EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS

EuPRAXIA

Use of Other Novel Technologies (WP10)

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Contents

- Fiber lasers
- Dielectric-based accelerators
- Use plasma for beam dump

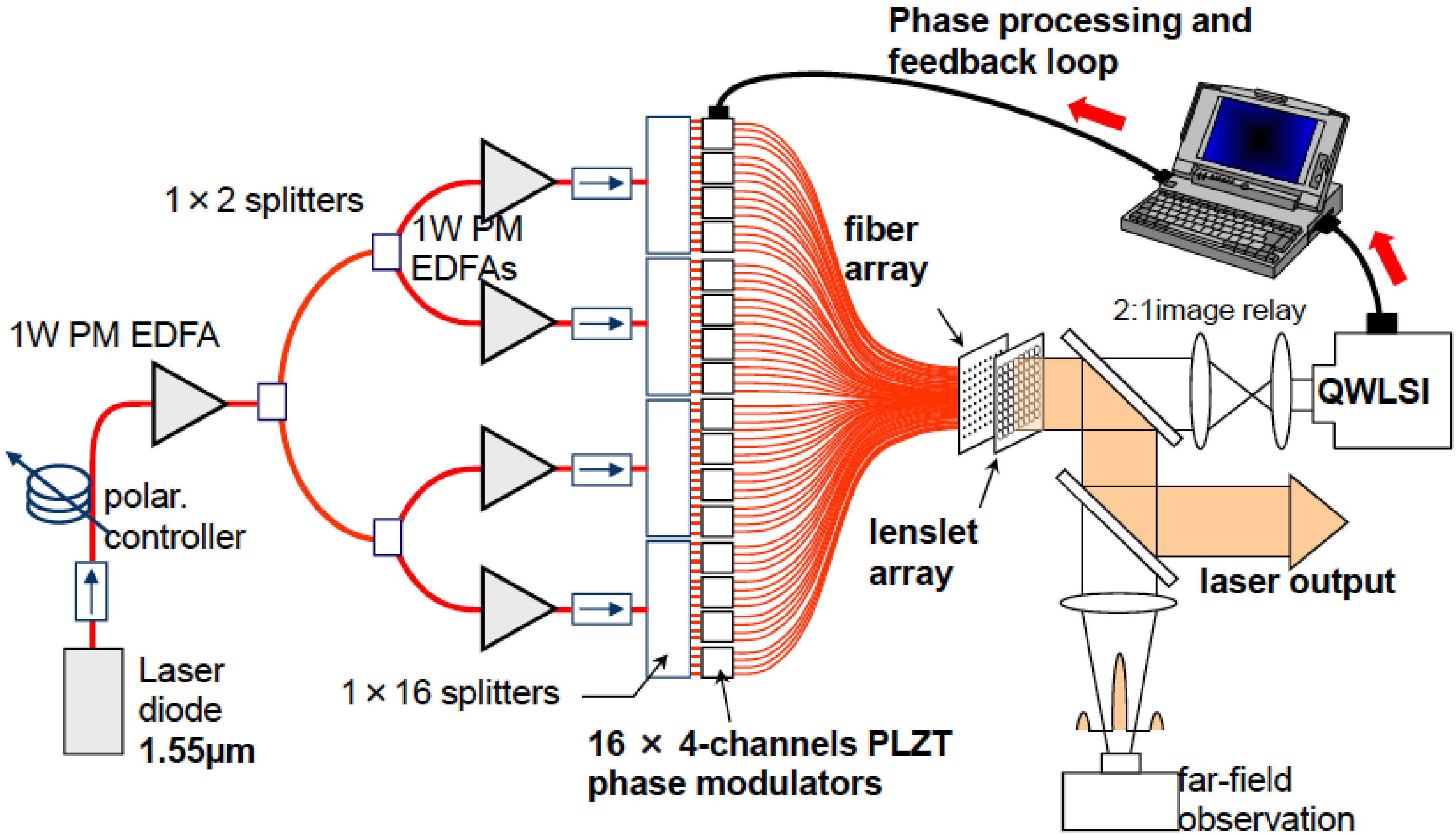
Fiber lasers

- Fiber lasers (advantages: high efficiency, high repetition rate, low loss, heating is not an issue)
- ICAN and XCAN (Gerard Mourou)
  - 61 pulsed fibers combined (CW), with each beam controlled separately on phase (adding flexibility), 91 next step, 500 fibers for future (1 μm precision core to core)
  - 10,000 fiber lasers can be combined in principle, 10s of Joules, more than 10 kHz repetition rate)
  - Combination of two high power Ti: Sapphire lasers planned
- Status, problems, limitations, potentials
- Involvement with Jena, Southampton University (other architecture), site visit?
- Industry involvement, Thales and others

Fiber lasers

J. Bourderionnet, A. Brignon (Thales), C. Bellanger, J. Primot (ONERA)

Coherent Fiber Combining



Achievement 2011
→ 64 phase-locked fibers

Dielectric based accelerators

- Current status of dielectric laser accelerators, THz driven dielectric accelerators and compact electron gun setup based on dielectric accelerators, the possibility as an external and compact electron injector for LWFA?

