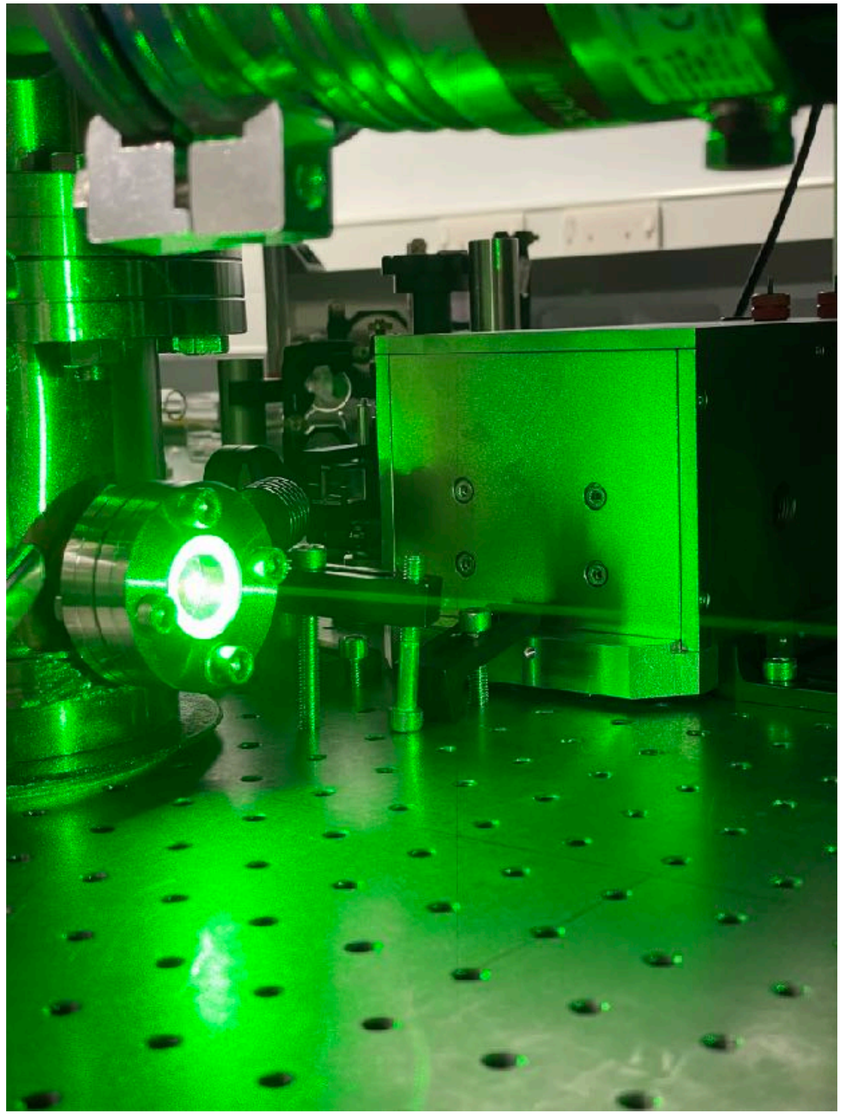
The Zhi Laser - a 100Hz laser for laser-plasma experiments



Oliver Ettlinger, Nuo Xu, Zulfikar Najmudin

JAI Fest

4th December 2023

Some motivation…

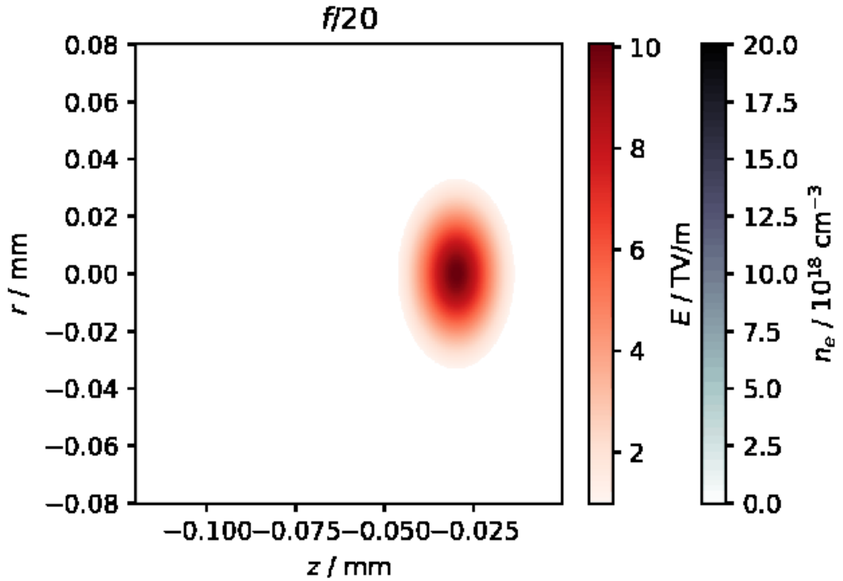
Plasmas can support >TV/m acceleration gradients

- high energies at laboratory scale

Some motivation…

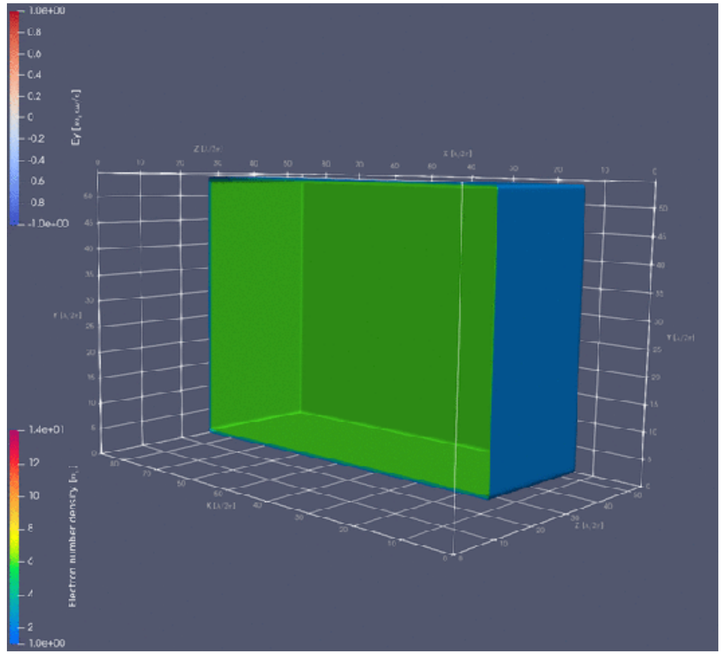
Plasmas can support >TV/m acceleration gradients

Wakefield acceleration - electron/ x-ray generation



Courtesy of Jon Wood

Ion/proton acceleration



Some motivation…

Plasmas can support >TV/m acceleration gradients

Wakefield acceleration - electron/ x-ray generation

J. M. Cole et al. PNAS (2018)

Ion acceleration - hadron therapy etc.

