^2$
10kHz	8.816kHz	$2^{14} \times 3^2$
100kHz	105.794kHz	$2^{12} \times 3$
1MHz	0.8464MHz	$2^9 \times 3$

This example shows possible pulse rates which are subharmonics of one another and are compatible with 216.67MHz and 162.5MHz clocks.

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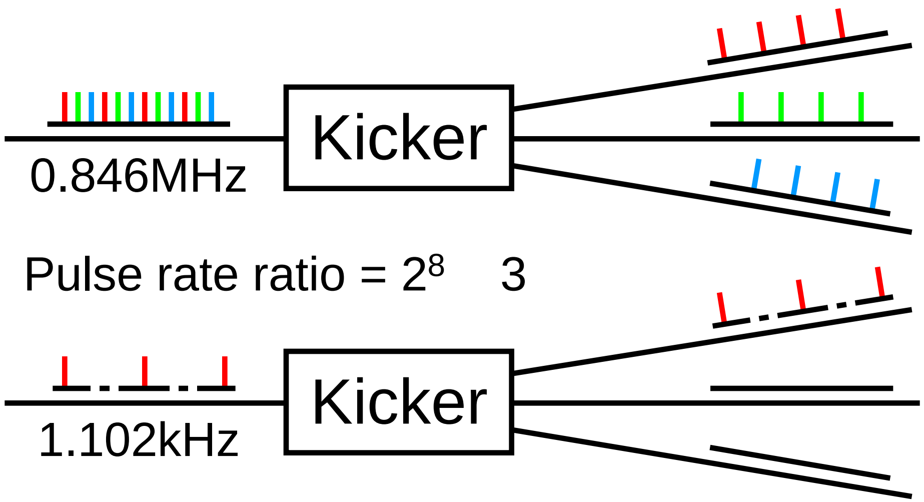

Pulse rates may also be constrained by the kicker used for simultaneous FEL operation. (The simplest kicker type will not work at pulse rates whose ratio has 3 as a factor.)

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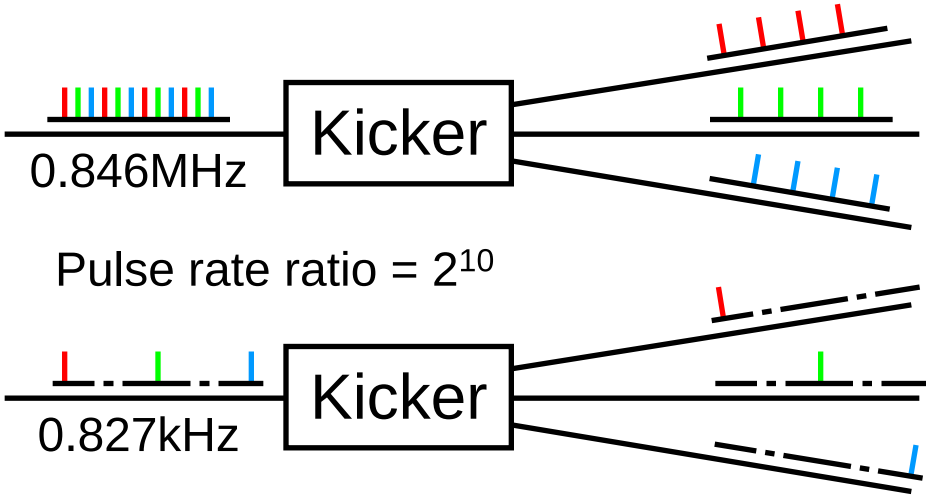

