NLS Timing and Synchronisation

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with a lot of helpful advice

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Talk Outline

- NLS overview
- T&S principles
- An example subsystem
- Issues
- Tests on ALICE
- Conclusions

NLS Overview

The New Light Source parameters were set by a consultation exercise which resulted in the published science case*:

- Equispaced pulses at 1kHz (day 1) rising to 100kHz/1MHz
- 20fs FWHM pulse duration (~8.5fs s)
- FEL1 50-300eV (direct seeding from tuneable HHG source)
  FEL2 250-850eV (direct HHG seeding to, perhaps, 400eV)
  FEL3 430-1000eV (short-pulse SASE or one-stage HGHG or direct seeding if/when possible)

  FEL harmonics up to 5keV
- 500-20mm synchronous THz/IR from spent beam undulators
- Variably-polarised FEL output

*http://www.newlightsource.org/documents/NLS%20Science%20Case%203Oct08.pdf

NLS Status and Plans

• Science case published	Oct 2008
• 1-year design effort approved	Dec 2008
• Open design meeting	Mar 2nd 2009
• Open community meeting	Apr 24th 2009
• Outline design ready	Early Q3 2009
• Detailed design submitted	Early/mid Q4 2009

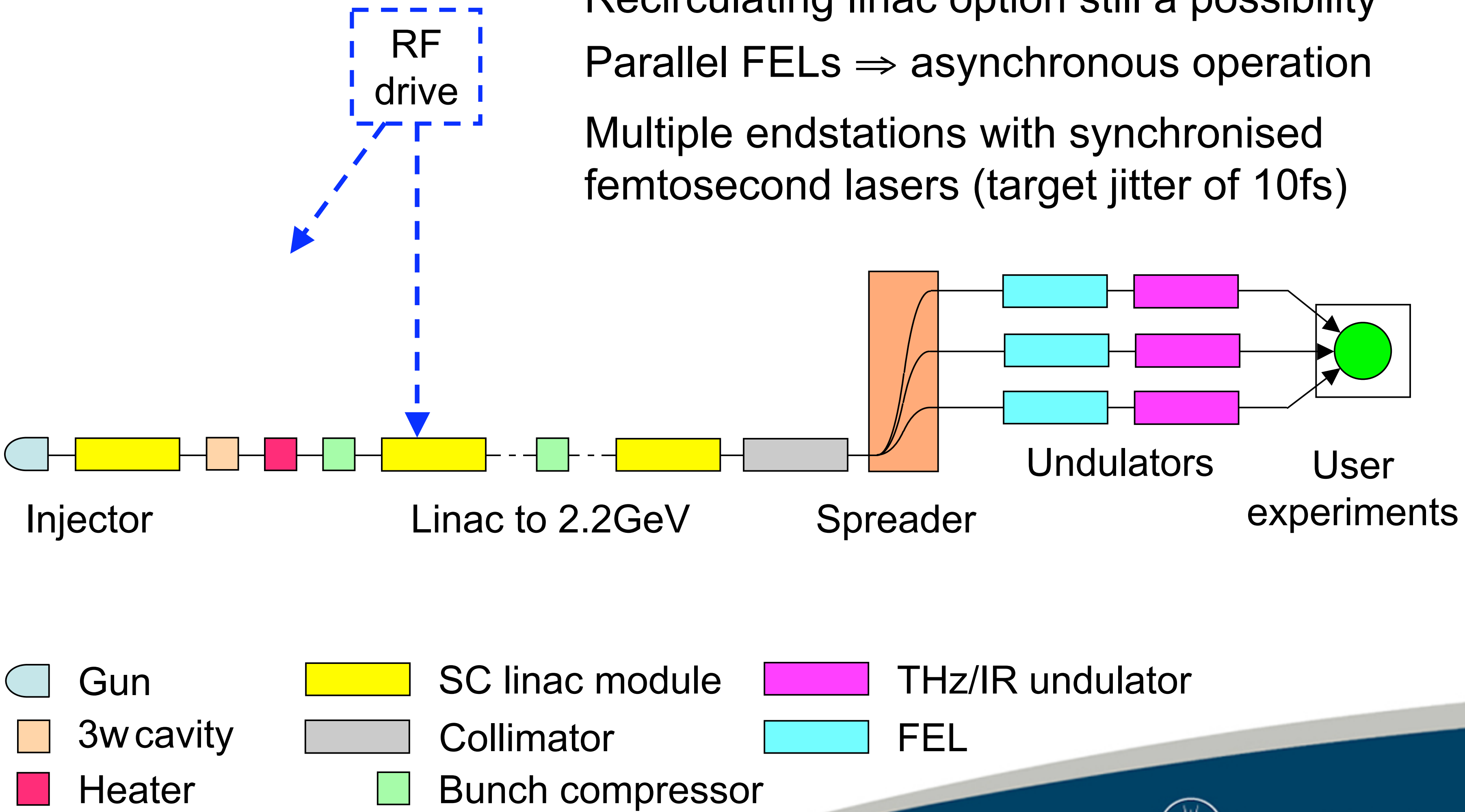
NLS Schematic

Time structure ⇒ SC acceleration

Recirculating linac option still a possibility

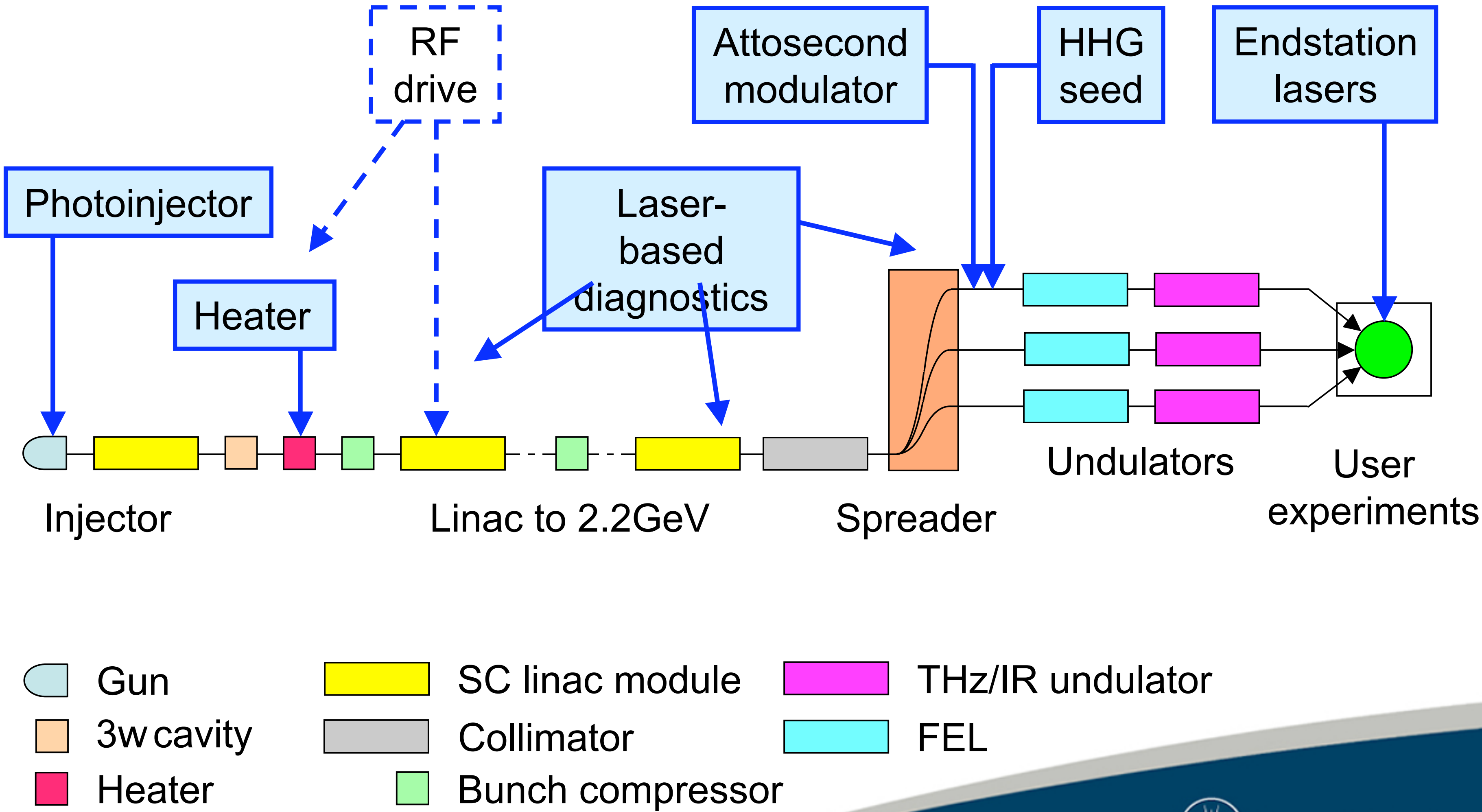
Parallel FELs ⇒ asynchronous operation

Multiple endstations with synchronised femtosecond lasers (target jitter of 10fs)