- Update from ACHIP project
  - ANL/UCLA/SLAC/RadiaBeam
  - DESY
  - PSI
  - …

- Update from DATA program at Cockcroft Institute
  - DLW as energy dechirper (for FELs)
  - DLW as THz source
  - DWA for two beam acceleration

Dielectric accelerators

Horizon 2020

Why dielectrics?

- Dielectrics can sustain high gradients (a few GV/m to tens of GV/m without breakdown)
- Dielectric can operate at high frequencies (~THz, smaller structures possible)
- Dielectrics can potentially have lower wakefields and easy to manufacture

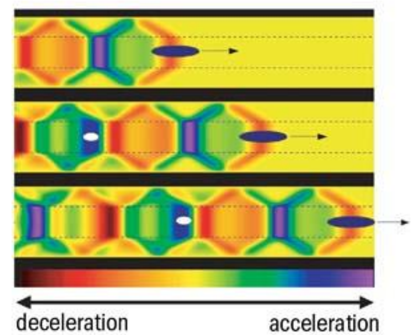
Principles

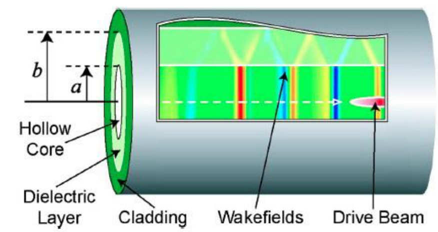
- Drive bunch excites wakefield in simple dielectric structures (via Cherenkov mechanism)
- Trailing bunch is accelerated in the wakefield

Experiments

- Beam deceleration/acceleration at dielectric structures
- High transformer ratio via tuning the bunch profile
- High power THz coherent Cherenkov radiation generation
- Reduce the correlated energy spread of the electron bunch

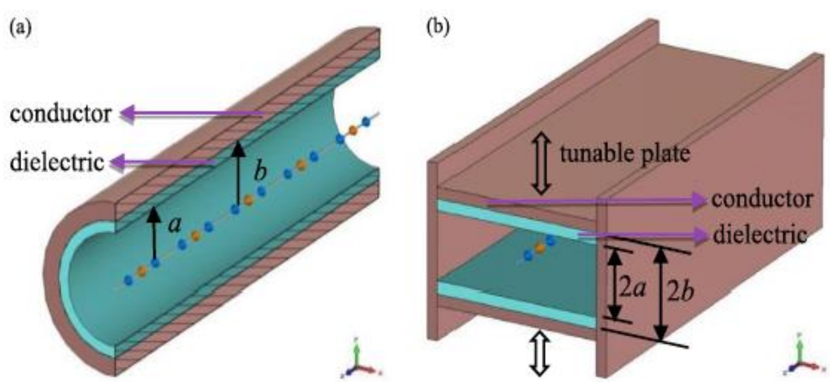
- ❑ Research involves accelerator physics, dielectric materials/structures, high performance computing and experiment
- ❑ Collaboration with ASTeC, CI Universities and international communities
- ❑ The first electron beam driven dielectric acceleration in UK, will give great impact to the advanced acceleration research field