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Take Home Message

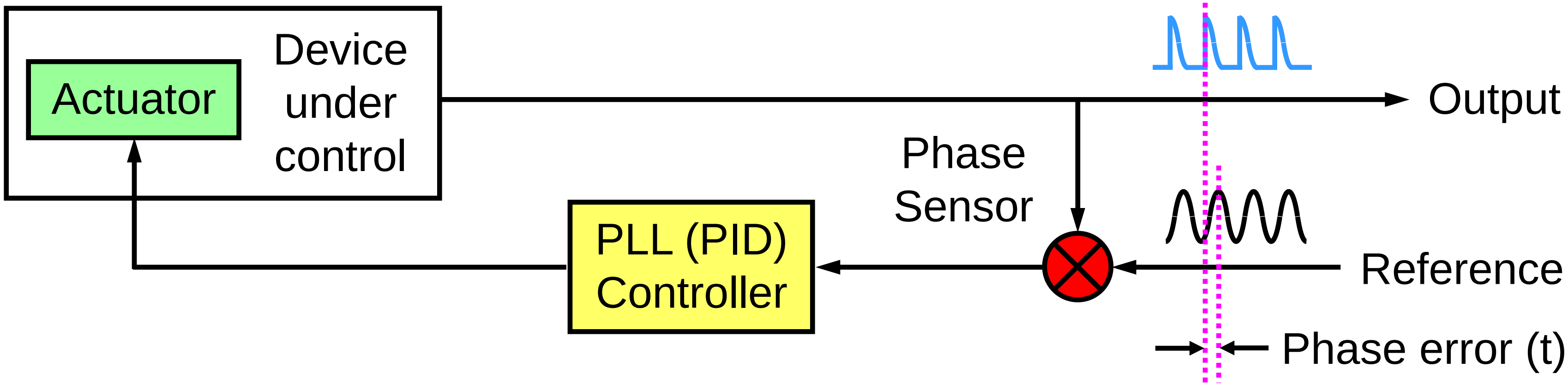
Even in a machine delivering a cw train of equally-spaced pulses:

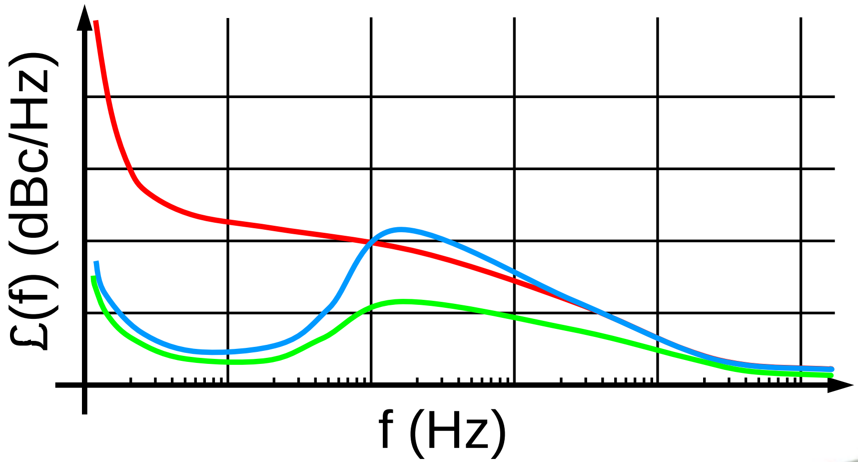
Primary and subsystem pulse rates are not, in general, free parameters

Synchronisation Overview

Synchronisation concerns two events happening at the same time or with a well-controlled delay