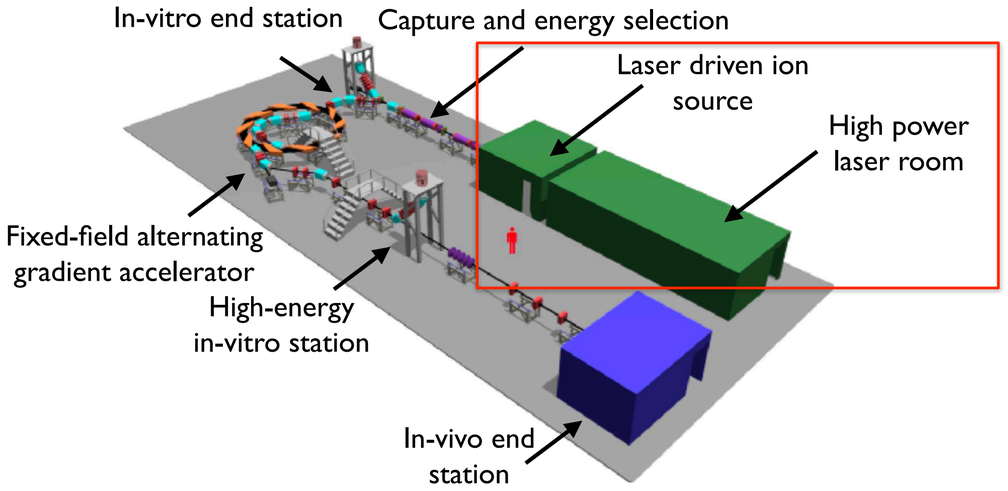


Image courtesy of Nick Dover

Some motivation…

Wakefield acceleration - electron/ x-ray generation

J. M. Cole et al. PNAS (2018)

Ion acceleration - hadron therapy etc.

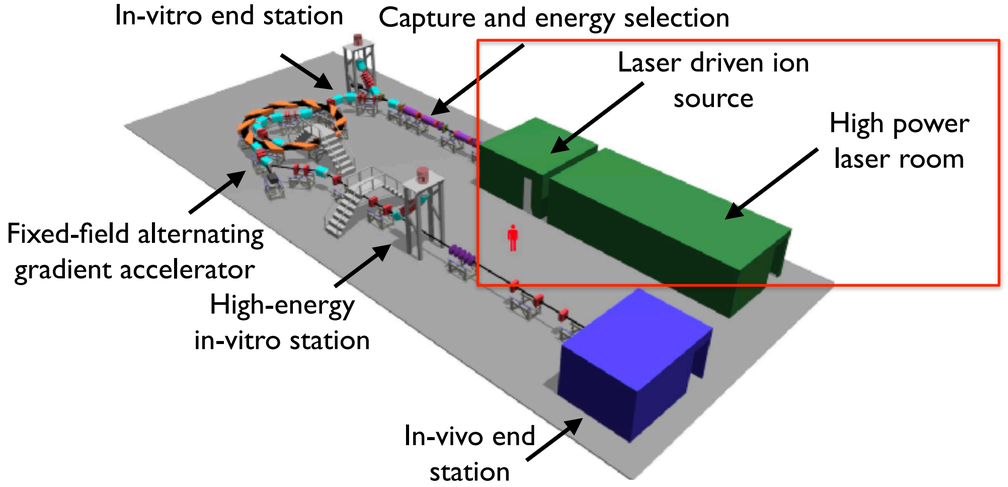


Image courtesy of Nick Dover

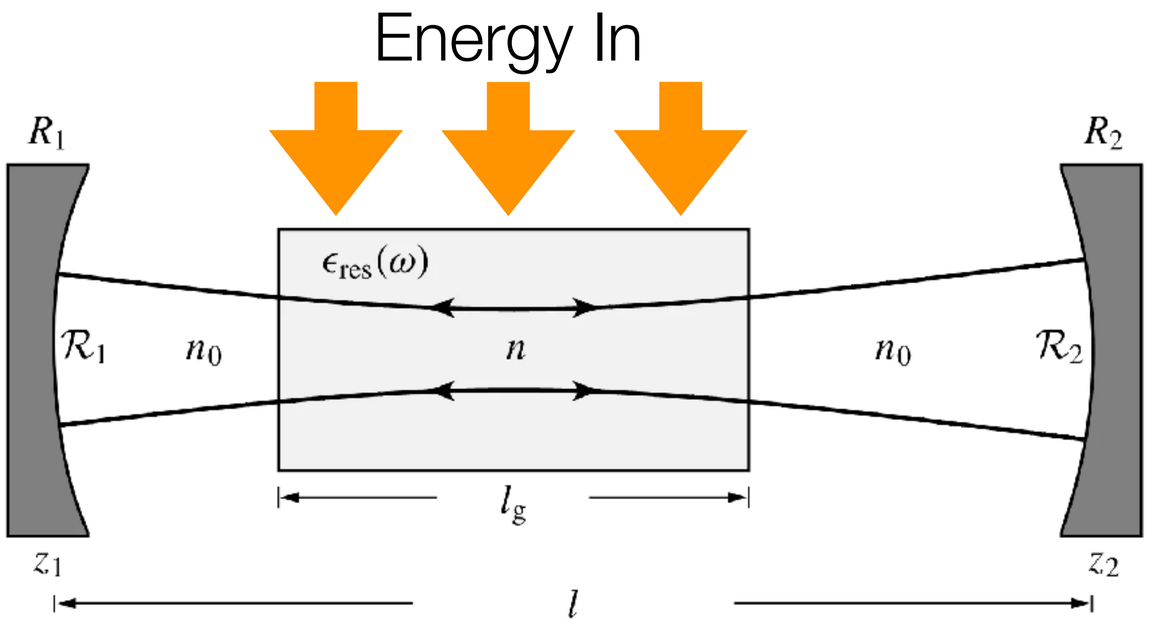
How do we go about using these radiation sources for useful, real-world applications?

How do we make a high power laser?

