RAL Laser Capabilities

Graeme Hirst

STFC Central Laser Facility
Rutherford Appleton Laboratory

Science & Technology Facilities Council

STFC

~~RAL~~ Laser Capabilities

Graeme Hirst

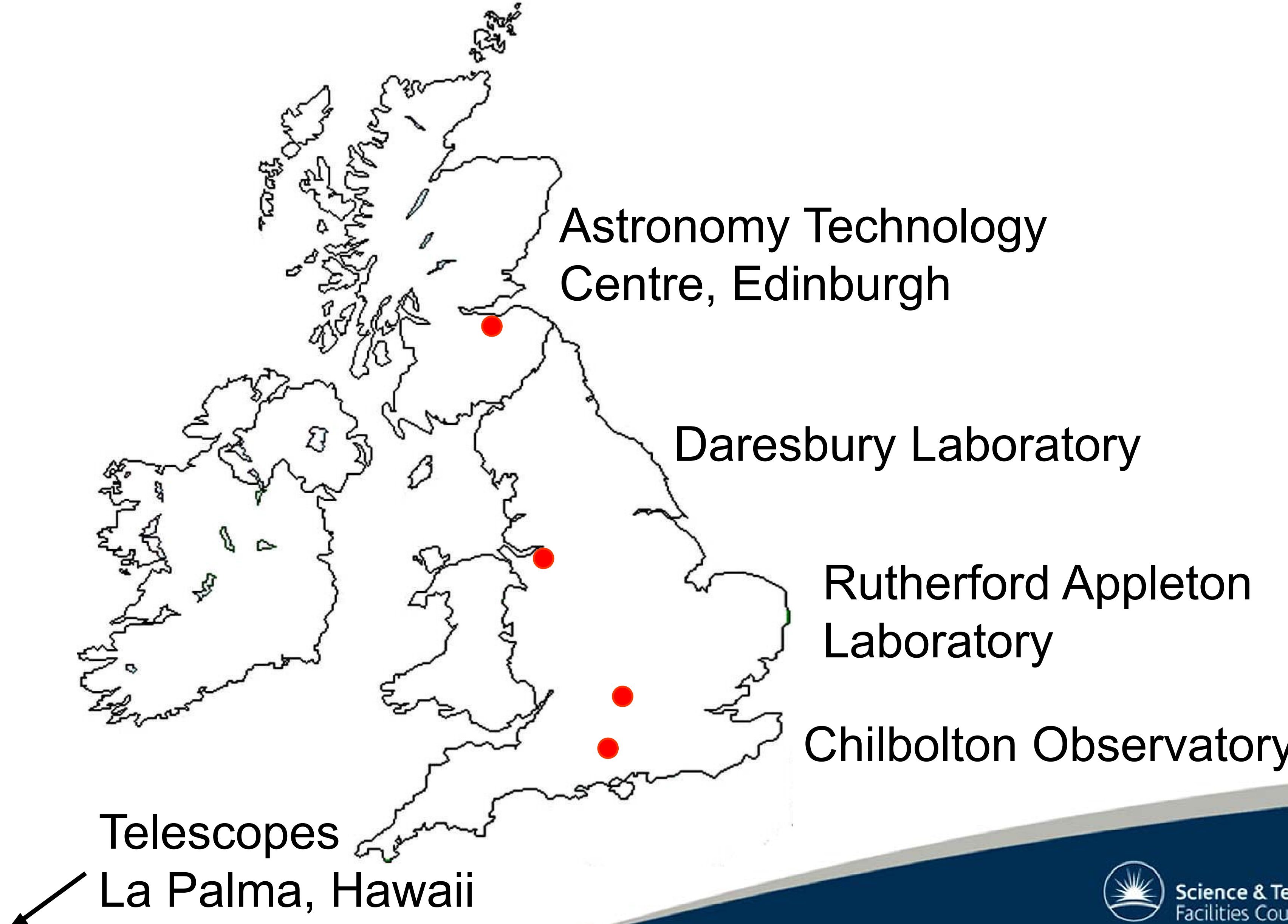
STFC Central Laser Facility
Rutherford Appleton Laboratory

Science & Technology Facilities Council

Talk Outline

- Introduction to STFC
- The Central Laser Facility
- Accelerator-related activities
- Relevance to laser stripping

STFC Facilities



Science & Technology Facilities Council

Daresbury Laboratory

ALICE
Electron ERL, THz irradiation suite, 20TW laser, IR FEL (in prep)

Cockcroft Institute

ASTeC
Accelerator Science and Technology Centre

EMMA
FFAG accelerator (in prep)

Science & Technology Facilities Council

Rutherford Appleton Laboratory

ISIS
Spallation
neutron
source

CENTRAL LASER FACILITY
Vulcan
Astra
Lasers for Science

DIAMOND
3rd generation
synchrotron
light source

Science & Technology Facilities Council

Central Laser Facility

Our mission* is to:

- Provide state-of-the-art laser facilities ...
- Pursue an imaginative and innovative science and technology development program ...
- Stimulate and support new laser application areas ...
- Work with our users to fulfil their research aspirations ...
- Provide expert laser advice to government, research councils and industry ...
- Promote public understanding of science ...