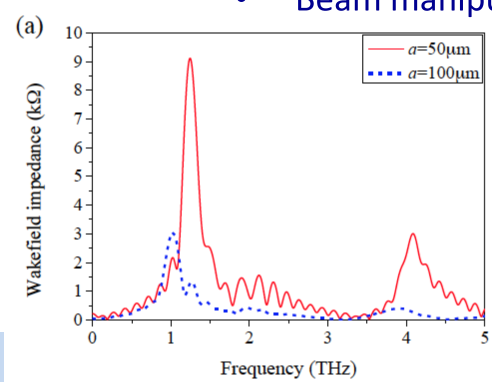


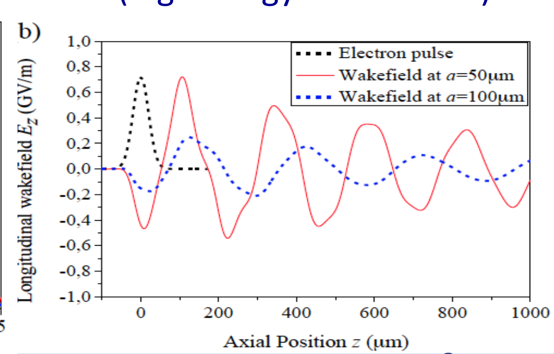


$$eE_{z\mathrm{dec}} \cong -\frac{4N_b r_e m_e c^2}{a\left[\sqrt{\frac{8\pi}{\varepsilon-1}\varepsilon\sigma_z}+a\right]},$$

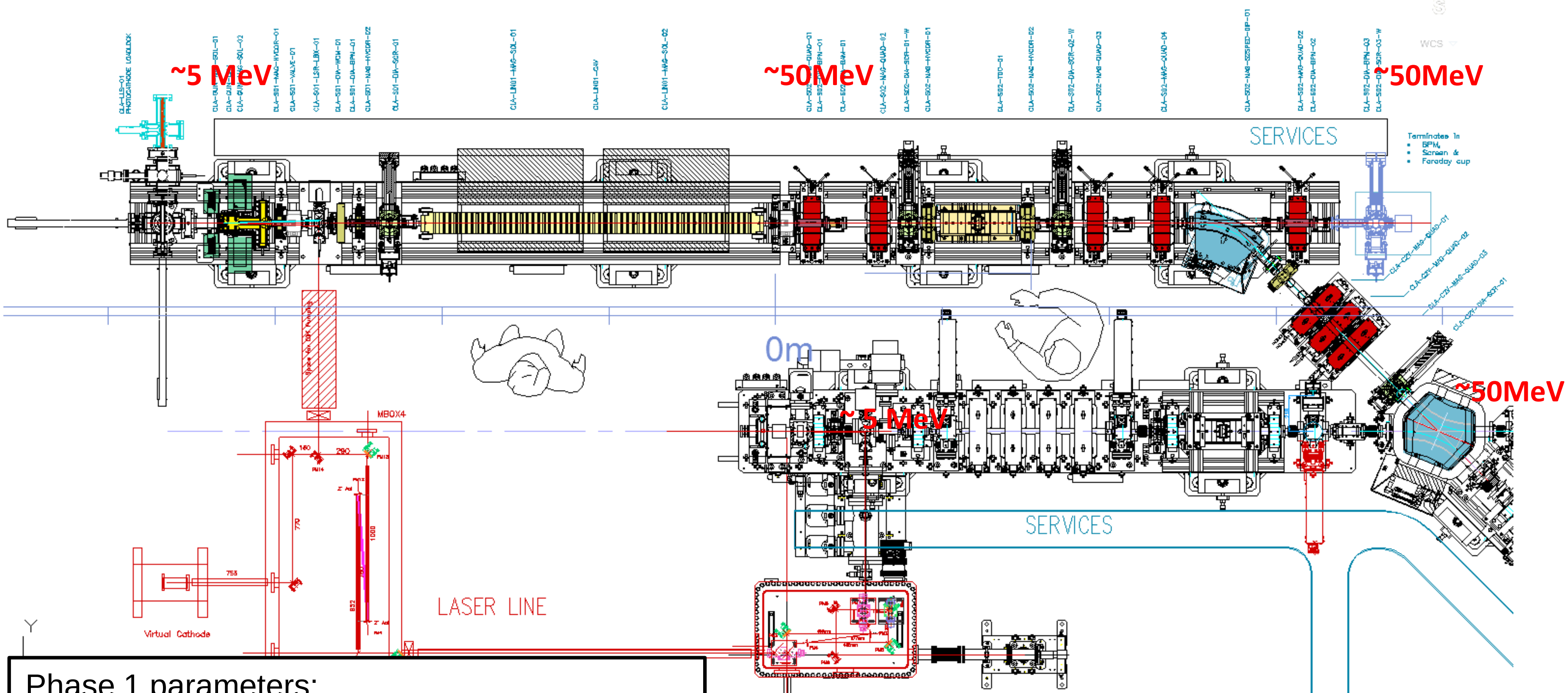
- Acceleration schemes (e.g. TeV linear colliders, XFELs , compact accelerators)
- Narrow band high power THz generation
- Beam manipulation (e.g. energy modulation)