Fundamentally it is pretty simple - start small and keep getting bigger and bigger

How do we make a high power laser?

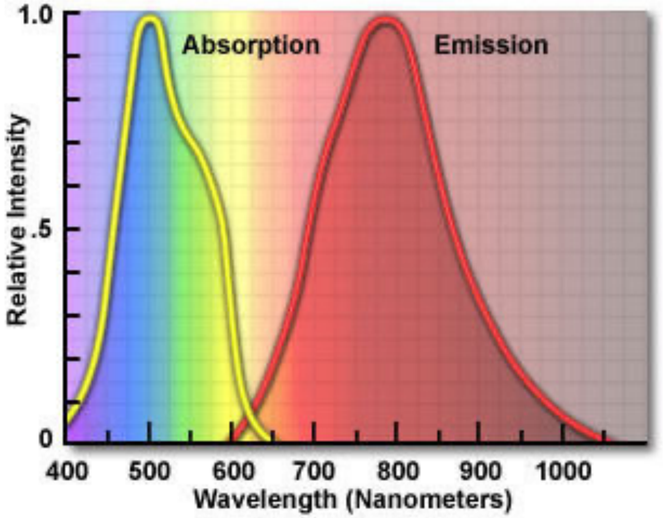
Fundamentally it is pretty simple - start small and keep getting bigger and bigger

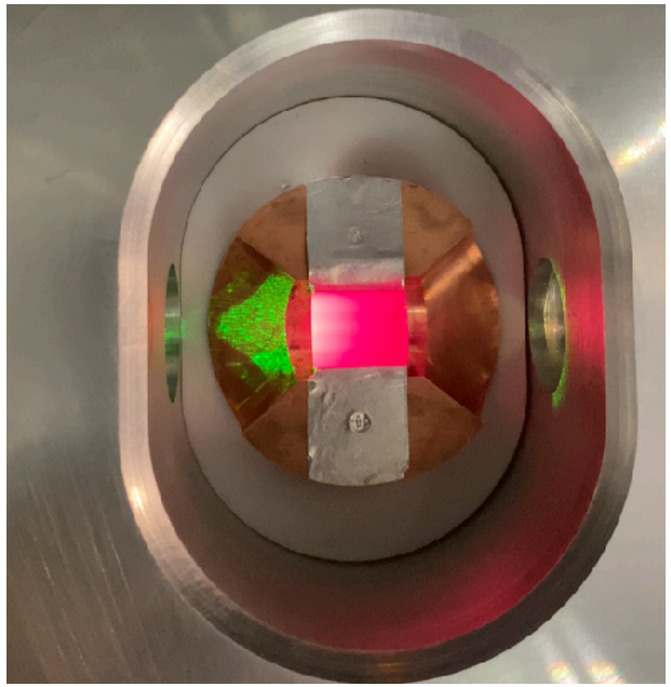


How do we make a high power laser?

Fundamentally it is pretty simple - start small and keep getting bigger and bigger

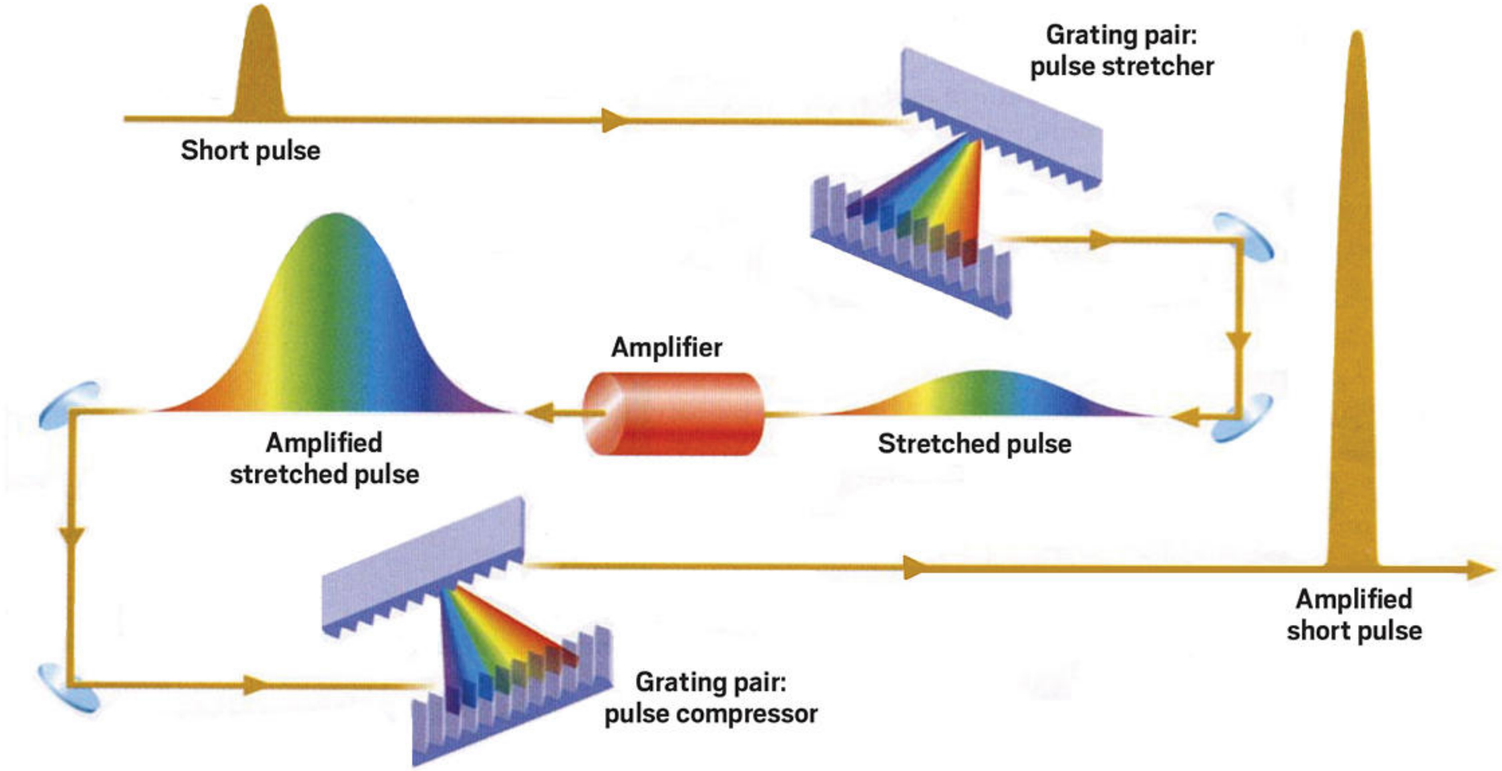
Slightly convolutedly, for the lasers here, we use other lasers to get energy gain