*Full text at:
http://www.clf.rl.ac.uk/Mission/Mission.htm

The CLF In Practice

The CLF provides high intensity pulses:

- Pulse energy up to 500J (VULCAN PW – >10^{21}Wcm^{-2})
- Pulse duration down to <10fs (ASTRA Artemis)
- Beam quality close to diffraction-limited (most systems)

A wide range of photon energies is also available:

- Tuneability from 0.2-20μm at 10kHz (LSF ULTRA)

Some users have laser expertise, but some don't

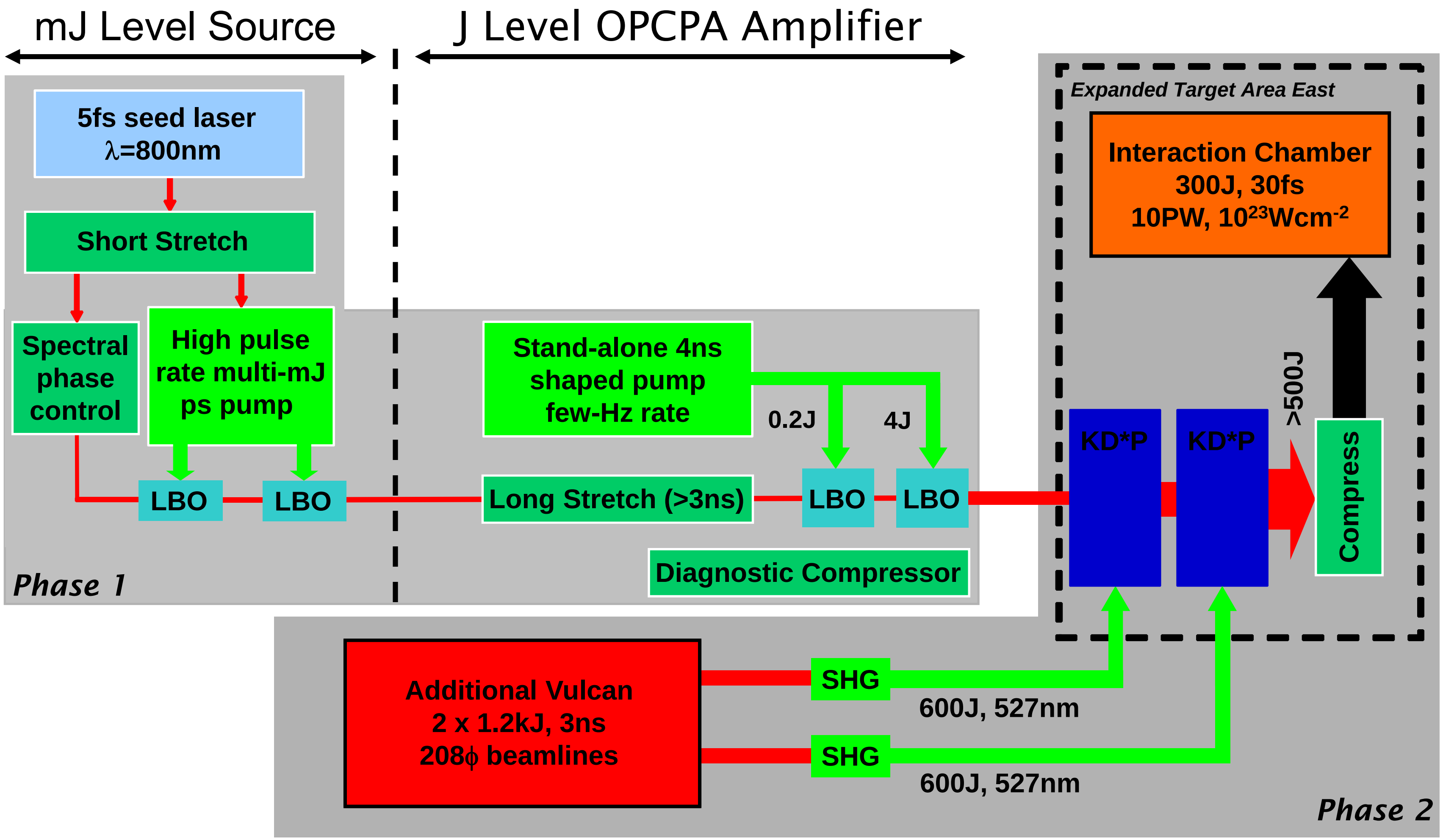
There is a long track record of collaboration, both structured (e.g. LaserLab Europe, MoUs, contract R&D) and informal.