HOW WE ACHIEVE IT



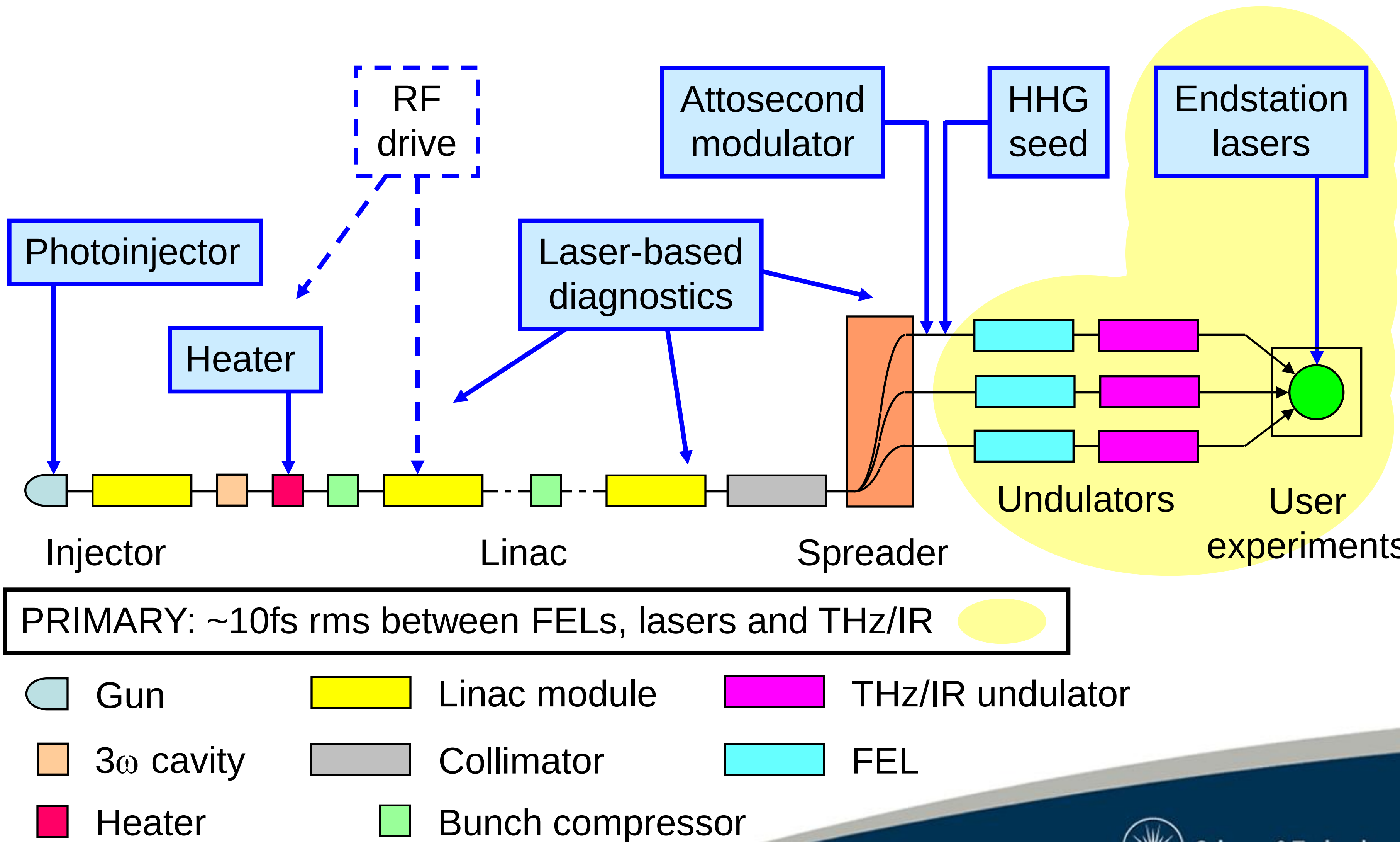


$$\Delta t_{RMS} = \frac{1}{n\omega_0}\sqrt{2\int_{f_1}^{f_2} \pounds(f)\,df}$$