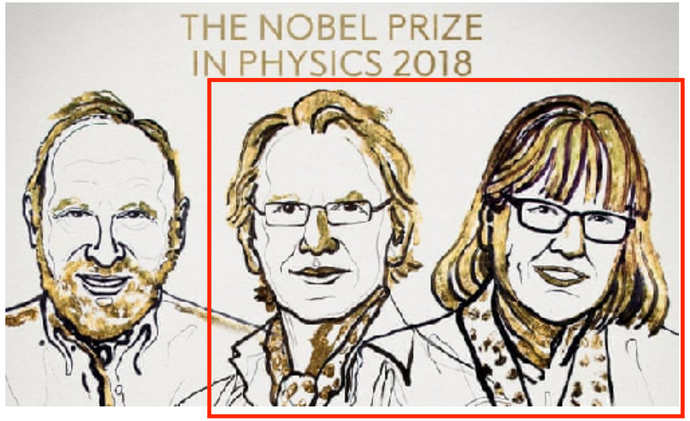




The Zhi laser - how does it work?

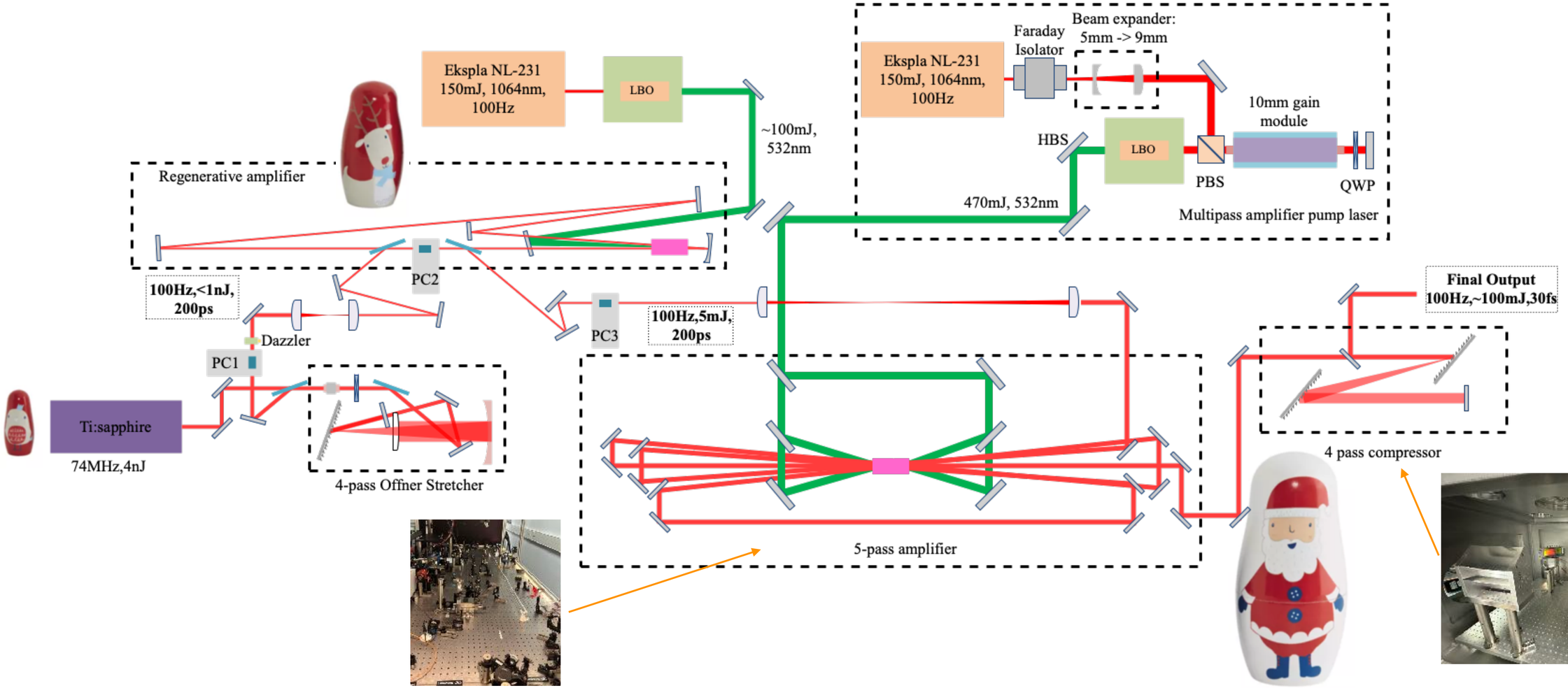
Based on “chirped pulse amplification” - 2018 Nobel Prize





The Zhi laser - how does it work?

Zhi laser is currently a 2 stage amplification design



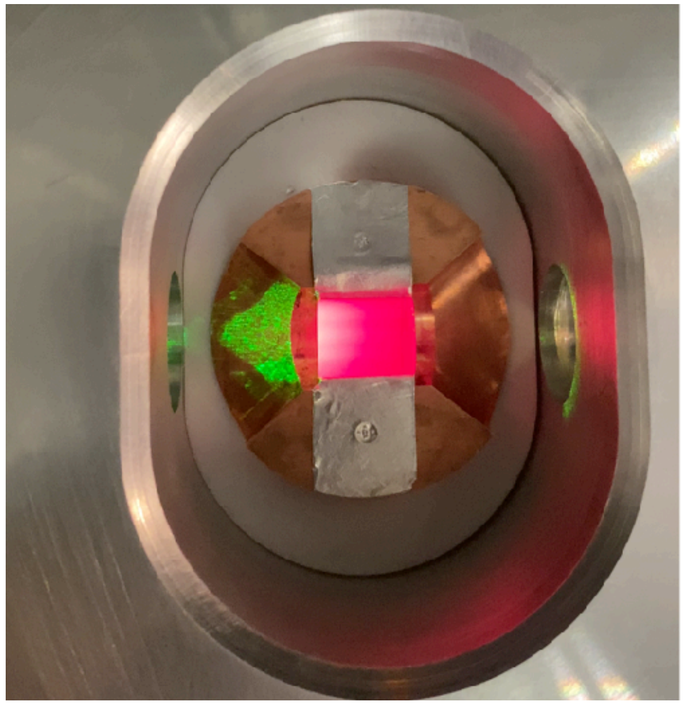
The Zhi laser - challenges?