In recent years we have worked closely with other STFC departments, e.g. ASTeC, and with DLS on accelerator-related laser applications

VULCAN

- 8 Beam CPA Laser
- 3 Target Areas
- 3 kJ Energy
- 1 PW Power

VULCAN 10PW



Will augment the existing VULCAN ns amplifiers and turn them into a pump laser for a very large, high contrast OPCPA system

ASTRA

ASTRA is the CLF's ultrashort pulse Ti:S facility, specialising in high-field molecular and plasma science

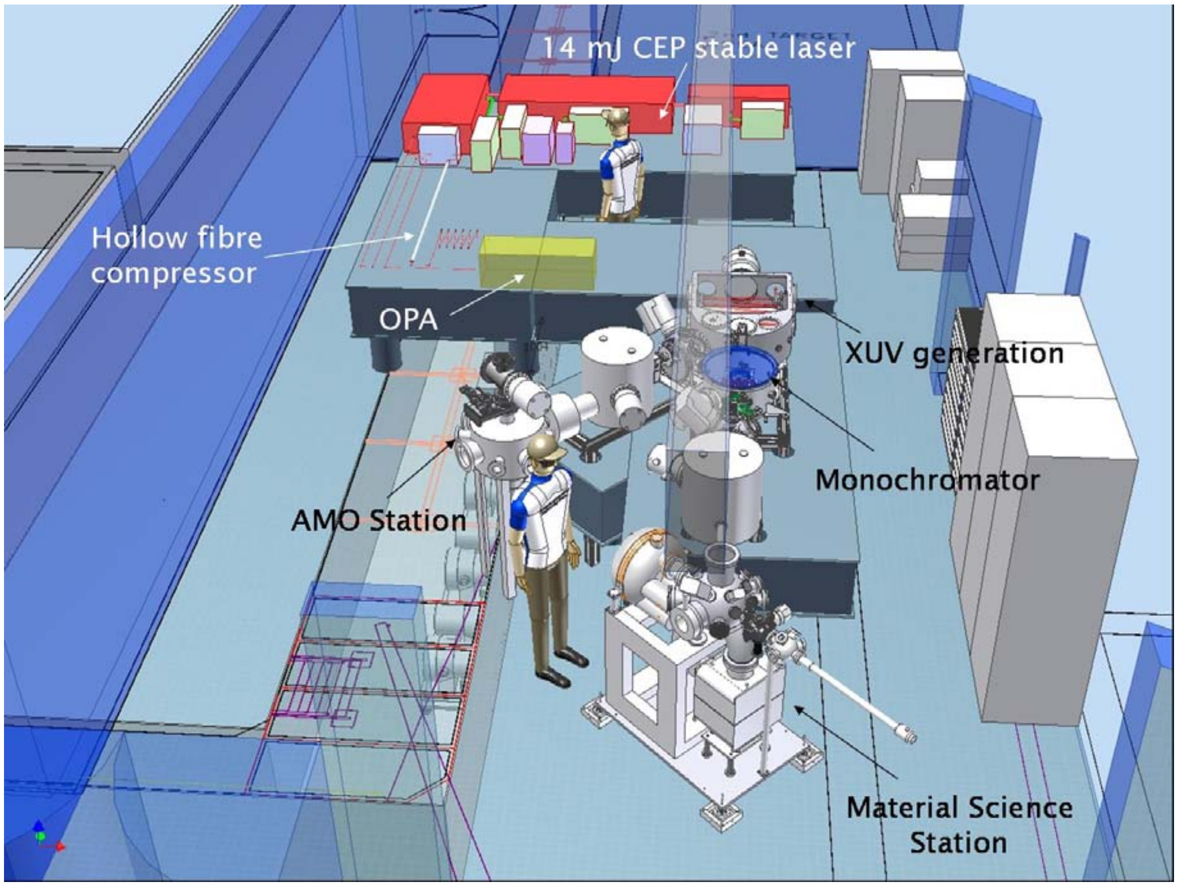
Two upgrades are currently under way:

- ASTRA Gemini will deliver two 0.5PW beams (each 15J in 30fs) at 0.05Hz, capable of generating 10^{22} Wcm^{-2} on target

- ASTRA Artemis will be a versatile laser suite capable of delivering multiple beams to experimental chambers developed for particular user communities

ASTRA Artemis

The Artemis drive laser is a commercial CEP-stabilised 14mJ, 30fs, 1kHz system, now completely decoupled from ASTRA



Additional capabilities will include:

- 0.5mJ, <10fs
- time-preserving monochromation of an XUV HHG beam
- Widely tuneable OPA beams
- Specialised end stations

DIPOLE

Many *high pulse energy* applications also need *high average power* (e.g. IFE, medical accelerators, transmutation ...)

Diode-pumping is the only viable route to this and, in addition, promises *high efficiency, stability and reliability*

Yb is an attractive gain medium because of its *low quantum defect, long upper-state lifetime and broad laser linewidth*

Ceramic host materials are *size-scalable* and allow for sophisticated *engineering of dopants and concentrations*