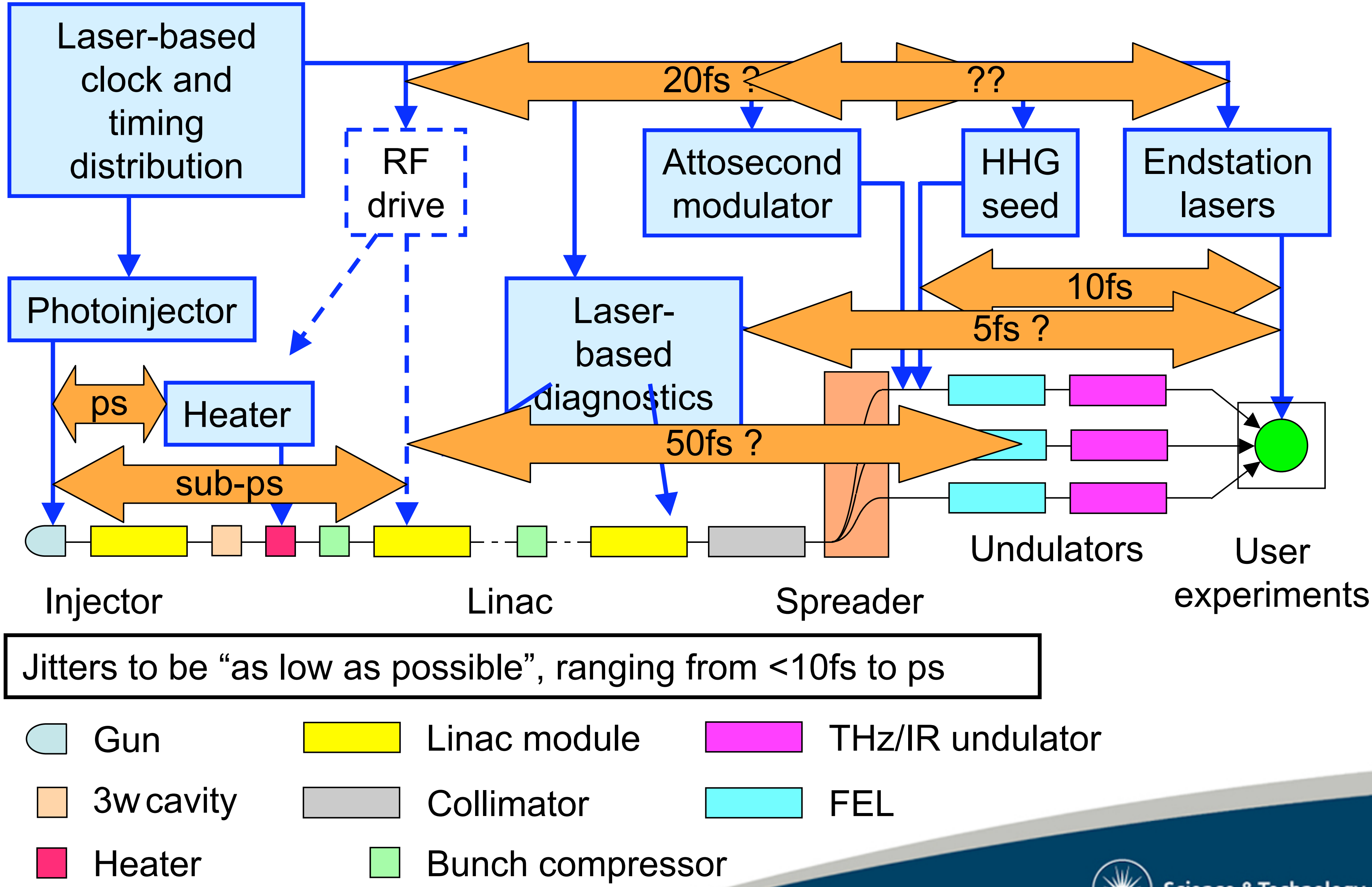


NLS Schematic

Conventional lasers



Synchronisation Requirements



Jitters to be “as low as possible”, ranging from <10fs to ps

T&S Design Principles

IN GENERAL