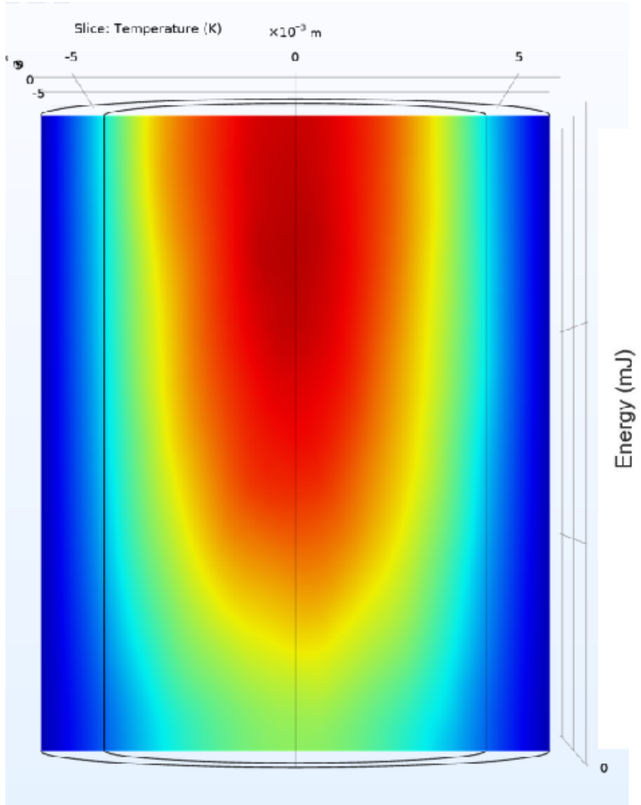
Why has this not been done before?

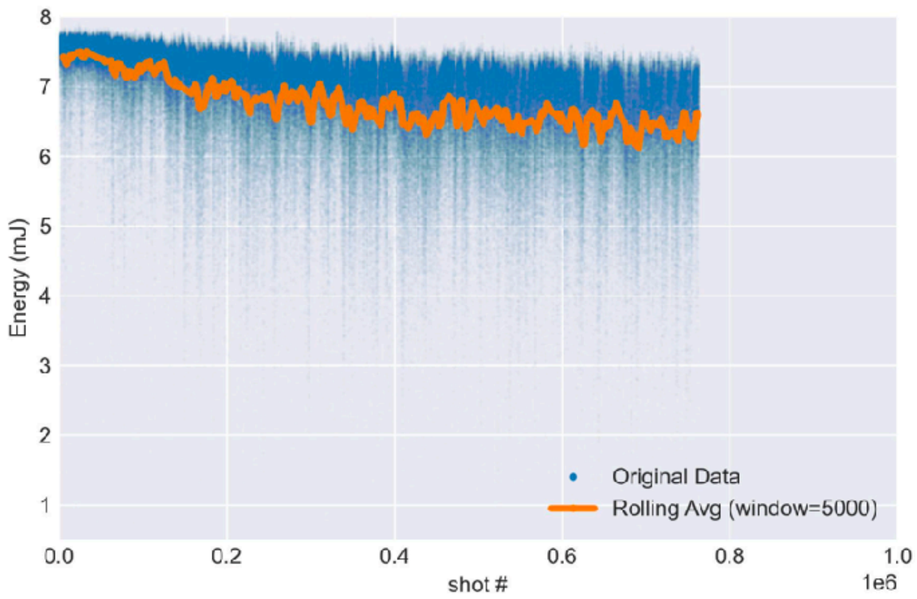
The Zhi laser - challenges?

Why has this not been done before?

- High average power and system architecture induce very large thermal lensing



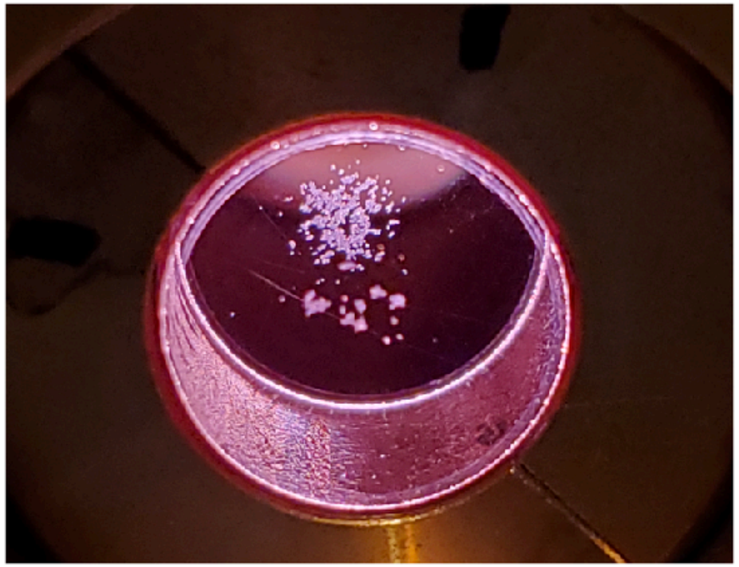


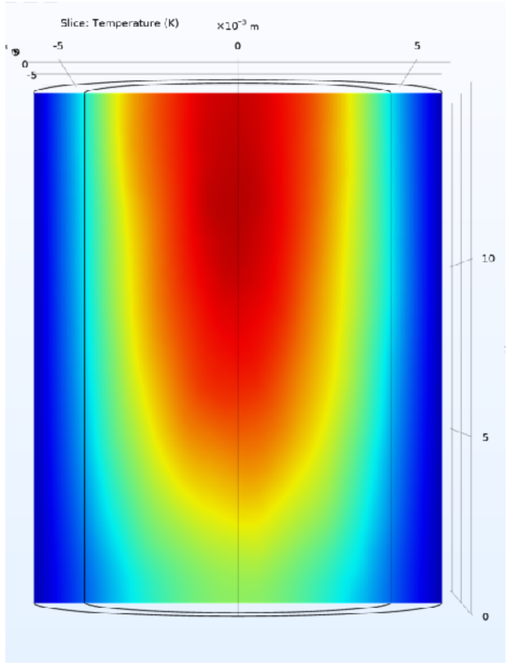


The Zhi laser - challenges?