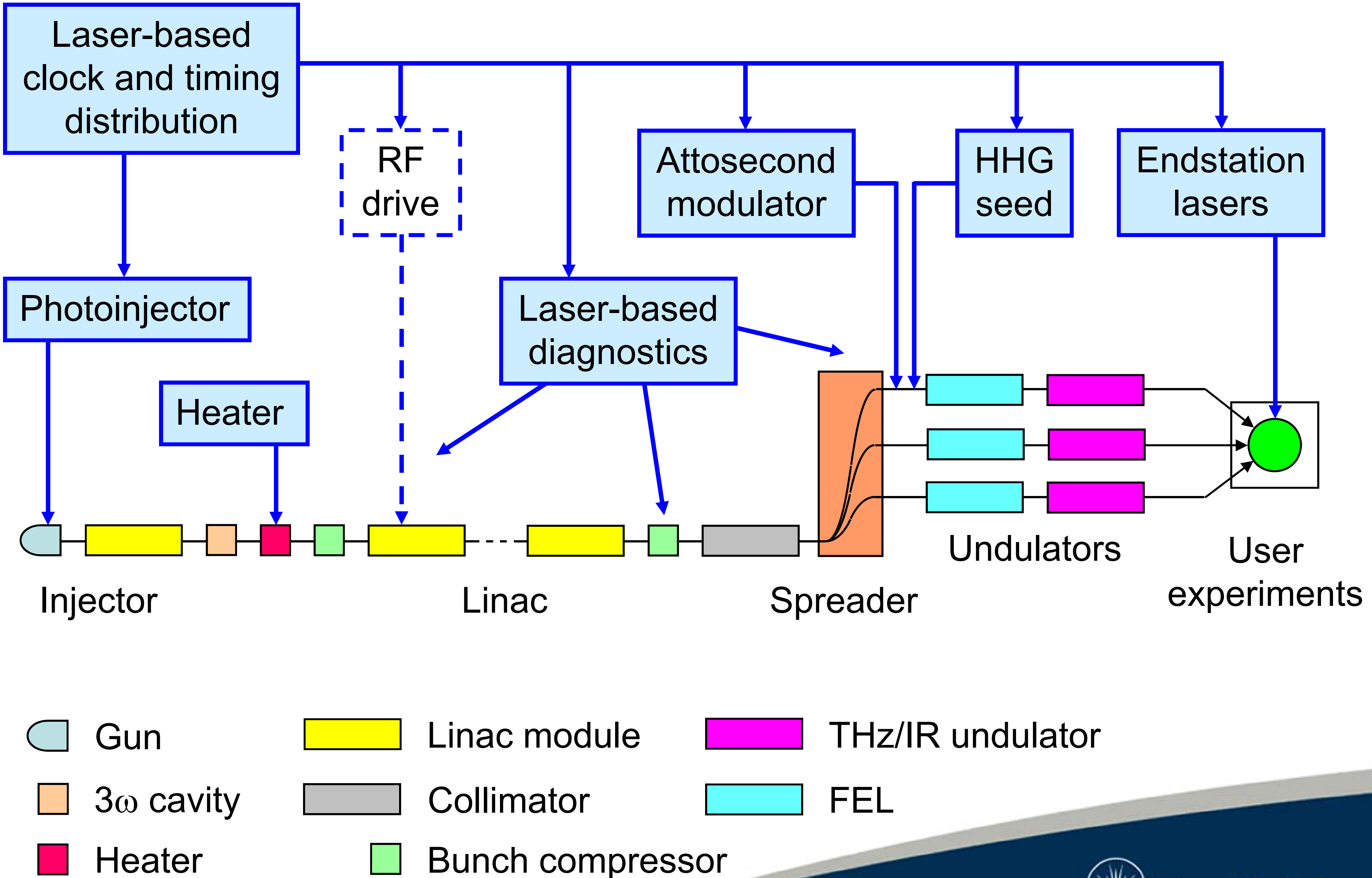
DIPOLE is a program studying kW-class options:

Medium to high pulse rate (~30J, ~30Hz and ~1J, ~1kHz)

High energy (~1kJ, >1Hz)