- Buy what we can, build what we must

  Reliability and availability of support are vital for a user facility

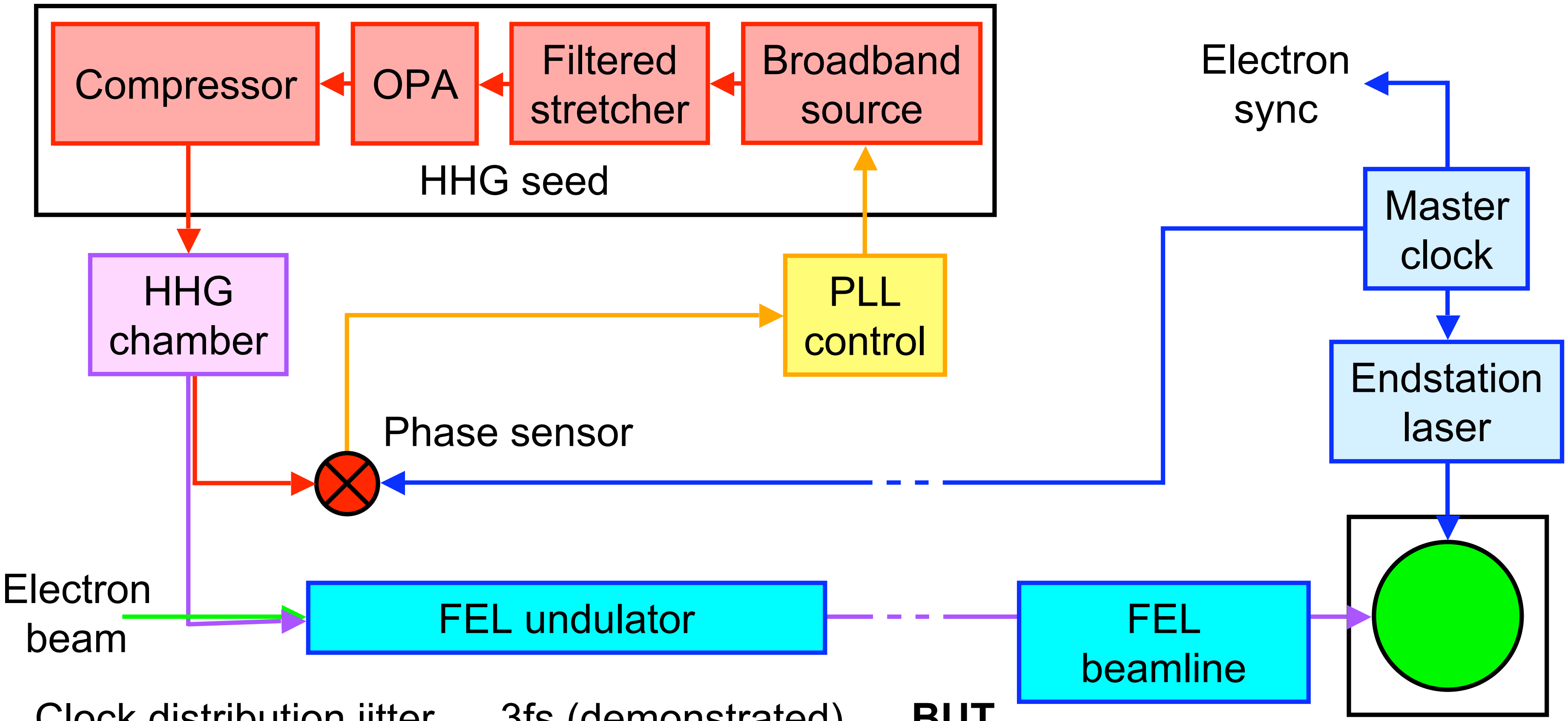
- Spend up to the budget limit on minimising intrinsic noise