High average power and system architecture induce very large thermal lensing

- Poor laser stability - destroys itself

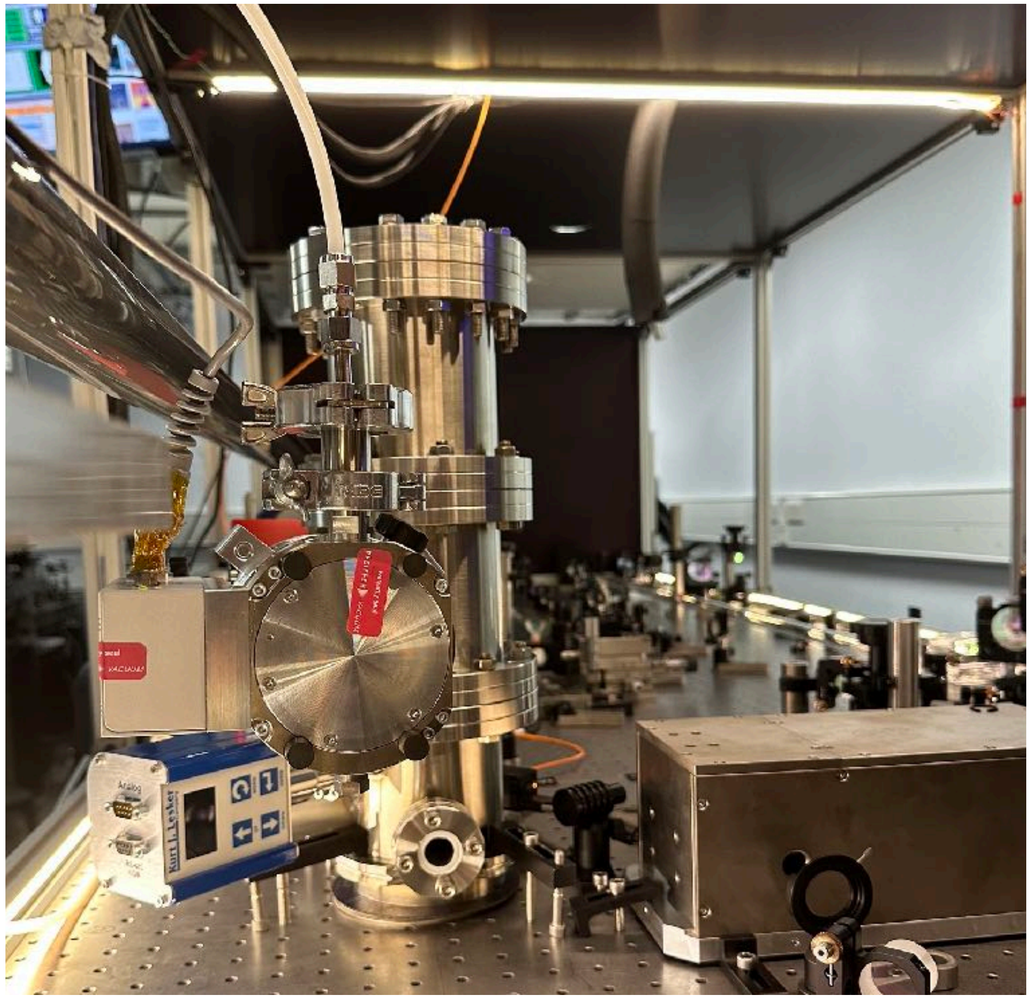




The Zhi laser - challenges?

High average power and system architecture induce very large thermal lensing

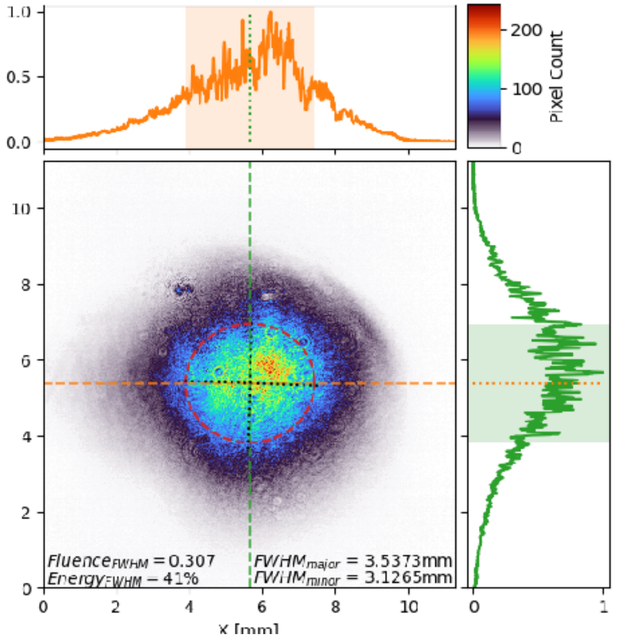
- Very poor laser stability - destroys itself
- Fortunately, there is a solution - cryogenic laser amplifiers



The Zhi laser - Final Output

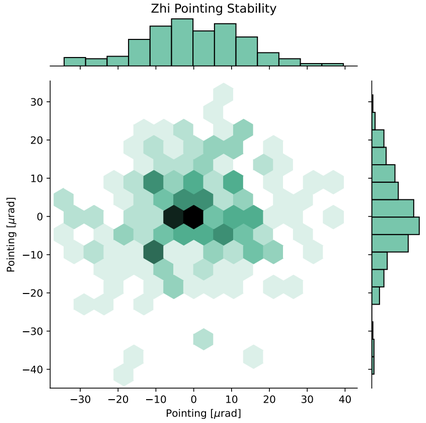
Lower energy output running now

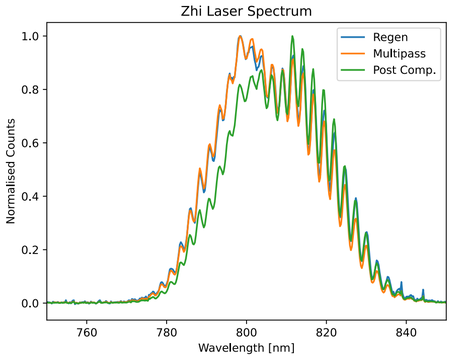
Parameter	Value (Cryogenic)	Value (Water cooled)
Average Value	12.26 mJ	3.45 mJ
Maximum Value	12.5 mJ	3.80 mJ
Minimum Value	10.7 mJ	1.82 mJ
RMS Stability	0.9114 %	7.805 %
PTP Stability	14.61 %	57.59 %
Repetition Rate	100.0 Hz	100.0 Hz
Average Power	1.23 W	0.34 W
Std Deviation	112 μJ	269 μJ