Science & Technology Facilities Council

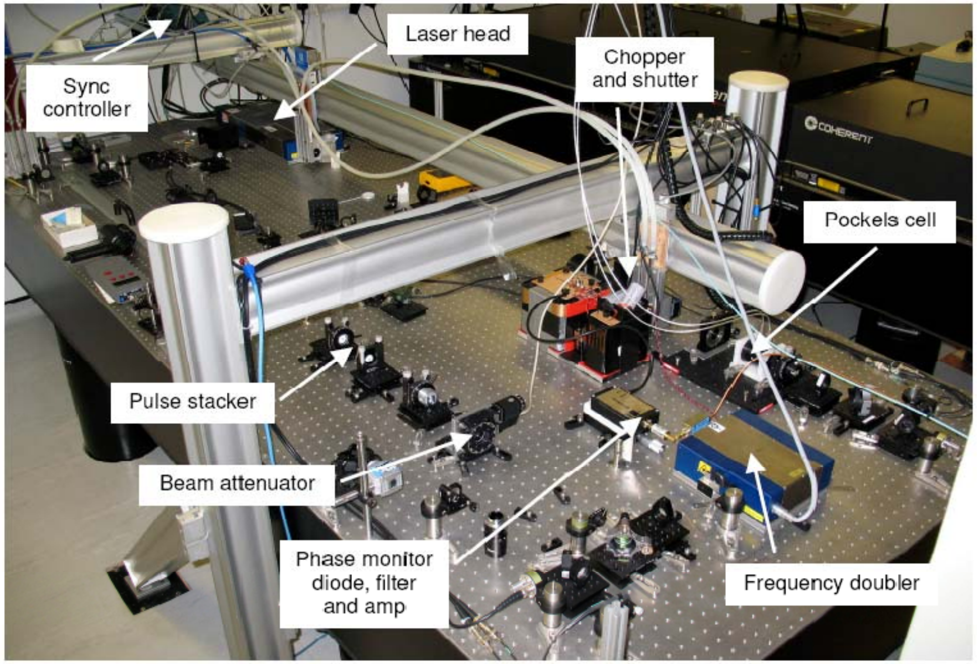
Lasers on the NLS

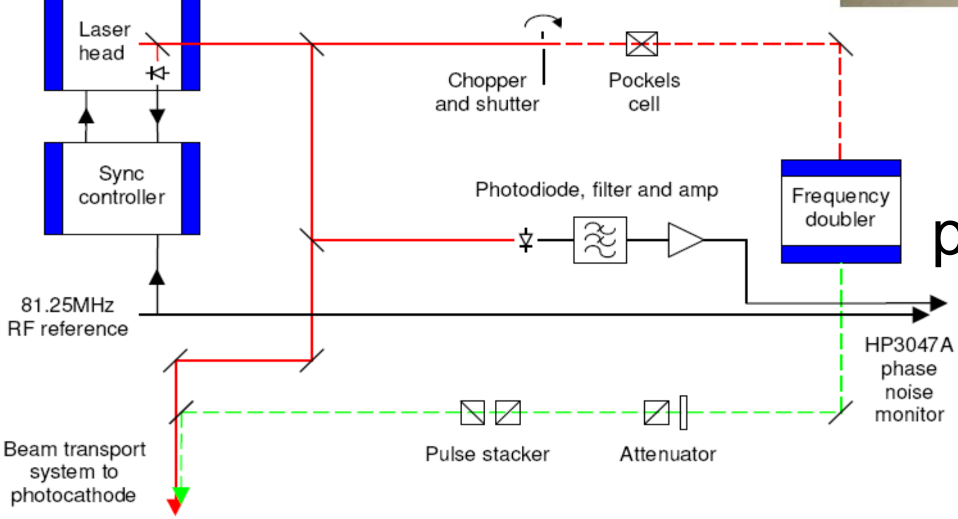


A Photoinjector Laser for ALICE

ALICE needs 20nJ of green light to deliver 80pC from a Cs:GaAs photocathode

The pulse train must be chopped at 20Hz to <100μs macropulses with >10^6 contrast

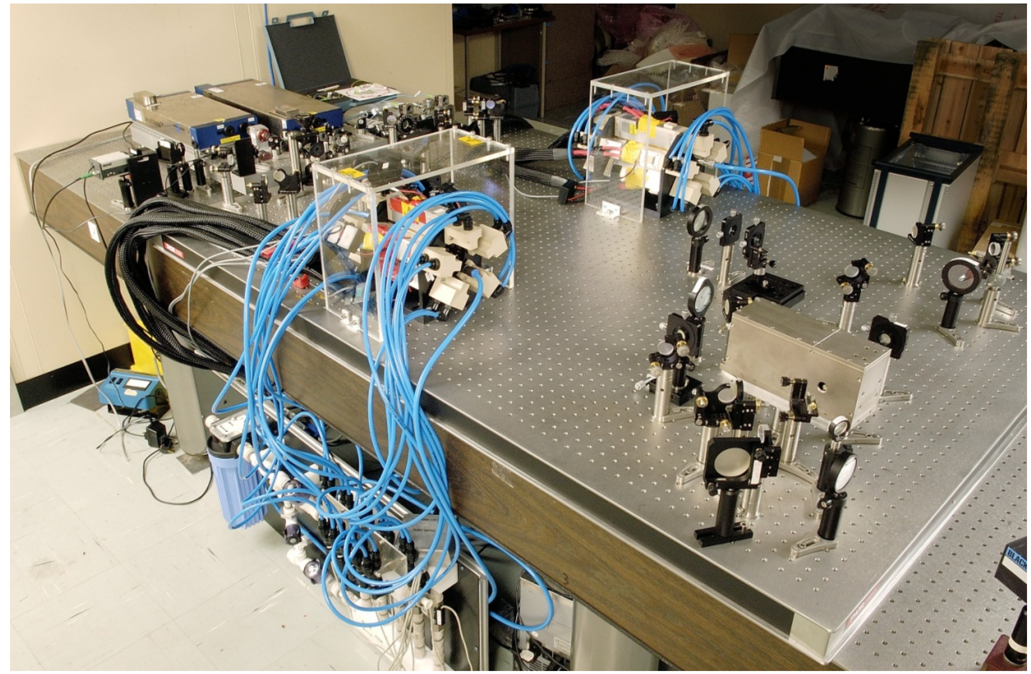




An industrial Nd:YVO_4 unit (High Q Laser) delivers 6-8ps pulses at 81.25MHz cw with up to 60nJ in the green stacked to ~20ps

