DEFINITIONS

- "causing things to *indicate* the same time" (clocking)

  "the relation that exists when things *occur* at the same time" (control)

WHAT NEEDS TO BE SYNCHRONIZED

- RF reference signals (distribution, detection, feedback control)

  Fibre-based distribution, optical-to-RF conversion, lasers with low HF noise and the latest electronics have delivered <100fs and promise to get to ~10fs

  CPE stabilized lasers make clocks with 45as jitter from mHz to MHz !

- Laser pulses to RF

  Few hundred fs is commercially available, <100fs is not too hard and <1fs is state-of-the art (but the RF can't be too noisy, and people mustn't talk !)

- Electron bunches

  Phase jitters of 0.03º at 1.3GHz (65fs - Rossendorf), 0.01º at 1.5GHz (20fs – Cornell/Jlab), 150fs over >30 minutes (TTF) and <200fs sustained (Jlab) have all been measured

WG4 SYNCHRONIZATION

CHARGE

- Minimising LF ERL phase noise (e.g. thermal, vibrational, machine re-tuning)
- Minimising HF ERL phase noise (e.g. microphonics, HOMs, beam instabilities)
- Dispersion management
- Modelling (incl beam effects on RF synchronization)
- Frequency-domain and time-domain electron timing sensors
- Timing prediction without electrons (e.g. microphones for microphonics)
- Control systems (feedback, feed-forward, closed-loop, open-loop)
- Complex time structures (missing bunches, time-varying bunch charge)
- Fast (>kHz ?) actuators to control electron timing
- Beam-derived synchronization signals (vs LLRF distribution)
- RF distribution
- Laser stability

STATUS

- Most subsystems have been shown to work “routinely” with jitters of ~100fs and with comparable phase stability for times ranging from minutes to days
- With state-of-the-art subsystems ~10fs jitter has now either been achieved or could be achieved (given enough money) on timescale of 2-3 years
- Demonstration of ~100fs jitter across large (0.1-1km) integrated systems is within reach
- Synchronization of subsystem pairs to ~10fs jitter seems plausibly achievable
- Issues that remain include:

  Long-term phase stability/referencing

  Environment control (temperature, vibration, EM noise, radiation damage)

  Maximizing time and frequency stability at the machine design stage

- The devil is in the detail !