  These decisions often need to be made at the design stage, before measurements or even reliable modelling can be carried out

FOR ACTIVE CONTROL SYSTEMS

- Put sensors where they measure what we *care* about
- Put actuators where they control the *source* of the noise
- Transport fast (input) signals only over short distances, and slow (output, control) signals over longer distances

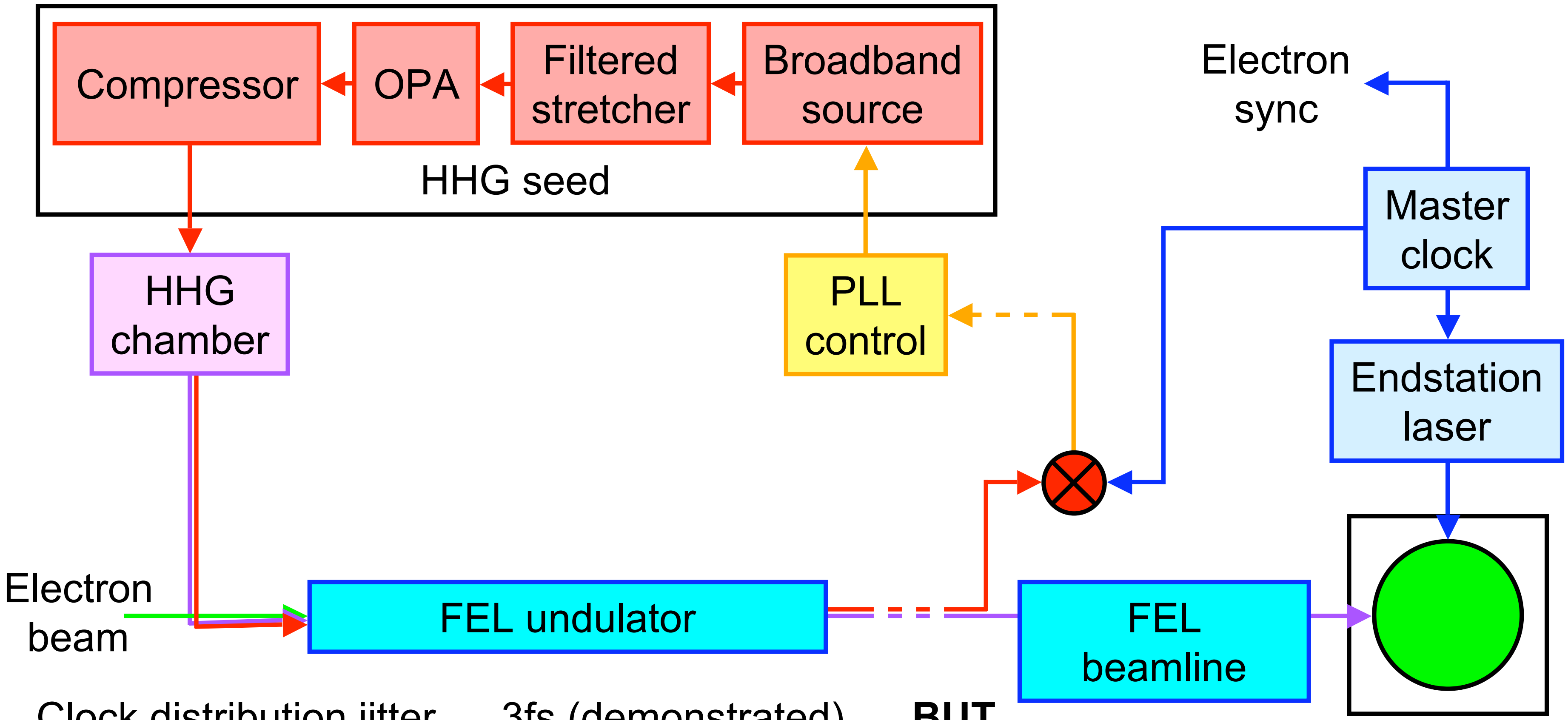