CLARA front-end

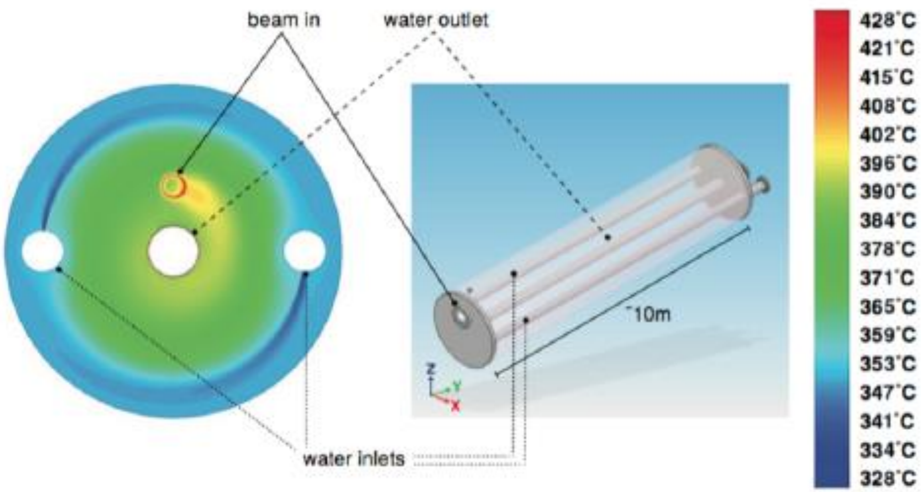


Phase 1 parameters:	
Max energy	~50 MeV
Max charge	250 pC
Norm. emitt.	< 1 mm mrad
Min bunch length	50 fs (rms)
Max peak current	2 kA
Bunches/RF pulse	1
Pulse rep. rate	10 Hz (400Hz later)

Plasma beam dump

Conventional beam dumps use high density materials – metal, water etc. They require high power density cooling, can produce radionuclides and (for water) explosive gasses through decomposition.

Stopping a beam with a low density material could have advantages.

