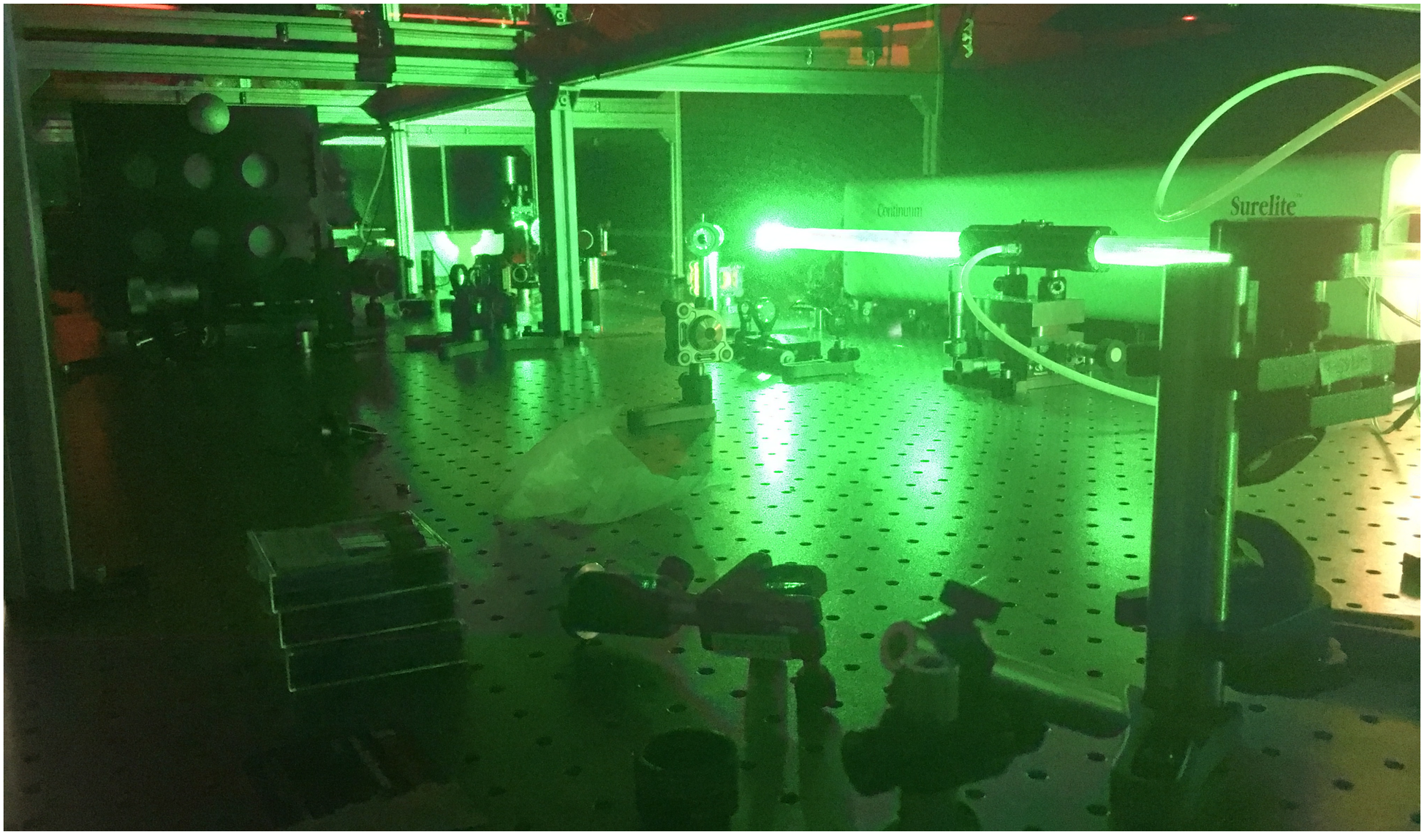
John Adams Institute for Accelerator Science

MURI MIR
MID-INFRARED STRONG-FIELD INTERACTION

ZHI LASER



Laser Development Status Update

07/08/2019

Motivation

- What are the USPs for a laser proton/ion source?
    - High instantaneous doses - full treatment doses possible in a single shot?
    - Source flexibility - simple switching of ion species by changing the target?

Where are we now?