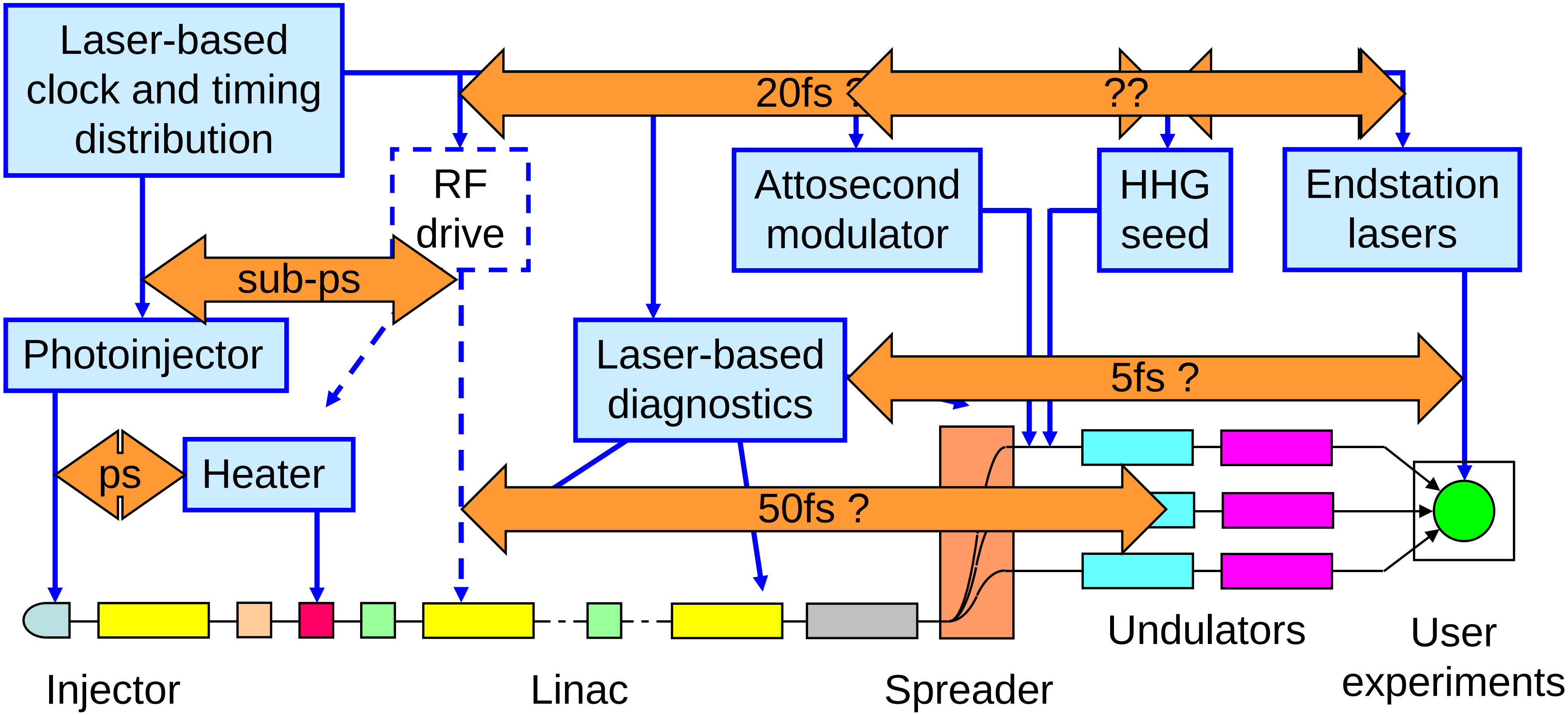
Feedback control (technically limited)

Passive control (budget limited)