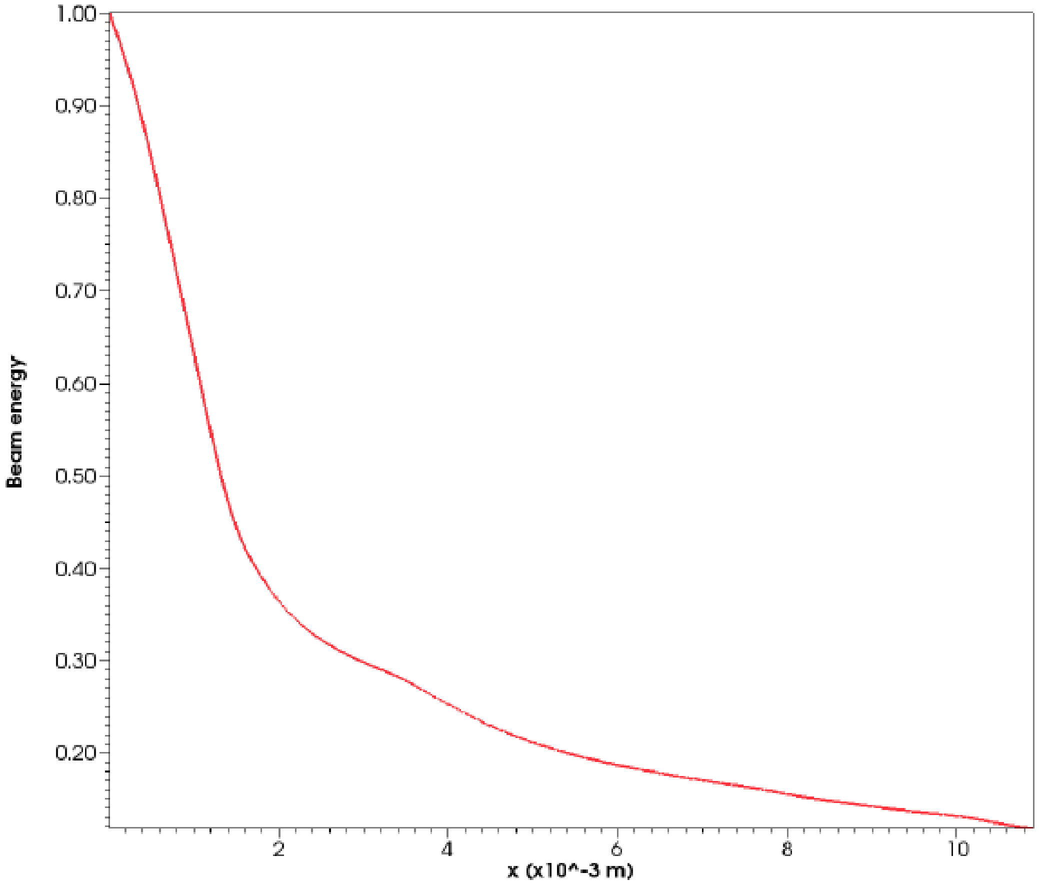


Plasma beam dump

H.C. Wu, T. Tajima et al. PR-STAB 13, 101303 (2010)

- **High decelerating gradients with low density dump medium.**
- **Effectiveness depends on bunch parameters.**
- **Possibility for electrical energy recovery.**