Seed Laser Synchronisation



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
May need >1kHz laser

Seed Laser Synchronisation



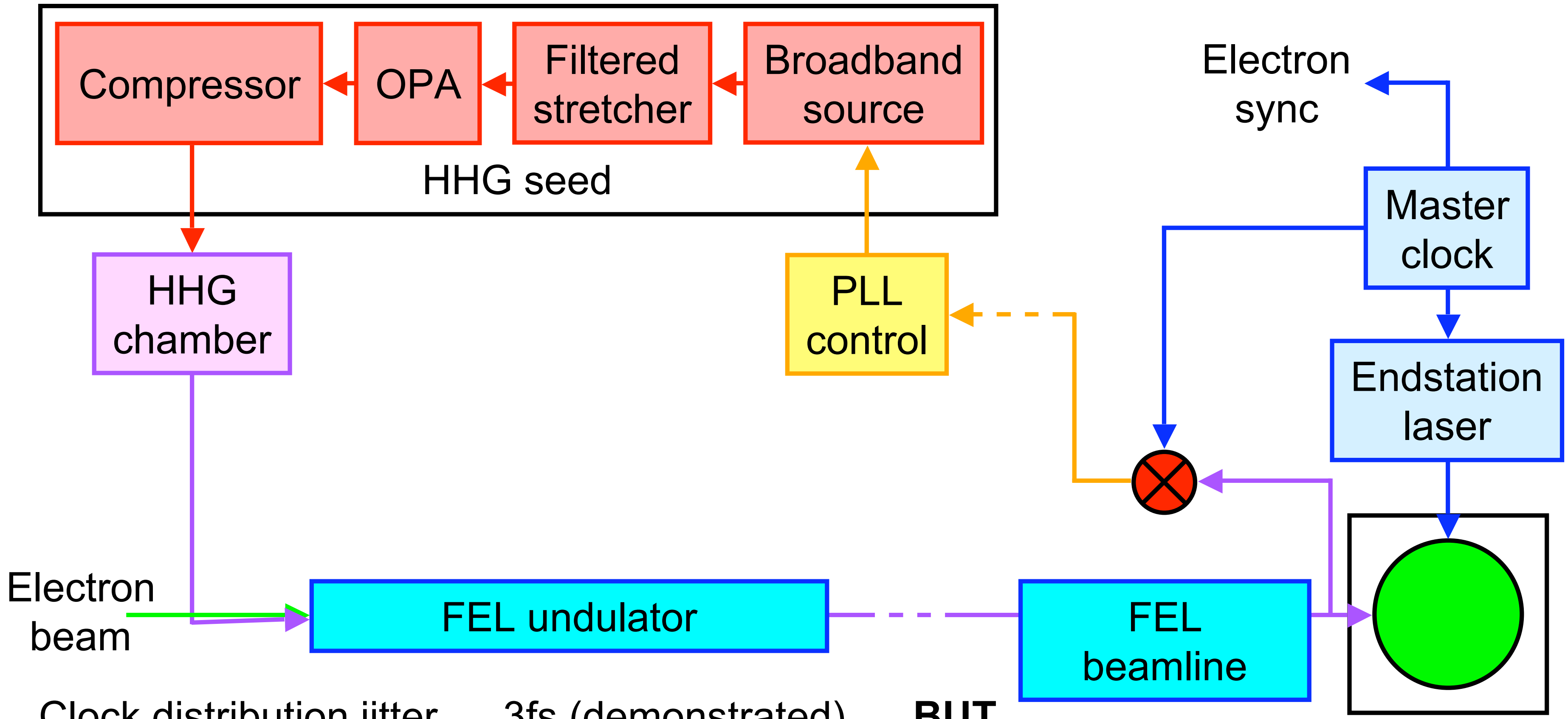
Clock distribution jitter	3fs (demonstrated)
Endstation laser locking	5fs (target)
HHG seed laser locking	5fs (target)
Harmonic to pump jitter	< 1fs (demonstrated)
Transport through FEL	5fs (target)
QUADRATURE SUM	**~9fs**