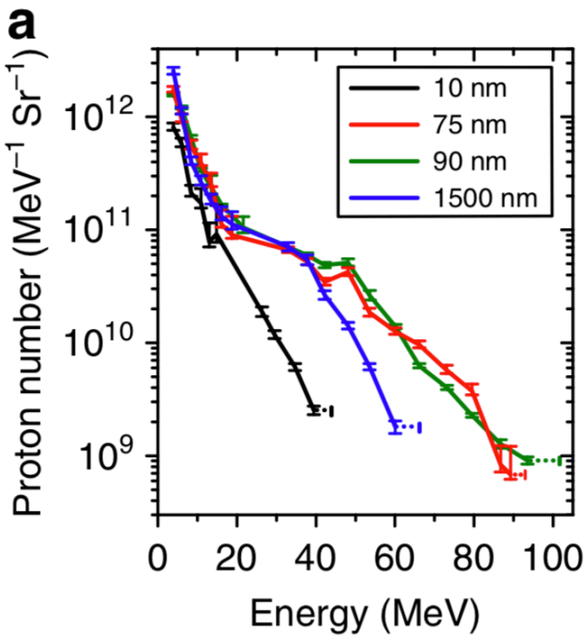
Current status:

Peak Energy - “nearly” 100MeV…*

DOI: 10.1038/s41467-018-03063-9 OPEN

Near-100 MeV protons via a laser-driven transparency-enhanced hybrid acceleration scheme

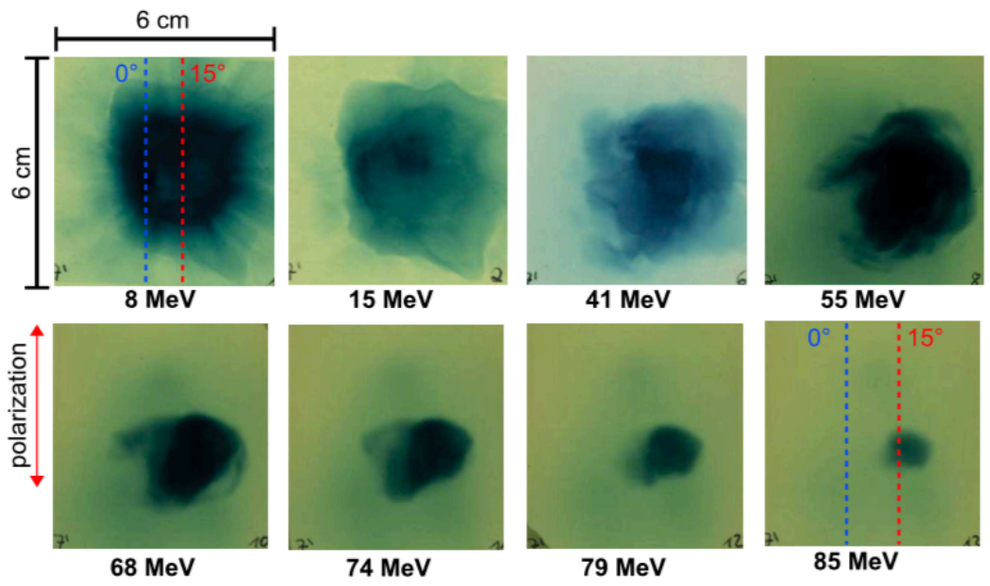
A. Higginson[1], R.J. Gray[1], M. King[1], R.J. Dance[1], S.D.R. Williamson[1], N.M.H. Butler[1], R. Wilson[1], R. Capdessus[1], C. Armstrong[1,2], J.S. Green[2], S.J. Hawkes[1,2], P. Martin[3], W.Q. Wei[4], S.R. Mirfayzi[3], X.H. Yuan[4], S. Kar[2,3], M. Borghesi[3], R.J. Clarke[2], D. Neely[1,2] & P. McKenna[1]



PRL 116, 205002 (2016) PHYSICAL REVIEW LETTERS week ending 20 MAY 2016

Maximum Proton Energy above 85 MeV from the Relativistic Interaction of Laser Pulses with Micrometer Thick CH_2 Targets

F. Wagner,[1,2,*] O. Deppert,[3] C. Brabetz,[1] P. Fiala,[3] A. Kleinschmidt,[3] P. Poth,[3] V. A. Schanz,[3] A. Tebartz,[3] B. Zielbauer,[1] M. Roth,[3] T. Stöhlker,[1,2] and V. Bagnoud[1,2]



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Current status:

Peak Energy - “nearly” 100MeV…

- work using “long pulse”, ps, high energy glass based systems

  - High flux and high energy (10^{9} - 10^{12} #protons/MeV/Sr^{-1})

  - Low repetition rates - shots on order of every 30 minutes due to cooling limitations

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Long pulses mainly in fusion energy research - but then ns, kJ type pulses

This laser technology has fallen out of favour… lower energy, shorter pulse, high rep. rate systems favoured

Current laser trends

Lower energy, short pulse Ti:Sapphire systems more fashionable… (because of other applications)

- similar peak intensities, but much higher repetition rates

	Vulcan	Gemi
Laser Energy	500J	15J
Pulse Length	1ps	30fs
Power	500TW	500TW
Rep Rate	0.0004Hz	0.05Hz

Ti:Sapphire generally lower energy, due to restriction in size of crystals that can be grown (except now in China)

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Proton Energy	100MeV	40MeV

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Acceleration schemes (TNSA/RT) which currently give highest energies inherently need these longer pulse lengths/higher energies to be most effective

What does this mean for us?