Plasma beam dump for LWFA generated beam

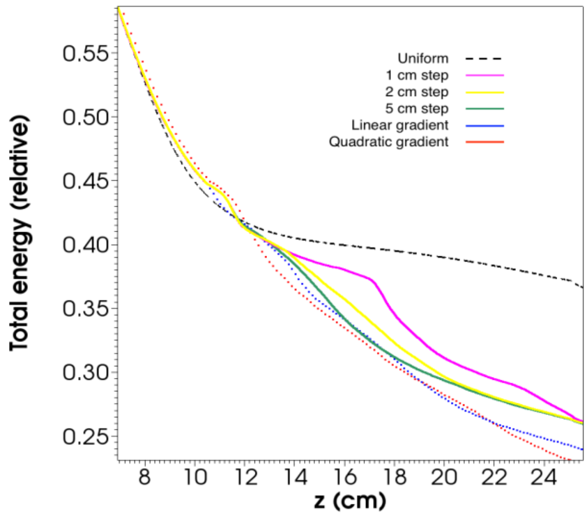


250 MeV initial energy
10% energy spread
3 μm bunch length
10 μm bunch radius

10 mm plasma length

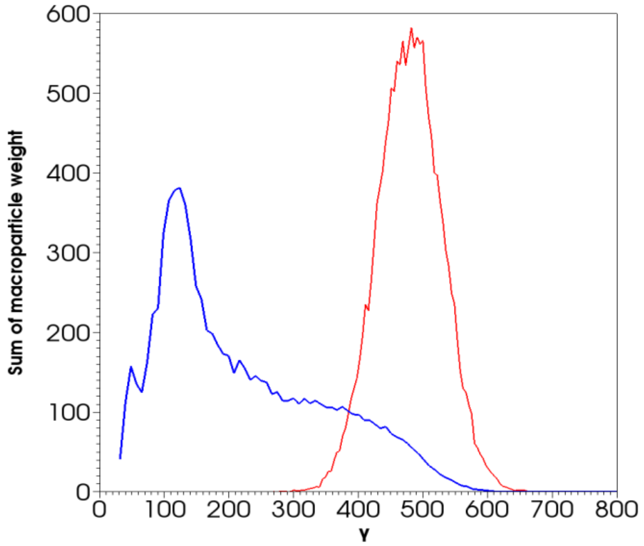
Plasma beam dump

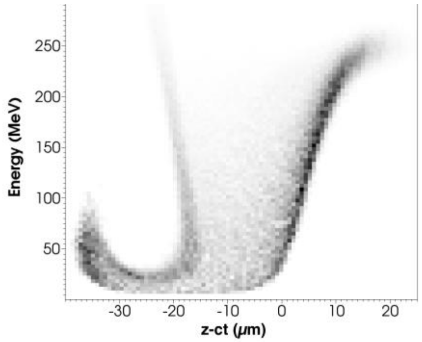
Simulations carried out for an ultrashort bunch: 7.5 µm rms bunch length, 100 pC, 250 MeV.
Initial decelerating gradient 4.5 GV/m (peak), 1.5 GeV/m (average).

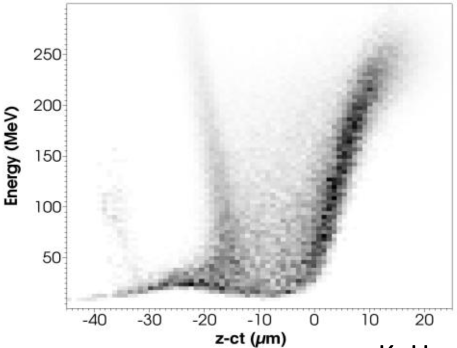


Left: Energy loss for different plasma profiles

Right: Initial and final energy spectra for gradient plasma.







Longitudinal phase space for uniform (L) and stepped (R) plasma.

K. Hanahoe, G. Xia et al., Physics of Plasmas **24**, 023120 (2017).

Conclusions

- Keep on tracking the latest development of fiber lasers, ICAN and XCAN (G. Mourou's involvement)
- Latest development of the dielectric based acceleration program worldwide. It might not be able to use as electron injector. However the dielectric structures might be used to improve the LWFA beam (energy dechirper), especially for FEL applications
- Plasma beam dump is very promising and will provide the key input to the EuPRAXIA novel beam dump design. Our next step is to model and design the plasma beam dump for EuPRAXIA beam. Further grant will be secured to continue this research experimentally, at CLEAR and CLARA
- Interaction with WP3 (Plasma structures), WP4 (Laser design and optimization) and WP5 (Electron beam design and optimization) will be discussed during this meeting.