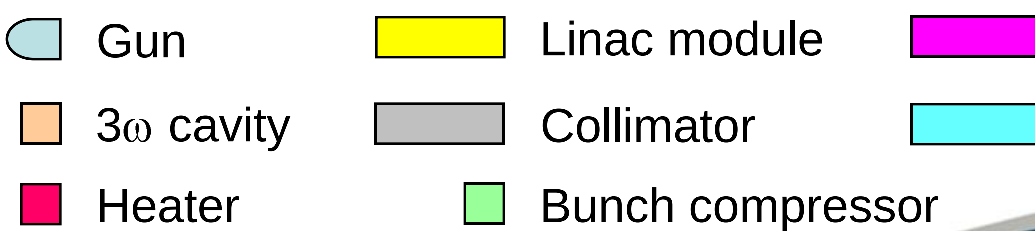
Synchronisation Requirements



Synchronisation Requirements



SECONDARY: “as low as possible”, ranging from <10fs to ps



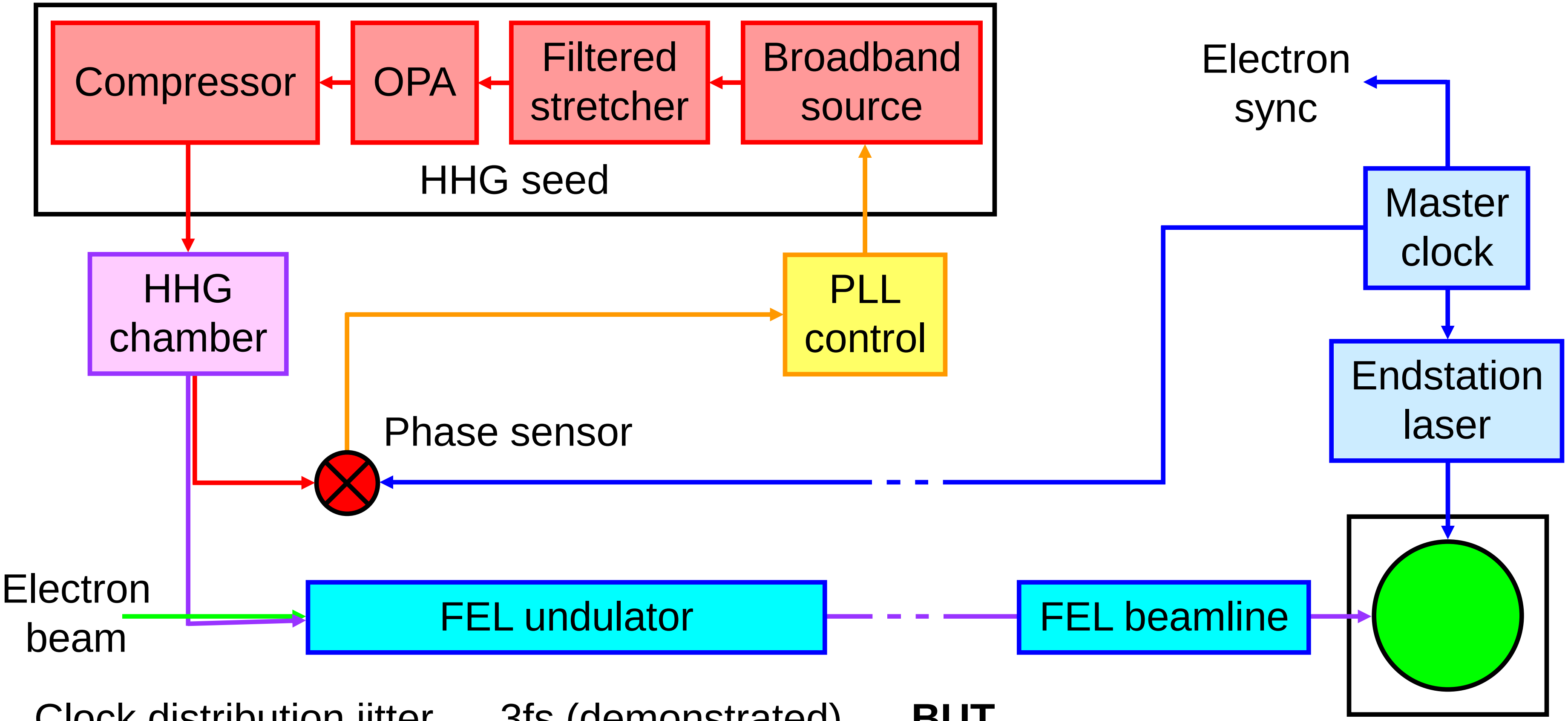
Status

- Clock distribution
  <10fs per link (published)
  1-2fs per link (demonstrated with optical phase sensor)

- Laser locking
  <10fs (demonstrated in accelerator environment)
  <1fs (demonstrated in “high quality” environments)
  will improve with direct seeding and optical sensing ?

- RF recovery
  ~10fs (demonstrated)
  may become less important in all-optical schemes