Science & Technology Facilities Council

A Photoinjector Laser for CTF3



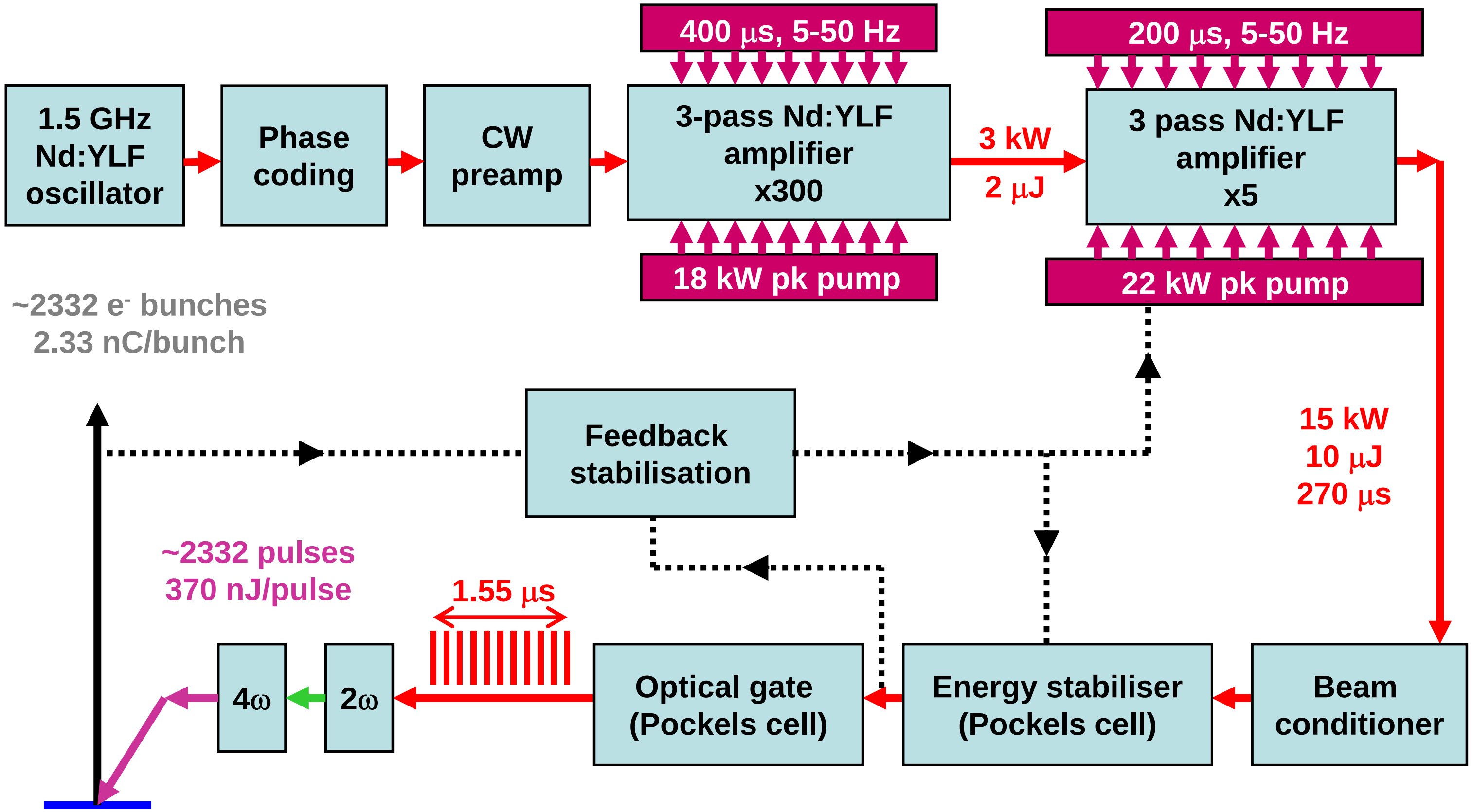
CTF3 needs 370nJ of UV light to deliver 2.33nC from a Cs_2Te photocathode.

Complex time structure: macropulses, up to 50Hz, of micropulses at 1.5GHz. 11 sub-groups of 212 micropulses alternately delayed and not delayed by 333ps.

Target UV pulse energy stability of 0.25% rms (ideally 0.1%).

Capacity for very rapid switch-off in the event of laser or accelerator RF failure.