Final Ti:sapphire output tested at ~65mJ with prototype amplifier

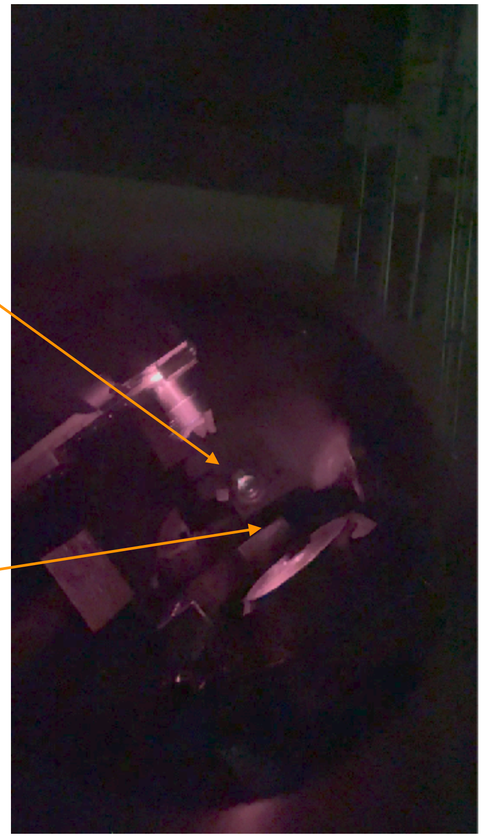
Final output previously limited by old amplifier - new amplifier about to be installed for >100mJ

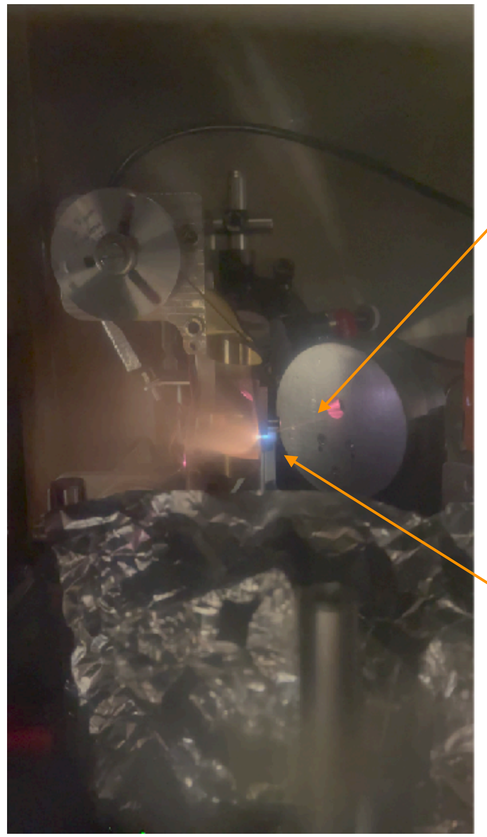




What can we do with the laser?

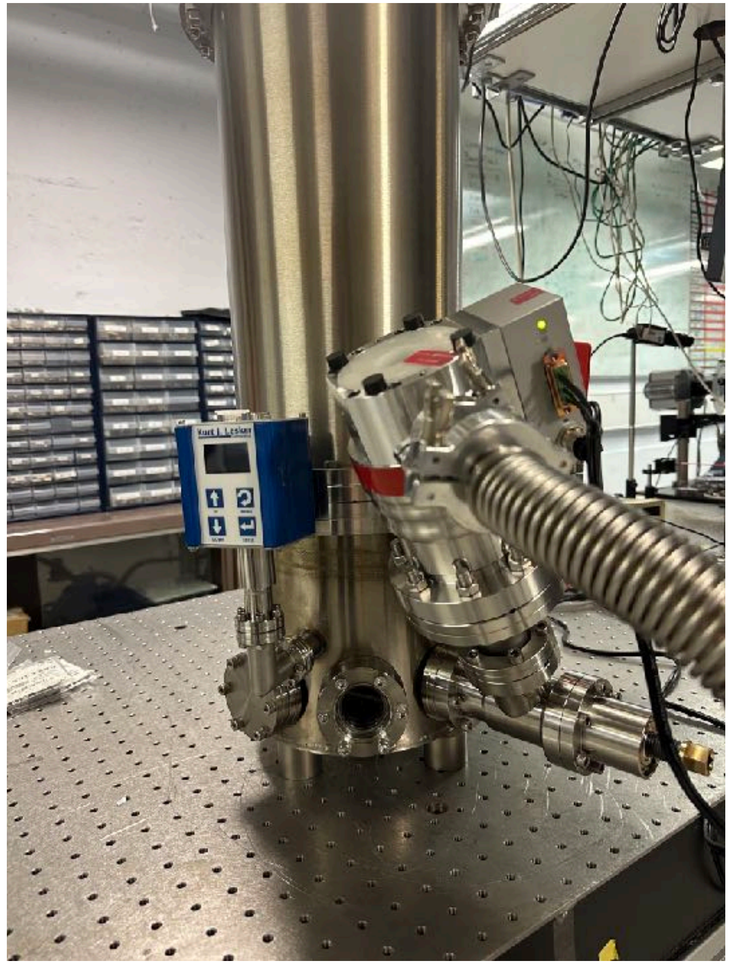
Building up experiments for ion/electron acceleration - already shot tape drive and wire targets





Future Plans

Install new amplifier and demonstrate >100mJ energies

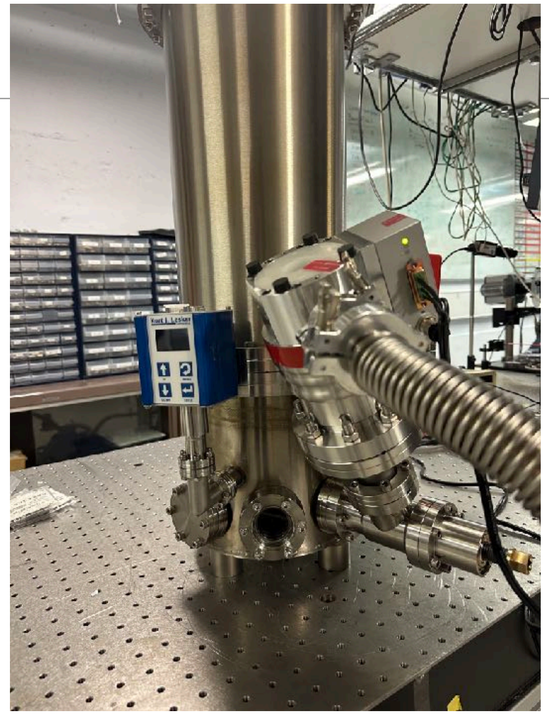


Future Plans

Install new amplifier and demonstrate >100mJ energies

Cryogenic amplifiers can scale to multi-kHz operation - 1 kHz front end soon to be received from the CLF