We have to adapt!

- Low rep rate, high energy systems are going to become more scarce (obsolete?)**

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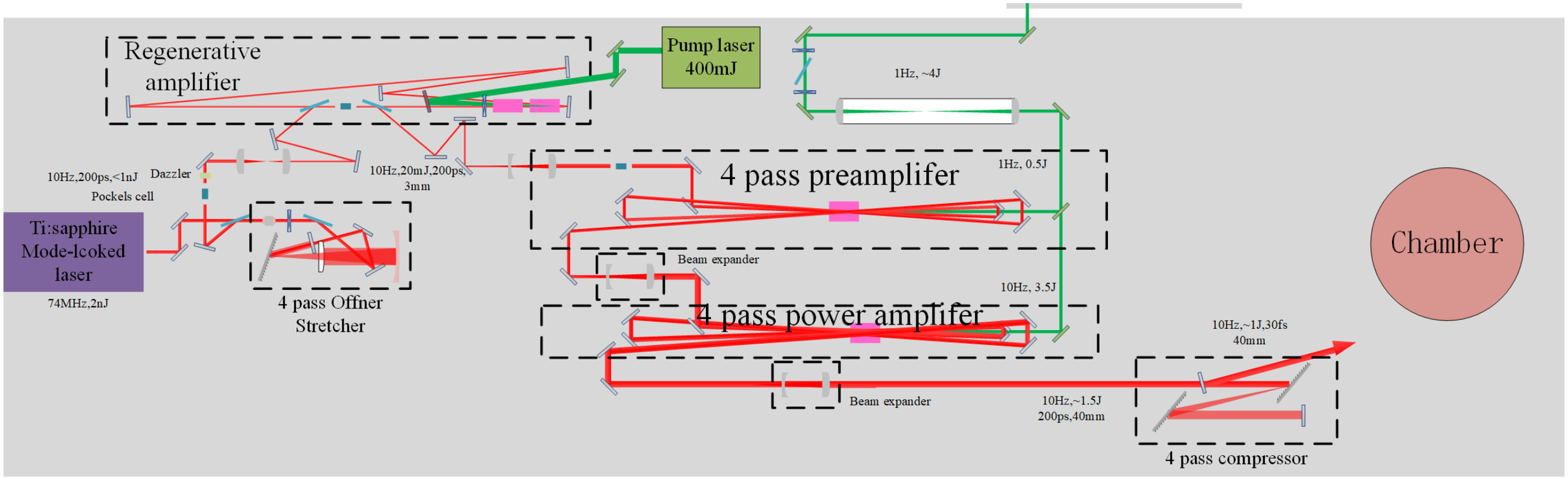
Fortunately, short pulse systems offer a number of benefits for ultra-high intensity acceleration schemes

- which also offer a number of desirable characteristics for particle therapy e.g. narrow energy spreads

What are we building here at Imperial?

- A short pulse, high rep. rate Ti:Sapphire system - Zhi Laser

- Current design - 150mJ in ~35fs @ 10Hz. ~4TW peak power, so relativistic intensities achievable, $>10^{18}$ Wcm^{-2}



What are we building here at Imperial?

- Phase 2 - £250k upgrade begins in September, offering 2 modes of operation

	Current Operation	Future Mode 1	Future Mode 2
Pulse Energy	150mJ	100mJ	1J
Pulse Length	35fs	35fs	35fs
Rep Rate	10Hz	100Hz	10Hz
Power	4TW	3TW	30TW

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How does this relate to CCAP?

- Predominantly interested in “Mode 2” - highest intensities
  - Study TNSA ion acceleration in a high rep. rate environment
    - generate ~15MeV protons reliably?
      - automatic optimisation of peak energies/spectra through genetic algorithms?
- Study effect of ultra-high dose rates and cell survival under these conditions?
- Test capture of ion beams with Gabor Lens?
- Develop (passive?) high rep. rate diagnostics - currently do not exist for these laser ion acceleration experiments

Summary

- Currently have TW class laser system in 027 lab in Blackett
  - First ion acceleration experiments ongoing
- Begin upgrade phase in September/October, which will offer two modes of operation
  - 100Hz, 3TW operation
  - 10Hz, 30TW operation