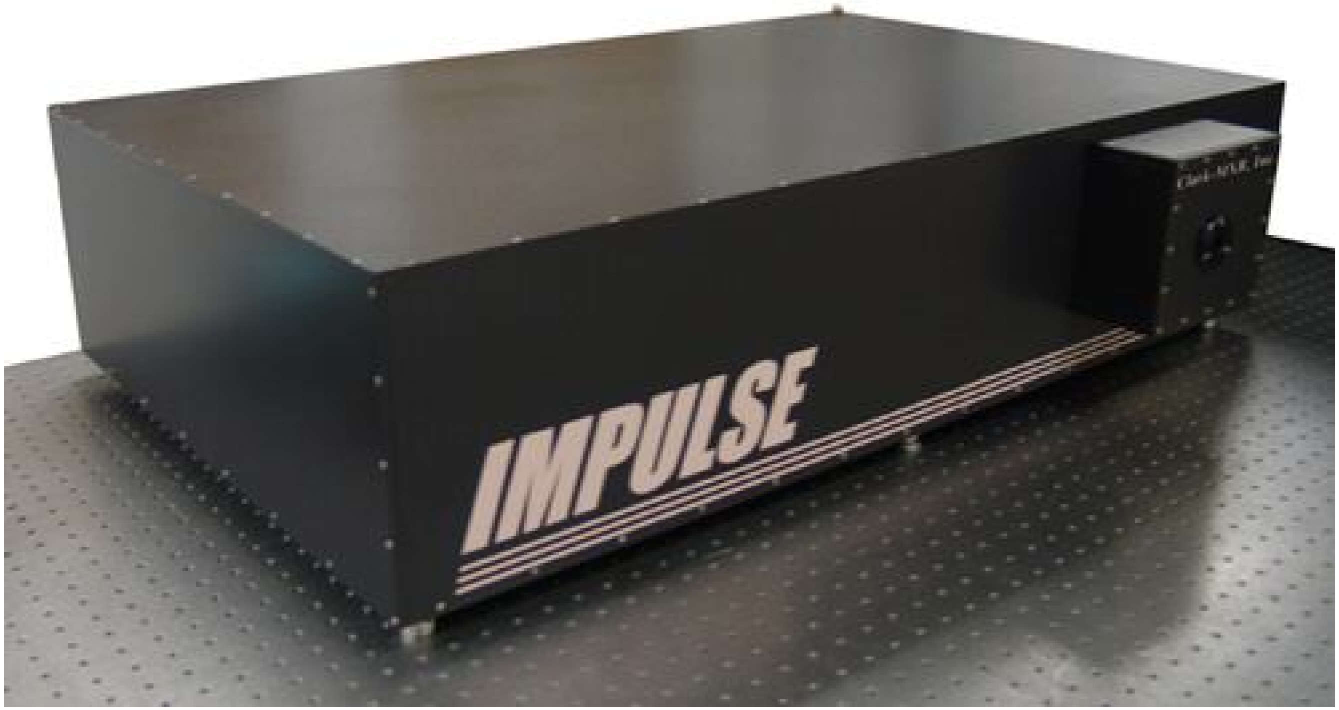
A Photoinjector Laser for CTF3



Diode-pumping for stability, reliability and high average power

Saturated quasi-cw architecture with optical gating for stability

A Commercial Photoinjector Laser ?



One-box Yb-fibre CPA system

Output: 10μJ (200kHz-2MHz), 20W (2MHz-25MHz)
Pulse length: 250fs-10ps (synchronisation needed)
Beam quality: M^2 = 1.2-1.5
Wavelength: 1.03μm