- Improved contrast and higher 100Hz energies
- Longer term, 10's mJ kHz amplifier, followed by multi-Joule scale 100Hz operation

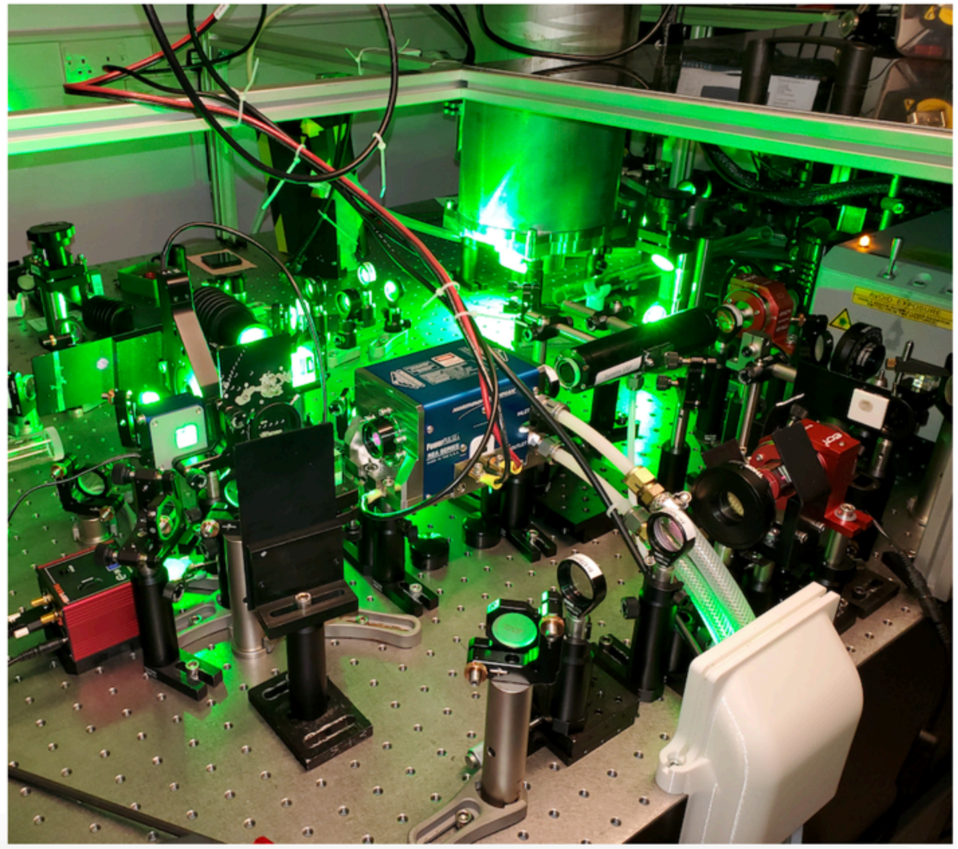


Summary

Developed a 100Hz, 100mJ class laser at Imperial for laser-plasma experiments

Larger scale experiments to start from January

Future upgrades to higher energies and kHz planned

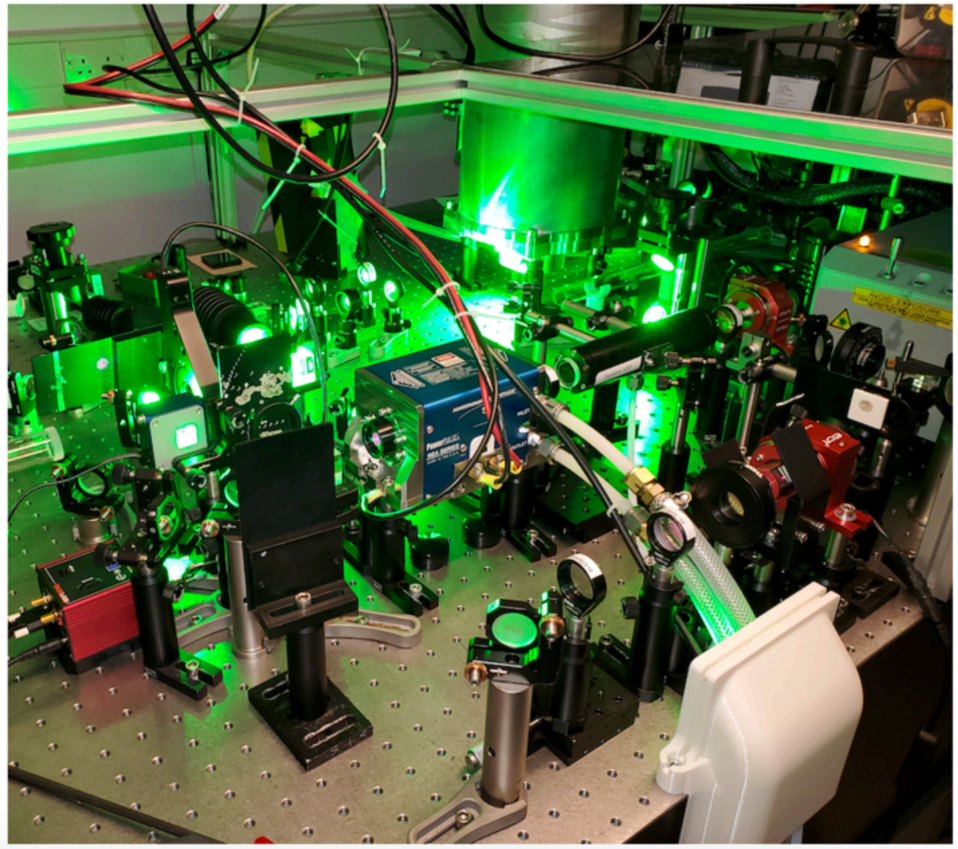


Summary

Developed a 100Hz, 100mJ class laser at Imperial for laser-plasma experiments

Larger scale experiments to start from January

Future upgrades to higher energies and kHz planned



Questions?