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 (Won't work for FEL set-up)

T&S Component Requirements

- Master clock
  fibre laser locked to stable RF (Rb ? GPS ?) at low f_{offset}
  pulse rate = 216.67MHz or 162.5MHz ?
- Clock distribution
  few-fs per link jitter, stable (connectorised vs spliced), durable (rad hard ?, temperature & vibration insensitive ?)
- RF recovery
  10-20fs jitter OK for direct seeding, <10fs for short-pulse SASE, compatible with beam-based feedback to LLRF ?
- Ultrafast laser locking
  5fs jitter target for ultrafast source (Ti:S ? broadband source for OPCPA ?)
- Electron BAM system
  including LLRF feedback

Timing and Synchronisation Issues

- The exact subsystem 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 sensitivities
- Beam-based feedback to LLRF (?) to control electron bunch arrival time
- Development of a fast VUV/XUV sensor (cross-correlator ?)
- THz/IR synchronisation to FELs

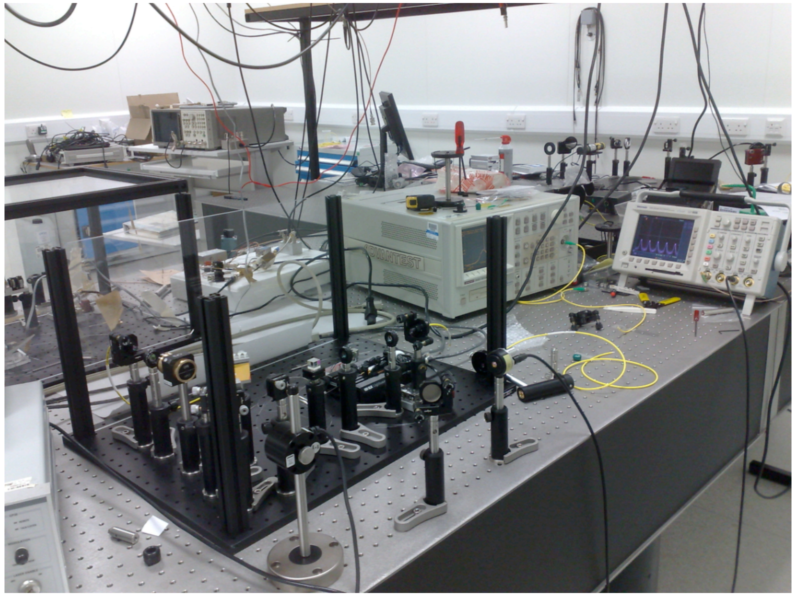
Optical Timing Tests at Daresbury

STATUS

ALICE is operational

Energy recovery Dec 2008, THz from compressed bunches Jan 2009
Compton scattering experiments begin Apr 2009 (sub-ps synchronisation required)

TIMING/SYNCHRONISATION TESTBED



Fibre laser oscillators are ready

Commercial – Toptica
Home-built Er system (through DESY collaboration)

Distribution hardware in hand

Installation on ALICE mid-late 2009
Initial implementation with phase mixers only (no optical cross-correlator)

Recruitment planned

For additional person to work on timing/synchronisation testbed

EO longitudinal profile testbed to be commissioned Apr 2009

This is to include simultaneous and direct monitoring of timing distribution laser pulses

Timing System Tests on ALICE

TIMING DISTRIBUTION

Vibration stability

Elements of the helium refrigeration plant are in the accelerator area

Temperature stability

Local temperature is not tightly controlled

Possible radiation effects

There is significant field emission from the SC cavities as well as beam loss and dump radiation

BEAM ARRIVAL MONITORING

Wakefield effects on BAM pickup

81 MHz microbunch rate (12 ns spacing)

81/N MHz pulse-picking under consideration

Centroid vs I_{peak} arrival time comparison

In conjunction with an EO longitudinal profile monitor

Performance at low charge (<80pC)

Mode-locked laser oscillator, fibre timing distribution and BAMs will be installed on ALICE in 2009...