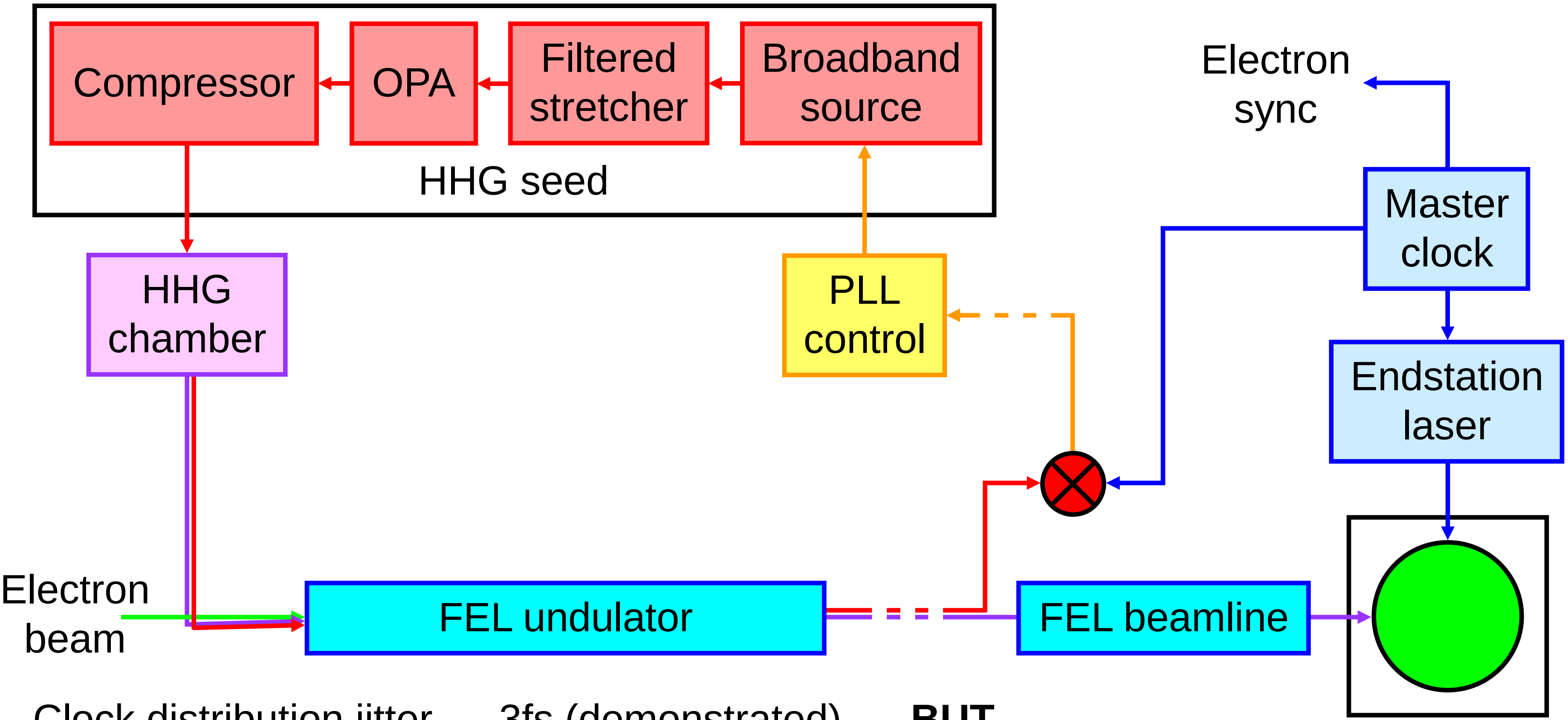
Seed Laser Synchronisation



Clock distribution jitter	3fs (demonstrated)
Endstation laser locking	5fs (target)
HHG seed laser locking	5fs (target)
Harmonic to pump jitter	< 1fs (demonstrated)
QUADRATURE SUM	**< 8fs**