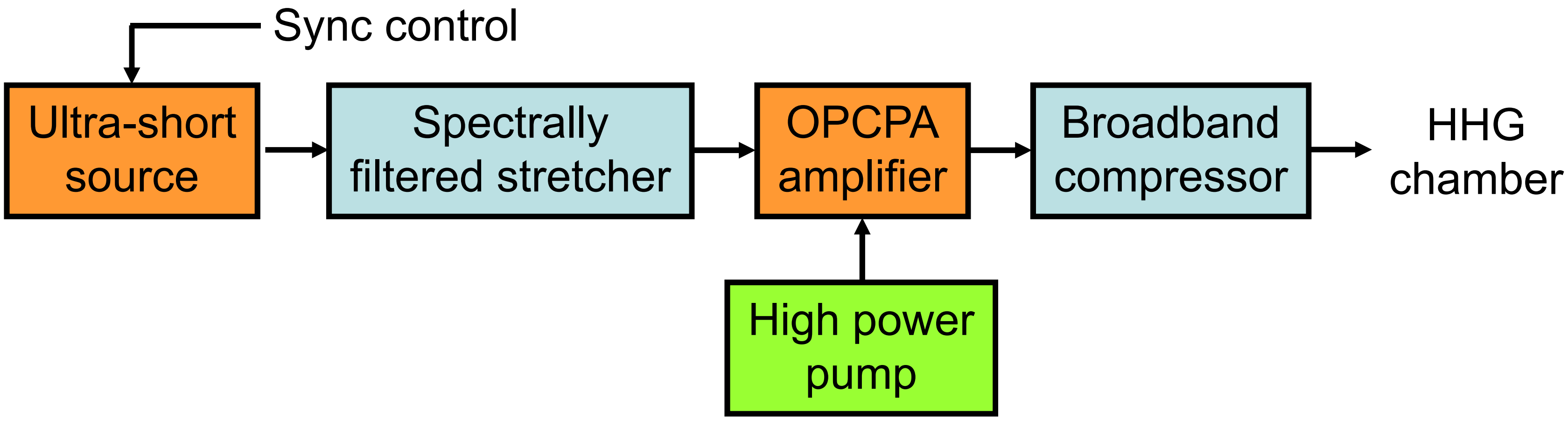
Data from Clark-MXR Inc

An HHG Seed Laser for NLS

REQUIREMENTS

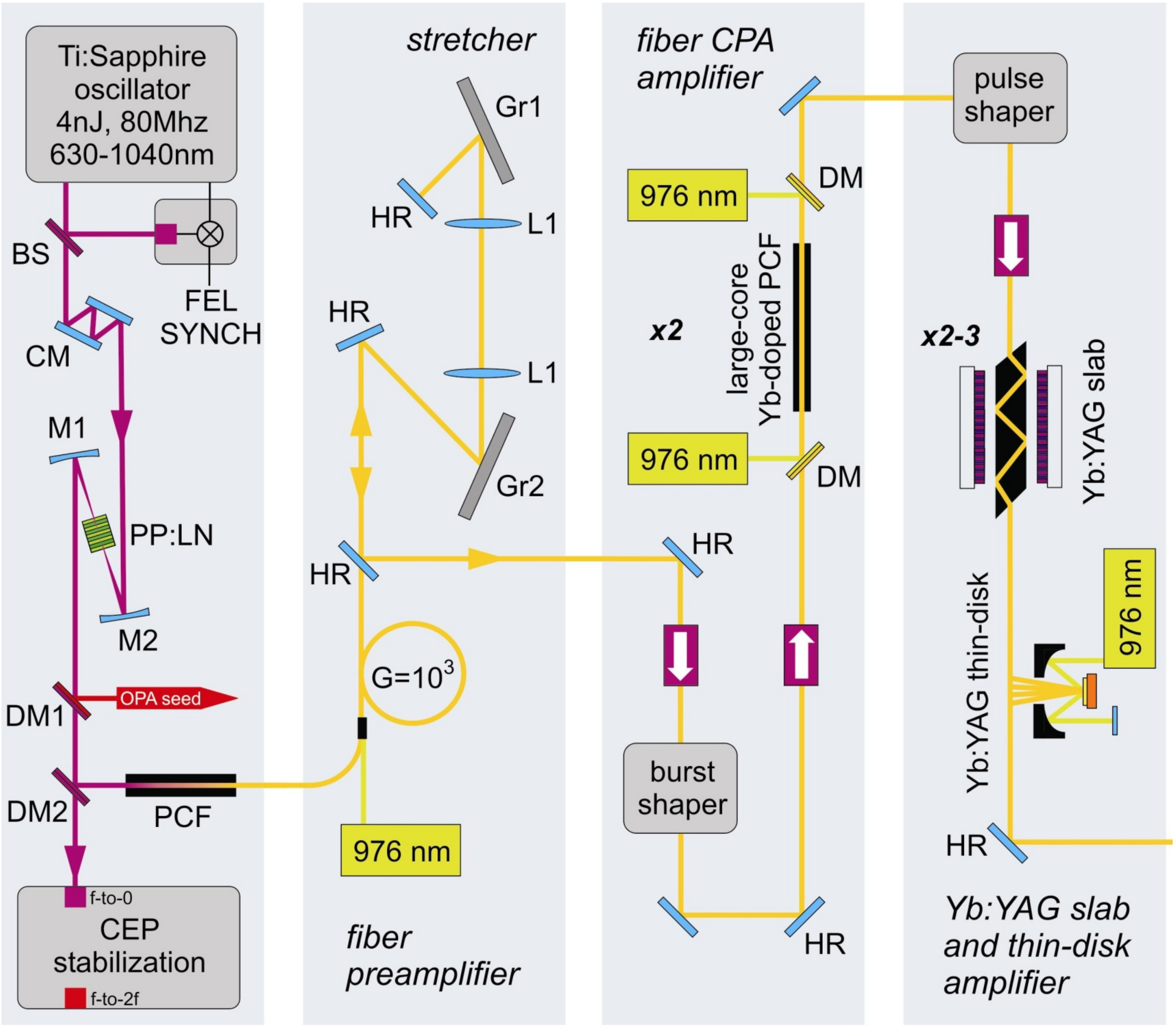
Pulse length: ~20fs
Pulse rate: 1kHz–1MHz
Timing jitter: ~10fs
Pulse energy: ~mJ
Tuneability: 2hν/N (spans HH gap)

POSSIBLE ARCHITECTURE



Isochronicity of stretcher-compressor minimises timing variation during tuning

Yb:YAG slab booster-amplifier



An HHG seed laser based on OPCPA is being built for FLASH at DESY*

The Yb-based pump system already delivers 3.5mJ, 100kHz, 800fs pulses with M^2=1.3 at 1μm

*F Tavella, S Düsterer and H Schlarb

An Yb Laser for H Stripping ?

$$P_a = 10^6\ \mathrm{W} \times 50 \times 10^{-12}\ \mathrm{s} \times 40.25 \times 10^6\ \mathrm{Hz} \times 0.06$$

$$\approx 120\ \mathrm{W}.^*\ \text{(Average laser power)}$$

Requirement*	Comment
τ_{pulse} = 50ps	Straightforward (seeded)
E_{pulse} = 1MW×50ps = 50μJ (UV)	If $\eta_{conversion}$≈0.12, ⇒ 0.42mJ (IR) Tavella has demonstrated 3.5mJ/pulse
PRR = 40.25MHz with 6% duty cycle (2.4×10^6 pulses/sec, 17kW macropulse)	Tavella's ave power ⇒ 8×10^5 pulses/sec so 3 × Tavella laser may suffice. 15kW macropulse in CTF3 laser design (not fibre, but Nd is less efficient than Yb)

*V Danilov et al, PRST-AB **10**, 053501 (2007)

Conclusions

- The CLF's core business is operating a diverse suite of lasers for an even more diverse community of users
- We specialise in high intensities, with high average power being driven by the need for volume and throughput
- Laser R&D keeps our facilities at the cutting edge
- In collaboration with other STFC departments we have worked on accelerator-related lasers, characterised by high pulse rates, high stability, long periods of operation and very high reliability
- Yb-based systems can satisfy many of these requirements and may also be suitable for H stripping