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Conclusions

- The NLS project is now in a one-year design phase in advance of design submission in Q4 2009
- The machine will be a 2.2GeV cw SC linac driving, on Day 1, 3 FELs spanning 50eV to 1keV in the fundamental
- The photon pulse length will be 20fs FWHM with HHG seeding to ~400eV
- The FEL pulses will be synchronised with ~10fs jitter to conventional lasers and to THz/IR from undulators
- The timing and synchronisation system will be fibre-based and will use common components where possible
- Tests on ALICE will begin soon

THANK YOU FOR YOUR ATTENTION !

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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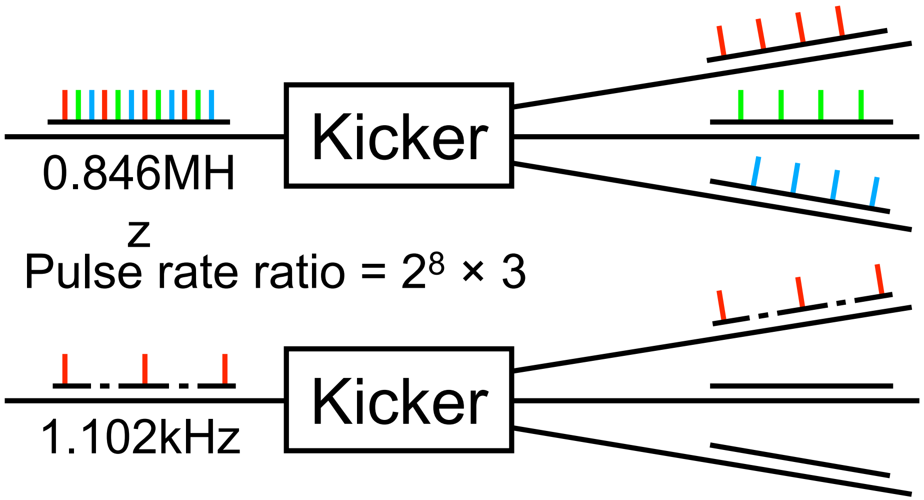

Pulse rates may also be constrained by the kicker used for simultaneous FEL operation. (The simplest kicker type will not work at pulse rates whose ratio has 3 as a factor.)

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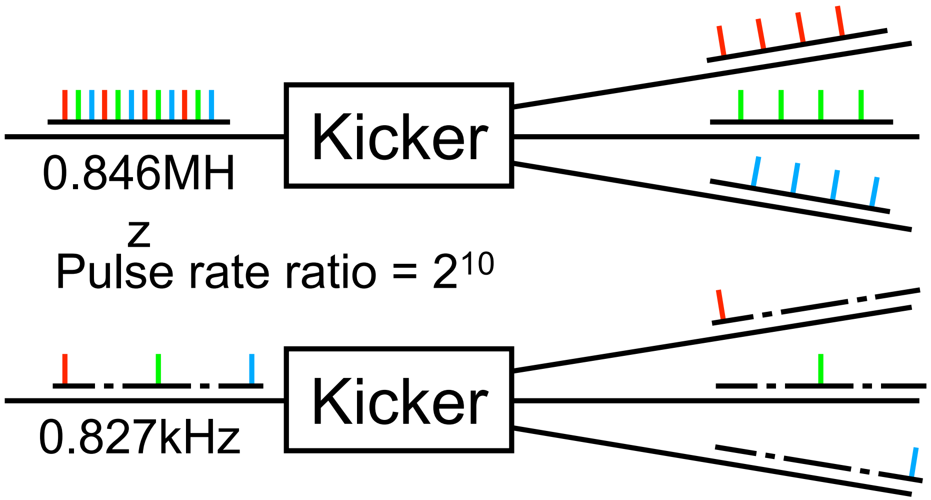

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