BUT
Neglects FEL/beamline transport

Seed Laser Synchronisation



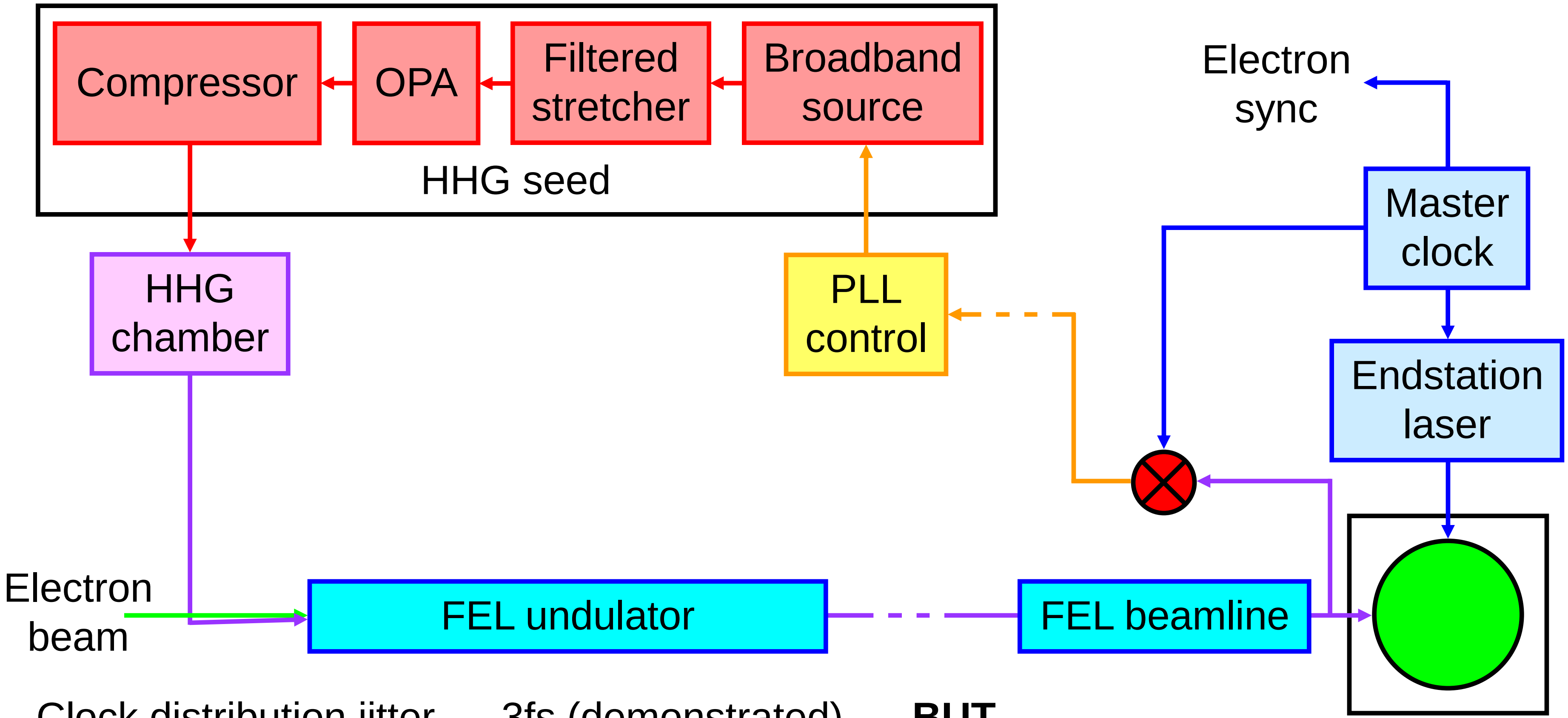
Clock distribution jitter	3fs (demonstrated)
Endstation laser locking	5fs (target)
HHG seed laser locking	5fs (target)
Harmonic to pump jitter	< 1fs (demonstrated)
Transport through FEL	5fs (target)
QUADRATURE SUM	**~ 9fs**

BUT

Neglects beamline transport

Needs probe through FEL

Seed Laser Synchronisation



Clock distribution jitter		3fs (demonstrated)
Endstation laser locking		5fs (target)
HHG seed laser locking		5fs (target)
Harmonic to pump jitter	<	1fs (demonstrated)
FEL/beamline transport		5fs (target)
QUADRATURE SUM	**~**	**9fs**

BUT

Needs fast VUV/XUV sensor

Timing and Synchronisation Issues

- The exact machine pulse rates (and time structures ?)
- The balance between passive stabilisation of the design (expensive) and feedback control (technically limited)
- Specification of common components for manufacture
- Day 1 operation at a pulse rate near 10kHz
- S2E modelling of electron bunch arrival time
- Beam-based feedback to LLRF to control electron bunch arrival time
- Development of a fast VUV/XUV sensor (cross-correlator ?)
- THz/IR synchronisation

Science & Technology Facilities Council

Conclusions

- The NLS synchronisation performance targets are technically demanding and are at the limit of what is achievable in the short term
- The management of electron bunch arrival time is particularly challenging
- Many of the issues are common to the FLASH and Fermi@ELETTRA systems and there is a strong collaborative development programme under IRUVX-PP/Eurofel
- The integration of synchronisation requirements into other aspects of the facility design is critical